THE INFLUENCE OF MOTORCYCLE ON THE CAPACITY OF TWO LANE TWO WAY UNDIVIDED URBAN ROAD LINKS IN DENPASAR, BALI

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Abstract: The proportion of motorcycle in Denpasar city is accounted for by more than 85%. This indicated that motorcycle dominated traffic flows in Denpasar city. Three types of vehicles consisting motorcycle, heavy and light vehicles make up such a mixed traffic condition. This certainly is potential to create traffic problems involving road capacity reduction. This study investigates the effect of motorcycle on capacity of two lane two way undivided urban roads in Denpasar city. Linear regression models were developed for two separate locations consisting mid blocks of Ahmad Yani Road and Hayam Wuruk Road. The motorcycle percentage on Ahmad Yani Road is less scattered than that on Hayam Wuruk Road. Therefore, the relationship between road capacity and motorcycle percentages on Hayam Wuruk Road (R^2 = 0.46) is less significant than that on Ahmad Yani Road (R^2 = 0.78). Both locations however, suggest the same results. This study found that road capacity decreases as the percentage of motorcycle in the traffic stream increases. The motorcycle equivalent unit (MEU) therefore, is suggested for future study to convert such a mixed traffic condition into a homogeneous condition.

Keywords: Motorcycle, Road Capacity, Urban Road Links

PENGARUH SEPEDA MOTOR TERHADAP KAPASITAS RUAS JALAN DUA LAJUR DUA ARAH TAK TERBAGI DI DENPASAR, BALI

Abstrak: Persentase sepeda motor pada lalu lintas di Kota Denpasar menunjukkan nilai yang lebih dari 85% dari total moda transportasi. Hal ini menunjukkan bahwa sepeda motor mendominasi arus lalu lintas di Kota Denpasar. Tiga tipe kendaraan bermotor yaitu sepeda motor, kendaraan berat dan kendaraan ringan menimbulkan adanya suatu kondisi lalu lintas campuran. Hal ini tentu saja dapat menyebabkan permasalahan lalu lintas seperti penuruan kapasitas jalan. Studi ini meneliti tentang pengaruh dari sepeda motor terhadap kapasitas ruas jalan dua lajur dua arah tak terbagi di Kota Denpasar. Model regresi linier disusun untuk dua lokasi studi pada segmen Jalan Ahmad Yani dan Jalan Hayam Wuruk. Proporsi sepeda motor pada segmen pengamatan di Jalan Ahmad Yani tidak menyebar seperti pada segmen pengamatan di Jalan Hayam Wuruk. Hubungan antara kapasitas ruas jalan dan persentase sepeda motor di Jalan Hayam Wuruk (R^2 = 0.46) kurang signifikan dibandingkan di Jalan Ahmad Yani Road (R^2 = 0.78). Kedua lokasi akan tetapi memberikan hasil yang sama yaitu kapasitas ruas jalan akan berkurang seiring dengan meningkatnya proporsi sepeda motor. Nilai ekuivalensi sepeda motor disarankan untuk digunakan pada studi berikutnya di dalam konversi volume lalu lintas campuran ke dalam suatu lalu lintas yang homogen.

Kata Kunci: Sepeda motor, Kapasitas Jalan, Ruas Jalan Perkotaan

INTRODUCTION

Two lane two way undivided (2/2 UD) is typical urban roads in many cities in Indonesia including Bali Province. In addition, three types of motor vehicles commonly observed in Indonesia are motorcycle, heavy and light vehicles. The proportion of motorcycle in Bali Province is more than 85% of all vehicle types (Bali Statistics Central Bureau, 2012). This shows that motorcycle dominates traffic in Bali. Under such a mixed traffic condition, these three types of vehicles share the roadways together. This may generate traffic problems involving traffic accidents, road congestions, queues and delay both on road links and intersections.

Lane discipline for motorists is rarely found under such a mixed traffic condition in Bali Province. In order to estimate road capacity using traffic volume and speed relationships however, lane discipline is essentially required (Tiwari, 2000). Currently, few studies have been conducted under a traffic stream dominated by motorcycles. Most of traffic studies are adopted from developed countries with a low motorcycle proportion (Minh, *et.al*, 2005).

Indonesian Highway Capacity Manual (MKJI) (1997), uses passenger car equivalent (PCE) to convert all types of vehicles into passenger car units (PCUs). Road capacity and traffic flows are estimated considering number of lanes on the assumption that motor vehicles passing and stopping consistenly on provided lanes. This is rarely the case under such mixed traffic conditions for which lane-based capacity estimation is considered inappropriate to carry out (Tiwari, 2000). For instance, when motorcyclists do not pass through a provided lane, this may cause other vehicles run slower and in turns making traffic delay (Minh, *et.al*, 2005). This certainly potentially reduces the road capacity. Having considered the motorcycle supremacy, this study investigates the effect of motorcycle on capacity of two lane two way undivided urban roads in Denpasar city.

LITERATURE REVIEW

Traffic flows are made up of individual movements and vehicles interrelating to each other on the road and its surrounding environment. Because of drivers/riders' perceptions and abilities are different, traffic behaviours can not be uniform. Traffic has its own characteristics depending on driver's local characteristics and driving habits. Traffic flows characteristics on a road therefore, vary by both time and location.

As a consequent, this has been a challenge for traffic engineers in planning and designing traffic merely not to consider physical conditions but also the complicated characteristics of human behaviours. Driver's behaviour certainly influences traffic behaviours. For example, the design speed on a particular road is 80 km/hour while a driver may have his/her actual speed on that road varies between 30 km/hour and 120 km/hour.

Given these conditions, a scale is required to express the influence of different types of vehicles on total traffic flow. Passenger car units (PCUs) are corresponding scales that express the effect of each type of vehicle in a comparison to a passenger car. Using this scale, traffic composition can be estimated. Meanwhile, passenger car equivalent (PCE) is a factor expressing the comparison between various types of vehicles and light vehicles in relation to light vehicle's speed in traffic flow (PCE for a light vehicle is equal to 1).

Three categories of vehicles (i.e. motorcycle, heavy and light vehicles) were normally identified in the traffic flows in Indonesia including Bali Province. Each vehicle category is converted using passenger car equivalent shown in Table 2.1 into passenger car

units (PCUs). Further, these are determined using both static and dynamic characteristics of the vehicles and the most important is the mean speeds and their projected rectangular areas (Sinha, *et.al*, 2012).

Table 2.1. Passenger Car Equivalent for Urban Roads

Undivided road	Total traffic flows (two way) (vehicles/hour)	Passenger Car Equivalent		
		Heavy Vehicles	Motorcycle	
			Carriageway width Wc(m)	
			≤ 6	> 6
Two lane two way (2/2 UD)	< 1800	1,3	0,5	0,40
	≥ 1800	1,2	0,35	0,25

Source: MKJI, 1997

Road capacity is the maximum hourly rate at which persons or vehicles can be expected to pass through a point or a uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions. Meanwhile, traffic volume is total number of vehicles passing through a point or a uniform section of a lane or roadway during a certain period of time (Indonesian Highway Capacity Manual, 1997). Total traffic volume varies considering total two way volumes, flow direction, traffic composition, daily, weekly and yearly flows. This traffic volume (Q) is expressed in equation 2.1

$$Q = \frac{n}{T} \quad \text{..... (2.1)}$$

where,
Q = volume (pcu/hour)
T = observation time interval (hour)
n = number of vehicles passing observation point (pcu)

Capacity (C) on two lane two way undivided urban road links are estimated using equation 2.2 adopted from MKJI (1997):

$$C = Co.\ F_{CW}.FC._{SP}.FC._{SF}.FC._{CS} \quad \text{..... (2.2)}$$

Base capacity and adjustment factors are estimated using these criteria below:

a. Base capacity (C_o) for two lane two way urban roads is 2900 pcu/hour.
b. Carriageway width adjustment factors (FC_W) for 7m of Ahmad Yani Road and 8m of Hayam Wuruk Road are 1.00 and 1.08 respectively.
c. Directional distribution adjustment factors (FC_{SP}) are determined using Table 2.2.

Table 2.2 Directional Distribution Adjustment Factors (FC_{SP})

Directional split %-%		50-50	55-45	60-40	65-35	70-30
FC_{SP}	Two lane two way	1.00	0.97	0.94	0.91	0.88

d. Side frictions adjustment factors (FC_{SF}) of Ahmad Yani and Hayam Wuruk Roads are 0.92 and 0.95 respectively.
e. The population of Denpasar city is of 804.905 so that the city size adjustment factor (FC_{CS}) is 0.94.

CASE STUDY AREA AND DATA DESCRIPTION

This study uses secondary data obtained from two previous studies (i.e. Suryawan, 2013 and Wijaya, 2013). Both studies investigate on the relationship among volume, speed and density on urban roads. Two separate mid blocks of Ahmad Yani Road and Hayam Wuruk Road located in Denpasar city were selected as the case study. The selected locations were straight, low side friction and level mid-block sections away from

intersections. Both locations are generally viewed on Figures 3.1 and 3.2. Traffic and motorcycle volumes data for the two separate locations are shown in Table 3.1.

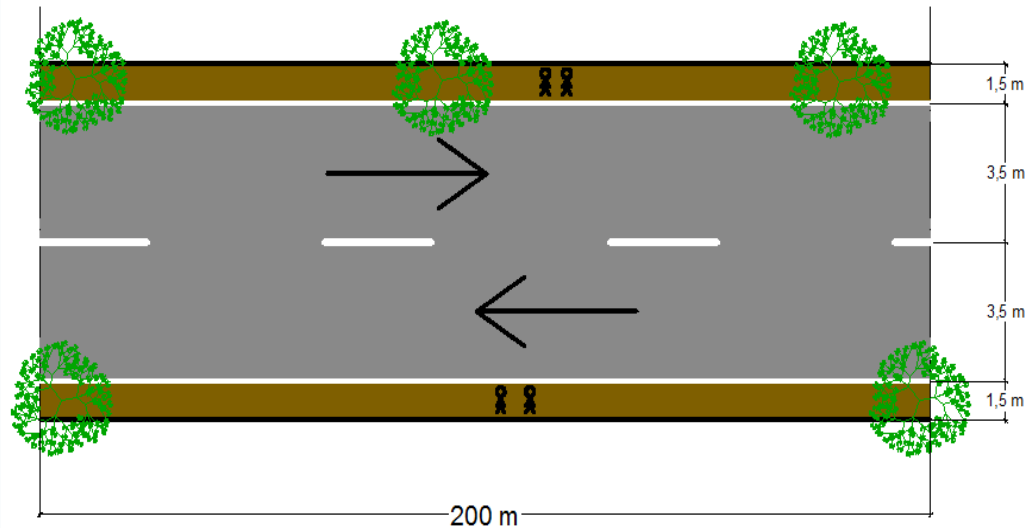

Figure 3.1 A Mid Block of Ahmad Yani Road
(Source: Suryawan, 2013)

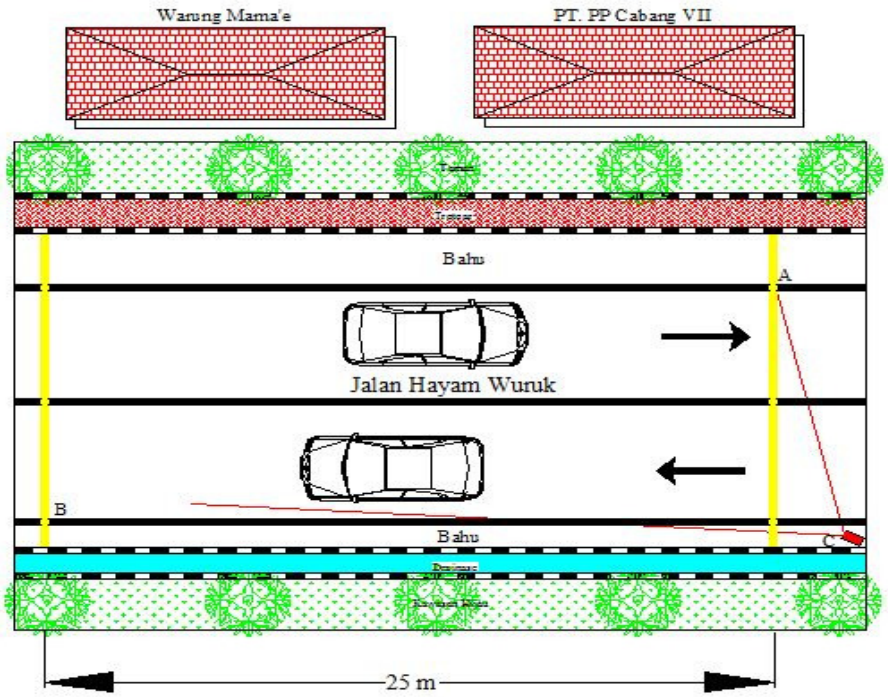

Figure 3.2 A Mid Block of Hayam Wuruk Road
(Source: Wijaya, 2013)

Table 3.1 shows hourly observed traffic and motorcycle volumes from 06.00 am to 5.00 pm. Passenger car units (PCUs) of Indonesian Road Capacity Manual (MKJI) (1997) expressed in Table 2.1 was used to estimate capacity and traffic volumes of these two lanes two ways undivided urban roads. In addition, Table 3.2 shows that there were slight variations in terms of road capacity for the

two locations. Both locations however, have quite and same range of variations in terms of motorcycle percentages.

Table 3.1 Traffic and Motorcycle Volumes

Time Period	Traffic Volume (pcu/hour)		Motorcycle (pcu/hour)	
	Ahmad Yani Road	Hayam Wuruk Road	Ahmad Yani Road	Hayam Wuruk Road
06.00-07.00	685	573	269	344
07.00-08.00	1285	1040	759	594
08.00-09.00	1227	1086	635	524
09.00-10.00	1013	983	433	434
10.00-11.00	1009	1075	414	464
11.00-12.00	1028	1011	411	414
12.00-13.00	452	1080	203	483
13.00-14.00	997	1018	432	457
14.00-15.00	982	1035	426	439
15.00-16.00	950	1116	405	481
16.00-17.00	1099	1143	467	575

Table 3.2 Road Capacity and Percentages of Motorcycle

Time Period	Road Capacity (pcu/hour)		Percentages of Motorcycle in Traffic Flows	
	Ahmad Yani Road	Hayam Wuruk Road	Ahmad Yani Road	Hayam Wuruk Road
06.00-07.00	2508	2713	39.29	59.98
07.00-08.00	2357	2629	59.05	57.16
08.00-09.00	2433	2629	51.74	48.28
09.00-10.00	2508	2713	42.78	44.14
10.00-11.00	2508	2797	41.02	43.10
11.00-12.00	2508	2797	40.01	40.90
12.00-13.00	2433	2797	44.95	44.70
13.00-14.00	2508	2797	43.34	44.87
14.00-15.00	2433	2797	43.40	42.40
15.00-16.00	2508	2797	42.66	43.07
16.00-17.00	2508	2629	42.46	50.25

RESULTS AND ANALYSIS

Using data shown in Table 3.2, linear regression models for two separate locations are developed to establish the relationship between road capacity and the percentage of motorcycles in the traffic flows. The first and second locations are defined as of Ahmad Yani Road and Hayam Wuruk Road respectively.

The linier regression models for the first and second locations are expressed in equations 4.1 and 4.2. These relationships are shown in Figures 4.1 and 4.2.

$C = 2824.15 - 7.86*MC$ ($R^2 = 0.78$; Ahmad Yani Road) ..... (4.1)

$C = 3122.45 - 8.20*MC$ ($R^2 = 0.46$; Hayam Wuruk Road).... (4.2)

where

C : Capacity (pcu/hr)

MC : Percentage of motorcycle in traffic flows

R^2 : Goodness of fit.

Figures 4.1 and 4.2 show that motorcycle percentages on Ahmad Yani Road is less scattered than that on Hayam Wuruk Road. As the results, the relationship between road capacity and motorcycle percentage on Hayam Wuruk

Road (R^2 = 0.46) is less significant than that on Ahmad Yani Road (R^2 = 0.78). Both equations subsequently are used to estimate the effect of the increase of motorcycle proportion on road capacity. Table 5.1 suggests that road capacity decreases as the percentage of motorcycle in the traffic stream increases.

This can be explained by the fact that passenger car equivalent (PCE) is used to convert different categories of vehicles into a common unit called passenger car units (PCUs). Under this circumstance, motorcycle equivalent number is of 0.25 compared to 1 as of passenger car. On the other hand, under such mixed traffic flows motorcycle dominates by almost 60% for the two locations. As the results, road capacity decreases as the motorcycle percentages increase.

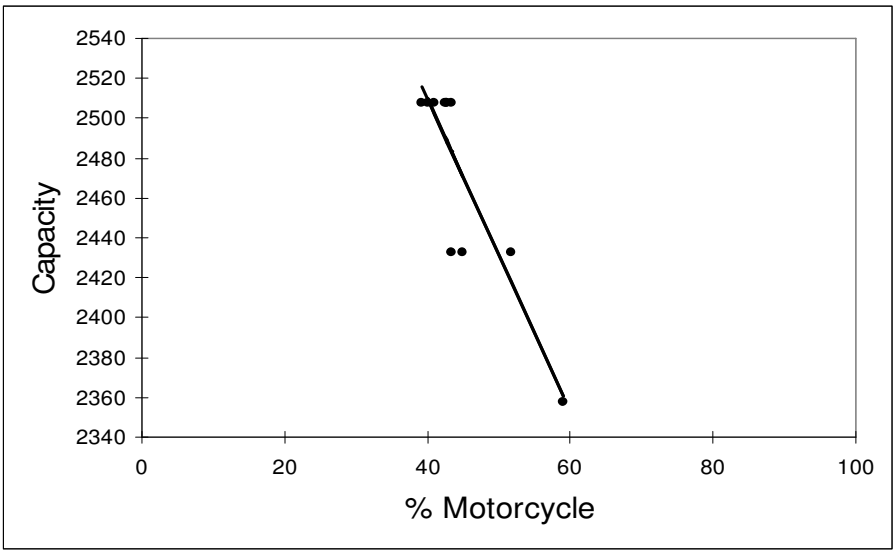

Figure 4.1. Road Capacity and Percentage of Motorcycle on Ahmad Yani Road

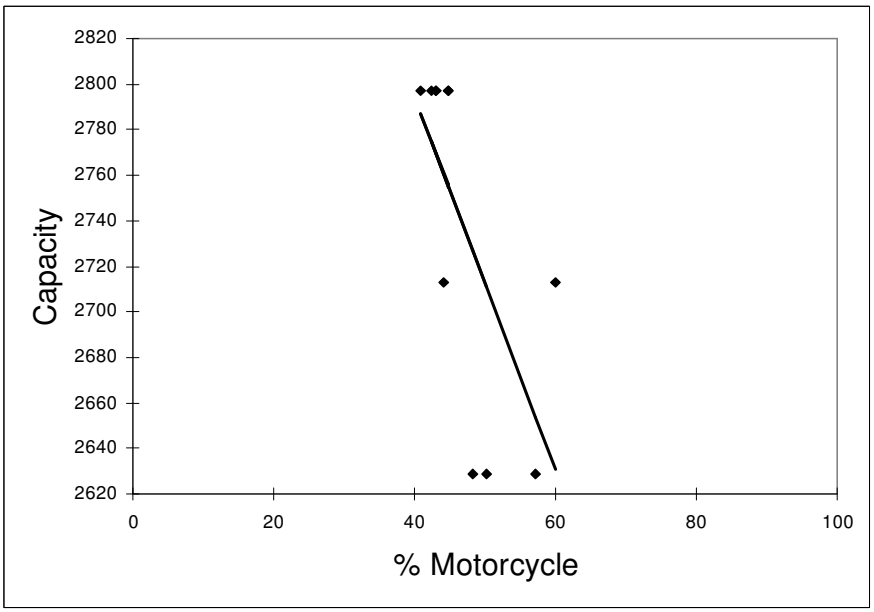

Figure 4.2. Road Capacity and Percentage of Motorcycle on Hayam Wuruk Road

Table 4.1 The Increase of Motorcycles and Road Capacity

The increase in % motorcycles	Road Capacity (pcu/hr)	
	Ahmad Yani Road	Hayam Wuruk Road
30	2588	2876
40	2510	2794
50	2431	2712
60	2353	2630
30	2588	2876
40	2510	2794
50	2431	2712
60	2353	2630

Meanwhile, Sinha, *et.al* (2012) studied the effect of motorcycle volume on capacity for four lane urban roads in India and Thailand. In contrast to this study, they found that the capacity in India and Thailand under mixed traffic increases with the proportion of motorcycle in the traffic stream. This may be explained that PCUs of MKJI (1997) do not reflect the expected traffic flows as motorcycle proportion increases. In other words, in a high proportion of motorcycle, the existing PCEs are inappropriate to convert a mixed traffic into a homogeneous condition. The use of motorcycle equivalent unit (MEU) therefore, is suggested for future study.

CONCLUSIONS

Two separate locations of Ahmad Yani Road and Hayam Wuruk Road are used as the case study area to investigate the effect of motorcycle proportion on road capactity. Data shows that motorcycle percentage on Ahmad Yani Road is less scattered than that on Hayam Wuruk Road. The relationship between road capacity and motorcycle percentage on Hayam Wuruk Road therefore, is less significant than that on Ahmad Yani Road. Having developed linier regression models, both locations give the same results in which road capacity decreases as the percentage of motorcycle in the traffic stream increases.

Passenger car equivalent (PCE) is used to convert different categories of vehicles into a common unit called passenger car units (PCUs). Under this circumstance, motorcycle equivalent number is of 0.25 compared to 1 as of passenger car. On the other hand, under such mixed traffic flows motorcycle dominates by maximum of 60% for the two locations. As the results, road capacity decreases as the motorcycle percentages increase.

This study indicated that the PCUs of MKJI (1997) do not meet the expected traffic flows as the proportion of motorcycle is high. The motorcycle equivalent unit (MEU) therefore, is suggested for future study to convert such mixed traffic conditions into homogeneous conditions.

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