Analyzing Passenger Car Equivalent for Motorcycle on Mixed Traffic Flows in Denpasar City during the COVID-19 Pandemic

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Abstract Passenger Car Equivalent (PCE) is the conversion factor of various vehicle types into passenger car units. Characteristics and geometric road conditions affect the PCE value. The PCE value on urban roads has been determined in the Indonesian Highway Capacity Manual (IHCM) in 1997. Previous studies show that the PCE value for motorcycles according to IHCM isn't appropriate. The COVID-19 outbreak that occurs at Denpasar in early March 2020 led to a policy to restrict community activities outside the home, affects the traffic flow conditions in Denpasar City. The study's aim is to estimate the PCE value for the motorcycle at COVID-19 pandemic on mixed traffic flows in Denpasar and compare it with the PCE value in the IHCM. The PCE value is determined using the time headway method. The analysis results show the PCE value of the motorcycle during the COVID-19 pandemic was different from the PCE value of the IHCM.

***Index Terms*— PCE, motorcycle, pandemic, time headway.**

I. INTRODUCTION

The first steps in determining road capacity and traffic flow are to convert the vehicle unit into a passenger car unit. A passenger car unit is a unit for traffic flow where the flow of various types of vehicles is converted into the flow of light vehicles/LV (including passenger cars) using the Passenger Car Equivalent (PCE) [1]. The PCE is a conversion factor of various types of vehicles into passenger car units to equalize the various types of vehicles operating on a road into one type of vehicle, namely a passenger car [1]. The PCE value depends on the characteristics of the road, road capacity, road traffic, and road geometric conditions in a certain area [1] [2] [3]. Several methods are used to determine the PCE value, namely the time headway ratio, regression, simulation, and equivalency criterion [4] [5] [6] [7].

The PCE value for urban roads in Indonesia refers to the Indonesian Highway Capacity Manual (IHCM) 1997. The PCE value in IHCM is 1.3 for heavy vehicles (HV), 1 for light vehicles (LV), and 0.5 for motorcycle (MC). However, from several previous studies, each road segment has a different PCE value. The correction value of PCE for a motorcycle on Teuku Umar Street in Bandar Lampung City is 0.323 by using the simulation/trial and error method [8]. The different PCE values also occur on Kartini street in Bandar Lampung. The results show PCE value for HV and MC is 1.347 and 0.564, respectively because it differs in the composition and volume of the vehicle [9]. The results of the analysis show that the PCE value for motorbikes at locations in Bandung and Semarang during peak hours is in the range 0.18 to 0.29, while for off-peak hours is in the range 0.19-0.35 [10]. The difference in PCE values in the field with IHCM is also found on the road and intersection in Gajah Mada street of Medan City. The analysis results show that the PCE value for HV and MC is 1.95 and 0.54, respectively [11]. The PCE values obtained at one of the major roundabouts in Aceh Besar, Aceh Province are 0.16 for motorcycle, 0.59 for a rickshaw, 1.07 for pickup, 1.91 for a medium vehicle, and 3.76 for the heavy vehicle [12]. Based on several previous studies, there are differences in the value

of PCE in the field and IHCM due to differences in vehicle composition, road geometric conditions, and regional developments. Therefore it is necessary to calculate PCE in the field so that the calculation of road capacity and traffic flow as the basis for the planning has an accurate value.

Denpasar City is the capital of Bali Province which has a population of 947,100 people and total vehicle ownership of 4,117,491 units in 2019, where this number has increased from the previous year [13]. The COVID-19 outbreak that spread at Denpasar in early March 2020 led to a policy to restrict community activities outside the home or work from home. This policy affects the traffic flow conditions in Denpasar City. Research on calculating the PCE value in Denpasar City is still limited. To our knowledge, the only PCE value of motorcycle study in Denpasar City was done by Purbanto in 2015 where the COVID-19 pandemic has not occurred. He determines the PCE of the motorcycle at mid-block of Sesetan Road. The study found that the PCE of motorcycles is in a range between 0.2 and 0.4 [14]. Previous research was carried out when conditions were normal or when the COVID-19 pandemic had not yet occurred, so a study was needed to find the PCE value of the motorcycle during of COVID-19 pandemic on mixed traffic flows in Denpasar City and compare it with the PCE value in the IHCM. The research was conducted on three roads, namely WR. Supratman Street, Hang Tuah Street, and Tukad Yeh Aya Street.

II. Case Study Site and Data Collection

The case study site is located in the three road segments in the city of Denpasar are Hang Tuah street, WR. Supratman street, and Tukad Yeh Aya street (Figure 1 to Figure 3). This road has a fairly heavy traffic flow. In addition, this road also contains a fairly high volume of mixed traffic. Therefore it is considered relevant for use in this research. Hang Tuah street has 9.4 meters and 2 meters of road width and road shoulder, respectively. WR. Supratman street has a road and shoulder width of 7.6 meters and 2.7 meters, respectively, while the road width and shoulder width of the Tukad Yeh Aya road is 4.8 meters and 0.4 meters, respectively. These three roads are classified into two lanes two ways of undivided road segment (2/2 UD).

This study analyzes PCE by making use of the time headway method. Time headway and traffic volume were collected using digital camera recording on Wednesday, 17 June 2020. Survey times were conducted during morning peak hours from 06:30 to 08:30, afternoon peak hours 12:00 to 14:00, and evening peak hours from 16:00 to 18:00 local time. The installation of a recording camera, road geometric measurements, and installation of tire tape on each road section were carried out the day before the survey, on Tuesday, 16 June 2020. The number of enumerators is three persons. Traffic volume data consists of all modes of the vehicle such as HV, LV, and MC.

Fig. 1. Data location site in Hang Tuah street.

Fig. 2. Data location site in WR. Supratman street.

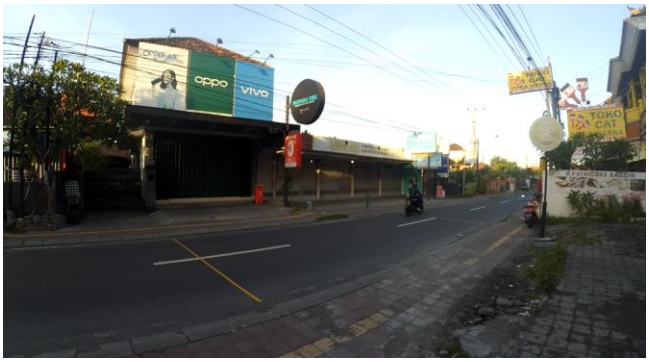

Fig. 3. Data location site in Tukad Yeh Aya street.

III. Method

The time headway method was used for estimating PCE. Time headway is the time interval between two vehicles passing at the observation point in sequence on the highway. Measurements can be made of the time between the front bumper of the vehicles in front and the front bumper of the vehicles that are behind when passing the observation point (Figure 4). Headway time data can be measured using a stopwatch. Time Headway is one way to determine the PCE value by recording the time between consecutive vehicles when the vehicle passes a predetermined point [15] [2] [16] [14]. In this study collected four vehicles combination to analyze time headway are LV following LV, LV following MC, MC following LV, and MC following MC.

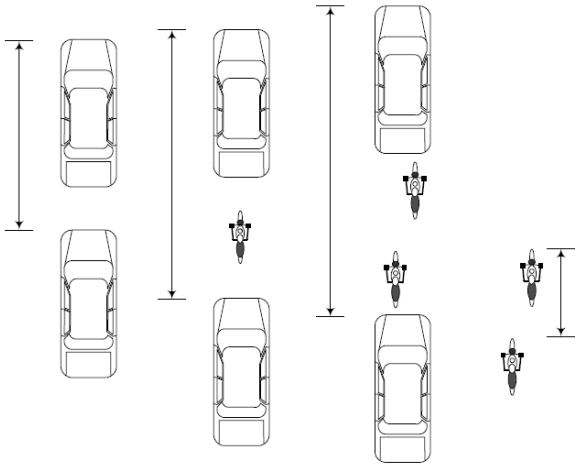

Fig. 4. Model of time headway between two consecutive vehicles [17] [14].

The characteristics of the vehicle are different and each driver has different driving abilities so that a correction factor (CF) is needed to the average headway time value with the following Equation (1) [2] [16]:

$$CF = \frac{a \cdot b \cdot c \cdot d \cdot (w-x-y+z)}{a \cdot b \cdot c + a \cdot b \cdot d + a \cdot c \cdot d + b \cdot c \cdot d} . \quad (1)$$

Where a is the number of time headway data for LV following LV, b is the number of time headway data for LV following MC, c is the number of time headway data for MC following LV, d is the number of time headway data for MC following MC, w is average of time headway for LV following LV, x is average of time headway for LV following MC, y is average of time headway for MC following LV, and z is average of time headway for MC following MC.

The adjusted mean time headway for different vehicles combination was calculated by Equation (2) to Equation (5) as below [2] [16]:

$$\bar{h}_{LVLV} = w - \frac{CF}{a} \quad (2)$$

$$\bar{h}_{LVMC} = x - \frac{CF}{b} \quad (3)$$

$$\bar{h}_{MCLV} = y - \frac{CF}{c} \quad (4)$$

$$\bar{h}_{MCMC} = z - \frac{CF}{d} \quad (5)$$

Where, $\bar{h}_{LVLV}$ is the adjusted average time headway for LV following LV, $\bar{h}_{LVMC}$ is the adjusted average time headway for LV following MC, $\bar{h}_{MCLV}$ is the adjusted average time headway for MC following LV, and $\bar{h}_{MCMC}$ is the adjusted average time headway for MC following MC.

Adjustment average time headway could satisfy with the two-side comparison equation if want to calculate PCE by the time headway ratio, as in the Equation (6) as below [2] [16]:

$$\bar{h}_{LVLV} + \bar{h}_{MCMC} = \bar{h}_{LVMC} + \bar{h}_{MCLV} \quad (6)$$

The PCE value for motorcycle is calculated using Equation (7) as below [2] [16]:

$$PCE_{MC} = \frac{\bar{h}_{MCMC}}{\bar{h}_{LVLV}} \quad (7)$$

IV. Results and Discussion

Ratio time headway has been used to estimate the PCE value for a motorcycle at three road sections in Denpasar City during the COVID-19 pandemic. Detail record of vehicle departure was made by the enumerators with camera recording equipment so that the time headway of inter-vehicle straight-ahead can be determined by vehicle types. The PCE was calculated based on the time headway ratio method for the motorcycle in the section of Hang Tuah street, WR. Supratman street and Tukad Yeh Aya street are shown in Tables 1, 2, and 3 respectively.

Table 1.
PCE calculation for MC in the section of Hang Tuah street.

Vehicle type	Number of time headway data	Average of time headway	CF	Adjusted average time headway	Comparison adjustment average time headway	PCE
LVLV	392	2.06	45.3	1.94	2.78	0.43
MCMC	392	0.96		0.84		
LVMC	164	1.21		1.49	2.78	
MCLV	152	1.00		1.3		

In Table 1, it shows the PCE value for MC in the section of Hang Tuah street is 0.43. This value turned out to be smaller than the PCE given by IHCM is 0.5, so that the difference is 0.07 or 14%. This is because when the research was carried out the traffic in the section of Hang Tuah street was still quiet due to the COVID-19 pandemic.

Table 2.
PCE calculation for MC in the section of WR. Supratman street.

Vehicle type	Number of time headway data	Average of time headway	CF	Adjusted average time headway	Comparison adjustment average time headway	PCE
LVLV	201	1.84	16.58	1.76	2.77	0.58
MCMC	343	1.06		1.01		
LVMC	124	1.37		1.50	2.77	
MCLV	160	1.16		1.27		

The result summarized in Table 2 were obtained the PCE value for MC in the section of WR. Supratman street is 0.58. This value is larger when compared to PCE value in IHCM with different 0.08 or 0.15%. This may due to the WR. Supratman street is a shopping area that is busy with community activities so that the traffic flow is a quite dense event though it is in the COVID-19 pandemic context.

TABLE 3.
PCE CALCULATION FOR MC IN THE SECTION OF TUKAD YEH AYA STREET.

Vehicle type	Number of time headway data	Average of time headway	CF	Adjusted average time headway	Comparison adjustment average time headway	PCE
LVLV	241	1.77	19.13	1.69	2.71	0.61
MCMC	267	1.09		1.02		
LVMC	99	1.26		1.46	2.71	
MCLV	87	1.03		1.25		

The PCE value of MC in the section of Tukad Yeh Aya street was found to be 0.61 which is slightly higher than the suggested value by IHCM (Table 3). The difference in PCE value is 0.11 or 21%. The estimated PCE for MC in Tukad Yeh Aya street is higher than other streets, indicating a greater individual effect on traffic in Tukad Yeh Aya street. This is probably because Tukad Yeh Aya street is a residential area that is crowded with community activities.

V. CONCLUSIONS

This paper has discussed the calculation of PCE for MC according to mixed traffic flows condition of three section streets in Denpasar city during the COVID-19 pandemic. The PCE value was determined using the time headway ratio method. The estimated PCE for MC in the section of Hang Tuah street, WR. Supratman street and Tukad Yeh Aya street are 0.43, 0.58, and 0.61, respectively. The comparison between the estimated PCE and the PCE in IHCM is demonstrated in this paper. The PCE presently in IHCM considerably differs from the PCE obtained from this study. In order to get PCE values, that really represented the traffic flow condition of Denpasar City, data from other section streets of Denpasar are needed. Hence, a study on the PCE in other road segments with mixed traffic flow is suggested for future research.

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