Analysis of Road Damage Using Road Condition Survey Data and Handling Designs (Case Study of the Pasangkayu - Baras Section)

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ABSTRACT

Inventory data and road conditions are the main road network data for measuring and monitoring road network conditions, making predictions of future conditions, and assisting in the strategic decision making process in road network management. This data is also the main data in general road network planning, programming and budgeting, research to evaluate the condition of road pavement to evaluate the condition of road pavement according to the level of damage so that later the budget can be determined. Data collection on road conditions uses a survey vehicle called Mata Garuda (MAGARU). The data obtained from MAGARU is road network data/RNI, pavement condition data/PCI and road unevenness data/IRI. Testing using the Benkelman Beam (BB) tool at 100 m intervals. Collecting traffic enumeration data uses CCTV equipment installed on the road section with an observation period of 7 x 24 hours. The results of the analysis showed that the proposed type of treatment was Preventive with an average value of 3.7, Minor Rehabilitation with an average value of 5.4 and Major Rehabilitation with a value of 8.8. For the PCI survey analysis, Preventive Treatment was obtained with an average value of 87.5, Minor Rehab with an average value of 65.3 and Major Rehab with an average value of 27.5. For the analysis of the deflection survey, a value of > 0.4 was obtained so the treatment was Major Rehab. The CESA4 value is 4,059 x 106 and the CESA5 value is 5,546 x 106. The results of pavement calculations show that Preventive Treatment uses Thin Layer Asphalt Concrete (LTBA), Minor Rehab uses Asphalt Concrete Wearing Course (AC-WC), Major Rehab uses Asphalt Concrete Wearing Course (AC-WC), Asphalt Concrete Binder Course (AC-BC) and Asphalt Concrete Binder Course Leveling (AC-BC Lev).

Keywords: IRI; Mata Garuda (MAGARU); PCI; preventive; major rehabilitation; minor rehabilitation and RNI.

INTRODUCTION

Roads are a means of transportation that is often used by Indonesian citizens to travel far and near and are very important in facilitating economic activities. Damaged road conditions will have a significant impact on traffic. The development of globalization also affects the level of mobility which has an impact on the increasing use of vehicles, resulting in vehicle volume loads exceeding the planned road class limits, so that the quality and age decreases (Nur Muhammad, 2022).

Road damage can occur due to several factors, including excessive vehicle loads, changing climate and environmental conditions, poor drainage systems which cause waterlogging, high traffic loads, inappropriate planning, planning not in accordance with existing plans, and lack of supervision and routine maintenance of road conditions.

Inventory data and road conditions are the main road network data for measuring and monitoring road network conditions, making predictions of future conditions, and assisting in the strategic decision making process in road network management. This data is also the main data in general planning of road networks, programming and budgeting,

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Analysis of road damage is very important to achieve appropriate handling, so that the budget can be used effectively and efficiently (Lasarus et al., 2020). Methods that can be analyzed for road maintenance include the IRI International Roughness Index (IRI) and the Pavement Condition Index (PCI). (PUPR, 2019a); (PUPR, 2016);(Rahman et al., 2022);(Yunus et al., 2022);(Hasibuan & Surbakti, 2019);(Soeseno & Tajudin, 2021);(Maghfiroh & Poerwanto, 2022).

Every year the government spends funds to carry out maintenance on roads throughout Indonesia, both routine maintenance and periodic maintenance which should not need to be carried out due to premature damage to these roads. Of the 33 national roads in West Sulawesi Province, one of them is the Pasang Kayu - Baras road, which is currently classified as a Primary Atreri road based on the Decree of the Minister of Public Works and Public Housing No. 430/KPTS/M/2022 its existence is very important, because this route is the main link between West Sulawesi and Central Sulawesi in land transportation modes with a road width of 6 m which is not yet standard for national roads. These road sections have been planned in accordance with established design standards. However, with changes in the composition of traffic loads, premature damage occurs which should not occur, considering that the design life has not yet been exceeded. The damage currently occurring includes holes, longitudinal and transverse cracks, crocodile skin cracks, edge cracks and patches.

Road condition assessments need to be carried out periodically, both structurally and non-structurally. So that roads can continue to accommodate movement needs with a certain level of service, efforts need to be made to maintain the quality of road services, where one of these efforts is evaluating road surface conditions (Ramli et al., 2018).

To evaluate the condition of road pavement according to the level of damage so that later budget determination is in accordance with appropriate handling in the field in connection with the concept of preservation, reconstruction or road widening by calculating the value of road unevenness using the IRI method and the Road Damage Index (IKP) using the PCI method in order to obtain recommendations effective and efficient handling, calculating pavement deflection values, calculating average daily traffic data and traffic axle loads and calculating pavement thickness.

The durability of concrete road pavement includes various aspects that ensure the road continues to function optimally and lasts a long time. First, it is important to carry out routine maintenance, including cleaning the road surface from dust, dirt and plants that can damage the concrete surface. Regular visual inspections are also necessary to detect cracks, holes, or other deformations that could develop into more serious problems if not treated immediately (Mubarak M et.al, 2020; Paikun P et.al, 2021).

Additionally, preventive maintenance such as resurfacing the surface with a protective agent can help extend the life of a concrete driveway. It is also important to monitor structural conditions through more in-depth inspections using technology such as ground-penetrating radar (GPR) to detect internal problems that are not visible from the surface. Concrete road rehabilitation is carried out when the damage is severe enough and can no longer be handled with routine maintenance. This process can include replacing part or all of the concrete layer to restore the road to its original condition. By carrying out a regular and comprehensive concrete pavement sustainability program, the life and quality of the road can be extended, and the cost of larger repairs in the future can be minimized (Paikun P et.al, 2021).

RESEARCH METHODS

Data Collection

This research was carried out on the Pasang Kayu - Baras National Road (53.002) West Sulawesi with a length of 54.62 km, in March - April 2020, the data processed was secondary data from road condition surveys and detailed road planning surveys in the form of deflection data from the Benkelmen Beam tool.

Inventory data and road conditions are the main road network data for measuring and monitoring road network conditions, making predictions of future conditions, and assisting in the strategic decision making process in road network management. This data is also the main data in general road network planning, programming and budgeting; monitor the performance of the road network, manage the procurement of contracts for road maintenance, preservation and reconstruction work. Thus, data on road network conditions must be of high quality.

In this research, before collecting data on road conditions using several survey tools, a calibration or inspection of the tools is first carried out to obtain accurate data so that recommendations for handling can be obtained correctly and followed by calculations of the pavement structure. Systematic procedures for this research can be seen in figure 1 below.

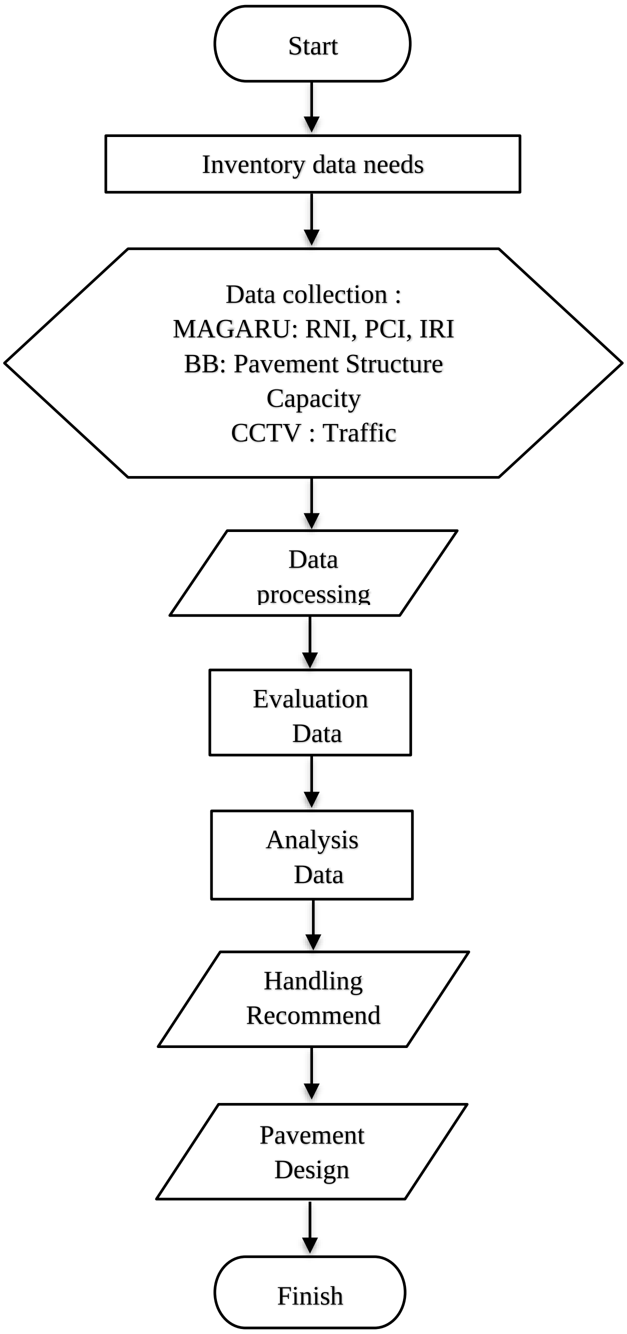

Figure 1. Flow chart alur penelitian

Data Collection Methods

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In this case study, the data used is data from a road condition survey in West Sulawesi taken using a survey vehicle called Mata Garuda (MAGARU) belonging to BBPJN South Sulawesi. The data obtained from MAGARU are road network data (Road Networking Inventory/RNI), pavement condition data (Pavement Condition Index/PCI) and road unevenness data (International Ruggedness Index/IRI). The data obtained will be analyzed using the Mata Garuda Analysis Software software. Figure 2 is a MAGARU road condition survey vehicle and figure 3 is a display of the results of road condition data processing. Figure 4 is a recapitulation of the results of IRI and PCI data processing.

Figure 2. Magaru Road Condition Survey Vehicle and Mata Garuda Live Dashboard Display

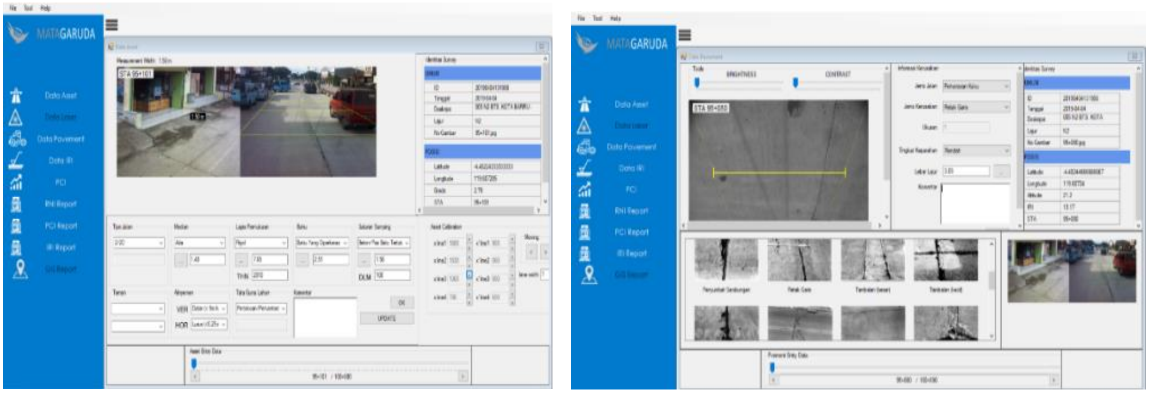

Figure 3. Road Damage Data Processing Display

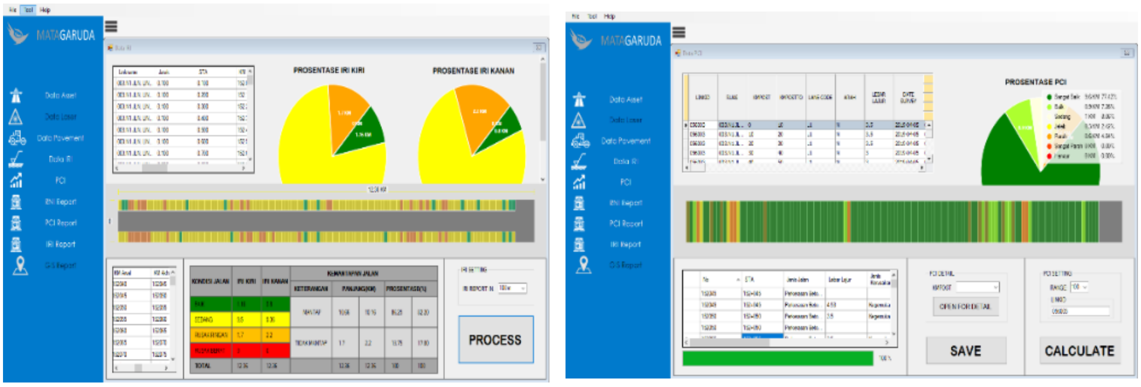

Figure 4. Display of recapitulation of IRI and PCI data processing results

Pavement Condition Index (IKP) which is often also called Pavement Condition Index (PCI) is a quantitative (numerical) indicator of pavement condition which is used to state the condition of road pavement, based on a visual observation of the type, severity and distribution of road damage. from 0 to 100, with a value of 0 representing the worst possible pavement condition and a value of 100 representing the best possible pavement condition, as in Figure 5 (PUPR, 2016); (PUPR, 2019b); (Kusmaryono et al. , 2022);(Kusmaryono & Sepinggan, 2020).

In this survey, data collection uses coordinated video images using a camera which must be able to produce digital images with a minimum resolution of 1280 x 1920 pixels which is equivalent to full HD video provided that the survey is only carried out when the weather is clear and the road surface is dry. Images are taken from a forward-facing camera with a minimum viewing angle of 120 from the front line of the vehicle, a maximum shooting interval of 10 meters and the types of damage that must be recorded are flexible pavement damage, rigid pavement damage, pavement without cover and road shoulders.

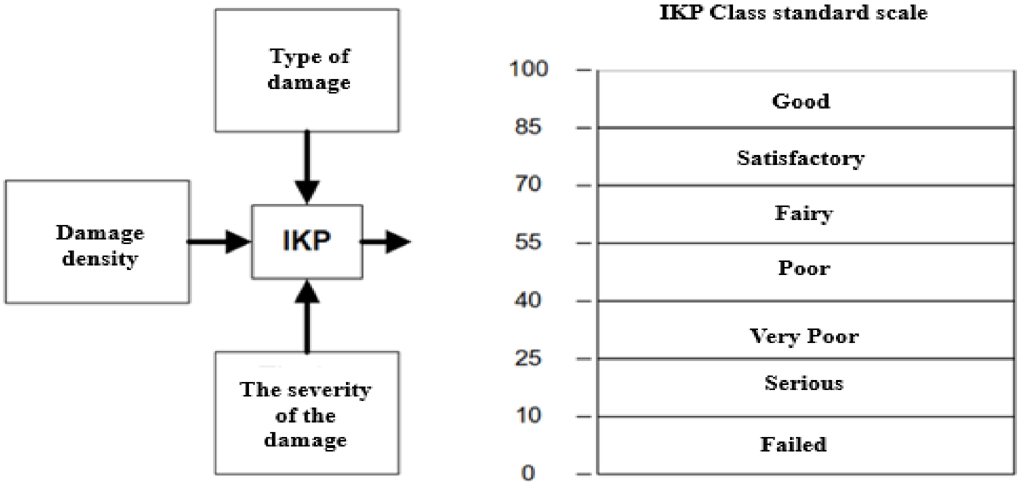

Figure 5. Principles for determining and scale of Pavement Condition Index (IKP) classes

As a numerical indicator of pavement condition, IKP shows the level of pavement surface condition. IKP shows a measure of the condition of the pavement at the time of survey, based on the damage observed on the pavement surface, which also shows the structural integrity and functional condition of the pavement (unevenness and roughness). IKP cannot measure the structural capacity of pavement, nor can it provide a direct measure of roughness or unevenness. IKP is an objective and rational basis for determining necessary maintenance and repair programs as well as treatment priorities. An example of using IKP to determine the type of treatment can be seen in Table 1 (PUPR, 2016).

Table 1. Use of IKP to determine the type of treatment

IKP	Handling Needs
≥ 85	Routine maintenance
70 – 85	Regular maintenance
55 – 70	Structural improvements
< 55	Reconstruction/recycling

International Roughness Index (IRI) is an index of road pavement surface unevenness, generally obtained from measurements in the longitudinal direction of the road. IRI is calculated using a mathematical model based on measurements using a vehicle, whose responses are accumulated to produce an unevenness index in units of m/km or in/mile. IRI was introduced in 1986 and became

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the most common road surface unevenness index used throughout the world to evaluate and manage roads. Examples of road conditions using IRI to determine the type of treatment can be seen in Table 2. (PUPR, 2019a)

Table 2. Road conditions with International Roughness Index (IRI) values

Road Conditions	IRI (m/km)	Handling Needs
Good	Average IRI ≤ 4	Routine maintenance
Currently	4 < Average IRI ≤ 8	Regular maintenance
Light Damage	8 < Average IRI ≤ 12	Road improvements
Heavy Damaged	Average IRI > 12	Road improvements

Factors influencing road unevenness measurements should be recorded during the survey and the data subject to correction. These factors include survey speed in congested areas, road construction activities, rain, puddles of water on the road surface, or due to obstacles in the traffic lane, survey vehicles must pass through alternative/emergency routes. In this survey, vehicle speed must not be less than 40 km/hour.

Road Network Inventory (RNI) is data that describes road assets in the form of physical elements in pavement, shoulders, channels, road terrain and land use. In this survey, data collection coincides with data collection in the PCI survey.

Testing using the Benkelman Beam (BB) tool is used as a guide in testing the deflection of flexible pavement structures which is carried out at intervals of 100 m. Road performance testing and overlay planning are carried out by measuring the maximum reverse deflection, while the turning point reverse deflection and concave deflection are used as comparative data. (PUPR, 2019c); (BSN, n.d.)

Collecting traffic enumeration data uses CCTV equipment installed on the road section with an observation period of 7 x 24 hours. In carrying out this survey, it was carried out under normal traffic conditions, there were no activities that resulted in abnormal traffic conditions such as the holiday season, campaign season, during the fasting month, etc. Recording activities begin at the beginning of the day (00.00). (PUPR, 2018a).

Data analysis

Data analysis was carried out using research methods by collecting data through road condition surveys. The results of this data analysis are compared to obtain recommendations for handling road construction, then road pavement design calculations are carried out using the Empirical Mechanistic Method contained in the Road Pavement Capacity Design Manual by analyzing the pavement structure using mechanical principles. To obtain optimal results, detailed and accurate input data on road material parameters and traffic loads is required (PUPR, 2017a).

RESULT AND DISCUSSION

The results obtained from analysis of IRI (International Rouhgness Index) data on the Pasang Kayu – Baras road section are presented in the form of table 3 and figure 6 below.

Table 3. Results of IRI data analysis

No.	KM./STA	IRI (N)	Uniformity Factor	IRI (O)	Uniformity Factor
1	226+000 – 240+000	4.1	26.41%	4.1	28.00%
2	240+000 – 245+500	4.6	24.34%	5.0	21.30%
3	245+500 – 249+800	8.7	29.98%	8.9	29.56%
4	249+800 – 253+500	7.1	23.80%	7.2	27.05%
5	253+500 – 263+700	3.6	22.29%	3.7	23.60%
6	263+700 – 272+100	4.5	25.36%	4.8	24.52%
7	272+100 – 273+700	3.8	14.26%	3.8	15.40%
8	273+700 – 279+700	4.9	29.19%	5.5	24.96%

No.	KM./STA	IRI (N)	Uniformity Factor	IRI (O)	Uniformity Factor
9	279+700 – 280+933	6.8	18.69%	6.2	18.03%

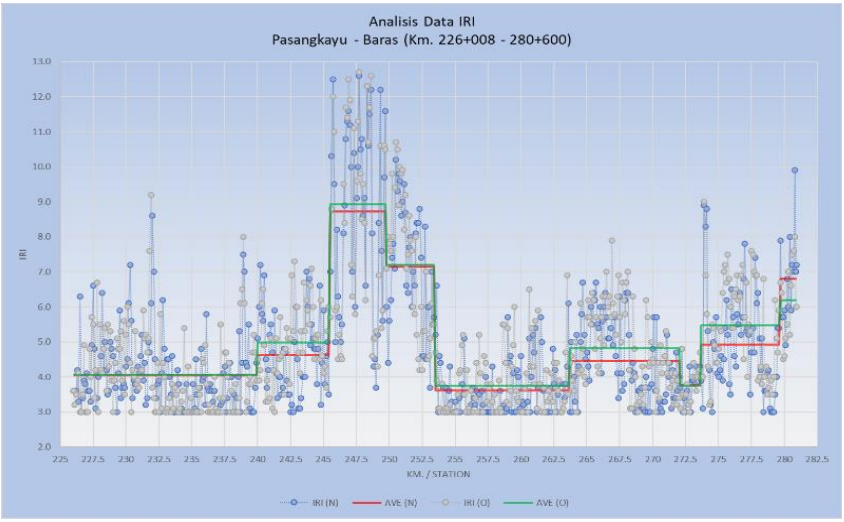

Figure 6. Graph of IRI data analysis results

The results obtained from PCI (Pavement Condition Index) data analysis on the Pasang Kayu – Baras road section are presented in the form of table 4 and figure 7 below.

Table 4. PCI data analysis results

No.	KM./STA	PCI (N)	Uniformity Factor	PCI (O)	Uniformity Factor
1	226+000 – 246+408	86.0	11.51%	92.5	12.45%
2	246+408 – 248+708	27.9	30.75%	28.5	27.21%
3	248+708 – 249+208	94.6	5.21%	88.5	11.68%
4	249+208 – 249+708	24.4	1.65%	29.1	15.94%
5	249+708 – 252+508	39.9	30.36%	90.7	12.98%
6	252+508 – 273+808	92.3	11.87%	90.7	12.98%
7	273+808 – 277+208	64.5	27.94%	90.7	12.98%
8	277+208 – 280+933	89.8	12.50%	85.5	14.95%

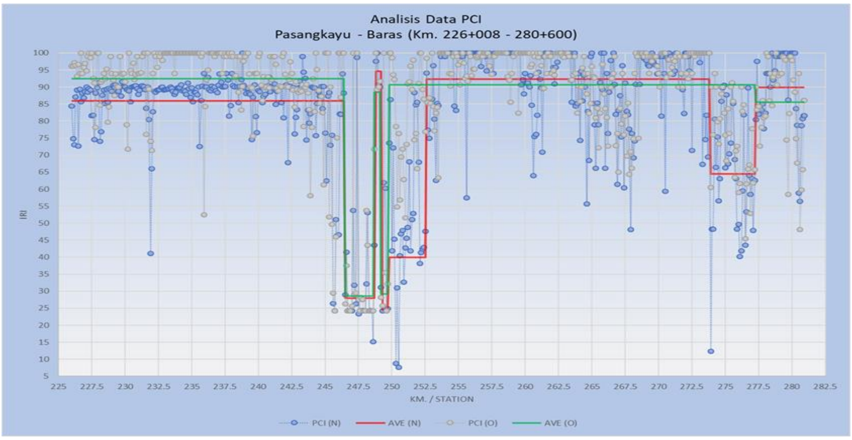

Figure 7. Graph of PCI data analysis results

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The results obtained from analysis of deflection data on the Pasang Kayu – Baras road section are presented in the form of table 5 and figure 8 below.

Table 5. Results of Deflection data analysis

No.	KM./STA	D_0 Avg (mm)	D_0 -D_{200} Avg (mm)	D_0 -D_{200} Wakil (mm)
1	240+000 – 240+800	0.934	0.526	0.645
2	240+900 – 242+000	0.854	0.539	0.627
3	242+100 – 244+500	0.798	0.506	0.591
4	244+600 – 245+500	1.161	0.692	0.857
5	251+900 – 253+500	0.774	0.481	0.539
6	263+700 – 266+600	0.962	0.583	0.713
7	266+700 – 268+000	0.954	0.613	0.749
8	268+100 – 269+800	0.761	0.476	0.556
9	269+900 – 272+000	0.834	0.531	0.634
10	273+600 – 274+600	1.063	0.630	0.776
11	274+700 – 276+900	1.149	0.693	0.861
12	277+000 – 279+300	0.960	0.595	0.712
13	279+400 – 280+100	0.746	0.477	0.523
14	280+200 – 280+700	1.172	0.684	0.851

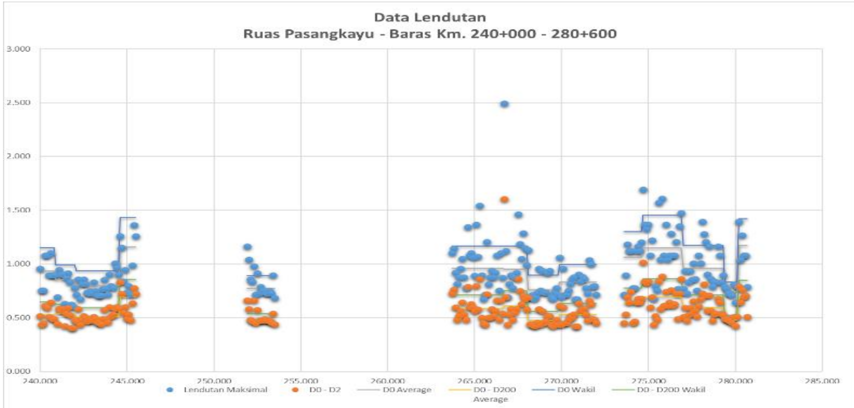


Figure 8. Graph of deflection data analysis results

The results obtained from traffic data analysis on the Pasang Kayu – Baras road section are presented in table 5 and the results of the CESA analysis in figure 9, figure 10 below.

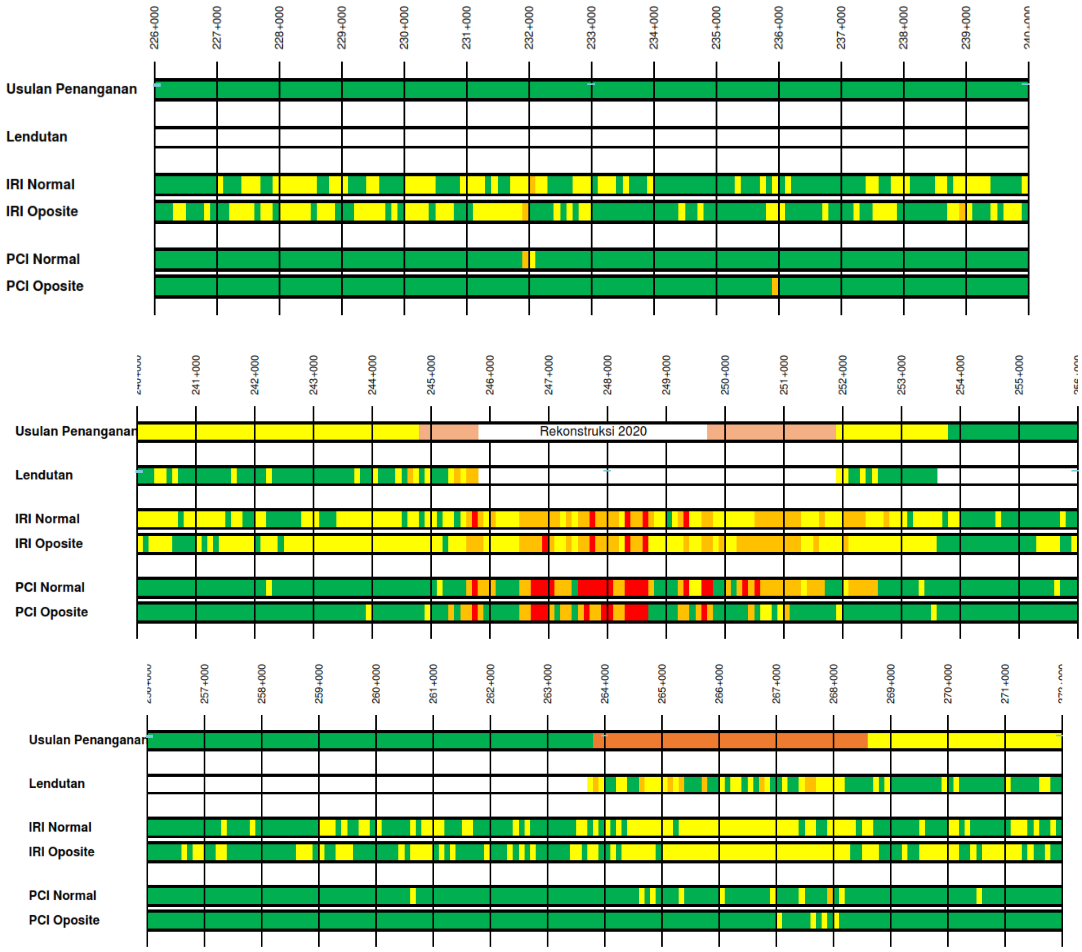
NO.	KLASIFIKASI	JENIS KENDARAAN	LHR 2020 Thn. 2020 Baras	LHR 2020 Thn. 2020 Karossa	LHR 2020 Thn. 2020 Total	(i)	LHR 2021 Thn. 2021 1	LHR 2022 Thn. 2022 2	$ESA4_{faktual}$	$ESA4_{normal}$
1	1	- Sepeda motor, skuter, roda 3	1947	1948	3895	3.5	4031	4172		
2	2,3,4	- Sedan/Angkot/Pick up / Station Wagon	703	697	1400	3.5	1449	1500		
3	5a	- Bus kecil	2	2	4	3.5	4	4	1.29	1.29
4	5b	- Bus Besar	9	6	15	3.5	16	16	16.07	16.07
5	6a.1	- Truk 2 sumbu cargo ringan	26	23	49	3.5	51	52	28.87	28.87
6	6a.2	- Truk 2 sumbu ringan	0	0	0	3.5	0	0	0.00	0.00
7	6b1.1	- Truk 2 sumbu cargo sedang	240	249	489	3.5	506	524	2566.76	1519.10
8	6b1.2	- Truk 2 sumbu sedang	0	0	0	3.5	0	0	0.00	0.00
9	6b2.1	- Truk 2 sumbu berat muatan umum	0	0	0	3.5	0	0	0.00	0.00
10	6b2.2	- Truk 2 sumbu berat (tanah, pasir.besi, semen)	0	0	0	3.5	0	0	0.00	0.00
11	7a.1	- Truk 3 sumbu ringan	16	16	32	3.5	33	34	246.81	167.97
12	7a.2	- Truk 3 sumbu sedang	0	0	0	3.5	0	0	0.00	0.00
13	7a.3	- Truk 3 sumbu berat	0	0	0	3.5	0	0	0.00	0.00
14	7b	- Truk 2 sumbu dan gandengan 2 sumbu	1	1	2	3.5	2	2	0.00	0.00
15	7c.1	- Semi Trailler 4 sumbu	1	1	2	3.5	2	2	28.28	13.93
16	7c2.1	- Semi Trailler 5 sumbu	0	0	0	3.5	0	0	0.00	0.00
17	7c2.2	- Semi Trailler 5 sumbu	0	0	0	3.5	0	0	0.00	0.00
18	7c.3	- Semi Trailler 6 sumbu	0	0	0	3.5	0	0	0.00	0.00
19		- Kendaraan tak bermotor	3	2	5	3.5	5	5		
		JUMLAH							**2888.08**	**1747.22**

Figure 9. Results of LHR data analysis

UMUR RENCANA	TAHUN	PERTUMBUHAN (i)	R	ESA4 DASAR	$CESA_4$	ESA5 DASAR	R	$CESA_5$
a	b	c	d	e	f	g	h	i
0	2023	3.5%	-	1,747.22	-	2,387.01	-	-
1	**2024**	**3.5%**	**1.00**		**318,867.93**		**1.00**	**435,629.45**
2	2025	3.5%	2.04		967,764.17		2.04	1,322,135.37
3	2026	3.5%	3.11		1,309,343.47		3.11	1,788,792.53
4	2027	3.5%	4.21		1,662,878.04		4.21	2,271,782.68
5	**2028**	**3.5%**	**5.36**		**2,028,786.33**		**5.36**	**2,771,677.49**
10	**2033**	**3.5%**	**11.73**		**4,059,632.99**		**11.73**	**5,546,169.76**
20	**2043**	**3.5%**	**28.28**		**9,336,351.54**		**28.28**	**12,755,091.59**
30	**2053**	**3.5%**	**51.62**		**16,779,684.19**		**51.62**	**22,923,987.79**
40	**2063**	**3.5%**	**84.55**		**27,279,240.01**		**84.55**	**37,268,220.17**

Figure 10. Results of Cumulative Equivalent Single Axle Load analysis

From the results of the survey data analysis above, treatment recommendations are presented in Figure 9 in the form of a strip map of proposed treatment.



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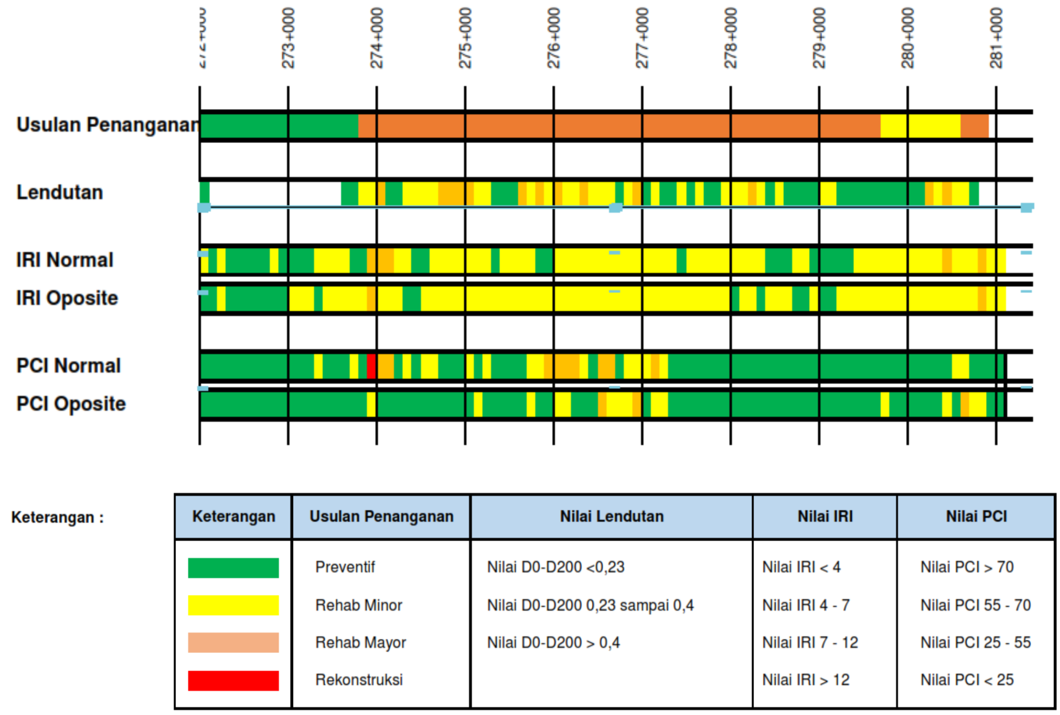

Figure 11. Strip Map of Proposed Treatment

The results of the IRI survey analysis obtained Preventive Treatment with an average value of 3.7, Minor Rehab with an average value of 5.4 and Major Rehab with a value of 8.8. For the PCI survey analysis, Preventive Treatment was obtained with an average value of 87.5, Minor Rehab with an average value of 65.3 and Major Rehab with an average value of 27.5. For the analysis of the deflection survey, a value of > 0.4 was obtained so that the treatment was Major Rehab. The results of analysis of traffic data obtained a CESA4 value of 4,059 x 106 for maximum deflection in accordance with Flexible Pavement Thickness Planning Pt T-01-2002-B (Settlements & Infrastructure, 2002), Planning for Adding Flexible Pavement Thickness Using the Pd T-05 Deflection Method -2005-B (Department of Public Works, 2005) and a CESA5 value of 5,546 fatigue).(Pattipeilohy et al., 2019)

From the proposed handling of the condition survey results, pavement thickness calculations were carried out using the empirical method of flexible pavement design using the Road Pavement Design Manual No. 02/M/BM/2017, Supplement to the 2017 Road Pavement Design Manual (MDP) and Planning for Additional Layer Thickness of Flexible Pavement using the Deflection Method Pd T-05-2005-B (PUPR, 2017a); (PUPR, 2020); (Department of Public Works, 2005). The results of the pavement thickness calculation can be seen in table 7 below.

Table 6. Calculation of Pavement Thickness

No.	Location (KM.)	Minimum overlay to lower IRI Value (mm)	Thin overlay of tightly graded asphalt concrete (mm)	Overlay Asphalt Concrete Mix Thicknes s (mm)	Analysis Results Existing (cm)	
1	226+008 - 240+000	40.0			3.0	LTBA
	253+424 - 263+670	40.0				Existing
	272+035 - 273+660	40.0				
2	240+000 - 240+900	45.0	**50.0**	100.0	5.0	AC-WC

No.	Location (KM.)	Minimum overlay to lower IRI Value (mm)	Thin overlay of tightly graded asphalt concrete (mm)	Overlay Asphalt Concrete Mix Thicknes s (mm)	Analysis Results Existing (cm)	
	269+900 - 272+035	45.0	**50.0**	100.0		Existing
3	240+900 - 244+600	45.0	**60.0**	100.0	6.0	AC-WC
	251+900 - 253+424	60.0	**60.0**	90.0		Existing
	268+100 - 269+900	45.0	**60.0**	80.0		
4	279+400 - 280+200	50.0	**70.0**	60.0	7.0	AC-WC
						Existing
5	244+600 - 245+505	45.0	Overlay	**120.0**	5.0	AC-WC
	263+670 - 266+700	45.0	Tebal	**120.0**	7.0	AC-BC
	277+000 - 279+400	50.0		**120.0**		Existing
6	249+503 - 251+900	80.0	Overlay	**130.0**	5.0	AC-WC
			Tebal		8.0	AC-BC
						Existing
7	266+700 - 268+100	45.0	Overlay	**130.0**	4.0	AC-WC
	273+660 - 274+700	50.0	Tebal	**130.0**	6.0	AC-BC
	274+700 - 277+000	50.0		**130.0**	4.0	AC-BC Lev.
	280+200 - 280+664	55.0		**130.0**		Existing

Based on the table of calculation results above, for preventive handling, the most appropriate maintenance technology based on the type, level and distribution of damage to the paved road section uses a thin layer of asphalt concrete (LTBA) 3 cm thick. (PUPR, 2017b)

Handling Minor Rehab on this road section uses Asphalt Concrete Wearing Course (AC-WC) with varying thicknesses of 5-7 cm. Meanwhile, the Major Rehab treatment on this road section uses Asphalt Concrete Wearing Course (AC-WC) with a thickness variation of 4-5 cm, Asphalt Concrete Binder Course (AC-BC) with a thickness variation of 6-8 cm and Asphalt Concrete Binder Course Leveling (AC -BC Lev.) with a thickness of 4 cm. (PUPR, 2020); (PUPR, 2018b).

CONCLUSION

The proposed types of treatment on the Pasang Kayu - Baras Road section are Preventive treatment with an average value of 3.7, Minor Rehab with an average value of 5.4 and Major Rehab with a value of 8.8. For the PCI survey analysis, Preventive Treatment was obtained with an average value of 87.5, Minor Rehab with an average value of 65.3 and Major Rehab with an average value of 27.5. For the analysis of the deflection survey, a value of > 0.4 was obtained so that the treatment was Major Rehab. The results of traffic data analysis obtained a CESA4 value of 4,059 x 106 and a CESA5 value of 5,546 x 106. The results of calculating the thickness of the pavement were obtained for preventive treatment using a thin layer of asphalt concrete (LTBA) with a thickness of 3 cm. Minor rehabilitation treatment on this road section used Asphalt Concrete Wearing Course (AC-WC) with a thickness variation of 5-7 cm. Major rehabilitation on the section. This road uses Asphalt Concrete Wearing Course (AC-WC) with a thickness variation of 4-5 cm, Asphalt Concrete Binder Course (AC-BC) with a thickness variation of 6-8 cm and Asphalt Concrete Binder Course Levling (AC-BC Lev.) with 4 cm thick.

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