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Abstract

In Malaysia, motorcycles represented more than halves of all registered vehicle population. In addition, motorcyclist contributed almost 70% of all injuries in accidents on Malaysian roads. This alarming figure warrants for some road safety strategies targeted specifically on motorcyclists. An effective engineering approach to tackle this problem is by segregating these vulnerable road users from other motorised traffic through the provision of an exclusive motorcycle lane. Prior to constructing an exclusive motorcycle lane, there is a need to understand the parameters involved in capacity analysis used to assess the supply side, quality of flow and also the design life of this facility. In order to comprehend the relative significance of these parameters, data were collected at five spots along the existing motorcycle track of Federal Highway Route 2. The Greenshields' method and multiple regression technique were then applied to scrutinise the data. The analysis resulted with the development of preliminary models on the relationships between flow, density and mean speed on motorcycle lanes. Further, a simple regression model that relates the saturation flow (capacity) and effective width of motorcycle lane was established.

Keywords : *High injury rates among motorcyclists, Exclusive motorcycle lanes, Capacity analysis of motorcycle lanes, Greenshields' method, Multiple regression, Saturation flow, Effective width.*

Introduction

Motorcycles seem to be the major mode of personal transport in Malaysia. From the last decades or so, the number of registered motorised two-wheelers (motorcycles and scooters) has been increasing tremendously in Malaysia. In 1979, the number of registered motorcycles was 1.19 million. By the year 2000, the number increased more than four-folds to about 5.36 million registered motorcycles. Their proportion on the road varies from 35%-65%, depending on places. In less developed states such as Perlis, motorcycles account for more than three-quarters of the total registered vehicle population. Meanwhile, in a more developed states and large cities such as Kuala Lumpur, the motorcycle is still one of the major modes of personal transport for the low-income urban community and constitutes at least one-third of the vehicle population (Radin et al., 1998). Figure 1 shows total registered vehicles (by type) for year 2000. It was indicated that motorcycles formed 51% of all registered vehicles.
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[1] Proceedings, Engineering Research, Universiti Putra Malaysia, 2001

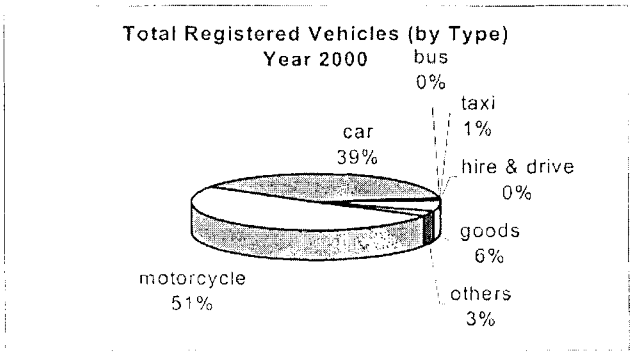

Figure 1 : Total Registered Vehicles in Year 2000
(Source: Road Traffic Volume Malaysia 2000, Highway Planning Unit)

Unfortunately, casualties among motorcyclists from road accidents also contribute a large portion of traffic problems in Malaysia. Approximately 68% of all injuries from road accidents in Malaysia involve motorcyclists and their overall relative risk is about 20 times higher compared to passenger cars (Radin et al., 1995). This is primarily because the vehicle itself offers little protection to the riders and pillion passengers in the event of collision.

In view of the high population of motorcycles in Malaysia and also their high injury risk, it is justified to pay serious attention to this vulnerable road user. In addition, addressing the problem of motorcyclist would also means solving the key problem of road accident in Malaysia. As such, it is essential that proper research on motorcycle safety be conducted to produce appropriate countermeasures in reducing the present high casualty and mortality rates among motorcyclists. One of the effective engineering approaches to improve motorcycle safety in Malaysia is to segregate motorcycles from other motorised traffic by the provision of an exclusive motorcycle lane.

In the early seventies, the first world motorcycle lane was constructed along the Federal Highway Route 2 under the World Bank project. An extension of the track was carried out in 1992 between the Subang International Airport to the towns of Shah Alam and Klang. The positive impact of this motorcycle lane was reported by Radin et al.(1995, 1998). The reduction in motorcycle accidents was highly significant ($p<0.05$) with a reduction of about 39% following the opening of the lane.

In another study, Radin & Barton (1997) showed that the benefit to cost ratio of providing an exclusive motorcycle lane ranged from 3.3 to 5.2 depending on the assumptions used in calculation of accidents costs and pavement design life of the exclusive lanes. Since the benefit is at least about 3 times higher than the cost, it was deduced that the provision of exclusive motorcycle lanes is highly cost effective in tackling motorcycle problems for highly motorcycled countries. Considering that the estimated benefit to cost ratio is strongly associated with the pavement design life, a more detailed understanding of the parameters involved in the capacity analysis of an exclusive motorcycle lane is necessary.

At present, there are no specified standards available to assess the design criteria of an exclusive motorcycle lane in Malaysia. The best available standards or precedents for motorcycle track design are "A Guide on Geometric Design of Roads (Arahan Teknik Jalan 8/86)" and "A Guide to the Design of Cycle Track (Arahan Teknik Jalan 10/86)" both published by the Public Works Department, Malaysia (PWD, 1986). Both of these guides covered the elements of design requirement for an exclusive track. However, some of the design parameters are combinations of the basic requirements of a bicycle track design and the requirements of a highway design. Apart from that, no previous experience elsewhere in the world could be referred to since the exclusive motorcycle lane is only available in Malaysia.

As such, there is a need to provide some specified design standards for preliminary determination of capacity of an exclusive motorcycle lane in Malaysia. Hence, the objective of this study is to preliminarily establish the speed, flow and density relationship of an exclusive motorcycle lane in Malaysia. This in turn, would result with a preliminary model that relates the saturation flow (capacity) and effective width of motorcycle lane. Since the estimated benefit to cost ratio of an exclusive motorcycle lane is strongly associated with the pavement design life, the outcome of this preliminary model would be useful in assessing the supply side, quality of flow and also the design life of this facility.

Methodology

The initial step of this study was to determine the suitable sites along the existing exclusive motorcycle lane of Federal Highway Route 2. The idea was to ensure that the selected spots are well distributed in terms of lane width and site condition. The rate of flow and mean speed at five minutes interval was collected continuously for seven days by means of an automatic traffic counting equipment (VDAS). Hence, by using the time occupancy theory, the flow rate-density relationship can be established.

In support to the VDAS technique, a video method was used to itemise the mean speed of typical platoon. The advantage of this method is that the mean speed and density platoons can be determined to supplement and validate the VDAS technique especially during the peak hour rate of flow between 7.00 a.m. and 9.00 a.m. of each working days. In addition, the jammed density was captured using the video method at selected places where motorcycles are forced to stop such as at a signalised junction or exit of a motorcycle lane. In this study, the number of motorcycles that occupied these selected areas was determined. A jammed density value of 0.237 mc/m^2 was determined based on the average value of sixty observations using the following formula:

Density (mc/m^2) = Number of motorcycles (mc) / Selected area (m^2) .... Eq. 1

Model Development

In this study, two modelling techniques were used namely Greenshields' General Model (Greenshields, 1935) and Descriptive Statistic Model in Multiple Regression.

Greenshields' General Model

In this first model of data analysis, the following formulas were used to correlate the parameters of mean speed (km/hr), flow rate (mc/hr) and density (mc/km).

$$v = v_f - (v_f)(k) / k_j \quad \text{Eq. 2}$$

$$q = (k)(v_f) - (v_f)(k^2) / k_j \quad \text{Eq. 3}$$

$$q = (k_j)(v) - (k_j)(v^2) / v_f \quad \text{Eq. 4}$$

where,

v	=	mean speed (km/hr)
v_f	=	mean free speed (km/hr)
k	=	density (mc/km)
k_j	=	jam density (mc/km)
q	=	flow rate (mc/hr)

These traffic flow models were computed according to an ideal mean speed and jam density value. They were used to compare the actual curve fitting and statistical testing based on the following assumptions:

- Flow is zero at zero density,
- Flow is zero at maximum density,
- Mean free speed occurs at zero density, and
- Flow-density curves are convex (i.e. there is a point of maximum flow).

Descriptive Statistics Model in Multiple Regression

The second model of data analysis is the multiple regression equation. This model was computed to determine the goodness of fit for the collected data. Like many other statistical procedures, multiple regression can summarise the collected data and examine the significant trends statistically. Regression techniques are closely related to the analysis of variance (ANOVA). The significance level and the R^2 of all the analysed data were used to select the best model.

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Results

Figure 2 shows the linear models of Mean Speed-Density at Spot 1. It renders a visual impression on the nature of the distribution that serves as the basis for this analysis. The model was generated with the best straight line such that the sum of squared deviations from the line is minimised. The intercepts of the regression line at the vertical and horizontal axes are the value of jam density and free mean speed respectively. The corresponding estimation of the jam densities and free mean speeds for all sites are tabulated in Table 1.

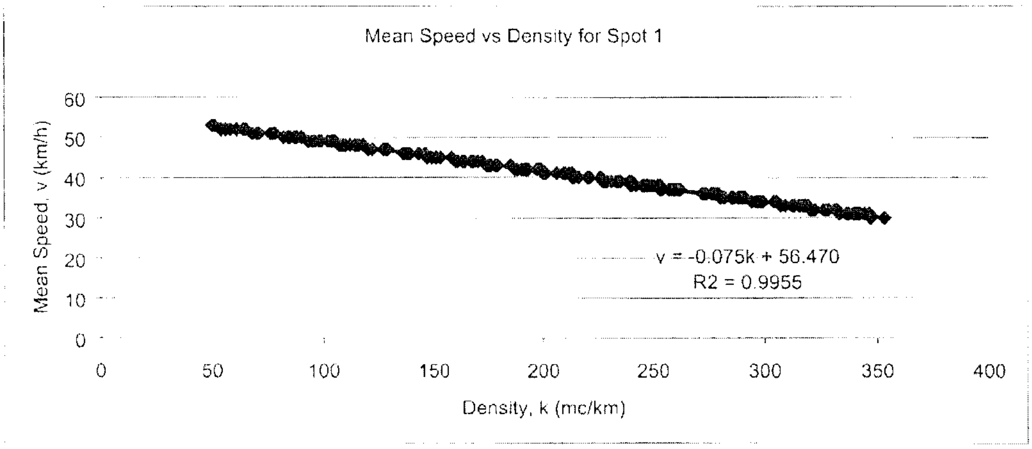

Figure 2: Regression Line & Regression Equation of Mean Speed-Density at Spot 1

Table 1 : Mean Speed – Density Relationship

Spot	Formula	Jam Density (mc/km)	Mean Free Speed (km/hr)
1	$v = -0.075k + 56.470$	753	56.5
2	$v = -0.086k + 59.004$	686	59
3	$v = -0.110k + 59.923$	545	60
4	$v = -0.080k + 58.785$	735	59
5	$v = -0.095k + 59.464$	626	59.5

(ANOVA Analysis Significance < 0.01)

Figures 3 and 4 show the relationship curves between flow rate, density and mean speed of the typical spot (Spot 1). It was indicated that there is no significant difference between Greenshields' model and Multiple Regression model approaches. The multiple regression results of all spots are considered good with all R^2 values higher than 0.980 and at significance levels lower than 0.001.

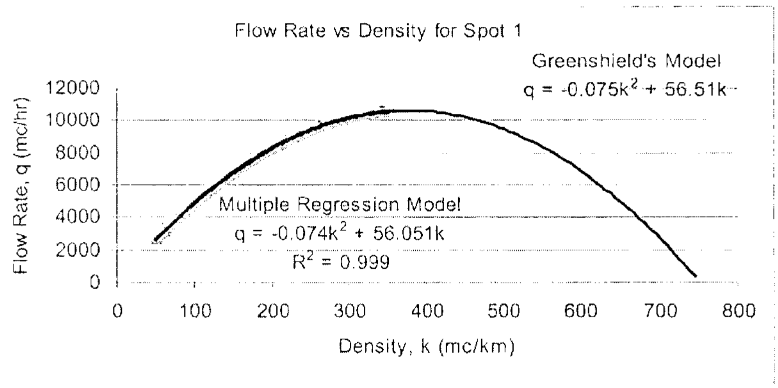

Figure 3: Flow Rate versus Density Models for Spot 1

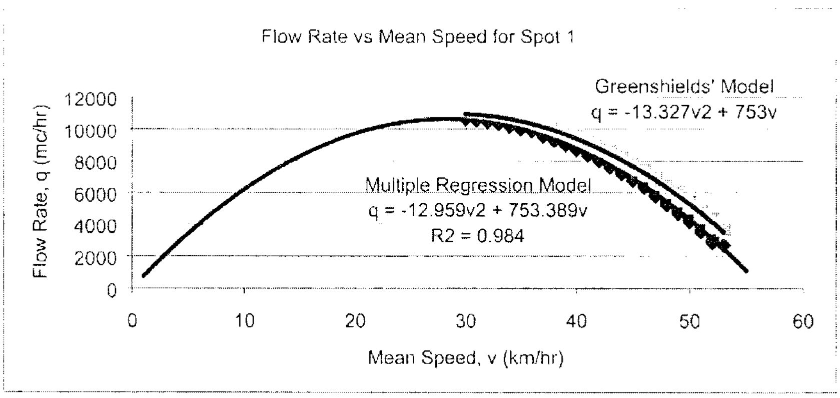

Figure 4: Flow Rate versus Mean Speed Models for Spot 1

The computed values of saturation flow obtained from the flow rate, density and mean speed models are tabulated in Table 2. The averaged saturation flow values were used in the simple regression analysis to establish the relationship between saturation flow and effective lane width of an exclusive motorcycle lane (Figure 5). Considering that the R^2 value obtained is 0.999, it is justified to use the equation as an initial guide in determining the effective width and capacity of the motorcycle lane.

Table 2 : Average Value of Saturation Flow

Spot	Effective Lane Width (m)	Saturation Flow		Averaged Saturation Flow
		Flow Rate Vs Density	Flow Rate Vs Mean Speed	
1	3.20	10,606	10,376	10,491
2	2.90	9,876	9,791	9,834
3	2.30	7,552	7,891	7,722
4	3.10	10,607	10,085	10,346
5	2.65	8,949	8,544	8,747

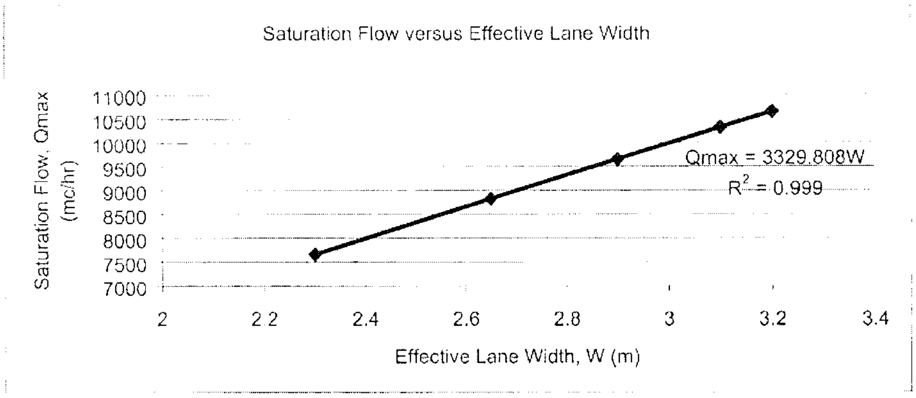

Figure 5: Regression Line and Regression Equation of Saturation Flow (Capacity)-Effective Lane Width Relationship

Discussion and Conclusion

In this study, the capacity of motorcycle lanes is the measurement of independent motorcycle traffic (expressed in saturation flow) on the effective lane widths. Saturation flow is defined as the maximum rate of flow of motorcycles that can cross the stop line of the approach where there is a continuous queue of motorcycles. Figure 5 shows the five data points that indicated a linear relationship between saturation flow and effective lane width of exclusive motorcycle lanes. Generally, the output of this study seems similar to the study conducted by Public Works Department, Malaysia (Arahan Teknik Jalan 13/87, PWD).

As shown in Figure 2, the majority of collected data accumulated at the first halves portion of the straight line with densities ranging up to about 350 mc/km while mean speed ranges from 30-55 km/hr. In addition, Figures 3 and 4 show that collected data lies within the initial halves of the flow rate, density and mean speed curves. These seem to indicate that Malaysian motorcyclists perceived good riding condition where there is no congestion along the exclusive motorcycle lane. This condition is termed "free flow" where motorcycle can travel at desired speed without being affected by the presence of another motorcycle. However, this free flow condition exist under low to moderate traffic flow and will cease as traffic increased steadily until capacity is reached, i.e. the maximum point of the parabolic curve.

From the comparison between multiple regression's model and Greenshields' model, it may be inferred that the descriptive statistical analysis in multiple regression of the relevant parameter relationship supports the generalised Greenshields' model used as the basic guide of this study. As such, the results of data in Figure 2 were useful since the values of jam density and mean free speed were appraised by simple regression modelling. Hence, the following equation derived from Figure 5 may be convenient as a preliminary model relating motorcycle lane capacity (Q_{max}) with the effective lane width (W):

$$Q_{max} = 3329.808W \quad \text{.. Eq. 5}$$

Note that these results need to be supported with data from higher occupancy conditions because a widely distributed data collection will incorporate better comprehensive models, for instance simulation models that describe the traffic operation in a realistic manner. The development of motorcycle lane standards in Malaysia is recognised as new knowledge and is vital and significant for the safe and economic design of exclusive motorcycle lanes. Similar to other design standards, it needs to be developed systematically in order to produce design guidelines and procedures that are dependable, feasible and practical. As such, further studies are needed to look into other aspects such as the design criteria of traffic flow, level of service, design life, cross-section, alignment, environmental conditions, traffic management and pavement structure. Due to the high population of motorcycles in Malaysia and their high injury risk involvement, the provision of a standard segregated motorcycle lane would means solving the key problem of road accident in Malaysia.

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