Civil Engineering Dimension
https://ced.petra.ac.id

The Value of Passenger Car Equivalent using the Time Headway Method on Urban Roads

Irwandi[1]*, Sutandi, A.C.[1], and Mukti, E.T.[2]
[1] Department of Civil Engineering, Parahyangan Catholic University
Jl. Ciumbuleuit No. 94, Bandung, INDONESIA
[2] Department of Civil Engineering, Tanjungpura University
Jl. Prof. Dr. Hadarawi Nawawi, Pontianak, INDONESIA

DOI: https://doi.org/10.9744/ced.27.1.33-46

Article Info:
Submitted: Dec 10, 2024
Reviewed: Feb 02, 2025
Accepted: Mar 06, 2025

Keywords:
Passenger Car Equivalent (PCE), Distribution Time Headway, Urban Road, Kolmogorov Smirnov.

Corresponding Author:
Irwandi
Department of Civil Engineering, Parahyangan Catholic University
Jl. Ciumbuleuit No. 94, Bandung, INDONESIA
Email: irwandih105@gmail.com

Abstract

The escalating proliferation of vehicles has had a significant impact on the existing Passenger Car Equivalent (PCE) values, making them less effective under current traffic conditions for assessing road performance. This study aims to redefine PCE values for urban highways using the Time Headway method. Data collection was conducted over four days during peak traffic hours. The methodology involved direct field observations, analysis footage, and statistical modeling of time headway data distributions. The Kolmogorov-Smirnov fit test identified the Wakeby distribution as the most suitable representation of time headway data. Results yielded PCE values of 0.413 for motorcycles and 1.416 for medium vehicles, with discrepancies of 65.37% and 18.02%, indicating that the measured PCE values surpass the established benchmarks. The rise in vehicle numbers and the methodologies employed contribute to the variations in observed PCE levels. This research provides valuable insights for urban road planning and foundation studies for future research.

INTRODUCTION

Passenger vehicles surged by 48.9 million units, reflecting a growth rate of 64%, while the count of commercial vehicles in Indonesia rose by more than 1.2 million units, representing a growth rate of 29% [1]. All of these advancements have altered the present traffic characteristics compared to the past. The evaluation of road performance in Indonesia is based on the Guidelines for Road Capacity in Indonesia [2]. The growing volume of cars and changes in traffic patterns have rendered the previously set Passenger Car Equivalent (PCE) values obsolete. The PCE values used in road capacity computations are significantly influenced by the evolving traffic circumstances and geometric attributes of the roadway over time [3]. In traffic analysis, PCE is a crucial indicator for assessing the impact of different vehicle types on traffic density within a road section. The Time Headway technique is the most suitable approach for assessing the utility of PCE on urban roads [4]. The Time Headway approach allows the modification of the PCE value in accordance with prevailing traffic circumstances [5]. The growth in vehicle numbers immediately impacts traffic congestion, particularly in metropolitan locales like Pontianak City, significantly altering traffic dynamics and presenting new issues for urban transportation planning.

The purpose of this research focused on determining the value of Passenger Car Equivalent (PCE) in Pontianak City using the Time Headway approach. The research concentrated on Adi Sucipto Road in Pontianak City, exemplifying urban traffic conditions. Adi Sucipto Road is selected due to its status as a business zone characterized by a varied

Note : Discussion is expected before July, 1st 2025, and will be published in the "Civil Engineering Dimension", volume 27, number 2, September 2025.
ISSN : 1410-9530 print / 1979-570X online
Published by : **Petra Christian University**

and uninterrupted flow of vehicular traffic. Adi Sucipto Road often has significant traffic congestion, particularly during peak hours [6], and is recognized as a high-risk zone for traffic accidents in Pontianak [7]. The assessment of the PCE value by the time headway approach is very pertinent and significant for comprehending the traffic characteristics on the Adi Sucipto Road segment. This information is valuable for assessing road performance and designing roadways according to traffic characteristics in Pontianak.

The significance of this study lies in addressing the increasing complexity and diversity of urban traffic patterns. This conceptual framework enables a more streamlined and methodical evaluation of roadway capacity and operational efficiency. By employing this approach, transportation engineers and urban planners can more effectively analyze and optimize traffic flow in congested metropolitan areas, ultimately leading to enhanced mobility and reduced congestion. The PCE value may fluctuate based on traffic characteristics, vehicle types, and road conditions [8]. This research improves the accuracy of traffic planning by using the time headway method to calculate passenger car equivalent values, hence providing more exact and relevant information for traffic planners. Effective road design, intersections, and traffic patterns are essential, especially in urban areas.

METHOD

Passenger Car Equivalent (PCE), a fundamental metric in transportation engineering, quantifies the impact of diverse vehicular categories on traffic dynamics by expressing their influence in terms of passenger vehicle units [9]. This concept serves as a crucial parameter in traffic flow analysis and infrastructure planning, enabling engineers to standardize the heterogeneous composition of vehicular traffic for more accurate capacity assessments and design considerations.

The Theory of Time Headway

Time headway refers to the temporal interval between two vehicles driving in the same lane as they traverse a certain place [10]. The time gap is defined as the interval between the front end of the succeeding vehicle crossing a certain spot and the rear end of the preceding vehicle passing the same observation point [11]. Time headway denotes the duration needed for a vehicle to traverse a certain observation site and the interval necessary for the subsequent vehicle's arrival [12]. The Highway Capacity Manual (HCM) [13] defines time headway as the duration, in seconds, required for two successive vehicles to traverse a certain place on a roadway section, determined by identical characteristics of both vehicles, such as the front axle or front bumper.

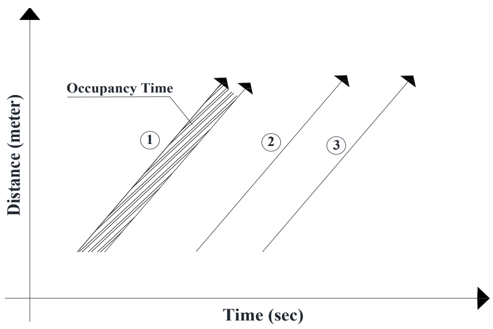

Figure 1. Microscopic Analysis of Time Headway vs. Distance

Figure 1. shows a comprehensive representation of the timeframe. The horizontal axis shows time, whereas the vertical axis signifies distance. t_1, t_2, t_3, and t_4 show the arrival times of each vehicle, supposing that the cars are traveling at a uniform velocity. The time headway for each arrival may be expressed using Equation (1).

$$H_{m-n} = n - m \quad (1)$$

This H_{m-n} is the time headway between vehicles m and n, where m is the time when vehicle m crosses the reference line, and n is the time when vehicle n crosses the reference line.

Analysis of the Time Headway Method

The PCE Medium Vehicle (MV) value is determined by dividing the average of MV followed by MV by the average of Passenger Car (PC) followed by PC. The outcome will be precise if the of the motorcycle vehicle is independent of the previous or succeeding vehicles. The scenario in which the average of PC followed by PC, in conjunction with the average of MV followed by MV, equals the aggregate of the average of PC followed by MV and the average of MV followed by PC, may be expressed as Equation (2).

$$t_a + t_d = t_b + t_c \tag{2}$$

t_a represents the average of PC followed by PC, t_b denotes the average of PC followed by MV, t_c signifies the average of MV followed by MV, and t_d indicates the average of MV followed by MV. According to the varying characteristics of each vehicle and the different abilities and levels of observation of drivers while operating their vehicles, it is difficult to create a situation that meets the aforementioned similarities. Therefore, the average time headway value obtained must be corrected using Equation (3).

$$\left[ta - \frac{k}{na}\right] + \left[td - \frac{k}{nd}\right] = \left[tb - \frac{k}{nb}\right] + \left[tc - \frac{k}{nc}\right] \tag{3}$$

Allow n_a represent the time interval between two successive data points where PC is succeeded by PC, n_b signify the time interval between two successive data points where PC is succeeded by MV, n_c represent the time interval between two successive data points where MV is succeeded by PC, and n_d indicate the time interval between two successive data points where MV is succeeded by MV. The average time headway of the vehicle pair is then adjusted using Equations (4a) - (4d).

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

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

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

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

By use the corrected average time headway value, as stated in Equation (5).

$$ta_k + td_k = tb_k + tc_k \tag{5}$$

The adjusted average values are as follows: t_{ak} represents the PC-PC average, t_{bk} represents the PC-MV average, t_{ck} represents the MV-PC average, and t_{dk} represents the MV-MV average. The value of PCE MV may be calculated using Equation (6).

$$PCE_{MV} = \frac{td_k}{ta_k} \tag{6}$$

Polynomial Regression

Polynomial regression is an extension of multivariate linear regression that characterizes the relationship between the independent variable (x) and the dependent variable (y) [14]. A polynomial trendline is a curved line used to depict data that shows volatility. The use of this trendline is appropriate when the data exhibits a fluctuating pattern that cannot be adequately accounted for by a linear relationship. The polynomial trendline may be mathematically represented by Equation (7).

$$y = ax^n + bx^{n-1} + k \tag{7}$$

In this context, y represents the dependent variable, x is the independent variable, while a, b, and k are the values of the regression coefficients, and n signifies the degree of the polynomial.

R Square (R^2)

This method is used to determine the magnitude or relative effect of the independent variables in the regression model on the dependent variables, either singularly or in combination [15]. R square, represented as R^2, is a statistical measure used in regression analysis to assess the degree to which the regression model explains variations in the dependent variable in relation to the independent variable [16]. R squared (R^2) is a statistic that measures the precision of a regression model. It provides significant information into the model's goodness of fit. In regression analysis, it functions as a statistical measure that evaluates how well the regression line fits the observed data. Consequently, it is crucial to use statistical models for the purpose of forecasting future results or conducting hypothesis testing. The coefficient of determination R square may be computed using Equation (8).

$$R^2 = 1 - \frac{\Sigma(y_i - y_i\hat{})^2}{\Sigma(y_i - \bar{y})^2} \quad (8)$$

With y_i is the actual value, R^2 is R square, y_i^ is Model predicted value, $\bar{y}$ is Average actual value. R squared is a statistic that measures the percentage of variation in the dependent variable explained by the independent variable. R squared is a scalar ranging from 0 to 1, signifying the degree to which the combined impact of independent variables influences the dependent variable's value. The R squared (R^2) value assesses the degree of influence that certain independent variables have on the dependent variable. The R-squared value may be classified into three categories strong (R-squared 0.75), moderate (R-squared 0.50), and weak (R-squared 0.25) [17].

The present research utilizes a quantitative technique via a field survey method to examine the Passenger Car Equivalent (PCE) values on urban route sections. A preliminary survey is performed to assess field conditions, establish observation sites, and identify any barriers that may arise throughout the course of the analysis. Research equipment includes writing utensils, CCTV, measuring tape, and spray paint for marking observation points. Data collection is conducted during peak hours (06.00-08.00, 11.00-13.00, and 16.00-18.00) for four days (Monday, Friday, Saturday, and Sunday) [18].

Primary Data Collection

Geometric road surveys include measuring the width of traffic lanes, the width of road shoulders, and determining the kind of road using measuring tools such as a rolling meter and other instruments.

Figure 2. Setting up of CCTV

Figure 3. Physical Marking

Figure 4. Results of CCTV

In Figure 2, the setting up of CCTV is used to record real-time traffic flow, enabling the collection of accurate data on vehicle movement, time headway between vehicles, and traffic volume. Install CCTV at a height of 3-5 meters [19]. This height is perfect for obtaining a wide and clear field of view, allowing for effective observation of the time intervals between vehicles [20]. Ensure that the device is capable of recording clearly and is not obstructed by any other objects. In Figure 3, there are physical markings on the road, such as lines or signs, that aid in measuring distance and time headway. By using appropriate labeling, the gathered data will become more precise, hence enabling more effective analysis of time intervals [21]. Figure 4 shows the ability of closed-circuit television (CCTV) to record and document various types of vehicles that pass through the region, such as Passenger Car (PC), Motorcycles (MC), and Medium Vehicles (MV). The camera records the time intervals between successive vehicles, known as the time headway. A traffic volume analysis quantifies the number of vehicles traversing a road segment, including Motorcycle (MC), Passenger Car (PC), and Medium Vehicle (MV). The data is separated based on hourly time intervals and the order of vehicle arrivals [22]. The sought-after data is the time headway between various combinations of vehicle pairs (MC-PC, PC-MC, MC-MC, MV-PC, PC-MV, MV-MV, PC-PC) [23].

Data Analysis

The distribution of time headway is analyzed using the application for distribution analysis and Kolmogorov-Smirnov goodness-of-fit test. The method includes collecting and submitting time headway data, choosing a distribution, doing a goodness-of-fit test, evaluating and showing the data, and identifying the optimal distribution [24]. The analysis of PCE values using the time headway approach juxtaposes the average time headway of various vehicle types with those of passenger cars. The processes include data collection via CCTV, adjustment of average time headway values, computation of PCE values, calibration of PCE values by polynomial regression, analysis of findings, and comparison with established PCE values [25]. This method means to provide an exhaustive comprehension of traffic features and precise PCE values. The use of the Time Headway method and distribution analysis using enables this study to provide more representative values of PCE for the dynamic traffic conditions in the city of Pontianak.

The present research employs a systematic and organized quantitative methodology, guaranteeing the validity and trustworthiness of the data produced. This project seeks to significantly enhance the knowledge and management of urban traffic in Pontianak by a mix of field surveys, statistical analysis, and comprehensive data interpretation.

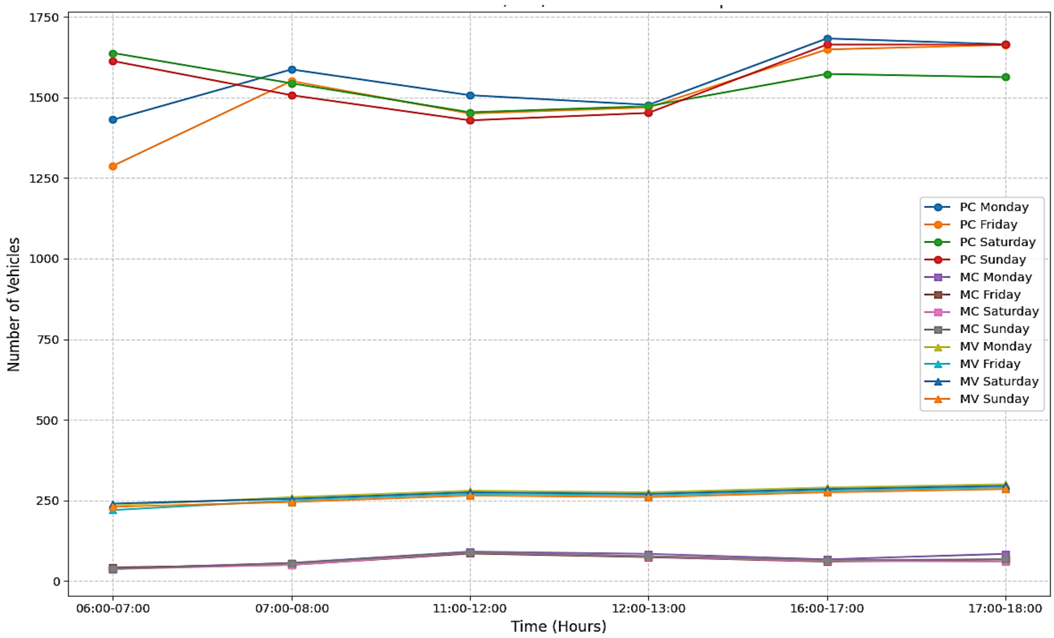

Figure 5. Graph of Traffic for PC, MC, and MV on Adi Sucipto Road

In Figure 5, the graph shows the fluctuation of traffic volume on Adi Sucipto Road. There is a consistent peak in traffic volume during the morning and evening rush hours, which is related to commuting to and from work or school. The peak during midday is caused by lunchtime activities or midday movements. Motorcycles and passenger cars dominate the traffic composition, medium vehicles maintain the most consistent pattern throughout the day, all vehicle types show reduced volumes during early morning and late evening periods, The combined peak for all vehicle types occurs during the 16:00-17:00 timeframe. This analysis demonstrates a clear correlation between time of day and vehicle type distribution, with distinct patterns for each category of vehicle on Adi Sucipto Road.

RESULTS AND DISCUSSION

Analyzing the distribution of observed headway data by means of many theoretical models with the system. The data time headway is input into the application table, and calculation and distribution matching may be executed by choosing the analysis menu and descriptive statistics. Four days of data time headway are being evaluated utilizing the program [26]. This distribution gives a satisfactory match for the data for Monday, Friday, Saturday, and Sunday [27].

Statistical Test of Time Headway Data on Monday

Analyzing the distribution of recorded time headway data using several theoretical models in the program. The time headway data from Monday indicates that the critical value, with a significance level of 0.01 and a sample size of 865, computed using Equation 1 is 0.0553. According to the accepted hypothesis, the critical value is compared with the Kolmogorov-Smirnov value of 65 distributions created by the tool. The analytical results of the Kolmogorov-Smirnov Test demonstrate that the Extreme Value Gene distribution is the most suitable for time headway data on Monday.

Figure 6 shows that the Gen Extreme Value (GEV) distribution is suitable for the observed frequency distribution of the time headway data. The shown GEV curves demonstrate that the GEV model well characterizes the distribution of the observed data. This distribution is especially beneficial in domains like transportation and traffic management, where comprehending severe occurrences may enhance planning and decision-making.

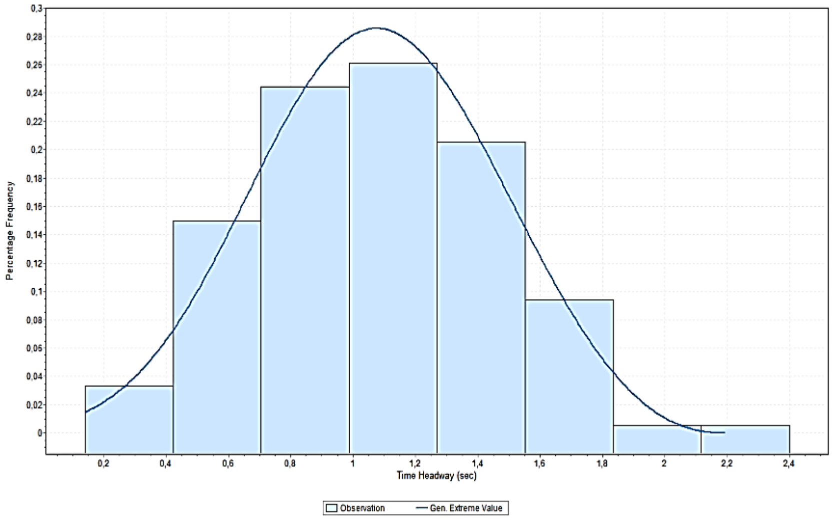

Figure 6. Comparison Chart of Observation Frequency and Extreme Value Gene Distribution

Statistical Test of Time Headway Data on Friday

The critical value for Friday time headway data, with a significance level of 0.01 and a sample size of 821, computed using Equation 2.2, is 0.0568. According to the accepted hypothesis, the crucial value is compared with the Kolmogorov-Smirnov value of 65 distributions created by the tool. The results of the Kolmogorov-Smirnov Test demonstrate that the Wakeby distribution is the best suitable for time headway data on Friday.

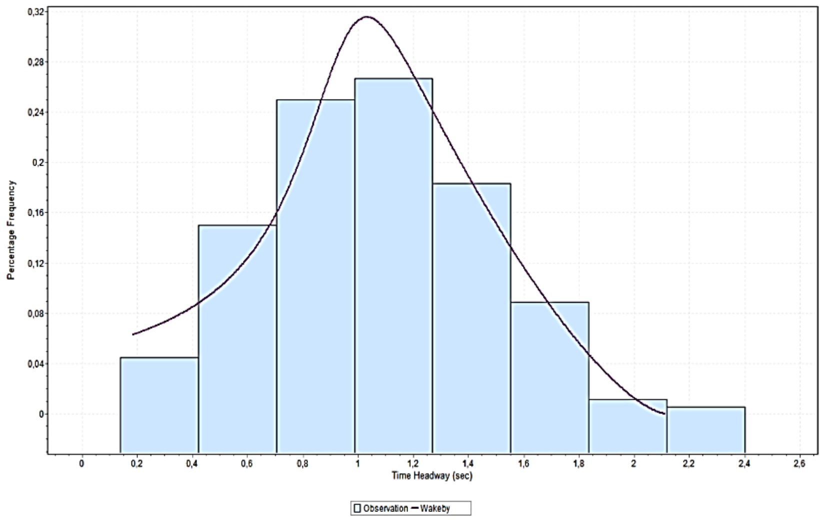

Figure 7. Comparison Chart of Observation Frequency and Wakeby Distribution

Figure 7. shows that the Wakeby distribution is suitable for the observed frequency distribution of the time headway data. The Wakeby distribution demonstrates a strong match to the observed data. Graphs provide a visual comparison between the observed frequency distribution and the Wakeby distribution, aiding in the comprehension of the observed data's alignment with a certain statistical model.

Statistical Test of Time Headway Data on Saturday

The critical value for Saturday time headway data, with a significance level of 0.01 and a sample size of 836, computed using Equation 2.2, is 0.0563. According to the accepted hypothesis, the crucial value is juxtaposed with the Kolmogorov-Smirnov value of 65 distributions produced by the tool. The analytical findings of the Kolmogorov-Smirnov Test indicate that the Weibull distribution is the best appropriate for time headway data on Saturdays.

Figure 8. shows the Weibull distribution is appropriate for the observed frequency distribution of the time headway data. The Weibull distribution exhibits a robust correspondence with the observed data. The green curve roughly corresponds with the blue histogram pattern. This significantly enhances traffic flow, facilitating traffic analysis and

planning. The graph demonstrates that the Weibull distribution accurately represents the distribution of time headways seen in the data, enabling additional research in traffic and reliability research.

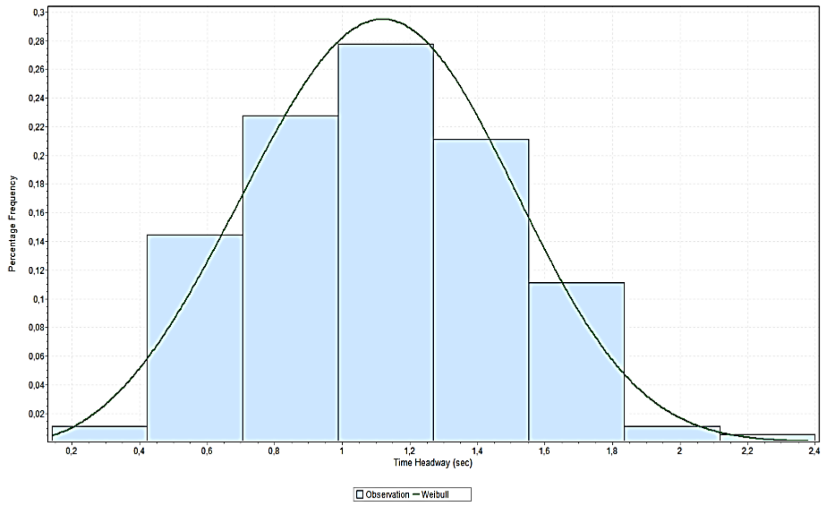

Figure 8. Comparison Chart of Observation Frequency and Weibull Distribution

Statistical Test of Time Headway Data on Sunday

A significance level of 0.01 and a sample size of 752, is 0.0595. According to the accepted hypothesis, the critical value is juxtaposed with the Kolmogorov-Smirnov value of 65 distributions produced by the tool. The analytical findings of the Kolmogorov-Smirnov Test indicate that the Johnson SB distribution is the best appropriate for time headway data on Sundays.

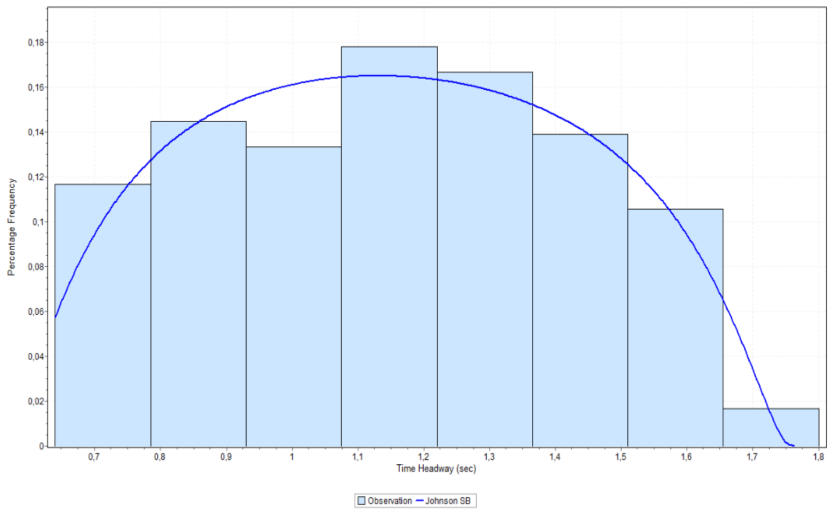

Figure 9. Comparison Chart of Observation Frequency and Johnson SB Distribution

Figure 9 shows that the Johnson SB distribution is suitable for the observed frequency distribution of the time headway data. This histogram visually depicts the distribution of observation data over several time periods. This graph clearly illustrates the alignment of the observed data with the Johnson SB distribution, applicable for further analysis in research or practical scenarios concerning vehicle time intervals.

The research results demonstrate that the time headway distribution on Adi Sucipto Road is ideal. The variance on Monday is represented by the Gen Extreme Value (GEV) distribution, which is suitable for the given data. On Friday, the Wakeby distribution exhibits a robust alignment with the observational data. On Saturday, the Weibull distribution is appropriate for the given data, however Sunday is represented by the Johnson SB distribution, which corresponds with the observed data and may be used for future analytical inquiry. This is a summary of the time headway data distribution shown in Table 1.

As shown in table 1, the Wakeby distribution is an appropriate statistical model for time headway data, offering a satisfactory fit for Monday, Friday, Saturday, and Sunday. The Wakeby distribution has a strong match to the observed data in time headway analysis and exhibits flexibility in characterizing diverse data patterns.

Table 1. Time Headway Data Distribution

Days		Critical Value (CV)	Distribution Accepted	Statistics
Weekdays	Monday	0.0553	Gen. Extreme Value	0.0417
			Wakeby	0.0438
			Weibull (3P)	0.0451
			Kumaraswamy	0.0456
	Friday	0.0568	Wakeby	0.0493
			Dagum	0.0563
			Weibull	0.0494
Weekends	Saturday	0.0563	Wakeby	0.0498
			Kumaraswamy	0.0514
			Weibull (3P)	0.0514
			Weibull (3P)	0.0514
			Inv. Gaussian (3P)	0.0550
	Sunday	0.0595	Johnson SB	0.0385
			Error	0.0419
			Wakeby	0.0424
			Dagum (4P)	0.0454
			Gen. Gamma (4P)	0.0456

Analysis of the Passenger Car Equivalent (PCE) Statistic

The passenger Car Equivalent (PCE) value influenced by elevated traffic volume may alter the PCE value, since increased traffic density often extends the time headway between vehicles. An analysis of the PCE value based on traffic volume using the Time Headway method with vehicles passing by the research location on Adi Sucipto Road in Pontianak City.

PCE Values based on Monday's Traffic Volume

The analysis of the Passenger Car Equivalent (PCE) value, predicated on Monday traffic volume, is performed to ascertain the influence of Monday traffic volume on the PCE value. Monday signifies the beginning of work and academic pursuits for the week and is characterized by increased traffic, especially during the morning hours [28]. On Mondays, there is often a higher density of vehicle travel due to the resumption of workplace and school activities after the weekend. Passenger cars and motorcycles exhibit higher PCE values in response to increased traffic volumes, suggesting that traffic density has an impact on these vehicles [29].

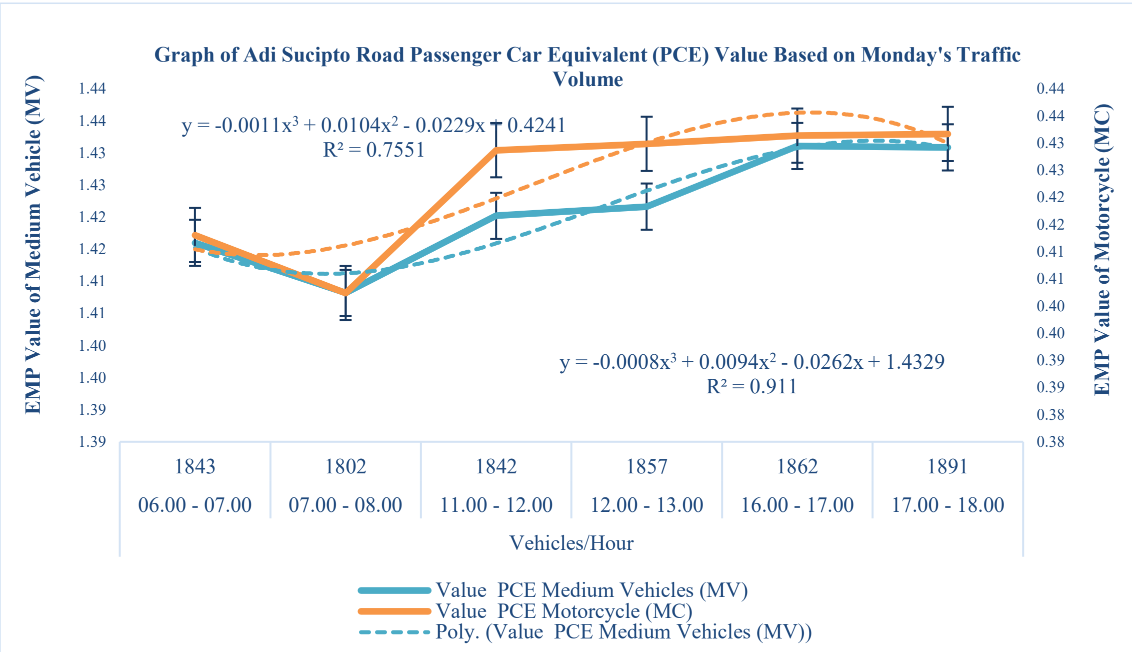

Figure 10. Graph of Passenger Car Equivalent (PCE) Values based on Monday Traffic Volume

In the Figure 10, the graph illustrates two polynomial regression equations for the values of PCE for Medium Vehicle (MV) and Motorcycles (MC). The observed trend indicates a clear daily pattern in the PCE value, which is influenced by the patterns of activity and traffic volume on Adi Sucipto Road. The coefficient of determination of 0.911 shows that 91.1% of the variance in PCE values for medium vehicles is elucidated by the regression model. This indicates that the model exhibits a robust alignment with the observed data. The coefficient of determination R result of 0.7551 shows that 75.51% of the variability in the PCE values for motorcycles is elucidated by this regression model. Although lower than medium vehicles, this model nonetheless has a strong level of compatibility.

PCE Values based on Friday's Traffic Volume

The analysis of the Passenger Car Equivalent (PCE) value, predicated on Friday traffic volume, is performed to assess the influence of Friday traffic volume on the PCE value. Friday has a consistent traffic flow pattern that directly impacts the PCE result. In Fridays, there is a distinctive traffic pattern that affects the PCE value [30]. The presence of Friday prayer activities leads to an increase in traffic volume at certain times, particularly before and after Friday prayer times. The composition of vehicles on Fridays may also vary, with an increased proportion of motorcycles for trips to the mosque, which affects the PCE value [31].

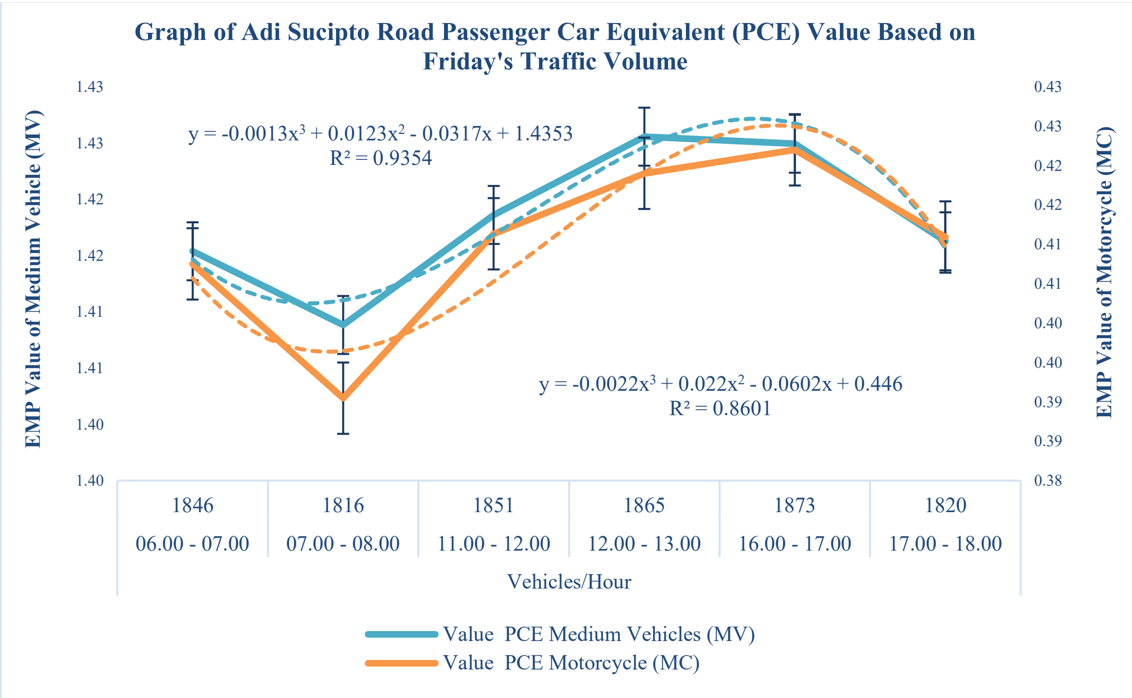

Figure 11. Graph of Passenger Car Equivalent (PCE) Values based on Friday Traffic Volume

In Figure 11, the graph illustrates two polynomial regression equations for the values of PCE for Medium Vehicle (MV) and Motorcycle (MC). The observed trend indicates a clear daily pattern in the PCE value, influenced by the activity patterns and traffic volume on Adi Sucipto Road. The coefficient of determination of 0.935 signifies that 93.5% of the variance in PCE values for medium vehicles is elucidated by the regression model, indicating a robust correlation between the model and the empirical data. The coefficient of variation R score of 0.860 shows that 86% of the variance in PCE values for motorcycles is elucidated by this regression model. Although lower than medium vehicles, this model nonetheless has a strong level of compatibility.

PCE Values based on Saturday's Traffic Volume

The analysis of the Passenger Car Equivalent (PCE) value relative to Saturday traffic volume is performed to assess the influence of Saturday traffic volume on the PCE value [32]. Saturdays exhibit more footfall compared to typical weekdays, particularly in business districts or retail precincts. Saturdays often exhibit a greater variety of activities, such as leisure outings, shopping, or family visits, which might lead to distinct traffic patterns characterized by a larger prevalence of motorcycles for transportation purposes.

In Figure 12, the graph displays two polynomial regression equations for the values of PCE for Medium Vehicle (MV) and Motorcycle (MC). The increasing trend in the value of PCE from morning to afternoon indicates that the influence of vehicles on road capacity tends to increase as traffic volume increases. A coefficient of determination of 0.942 indicates that 94.2% of the variability in PCE values for medium vehicles can be determined by the regression model. This indicates that the model aligns closely with the observed data. The coefficient of determination R result of 0.919 indicates that 91.9% of the variance in the PCE values for motorcycles has been identified by the regression model. Although lower than medium vehicles, this model nonetheless has a strong level of compatibility.

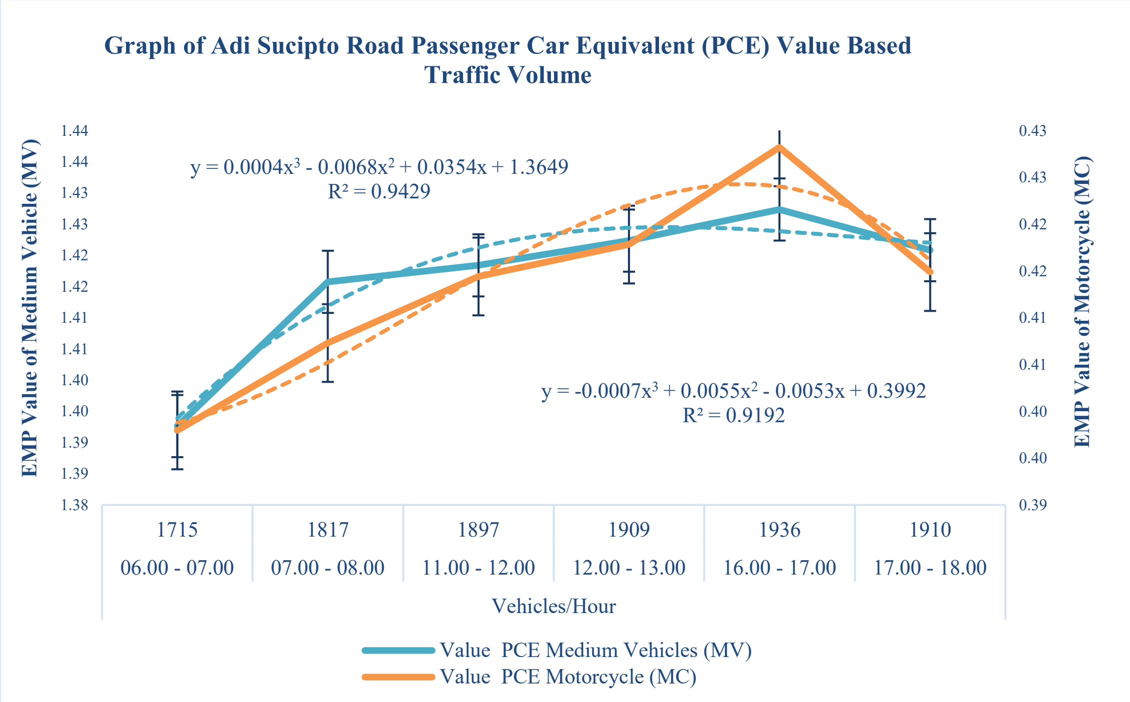

Figure 12. Graph of Passenger Car Equivalent (PCE) Values based on Saturday Traffic Volume

PCE Values based on Sunday's Traffic Volume

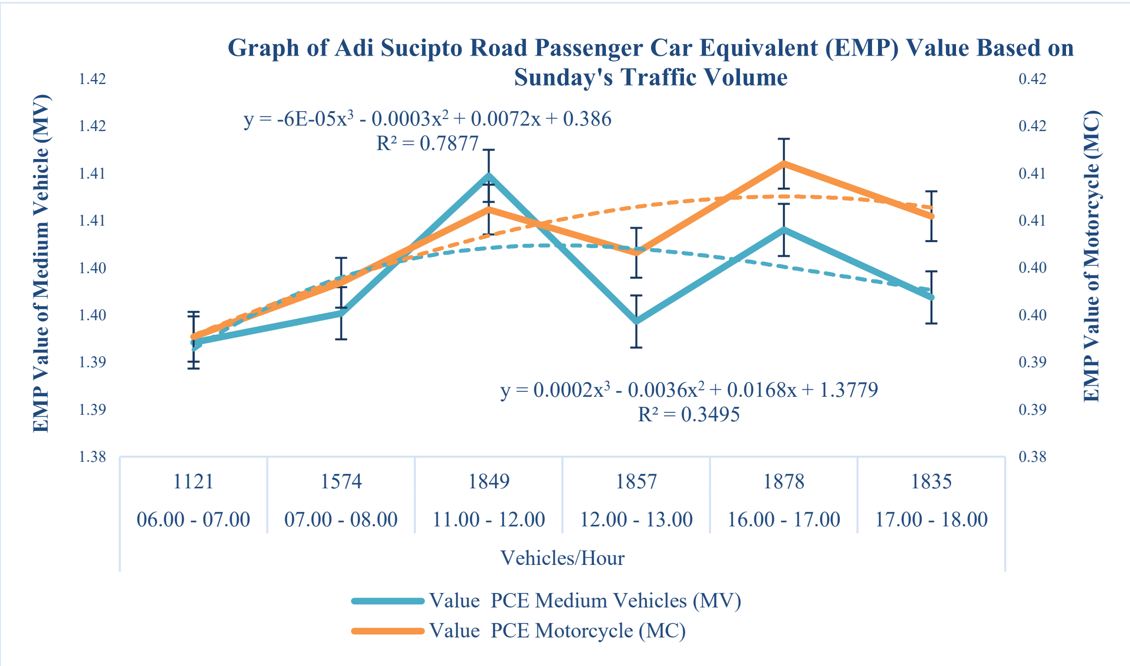

Figure 13. Graph of Passenger Car Equivalent (PCE) Values based on Sunday Traffic Volume

The analysis of the Passenger Car Equivalent (PCE) value based on Sunday traffic volume is performed for assessing the effects of Sunday traffic volume on the PCE value. During Sundays, drivers tend to be more relaxed and unhurried, resulting in a different traffic flow compared to weekdays [33]. Differences in traffic composition. On Sundays, the prevalence of medium vehicles (trucks and buses) is greater, while on weekends, passenger cars are dominant. In the morning, the traffic volume is lower due to the slower start of people's activities and their more relaxed driving behavior, which might alter the traffic dynamics [34]. In average, traffic numbers are lower compared to weekdays. Peak traffic levels often occur in the afternoon when there is a rise in community activities. Comparing traffic volumes and patterns on Sundays with weekdays allows for the identification of disparities in traffic behavior and facilitates the implementation of appropriate traffic management solutions.

In Figure 13, the graph illustrates two polynomial regression equations for the values of PCE for Medium Vehicle (MV) and Motorcycle (MC). The observed trend indicates a clear daily pattern in the PCE value, which is influenced by the activity patterns and traffic volume on Adi Sucipto Road. The coefficient of determination R for Medium Vehicle (MV) is 0.3495, indicating that about 34.95% of the variability in PCE values is accounted for by the regression model. This signifies that the model exhibits a poor match with the observed data. The coefficient of variation R result for Motorcycles (MC) (0.7877) indicates that about 78.77% of the variability in PCE values is elucidated by the regression model. This signifies that the model exhibits a strong alignment with the observed data. The research and discussion indicate that the value of PCE fluctuates with traffic volume. The following is a summary of the PCE findings derived from the traffic volume shown in Table 2.

Table 2. A Review of the PCE Results based on Traffic Volume

Indicator	Value PCE			
	Motorcycles (MC)		Medium Vehicle (MV)	
	R square (R^2)	Average	R square (R^2)	Average
Traffic Volume Monday	0.755	0.423	0.911	1.421
Traffic Volume Friday	0.860	0.410	0.935	1.418
Traffic Volume Saturday	0.919	0.413	0.942	1.416
Traffic Volume Sunday	0.787	0.403	0.349	1.399

As shown in Table 2. the polynomial regression analysis and R-squared value for Saturday demonstrate that the model for calculating the Passenger Car Equivalent (PCE) value for motorbikes and medium-sized cars on Adi Sucipto Street has an excellent match with the observed data. This signifies that traffic patterns may be precisely forecasted using the model. The polynomial regression model for Motorcycles (MC) produces the greatest R-squared value of 0.919, accompanied by a PCE value of 0.413. Therefore, the model accounts for 91.9% of the variability in the data, suggesting a strong correspondence between the model and the actual data. The PCE result of 0.413 indicates that one motorbike has a road capacity and traffic flow comparable to around 0.4 passenger automobiles. For Medium Vehicles (MV), the model produces a higher R-squared value of 0.942 and a PCE value of 1.416. This signifies that 94.2% of the data variance can be elucidated by the model, indicating an exceptionally high degree of fit. The PCE value of 1.416 shows that one vehicle equates to around 1.4 passenger vehicles regarding its effect on traffic flow. The elevated R-squared values for both vehicle categories (0.919 for MC and 0.942 for MV) demonstrate that the independent variable, traffic volume, has a substantial impact on the dependent variable, PCE value. This enhances the model's validity in forecasting PCE values depending on traffic volume. Further analysis of traffic patterns reveals that Saturdays exhibit distinct characteristics. Traffic patterns on Saturdays tend to be more consistent compared to other days. On Saturday, there is a more diverse and scattered pattern of movement between work and recreational activities. Unlike working days, which have clear busy hours in the morning and afternoon, Saturdays tend to have a more evenly distributed traffic throughout the day, resulting in a high R-squared value in determining the Passenger Car Equivalent (PCE) for motorcycles and medium vehicles on Adi Sucipto Road shows a strong correlation with observational data.

Comparison of PCE Values based on Observational Findings with PCE Values in the Indonesian Road Capacity Guidelines

Observation is conducted using the time headway method, which measures the time gap between vehicles to determine the value of PCE. This observation is often conducted in locations with specific traffic characteristics, such as urban roads with a high proportion of motorcycles. The use of direct field observation methods may provide differing values of PCE in comparison to the employed strategy. The article compares the Passenger Car Equivalent (PCE) value as defined by the Indonesian Road Capacity Guidelines (IRCG), particularly in Figure 14.

Figure 12 in shows the recorded values for Motorcycle (MC) and Medium Vehicle (MV). The observed motorcycle PCE value differs from the IRCG PCE value by 65.37%, whereas the observed medium vehicle PCE value differs by 18.02%. This suggests that the observed PCE value for medium cars exceeds the value specified by IRCG.

Passenger Car Equivalent (PCE) value is affected by the rise in vehicle quantity and the chosen study approach. The increase in vehicle quantity results in traffic congestion, impeding vehicular movement and decreasing average speed. This is caused by the interaction between vehicles that occur more often and limited space for maneuvering, which compels drivers to reduce speed and increase reaction time to maintain safe and smooth traffic flow. The methodology used in this study involves observing and analyzing the varying characteristics of traffic at different times, which affects the amount of data collected to calculate data variability and the representativeness of the resulting PCE values.

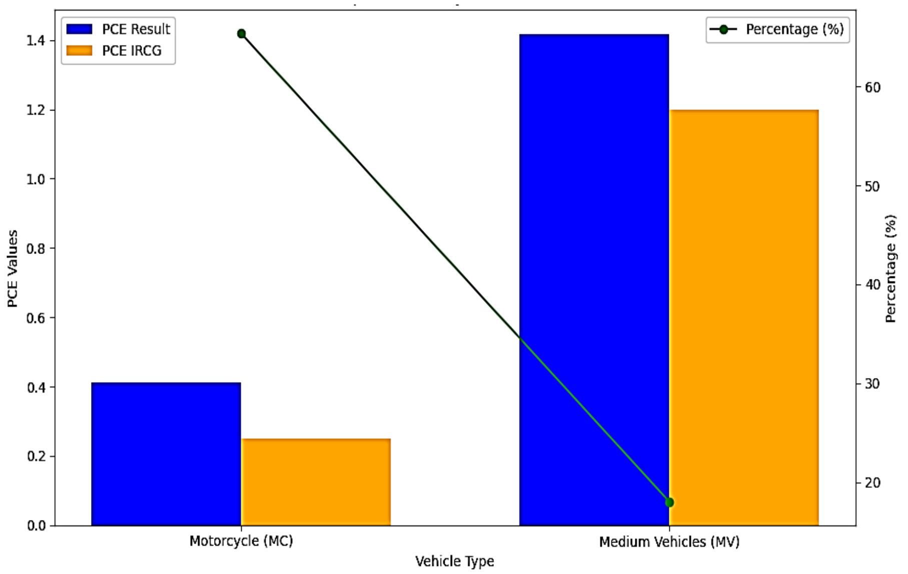

Figure 14. Comparative Analysis of Passenger Car Equivalent Values between Observations and the Indonesian Road Capacity Guidelines (IRCG)

CONCLUSIONS

The analysis identification results indicate that the statistical distribution that best fits the time headway data is the Wakeby distribution, since each provides an acceptable fit for Monday, Friday, Saturday, and Sunday. The Wakeby distribution in time headway analysis demonstrates good fit to observational data and flexibility in depicting various data patterns. Thus, it becomes a preferred choice in traffic analysis for planning purposes in order to better understand and manage traffic flow. The analysis for the Passengers Car Equivalent (PCE) values for Motorcycles (MC) and Medium Vehicles (MV) on Mondays, Fridays, Saturdays, and Sundays along Adi Sucipto Road was performed using direct field observations, video CCTV recordings, and time headway analysis. The research used empirical field circumstances, using time headway data obtained from traffic volume during peak hour intervals in the morning (06:00 - 08:00), the afternoon (11:00 - 13:00), and evening (16:00 - 18:00). The PCE result for Motorcycles (MC) was 0.413, while for Medium Vehicles (MV) it was 1.416. The percentage difference between the observed motorcycle PCE value and the PCE value of the Indonesian road capacity guideline is 65.37%, while the percentage difference between the observed medium vehicle PCE value and the PCE value of the Indonesian road capacity guideline is 18.02%. This indicates that the observed PCE value for medium vehicles is higher than the value set by the Indonesian road capacity guideline. The PCE observation result is affected by an increase in vehicle quantity and research techniques.

REFERENCES

1. Chapman, G.P. and Dutt, A.K., *Urban Growth and Development in Asia: Volume I: Making the Cities*, Routledge, London, 2019.
2. Direktorat Jenderal Bina Marga, *Pedoman Kapasitas Jalan Indonesia*, Surat Edaran Direktur Jenderal Bina Marga Nomor 09/P/BM/2023, Direktorat Jenderal Bina Marga, Jakarta, 2023.
3. Sumarsono, A., Mahmudah, A.M., and Yulistianto, E., Evaluasi Nilai EMP MKJI dan EMP Time Headway pada Simpang Bersinyal dengan Validitas Panjang Antrian (Studi Kasus pada Simpang Bersinyal Kerten Surakarta), *Matriks Teknik Sipil*, *5*(3), 2017, pp. 689-702.
4. Krammes, R.A. and Crowley, K.W., Passenger Car Equivalents for Trucks on Level Freeway Segments, *Transportation Research Record*, 1091, 1986, pp. 2107-2117.

5. Alfiansyah, A.D. and Bowoputro, H., Implementasi Koreksi Nilai EMP MC Menggunakan Metode Rata-Rata Headway terhadap Kinerja Ruas Jalan Veteran Kota Malang, *Prosiding Forum Ilmiah Nasional Teknik*, *1*(1), 2022, pp. 260-268.
6. Hadi, F., Khumairah, M., Melianti, I., and Widiyanti, V., Perhitungan Lalu Lintas Harian Rata-Rata pada Persimpangan Adi Sucipto, *Georeference*, *1*(1), 2023, pp. 23-35.
7. Gunawan, A., Azwansyah, H., and Erwan, K., Identifikasi Lokasi Titik Rawan Kecelakaan (Black Spot) pada Ruas Jalan Adi Sucipto, *JeLAST: Jurnal Teknik Kelautan, PWK, Sipil, dan Tambang*, *3*(2), 2015, pp. 187-199.
8. Yulipriyono, E.E. and Purwanto, D., Perubahan Nilai Ekivalensi Mobil Penumpang Akibat Perubahan Karakteristik Operasional Kendaraan di Jalan Kota Semarang, *Media Komunikasi Teknik Sipil*, *23*(1), 2017, pp. 69-76.
9. Wirahaji, I.B. and Laintarawan, I.P., Studi Nilai Ekuivalensi Mobil Penumpang (EMP) dengan Metode Time Headway, *Widya Teknik*, *17*(1), 2022, pp. 27-34.
10. Salter, R.J. and Hounsell, N.B., *Highway Traffic Analysis and Design*, Bloomsbury Publishing, London, 1996.
11. May, A.D., *Traffic Flow Fundamentals*, Prentice-Hall, Englewood Cliffs, NJ, 1990.
12. Luttinen, R.T., *Statistical Analysis of Vehicle Time Headways*, Helsinki University of Technology, 1996.
13. Transport Research Board. *Highway Capacity Manual*, Washington, DC: Transport Research Board, 2010.
14. Galton, F., Regression towards Mediocrity in Hereditary Stature, *The Journal of the Anthropological Institute of Great Britain and Ireland*, *15*, 1886, pp. 246-263.
15. Wirahaji, I.B. and Laintarawan, I.P., Studi Nilai Ekuivalensi Mobil Penumpang (EMP) dengan Metode Time Headway, *Widya Teknik*, *17*(1), 2022, pp. 27-34.
16. Ghozali, I., *Aplikasi Analisis Multivariete dengan Program IBM SPSS 23*, Badan Penerbit Universitas Diponegoro, Semarang, 2018.
17. Hair, J.F., Jr., Black, W.C., Babin, B.J., and Anderson, R.E., *Multivariate Data Analysis*. 5th ed, Prentice Hall, New Jersey, 1998.
18. Roads, T.S.P.A., Estimation of Carbon Dioxide Emission in the Transportation Sector on Primary Arterial Roads in Wonokromo District, Surabaya Before and After Covid-19, *Malaysian Journal of Analytical Sciences*, *25*(6), 2021, pp. 1107-1121.
19. Hautière, N., Tarel, J.P., Halmaoui, H., Brémond, R., and Aubert, D., Enhanced Fog Detection and Free-Space Segmentation for Car Navigation, *Machine Vision and Applications*, *25*, 2014, pp. 667-679.
20. Leonard, J., How, J., Teller, S., Berger, M., Campbell, S., Fiore, G., Fletcher, L., Frazzoli, E., Huang, A., Karaman, S., and Koch, O., A Perception-Driven Autonomous Urban Vehicle, *Journal of Field Robotics*, *25*(10), 2008, pp. 727-774.
21. Guo, H., Li, Y., Shang, J., Mingyun, G., Yuanyue, H., and Bing, G., Learning from Class-Imbalanced Data: Review of Methods and Applications, *Expert Systems with Applications*, *73*, 2017, pp. 220-239.
22. Ingvardson, J.B., Nielsen, O.A., Raveau, S., and Nielsen, B.F., Passenger Arrival and Waiting Time Distributions Dependent on Train Service Frequency and Station Characteristics: A Smart Card Data Analysis, *Transportation Research Part C: Emerging Technologies*, *90*, 2018, pp. 292-306.
23. Arasan, V.T. and Arkatkar, S.S., Microsimulation Study of Effect of Volume and Road Width on PCU of Vehicles under Heterogeneous Traffic, *Journal of Transportation Engineering*, *136*(12), 2010, pp. 1110-1119.
24. Roy, R. and Saha, P., Headway Distribution Models of Two-Lane Roads under Mixed Traffic Conditions: A Case Study from India, *European Transport Research Review*, *10*, 2018, pp. 1-12.
25. Hu, J., Chen, S., Behrangi, A., and Yuan, H., Parametric Uncertainty Assessment in Hydrological Modeling using the Generalized Polynomial Chaos Expansion, *Journal of Hydrology*, *579*, 2019, pp. 124-138.
26. Obaidat, M.T. and Alomari, L.D., Time Headway using Computer Vision Integrated with Artificial Intelligence, *Jordan Journal of Civil Engineering*, *18*(3), 2024, pp. 456-467.
27. Taylor, J.W. and Snyder, R.D., Forecasting Intraday Time Series with Multiple Seasonal Cycles using Parsimonious Seasonal Exponential Smoothing, *Omega*, *40*(6), 2012, pp. 748-757.
28. Goyal, R. and Khare, M., Indoor–Outdoor Concentrations of RSPM in Classroom of a Naturally Ventilated School Building Near an Urban Traffic Roadway, *Atmospheric Environment*, *43*(38), 2009, pp. 6026-6038.
29. Abdulrazzaq, L.R., Abdulkareem, M.N., Yazid, M.R.M., Borhan, M.N., and Mahdi, M.S., Traffic Congestion: Shift from Private Car to Public Transportation, *Civil Engineering Journal*, *6*(8), 2020, pp. 1547-1554.
30. Necula, E., Analyzing Traffic Patterns on Street Segments based on GPS Data using R, *Transportation Research Procedia*, *10*, 2015, pp. 276-285.
31. Ingvardson, J.B., Nielsen, O.A., Raveau, S., and Nielsen, B.F., Passenger Arrival and Waiting Time Distributions Dependent on Train Service Frequency and Station Characteristics: A Smart Card Data Analysis, *Transportation Research Part C: Emerging Technologies*, *90*, 2018, pp. 292-306.
32. Chmielewski, J., Impact of Sunday Trade Ban on Traffic Volumes, *Modern Traffic Engineering in the System*

Approach to the Development of Traffic Networks: 16th Scientific and Technical Conference 'Transport Systems. Theory and Practice 2019' Selected Papers, Vol. 16, Springer International Publishing, 2020, pp. 231-241.

33. Borowska-Stefańska, M., Kowalski, M., and Wiśniewski, S., Changes in Urban Transport Behaviors and Spatial Mobility Resulting from the Introduction of Statutory Sunday Retail Restrictions: A Case Study of Lodz, Poland, *Moravian Geographical Reports*, *28*(1), 2020, pp. 29-47.
34. Jamson, A.H., Merat, N., Carsten, O.M., and Lai, F.C., Behavioral Changes in Drivers Experiencing Highly-Automated Vehicle Control in Varying Traffic Conditions, *Transportation Research Part C: Emerging Technologies*, *30*, 2013, pp. 116-125.