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MEDIAN-TYPE ADJUSTMENT FACTOR FOR ROAD CAPACITY CALCULATION

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ABSTRACT

A median is required for a two-way road to separate the opposite traffic and prevent head-on collisions. In road capacity calculation, the median factor contributes in terms of its existence regardless of the difference in median types. Road capacity is determined by a number of geometric factors such as road types, width of carriageway, shoulder/curb characteristics, and the presence/absence of medians, etc. The contributions of these factors are represented by the coefficients in the capacity calculations. Despite the different types of medians, the Indonesian Highway Capacity Manual (IHCM) does not adopt different coefficients to accommodate the effects in the capacity. The aim of this study is to obtain an adjustment factor for road capacity calculation based on median types. The method of this study adopts video recordings of real traffic moving along three different types of medians: raised medians, fenced medians, and line medians. As it is assumed that the effects of different median types are expressed in the vehicles' safety distances from medians, the capacity of the road will also vary by types of medians. The adjustment coefficients for roads with raised medians, fenced medians, and line medians obtained are: 0.79, 0.78, and 0.81, respectively. The results of this study confirm that in addition to the presence of the medians, the types should essentially be considered in calculating the road capacity. The result of this study will contribute to the enrichment of the road capacity calculation in the IHCM.

Keywords: Drivers' hazard perception; Median; Median-type adjustment factor; Road capacity; Vehicle-to-median distance

1. INTRODUCTION

Among the cross-section elements of geometric features of a roadway that serves the safety function is the median. The American Association of State Highway and Transportation Officials (AASHTO, 2011) defines a median as the portion of highway separating opposing directions of the traveled way. Some of the principal functions of a median are to separate opposing traffic, provide a recovery area for out- of-control vehicles, provide a stopping area in case of emergency, and allow space for speed changes. Medians, either raised or painted, provide a physical separation between opposing traffic flows. They also provide a refuge area for pedestrians to wait at crossing locations (Tay & Churchill, 2007; Gaca & Tracz, 2012). Medians, according to Departemen Pekerjaan Umum (2004) are a standard form of channelization at rural roadways and urban street intersections carrying four or more lanes. Departemen Pekerjaan Umum (1997), the Indonesian Highway Capacity Manual, defines

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capacity as the maximum flow past a point on the road that can be sustained on an hourly basis under prevailing conditions. This is a two-way flow for two-lane and four lane two-way roads, and a one-way flow for urban motorways and one-way streets. Road capacity increases with carriageway width and, adversely, the reduction in carriageway width reduces the capacity. The IHCM adopts an adjustment factor for the existence or absence of a road median. The manual states that well-designed medians increase capacity; this implies that the physical properties of medians influence the capacity. The influence of median type is represented by the presence or absence of medians (divided or undivided) as well as median continuity (with gaps or no gaps). However, no similar types of values that represent the effect of lane width reduction due to different types of medians such as raised medians, fenced medians, and line medians on road capacity are available and, thus to date, no such factor has been found to be integrated in the calculation.

In the manual, median adjustment factor is also termed the directional split adjustment factor (Fsp). In the calculation, median effects are taken into account in the capacity calculation as it removes the possibility of interaction between opposing streams and so increases capacity and performance. The nonexistence and existence of a few gaps increase the capacity, but the existence of frequent gaps decreases the road capacity. The size and the types are equally considered and no different adjustment factors are adopted. Other geometric features, when combined, may imply some operational and safety issues that need to be considered in the calculation of road capacity (Wanga et al., 2011). Table 1 shows the different adjustment factors due to the frequency of gap existence along a median in IHCM.

Table 1 IHCM directional split adjustment factors

Median Continuity	Fsp
No gaps	1.12
Few gaps	1.05
Frequent gaps	0.98

It is noted that there is an increase in the number of crashes with median presence but a reduction of the level of severity for these crashes. Medians, contrary to their safety functions, are also perceived as hazards (Underwood et al., 2011). Hazard perception is defined as the process of identification of hazards and hazard potentials. The existence of medians may also have an impact on the drivers' hazard perception (Bella, 2013), and the various types of medians relate to the different types of accidents (Rusmawan, 2011). A study on vehicle-to-median safe distance by Siregar (2015) found that, using 90% and 10% of vehicle-to-median distances percentiles, different types of medians cause the vehicles to move 0.27 m to 0.82 m away from the medians. These distances indicate that the capacity of the road can be extremely influenced by different types of medians due to the reduced effective lanes.

This present study tries to determine how the types of medians give different effects on the occupancy of carriageway widths and what values of adjustment factors can be applied on the capacity calculation for roads with raised medians, fenced medians, and line medians.

2. METHODOLOGY

2.1. Survey and Observations

This study utilizes real traffic data recordings to obtain the characteristics of different types of vehicles when moving along three different types of medians. The survey was conducted on three road segments with different types of medians: raised median, line median, and fenced median. Traffic was video-recorded on three 4/2 D urban roads in one off-peak afternoon time, and data of vehicle-to-median distances were measured. Vehicles were classified as passenger car, bus/truck, and motorcycle, and the obtained data were analyzed. A collection of data for each category as shown in Table 2 was recorded and measurements of vehicle-to-median distances were taken.

Table 2 Number of vehicles by types of medians

Type of Median	Type of vehicles (number)		
	Passenger car	Motorcycles	Truck/buses
Raised median	1175	69	156
Fence median	1169	62	125
Line median	412	151	131

Assuming that drivers' decision on positioning the vehicles at a distance more than 1.00 m from the medians is not influenced by the existence of the median to any perceptible degree and is not based on their hazard perception of the median types, observations and data collection were carried out for the vehicle-to-median distance within the range of 0–1.00 m. As the study is aimed at the tendency of drivers to position the vehicles and occupy the width of the carriageway, the surveys were conducted on road segments and some conditions were adopted to avoid bias caused by the effects of geometric features, lighting, and traffic conflicts in data recording and data measurements, such as:

a) flat or essentially flat terrain,
b) straight or essentially straight horizontal alignment,
c) lack of pedestrian crossings,
d) the road surface shows very minimal pavement defects, and
e) on segments of roads that are not affected by queuing caused by intersections, nor by severe clumping downstream from signalized intersections.

Road segment is defined as a length of road; between and unaffected by signalized or major unsignalized intersections and having similar characteristics along its length.

2.2. Measurements and Analysis

The video-recorded data were collected and the positions of the tires closest to the medians at a defined line were measured for each type of vehicle. To obtain the adjustment factors for the three different medians, the relationship between the lane occupancy, which is indicated by the vehicle distances from medians, and the frequency distribution are established. The proportions of the most occupied lane portion to the total lane width indicate the value to be adopted according to the adjustment factors due to various median types.

3. RESULTS AND DISCUSSION

The following figures show the vehicles' tendency to behave differently toward the medians, which is manifested in preferred distances away from the median for the safety margins. The distance of vehicles from medians may imply the drivers' hazard perception on medians and on opposite traffic as well as drivers' free choice on lane positioning.

3.1. Raised Medians

The majority of passenger cars (21.4%) travelling along roads with raised medians spare a safe distance of 50–60 cm from the medians, while 27% of motorcycles move 80–90 cm from the median, and 17.3% of trucks move 50–60 cm from the median (Figure 1).

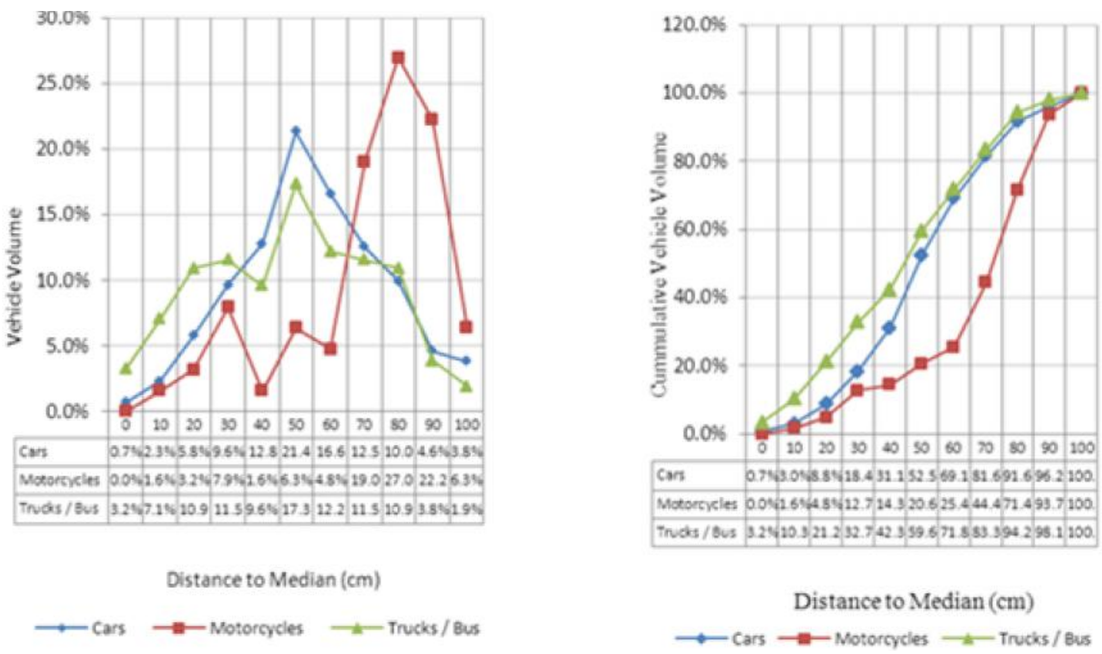


Figure 1 Percentage distribution of vehicle lane occupancy for raised medians

3.2. Fenced Medians

With fenced medians, a slightly different distribution pattern from that of raised medians is observed: 17.7% of cars move 50–60 cm from the median, 23% of trucks move 50–60 cm from the median, and a bigger percentage of motorcycles choose to move 80–90 cm from the median (Figure 2).

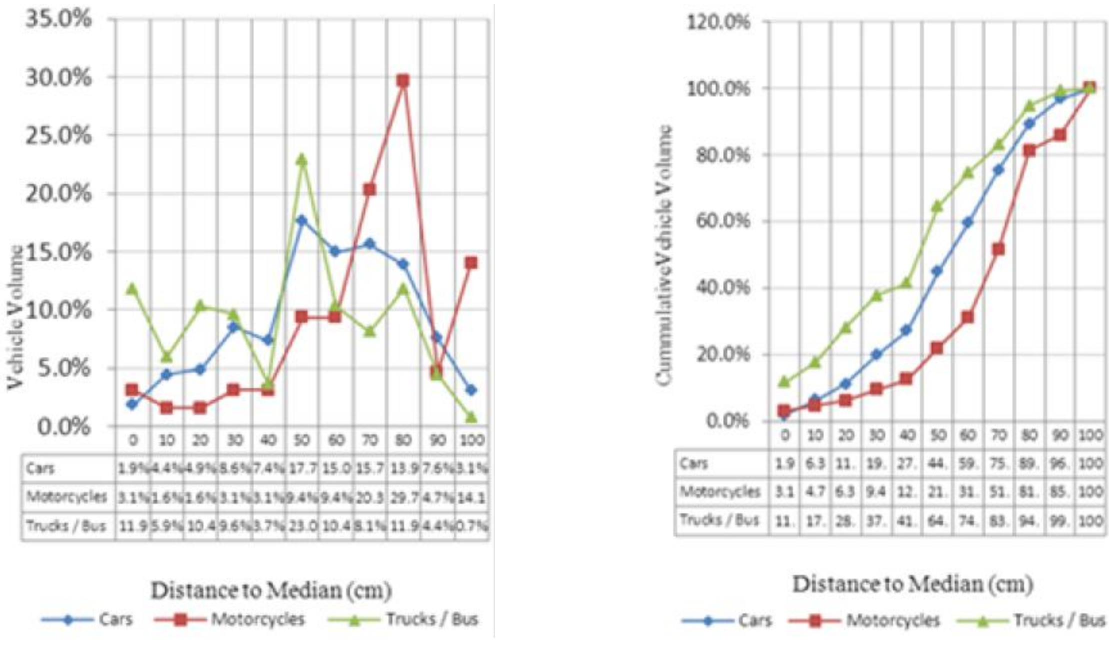


Figure 2 Percentage distribution of vehicle lane occupancy for fenced medians

3.3. Line Medians

Vehicles positioning along line medians seem to have a very different pattern from those of raised and fenced medians as the motorcycle distribution peaks at the distance of 50–60 cm from medians while trucks show a tendency to move away from the median; as indicated in the graph, 20% of trucks move 10–20 cm from the line median (Figure 3).

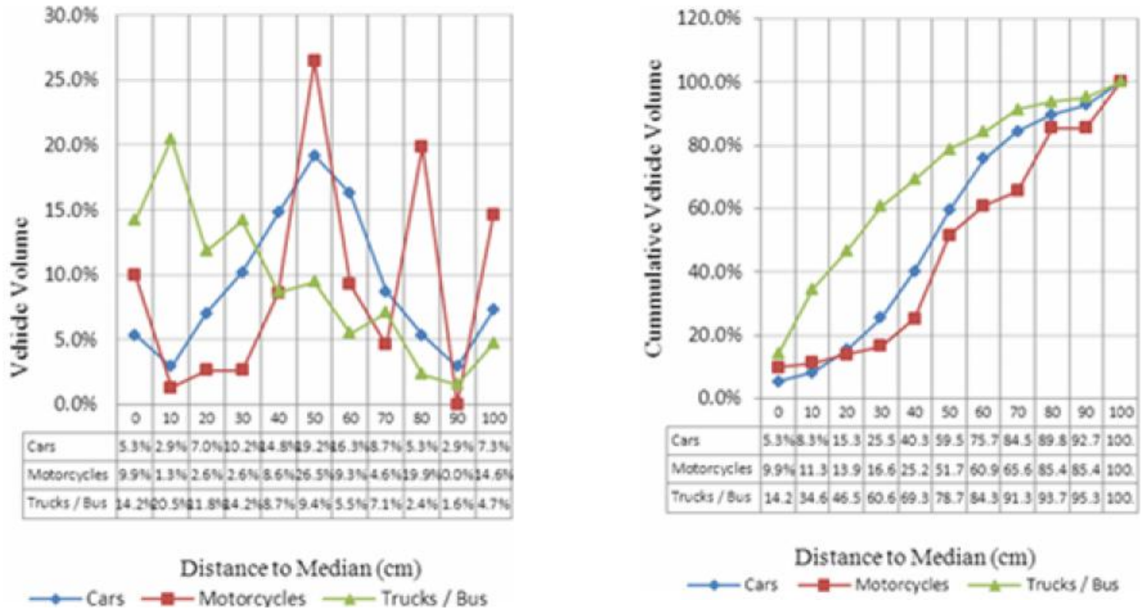
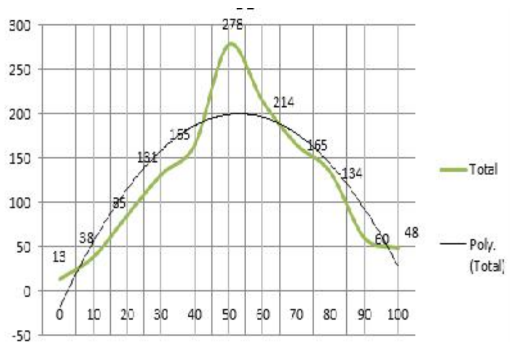


Figure 3 Percentage Distribution of Vehicles Lane Occupancy for Line Medians

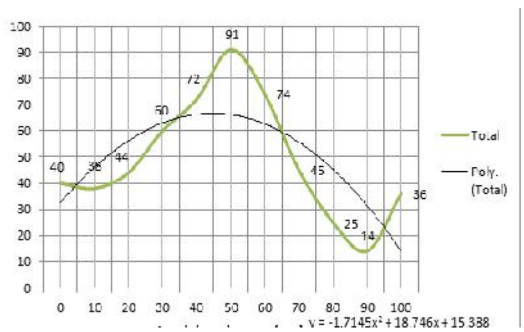
As indicated in Figures 1 to 3, the phenomenon of different lane positioning of vehicles and the median-to-vehicles' distances needs to be taken into consideration in the calculation of road capacity as it reflects the real drivers' reaction on the road. Effective carriageway width is therefore influenced by the presence and the types of medians and thus a separate adjustment factor should be produced. The IHCM has not included adjustment factor based on the median physical types such as raised medians, fenced medians, and line medians.

The median-type adjustment factor in this study is termed **Fm.** Different adjustment factors are obtained for roads with raised medians, fenced medians, and line medians. Types of vehicles are grouped into passenger cars, motorcycles, and trucks/buses. As the drivers position the vehicles differently towards different medians, it is expected that the lane width is reduced to an effective width for carrying a reduced capacity. Effective lane width is obtained by deducting the distance of the highest frequency of vehicles from the lane width and the median-type adjustment factors are obtained proportionally.

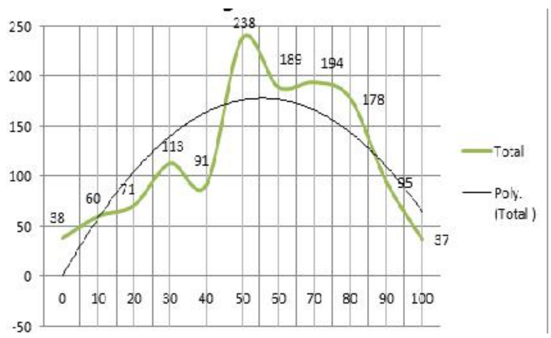
The correlation between the lane occupancy of combined vehicles along the road with a raised median can be expressed in the relationship of $Y = -7.789x^2 + 98.259x – 110.26$ ($R^2 = 0.8227$). Y is the number of vehicles distributed at certain distances, and x is the vehicle distance to the raised median. The graph shows that the majority of vehicles use the lane section 63.07 cm from the median, and the highest frequency is 200 vehicles (Figure 4a). Vehicles moving along the road section with a line median are represented in a graph that is skewed to the right indicating that there are more vehicles occupying closer distances to the median (Figure 4b). The graph shows that the majority of vehicles occupy the distance of 54.67 cm from the median. The relationship between the distribution of the combined number of vehicles excluding motorcycles and the distance to the median is expressed as: $Y = -1.7145x^2 + 18.746x + 15.388$, ($R^2 = 0.5501$). The road section with a fenced median shows that the majority of vehicles, 177 vehicles, are moving 65.66 cm from the median (Figure 4c). Comparing the graphs, as the line median tends to attract vehicles toward the median while the fenced median tends to push the vehicles away from the median, the lane capacity of a road with a line median is higher than that of fenced medians.



(a)



(b)



(c)

Figure 4 Relationship between Distance from Median and Vehicle Frequency: (a) raised; (b) line; (c) fenced medians

For a lane with a raised median (Figure 4a), with the peak frequency of 63.07 cm, and taking a safety factor of ±5%, the maximum lane reduction to be adopted is 59.92 cm. As the lane under study is 2.8 m, thus the effective lane width to be considered becomes 220.08 cm or 78.6% ∈ 79% of the lane width.

For a carriageway with a line median (Figure 4b), the peak frequency is 65.66 cm. The maximum lane reduction with a ±5% range results in a 62.37 cm lane reduction. Therefore, the effective carriageway width to be considered is 217.63 cm, which is 78% of the carriage width.

As with a carriageway with a fenced median (Figure 4c), the peak frequency is 54.67 cm. The maximum lane reduction with a ±5% range causes a 51.93 cm lane reduction. The effective carriageway width to be considered is 228.07 cm or 81% of the carriageway width.

Based on the lane occupancy indicated by the reduced travelled lane width for different types of medians, the different values of proposed median-type adjustment factors are as presented in Table 3.

The IHCM has not included an adjustment factor based on the median physical types such as raised medians, fenced medians, and line medians. No comparative values with other **Fm** from other countries are yet available.

Table 3 Proposed Median-type Adjustment Factor (**Fm**)

Median Types	Median-type Adjustment Factor (**Fm**)
Raised median	0.79
Fenced median	0.78
Line median	0.81

4. CONCLUSION

Medians function to separate traffic flows of different directions by eliminating the potential conflicts, in particular, those of head-on conflicts. The existence of medians therefore is generally perceived to contribute to the increase of road capacity that is expressed in the adjustment factors. More frequent gaps' existence, however, will slightly decrease the capacity. Different road classifications require certain median specifications: types and dimensions and also some openings or gaps for turning maneuvers, that effectively influence the resulting distances maintained from the medians. In this study, apart from the existence and the frequency of gaps along the medians, the types of median considerably influence the vehicle lane positioning thus having different effects on the capacity calculation. The tendency of vehicles to occupy the width sections with a certain distance away from the median is the manifestation of perceived hazards generated by the medians. The different tendencies of vehicle distributions along the width reflect that different types and dimensions of medians have different effects on the drivers. Therefore, apart from the presence or absence of medians as well as the continuity, the physical types of medians also influence the carrying capacity of lanes. The adoption of this median-type adjustment factor (**Fm**) in the calculation of road capacity will lead to more realistic results as the factor basically implies the drivers' behavior in choosing the lane positioning of the vehicles. In addition, from the perspective of road capacity optimization, this median-type **Fm** can help determine the physical types of median to be provided on a certain road development. It is therefore of paramount importance that the road capacity calculation take into account and adopt these median-type adjustment factors.

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