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EVALUATION OF THE OPERATIONAL METHODS FOR THE ANALYSIS OF SIGNALISED INTERSECTIONS

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Abstract

The problem of traffic congestion in urban areas is worse at road intersections. Junction design, traffic light capacity, and driver behaviour are prevalent influences on traffic congestion. Since the traffic signal is one of the traffic controls to alleviate road congestion, adequate traffic capacity with a good design and an optimum delay is the key to improving the signalised junction. Hence, this research aims to determine the performance of signalized junctions with different traffic methods compared to on-site data. Two methods were selected for the analysis: Signalised Intersection Design and Research Aid (SIDRA) and the Malaysia Highway Capacity Manual (MHCM). Prominent signalised intersections along Jalan Kempas in the Kempas neighbourhood of Johor Bahru were selected for this study to measure the length of the vehicle line-up during rush hour. Based on these two (2) methods used, the significant different are related to traffic parameters, namely capacity analysis and level of service and by different conditions of traffic, geometric and type of traffic signal. It was determined that the parameter used for both SIDRA and MHCM is suitable; however, the output of SIDRA resulted in a more similar performance to the site observation. Based on the findings, this research is able to measure the efficiency of traffic assessment tools compared to the actual situation on site and assist the traffic engineer in efficiently investigating and evaluating the performance at signalised junctions.

Keywords*:* Signalised Junction, Traffic Method, Malaysia Highway Capacity Manual, SIDRA

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INTRODUCTION

Each day, billions of people and trillions of dollars rely on the transportation network. It's a complex and far-reaching system with many layers and players (Almasri, 2014). Many factors affect how well transportation systems work these days, including safety, efficiency, and reliability. These factors are essential to everyone, from consumers to the business community (The World Bank, 2015). With traffic congestion increasing in much of the world and continuously worsening, it represents an absolute menace to the quality of urban life (Findley et al., 2015). Therefore, this paper presents the assessment of the operational methods for analysing signalised junctions, namely Signalised Intersection Design and Research Aid (SIDRA) and the Malaysia Highway Capacity Manual (MHCM) conducted at Johor Bahru's neighbourhood as a case study.

PROBLEM STATEMENT

The primary cause of traffic congestion is the high number of vehicles, and most Malaysian car owners use them daily or regularly. As a result, it is estimated that 1 million wasted hours are spent each day stuck in traffic (The World Bank, 2015). Also, the main cause of traffic jams is an imbalance between how much traffic there is and how much people want to drive. This problem gets worse at road intersections in cities (Findley et al., 2015). Installing traffic lights is one of the traffic control measures to alleviate traffic congestion. An efficient traffic light system will make the traffic flow smoothly and save time. However, junction design, traffic light capacity, and driver behaviour are prevalent influences for traffic congestion (Bull, 2004; Kumala et al., 2016). For example, some drivers like to cut a few seconds off their journey times by forcing their way into intersections and blocking the passage of other motorists, which causes congestion.

A traffic signal is one of the traffic controls to alleviate road congestion and adequate traffic capacity with a good design, and optimum delay is the key to improving the signalised intersection (Almasri, 2014). Therefore, this study has been undertaken to assess the different aspects of junction performance at the signalised junction, using two different capacity methods, SIDRA and MHCM methods.

LITERATURE REVIEW

Signalised Intersection Operation Elements

Signalized intersection operations are a function of three elements: traffic volume characteristics; roadway geometry; and signal phasing.

Traffic Volume, Geometry Design and Signal Phasing

Volume plays a critical role in traffic engineering (Akçelik, 2017). These volumes can be used to quantify events such as traffic accidents, congestion, and speed variations and to determine the effectiveness of control measures to mitigate these events (e.g. road widening or the introduction of new traffic signals). Volume studies are used at various stages in the planning, design, and operation of transportation infrastructure. They can be conducted by either human observers or by sensors installed along the roadway surface.

Geometry design describes the possible impact on intersection performance and safety, an intersection's geometry is crucial (Yusuf & Jordan, 2018). Sight distance, vehicle separation, operations, and capacity are all directly impacted by geometry. Because of this, intersection geometrics must constantly be considered when working with existing conditions, newly constructed, or signalised intersections.

Signal phasing refers to the way in which different traffic signals are timed and synchronized (Adeke et al., 2020). Improper phasing can result in overcrowded roads, delayed bus schedules and wasted fuel. The effects of signal phasing on transportation service can be seen during rush hour when multiple vehicles attempt to travel simultaneously on the same road. Proper signal phasing can help manage traffic flow and reduce congestion during peak hours. Conversely, poor signal phasing can worsen congestion by causing delays for buses and other vehicles crossing the road while congested. Improper signal phasing can also increase fuel consumption and emissions due to increased idling time and unnecessary speed changes while driving.

Parameters for Evaluating Intersection Operations

In order to analyse the performance of signalised junction, several factors need to be considered such as capacity, delay, vehicle queue, and Level of Service (LOS).

Capacity Analysis, Vehicle Queue, Delay and Level of Service

Roads have certain capacities, which are determined by the width of the lanes and their surface (Reilly & Levinson, 2011). The capacity of a road can be measured in various ways, and it varies depending on the intended use of the road in question. Some of these methods include load rating method (Sameni & Moradi, 2022), speed rating method (Hansen, 2017), and occupancy rate method (Ghiasi et al., 2017).

All evaluations of signalised intersections may consider vehicle queuing as a critical indicator of effectiveness (Ghiasi et al., 2017). To determine the amount of storage needed for turn lanes and to assess whether overflow occurs at upstream facilities, estimates of vehicle waits are necessary (driveways, unsignalized intersections, signalised intersections, etc.).

Delay involved three methods of calculating the LOS performance indicators that can be differentiated depending on the performance measure: analytically, by measurement or by simulation (Axer et al., 2012). Queue delays and level of service for signalized intersections are principal performance measures that contribute to driver discomfort, frustration, fuel consumption, and increased travel time (Zalfi et al., 2013). Therefore, the evaluation of signalized junction capacity is critical since it is directly related to delay, level of service, accident, operation cost, and environmental issues.

Level of Service (LOS) is directly related to the controlled delay value (Albrka Ali et al., 2018). The average controlled delay per vehicle is estimated for each lane group and aggregated for each approach and for the intersection as a whole. Delay and the level of service when waiting at an intersection indicate the potential capacity and performance of that intersection. A major factor causing moderate traffic congestion at the traffic light is the length of cycle time and the number of phase numbers at the intersection (Kumala et al., 2016). The signalized intersection LOS is the average delay of all vehicles entering or exiting an intersection.

Traffic Operational Analysis

Traffic operational analysis is an invaluable tool for understanding traffic behaviour and creating strategies for improving the existing transportation infrastructure. For this study, two traffic operational analyses were involved: Malaysian Highway Capacity Manual (MHCM) and Signalised Intersection Design and Research Aid (SIDRA).

Malaysian Highway Capacity Manual (MHCM)

In Malaysia, in order to measure the performance of existing roads, the Highway Planning Unit (HPU) of the Ministry of Works Malaysia has come up with the Malaysian Highway Capacity Manual (MHCM). The MHCM has developed its own formulation, and adjustment factors based on extensive research carried out in several states throughout Malaysia to carry out its job (Figure 1).

MHCM, specific to Malaysian road conditions, offers transportation practitioners and researchers a standardised and up-to-date system of techniques for evaluating the quality of service on a two-lane highway, multilane highways, basic segment, and ramps motorways.

The guidelines and instructions in this manual offer a methodical and uniform way to evaluate the transportation facilities' capacity and level of service. Determining the capacity and level of services for each lane group and the entire intersection is the goal of traffic analysis under MHCM. In addition, detailed information on the intersection's geometry, traffic flow, and signalization is required based on the existing or proposed new intersection.

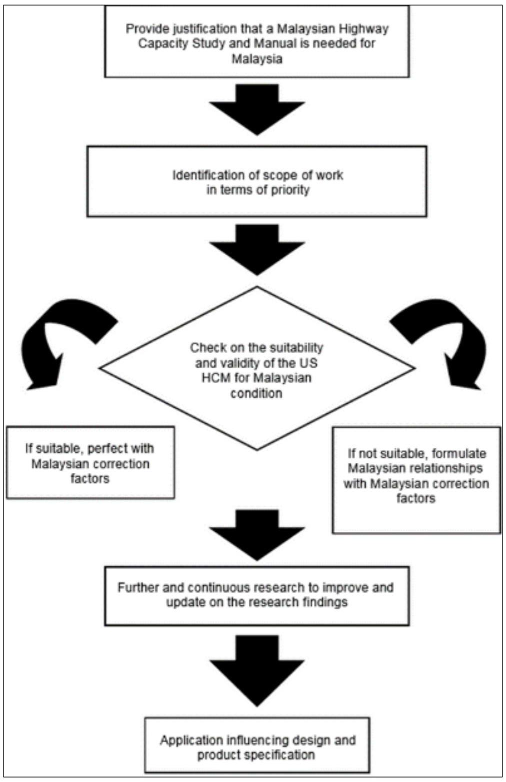

Figure 1: Approaches for the Malaysian Highway Capacity Study
Source: Malaysia Highway Capacity Manual, Highway Planning Unit

Signalised Intersection Design and Research Aid (SIDRA)

Signalised (and unsignalised) Intersection Design and Research Aid, also known as SIDRA, was developed in 1984 which is a simulation software mainly used for road intersection analysis and design (Nicoli et al., 2015). SIDRA emphasises a micro-analytical traffic evaluation tool that employs lane-by-lane and vehicle drive cycle models by comparing the alternatives of the intersections and network intersections (Yumlu et al., 2014). For determining an appropriate junction and network design, SIDRA offers a wide number of intersection and network performance measurements, various alternate Level of Service (LOS) techniques and LOS target settings (Akmaz & Çelik, 2016). In addition, there are standard performance indicators like delays, queue lengths, and stop counts, as well as indicators to help with economic and environmental effect analyses.

METHODOLOGY

The flowchart of the research process to assess the operational methods for analysing signalised junctions namely Signalised Intersection Design and Research Aid (SIDRA) and the Malaysia Highway Capacity Manual (MHCM). Prominent signalised intersections along Jalan Kempas in the Kempas neighbourhood of Johor Bahru were selected for this study to measure the length of the vehicle line-up during rush hour. The selected junction was known to be one of the busiest roads and traffic in Taman Kempas Utama and Taman Kempas Indah.

Field Data Collection

The selected signalised junction conditions in the study area were ascertained through visual reconnaissance surveys and comprehensive traffic counts. Traffic counts is collected using two methods, manual count and automatic count.

Traffic Data Collection

The survey was recorded via mounted camera for a 6-hr count consisting of the morning peak (7.00am to 10.00am), and evening peak (4.30pm to 7.30pm). It will be classified into four vehicle categories: car/van, motorcycle, light truck and heavy truck/bus at a 15-minute interval. Subsequently, these classified counts were converted to equivalent passenger car units (pcu) which corresponding to various directions identified during the traffic survey as recommended by Malaysian Highway Capacity Manual (MHCM).

Geometry Characteristics

Reconnaissance surveys obtained the geometric information of the study area and Figure 2 tabulates the geometric data at the Jalan Kempas intersection.

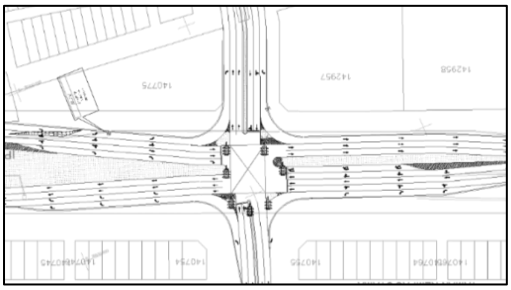

Figure 2: Condition scenario for geometric condition

Signalised Conditions

Signal phasing is the basic control mechanism for a signalized intersection and determines the efficiency and safety of the procedure. Figure 3 shows the Jalan Kempas intersection phasing plan according to the current cycle time.

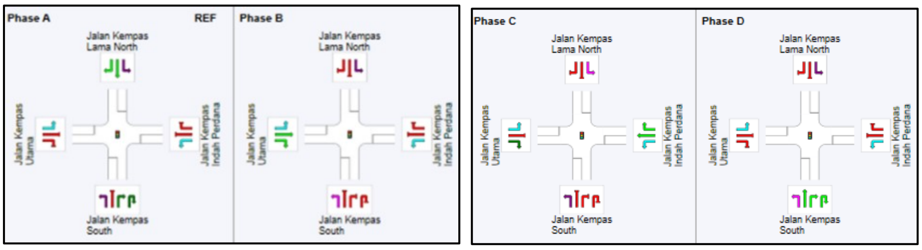

Figure 3: Jalan Kempas intersection phasing plan according to current cycle time

Data Analysis

Two traffic signal analysis methods were used to estimate queue length: SIDRA Intersection 9.1 and Malaysian Highway Capacity Manual (MHCM). SIDRA Intersection 9.1 is a micro-analytical software used to aid the design and evaluation of single intersections and networks of intersections. Meanwhile, MHCM is a logical method to measure the performance of highways for each study facility, assure that practitioners have access to the latest research result, and present sample problems.

RESULT AND DISCUSSION

Input Parameters for SIDRA and MHCM Models

Table 1 highlights the parameters used for two traffic signal analysis methods, SIDRA Intersection 9.1 and Malaysian Highway Capacity Manual (MHCM). The parameters involved in these methods are based on the type of condition, namely geometric conditions (7 parameters), traffic conditions (8 parameters), and signalised conditions (9 parameters).

Table 1: Parameters used for SIDRA and MHCM

Type of Condition	Parameter	SIDRA	MHCM
Geometric Conditions	Area Type	1	1
	Number of Lanes	Input User	Input User
	Average Lane Width	3.5m/lane	3.5m/lane
	Grades	0%	0%
	Existence of Exclusive RT or LT Lane	Yes	Yes
	Length of Storage Bay, LT or RT Lane	Yes	Yes
	Parking Conditions	No	No
Traffic Conditions	Volumes by Movement	pcu/hr	pcu/hr
	Ideal Saturation Flow Rate	1950 tcu/hr	1930 pcu/hr
	Peak Hour Factor	Default	Input User
	Percent Heavy Vehicles	Default	Default
	Conflicting Pedestrian Flow Rate; peds/hr	N	N
	Local Buses Stopping in Intersection NB	N	N

Type of Condition	Parameter	SIDRA	MHCM
	Parking Activity, pkg manoeuvres /hr	N	N
	Approach Speed, km/hr	N	N
Signalised Conditions	Cycle Length, sec	132 secs	132 secs
	Green Time, sec	25 secs & 33 secs	25 secs & 33 secs
	Amber-Plus -All-Red Change and Clearance	5 secs	5 secs
	Interval (intergreen), sec	2 secs	2 secs
	Actuated or Pretimes operation	A	A
	Pedestrian push-button	N	N
	Minimum Pedestrian green, sec	N	N
	Phase Plan	Yes	Yes
	Analysis Period, hr	AM Peak	AM Peak

Parameter Used for Geometric Condition

Table 2 highlighted the parameters used for geometric condition (based on the current condition scenario): Area Type, Number of Lanes, Average Lane Width, Grades, Existence of Exclusive RT or LT Lane, Length of Storage Bay, LT or RT Lane, and Parking Conditions.

Table 2: Geometric data and flow direction for all approaches of the intersection

Intersection Leg, Road Name		Lane No	Direction of Flow	Lane Width (m)	Approached width	Grade %
S	Jalan Kempas Lama South	1	L	3.5	14	-0.5
		2	T	3.5		
		3	T	3.5		
		4	T	3.5		
		5	R/UT	3.5		
W	Jalan Kempas Utama	1	LT	3.5	7	-0.5
		2	TR	3.5		
N	Jalan Kempas Lama North	1	R/UT	3.5	14	-0.5
		2	T	3.5		
		3	T	3.5		
		4	R	3.5		
E	Jalan Kempas Indah Perdana	1	LT	3.5	7	-0.5
		2	TR	3.5		

Parameter used for Traffic Volume

Figure 4 highlights the parameters used for traffic volume (based on the current condition scenario) comprised of peak hour traffic volumes by the directions.

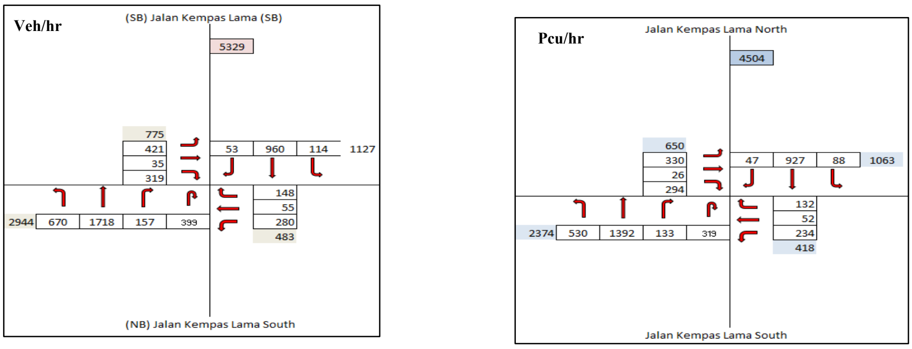

Figure 4: Condition scenario for traffic volume

Parameter Used for Signal Phasing

Figure 5 highlights the parameters used for signal phasing (based on the current condition scenario) comprised of Cycle Length (sec), Green Time (sec), Amber-Plus -All-Red Change and Clearance, Interval (intergreen) (sec), Actuated or Pretimes operation, Pedestrian push-button, Minimum Pedestrian green (sec), Phase Plan, and Analysis Period (hr).

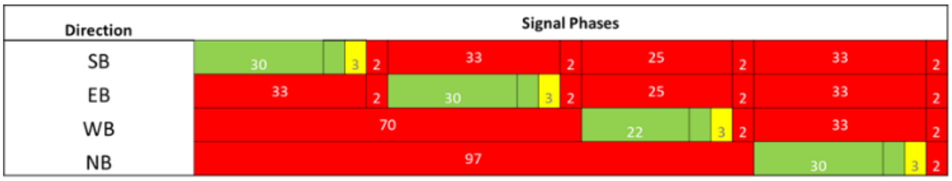

Figure 5: Condition scenario for signal phasing

Indicator Used that Relates to Queue Length and Delay

Table 3 tabulates the relationship between the traffic volume and the average delay as per the present condition scenario at the signalised intersections.

Table 3: Current condition scenario of delay

Approach	Traffic Volumes (pcu/hr)	Longest Queus (m)	Average Delay sec)
Northbound	2374	316.00m	178
Eastbound	650	27.00m	141
Westbound	418	8.00m	90
Southbound	1063	306m	155

Comparison Result of Junction Performance Analysis Between SIDRA and MHCM Methods

The analysis is to determine whether junction performance analysis was different between SIDRA Intersections and MHCM methods. Table 4 showed the result of junction performance analysis between SIDRA and MHCM methods. Based on the same parameter used for both SIDRA Intersections and MHCM, output in SIDRA resulted more similar performance with the site observation.

Table 4: Comparison Result of Junction Performance Analysis between SIDRA and MHCM Methods

Approach	Traffic Volumes		Site Observation	SIDRA Default		
				Default	Change Basic Saturation	Change Lw (f_w)
Basic Saturation (S)			N/A	**1950**	1930	1930
Lane width (f_w)			3.5	**3.3m**	3.3m	3.5
Northbound	2734	178	178	**174.1**	183.4	174.1
Eastbound	650	141	141	**148.3**	142.3	148.3
Westbound	418	90	90	**156.9**	81.1	81.8
Southbound	1063	155	155	**149.3**	157.9	149.3
Intersection Delay				**103.1**	109.6	104.6
Approach	**Traffic Volumes**		**Site Observation**	**MHCM**		
				Default	**Change Basic Saturation**	**Change Lw (f_w)**
Basic Saturation (S)			N/A	**1930**	1930	1950
Lane width (f_w)			3.5	**3.5m**	3.3m	3.5
Northbound	2734	178	178	**160.1**	185.3	154.9
Eastbound	650	141	141	**47.83**	49.23	47.56
Westbound	418	90	90	**42.53**	43.21	42.4
Southbound	1063	155	155	**79**	94.51	76.29
Intersection Delay				**109.7**	126.5	106.5

CONCLUSION

In conclusion, the result findings summarised that parameters involved for SIDRA and MHCM methods are based on type of condition namely geometric conditions (7 parameters), traffic conditions (8 parameters), and signalised conditions (9 parameters) is suitable and the differences results between these two methods is not quite different between each other. However, the output in SIDRA resulted more similar performance with the site observation.

Hence, both SIDRA Intersection and MHCM are tools suitable for planning, analysing and designing purposes for the intersections in Malaysia context. Both have different advantages and disadvantages, which can differentiate them from other tools and make them suitable in Malaysia. However, for SIDRA Intersection to be used in Malaysia, some of the parameters need to be adjusted first to get a desirable result that can reflect on the intersection's real-life situation. As for MHCM, it is a manual which has been developed based on the current situation and condition of the Malaysia road. Therefore, the manual gives a significant advantage compared to other tools, which contain general guidelines and parameters that can be used in whole countries, unlike MHCM, which can only be used in Malaysia. Therefore, combining these tools can help produce a suitable and desirable result for planning, analysing and designing the intersections in Malaysia to make Malaysia one of the best countries in the world in terms of designing a good transportation network.

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