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PAVEMENT CONDITION INDEX (PCI) ANALYSIS IN MEASURING ROAD DAMAGE LEVELS AND ITS EFFECT ON VEHICLE SPEED IN LEMBAR-SEKOTONG-LOMBOK BARAT ROAD SEGMENT

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ABSTRACT

As a means of transportation, the position and role of the road network in essence concern the livelihoods of many people to maintain the sustainability and service quality of these roads. If the road section is damaged, it will have a significant impact on the condition of the traffic flow. Many road damages occur due to the high use of the road which causes a high volume of vehicles, overloaded vehicles, rainwater runoff or poor drainage systems and others. The Sheet-Sekotong-Pelangan road section is a provincial road section located in West Lombok Regency, NTB. This road segment has been damaged in several road segments and disrupted traffic flow so it requires handling. In this regard, the purpose of this study is to determine the level of road damage using the Pavement Condition Index (PCI) method and to determine the effect on vehicle speed and to find recommendations that are appropriate to the level of road damage. This study includes a visual survey to determine the condition of road damage and vehicle speed. The analysis used to determine the effect of road damage on vehicle speed is Simple Linear Regression. The results of the analysis show that the R square value is 0.893, which means that road damage has an influence on vehicle speed of 89.3%. Regression model y (vehicle speed) = 9.012 + 0.581x (PCI), which means that if the PCI 9.012 variable increases by 1 unit or 1%, the vehicle speed will increase by 0.581 units or by 58.1%. The lower the PCI value, the slower the vehicle speed will be. Conversely, the greater the PCI value, the faster the vehicle speed.

Keywords: *Pavement Condition Index (PCI), Vehicle Speed, Spot Speed, Handling Recommendations.*

Introduction

Roads are one of the elements of land transportation intended to facilitate the movement of people and/or goods. Roads are also a transportation infrastructure that has a vital function in the economic, social and cultural and environmental fields and is developed through a regional development approach in order to achieve balance and equity in inter-regional development, form and strengthen national unity, and form a spatial structure in order to realize national development goals [1]. As a means of transportation, the position and role of the road network in essence concern the livelihoods of many people to maintain the sustainability and service quality of these roads. If the road section is damaged, it will have a significant impact on the condition of the traffic flow. Many road damages occur due to high use of the road which causes high vehicle volume, overloaded vehicles, rainwater runoff or poor drainage systems and others. Road damage that occurs on several roads causes enormous losses, especially for road users such as long travel times, congestion, accidents, and others. In general, there are various causes for road damage, namely the design life of the road that has been passed, puddles of water on the road surface that cannot flow due to poor drainage, overloaded which causes the life of the road to be shorter than planned [2].

Likewise with the Lembar-Sekotong-Pelangan highway which is the status of a West Nusa Tenggara Province road section which has a length of 41.00 km and is a 2-lane 2-way (2/2 UD) type road and is a class III road based on the Letter Decree of the Governor of West Nusa Tenggara Number 620-351 of 2016 [3]. Concerning the Status of West Nusa Tenggara Provincial Roads. The Sheet-Sekotong-Pelangan highway is an alternative road from the Lembar Port to the Kuta Mandalika Special Economic Zone (KEK) in Central Lombok Regency, which means this road is an important road to support accessibility to tourist attractions to speed up the movement of people and or goods. Assessment of road conditions needs to be carried out periodically both for structural buildings and road auxiliary buildings. This road condition value will later be used as a reference to determine the type of evaluation program that must be carried out, whether it is an improvement program, periodic maintenance, or routine maintenance [4].

However, in the existing condition of the Lembar-Sekotong-Pelangan Highway, road damage was still encountered at several points of the road section. Specifically at STA 0-200, STA 600-800, STA 1600-1800,

STA 3600-3800, STA 4600-4800, STA 5000-5200, STA 14600-14800, and STA 15400-15600. The types of damage found were surface defects (disintegration), cracks, patch marks, holes and collapse. Therefore, this study wanted to find out how much influence the level of road damage has on the speed of vehicles crossing the Jalan Lembar Sekotong Pelangan to know the handling efforts [5].

Types of flexible pavement damage include: deformation, cracks, pavement edge damage, road surface texture damage, potholes, patching and utility cut patching [6]. Severity level is the level of damage for each type of damage. The level of damage used in calculating PCI is low severity level (L), medium severity level (M), and high severity level (H). In evaluating road damage using the Pavement Condition Index (PCI) method, things that need to be determined are the type of damage (distress type) and its cause, the level of damage (distress severity) and the amount of damage (distress amount). These parameters are used to determine the appropriate type of handling [7].

Handling Of Road Surface Pavement Construction , Routine Maintenance (Road Maintenance); Periodic Maintenance (Periodic Maintenance); Road Rehabilitation (Rehabilitation); Reconstruction (Upgrade) . The purpose of this study is to analyze the equipment condition index (PCI) in measuring the level of road damage and its effect on vehicle speed on the west sheet-sekotong-lombok road. [8]

Research Methods

This type of research is quantitative research, namely a systematic study of parts and phenomena and their relationships. The purpose of quantitative research is to develop and use mathematical models, theories and hypotheses related to natural phenomena [9], [10]. Quantitative research results in numbers, scales or levels of data. The quantitative research in this study was to determine the effect of the level of road damage on vehicle speed. The research begins by conducting a preliminary survey. At this stage data collection is carried out to identify problems and create problem boundaries. The next stage is to conduct a data survey to collect data analysis to achieve research objectives.

Primary data was obtained by making observations at the research location, including: the type of damage and vehicle speed at the research location. While secondary data as a support was obtained from the Office of Public Works and Spatial Planning of the Province of West Nusa Tenggara. Tools used in data collection survey activities include writing instruments, small whiteboards, tape measure (to measure the length and width of road damage), ruler (to measure the depth of gully and subsidence damage), observation form sheets. Stopwatch to look for average vehicle speed data and red flags for markers when surveying vehicle speed. [11], [12]

Data collection was carried out by direct survey to the research location on the Lembar-Sekotong-Pelangan Road Section at STA 0-200, STA 600-800, STA 1600-1800, STA 3600-3800, STA 4600-4800, STA 5000-5200, STA 14600-14800, and STA 15400-15600. Visual survey for road damage including type and level of damage. Vehicle speed survey using the spot speed method to determine the average vehicle speed. Data were analyzed using the SPSS 16.0 application. The research location is the Lembar-Sekotong-Pelangan Road Section which is a Provincial Road, as shown in Figure 1 below.

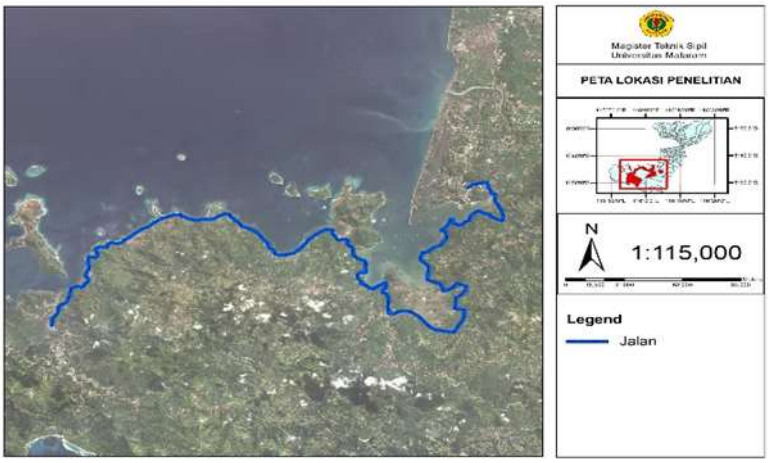

Figure 1. Research sites

Results and Discussion

Visual survey results The types of road damage that commonly occur on Jalan Lembar-Sekotong-Pelangan are alligator skin cracks, block cracks, subsidence, patches, potholes, and loose grain. Percentage of area per type of road damage found in STA 0-200 (Segment One), STA 600-800 (Segment Two), STA 1600-1800 (Segment Three), STA 3600-3800 (Segment Four), STA 4600-4800 (Segment Five), STA 5000-5200 (Segment Six), STA 14600-14800 (Segment Seven), and STA 15400-15600 (Segment Eight) on the Lembar-Sekotong-Pelangan Road section in Figure 2.

Figure 2. Area Percentage Per Damage Type

In Figure 2. It can be seen that the highest percentage of damage to alligator skin cracks is 31% and the lowest percentage of damage to block cracks is 2%. In Table 1. are the types of damage, the extent of the damage and the quality of the damage broken down per segment. In Figure 3 is the documentation of the results of a survey on the types of damage to alligator skin cracks and collapse.

Figure 3. Alligator Skin Cracking And Subsidence
Source: Survey Results (2022)

Figure 4. Patch Damage And Holes

Table 1. Extensive Data and Types of Damage

Segment	Damage Type	Extent and Quality of Damage(m^2)
1	Cracked Crocodile Skin	100 (H)
	Patch	30 (M)
	Hole	30 (M)
2	Cracked Crocodile Skin	60 (L)
	Hole	30 (L)
3	Cracked Crocodile Skin	90 (H)
	disappear	30 (M)
	Hole	30 (M)
4	Cracked Crocodile Skin	90 (H)
	Block Crack	60 (M)
	disappear	30 (M)
5	Cracked Crocodile Skin	60 (M)
	disappear	30 (L)
	Hole	30 (H)
6	Cracked Crocodile Skin	90 (H)
	disappear	30 (M)
	Patch	60 (M)
7	disappear	30 (L)
	Patch	60 (L)
8	disappear	30 (L)
	Patch	30 (L)

Vehicle Speed

The average vehicle speed in this study uses the spot speed method, spot speed is the instantaneous speed which is the average value of a series of instantaneous speeds of individual vehicles that cross certain points on a road section [13]. In Table 2. is the vehicle speed data per segment.

Table 2. Average Vehicle Speed

Segment	Motorcycle (km/jam)	Light Vehicles (km/jam)	Heavy Vehicle (km/jam)	Total Vehicles (km/jam)
1	28,84	25,33	18,96	25,05
2	32,34	32,62	29,36	32,03
3	22,22	22,13	18,65	21,43
4	31,99	32,39	32,23	32,16
5	29,99	29,98	30,96	30,05
6	33,69	33,75	32,83	33,65
7	65,44	62,11	60,26	63,54
8	66,23	60,46	60,28	63,47

Source: Survey Results (2022)

Based on Table 2. it can be seen in segment one that the highest average vehicle speed by type of vehicle is the average speed of a motorcycle, which is 28.84 km/hour. The highest average vehicle speed in the two light vehicle segments is 32.62 km/hour. The highest average vehicle speed in the three motorcycle segment is 22.22 km/hour. The highest average vehicle speed in the four light vehicle segments is 32.39 km/hour. The highest average vehicle speed in the five heavy vehicle segment is 30.96 km/hour. The average vehicle speed in the six motorcycle segment is 33.69 km/hour. The average speed of vehicles in the seven motorcycle segment is 65.44 km/hour. The average vehicle speed in the eight motorcycle segment is 66.23 km/hour. While the highest total average vehicle speed is in segment seven with an average vehicle speed of 63.54 km/hour.[14], [15]

Pavement Condition Index (PCI) Analysis

Pavement Condition Index (PCI) is a quick method to compare the overall condition of the pavement and the amount of rehabilitation needed [13]. In Table 3. is the PCI value per segment. The steps for conducting a PCI analysis are:

1. Degree of Damage (Density)

   Density or level of damage is the percentage of the area of a type of damage to the area of a unit segment that is measured in square meters or meters long. The density value of a type of damage is also distinguished based on the level of damage. The formula for finding the density value:

$$Density = \frac{Ad}{As} \text{ x } 100\%$$

or

$$Density = \frac{Ld}{As} \text{ x } 100\%$$

   with :

   Ad = total area of damage for each level of damage(m^2);

   Ld = the total length of the type of damage for each level of damage(m);

   As = segment unit total area(m^2). [16]

2. Dedeuct Value

   The deduct value is the reduction value for each type of damage obtained from the curve of the relationship between density and deduct value by entering the percentage of density in the graph for each type of damage, then drawing a vertical line until it intersects at the level of damage (low, medium, high) then At the intersection, a horizontal line is drawn and the deduct value will be obtained.

3. Total Deduct Value,TDV

   The total reduction value is the total amount of the reduction value in each sample unit or the total value of the individual deduct value for each type of damage and the level of damage that exists in a segment unit.

4. Corrected Deduct Value, CDV

   The corrected deduct value (CDV) is obtained from the relationship curve between the TDV value and the CDV value by selecting the curve according to the number of individual deduct values that have a value greater than 2.

5. PCI Value

   After the CDV value is obtained, the PCI value for each sample unit is calculated. This value uses a formula :

   PCI (s) = 100 – CDV

   where:

   PCI (s) = *Pavement Condition Index* sampel units;

   CDV = *Corrected Deduct Value* of sampel units.

   For the overall PCI value on the roads in this study location is shown by the formula:

   PCI = $\frac{\Sigma PCI\ (S)}{N}$

   Shut Up:

   PCI =*Pavement Condition Index*

   PCI(s) = Sample unit PCI value

   N = Number of sample units

6. The assessment of the condition of the pavement is carried out by referring to the division of values for the condition of the pavement. The assessment is carried out using the PCI value as a reference for rating the condition of the pavement.

Table 3. PCI Value and Damage Category

Segment	PCI	Damage Category
1	38	*Poor*
2	40	*Poor*
3	35	*Poor*
4	39	*Poor*
5	20	*Very Poor*
6	39	*Poor*
7	91	*Excellent*
8	92	*Excellent*

Source: Analysis of Resuls (2022)

In Table 3, it can be seen that the lowest PCI value is in segment five with a value of 20 and is included in the category of very poor damage (very poor). The highest PCI value is in segment eight with a value of 92 and is included in the excellent category.

Simple Linear Regression Analysis

A simple regression analysis technique is used to prove the first hypothesis which reads:

H0 : There is no relationship between PCI and vehicle speed,
Ha : There is a relationship between PCI and vehicle speed.

In this case the variables entered are PCI variables as the independent variable (x) and speed as the dependent variable (y) and the method used is the enter method. The steps for simple linear regression analysis in this study are.

1. Normality Test
   The normality test is carried out to find out whether the data from the research variables are normally distributed as a prerequisite for testing the hypothesis. The normality test was performed using the Kolmogorov-Smirnov (K-S). The table of normality test results for the type of motorcycle vehicle is known to have a significance value of 0.785 > 0.05, so it can be concluded that the residual values are normally distributed.
2. Linearity Test
   Linearity test was conducted to determine the relationship between the independent variable and the dependent variable whether it has a linear relationship or not. This test is used as a prerequisite for linear regression testing. The results of the linearity test show that the Sig deviation from linearity value is 0.167 > 0.05, so it can be concluded that there is a linear relationship between speed and road damage.
3. R-Test and Determinasi R-Square
   In this study, to find out whether there is an influence between the variables X (PCI) and Y (vehicle speed), the researchers conducted an analysis using simple linear regression using SPSS. After performing a simple linear regression analysis, the output below is obtained. The following are the results of the Correlation Test (R) and the Determination Test (R Square).

Table 4. R-Test dan R square

Modle	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.945[a]	.893	.875	5.844

a. Predictors: (Constant), PCI
b. Dependent Variable: Velocity

Based on Table 4, it is known that the correlation value between X and Y ($r_{x1,y}$) is 0.945 because the correlation value is positive ($r_{x,y} > 0$) which means that there is a positive influence between road damage and vehicle speed. The higher the PCI value, the faster the vehicle speed. Based on the table, it is known that the R square value is 0.893 (89.3%). This shows that by using the regression model, where the independent variable (PCI) has an influence on the dependent variable (vehicle speed) of 89.3%. Meanwhile, 10.7% is influenced by other variables.

4. The ANOVA table explains whether there is a significant (significant) effect of the PCI variable (X) on the vehicle speed variable (Y).

Table 5. Anova

	Modle	Sum of Squares	df	Mean Square	F	Sig.
1	**Regression**	1704.990	1	1704.990	49.930	.000[a]
	Residual	204.885	6	34.147		
	Total	1909.875	7			

Source: Analysis of Results (2022)

In Table 5, it can be seen that F count is 49.930 with a probability significance level of 0.000 < 0.05, so the regression model can be used to predict vehicle speed variables

5. Hypothesis Test (T-Test)
From the simple linear regression analysis with SPSS for Windows, the output of the simple linear regression equation coefficients is obtained in Table 6.

Table 6. T-Test

Modle		Unstandardized Coefficients		Standardized Coefficients	t	sig
		B	Std. Error	Beta		
1	(Constant)	9.012	4.546		1.983	.095
	PCI	.581	.082	.945	7.066	.000
a. Dependent Variable: Velocity						

Source: Analysis of Results (2022)

From Table 6. the output of the simple linear regression equation coefficientsa results obtained the following regression equation:

Y = a + bX
Y = 9,012+ 0,581X
Speed = 9,012+ 0,581 PCI

This model shows that if the PCI 9.012 variable increases by 1 unit or 1%, the vehicle speed will increase by 0.581 units or by 58.1%. In addition to describing the output regression equation, it also displays a significance test with the t test, namely to find out whether there is a real (significant) effect on variable X (PCI) on variable Y (vehicle speed)[14], [15], [17]–[19]. This is in accordance with the opinion [2], which states that the lower the PCI value, the will affect the slow speed of the vehicle. Conversely, the greater the PCI value eating will accelerate the speed of the vehicle and Speed is the distance traveled in one unit of time. Speed units are expressed in km/hour or m/second [20].

6. Residual Studies in Regression Analysis
Residual studies in the regression analysis were carried out to determine the deviation value or the difference in the total value of the Y segment based on the existing value and the Y model that had been formed from the regression results.

Tabel 7. Regression Residual Value

No	a	bx	Y Prediksi	Y Eksisting	Residu
1	9,012	0,581 (38)	31,09	25,05	6,04
2	9,012	0,581 (40)	32,25	32,03	0,22
3	9,012	0,581 (35)	29,35	21,43	7,92
4	9,012	0,581 (39)	21,67	32,16	-10,49
5	9,012	0,581 (20)	20,63	30,05	-9,42
6	9,012	0,581 (39)	31,67	33,65	-1,98
7	9,012	0,581 (91)	61,88	63,54	-1,66
8	9,012	0,581 (92)	62,46	63,47	-1,01

Source: Analysis of Results (2022)

From the absolute value of the residual, the upper quartile (Q3 = 1.68) and the lower quartile (Q1 = -3.84) are determined and the deviation is dQ = Q3 - Q1 = (1.68-(-3.84)) = 5.51 . To detect outlier data, the lower limit of outlier = Q1- 1.5 dQ = -3.84 - 1.5 × 5.51 = -12.11 and the upper limit of outlier = Q3 + 1.5 dQ = 1.68 + 1.5 × 5.51 = 9.95. All residual values are not outside the outlier limit (nothing is smaller than the lower limit and also greater than the upper limit), so for the observations above there is no data that is considered an outlier.

So that it can be said that the regression model Y = 9.012 + 0.581 PCI meets the requirements to be used as an estimator to determine the relationship of road damage to the speed of motorcycle type vehicles. Based on the results of the R square test, the R square value obtained is 0.893 or 89.3%, which means that the relationship between road damage and heavy vehicle speed is 89.3%. The following is a graph of the relationship between road damage and vehicle speed.

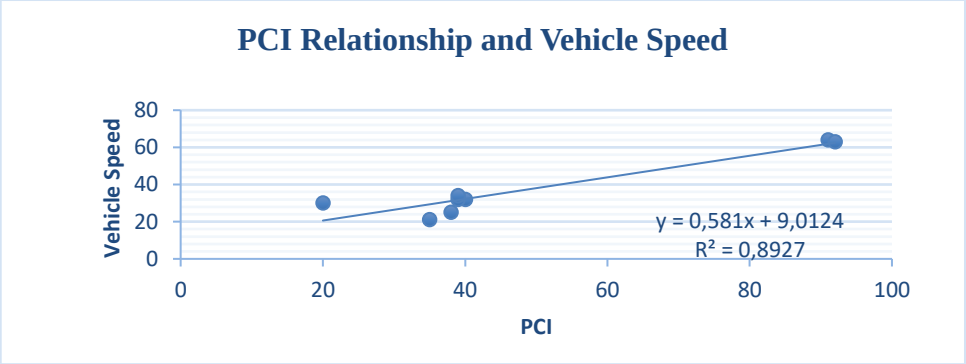

Figure 5. PCI Relationship and Vehicle Speed
Source: Analysis of Results (2022)

From the graph of the relationship between the level of road damage and vehicle speed, it can be concluded that the higher the level of damage, the lower the PCI value, the slower the vehicle speed will be. Conversely, the greater the PCI value, the faster the vehicle speed.

Recommendations For The Appropriate Type Of Treatment

After a calculation survey was carried out using the PCI method, repair activities were continued in order to prevent widespread and more severe damage. Based on the type of damage in STA 0-200 (Segment One), STA 600-800 (Segment Two), STA 1600-1800 (Segment Three), STA 3600-3800 (Segment Four), STA 4600-4800 (Segment Five) , STA 5000-5200 (Segment Six), STA 14600-14800 (Segment Seven), and STA 15400-15600 (Segment Eight) on Jalan Lembar-Sekotong-Pelangan. Damage handling refers to the PCI result value that has been analyzed [5], [21]. In Table 8. are recommendations for types of treatment for road damage per segment based on the PCI values that have been analyzed.

Table 8. Damage Handling Recommendations

Segment	PCI Value	Road Damage Handling Category
1	38 (poor)	Reconstruction Maintenance
2	40 (poor)	Reconstruction Maintenance
3	35 (poor)	Reconstruction Maintenance
4	39 (poor)	Reconstruction Maintenance
5	20 (very poor)	Reconstruction Maintenance
6	39 (poor)	Reconstruction Maintenance
7	91 (perfect)	Routine Maintenance
8	92 (perfect)	Routine Maintenance

Source: Analysis of Results (2022)

Based on Table 8. the lowest Pavement Condition Index (PCI) value is in segment five with a value of 20 (very bad) then the maintenance carried out is reconstruction maintenance. While the highest Pavement Condition Index (PCI) value is in segment eight with a value of 92 (perfect) then the maintenance carried out is routine maintenance. In line with research conducted by [16] that based on the graph of the relationship between the level of road damage and speed, it is concluded that the higher the level of damage, the lower the PCI value and will affect the slow speed of the vehicle. Conversely, the greater the PCI value, the lower the level of damage and the faster the speed of the vehicle. Evaluation of the damaged condition of Jalan Panglima

Sudirman using the IRI and PCI methods resulted in different conditions for each segment. In general, the results obtained are moderate conditions based on the highest percentage of scores. So that the right type of handling is routine and preventive maintenance for good or moderate road conditions, while minor rehabilitation for lightly damaged road conditions Based on Ministerial Regulation PUPR No. 13/ PRT/ M/ 2011[22].

Conclusion

Based on the results of simple linear regression analysis the value of road damage PCI (x) to the type of vehicle speed (y) obtained the R square value of 0.893 which shows using the regression model, where the x variable (PCI) has an influence on the y variable (vehicle speed) of 89 .3%. The regression model is y (type of vehicle speed) = 9.012 + 0.581 PCI, which means that if the PCI 9.012 variable increases by 1 unit or 1%, the vehicle speed will increase by 0.581 units or by 58.1%. The lower the PCI value, the slower the vehicle speed will be. Conversely, the greater the PCI value, the faster the vehicle speed.

In this study using the Simple Linear Regression analysis method where the findings in this regression analysis can explain that the dependent variable (vehicle speed) can be influenced by the independent variable (Road Damage). In addition, the output of this simple linear regression is a model, in which this model can be used on roads that have the same characteristics as the Lembar-Sekotong-Pelangan Road. While the shortcomings in this study are that there should be more independent variables (x) so that the output of the results of the analysis is more precise to determine the value of the dependent variable (y). So that for further research, you can add and examine other x variables on y (vehicle speed). The results of the research can be used as a consideration for the NTB Provincial government and related agencies in seeking to overcome or repair the road so that the flow of people, goods and services runs smoothly again and the economy can continue to improve.

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