FUNCTIONAL PERFORMANCE ASSESSMENT AND METHOD DEVELOPMENT OF FLEXIBLE ROAD PAVEMENT IN INDONESIA NATIONAL ROAD

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Abstract

Pavement quality can be maintained by assessing its performance both structurally and functionally. This study aims on knowing pavement functional performance in Indonesia focus on flexible pavement road, develop the utilization of provided data in various assessment methods and give reasonable recommendation on current Indonesia practice. The method covers pavement performance analysis uses the combination of International Roughness Index and Surface Distress Index, and try the implementation of other method such as Present Serviceability Index, Pavement Condition Rating, as well as generating Remaining Service Life. The results reveal that Present Serviceability Index gives lower performance thus generate earlier warning toward road maintenance compared to International Roughness Index and Surface Distress Index. On the contrary, Pavement Condition Rating gives higher performance caused by limited data which leaded from discrepancy in distress record. Remaining Service Life results are vary depending either on loads or pavement deflection.

Keywords: flexible pavement, pavement performance, road maintenance, pavement deflection

Abstrak

Kualitas perkerasan jalan dapat dipelihara secara rutin dengan menilai kinerjanya, secara struktural maupun fungsional. Penilitian ini bertujuan untuk mengetahui kinerja fungsional perkerasan lentur di ruas jalan nasional Indonesia, mengembangkan pemanfaatan data survei yang tersedia dalam berbagai metode penilaian, dan memberikan rekomendasi pada perbaikan sistem yang berlaku saat ini. Metode yang dibahas dalam studi ini meliputi analisis kinerja perkerasan dengan metode gabungan International Roughness Index and Surface Distress Index, kemudian mencoba metode lain seperti metode Present Serviceability Index dan Pavement Condition Rating, serta Remaining Service Life. Hasil analisis menunjukkan bahwa penilaian kinerja dengan metode Present Serviceability Index memberikan hasil kinerja yang lebih rendah, sehingga memberikan peringatan lebih awal untuk perbaikan jalan dibandingkan dengan metode kombinasi International Roughness Index and Surface Distress Index. Sebaliknya, metode Pavement Condition Rating memberikan hasil kinerja yang lebih baik, yang disebabkan oleh keterbatasan data kerusakan jalan yang dapat mempengaruhi keandalan hasil analisis. Metode Remaining Service Life memberi hasil yang bervariasi bergantung pada beban dan lendutan perkerasan.

Kata-kata kunci: perkerasan lentur, kinerja perkerasan, pemeliharaan jalan, lendutan perkerasan

INTRODUCTION

National road network is known to have primary role in transporting people and goods for long distance journey. Ministry of Public Works and Housing Indonesia asserted that more than 80% freight traffic and more than 82% people traffic use road network for mobilization. Therefore, road infrastructures need to be maintained well so that the economic growth targets could be achieved..

As to date, Indonesia road network condition is assessed frequently just by using two indicators, International Roughness Index (IRI) and Surface Distress Index (SDI). The method merely considers the usage of roughness and surface distress data obtained from annual survey held by Ministry of Public Works and Housing in each local area for determining the recommended road maintenance. However, in order to increase reliability of the current assessment method, similar assessment can be applied into several different methods so as the final result can be distinguished each other.

For further consideration, the current bank data of annual survey conducted will be more beneficial if it can be processed using another method as a comparison. It is also become more meaningful if it can accommodate prediction on upcoming planning and budgeting as a preparation toward the future maintenance. To overcome the situation, the concept of Remaining Service Life (RSL) is perceived to be proper in helping decision maker to estimate long-term condition of pavement, for instance by considering several structural factors and traffic volume passing by over the road sections observed.

Particular limitations are taken into account for supporting the discussion of this study tailored with the availability of continuous data so as to get relevant correlation in each step of assessment. Several limitations intended are:

1) Study case is located in Central Java Province in national road segment with focus on 5 segments chosen for 1 km length in each segment.
2) All road identified uses flexible pavement type.
3) Pavement performance is analysed merely utilising provided data from Ministry of Public Works and Housing such as Roughness Data, Road Condition Survey (RCS) Data, Traffic Data and Deflection Data.
4) Performance assessment are conducted in 3 ways through combination IRI (International Roughness Index)-SDI (Surface Distress Index), PSI (Present Serviceability Index) and PCR (Pavement Condition Rating).
5) Remaining Service Life is calculated by considering Traffic Data with the support of Deflection Data.

Indonesia Pavement Performance Assessment

For the term of maintenance applied in Indonesia to increase pavement performance, two survey results are mainly used as consideration by using combination between two indicators i.e. roughness value (stated with IRI) and distress value (stated with SDI) value. IRI value is derived from roughness survey with NAASRA method. While Surface Distress Index (SDI) is defined as score of Road Condition Survey (RCS) based on total area of cracks, average crack width, total number of potholes and average depth of rutting wheel. The combination between IRI and SDI is used to determine the damage level of certain segment of pavement as shown in Table 1.

Table 1 Road Condition Matrix

IRI (m/km)	Surface Distress Index (SDI)			
	< 50	50–100	100–150	> 150
< 4	Good	Fair	Fair	Light Damage
4–8	Fair	Fair	Light Damage	Light Damage
8–12	Light Damage	Light Damage	Light Damage	Heavy Damage
> 12	Heavy Damage	Heavy Damage	Heavy Damage	Heavy Damage

After pavement severity has been determined, an appropriate maintenance should be delivered so that optimum pavement performance can be achieved. Detail field works for the preservation is explained in Table 2.

Table 2 Maintenance Determination Matrix

	Value					
IRI	< 3	3–4	4–6	6–8	8–12	> 12
SDI	0–30	30–50	50–80	80–100	100–150	> 150
Action	Routine	Condition Routine	Periodic	Minor Rehab	Major Rehab	Reconstruction

Present Serviceability Index

Present Serviceability Index is defined as a concept of correlation between road users' opinion with roughness measurement and road distress. The number rating can be used to determine the appropriate maintenance by using the term of Table 4.

Table 3 Serviceability Rating (Huang, 2004)

Value	0–1	1–2	2–3	3–4	4–5
Rating	Very Poor	Poor	Fair	Good	Very Good

In order to simplify the method in obtaining PSI, a model to predict PSI merely from roughness indicator through IRI value both for flexible and rigid pavement (NCHRP, 2001) was developed. For flexible pavement, PSI is generated from IRI function with equation as follows:

PSI = 5 - 0.2397x^4 + 1.771x^3 - 1.4045x^2 - 1.5803x^

x = log (1 + SV)

SV = 2.2704 $(IRI)^2$

Pavement Condition Rating Assessment

Pavement Condition Rating (PCR) is one of many distress-based ratings that examine overall condition of road pavement in 13 different distresses i.e. raveling, bleeding, patching, debonding, crack sealing deficiency, rutting, settlement, potholes, wheel track cracking, transverse cracking, longitudinal cracking, edge cracking, and thermal cracking. The models for computing PCR is based on mathematical expression for PCR as follows:

$$PCR = 100 - \sum_{I=1}^{n} Deduct\ i \tag{1}$$

with:
n = number of distress identified;
Deduct = (weight of distress)*(weight for severity)*(weight for extent).

Shortly, PCR is generated from the subtraction of 100 with sum of all distress value. Description about pavement condition in certain range of PCR value is illustrated with Table 3.

Table 4 Pavement Condition Rating (PCR) Scale (Balla, 2010)

Value	0–40	40–55	55–65	65–75	75–90	90–100
Rating	Very Poor	Poor	Fair to Poor	Fair	Good	Very Good

Correlation

Correlation between each aspect is analyzed by inputting average value of each index with the support of Microsoft Excel program. In order to give simple estimation toward correlation coefficient, Table 5 can be used as a measurement.

Table 5 Interpretation on Coefficient Correlation (Guilford, 1956)

Coefficient Interval	0,00–0,20	0,21–0,40	0,41–0,70	0,71–0,90	0,90–1,00
Correlation	Very Low	Low	Moderate	Strong	Very Strong

DISCUSSION AND ANALYSIS

Research Location

The study location addressed to several segment scattered along North Coast Line (Pantura) of Central Java Province as seen in Figure 1, consisting of Bts. Kota Batang–Bts. Kab. Kendal, Bts. Kota Kendal–Bts. Kota Semarang, Bts. Kota Semarang–Bts. Kota Demak, Trengguli–Bts. Kab. Demak/Kudus, and Sp. 3 Lingkar Kudus Timur–Bts. Kab. Pati. The data of the roads are presented in Table 6.

Figure 1 National Road Map of Central Java

Table 6 Data of Road Pavement Type and Size

Road Status	Arterial	
Traffic Class	A	
Traffic Growth	5%	
Road width	14 m	
Number of Lane	4 lanes	
Pavement Type	Flexible Pavement	
Layer Thickness	Asphalt Concrete	18 cm
	Sub-base	55 cm
	Subgrade	unlimited

Assessment of Indonesia National Road Pavement Performance

Indonesia road pavement is assessed through a method by combining IRI and SDI value. IRI value is generated from roughness survey while SDI value is taken from road condition survey observed every 100 m in each road section. IRI is already obtained directly from roughness survey while SDI value should be calculated in advance by using reference based on code of practice No. SDM-03/RCS about Road Condition Survey. Figure 2 and Figure 3 summarised the result given from the analysis. Briefly, it can be stated that most road is in fair condition and, therefore, need periodic maintenance.

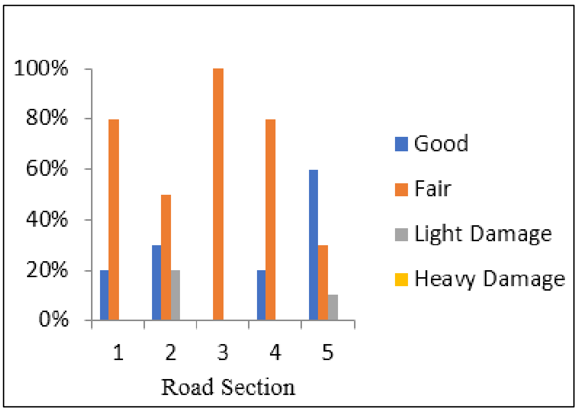


Figure 2 Percentage of Road Condition

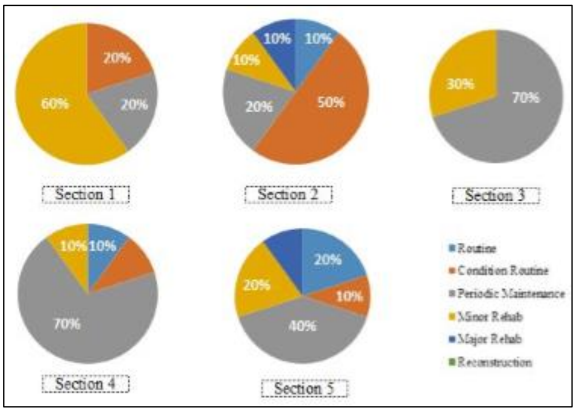


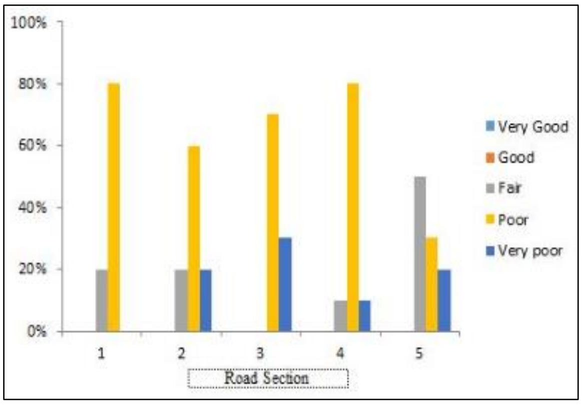
Figure 3 Percentage of Maintenance

Pavement Serviceability Index Analysis

In this study, the analysis of Present Serviceability Index is conducted using a methord presented in NCHRP (2001). Using the PSI method, most roads indicate poor or lower condition compared to IRI-SDI method. Consequently, major rehabilitation is required in all road segments.

Pavement Condition Rating Analysis

After a comprehensive analysis, PCR result is shown through Figure 6 and 7. It can be seen that road condition produced by PCR method categorised in high performance such in good level. This is significantly contrast with the performance resulted from previous methods that stated mostly poor condition almost in all road section. It is apparently caused by the small coverage of data processed with PCR method thus affecting the final score result. The less distress analysed automatically means less actual distress occurred even though the fact may be different. The other distresses might be existed but are not included into the RCS variables thus they are not recorded.



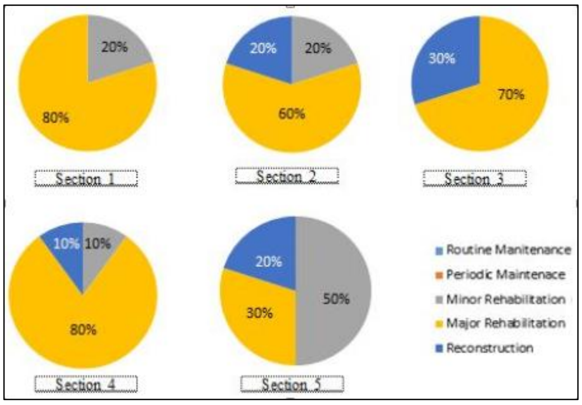
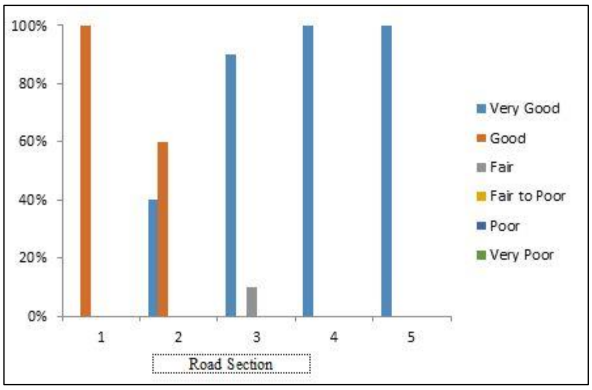


Figure 4 Percentage of Road Condition

Figure 5 Percentage of Maintenance



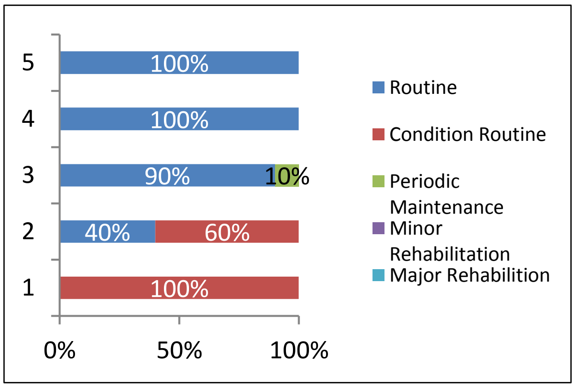


Figure 6 Percentage of Road Condition

Figure 7 Percentage of Road Maintenance

Remaining Service Life Analysis

Remaining Service Life analysis can be accomplished using several steps. The process in obtaining RSL is divided into two phases. The first phase related to deflection data. In this study, pavement thickness is assumed to be similar from one to another, 18 cm or 180 mm. Secondly pavement temperature while FWD load is applied is known as 31 Celsius degree, while pavement standard temperature in daylight for Indonesia is determined as 41 Celsius degree based on Indonesia Road Design Manual (2013). Both temperatures are stretched into the graph resulting on correction factor 1.38 as seen on Figure 8. Correction factor 1.38 is used to be multiplied with each dinitial and resulting on dcorrection. After that, all dcorrected within 1000 meter road length (one section) is calculated for its average. An example of the calculation is written in Table 7.

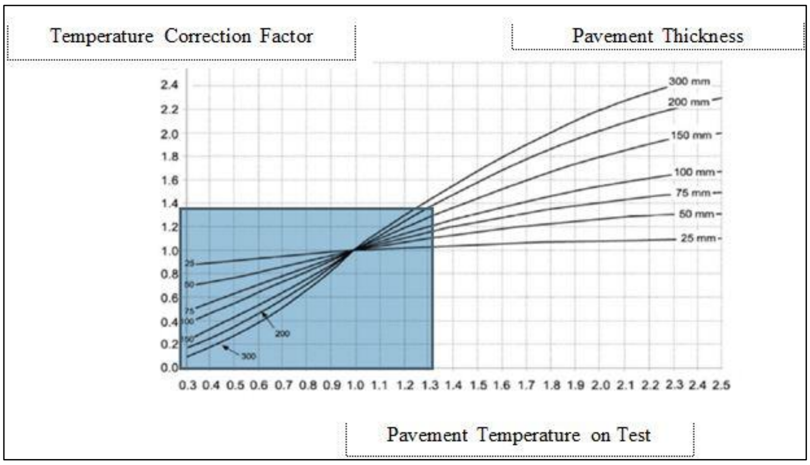


Figure 8 Corrected Temperatures for Deflection

Table 7 Deflection Data Analysis

Section 1	$d_{initial}$ (Micron)	$d_{initial}$ (mm)	$d_{corrected}$ (mm)	$d_{average}$ (mm)
Bts. Kota Batang - Bts. Kab. Kendal	162.10	0.162	0.22	0.17
	103.40	0.103	0.14	
	100.20	0.100	0.14	
	111.34	0.111	0.15	
	150.40	0.150	0.21	
		$\sum d^2$	0.16	
		$(\sum d)^2$	0.75	

The next step is finding standard deviation for each road section. By using manual calculation, the standard deviation of all road section can be obtained simultaneously.

$$s = \sqrt{\frac{ns(\sum_1^{ns} d^2) - (\sum_1^{ns} d)^2}{ns(ns-1)}} \tag{2}$$

$$s = \sqrt{\frac{5*(0.16)-0.75}{5(5-1)}} = 0.04$$

Standard deviation of each section is then used for calculating d_{rep} for arterial road.

$$d_{rep} = d_{average} + 2s \tag{3}$$

$$d_{rep} = 0.17 + 2*0.04$$

$$d_{rep} = 0.252$$

The value of d_{rep} is inputted to d_{rep} equation for FWD device in order to obtain the value of designed CESA for further analysis, as follows:

$$d_{rep} = 17.004 \text{ x } CESA^{-0.2307} \tag{4}$$

$$0.252 = 17.004 \text{ x } CESA^{-0.2307}$$

$$\text{CESA} = 84,406,415$$

Using the same process, CESA of each road section is obtained and recapitulated in Table 8.

Table 8 Recapitulation of CESA in All Section

Section 1	CESA
Bts. Kota Batang - Bts. Kab. Kendal	84,406,415
Bts. Kota Kendal - Bts. Kota Semarang	9,527,240
Bts. Kota Semarang - Bts. Kota Demak	178,991,707
Trengguli - Bts. Kab. Demak/Kudus	114,397,835
Sp. 3 Lingkar Kudus Timur - Bts. Kab. Pati /Kudus	109,097,408

The next calculation is converting road traffic counting data into average daily traffic unit. Road traffic count data should be categorised into some categories from class 2 until 7c. Since the survey was delivered Class A arterial road in Tuesday, hence the multiply factor is 0.55. All number of each vehicle category is simply times to 0.55 resulting on Average Daily Traffic Data as seen in Table 9.

Then ADT numbers shall be converted into Equivalent Single Axle Load unit. The values involved in the conversion process are Vehicle Damage Factor, Distribution Lane, and Directional Split. Distribution Lane 0.8 is chosen due the number of lane, while Directional Split is chosen 0.5 since the roads are categorized as divided road with median. Short example of the calculation is presented as follows:

$$ESA4 = \sum AADT \ x \ VDF4 \ x \ DL \ x \ DD \quad (5)$$

$$\text{ESA4} = 474 * 0.3 * 0.8 * 0.5$$

$$\text{ESA4} = 57$$

Table 9 Average Daily Traffic Calculation

Vehicle Category	Segment 1	
	RTC	ADT
2	13,054	7,180
3	3,868	2,127
4	4,809	2,645
5a	861	474
5b	2,848	1,566
6a	3,834	2,109
6b	14,284	7,856
7a	7,804	4,292
7b	2,115	1,163
7c	3,083	1,696
Total	56,560	31,108

The same calculation is done for ESA5 considering VDF5 for all type and road section. The value of VDF4 and VDF5 is based on Indonesia Road Design Manual 2013. Table 10 shows calculation of Road Section 1 traffic from ADT to ESA4 and ESA5.

Table 10 Traffic Multiplier Calculation

Class	Segment 1		
	ADT	ESA4	ESA5
2	7,180	2,872	2,872
3	2,127	851	851
4	2,645	1,058	1,058
5a	474	57	38
5b	1,566	627	627
6a	2,109	675	675
6b	7,856	2,828	2,514
7a	4,292	13,048	19,229
7b	1,163	17,170	42,063
7c	1,696	20,551	47,275
	CESA4C/ESA5	59,736	117,201
	Traffic Multiplier = 1.96		

All road sections are subjected to Traffic Multiplier factor in order to be used in further calculation related to Remaining Service Life. The next step is calculating design life factor of each road section.

$$TMasphalt = CESA5 / CESA4 \quad \text{with: } CESA4 = ESA4 \times 365 \times R \tag{6}$$
$$TMasphalt = CESA5 / (ESA4 \times 365 \times R)$$
$$1.96 = 84{,}406{,}415 / (59{,}736 * 365 * R)$$
$$R = 1.97$$

Finally the Remaining Service Life of each section can be determined by using growth factor equation.

$$R = \frac{(1+i)^{UR}-1}{i} \tag{7}$$
$$1.97 = \frac{(1+5\%)^{UR}-1}{5\%}$$
$$UR = 1.93 \text{ years}$$

Table 11 Remaining Service Life of All Road Section

Section	ESAL4	TM	Day	CESAL5	Design Life Factor ®	Traffic growth	RSL
Bts. Kota Batang–Bts. Kab. Kendal	59,736	1.96	365	84,406,415	1.97	5%	1.93
Bts. Kota Kendal–Bts. Kota Semarang	6,211	1.56		9,527,240	2.70		2.59
Bts. Kota Semarang–Bts. Kota Demak	65,235	2.01		178,991,707	3.74		3.51
Trengguli–Bts. Kab. Demak/Kudus	50,609	1.97		114,397,835	3.15		3.00
Sp. 3 Lingkar Kudus Timur–Bts. Kab. Pati /Kudus	37,434	1.88		109,097,408	4.25		3.95

Overall result of prediction on Remaining Service Life is provided in Table 11. It can be found that high traffic volume which commonly known as the cause of road deterioration thus resulting lower pavement life, in this case, it becomes an odd phenomenon where lower ESAL (represent less traffic) yielded lower RSL while another road with higher ESAL generated better RSL. This anomaly is basically affected by the value of deflection occurred in each section. If deflection is significantly higher, it can influence final result of RSL to be poor and vice versa, if deflection is small it could lead on higher RSL even though traffic was known to be high.

Correlation between RSL and All Assessment Method

By using the operation of Microsoft Excel program, correlation between RSL and and all assessment rating is created. The summary is available on Table 12.

Table 12 Correlation between RSL and All Assessment Method

RSL	IRI	SDI	PSI	PCR
1.93	4.8	72	1.55	82
2.59	5.0	18	1.53	93
3.51	5.4	20	1.33	94
3.00	4.7	3	1.60	99
3.95	4.5	1	1.67	99
Type	Polynomial	Exponential	Polynomial	Exponential
y	$y = 7.85x^2 - 78.4x + 197.9$	y = 3.4992e^ - 0.008x	$y = 52.133x^2 - 155.4x + 118$	y = 0.1096e^0.0351x
R^2	0.780	0.727	0.8514	0.7747

In addition, comparison of maintenance method is summarized to see how different method affecting the result of suggested maintenance. The average number of each section is given in Table 13.

Table 13 Comparison of Maintenance Resulted

Maintenance	IRI SDI	PSI	PCR
Routine	8%	0%	68%
Condition Routine	18%	0%	32%
Periodic Maintenance	44%	0%	0%
Minor Rehabilitation	26%	20%	0%
Major Rehabilitation	4%	64%	0%
Reconstruction	0%	16%	0%
Total	100%	100%	100%

PSI gives the earliest warning compared to other method. PCR gives higher performance caused by limited data to be inputted into PCR calculation.

Recommendation on Indonesia Practice

1) Indonesia pavement performance assessment is better to be conducted by combining it with structural aspect therefore more preventive warning can be obtained thoroughly altogether either from road function or road strength.
2) It can also be recommended the consideration toward other functional aspect of pavement can be enclosed in the analysis, for example the implementation of skid resistance, so that complete assessment can be achieved.

3) The quality of manual survey can be intensified by not only relies on manual human-based survey but should be gradually upgraded by using machine-based survey device that can record road condition precisely to its original condition, completed with location detector thus may create sustainable locational referencing
4) Instead of considering the current assessment method, it is better for Indonesia to take into account of another pavement performance indicator for implementation which has not been previously used such as PSI, PCR or PCI since the method is proven to give earlier warning toward pavement condition in Indonesia.
5) Due to anomaly result on PCR method, thus in the next implementation, this method still can be considered to be used provided that complete and detail data toward distress and its severity and frequency is available over many kind of distress occurred in road pavement.

CONCLUSION

After all assessment method has been comprehensively analysed, several conclusions can be presented as follows:

1) From the analysis, Indonesia national road pavement assessment toward five road sections in North Coast Line-Central Java reveals that 4% of road length needs major rehabilitation, while minor rehabilitation is required for 26% of the observed road. The highest maintenance would be periodic maintenance for 44%, ended up by condition routine and routine maintenance for 18% and 8% respectively.
2) On the other hand, Present Serviceability Index generated significant difference compared to the previous method. From the analysis it can be perceived that there is 16% reconstruction needed within the five road sections. Major rehabilitation even increases steeply on 64%, more than half of the whole road sections. The lowest maintenance level subjected to minor rehabilitation for 20%.
3) In this case, Pavement Condition Rating gives drastic higher performance rating toward all road section compared to the previous methods used. This oddity is caused by limited data available from Road Condition Survey that can be inputted into PCR calculation.
4) Despite of considering PCR anomaly result, significant difference between the methods used gives conclusion that Indonesia method tends to create later warning compared to another method such PSI. This condition might be similarly happened toward PCR if all distress type is comprehensively recorded.
5) Various Remaining Service Life measured on the five road sections reveals that Section 1 only has 1.93 years left for saving its life, followed by Section 2 with 2.59 years RSL. Section 4 RSL is higher for 3.00 years but still needs speedy recovery immediately. The two highest RSL is owned by Section 3 for 3.51 years and Section 5

for 3.95 years that even might be seen fine but should not be carelessly ignore required maintenance in order to prevent worse condition

6) The correlation between RSL and the method used illustrated that all aspect IRI, SDI, PSI or PCR has quite good correlation with RSL.
7) High traffic volume which commonly known as the cause of road deterioration thus resulting lower pavement life. In this case, it becomes an odd phenomenon where lower ESAL (represent less traffic) yielded lower RSL while another road with higher ESAL generated better RSL. This anomaly is basically affected by the value of deflection occurred in each section. If deflection is significantly higher, it can influence final result of RSL to be poor and vice versa, if deflection is small it could lead on higher RSL even though traffic was known to be high.
8) Several recommendations are given in order to establish current Indonesia practice to be more reliable implemented in the next period such as detail data collection, operation on machine-based survey.

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