Level vulnerability damage of pavement using Pavement Condition Index method

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Abstract. This study aims to assess the vulnerability of road pavement damage using the Pavement Condition Index (PCI) method, including the direction of handling pavement road damage. Assessment of the level of road surface damage is based on the type of damage, the degree of damage, and amount of damage. Field observations and surveys were conducted on several Collector roads in Kendari. The mean PCI score as an indicator of damage to the Mokodompit road segment shows moderate damage conditions with a mean the value PCIaverage = 53 and surface damage area = 34.419% and the countermeasures according to the Bina Marga Standard recommend patching and adding pavement layers. Assessment of vulnerabilities Manunggal road damage indicates moderate damage to the value PCIaverage = 49 With the extent of surface damage = 34,419% and the response according to Standard by filling a crack with a mixture of liquid asphalt and sand.

1 Introduction

Road transport infrastructure plays an important role in supporting all human activities, the availability of adequate road network and able to connect the flow of transportation of goods and services more efficient and cheaper than other areas to enter into the city or vice versa. And the increase of traffic volume in each road segment is not accompanied by the addition of road length. Until now, Indonesia has only 296,968 km of road length (Minister of PUPR Basuki Hadimuljono, 2016), on the other hand the total road damage in Indonesia along 1,300 Km (2016) is a condition of vulnerable road damage. This is due to several physical factors / structures, environmental factors, social, and economic factors that badly affect the efforts to prevent and overcome the damage paved roads.

Similarly, the state of highways in Kendari city in post-flood 2013 and 2017 many broken collector roads, among others, on the road along the road Mokodompit 2.3 Km and, among others, on the road along the road Mokodompit 2.3 Km and Manunggal road along the 1.6 km suffered damages, including mild or severe damageThe road damage is quite disturbing the smooth flow of traffic there, head towards the city of Kendari and vice versa. The cause of pavement damage on this road segment is due to poor subgrade, excessive vehicle loads, unfavorable climatic influences (the amount of rainfall), Road materials that do not meet established standards, poor implementation of work and unavailability of drainage on the left and right side of 2 (two) road segments.

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Observing the strategic issues of road pavement damage, this study aims to assess the vulnerability of pavement damage by applying the method Pavement Condition Index and seek guidance for handling the damage of pavement layer and provide scientific input to local government especially related technical institution, so that in the implementation of repair of road damage will get more optimal result. In this study, we specifically surveyed and assessed the damage of pavement on the type of crack damage, wavy, decreased road shoulder, transverse and lengthwise damage, damage caused by water puddle and pothole damage.

2 Literature review

Road infrastructure in all areas will suffer damage, disturbance or deterioration of the condition, its quality when used to serve the activities of transporting people (passengers) or goods and services [1]. It is very necessary for pavement construction handling well, especially bending Pavement construction, including the building of new pavement or road improvements should be handling maintenance / rehabilitation periodically. In this condition the ability of the subgrade to support the load can be said to be very small. While the vehicle will still pass, due to the burden of vehicles pressing the surface of the road then there is release of the bond between the grains on the ground, and will cause the surface of the road to be broken and disappear. Well this is the initial process of road damage. Therefore almost every rainy season will appear many roads are damaged, ranging from a small hole to a very large hole. This results from an imperfect drainage condition.

According Sukirman [2] generally damage pavement effect to the road construction is not only caused by one factor, but a combination of many factor that are interconnected. The damage may be caused by:

1. Traffic, that can be an increase in load and load repetition and fatigue cracks load, resulted in layers of asphalt as well as deformation at all levels
2. Water can come from rain water and road drainage system is not good.
3. Pavement construction materials caused by the nature of the material it self or can be caused by a processing system that is not good.
4. Climate because Indonesia has tropical climate, where air temperature and rainfall are generally high, which can be one cause of road damage.
5. Unstable ground ground conditions caused by poorly implemented systems, or caused by subgrade poorly ground nature.
6. The compaction process over the underlying soil layers.
7. Damage to the pavement can occur due to vehicle load, on each layer of pavement voltage and strain occur.

2.1 Concept pavement condition index (PCI)

To determine the value of the Pavement Condition Index is the level of pavement surface conditions and Measure the usefuly of function referring to the conditions and damage to the pavement surface. PCI was developed to provide an index of pavement structure integrity and its surface layer conditions. The damage data obtained can provide information on the causes of damage and whether the damage is related to the load or climate. By conducting periodic condition surveys, the pavement condition information can be useful for predicting future road pavement performance, but can also be used as a more detailed and focused measurement input. By looking at various types of damage to the pavement construction, the Pavement Condition Index method classifies the types of pavement damage as follows:

a) Deformation Damage is wavy damage, groove, collapse, sungkur, fluffy, bumps and descend.
b) Cracked Damage is the longitudinal, transverse, diagonal, block and crocodile damage.
c) Damage to surface texture is damage to loose granules, bledding, slippery aggregates, and exfoliation.
d) Damage to the pothole is damage to patches and railroad crosses.
e) Damage at the edge of the pavement is damage; Edge crack/break and decline shoulder.

This PCI method is a numerical index whose value ranges from 0 to 100. A value of 0 indicates that the pavement is very damaged and the value 100 indicates perfect pavement. This PCI method is based on visual pavement condition survey results by looking at the type of damage, level of damage, and size identified during the survey of the condition. The degree of damage used in the calculation of the Pavement Condition Index method is *low severity level (L), medium severity level (M),* dan *high severity level (H).*

Table 1 Relationship between PCI value and road conditions

Value PCI	Damage Conditions
0 - 10	*failer*
11 - 25	*Very Poor*
26 - 40	*Poor*
41 - 55	*Fair*
56 - 70	*Good*
71 - 85	*Very Good*
86 - 100	*Excellent*

2.2 Assesment pavement condition index (PCI)

In analyzing road damage by PCI method is done by sequential way as follows [3-9]:

2.2.1 Density

Density is the percentage of area or total length of one type of damage to the total width or length of the road section measured in meters. Thus, the damage density can be expressed by the Equation Value equation (Deduct Value, DV).

The formula looks for density values:

$$Density = Ad/As \times 100\ \%\ \text{Atau} \quad (1)$$

$$Density = Ld/As \times 100\ \% \quad (2)$$

Where :
Ad = Total damage area for each level of damage (m^2)
Ld = Total length of damage type for each level of damage (m)
As = The total area of the segment unit (m^2)

2.2.2 Reduced value (DV)

The Reduction Value is a deduction value for each type of damage obtained from the density relation curve and the severity of the damage, is Low (L) is the degree of minor damage, medium (M) Moderate damage rate, dan Hight (H) high levels of damage.

2.2.3 Total deduct value (TDV)

Total Deduct Value (TDV) is the total value of the individual Reductions for each type of damage and the extent of damage existing in a research unit.

2.2.4 Finding Value q

The requirement to determine the value of q is determined by the amount of the individual Reducer value greater than 5 in each segment of the road segment under study.

2.2.5 Calculating value correct deduct value

CDV value can be sought after the value of q is known by summing the Reduce value Further deducting the amount of the subtraction value in the graphic image CDV corresponds to the value of q obtained.

2.2.6 Calculating the value of pavement conditions

After the CDV is obtained, the PCI for each sample unit is calculated using the equation:

$$PCIs = 100 - CDV \tag{3}$$

The PCI value of pavement as a whole on certain road segments is:

$$PCIf = \frac{\sum PCI(s)}{N} \tag{4}$$

Where :

$\sum PCI(s)$ = PCI for each segment unit
CDV = CDV of each sample unit.
PCIf = Value PCI average of all research areas.
PCIs = Value PCI For each sample unit
N = Number of sample units

2.2.7 Corrected deduct value (CDV)

Dikoreksi Deduct Value (CDV) Obtained from the curve of the relationship between the value of TDV with the value of CDV with the selection of curve curve in accordance with the number of individual values of deduct value that has a value greater than 2.

2.2.8 Classification of pavement quality

Value of (PCI) for each research unit can be known pavement unit quality pavement segment based on certain condition that is excellent, very good, good, fair, poor, very poor and failed [10].

2.3 Standard of handling of road damage

The handling for road damage in this study is guided by the Road Maintenance Manual [11] issued by the Directorate of Highways and the Routine Maintenance Manual for National Roads and Provincial Road Volume II Title Standard Repair Method [12] issued by the Directorate of Highways. Both manuals describe all types of damage, causes of road damage, the process of handling road damage and road maintenance processes.

3 Result

3.1 Assessment rate of road damage

Based on road damage assessment using PCI method on Mokodompit road and Manunggal road segment with the formula: PCI - 100 - CDVmax obtained average PCI value on both roads there is difference of value of road damage condition in table 2 as follows:

Table 2. Result of calculation of road damage condition by PCI method

No	Station (m)	Mokodompit Road		Manunggal Road	
		Value PCI	Road Condition	Value PCI	kondisi jalan
1.	0 + 000 - 0 + 100	38	Poor	48	Fair
2.	0 + 100 - 0 + 200	90	Perfect	68	good
3.	0 + 200 - 0 + 300	25	Poor	40	Fair
4.	0 + 300 - 0 + 400	42	Fair	32	Poor
5.	0 + 400 - 0 + 500	81	Very Good	56	Good
6.	0 + 500 - 0 + 600	38	Poor	41	Poor
7.	0 + 600 - 0 + 700	68	Good	36	Poor
8.	0 + 700 - 0 + 800	88	Perfect	35	Poor
9.	0 + 800 - 0 + 900	65	Good	78	Very Good
10.	0 + 900 - 1 + 000	20	Very Poor	65	Good
11.	1 + 000 - 1 + 100	78	Very Good	36	Poor
12.	1 + 100 - 1 + 200	66	Good	31	Poor
13.	1 + 200 - 1 + 300	35	Poor	69	Good
14.	1 + 300 - 1 + 400	51	fair	57	Good
15.	1 + 400 - 1 + 500	40	Fair	70	Good
16.	1 + 500 - 1 + 600	80	Very Good	24	Poor
17.	1 + 600 - 1 + 700	30	Poor		
18.	1 + 700 - 1 + 800	34	Poor		
19.	1 + 800 - 1 + 900	68	Good		
20.	1 + 900 - 2 + 000	34	Poor		
21.	2 + 000 - 2 + 100	47	Fair		
22.	2 + 100 - 2 + 200	51	Fair		
23.	3 + 200 - 2 + 300	40	Fair		
amount		***1209***		***786***	
Average PCI value for ***road. Mokodompit*** is = $\sum PCI / n = 1209 / 23 = 52,56 = \mathbf{53}$ With condition value = ***Fair***					
Average PCI value for ***road. Manunggal*** is = $\sum PCI / n = 786 / 16 = 49,125 = \mathbf{49}$ With condition value = ***Fair***					

3.2 Types and percentage of road damage level

Type of damage that occurred on the road Mokodompit damage pothole with damage area of 39.625m2 with the percentage of damage 34.419%, alligator cracking cracks with damage area of 14.875m2 with the percentage of damage 12.921%, patches with an area of damage of 8,688 M2 with damage percentage 7,547%, roadside crack with damage area equal to 11.000m2 with percentage of damage 9,555%, weathering and loose grane with damage area 3,75 m2 with damage percentage 3,257%, city-box crack with damage area 13 , 75m2 with damage percentage 11,943% , and damage of rutting with damage area equal to 23,438m2 with damage percentage 20,359%. But the most dominant type of damage is hole damage (pothole).

As for the road of Manunggal there is damage to the type of hole (pothole) with damage area of 39,625 m2 with damage percentage 34,419%, crack lengthwise or transverse with damage area equal to 39,625 m2 with damage percentage 34,419%, alligator cracking 14,875m2 with damage percentage 12,921%, road shoulder damage with damage area equal to 39,625m2 with percentage of damage 34,419%, patch with damage area 8,688m2 with damage percentage 7,547%, crack edge / side of road with damage area equal to 11.000m2 with percentage 9,555% damage, rutting with damage area equal to 23,438m2 with damage percentage 20,359% and damage of basin with damage area equal to 39,625m2 with damage percentage 34,419%, but the most dominant type of damage is damage crack length / transverse.

Table 3. Result of calculation of road damage condition by PCI method

No	Type of Damage	Mokodompit Road		Manunggal Road	
		Area (m2)	% kerusakan	Area (m2)	% kerusakan
1.	Hole (*pothole*)	39,625	34,419	13,87	19,403
2.	Cracks extend and transverse	----	----	15,00	20,984
3.	A*lligator cracking*	14,875	12,921	14,55	20,354
4.	Path / descent of road shoulder	----	----	5,75	8,044
5.	Patch Roadside / side fracture	8,688	7,547	7,313	10,230
6.	Roadside / side fracture	11,000	9,555	3,25	4,547
7.	Weathering and granular discharges	3,75	3,257	----	----
8.	Crack the boxes	13,75	11,943	----	----
9.	*rutting*	23,438	20,359	9,75	13,640
10.	Basin	----	----	2,00	2,798
Amount		***115,126***	***100***	***71,483***	***100***

On both sides of the road that suffered the most severe damage and need serious attention, so that damage does not increase if not quickly repaired. Damage to both roads causing inconvenience for motorists who use the road, either damaged holes light, medium or heavy hole. This occurs as a result of the development of other types of damage that are not immediately addressed, the effects of weather (especially rain/ flood) and vehicle traffic that exceeds the implied load that accelerates the formation of holes.

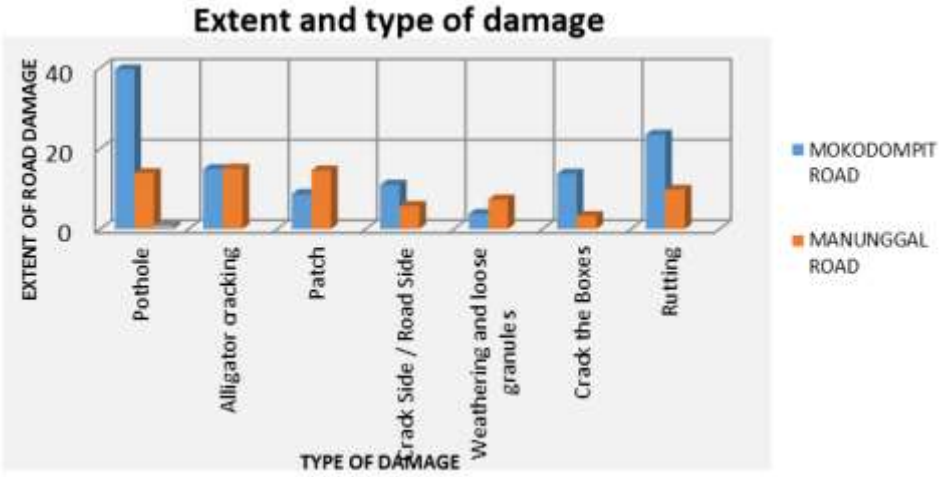

Fig.1. Area and type of road damage

3.3 Direction for improvement and handling of road damage

Based on the analysis with PCI method, the condition of the road pavement of each segment unit obtained in the field can be used to know the most vulnerable road pavement damage and to determine the priority of handling the damage by prioritizing the damage handling on the road pavement which has a pavement damage condition value which Greatest.

On Mokodompit road, the most vulnerable type of damage is damage of hole 39,625 m2 with damage percentage 34,419%, repair effort or handling according to Bina Marga regulation (1993) the corrective action is by hole patching and addition of pavement layer. While on Manunggal road type of the most vulnerable damage is the damage of crack lengthwise/transverse with damage area equal to 39,625 m2 and percentage of damage 34,419% improvement effort done by filling gap with liquid asphalt mixture and sand.

4 Conclusion

Based on the analysis results obtained conclusion as follows:

1. The average PCI score as an indicator of damage to the Mokodompit road segment showed moderate damage conditions with an average PCI value = 53 and surface damage area = 34.419% and the Assessors of susceptibility to road damage indicated moderate damage with a mean PCI value = 49 with area surface damage = 34.419%.
2. Countermeasures for Mokodompit road according to Bina Marga standard recommends to patch and add pavement layer and handling for Manunggal road by filling crack gap with liquid asphalt mixture and sand.
3. The practical implications of assessing the vulnerability level of pavement damage on collector roads become a consideration in the formulation of the improvement and maintenance of urban collector roads.

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Time	Movement of Vehicles from Land Use (V_i)	Continuous Flow Movement ($V_{eksternal}$)	Total Volume Movement	Capacity	Ratio V/C	LOS
06.00 - 07.00	11739	5663	17402.0	5023.2	3.46	F
07.00 - 08.00	8815	5887	14701.5	5023.2	2.93	F
08.00 - 09.00	8199	5093	13292.1	5023.2	2.65	F
09.00 - 10.00	7977	4663	12640.2	5023.2	2.52	F
10.00 - 11.00	7970	4404	12374.1	5023.2	2.46	F
11.00 - 12.00	7640	4037	11677.4	5023.2	2.32	F
12.00 - 13.00	8047	3978	12025.2	5023.2	2.39	F
13.00 - 14.00	8313	4008	12321.2	5023.2	2.45	F
14.00 - 15.00	7887	4183	12070.0	5023.2	2.40	F
15.00 - 16.00	7804	4386	12190.7	5023.2	2.43	F
16.00 - 17.00	11553	4498	16051.1	5023.2	3.20	F
17.00 - 18.00	12253	4866	17118.8	5023.2	3.41	F
18.00 - 19.00	11777	4579	16355.9	5023.2	3.26	F
19.00 - 20.00	7578	4040	11617.5	5023.2	2.31	F