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Analysis of Passenger Car Equivalency (EMP) Values on Road Sections in Bandar Lampung City (Case Study: Ratu Dibalau Road Section and Damar Island Road Section)

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ABSTRACT

The increase in vehicle volume in Lampung Province has resulted in a decrease in road performance. Capacity evaluation is prevention, determining capacity there are several parameters, one of which is EMP. In this case, the analysis of road section performance refers to MKJI 1997. The characteristics of MKJI 1997 are strongly influenced by the traffic of major cities in Indonesia which are made the place of empirical research in 1991 - 1995. Of course, there are differences in the characteristics that occurred in that year with the current situation. This study was conducted to determine whether there is a difference in the EMP value in MKJI with the current field EMP. This research uses field survey data including traffic volume, road section geometry, and Time Headway data between vehicles. In this study, the emp value is analyzed using the Time Headway method and the data for analyzing the performance of road sections refers to the 1997 Indonesian Road Capacity Manual (MKJI). The results of the emp MC value for the morning and afternoon peak hours on Section 1 are 0.48 and 0.46. Section 2 is 0.46 and 0.44. This value is significantly different from the 1997 MKJI emp of 0.25. for the DS value using emp MKJI on section 1, the results are 0.45 and 0.68. for DS emp calculations on section 0,3 of 0,43 and 1. For section 2 DS emp MKJI of 0.33 and 0.48. For DS emp calculations on section 2 of 0,48 and 0,65. It can be seen that significant differences can be caused by traffic flow conditions, differences in road characteristics, road gemetry conditions, and environmental conditions in 1997 with current conditions. It can also be seen that the greater the emp value will affect the amount of traffic volume so as to make the degree of saturation value greater.

Keywords: *EMP; Timeheadway; MKJI 1997; Road Performance.*

INTRODUCTION

The population of Lampung Province always increases every year, this has an impact on increasing the volume of traffic flow on a road and intersection. The increase in volume that occurs must be evaluated with the existing road capacity, road capacity can be calculated using traffic volume which is first converted into passenger vehicle units (smp). The passenger car unit is a traffic movement that is equated with light vehicles or passenger cars that are converted using passenger car equivalency values. The passenger car equivalent value depends on the size and speed of the vehicle, which has an impact on the performance of the road section. This value varies greatly for each section of the road, so it is necessary that the

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passenger car equivalent value is in accordance with the actual road conditions so that the policies applied are in accordance with the conditions and situations in the field.

In calculating road capacity in Indonesia, the passenger car equivalency value refers to the 1997 Indonesian Road Capacity Manual (MKJI). Where the characteristics contained in MKJI 1997 are the results of empirical research by the Bina Marga team whose data were obtained in 1991-1995 in major cities in Indonesia. Based on the differences in the current situation, it is possible that there are differences in the values contained in MKJI 1997 and it is possible to calibrate. This research was conducted to review the passenger car equivalency value on the Ratu Dibalau road section and the Damar Island road section to determine the performance of the road section which aims to optimize the performance of the section and provide comfort to motorists passing through the section.

METHOD

Passenger Car Equivalency

Passenger car equivalency is a factor indicating the effect of different types of vehicles compared to other light vehicles with respect to their effect on the speed, maneuverability, and dimensions of light vehicles in the traffic stream (usually for passenger cars and light vehicles, the emp value is 1.0). The parameters that influence the emp value are vehicle dimensions and speed, and traffic volume. The larger the size of the vehicle, the smaller the speed to initiate movement, resulting in disruption to the overall traffic flow. Because of this, the time headway of large vehicle pairs is relatively larger than that of light vehicles. Another thing that also affects the calculation of passenger car equivalency (emp) is vehicle accompaniment (platoon). Platoon is a traffic condition where vehicles are in a queue with the same speed because they are held up by the vehicle in front of them. The time between vehicles so that they are included in the platoon is < 5 seconds.

TimeHeadway Method

In the book "Highway Traffic Analysis and Design", R.J. Salter explains how to determine the emp value by recording the time between (time headway) consecutive vehicles when the vehicle passes a predetermined observation point. The required headway ratio includes seven kinds of vehicle combinations, namely: [1]

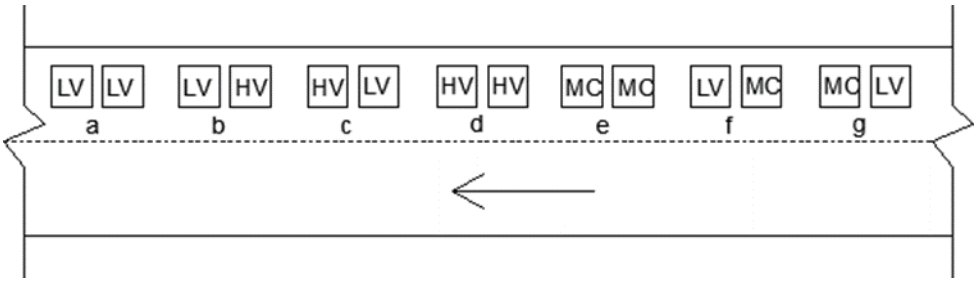

Figure 1. Combination of vehicle pairs under review

Then, the emp MC value can be calculated using the formula:

$$ta + td = tb + tc \quad (1)$$

Description:

ta = Average value of LV headway time followed by LV

tb = Average value of time headway for LV followed by MC

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tc = Average value of time headway MC followed by LV

td = Average value of time headway MC followed by MC

The situation that can fulfill the above equation is difficult to obtain because each vehicle has different characteristics. Therefore, a correction to the average time headway value is required as follows:

$$k = \frac{na.nd.nc.nd.[\ ta+td-tb-tc\ ]}{nd.nb.nc+na.nb.nc+na.nd.nc+na.nb.nb} \qquad (2)$$

Description:

na = Number of LV time headway data followed by LV

nb = Number of time headway data LV followed by MC

nc = Number of time headway data MC followed by LV

nd = Number of time headway data MC followed by MC

Then the average time headway value of the vehicle pair is corrected with the formula:

$$ta_k = ta - \frac{k}{na} \qquad (3)$$

$$tb_k = tb - \frac{k}{nb} \qquad (4)$$

$$tc_k = tc - \frac{k}{nc} \qquad (5)$$

$$td_k = td - \frac{k}{nd} \qquad (6)$$

By using the corrected average time headway value then:

$$ta_k + td_k = tb_k + tc_k \qquad (7)$$

with:

tak = Average value of LV time headway followed by corrected LV

tbk = Average value of time headway LV followed by corrected MC

tck = Average value of time headway MC followed by corrected LV

tdk = Average value of time headway MC followed by corrected MC

If the calculation meets the requirements, the emp MC value can be calculated with the equation:

For the calculation of the emp value of other types of vehicles, it can be calculated using the same formula as above, but the MC variable is replaced according to the variable type of vehicle that you want to know the emp value.

Traffic Performance Analysis

After obtaining the EMP value of each vehicle, the next analysis is to calculate the performance of the road section for type 2/2 UD using the MKJI 1997 method. Performance analysis is carried out to compare the performance of road sections using EMP calculation results and road performance using EMP MKJI 1997. [1]

Free Flow Speed

Free flow speed is defined as the speed at zero flow level, which is the speed that a driver would choose if driving a motor vehicle without being influenced by other motor vehicles on the road. Free flow speed can be calculated with the formula:

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$$FV = (FV_0 + FV_w) \times FFV_{SF} \times FFV_{CS} \quad (8)$$

where:

FV = Free flow speed of light vehicles in field conditions (km/h)
FV0 = Basic free flow speed of light vehicles (km/h)
FV = Traffic lane effective width adjustment factor (km/h), the addition of
FFVSF = Adjustment factor for side obstacle conditions, multiplication
FFVCS = City size adjustment factor, multiplication

Capacity

Road section capacity is the maximum traffic flow that can pass stably on a road cross section under certain conditions (geometrics, separation, direction, traffic composition, environment). For two-lane two-way roads, the capacity is determined for two-way flow, but for roads with many lanes, the flow is separated and the capacity is determined for each lane. According to MKJI, 1997, road capacity is calculated using the formula:

$$C = C_0 \times FC_w \times FC_{SP} \times FC_{SF} \times FC_{CS} \quad (9)$$

where:

C = Capacity

Co = Base Capacity (smp/hr)

FCW = Traffic lane width adjustment factor

FCSP = Directional separation adjustment factor

FCSF = Side obstacle adjustment factor

FCCS = City size adjustment factor

Degree Saturation

The degree of saturation is defined as the ratio of flow to capacity which is used as a key factor in determining traffic performance at intersections and road sections. The DS value indicates whether the road section has a capacity problem or not (Andiani, C. A., Sumarsono, A., 2013). DS is calculated using the flow and capacity expressed in smp/hour. The degree of saturation is calculated using the formula:

$$DS = \frac{Q}{C} \quad (10)$$

Where :

DS = Degree of saturation

Q = Traffic flow (smp/hr)

C = Capacity (smp/hr)

Relationship of Traffic Characteristics

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The relationship between parameters in traffic characteristics describes the uninterrupted traffic stream where the volume value is the result of speed and density. The relationship between traffic characteristics can be presented as follows: [2]

1. Relationship between speed and density (S-D)
2. Relationship between volume and velocity (V-S)
3. Relationship between volume and density

Based on the 3 (three) relationships that have been presented, there are important parameters in traffic flow. The parameters include the following:

VM = Maximum volume (kend/hr).
SM = Speed under maximum traffic volume conditions (km/h).
DM = Density under maximum traffic volume conditions (kend/km).
DJ = Density when traffic is at a complete standstill (kend/km).
Sf = Free flow speed when traffic volume is low or density is close to 0 (km/h) or density close to 0 (km/h).

Relationship Model of Traffic Flow Characteristics

The relationship between the three traffic variables will then be analyzed by linear regression analysis. Linear regression analysis is a statistical method used to study the relationship between parameters under investigation. Linear regression analysis can model the relationship between two or more variables. In general, the most commonly used equations are as follows: [3]

$$Y = A + B \qquad (11)$$

Where:
Y = Non-independent variable
A = Regression constant
B = Regression coefficient
X = Independent variable

The values of parameters A and B can be obtained by the least squares method that minimizes the total quadratic residual between the model results and the observations. Parameters A and B can be obtained with the following equation: [4]

$$B = \frac{N\,\Sigma_{i=1}^{N}(Xi\,Yi) - \Sigma_{i=1}^{N}(Xi) \times (\Sigma_{i=1}^{N}(Yi))}{\Sigma_{i=1}^{N}(Xi^2) - (\Sigma_{i=1}^{N}(Xi))^2} \qquad (12)$$

$$A = Y - B\,X \qquad (13)$$

There are 3 (three) models that are commonly used to describe the relationship between volume, velocity and density.The modeling includes greenshields, greenberg, and underwood. [5]

Research Location

This research was conducted on Ratu Dibalau Road Section and Damar Island Road Section, Bandar Lampung City, Lampung 35226.

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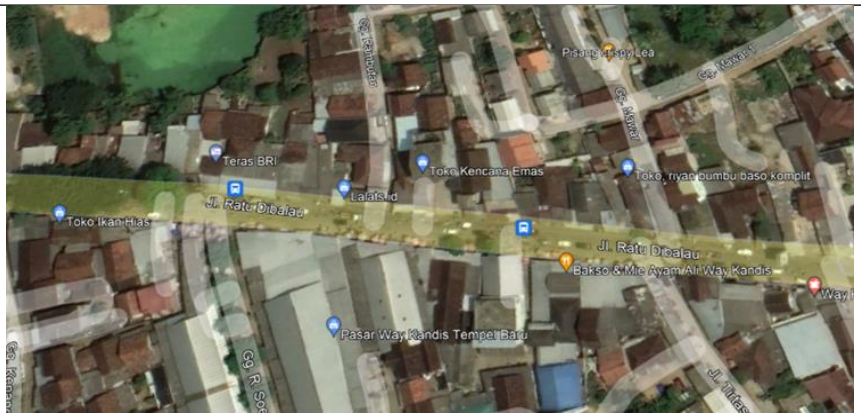

Figure 2. Research Site Plan 1

Figure 3. Research Location Plan 2

Research Data

This research uses primary data obtained by direct field surveys and secondary data obtained from BPS Lampung. The data used are as follows:

1. Geometric road section
2. Traffic conditions (vehicle volume)
3. TimeHeadway of vehicles
4. Population data

TimeHeadway Method EMP Value Analysis

From the results of data collection that has been carried out, a number of vehicles are obtained when the flow is in saturated conditions. The time headway of vehicles passing the stop line during the saturated flow was also measured during data extraction with the help of a stopwatch to calculate the time headway. Time headway data is used for headway ratio analysis obtained from reading the results of video recordings. Then the data is processed with the following steps: [6]

1. Normal distribution using excel application software, which is one of the theoretical distributions with random variables (random continue). Because the sample is chosen randomly, there is a standard deviation error of the distribution which is expressed as standard error (E). Standard error (E).
2. Calculate the standard deviation.
3. Calculating the confidence of the normal distribution.
4. Calculating the average time headway value for normal distribution of more than 30 samples ($n \geq 30$).
5. Calculating the average value of time headway.
6. Calculating the corrected average time headway value.

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7. If the results of the calculation of the corrected average time headway value meet the requirements, the EMP value.

RESULTS AND DISCUSSION

The data that has been taken in the form of vehicle volumes (light vehicles, heavy vehicles, and motorcycles) is then accumulated to determine when peak hours occur. The table below describes the volume of vehicles (light vehicles, heavy vehicles, and motorcycles) from the two sections observed directly by breaking it down per 1 hour so that the data taken at the research location represents the actual volume of vehicles (light vehicles, heavy vehicles, and motorcycles) at the research location. The traffic volume survey data for the weekday and weekend periods are as follows:

Table 1. Traffic Volume Data of Ratu Dibalau Road Section

No	hours	Amount Saturday (Vehicle/hour)	Amount Monday (Vehicle/hour)
1	07.00-08.00	3004	3049
2	07.15-08.15	2979	3070
3	07.30-08.30	2801	2906
4	07.45-08.45	2814	2867
5	08.00-09.00	2820	2894
6	16.00-17.00	4332	4448
7	16.15-17.15	4198	4303
8	16.30-17.30	4061	4113
9	16.45-17.45	3749	3870
10	17.00-18.00	3512	3642

Based on the results of the traffic volume survey in the field conducted on Monday and Saturday, the peak hours were obtained at 16.00-17.00 in the afternoon.

Table 2. Traffic Volume Data of Damar Island Road Section

No	Hours	Amount Saturday (Vehicle/hour)	Amount Monday (Vehicle/hour)
1	07.00-08.00	1324	1844
2	07.15-08.15	1352	1849
3	07.30-08.30	1347	1851
4	07.45-08.45	1354	1861
5	08.00-09.00	1293	1784
6	16.00-17.00	1839	2349
7	16.15-17.15	1802	2386
8	16.30-17.30	1813	2417
9	16.45-17.45	1832	2358
10	17.00-18.00	1776	2323

Based on the results of the traffic volume survey in the field conducted on Monday and Saturday, the peak hour was obtained at 16:30 - 17:30 in the afternoon.

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TimeHeadway Method EMP Value Calculation

Headway data on each vehicle is obtained by surveying the time between the vehicles under review, the data is then analyzed in accordance with the equations listed in section 2. To determine the value of the Equivalent Passenger Car (EMP) for motorcycles. The following are the results of the recapitulation of the EMP value of motorcycles on the two sections that are used as research locations.

Table 3. Recapitulation of EMP MC Value

Day	Time	Direction	EMP
Saturday	07.00-09.00	Road Sections R.Dibalau	0.57
		Road Sections P.Damar	0.46
	16.00-18.00	Road Sections R.Dibalau	0.44
		Road Sections P.Damar	0.46
Monday	07.00-09.00	Road Sections R.Dibalau	0.48
		Road Sections P.Damar	0.46
	16.00-18.00	Road Sections R.Dibalau	0.46
		Road Sections P.Damar	0.44

Section Performance Analysis

After obtaining the EMP MC value on each section, the analysis is continued by calculating the traffic flow and capacity of the road section, so that the performance value of the road section is obtained on each road section conducted in the study. The following is table 4.4. and 4.5. which contains a recapitulation of the results of the calculation of the performance of road sections on each road section carried out by research which has previously been calculated using the calculated passenger car equivalence value and the MKJI 1997 passenger car equivalence value.

Table 4. Recapitulation of Section Performance Value with EMP MKJI 1997

Roads	Hours	Q	C	DS
Ratu Dibalau	Morning Peak	1079.1	2413.38	0.45
	Afternoon Peak	1632.35	2413.38	0.68
Damar Island	Morning Peak	686.7	2068.86	0.33
	Afternoon Peak	996.3	2068.86	0.48

Table 5. Recapitulation of Section Performance Values with EMP Calculation Results and Modeling Results Capacity Values

Roads	Hours	Q	C	DS
Ratu Dibalau	Morning Peak	1691.36	5591,9	0.30
	Afternoon Peak	2422.58	5591,9	0.43
Damar Island	Morning Peak	1016.4	2087,5	0.48
	Afternoon Peak	1356.92	2087,5	0.65

Comparison of Section Performance Values Calculated Using EMP Calculated Results with Calculations Using EMP MKJI 1997

After getting the performance value of each section, the next analysis is to compare the second value of performance using the EMP calculation results with the MKJI 1997 EMP.

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table 4.6. contains a comparison of the performance value of the calculated road section using the calculated passenger car equivalency value with the 1997 MKJI passenger car equivalency value.

Table 6. Comparison of Road Section Performance Values Using MKJI EMP and EMP Calculation Results

Road Section	Hours	EMP MC MKJI	DS EMP MKJI	EMP MC Field	DS EMP Field
Ratu Dibalau	Morning Peak	0.25	0.45	0.48	0.30
	Aftrenoon Peak	0.25	0.68	0.46	0.43
Damar Island	Morning Peak	0.25	0.33	0.46	0.48
	Aftrenoon Peak	0.25	0.48	0.44	0.65

From the results of table 3. The results of the EMP MC value obtained at each peak hour and road section conducted research, it can be seen that the largest EMP MC value was obtained on the Ratu Dibalau Road Section in the Saturday period in the morning peak hour of 0.57. This value is very different from the EMP MC value contained in MKJI 1997 of 0.25, one of the factors causing the difference in value is the different number of motorized vehicles in the EMP observation year contained in MKJI 1997, namely in 1991-1995 with the number of motorized vehicles at this time. For example, the number of motorized vehicles in BandarLampung City in 1995 amounted to 24,296 vehicles (BPS Lampung Province, 1995), this number is significantly different from the number of motorized vehicles in 2022 of 737,410 vehicles (BPS Lampung Province, 2022). So it is very possible that there is a difference in the EMP value of the MC, for the EMP value of HV in this study, the calculation cannot be continued using the timeheadway method. this is because the number of HV vehicles passing through the two sections conducted in the study is very small and also has a large interval time between HV - HV vehicles so that the corrected timeheadway value is not obtained. The magnitude of the EMP value can also be influenced by factors of vehicle operational characteristics, roads, the environment, and traffic control conditions. The EMP value in the timeheadway analysis is different for each lane because the main variable of this analysis is the time between vehicles, so this value depends on driver behavior and traffic conditions for each lane.

In tables 4,5, and 6. is a comparison of the results of analyzing the performance of road sections using EMP MKJI 1997 and EMP timeheadway. The comparison looks very significant, this is due to the difference in the value of traffic flow obtained using EMP timeheadway is greater because the EMP value used is also greater than the value of traffic flow using EMP MKJI, there is also a difference in capacity value when calculating DS using EMP timeheadway relatively greater than the capacity of MKJI 1997, this is due to the field capacity that can be highly dependent on the modeling results between flow and density, where the resulting density value will greatly affect the maximum current value or field capacity. In contrast to the capacity value contained in MKJI 1997 by considering various aspects that make the capacity value smaller. This difference can be caused by differences in traffic characteristics in the observation year of MKJI 1997 which was conducted in 1991 - 1995 with the current traffic flow situation. An example is the difference in vehicle volume, where the number of vehicles in BandarLampung City in 1995 amounted to 37,394 vehicles (BPS Lampung Province, 1995) while the number of vehicles in BandarLampung City in 2022 amounted to 927,516 vehicles (BPS Lampung Province, 2023). The significant difference in the number of vehicles is very possible that there are differences in the coefficient values contained in MKJI 1997 so that there are differences in the results of the

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degree of saturation itself. In addition to traffic flow conditions, these differences can be influenced by different road geometry conditions in 1995 with road geometry conditions in 2023.

CONCLUSION

The conclusion of this research is as follows:

1. The equivalent value of motorcycle passenger cars calculated using the timeheadway method on Jalan Ratu Dibalau for the morning peak hour is 0.48 and 0.46 for the afternoon peak hour. The equivalent value of motorcycle passenger cars calculated using the timeheadway method on Jalan Pulau Damar for the morning peak hour is 0.46 and 0.44 for the afternoon peak hour. These values differ significantly from the MKJI 1997 emp of 0.25. This difference can be caused by differences in traffic flow conditions in 1997 with current traffic flow, other examples of differences can be road characteristics, road geomteric conditions and the surrounding environment. The passenger car equivalency value for trucks on the two roads studied could not be further calculated due to the small number of accompaniments on trucks and also the intermediate time or timeheadway value has a large value.
2. The results of the performance analysis of the Ratu Dibalau Road section using the 1997 MKJI emp in the morning peak hour obtained a degree saturation value of 0.45 and a degree saturation value in the afternoon peak hour of 0.68. For the performance results of Jalan Pulau Damar Road Section in the morning peak hour, the degree of saturation value is 0.33 and in the afternoon peak hour it is 0.48. While for the performance results of the Ratu Dibalau Road Section using EMP, the calculation results in the morning peak hour obtained a degree of saturation value of 0.30 and in the afternoon peak hour of 0.43. For the performance results of Jalan Pulau Damar using EMP, the calculation results in the morning peak hour obtained a degree of saturation value of 0.48 and in the afternoon peak hour of 0.65. It can be seen that there is a significant difference in the results of the degree of saturation of the calculation results using emp calculation results with the degree of saturation of the calculation results using emp MKJI 1997. This is because the difference in the value of the flow calculated using the MKJI 1997 EMP value with the value of the flow calculated using the calculated EMP value is greater than the EMP value in MKJI 1997. And there is also a difference in the capacity value of MKJI 1997 with the capacity of the modeling results where the capacity value of MKJI 1997 is smaller than the capacity value of the modeling results obtained. Thus, making the results of the degree of saturation even greater.

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