KEY COMPONENTS OF A MOTORCYCLE-TRAFFIC SYSTEM

– A Study Along the Motorcycle Path in Malaysia –

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(Received July 2, 2004)

The key road safety problem in developing world like ASEAN countries is motorcycle safety. Motorcycle is a popular mode of personal travel and formed as the major road user. Studies proved that segregation is the best engineering practice to save lives of motorcyclists. Acknowledging these benefits, the Malaysian government adopted a policy to provide motorcycle facility along its new highways and federal roads. The need to provide this special facility brought to light on the deficiencies in studies of motorcycle traffic sciences and facility design. This paper attempts to establish the characteristics of key components of a motorcycle-traffic system in Malaysia, i.e. the motorcycle/rider unit, motorcyclist space requirement and riding manner along motorcycle paths of various lane widths. It serves as useful input in developing design guidelines of motorcycle facilities for highly motorcycled countries in their effort to curb motorcycle safety problems.

Digital recordings of motorcyclists along the existing motorcycle path in Malaysia were captured at six sites and transcribed into two types of motorcycle-sizes. Basic dimensions of a motorcycle/rider unit were directly measured. The separation distance between side-by-side motorcyclists was obtained by employing the digital recording technique. The motorcyclist operating space was then established. Three-stages of field and experimented studies was conducted to observe the motorcyclists riding manner along various lane widths from low to high volume conditions.

The small- and medium-sized type motorcycles (150c.c. and below) made up 99% of the motorcycles population in Malaysia. A static motorcyclist measured about 0.8m in width, 2.0m in length, and requires an operating width of 1.3m. At a lane width of 1.7m or below, motorcycle flow applies the lane or headway concept. Above this optimum value, motorcycle flow adopted the space concept. This implied that a motorcycle path should be more than 1.7m wide to allow two motorcyclists to pass each other.

Key Words: Developing ASEAN countries, Motorcycle accidents, Motorcycle facility, Motorcycle-traffic science

1. MOTORCYCLE SAFETY PROBLEMS IN DEVELOPING ASEAN COUNTRIES

According to the Asian Development Bank[1], developing world like ASEAN countries is facing deteriorating problems in road safety. In all, ASEAN member countries saw a total loss of some USD11 billion in year 2000 due to the 73,000 road deaths and 1.8 million injuries. Apart from the problems of mixed traffic and underdeveloped infrastructure and institutions, the fact that recent vehicle growth has been in motorcycles makes the matter worse. A high proportion of two- and three-wheeled vehicles were recorded in some ASEAN countries like Vietnam (95%), Lao People's Democratic Republic (79%), Cambodia (75%), Indonesia (73%) and Malaysia (49%).

The Asian Institute of Technology in Bangkok generalized that the high proportion of motorcycles on Thailand's roads is linked to a higher death rate. Of the country's 26 million registered vehicles, 12 million are two-wheelers while there are another 6 million unregistered motorcycles. About 80% of all fatal accidents in Thailand involve motorcycles[2]. Motorcycles are popular in many ASEAN countries because almost anyone can afford one. It seems that motorcycle-only lanes are needed on their roads to keep riders from tangling with heavier forms of vehicles.

In Malaysia, the number of registered motorized two-wheelers had increased more than five-folds from 1.19 million in year 1979 to 6.2 million in the year 2003[3]. The proportion of motorcycles on the Malaysian roads varies from 35%-75% depending on states. In less developed states such as Perlis, motorcycles account for more than three-quarters of the total vehicle population. While in a more developed states such as Kuala Lumpur, motorcycles formed one-third of the total vehicle population and were the major mode of personal transport for the low-income urban community[4]. About 68% of all road accident injuries in Malaysia involved motorcyclists and their overall relative risk is about 20 times higher than passenger cars[5].

Historically, what was known as the 'first' exclusive motorcycle path in the world was constructed along the Federal Highway Route 2 (F02) in the state of Selangor, Malaysia under the World Bank project during the early seventies. Studies had proven that following the introduction of this 30km long (per direction) exclusive motorcycle path, the motorcycle accidents per year was significantly reduced by 39%[4,6]. The findings supported the general notion that segregation is the best engineering practice to save lives of vulnerable road users such as pedestrians, bicyclists and motorcyclists. In its continuous efforts to curb the key road safety problems in Malaysia, the government recognised this positive benefit and recently adopted a policy to provide motorcycle path along its new highways and the federal roads. However, this need to provide motorcycle-only facility brought to light on the deficiencies in studies of motorcycle traffic sciences and facility design.

This paper attempts to establish the characteristics of the key components of a motorcycle-traffic system in Malaysia, i.e. the motorcycle/rider unit, motorcyclist space requirement, and motorcyclists riding manner along motorcycle paths of various lane widths. The scope of study focused on the basic segments of an uninterrupted exclusive motorcycle path (one-directional) under good pavement and weather conditions. Results would contribute new knowledge to the basic research in motorcycle traffic sciences, traffic operations and facility design. It would also provide some basis in planning future research to further understand the motorcycle-traffic stream, to establish the motorcycle speed-flow-density relationships and to estimate the capacity and level-of-service (LOS) for an uninterrupted motorcycle path in Malaysia. The outcome would be useful guidelines for designing motorcycle facilities in developing and highly motorcycled countries as a measure to address the motorcycle safety problems.

2. UNDERSTANDING THE VULNERABLE ROAD USERS

There does not seem to be much information related to motorcycle traffic sciences and facilities. In the closest related document[7,8], the design elements of the facility seem to be a cross-reference between the design standards of a road and a bicycle track. Lane widths of 2.0m (6.6ft), 2.5m (8.25ft), and 3.0m (9.9ft) were recommended for motorcycle volumes ranging from 1000-1500, 1500-2000, and above 2000 per hour respectively. However, there was no mentioned on the sources of reference and no discussion of the motorcycle/rider unit.

Compared to motorcycles, it seems that more research efforts were done on bicycles. This would be useful input for motorcycle studies since both are two-wheeled vehicles with many similarities except that one is motorized. It was stated that bicyclists are not as regimented as vehicles and tend to operate in distinct lanes of varying widths. Thus, the capacity and LOS of a bicycle facility depends on the number of effective lanes used by bicycles[9]. Studies in the United States found that a typical bicycle is 1.75m (5.75ft) in length with a handlebar width of 0.6m (2.0ft)[10]. The physical space was recommended to be 0.61m (2.0ft) wide by 2.3m (7.5ft) high[11]. In the Netherlands, it was reported that 95% of bicycles are less than 1.9m (6.25ft) in length while 100% of bicycle handlebar widths are less than 0.75m (2.5ft)[12]. It may be inferred that generally, bicycle widths are less than 0.75m (2.5ft) while the length is less than 1.9m (6.25 ft). It is appreciated that a bicyclist needs a certain amount of operating space and no bicyclist can ride a bicycle in a perfectly straight line at any speed. A U.S. study reports that a typical bicycle needs between 0.75m (2.5ft) and 1.40m (4.5ft) of width to operate[10]. This amount of space can also be referred to as the *effective lane width* for a bicycle. FHWA recommends an operating space (minimum design LOS C) of 1.1m (3.5ft) wide[11]. As for the width of bicycle lane, a study in California[13] recommends a minimum width of 1.28m (4.2ft) with additional width at higher volumes. AASHTO[14] suggested a standard bicycle lane width of 1.2m (4.0ft). The Netherlands and Germany generally recommended 1m (3.3ft) as the normal width of one bicycle lane[12,15].

Even though there is a clear physical difference between a motorcycle and a pedestrian, both belong to the vulnerable road users group. Therefore, some basic findings from the research efforts in pedestrian studies may be useful input to motorcycle traffic study. The qualitative measures of pedestrian flow such as the freedom to choose desired speeds and to bypass others are similar to those used for vehicular flow. It used a simplified body ellipse of 0.50m (1.65ft) × 0.60m (1.98ft), with total area of 0.30m^2 (3.27ft^2) as the basic space for a single pedestrian, and an area of 0.75m^2 (8.17ft^2) is used as the buffer zone[9,16]. Similar to analyzing a highway lane, the lane or headway concept was used to analyze pedestrian flow. However, the lane or headway concept was not be used for pedestrian analysis, because studies have shown that pedestrians do not walk in organized lanes[9,16].

3. METHODOLOGY

3.1 Design motorcycle

The digital recordings of motorcyclists riding along the exclusive motorcycle path were captured from the overhead pedestrian bridges at six sites of the F02 highway in the state of Selangor, Malaysia. In the laboratory, the pre-recordings were played on a large screen television. Using a tally counter, the observed motorcycles (N = 16,219) were transcribed into two classes based on their physical sizes, namely:

i. Small- and medium-sized motorcycles (engine sizes 150c.c. and below)
ii. Large-sized motorcycles (engine sizes above 150c.c.)

3.2 Space requirement

3.2.1 Static space

To elicit the physical width and length of a rider on a design motorcycle, direct measurements were taken from the motorcyclist by means of a measuring tape. The dimensions used a simplified outline of the motorcycle/rider unit in the front and side views. The physical space occupied by a static motorcyclist was derived from the static width and length of the motorcycle/rider unit.

3.2.2 Operating space

With reference to the bicycle research efforts, the videotape techniques had shown to produce reliable results in determining the adequacy of varying curb lanes for shared use by motor vehicles and bicycles[17], and to evaluate shared-used facilities for bicycles and motor vehicles[18]. The separation distance between bicyclist and motor vehicle was recorded as the motor vehicle passed the bicyclist.

By employing the digital recording technique, motorcyclists traveling along the motorcycle path of F02, Selangor were observed from an overhead pedestrian bridge concealed from the unknowing motorcyclists. Simultaneously, the motorcyclists spot speeds were captured using a portable laser speed detector. The study site is a level and straight basic segment with an effective width of 2.71m measured between the two white edge markings in the field. Back in the laboratory, the pre-recordings were observed on a large screen television. Motorcycle volume counts at one-minute interval were transcribed over the two-hour study and the equivalent hourly rate of motorcycle flows were then computed.

While observing their interactions from the screen, the pre-recordings were paused as the faster motorcyclist passed the slower ones (Figure 1). The distance between the centers of their rear tires is directly measured, i.e. when their rear tires were even. The perpendicular line was extended to directly measure the effective width. Since the actual effective width is 2.71m, the actual distance between the centers of the rear tires was computed.

The separation distance of side-by-side motorcyclists was obtained by subtracting the basic width of a static motorcyclist in Malaysia obtained in this study from the calculated distances between the centers of the two rear tires. All data of the computed separation distances, the time-mean speeds converted to space-mean speeds[19], and the motorcycle flow rates were summarized using SPSS software. Halves of the mean separation distance of side-by-side motorcyclists was taken to represent the buffer zone on each side of a single motorcyclist, thus the operating width could be recommended.

Fig. 1 Distances between centers of rear tires (d1) and effective width (d2) as the faster motorcyclist passed the slower ones

3.3 Riding manner

3.3.1 Parameters measured in the field and laboratory

Key parameters measured at the study sites were motorcycle volumes, individual motorcycle spot speeds, and total paved widths of the motorcycle path. Motorcyclists riding along the paths were captured using a digital video recording camera, and volumes counted in the laboratory from a large screen television. Simultaneously, individual motorcycle spot speeds were measured using a portable laser speed detector. Time of internal clocks for both laser speed detector and digital video recorder were synchronized before conducting the observations. Total width of motorcycle path was measured across the paved section using a horizontal distance measurer. Data were reduced into a mean one-minute condition.

3.3.2 Field and experimented studies

In order to observe motorcyclists riding along motorcycle paths of various lane widths under low and high volume conditions, the study was conducted in three stages. Initially, data was collected at three sites of the motorcycle path along the F02, Selangor. The sites were level and straight basic segments with total paved widths of 2.4m, 3.0m and 3.3m respectively. However, only the low volume conditions were covered since it is not possible to observe high motorcycle volumes even during the peak hours. Observations of high flow conditions may be possible if the lane widths were made smaller than 2.4m, and coupled with considerably high motorcycle flows. Therefore, experimented studies on three different widths of less than 2.4m were conducted in the Universiti Putra Malaysia campus. It involved 100 motorcyclists riding along level and straight basic segments that were narrowed down on one side by safety cones. The experimented total widths were 1.5m, 1.7m and 1.9m respectively. Finally, similar experimented study was conducted along the motorcycle path of F02. It was conducted during the morning peak-hour motorcycle traffic traveling along the basic segments of the path with experimented total widths 1.4m, 1.6m and 2.0m respectively. The measured parameters and motorcyclists riding manner observed over the ranges of lane widths and motorcycle flow conditions were summarized in a matrix form.

Fig. 2 Motorcycle of engine size 110c.c. commonly found in Malaysia

Fig. 3 Type of motorcycle representing the design motorcycle

4. RESULTS

4.1 Design motorcycle

Of the total 16,291 motorcycles observed at six sites along the motorcycle path of F02, Selangor, it was found that 99% (16,126) were small- and medium-sized motorcycles of engine sizes 150c.c. and below, thus representing the "design" motorcycle-vehicles. Only 1% (165) of the motorcycles were large-sized motorcycles of engine sizes above 150c.c.. Direct measurements of the design motorcycle-vehicle revealed that the length of the motorcycle is about 2.0m (Figure 2).

The breadth of the design motorcycle-vehicle spans about 0.8m measured between outer ends of the two side mirrors (Figure 3).

4.2 Space requirement

4.2.1 Static space

Figure 4 and Figure 5 showed the simplified outline and dimensions for a static motorcyclist. A motorcyclist physically spans 0.8m wide, and measured 2.0m in length. Thus, an area of 1.6m^2 (0.8m × 2.0m) represents the physical space occupied by a static motorcyclist. The motorcyclist eye-level is about 1.4m high from the ground level while the total height of the motorcyclist is about 1.6m.

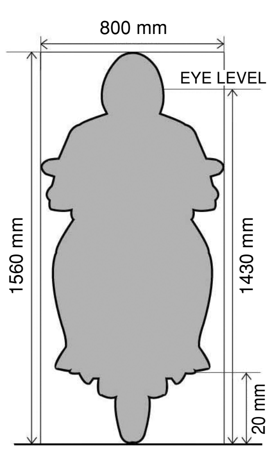

Fig. 4 Physical width of a static motorcyclist - 0.8m

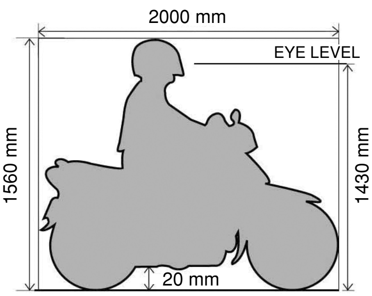

Fig. 5 Physical length of a static motorcyclist - 2.0m

4.2.2 Operating space

Data summary revealed that the mean separation distance was 0.52m with a standard deviation of 0.18 (N=178). The range covers a minimum and maximum separation distances of 0.10m and 0.92m respectively. The mean speed was 61km/hr with a standard deviation of 6km/hr (N=1284). The mean flow rate was 1190motorcycles/hr/ln with a standard deviation of 337motorcycles/hr/ln (N=120). For simplicity purposes, the values of the motorcycles separation distance, speed, and flow rate may be reasonably rounded-off as 0.50m, 60km/hr, and 1200motorcycles/hr/ln respectively (Figure 6).

Halves of the mean separation distance (0.25m) was taken as the side-buffer zone for a motorcycle/rider unit. Therefore, the mean operating space required by a single motorcyclist riding under the mean speed of 60km/hr and flow rate of 1200mc/hr/ln conditions is 1.3m (Figure 7).

4.3 Riding manner

Even though the matrix of Table 1 seems incomplete, the observations were adequate to reasonably indicate that motorcyclists ride in a single file throughout

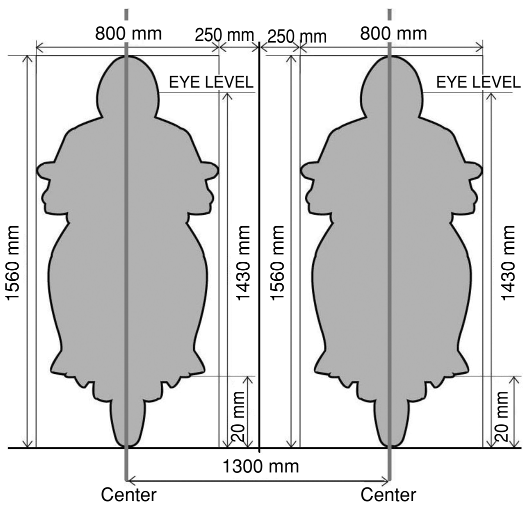

Fig. 6 Side-by-side motorcyclists separation distance of 0.50m

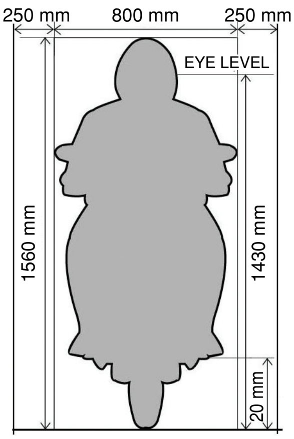

Fig. 7 Operating space of 1.3m required by a motorcycle/rider unit

the low-and high volume conditions within motorcycle lanes of 1.7m wide or less. This platoon-riding manner seems related to the constraint in the total width of the motorcycle path.

It is interesting to note that for lane widths of 1.9 to 2.0m, motorcyclists ride in a single file under low volume conditions. However, they would form into two imaginary lines under high volume condition. For lane widths of 2.4m and above, motorcyclists formed more than one imaginary line even under low volume conditions. For the purpose of simplicity, it indicated that for motorcycle lanes wider than 1.7m, motorcyclists formed themselves into more than one imaginary line either under low volume or high volume conditions. It may arise from the availability of operating space for motorcyclists to pass the slower ones within the motorcycle path.

Table 1 Motorcyclists riding manner along various lane widths under low and high flow conditions

Sites	Total lane width (m)	Low volume condition (Flow < 1900 mc/hr/ln)			High volume condition (Flow > 2500 mc/hr/ln)			Motorcyclists riding manner
		Mean flow rate (mc/hr/ln)	Mean speed (km/hr)	Nos. of lines formed	Mean flow rate (mc/hr/ln)	Mean speed (km/hr)	Nos. of lines formed	
F02	3.3	902	61	2	–	–	–	Space concept
F02	3.0	1799	51	2	–	–	–	
F02	2.4	1343	52	2	–	–	–	
F02-Exp	2.0	1381	46	1	–	–	–	
UPM-Exp	1.9	–	–	–	2694	34	2	
UPM-Exp	*1.7*	–	–	–	*3106*	*25*	*1*	*Lane or Headway concept*
F02-Exp	*1.6*	*1046*	*45*	*1*	–	–	–	
UPM-Exp	*1.5*	–	–	–	*2845*	*11*	*1*	
F02-Exp	*1.4*	–	–	–	*2548*	*11*	*1*	

5. DISCUSSION AND CONCLUSIONS

This study highlighted on some basic characteristics of the key components of a motorcycle-traffic system in Malaysia, i.e. the design motorcycle-vehicle, the motorcycle-rider unit space requirement, the motorcycle-riding manner along motorcycle paths of various lane widths, and how one influenced the other. These components interact with each other to form motorcycle-traffic stream. It was found that 99% of the motorcycles population in Malaysia comprises those of small- and medium-sized type motorcycles with engine sizes 150c.c. and below (Fig. 2 and Fig. 3). Because of their small in size, a rider does not require much space for maneuvering. A static motorcyclist measured about 0.8m in width and 2.0m in length, and occupies a physical space of 1.6m^2 (Fig. 4 and Fig. 5). This indicated that a lane width must be greater than 1.6m for two motorcyclists to pass each other within the motorcycle path. It is noted that these small-sized motorcycles were slightly larger than bicycles. Generally, the bicycle handlebar width is less than 0.75m, and its length less than 1.9m[12]. Even though the physical widths of these two-wheeled vehicles are quite close, their operating spaces are expected to differ because comparison is between a motorized and non-motorized two-wheeled vehicle of different travel speed capacities.

A motorcyclist requires a certain amount of operating space to ride along a motorcycle path. Results suggested that at a motorcycle flow rate of 1200mc/hr/ln corresponding to a mean speed of 60km/hr, a typical motorcyclist needs between 0.9m and 1.7m of width to operate, while the mean operating width is 1.3m (Fig. 7). Meanwhile, a typical bicyclist needs between 0.75m and 1.40m of width to operate[12] and a bicycle operating space (min. design LOS C) of 1.1m wide was recommended[11]. The required space referred to as the "effective lane width" for a bicycle is much smaller than motorcycle because of its lower travel speed and shorter width. The ranges in motorcyclists operating widths (0.9m-1.7m) inferred that a 1.7m wide motorcycle path would expect motorcyclists to ride in a single file even though not in a perfectly straight line due to the constraint in space to pass each other. From another aspect, a motorcycle path should be 1.8m wide or more for two motorcyclists to conveniently pass each other.

These values complement the findings on the motorcyclists riding manner along motorcycle paths of various widths (Table 1). It revealed that motorcyclists ride in a single file within motorcycle paths of 1.7m wide and less throughout the low and high volume conditions. Under these conditions, the lane or headway concept as established to automobiles flow may be adopted to motorcycle flow. Hence, the motorcycle flow would be measured in mc/hr/ln, motorcycle speed in km/hr and density in mc/km/ln. An "ideal lane" is expected to lie between 1.4m and 1.7m lane widths, and this warrants further studies.

It was also observed that motorcyclists tend to form themselves into more than one-line within motorcycle paths wider than 1.7m either during the low or high volume conditions (Table 1). This is much related to the available space within the motorcycle path that allow faster motorcyclists to utilize it for overtaking slower motorcyclists, thus leading them to form another imaginary line along the path. This seems in line with the earlier suggestion that a motorcycle path should be 1.8m wide or more to enable two motorcyclists to conveniently pass each other. This condition indicated that the space concept as established in pedestrian studies[9,16] could be adopted to motorcycle flow. The motorcycle flow would therefore be measured in mc/hr/m-width, speed in km/hr and density in mc/m^2 (or space in m^2/mc).

Overall, this study gives some new understanding in the key components of a motorcycle-traffic system and the parameters of a motorcycle-traffic stream for an uninterrupted exclusive motorcycle path (one-way) in Malaysia. It highlights that the qualitative measures of motorcycle flow are similar to those used for vehicular flow, i.e. the freedom to choose desired speeds and to bypass others. Therefore, engineers should generally avoid providing motorcycle paths of 1.7m wide or less unless the space is greatly constrained. The knowledge of the motorcycle macroscopic parameters provides some basis in planning future research to further understand the motorcycle-traffic stream, to establish the motorcycle speed-flow-density relationships and to estimate the capacity and level-of-service for an uninterrupted motorcycle path in Malaysia. Findings would be useful for engineers in developing and highly motorcycled countries like ASEAN to maximize the benefits while minimizing the space consumptions and construction costs when providing motorcycle paths in their effort to address the key road safety problems.

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ACKNOWLEDGEMENTS

Data, grants and support for field data collections were provided by the Public Works Department, Ministry of Works Malaysia, National Science Council IRPA Malaysia and Roadcare (Malaysia) Sdn. Bhd..