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# IMPACT OF THE PCE MC CORRECTION VALUE USING MODIFIED AVERAGE TIME HEADWAY METHOD TO ROAD PERFORMANCE (CASE STUDY: VETERAN STREET, MALANG CITY)

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## Abstract

Passenger Car Equivalent (PCE) is a conversion factor of various types of vehicles compared to passenger cars or other light vehicles concerning their impact on traffic behavior. The PCE value used in calculating the performance of urban roads refers to Manual Kapasitas Jalan Indonesia (MKJI 1997) as an Indonesian Highway Capacity Manual. There have been many changes in traffic behavior nowadays compared to in 1997. The calculation of the PCE MC value using the average time headway method does not match the actual conditions. Therefore, modifications are needed by calculating the vehicle dimension factors to obtain the PCE value. The result of the PCE MC calculation using the modified average time headway method shows 0.17. This value is smaller than the value of the PCE MC set by the MKJI 1997, which shows 0.25. Based on the analysis of traffic conditions for ten years, the DS value using the PCE MC according to the MKJI 1997 obtains  $DS > 1$ . Meanwhile, the DS value calculated based on the corrected PCE MC has  $DS < 1$ . The difference in the value of PCE MC has implications for road performance. As a result, it affects traffic maintenance management in the form of maintenance costs and decision-making.  
*Keywords: Urban Road, Passenger Car Equivalent, MKJI 1997, Time Headway*

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## INTRODUCTION

Malang is the second largest city in East Java after Surabaya. Malang city also has several business and trading areas that it has a crowded activity [1]. The number of public facilities on Jalan Veteran Malang is one of the factors that cause congestion in the area. As a result of high vehicle growth while it is not followed by infrastructure growth, it can cause a decrease in road performance. [2] Previous study also has been investigated and showed the result about the value of degree of saturation in the existing condition of the four-foot signalized intersection Jalan Sumbersari-Veteran Street-Bendungan Sutami Road-Bendungan Sigura-gura Road is 0.46 for the northern approach; 1.13 south approach; 1.24 approach east and 1.75 approach west. So, the level of service at this intersection is F. This result implies that the road services is not satisfaction [3].

Passenger Car Equivalent (PCE) is a conversion factor of various types of vehicles compared to passenger cars or other light vehicles concerning their impact on traffic behavior. The PCE value used in calculating the performance of urban roads refers to Manual Kapasitas Jalan Indonesia (MKJI 1997) as an Indonesian Highway

Capacity Manual [4]. Not only the traffic conditions on roads in Indonesia but also on India and many other countries are heterogeneous in nature, with fast-moving vehicles (such as cars) and slow-moving vehicles (such as auto-rickshaws) sharing the same roadway [5]. There have been many changes in traffic behavior nowadays compared to the condition in 1997 [4]. The changes are caused by various factors, including the percentage of the number of motorcycles and the aggressiveness of motorcycle drivers. Therefore, it is necessary to adjust the PCE value, especially the PCE of the motorcycle (PCE MC). One of the methods used to calculate the PCE value is using the average time headway method. Based on case study research conducted by Alfiansyah (2021) on Veteran Street, Malang City, it concluded that the calculation of the PCE MC using the average time headway method is not suitable for direct use [6]. This is because the principle of measuring time headway is used for concurrent vehicles. In consequence, the principle is inappropriate to the actual conditions where motorcycles can move in a row in a similar lane. Modifications should be done on the average time headway method so that the PCE MC calculation can reflect actual conditions. One of the adjustments is considering the dimensional factor of motorcycles in Indonesia.

**RESEARCH METHODS**

**A. Passenger Car Equivalent**

The passenger car equivalent (PCE) was first introduced in the 1965 Highway Capacity Manual (HCM) version. The PCE value is used to analyze traffic flow [7][8]. The PCE value is also different for each part of the road, for example, the PCE value of the road section is different from the PCE value of the intersection[9]. Each type of vehicle has different movement characteristics because the dimensions, speed, acceleration, and maneuverability of each type of vehicle are different and affect the road geometry, therefore a unit that can be used in traffic planning is called the Passenger Car Unit or abbreviated as PCU[8]. According to the Transportation Research Board (2000), PCE is the number of various types of vehicles converted to one type of vehicle (passenger car) [10]. The PCE value depends on traffic conditions, the queuing system, and the selected highway. Indar (2010) explains that PCE is a unit for converting traffic flow units from vehicles/hour to passenger car unit per hour (PCU/hour) [11]. Based on the MKJI 1997, the Directorate General of Highways regulates that the PCE value varies based on the type of vehicle, road, and Vehicle hour traveled (vehicles/hour).

**B. Average Time Headway Method**

According to R.J. Salter in his book entitled "Highway Traffic Analysis and Design," the PCE value is calculated by recording the time between successive vehicles (time headway) when the vehicle passes a predetermined observation point. There are seven types of vehicle combinations in the time headway, which are as follows [42]:

- a. Light Vehicle (LV) followed by Light Vehicle (LV)
  - b. Light Vehicle (LV) followed by Heavy Vehicle (HV)
  - c. Motor Cycle (MC) followed by Light Vehicle (LV)
  - d. Motor Cycle (MC) followed by Motor Cycle (MC)
  - e. Heavy Vehicle (HV) followed by Light Vehicle (LV)
  - f. Heavy Vehicle (HV) followed by Heavy Vehicle (HV)
  - g. Light Vehicle (LV) followed by Motorcycle (MC)
- The measurement of time headway can be seen in Figure 1.

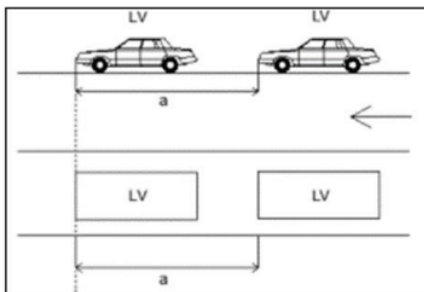


Figure 1. The Illustration of Time Headway Recording

The PCE MC value is calculated using the following formula:

$$ta + td = tb + tc \tag{1}$$

Description:

- ta = the average time headway of LV-LV
- tb = the average time headway of LV-MC
- tc = the average time headway of MC-LV
- td = the average time headway of MC-MC

Conditions that can meet the above equation are difficult to obtain because each vehicle has different characteristics. Moreover, drivers have different aggressiveness. Therefore, it is necessary to correct the average time headway using the following formula:

$$\left[ ta - \frac{k}{na} \right] + \left[ td - \frac{k}{nd} \right] = \left[ tb - \frac{k}{nb} \right] + \left[ tc - \frac{k}{nc} \right] \tag{2}$$

$$k = \frac{na \cdot nb \cdot nc \cdot nd \cdot (ta + td - tb - tc)}{nd \cdot nb \cdot nc + na \cdot nb \cdot nc + na \cdot nd \cdot nc + na \cdot nd \cdot nb} \tag{3}$$

Description:

- na = total time headway of LV-LV
- nb = total time headway of LV-MC
- nc = total time headway of MC-MC
- nd = total time headway of MC-LV

Then, the corrected average time headway is calculated using the following equation:

$$ta_k = ta - \frac{k}{na} \tag{4a}$$

$$tb_k = tb + \frac{k}{nb} \tag{4b}$$

$$tc_k = tc + \frac{k}{nc} \tag{4c}$$

$$td_k = td - \frac{k}{nd} \tag{4d}$$

So, the PCE MC value can be calculated using the following equation:

$$empMC = \frac{td_k}{ta_k} \tag{5}$$

**C. Free Flow Speed**

Free-flow speed is the speed at the zero-current level, i.e., the driver's speed while driving a vehicle without being affected by other vehicles. The free-flow speed on urban

DS according to MKJI 1997 was calculated by the following equation [4]:

$$FV = (FV_0 + FV_w) \times FFV_{SF} \times FFV_{CS} \quad (6)$$

Description:

FV = Actual free-flow speed for Light Vehicles (km/h)

FV<sub>0</sub> = Basic free-flow speed (km/h)

FV<sub>w</sub> = Adjustment factor for the traffic lane effective width (km/h)

FFV<sub>SF</sub> = adjustment factor for side resistance

FFV<sub>CS</sub> = adjustment factor for city size

#### D. Capacity

Road segment capacity is the maximum traffic flow that can be maintained under certain conditions (geometry, distribution of traffic directions and composition, environmental factors). The calculation of road capacity according to the MKJI 1997 used the following formula [4]:

$$C = C_0 \times FC_w \times FC_{SF} \times FC_{SP} \times FC_{SC} \quad (7)$$

Description:

C = Road capacity (pc/h)

C<sub>0</sub> = Basic capacity

FC<sub>w</sub> = Speed adjustment factor for the width of the traffic lane

FC<sub>SF</sub> = Speed adjustment factor for side resistance

FC<sub>SP</sub> = Speed adjustment factor for the direction separator

FC<sub>SC</sub> = Speed adjustment factor for the city size

#### E. Degree of Saturation

The degree of saturation, called DS, is the ratio of traffic flow to capacity, which is used to determine traffic performance. The DS value was calculated using the following equation [7]:

$$DS = \frac{Q}{C} \quad (8)$$

Description:

Q = Traffic flow (pc/h)

C = Capacity (pc/h)

#### F. Previous Study

Alfiansyah (2021), in his research, calculated PCE motorcycles on Veteran Street Malang City using the average time headway method [6]. Based on the calculation results, the value of PCE MC produces a value of 0.54. This value was used as the basis for calculating the performance of the road segment. The resulting DS value produced a DS value > 1. This value was considered not in accordance with the conditions in the field where the vehicle was still possible to be ready at peak hours in the morning and peak hours in the afternoon. The calculation results were irrelevant because the principle of calculating the time headway is not in accordance with the conditions in the

field. The difference in the concept of calculating time headway and actual conditions can be seen in Figure 2 [6].

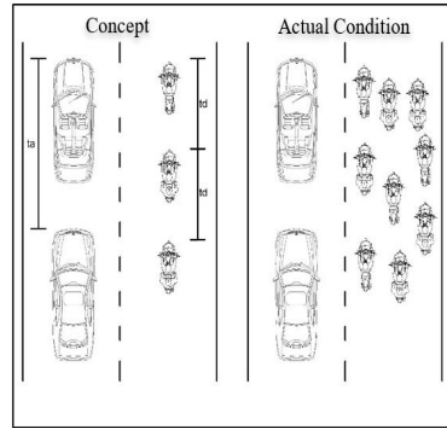


Figure 2. Concept Comparison of Time Headway Calculation with Actual Conditions  
Source: Alfiansyah (2021) [6]

#### G. Methodology

Traffic volume census surveys were conducted on Monday at 06.00-11.00 and 15.00-21.00 to obtain the volume of peak hours in the morning and the volume of peak hours in the afternoon, which are used as input for road performance. Traffic volume recording is recorded every 5-minute interval during the survey hour period using a hand tally counter. Meanwhile, the headway time survey took 60 minutes of video to obtain the LV-LV, LV-MC, MC-MC, and MC-LV headway times. The headway time is recorded with the help of a stopwatch and is recorded one by one according to the vehicle time headway category. [5] The results of the time headway recording are then processed using the PCE MC calculation formula. After getting the renewable PCE value, the PCE value is adjusted to the width factor of motorcycles in Indonesia. The modified PCE MC value is used to calculate road segment performance. The width of the dimensions of the motorcycle vehicle is very influential in determining the PCE MC. This is in line with the opinion of Izumi Okura (2003) in his study of calculating the PCE of heavy vehicles, which states that the vehicle's dimensions will affect the value of the PCE [13].

### RESULTS AND DISCUSSIONS

#### A. Traffic Flow Calculation

The results of the traffic volume survey on Veteran Street are depicted on the traffic fluctuation graphs in Figure 3 and Figure 4.

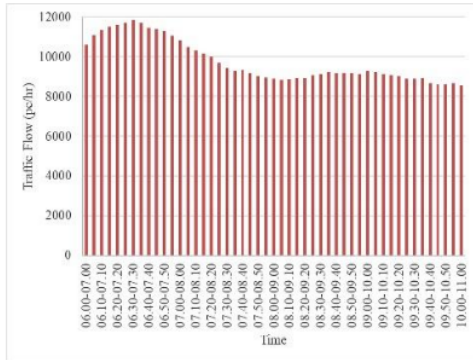


Figure 3. The Fluctuation Morning Traffic Volume

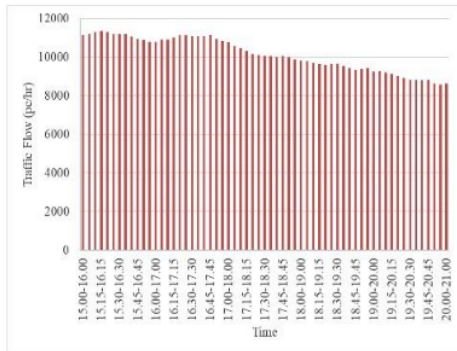


Figure 4. The Fluctuation Afternoon Traffic Volume

Based on the two figures above, the morning peak hour volume occurs at 06.30-07.30 and the afternoon peak hour volume occurs at 15.15-16.15. The composition of vehicles at peak hours can be seen in Table 1.

Table 1. The Composition of Vehicles at Peak Hours

Peak Time	Amount of Vehicle (vehicle/h)		
	MC	LV	HV
Morning	15450	2034	45
Evening	29953	3949	85

**B. The Dimension Factor of Motorcycle**

Vehicle dimensions are calculated based on the dimensions of motorcycles in Indonesia. The sample used to calculate vehicle dimensions is 5 (five) brands of the motorcycle industry. The vehicle dimension data that has been collected is multiplied by the Safety Factor (SF) of 1.25. The addition of vehicle dimensions due to SF serves as a safe distance between motorcycles when moving in a row in one lane. Then the dimension factor is calculated by dividing the dimensions by the ideal width of the road according to MKJI 1997, which is 3 m (3000 mm).

results of the calculation of the dimension factor can be seen in Table 1.

Table 2. The Calculation of The Dimension Factor

Brand	Width (mm)		Width (mm) x SF		Dimension Factor	
	Min	Max	Min	Max	Min	Max
H***A	669	750	803	900	0.27	0.30
Y****A	685	765	822	918	0.27	0.31
K*****I	740	895	888	1074	0.30	0.36
S****I	655	740	786	888	0.26	0.30
Total	650	1300	780	1560	0.26	0.52
Average					0.31	

**C. Calculation of PCE MC**

The headway time data was obtained from the survey results using a video camera. Then the headway time was recorded in the LV-LV, LV-MC, MC-LV, and MC-MC categories. Based on the recording results, the average time headway for LV-LV is 2.77 seconds, LV-MC is 2.13 seconds, MC-LV is 2.29 seconds, and MC-MC is 1.52 seconds. PCE MC is calculated using equation (3) to equation (5). This value is then multiplied by the previously calculated dimensional factor. The results of the PCE MC calculation using the modified average time headway can be seen in Table 2 and Table 3.

Table 3. The Calculation Table of PCE (1)

N				t				k (3)
na	nb	Nc	nd	ta	tb	tc	td	
56	80	65	205	2.77	2.13	2.29	1.52	-2.41

Table 4. Table of PCE Calculation (2)

tk (4)		PCE MC (5)	Dimension Factor	PCE MC x Dimension Factor
tak	tdk			
2,82	1,53	0,54		0,17

Based on the calculation of PCE MC using the modified average time headway method, the PCE MC value is 0.17. This is due to the dimension factor of 0.31. In conclusion, one lane of the road can be traversed by three motorcycles in a row.

**D. Road Performance**

The road performance calculated in this study is the value of the Degree of Saturation (DS) and Theoretical Speed (VLV). The road lane performance was calculated based on the MKJI 1997 using the corrected PCE MC of 0.17. Furthermore, it was compared with the road lane performance calculated with the PCE MC in accordance with the MKJI 1997 which was 0.25. The results of the

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calculation of road lane performance can be seen in Table 5 to Table 8.

Table 5. The Calculation of Free Flow Speed

FV <sub>0</sub> (km/h)	FV <sub>w</sub>	FFV <sub>SF</sub>	FFV <sub>CS</sub>	FV (km/h)
55	2.8	0.98	0.95	54

Table 6. The Calculation of Capacity

C <sub>0</sub> (pc/h)	FC <sub>w</sub>	FC <sub>SP</sub>	FC <sub>SF</sub>	FC <sub>CS</sub>	C (pc/h)
3300	1.06	1	0.94	0.94	3079

Table 7. The Calculation of Road Lane Performance

Peak Time	Direction	Flow (pc/hr)		Capacity (PCU/hr) (7)	DS (8)		FV (km/hr) (6)	VLV (km/hr)	
		MKJI 1997	Corrected PCE		MKJI 1997	Corrected PCE		MKJI 1997	Corrected PCE
Morning	1	2226	1752	3079	0.72	0.57	54	44	48
	2	1790	1426		0.58	0.46		48	52
Evening	1	1916	1522		0.62	0.49		46	50
	2	2068	1674		0.67	0.54		46	49

Table 8. The Comparison of DS Value

Peak Time	Flow	DS		Percentage (a/b) *100%
		MKJI 1997 (a)	Corrected PCE (b)	
Morning	1	0.72	0.57	79%
	2	0.58	0.46	80%
Evening	1	0.62	0.49	79%
	2	0.67	0.54	81%

Based on the calculation, the road lane performance using the corrected PCE MC is better than the road lane performance using the PCE MC value according to the MKJI 1997. The DS value calculated using the corrected PCE MC is 79%-81% smaller than the DS value calculated using the PCE MC in accordance with MKJI 1997. Smaller value of PCE MC had an effect on mitigating traffic problems on Jalan Veteran Malang. The implications for mitigating traffic problems can be described in the analysis of traffic conditions in the next 10 years.

**E. The Analysis of 10-year Traffic Performance**

Analysis of traffic conditions in the next 10 years was carried out by projecting the DS value with the traffic growth rate. The traffic growth rate was determined based on data from the Manual Desain Perkerasan 2017 as a Indonesia Pavement Design Manual [14]. The traffic growth factors can be seen in Table 9.

Table 9. Factors of Traffic Growth (%)

Road Class	Java	Sumatera	Kalimantan	Average value in Indonesia
Arterial and Urban	4.8	4.83	5.44	4.75
Rural Collector	3.5	3.5	3.5	3.5
Village Road	1	1	1	1

Jalan Veteran Malang is an urban road located on the island of Java [15]. Hence, the traffic growth factor used for analysis of traffic conditions in the next 10 years is  $i=4.8\%$ .

Table 10. The Analysis of Traffic Performance

Category	Peak Time	Direction	DS			
			2027	2028	2029	2030
Corrected PCE	Morning	1	0.754	0.790	0.828	0.868
		2	0.614	0.643	0.674	0.706
	Evening	1	0.655	0.686	0.719	0.754
		2	0.720	0.755	0.791	0.829
MKJI 1997	Morning	1	0.958	1.004	1.052	1.102
		2	0.770	0.807	0.846	0.886
	Evening	1	0.824	0.864	0.905	0.949
		2	0.890	0.933	0.977	1.024

Based on the Table 10, in 2028, the DS value of the road lane calculated based on the MKJI 1997 has a value of  $>1$ . The DS value which has a value  $>1$  illustrates that the road capacity has been exceeded so that congestion and traffic density will occur in the area [16], [17]. This implies that in that year, theoretically, Jalan Veteran Malang requires traffic mitigation presumably in the form of widening the road or simulating traffic management around the road lanes. In contrast to traffic conditions calculated using Corrected PCE MC, the DS value is  $<1$  until 2030. This means that Veteran Street does not require traffic mitigation until 2030. Of course, these differences affect traffic

maintenance management related to maintenance costs and decision making.

Correction of the PCE MC value needs special attention because the number of dominant motorcycle vehicles on a road lane may affect the road performance. Hence, further research requires to observe the value of PCE with different characteristics in various regions in Indonesia. Massive research related to PCE MC is expected to be an impetus for updating the value of PCE MC in the MKJI 1997.

## CONCLUSION

The PCE MC value calculated using the modified average time headway method is 0.17. This value is smaller than the value of PCE MC set by the MKJI 1997 which was 0.25. The difference in these values affects the DS value where in the analysis over a 10-year period the DS value calculated using the corrected PCE MC value is  $DS < 1$ . These difference affects traffic maintenance management related to costs and decision making. Hereupon, further research needs to be conducted especially on roads that have different characteristics from the Veteran Street Malang. Hence, the results of this studies can be widely functioned in various regions in Indonesia.

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