ANALYSIS OF THE EFFECT OF PAVEMENT CONDITIONS ON VEHICLE SPEED

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ABSTRACT

The Jakarta Outer Ring Road (JORR) Toll Road is a logistics route that acts as an essential transportation artery to facilitate logistics distribution. This toll road connects strategic locations to support logistics distribution. It can lead to the repetition of traffic loads, causing a decrease in the pavement quality marked by road damage. Road damage that occurs can reduce the level of safety and comfort of road users. To minimize accidents due to road damage, road users will drive their vehicles at lower speeds in locations/segments that have damage. In the study, the level of road damage was analyzed using the Pavement Condition Index (PCI) method. Vehicle speed using the time mean speed method and then statistically analyzed using linear regression using SPSS v.26 software to determine how much influence road pavement conditions have on vehicle speed. Based on the results of the analysis on the Jakarta Outer Ring Road (JORR) KM 35+000 – 45+000 toll road, the pavement conditions of the toll road are in the good category with various vehicle speeds for each group with a range of 44.80 km/hour to 79,98 km/hour and the effect of pavement conditions on vehicle speed is 51.6% for class 1 vehicle, 58,1% for class 2 vehicle, 42,2% for class 3 vehicle, 42,9% for class 4 vehicle, 44,8% for class 5 vehicle.

Keywords : Pavement Condition Index (PCI) ; Road Damage ; Time mean speed ; Vehicle Speed

INTRODUCTION

A good toll road is a toll road that can provide quality services, one of which is influenced by the condition of the road structure. The Jakarta Outer Ring Road (JORR) Toll Road is a logistics route that acts as an essential transportation artery to facilitate the flow of logistics distribution and mobility of the people of Jakarta and its surroundings. This toll road is integrated with other toll roads, there is the Jakarta – Cikampek, Jagorawi, Jakarta – Tangerang, and Prof. Dr. Sedyatmo (PT Jasa Marga (Persero) Tbk, 2020). In addition, this toll road connects the strategic locations in supporting the implementation of logistics distribution, such as Merak Port, Tanjung Priok Port, and Soekarno – Hatta International Airport. As a toll road that plays an essential role in the implementation of logistics distribution, it will lead to the repetition of traffic loads and excessive vehicle load so which causes a decrease in the quality of the pavement (Ibnu & Nugroho, 2018), which is marked by the occurrence of damage to the pavement. Excessive vehicle load or overloading is the amount of the load weight exceeds the allowed weight (Sutjahjo et al., 2020).

Road damage is a condition where the road can longer provide optimal service again to the traffic, both from the structural and functional aspects (Sholichin & Rumintang, 2018). Road damage usually occurs on the road surface (Shehu et al., 2014). Road damage that occurs can be classified into 19 types of damage, including alligator

Accepted : 31 January 2022

cracking, bleeding, block cracking, bumps and sags, corrugation, depression, edge cracking, joint reflection cracking, lane/shoulder drop, longitudinal and transverse cracking, patching and utility cut patching, polished aggregate, potholes, railroad crossing, rutting, shoving, slippage cracking, swell, weathering and raveling (Shahin, 1994).

A road condition assessment system is needed to determine the condition of the pavement. The evaluation of pavement performance using pavement condition indicators is a basic component of any pavement management system. One of the various indicators is to use the Pavement Condition Index (PCI) (Shah et al., 2013) developed by the U.S. Army Corps of Engineers (Temimi et al., 2021) and this method that adopted for many highway agencies (Al-Obaedi et al., 2020). The PCI evaluation is carried out based on the visual survey (Zafar et al., 2019). The PCI is a scoring that rates the surface conditions of the pavement, and it provides a measure of the present conditions based on the distress observed on the surface of the pavement (ASTM D 6433-07, 2007). In addition, PCI can be used as a reference in the maintenance business (Syaiful & Lasmana, 2020). PCI value is a number 0 to 100, where 100 represents the pavement in excellent condition (Karim et al., 2016).

Road damage that occurs can reduce the level of safety and comfort of road users. As a form of prevention of accidents caused by road damage, road users will drive their vehicles at lower speeds at locations or damaged segments. Vehicle speed is the average distance reached in a specific time unit, generally as kilometers per hour (km/h) (Highway Capacity Manual, 2000).

Based on the background above, this research aims to determine the pavement conditions on the Jakarta Outer Ring Road (JORR) Toll Road, vehicle speed in various pavement conditions on those sections, and how the influence of pavement conditions on vehicle speed. This research is expected to be beneficial for multiple parties, for companies, it is expected to become company information about toll road conditions, and for other research, it is expected to be a reference for those who want to analyze the state of toll road pavements further. State of the art of this research is the research conducted on toll road by classifying vehicles based on the class of vehicles that apply on toll roads.

METHODS

Location

This research is located on Lane 1 of the Jakarta Outer Ring Road (JORR) Toll Road section KM. 35+000 – 45+000.

Research Process

The process in this research can be seen in Figure 1.

Data Collection Methods

This research requires a variety of data in the form of primary data and secondary data. The primary data and the method of collection are as follows.

a. Road Pavement Condition Survey

Road damage is identified based on the type, level, and dimension of damage. Measurements are carried out for each segment length of 50 meters along 10 kilometers start from KM. 35+000 and ends in KM. 45+000.

b. Vehicle Speed Survey

The vehicle speed survey is carried out by collecting travel time data for 200 meters on segments/locations that have damage and one segment/location that has no damage. A segment/location that are not damaged is assumed to represent other segments that are not damaged.

Accepted : 31 January 2022

This data collection is based on the class of vehicles that apply on the toll road in accordance with Keputusan Menteri Pekerjaan Umum No. 370/KPTS/M/2007. Meanwhile, the secondary data needed is geometric road data obtained from PT Jasa Marga (Persero) Tbk.

Research Variable

The variables in this research consisted of 2 variables, namely the variable x and the variable y. Variable x is the Pavement Condition Index (PCI) value, and variable y is the vehicle speed value.

Data Analysis Method

Data analysis in this research was carried out in 3 stages, including.

Pavement Condition Index (PCI) Value Analysis

This analysis uses primary data of road damage that has been carried out. The calculation is carried out using the PCI method. Start from calculating the density value, deduct value (DV), corrected deduct value (CDV), total deduct value (TDV), and finally calculating the PCI value and determining the PCI ratings (Sholichin & Utomo, 2018).

The analysis was carried out for each segment length of 50 meters based on the sample unit of Shahin's rule. According to Shahin, the sample unit is an area of about 2500 ± 1000 sq.ft. The size for the sample unit should be determined close to the recommended average value so that the analysis results are correct (Shahin, 1994). The PCI rating is determined based on the PCI range contained in Figure 2.

After obtaining the PCI value with a segment length of 50 meters, the PCI value is calculated for a segment length of 200 meters by averaging 4 sample units in the segment for which the speed data is taken.

Vehicle Speed Analysis

This analysis uses primary data of vehicle travel time along 200 meters. Analysis using the time mean speed method. Time mean speed is defined as the arithmetic mean speed of the spot speed data (Ahsani et al., 2018). This speed is analyzed for each vehicle class and segment for which speed data is taken.

Analysis of the Effect of Road Pavement Condition on Vehicle Speed

This analysis uses data from PCI value analysis and vehicle speed analysis. Analysis of the influence of road pavement conditions on vehicle speed using statistical analysis in the form of simple linear regression using SPSS v.26 software. Before carrying out statistical analysis, it is necessary to carry out various classical assumption tests first.

RESULTS AND DISCUSSION

Pavement Condition Index (PCI) Value Analysis

Based on the analysis of the PCI value in the 50 meters segment, the PCI value in each segment is obtained. The result of the analysis can be seen in Figure 3 and 4. Various PCI values were obtained, consisting of 179 units with a good value, 11 units with a satisfactory value, 3 units with a fair value, 5 units with a poor value, and 2 units with a very poor value. Based on the existing PCI values, the percentage of good value is 89,50%, satisfactory value is 5,50%, fair value is 1,50%, poor value is 2,50%, and very poor value is 1,0%. Based on the accumulation of all PCI value segments, the average PCI value on the Jakarta Outer Ring Road (JORR) Toll Road KM. 35+000 – 45+000 section is 96,1045. Following ASTM D 6433-07, this value

Accepted : 31 January 2022

indicates that the pavement condition is in a good category. A calculation is carried out by averaging the 4 sample units of PCI value according to the segment whose speed is calculated to get the PCI value with a segment length of 200 meters so that the PCI value with a segment length of 200 meters is obtained, as shown in Table 1.

Vehicle Speed Analysis

Based on the vehicle speed analysis results, the vehicle speed in each vehicle class in each segment under review is obtained. The results of the analysis can be seen in Figure 5. The results of the analysis show different speed values in each segment and class of vehicle. In good pavement condition, the value of the vehicle speed is high. However, when the pavement condition decreases, the value of vehicle speed decreases. It is following Setyawan et al. (2015) research that the lower PCI value reduced the vehicle speed.

Analysis of the Effect of Road Pavement Condition on Vehicle Speed

The classical assumption test is carried out to determine whether the regression model obtained is unbiased (Sari & Amalia, 2019). Several tests were carried out in this test, including the Shapiro-Wilk test for normality test, curve estimation test for linearity test, and scatter plot test for heteroscedasticity test. Table 2 shows the results of the classical assumption test.

In the normality test, it is required that the value of sig. > α (0,05), the test result shows that the value of sig. of the normality test in all vehicle classes is greater than 0,05, so it can be interpreted that the data is normality distributed. In the linearity test, it is required that the value of sig. < α (0,05), the test result shows that the value of sig. of the linearity test in all vehicle classes is less than 0,05, so it can be interpreted that the variable between PCI value and vehicle speed has a linear relationship.

In the heteroscedasticity test, the data will be homogeneous or have no symptoms of heteroscedasticity if the data points are spread out and do not form a pattern. The test result shows that the data points in all vehicle classes are spread out and do not form a pattern, so it can be interpreted that the variables involved do not have symptoms of heteroscedasticity.

The classical assumption test results showed no disruption of normality, linearity, and heteroscedasticity symptoms. Linear regression has the classical assumptions required to obtain a "good" OLS estimate (known as the best linear unbiased estimator (BLUE)) (Casson & Farmer, 2014), and all tests have been met so that a simple linear regression method can be used in the analysis of this effect.

Regression Analysis on Class 1 Vehicles

Based on the analysis using SPSS v.26 software, a simple linear regression equation obtained is $y = 0{,}811x - 2{,}514$ with a correlation value of 0,718 with a strong category and a coefficient of determination value of 0,516, which means that the condition of the road pavement determines the vehicle speed of class 1 by 51,6%. The remaining 48,4% is determined by other factors outside of this research. The graph of regression analysis on class 1 vehicle can be seen in Figure 6.

Regression Analysis on Class 2 Vehicles

Based on the analysis using SPSS v.26 software, a simple linear regression equation obtained is $y = 0{,}413x + 22{,}722$ with a correlation value of 0,762 with a strong category and a coefficient of determination value of 0,581, which

Accepted : 31 January 2022

means that the condition of the road pavement determines the vehicle speed of class 2 by 58,1%. The remaining 41,9% is determined by other factors outside of this research. The graph of regression analysis on class 1 vehicle can be seen in Figure 7.

Regression Analysis on Class 3 Vehicles

Based on the analysis using SPSS v.26 software, a simple linear regression equation obtained is y = 0,183x + 36,485 with a correlation value of 0,649 with a strong category and a coefficient of determination value of 0,422, which means that the condition of the road pavement determines the vehicle speed of class 3 by 42,2%. The remaining 57,8% is determined by other factors outside of this research. The graph of regression analysis on class 1 vehicle can be seen in Figure 8.

Regression Analysis on Class 4 Vehicles

Based on the analysis using SPSS v.26 software, a simple linear regression equation obtained is y = 0,208x + 31,146 with a correlation value of 0,649 with a strong category and a coefficient of determination value of 0,429, which means that the condition of the road pavement determines the vehicle speed of class 4 by 42,9%. The remaining 57,1% is determined by other factors outside of this research. The graph of regression analysis on class 1 vehicle can be seen in Figure 9.

Regression Analysis on Class 5 Vehicles

Based on the analysis using SPSS v.26 software, a simple linear regression equation obtained is y = 0,121x + 37,345 with a correlation value of 0,669 with a strong category and a coefficient of determination value of 0,448, which means that the condition of the road pavement determines the vehicle speed of class 5 by 44,8%. the remaining 55,2% is determined by other factors outside of this research. The graph of regression analysis on class 1 vehicle can be seen in Figure 10.

Hypothesis Testing

Based on simple linear regression analysis, it was found that all sig. value < 0,05 in each vehicle class. It indicates an influence between the pavement condition and the vehicle speed in each vehicle class. The results of the sig. values are obtained as attached in Table 3.

According to research conducted by Setyawan et al. (2015), road damages could affect vehicle speed. From the graph of the relationship between road pavement condition and vehicle speed, it can be concluded that if the level of damage occurs is higher, and the PCI value will be lower in a segment, resulting in low vehicle speed. Conversely, if the level of damage is lower, the PCI value will be higher in a segment, resulting in high vehicle speed.

CONCLUSION

The average pavement condition value is based on the PCI method on the Jakarta Outer Ring Road (JORR) KM. 35+000 – 45+000 section is 96,1025, meaning that the pavement condition at KM 35+000 – 45+000 is in good condition with a value of various vehicle speeds according to the type of vehicle and pavement condition in the review segments. Based on the statistical test in the form of simple linear regression, it was found that there was an influence between road pavement condition and vehicle speed with the largest effect value in class 2 vehicle, which was 58,1%, and the smallest influence value in class 3 vehicle which was 42,2%. The simple

Accepted : 31 January 2022

linear regression graph can be concluded that if the level of damage is higher, the PCI value in a segment will be lower, resulting in lower speed. But the result achieved are with a few methodological flaws, such as the sample size for taking the speed variable is too small and vehicle classification should be carried put in more detail based on the vehicle axle load and vehicle specification.

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Accepted : 31 January 2022

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Accepted : 31 January 2022

Appendix

Table 1. PCI value with a segment length of 200 meters

Segment	PCI Value
35+400 - 35+600	84.3265
35+600 - 35+800	82.2260
35+800 - 36+000	76.0156
37+000 - 37+200	79.2707
37+400 - 37+600	80.8824
37+600 - 37+800	83.1882
38+200 - 38+400	96.1884
38+400 -38+600	73.8424
38+800 - 39+000	84.5483
39+400 - 39+600	79.1503
40+400 - 40+600	92.8160
40+600 - 40+800	90.7932
43+200 - 43+400	100.0000

Table 2. Classic Assumption Test Results

Vehicle Classification	Classic Assumption Test		
	Shapiro-Wilk Test	Curve Estimation Test	Scatterplot Test
1	0.396	0.006	Spread and unpattern
2	0.802	0.002	Spread and unpattern
3	0.091	0.016	Spread and unpattern
4	0.448	0.015	Spread and unpattern
5	0.502	0.012	Spread and unpattern

Table 3. Sig. Value

Vehicle Classification	Sig.
1	0,006
2	0,003
3	0,023
4	0,019
5	0,011

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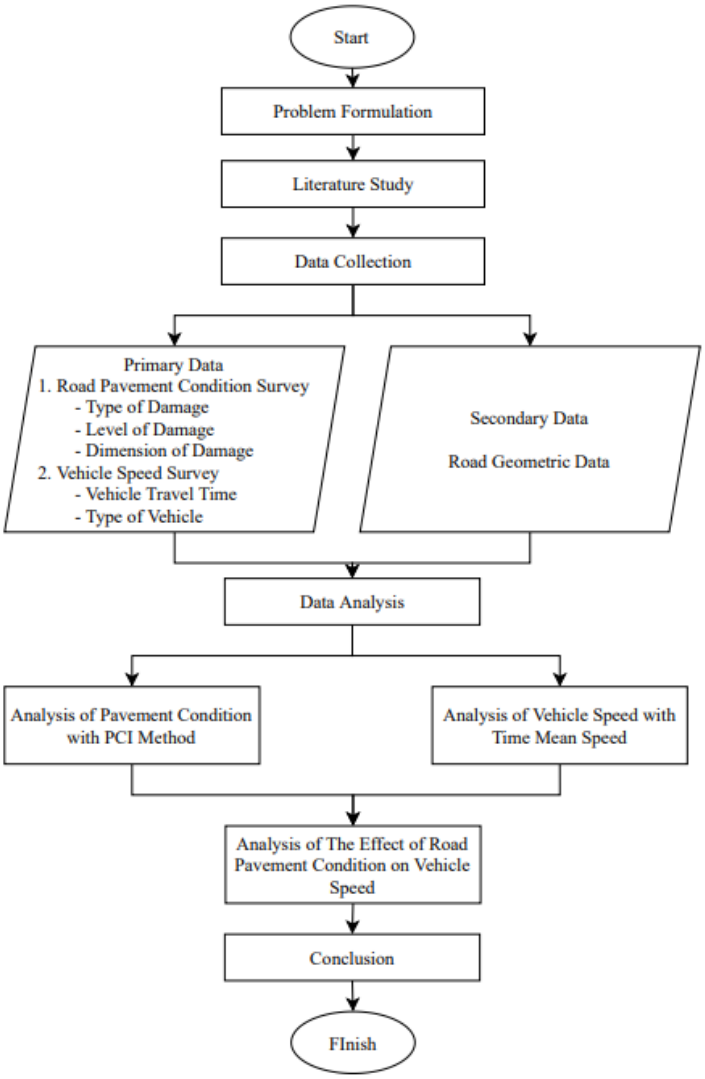

Figure 1. Flowchart

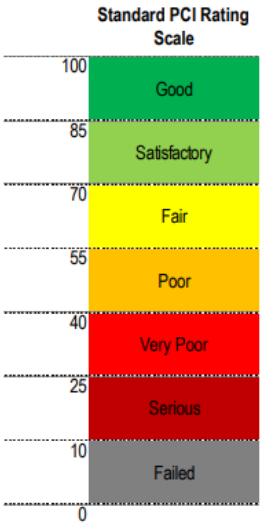

Figure 2. PCI Rating

Accepted : 31 January 2022

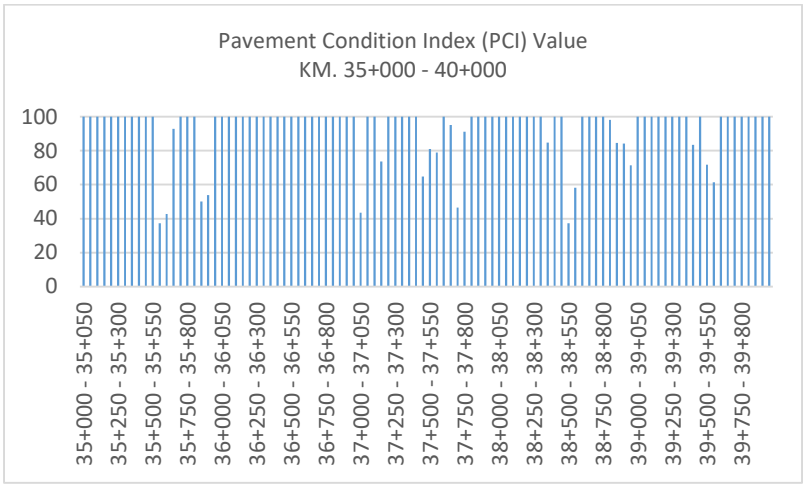

Figure 3. Pavement Condition Index (PCI) Value KM. 35+000 – 40+000 section

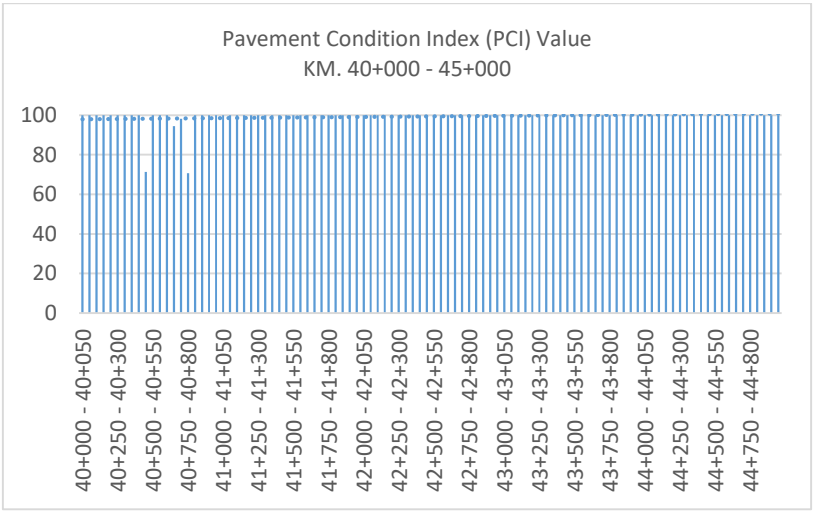

Figure 4. Pavement Condition Index (PCI) Value KM. 35+000 – 40+000 section

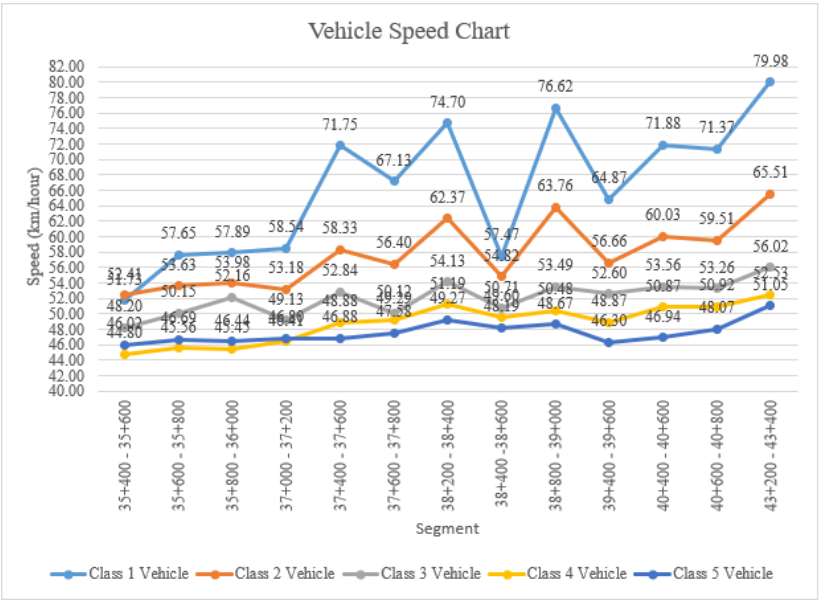

Figure 5. Vehicle Speed Chart

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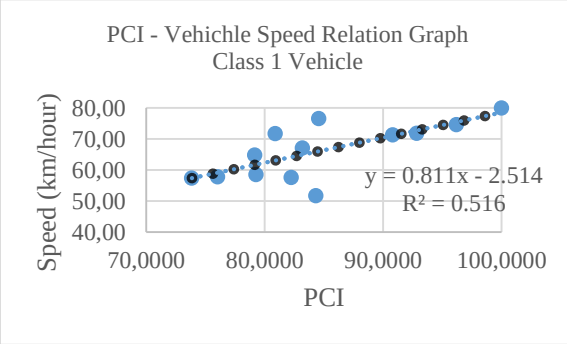

Figure 6. PCI – Vehicle Speed Relation Graph for Class 1 Vehicle

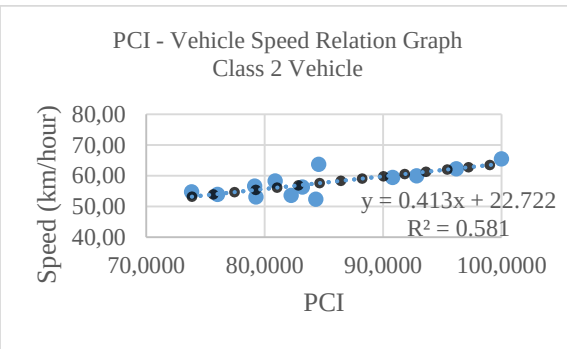

Figure 7. PCI – Vehicle Speed Relation Graph for Class 2 Vehicle

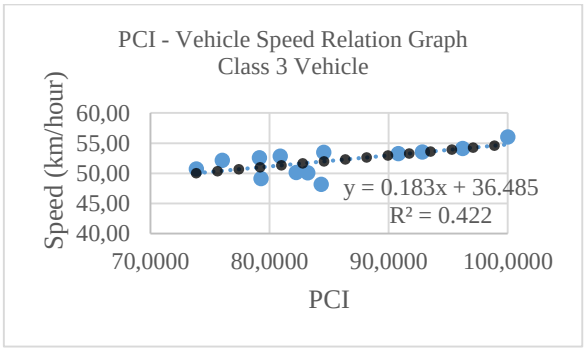

Figure 8. PCI – Vehicle Speed Relation Graph for Class 3 Vehicle

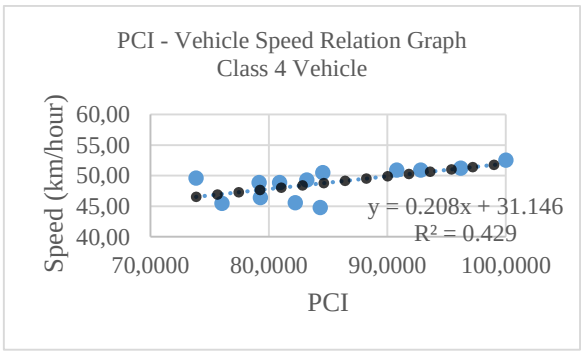

Figure 9. PCI – Vehicle Speed Relation Graph for Class 4 Vehicle

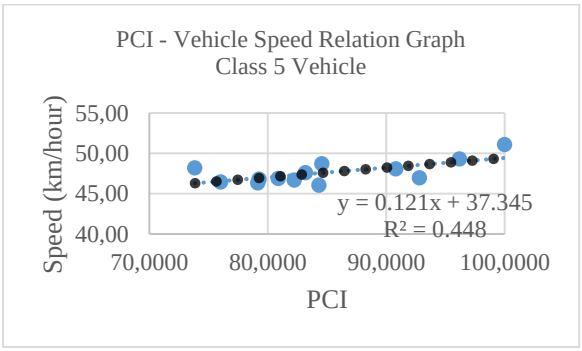

Figure 10. PCI – Vehicle Speed Relation Graph for Class 5 Vehicle

Accepted : 31 January 2022