Land Based Transport System: Related Issues & Improvement Strategies

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INAUGURAL LECTURE

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ABSTRACT

Land based transportation is a major mean of transportation for the majority of commuters in Malaysia. Road transport alone accounts for 96% of total passenger and goods transport in Malaysia. In this paper, two common issues associated with land based transportation are discussed, namely traffic congestion and road safety issues. To address the road congestion issue, several strategies and recommendations are proposed which if implemented strategically and with full cooperation from all parties, will help mitigate traffic congestion. One important strategy is to develop Malaysian own traffic engineering standards to plan and design transportation engineering facilities. Also highlighted is the importance of public transportation in addressing traffic congestion issue. As the issue of road safety is tackled, traffic engineering strategies were highlighted to reduce the fatality rates in the country. And with the relatively high number of motorcyclist making the journey on Malaysian roads, special consideration is given to reduce the number of road accident fatalities involving these users.

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1 INTRODUCTION

The majority of commuters in Malaysia uses land based transportation for their daily commute to work and for other travelling purposes. Road transportation in Malaysia accounts for 96% of total passenger and goods transport in the country. Land based transportation in Malaysia, therefore, deserve a special consideration.

The two main issues related to land based transportation, namely, congestion and safety issues is discussed here. Traffic congestion is one of the culprit behind the current global warming phenomenon as slow moving vehicles emit more pollutants to the air (Ahmad Farhan et al. 2001, Hamidi et al. 2000, Wan Hashim and Wan Chan Peng 2000, Wan Hashim et al. 2000, Norazam et al. 2001a, 2001b, 2006a, 2006b, 2007, Wan Hashim and Hamidi 2008, Wan Hashim 1999, Wan Hashim and Norazam 2001, Wan Hashim and Norazam 2004).

It is an unnecessary wastage of precious energy as congestion causes the continuous burning of huge amount of fossil fuel which took mother earth million of years to create. It also involves time lost on the roads as vehicles are reduced to a crawl during traffic jams and queuing for their turn at traffic light junctions. In addition, the lost time inevitably translates to millions of dollars lost in opportunity cost (Nurikhwani et al. 2004, Nurikhwani et al. 2006, Quazzi et al. 2006, Wan Hashim and Ahmed 1999).

Malaysia is also experiencing an increase in the number of fatality due to road accidents on its roads. The causes are many and involve interaction between human factors, vehicle and road environment. In traffic engineering, the emphasis is given toward the improvements of the road environment in order to ensure, regardless of the causes of accident, that severity of the accidents are lessen and will help reduce the number of fatality (Nor Rizan et al. 2001, Quazi et al. 2005a, Quazi et al. 2005b, Wan Hashim 1997, Wan Hashim 1998b, Wan Hashim 1998c, Wan Hashim 1998d, Wan Hashim and Azman 1998, Wan Hashim 1999a, 1999b).

Malaysia's road, in general, has to accommodate a high number of motorcyclists. Since more than half of the accident cases in Malaysia involved motorcyclists, greater emphasize in traffic engineering are given to the design of road environment which accommodate motorcycles. And taking its role further, traffic engineering also tries to educate the public on the importance of abiding to rules and regulations related to road safety.

The number of vehicles on the Malaysian road is increasing annually (Figure 1.1 and Table 1.1). And as shown in Figure 1.1, the number of motorcycles is higher than the number of cars on the road. In most developed countries, the number of motorcycles is almost negligible. However, most of the traffic engineering standards were developed and produced by the developed countries. Thus, there is a great need for Malaysia to have its own traffic engineering standards to take into account its unique drivers behaviour and road characteristics.

It is important to be able to understand better the characteristics of Malaysian drivers in order to effectively design the road facilities for them. As it is now, most of the applied local standards in relation to traffic engineering are based on overseas standards, such as the U.S. Highway Capacity Manual (TRB, 2000).

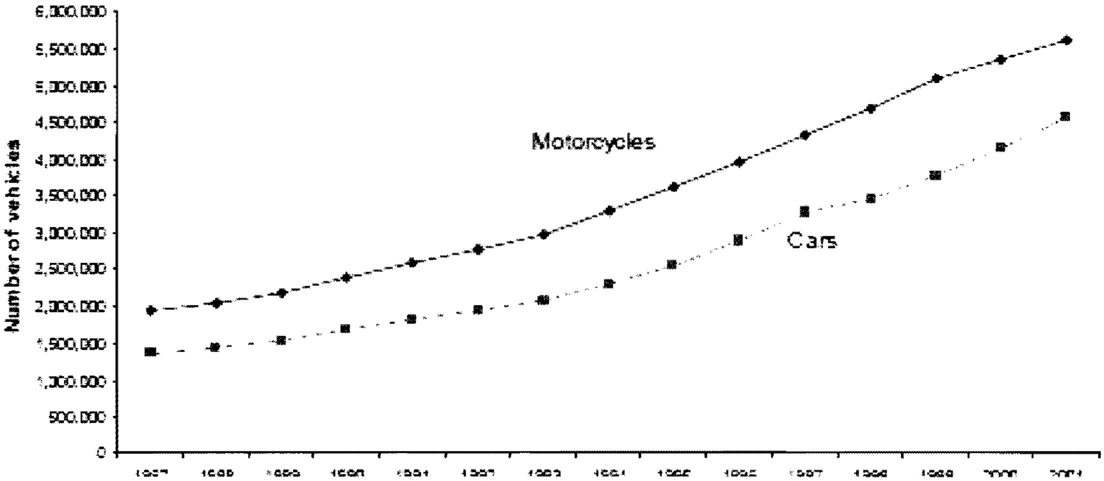

Figure 1.1: Traffic Growth in Malaysia (Road Transport Department, 2002)

Table 1.1:Total number of vehicle registered in Malaysia (Road Transport Department, 2005)

Year	1999	2000	2001	2002	2003	2004	2005
Number of vehicles	9.929.951	9.141.354	11.302.545	11.975.641	12.821.248	13.764.837	13,851,649

Traffic congestion is a global issue, and most developed nations such as USA, Japan, Germany and U.K. have hundreds of thousands kilometres of road as shown in Table 1.2. Compared to Malaysia, the total number of populations in those countries is staggeringly high and so is the total number of vehicles. Malaysia, therefore, has plenty of space to solve the traffic congestion issue due to its relatively lower traffic volume and lesser inhabitants compared to other developed nations.

Table 1.2: Roadway length and mobility index of different countries (Adapted from Kahinoor and Tapan, 2009)

Country	Total length of all roads (km)	Total length of motorway/ freeway/ national highway (km)	Population in thousands	Land area (sq. km)	Population density (population in thousands/ 1,000 sq. km)	Mobility index (based on all roads)		Mobility index (based on motorway/ freeway/national highway)	
						km/1,000 sq. km of land	km/10,000 population	km/1,000 sq. km of land	km/10,000 population
India	3,315,231 [2]	58,112 [1-1]	1,045,547 [3]	2,973,190 [4]	352	1115.0	31.71	19.5	0.56
Pakistan	255,856 [5]	8,885 [1-2]	148,720 [5]	778,720 [4]	191	328.6	17.20	11.4	0.60
Bangladesh	239,226 [1-2]	3,485 [6]	141,340 [7]	133,911 [4]	1,055	1786.5	16.93	26.0	0.25
USA	6,358,571 [8]	90,205 [8]	282,909 [9]	9,161,923 [4]	31	694.0	224.76	9.8	3.19
Germany	231,400 [10]	12,000 [10]	82,501 [10]	357,045 [10]	231	648.1	28.05	33.6	1.45
U.K.	387,674 [11]	3,100 [11]	59,834 [12]	241,590 [4]	248	1604.7	64.79	12.8	0.52
France	863,100 [13]	10,390 [4]	62,324 [14]	545,630 [4]	114	1581.8	138.49	19.0	1.67
Japan	1,183,000 [15]	7,200 [15]	127,619 [15]	324,200 [15]	394	3649.0	92.70	22.2	0.56
China	1,624,952 [16]	34,300 [16]	1,299,880 [16]	9,326,411 [4]	139	174.2	12.50	3.7	0.26

Sources of Data

[1-1] World Bank, 2002

[1-2] World Bank Local Staff, 2004

[2] Department of Road Transport and Highways, GOI, 2002

[3] 2002 Projection from Census of India (http://www.censusindia.net)

[4] www.infoplease.com

[5] Federal Bureau of Statistics, Pakistan, 2004

[6] Roads and Highways Department of Bangladesh, 2004

[7] Bangladesh Bureau of Statistics (BBS), 2004

[8] United States Bureau of Transportation Statistics, 2003

[9] U.S. Census Bureau, 2003

[10] Federal Statistical Office, Germany, 2004

[11] Road Traffic Statistics-2004, Department of Transport, U.K.

[12] Official U.K. Statistics, 2004 (www.statistics.gov.uk)

[13] OECD, 2004 (http://www.oecd.org/statsportal)

[14] National Institute for Statistics and Economic Studies France, INSEE, 2004

[15] Japan Statistical Yearbook, 2006

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2 LAND TRANSPORTATION

Efficient movement of goods and people has been proven to be vital for the economic success of any country. In most developed countries, the transportation systems are very systematic, well planned and properly maintained by the relevant authorities. For example, the U.S. Interstate system was constructed since 1950's and has contributed toward the movement of people and goods throughout the United States. Likewise, in order for Malaysia to achieve its Vision 2020, it needs to properly planned and developed the transportation systems network throughout the country.

However, it is no argument that the development of any transportation infrastructure requires extensive amount of money and investment. Therefore, in order to be able to provide the much needed facilities, several major road construction in Malaysia are privately financed; mostly through Build, Operate and Transfer (BOT) concept.

LAND TRANSPORTATION CHARACTERISTIC IN MALAYSIA

By 2006, Malaysia has a road network infrastructure of 90,129 km of which 79% are paved roads. Most of the operating highways are interurban highways (HPU, 2008). Existing transportation facilities need to be properly maintained in order to achieve the desired level of service (LOS), which is a measure of effectiveness to indicate user's perspective of the serviceability of the relevant facilities (Madanat et al. 1994).

Through proper planning, congestion level can be controlled through the provision of an appropriate supply of road facilities to accommodate traffic growth in the country (Ahmad Farhan and Wan Hashim 2000a, 2000b, Wan Hashim 1996). Proper management of transportation facilities can also be planned properly in order to ensure the expected LOS for the facilities are achieved.

The quality of roads should be continuously improved to ensure the safety and comfort of road users. By carrying out proper planning, sustainable development with respect to the increasing number of traffic can be achieved (Ahmad Farhan and Wan Hashim 2001).

DESIGN STANDARDS THAT FIT LOCAL NEED

Several design standards are currently used to analyze the LOS of the transportation facilities. Most of the standards, however, are relevant and applicable only to the specific countries where the standards were developed as each country demonstrate unique drivers' behaviour, vehicles characteristics and driving culture. For example, the number of motorcycles on Malaysian roads is considerably much higher compared to those in the USA, U.K., Germany or Japan.

In addition, the behaviour of local drivers also needs to be taken into consideration in outlining the proper design standard. Unfortunately, in the absence of local design standards, local consultants normally adopt overseas design standard for designing our transportation infrastructure. We have shown in our previous studies that the use of overseas standard for designing local transportation facilities incurs several drawbacks (Wan Hashim and Nurikhwani, 2004b).

3 TRAFFIC CONGESTION

The operation of everyday traffic is governed by the interaction between traffic, drivers and roadways. Traffic flows vary according to time and locations; mostly it fluctuates throughout the day with peak periods in the morning and evening. Some locations may experience very high traffic volume due to the active economic activities within its area such as within the Central Business District (CBD) of major towns. However, other areas such as recreational roads, may only have to cater for very heavy traffic during the weekends and also during holiday seasons. It requires proper planning and appropriate engineering judgment to plan and design for such a facility that is not predictable.

Congestion occurs when the number of traffic is much higher compared to the supply (capacity) of existing highway facilities. When the number of traffic exceeds the capacity of the existing facilities, the LOS of such facilities deteriorates. The users of the affected highways will perceive a lower LOS due to changes in their comfort level i.e. the experience of reduced speed, longer travel time, or longer waiting time at road junctions. All of these contributed to them losing precious time which they could have utilized for other beneficial and more productive ventures. Figure 3.1 and 3.2 show the congestion during peak hours in Kuala Lumpur and Kota Kinabalu, respectively.

There are two distinct types of congestion, namely, recurring congestion and non-recurring congestion. Each type differentiated by the nature of its cause.

RECURRING CONGESTION

Recurring congestion occurs when the existing transportation facilities are unable to carry the intended number of traffic. In a case where the number of lanes in a highway is limited, this can be solved through the construction of more highway lanes. Additional capacity can also be obtained through the construction of adjacent highway facilities.

Recurring congestion can also be due to poorly maintained traffic light junctions, especially in the city center. Properly retimed existing traffic light junction can improve the LOS of the facilities quite substantially (Wan Hashim and Ahmad Farhan, 2002a).

In most location in Malaysia, however, recurring congestion could be due to parents dropping off their children at schools. This congestion occurs when the school is located along a busy road in the city center. Most parents and school bus operators park their vehicles on the side of the busy road in order to drop off students, causing severe congestion which could last for several hours. This particular problem can be solved in the future by ensuring that new schools are located farther away from busy streets and adequate parking spaces are provided.

Figure 3.1: Traffic Congestion in Kuala Lumpur, Federal Territory

Figure 3.2: Traffic Congestion in Kota Kinabalu, Sabah

NON-RECURRING CONGESTION

Nonrecurring congestion occurs due to unpredictable incidents such as traffic accidents or vehicle breakdown. This type of congestion can be avoided through proper traffic management system such as by the ability to immediately detect the incident and dispatch relevant response team to clear the incident and therefore, allowing a quick return to unobstructed traffic.

The ability to clear those unpredictable incidents requires the local authorities to have proper incident management system as part of their advanced traffic management system. The local authority also needs to have competent personnel in their respective fields in order to maintain and to optimally operate the system.

STRATEGIES FOR EFFICIENT TRAFFIC FLOW

In order to reduce congestion level, the local authority must ensure that any development within their jurisdictions must comply with the local traffic engineering requirements. The local authority must ensure that proper Traffic Impact Assessment (TIA) is carried out by qualified consultants to ensure that the development for the area is sustainable. Proper TIA will allow development to proceed with minimal impact to the congestion level of the area.

Several examples of Traffic Impact Assessment (TIA) had been carried out to ensure that the proposed development has minimal impact on the existing transportation facilities (Wan Hashim et al., 1996, 1997a, 1997b, 1997c, 1997d, 1997e, 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d, 1999e, 1999f, 1999g, 2000, 2001, 2002, 2002b, 2002c, 2002d). The latest version of the Malaysian Trip Generation Manual should be used for Traffic Impact Assessment in order to take into consideration Malaysian travel characteristics (HPU, 2005).

Commuters in the big cities usually experience daily congestion, especially in the morning peak period and in the evening peak period. The duration of each peak period is getting longer in megacities due to the increasing number of vehicles on the road. Thus, in order to ease traffic congestion on the highways, megacities must rely on efficient public transportation system.

HIGHWAY FACILITIES TO REDUCE CONGESTION LEVEL

There are two types of highway facilities that need to be taken into consideration in order to ease congestion level: interrupted flow facilities and uninterrupted flow facilities. Examples of interrupted flow facilities included signalized intersection, roundabout and stop-controlled intersections. Examples of uninterrupted flow facilities include two-way two-lane highway, expressways, multi-lane highways, weaving sections, and ramp junctions.

The measure of effectiveness (MOE) of the interrupted flow facilities is shown in Table 3.1. MOE is used to determine the facilities LOS, respectively. LOS is represented through a designated letter (usually A to F) that describes a range of operating conditions on a particular type of facility: For example, LOS A represents free flow condition, while LOS F represents breakdown condition. The MOE for signalized intersection is delay (sec/veh). Thus, the higher the average delay per vehicle on the signalized facilities, the lower the LOS of the facility (Table 3.2).

Table 3.1: Measure of Effectiveness (MOE) for Interrupted Flow Facilities (TRB, 2004)

Type of Facility	Measure of Effectiveness (MOE)
Signalized	Delay (sec/veh)
Priority Junction	Delay (sec/veh)

Table 3.2: Level of Service (LOS) Criteria for Signalized Intersection (TRB, 2004)

Level of service	Stopped delay per vehicle (sec)
A	≤ 5.0
B	> 5 and ≤ 15.0
C	>15.0 and ≤ 25.0
D	> 25.0 and ≤ 40.0
E	> 40.0 and ≤ 60.0
F	> 60.0

The relevant authority should conduct proper study to ensure that the signalized intersection is able to support the prevalent traffic flows. The study should consider proper geometric layout, timing and phasing for the signalized intersection to ensure that the respective signalized intersections operate within the desired LOS. Relevant authorities at the city centers are recommended to use adaptive traffic control strategies as part of the overall advanced traffic management system for signalized intersections network. For uninterrupted flow facilities, the respective MOE for the facilities is as shown in Table 3.3.

Table 3.3: Measure of Effectiveness (MOE) for Uninterrupted Flow Facilities (TRB, 2004)

Type of Facility	Measure of Effectiveness (MOE)
Basic Sections Freeway	Density (pc/km/ln)
Weaving Areas	Density (pc/km/ln)
Ramp Junctions	Density (pc/km/ln)
Multilane Highways	Density (pc/km/ln)
Two-Lane Highways	Percent Time-Spent Following

4 INTERRUPTED FLOW HIGHWAY FACILITIES

For any town or major cities, the operation and design of the interrupted flow highway facilities have a critical role in reducing traffic congestion. The characteristic of three major interrupted flow highway facilities, i.e. signalised intersection, unsignalised intersection and arterial streets are discuss in this chapter.

SIGNALISED INTERSECTION

One of the most important type of interrupted flow highway facilities is signalised intersection. Signalised intersections are an essential part of a road network, particularly in urban areas where traffic congestion is a major problem. The key factor in the design of signalized intersections is capacity, and saturation flow rate plays an important role in determining the capacity of each individual approaches.

Saturation Flow

Saturation flow is defined as the maximum constant departure rate of a queue from the stop line of an approach lane during the green period. This definition was based on the conventional graphical representation of saturation flow (as shown in Figure 4.1). It assumes that when the signal changes to green, traffic discharges at a constant rate, which is the saturation flow rate until either the queue is cleared or the green period ends (Leong et al. 2006, Wan Hashim et al. 2001a). The departure rate is lower during the first few seconds as vehicles accelerate to normal running speed and similarly during the period after the end of green interval as the flow of vehicles decline (Akcelik, 1981).

Saturation flows, however, are influenced by the proportion and type of vehicles in the traffic stream. Therefore, passenger car equivalents (PCE) are usually assigned to various categories of vehicle in order to normalize the saturation flow to the common base of passenger car units per hour (pcu/hr). The term "passenger car equivalent" is used to proportionately convert other types of vehicles (motorcycles, medium lorries, heavy lorries, and buses) to that of equivalent passenger cars.

In other words, PCE represents the number of passenger cars displaced in the traffic flow by other vehicle types, under the prevailing roadway and traffic conditions. A well established methodology has been used to estimate the PCE for the different types of vehicles (Leong and Wan Hashim 2002a, 2002b, Leong et al. 2003, Leong et al. 2004, Leong et al. 2008, Md.

Ehteshamul et al. 2004, Wan Hashim et al. 2000, Wan Hashim and Wan Chan Peng 2000, Wan Hashim and Leong 2001b, Wan Hashim et al. 2001b, Wan Hashim and Leong 2002, Wan Hashim and Leong 2002d, Wan Hashim et al. 2002e).

The values of PCE for Malaysian traffic condition are as shown in Table 4.1 (HPU, 2006a). Compared to other countries, the PCE values of Malaysian traffic condition cover the respective types of vehicles which are more representative of the Malaysian driving condition. In the U.S. and Australian standard, vehicles are only categorized into either light or heavy vehicles. Thus, the use of U.S. or Australian standards for studying Malaysian traffic condition needs to be used with caution. The Malaysian Highway Capacity Manual is recommended for analyzing and designing interrupted flow facilities in Malaysia (HPU, 2006a).

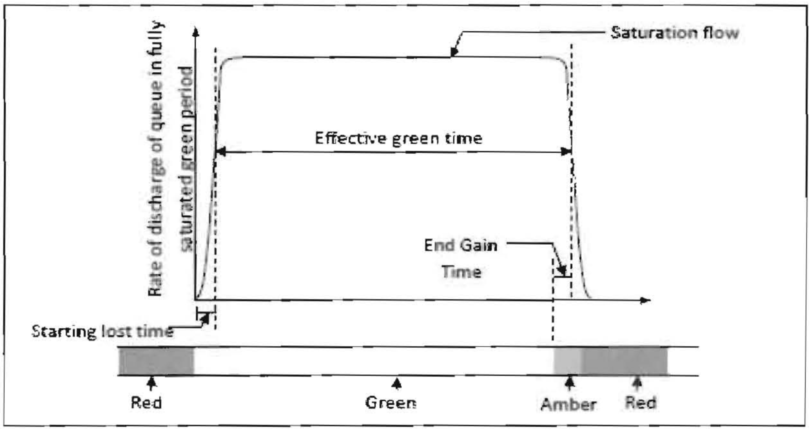

Figure 4.1: Graphical Illustration of Saturation Flow

Table 4.1: The PCE values of some of the countries in the world

Vehicle Types	PCE values				
	MHCM 2006	Indonesia HCM 1997	U.S. HCM (TRB 1994)	U.K Webster 1996	Australia Miller (1968)
Passenger Cars	1.00	1.00	1.00	1.00	1.00
Motorcycles	0.22	0.20	-	0.33	-
Lorries	1.19	1.30	2.00	1.75	-
Trailers	2.27	(Heavy Vehicles)	(Heavy Vehicles)		2.00
Buses	2.08			2.25	

The saturation flow prediction models for Malaysian Highway Capacity Manual (MHCM) 2006 are as shown in Table 4.2. As compared with the saturation flow prediction models from other countries, the saturation flow prediction models for Malaysian traffic condition take into account the different types of vehicles associated with Malaysian traffic characteristics (Wan Hashim et al. 2002k). The saturation flow rate is used to estimate the capacity of the signalized intersection (Wan Hashim 2003, Wan Hashim et al. 2003e, Wan Hashim 2004).

Table 4.2: Saturation Flow Prediction Models for Malaysian Highway Capacity Manual (MHCM) 2006 (Wan Hashim and Leong, 2001a)

Sources	Saturation Flow Prediction Models	Lane width unit	Saturation flow unit
aaSidra (Akcelik, 2000)	$S = 1{,}950 \times \left(1 + \frac{w - 3.3}{3.23}\right)$	Meter	pcu/hr
Indonesia HCM (BINKOT, 1996)	$S = 600w$	Meter	pcu/hr
U.S. HCM (1994)	$S = 1{,}900 \times \left(1 + \frac{w - 12}{30}\right) \times f_{hv}$	Feet	Veh/hr
U.S. HCM (2000)	$S = 1{,}900 \times \left(1 + \frac{w - 3.66}{9}\right) \times f_{hv}$	Meter	Veh/hr
MHCM 2006	$S = 1{,}930 \times \left(1 + \frac{w - 3.56}{3.663}\right) \times \left(\frac{1}{f_{car} + f_{hv} + f_{m}}\right)$	Meter	Veh/hr

MOTORCYCLES CHARACTERISTIC ON MALAYSIAN ROADS

The relatively large number of motorcycles riding on Malaysian roads gives a unique characteristic to Malaysian road traffic. This section describes briefly the unique behavior of motorcycles especially at the traffic light junction.

Motorcycles characteristics need to be taken into consideration in estimating the procedures for signalized intersection. According to Leong et al. (2004), there are several ways motorcycles travel through a signalized intersection. During the red light period, motorcycles often weave in and out of the traffic stream to get as close as possible to the stop line of signalized intersection; and because the percentage of motorcycles is high, most will go beyond the stop line. These motorcycles are categorized as "the motorcycles in front of stop line".

Apart from that, most of the lane widths at signalized intersections in Malaysia are about 3.0 to 4.5 meters and with these lane widths, motorcyclists can travel alongside other vehicles. Therefore, the second category of motorcycles consists of "motorcycles that make their way along side other vehicles" (such as cars, heavy lorries, bus, etc.) within the same traffic lane while the third category consists of "motorcycles following other vehicle types in a structured discipline".

In the analysis and design of signalized intersections, the queuing discipline of first-in first-out (FIFO) rule is normally adopted (Papacostas, 1987). According to this rule, the first vehicle that reaches a signalized intersection will be the first to get out of the intersection and similarly the last vehicle that reaches the intersection will be the last to depart the intersection.

However, in the case of motorcycles, another rule which is the last-in first-out (LIFO) might be adopted (Papacostas, 1987). This rule is engaged when a motorcycle that reaches an intersection normally move to the front of queuing vehicles through the available lateral gaps between vehicles, and stopped either at the front or beside other vehicles in front of the queue.

The scenario described above indicates a violation of the FIFO rule. Hence, the flow of motorcycles is divided into categories, namely, motorcycles inside flow which follows the FIFO rule (motorcycles following other types of vehicles in a structured discipline); and motorcycles outside flow which violates the FIFO rule (motorcycles in front of stop line and motorcycles that make their way alongside other vehicles).

UNSIGNALIZED INTERSECTION

Unsignalized intersection is a major type of interrupted flow facilities which can be found abundantly along any types of road; available in any town or town centers. Therefore, it is crucial to address the congestion and safety issues related to unsignalized intersection. And as part of the Malaysian Highway Capacity Manual development, unsignalized intersection is another facility that was investigated.

Unsignalized intersection is a priority junction controlled by stop or yield sign. The most important parameter associated with unsignalized intersection is the gap acceptance, i.e. the acceptable time headway on major roads for drivers on a minor movement to enter the major road (Wan Hashim and Ade 2001, Wan Hashim et al. 2001c, Wan Hashim et al. 2001e, Wan Hashim and Ade 2002, Wan Hashim and Ade 2002a, 2002b, Wan Hashim et al. 2002f, Wan Hashim et al. 2002i, Wan Hashim et 2003f, Wan Hashim et al. 2004d). An extensive amount of data were collected throughout Peninsular Malaysia to observe drivers characteristics at unsignalized intersection.

A composite critical gap acceptance formulation is proposed to take into consideration the differences in vehicle characteristics (Wan Hashim and Mohd Erwan, 2004a). It was found that there is a significant effect of motorcycles on the characterisitics of gap acceptance at unsignalized intersection. The generalized composite critical gap formula is as shown in equation (1) for single lane facility and equation (2) for multi-lane facility. The equations were used to estimate the overall critical gap as a function of the base critical gap (passenger car critical gap values) and proportion of motorcycles in the traffic stream.

Table 4.3 shows the comparison between Malaysian Highway Capacity Manual critical gap values with other critical gap values observed from other countries. The critical gap for Malaysia is very low compared to other countries indicating a very aggressive maneuver especially at unsignalized intersection. The results show that for Malaysian road condition, specific traffic parameters for Malaysian driving condition need to be established for the planning and design of some of its facilities.

$$t_{c,x} = t_{c,base} - 0.555PM \quad (1)$$

$$t_{c,x} = t_{c,base} - 0.358PM \quad (2)$$

Where,

$t_{c,base}$ = Base critical gap (sec)

PM = Proportion of motorcycle

Table 4.3: Comparison of the critical gap values

Procedure	Lane type or no. of lane in major road	Vehicle type	Critical gap		
			RTMaj	LTMin	RTMin
MHCM (2006)	Single-lane	Base value (passenger car)	3.5	3.2	4.0
	Multi-lane		3.7	3.3	4.2
Arahan Teknik (Jalan) 11/87 (1987)	2	Passenger car (base value with average running speed 30 mph or 48.3 km/h)	5.0	5.5 (s)* 5.0 (y)**	6.5 (s) 6.0 (y)
	4		5.5	5.5 (s) 5.0 (y)	7.0 (s) 6.5 (y)
	2	Passenger car (base value with average running speed 55 mph or 88.5 km/h)	5.5	6.5 (s) 5.5 (y)	8.0 (s) 7.0 (y)
	4		6.0	6.5 (s) 5.5 (y)	8.5 (s) 7.5 (y)
U.S. HCM 2000	2	Base value	4.1	6.2	7.1
	4		4.1	6.9	7.5
Poland (large towns) (Chodur, 2005)	1***	Base value	5.2	5.4	5.6
	2***		5.7		

*(s) stop-controlled
**(y) yield-controlled
*** numbers of priority road lanes