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Microscopic Simulation & Microscopic Analytical Model Comparison in Analyzing a Signalized Intersection

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ABSTRACT

Most of intersections are complex maneuvering areas with high number of traffic conflicts of crossing, merging and diverging. It is also suffered from the problem of flow and capacity that passing through the intersections since many factors have influenced the efficient of the intersections. Due to the complexity task in analysis of a signalized intersection, the used of microscopic simulation model has become very popular for traffic engineers and planners in dealing with such activities. This is because of great advantage that offers by this model especially on the ability to realistically model a complex transport system and it provides users with the most desirable statistics and performance measures of alternative design or existed transport system. This study aims to assess the consistency of the results generated by micro simulation models in analysis the performance of a signalized intersection. In this case, a micro analytical model will be used alongside micro simulation model. Therefore, the results produced by both models could be compared in order to assess for the consistency of micro simulation model. To carry out the modelling of micro simulation and micro analytical, CUBE Dynasim and aaSIDRA has been used as a tool accordingly. A four legged signalized intersection at South Road and Henley Beach Road in Adelaide was selected to serve as a case study. The result comparison was based on the performance measures of the signalized intersection such as the traffic flows, delay and level of service (LOS). In this study, the results demonstrated by CUBE Dynasim microscopic simulation model was reasonably consistent with aaSIDRA microscopic analytical model in analyzing a signalized intersection.

1. Introduction

Nowadays the number of vehicles keeps increasing and the transportation systems become more complex, traditional method seems not comprehensive enough to be used in analysis especially for a large scale transportation system. It is thus requires thorough analysis and modelling to obtain an efficient transportation system.

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According to Taylor et al, (2000) and Sadoun (2003), signalized intersections are the most critical locations in designing a transport system, because it has high tendency to experience traffic problems such as traffic accidents, congestions and delays. Considering such issues, it is necessary to analyze the efficiency and the performance of signalized intersections.

In recent years, there have been a broadly development of traffic modelling approaches in analysing transportation system (Dowling, 2003). Traffic modelling is a tool that offers a great potential for large scale transportation system analysis by using an approach of actual measurements and historic data to make predictions on some changes or modifications to a system. By carrying out the modelling it could provide traffic engineers an understanding on the impact that a chosen option has had, or will have on the current problems. Hence, possible solutions could be proposed immediately.

Traffic modelling could be classified in three different levels known as macroscopic, mesocopic and microscopic (Boxill and Yu, 2000; Barcelo et al, 2005). Then, these three modeling levels could be carried out by using two different modeling principles which were known as simulation and analytical model or combination of the two principles. To date, several modeling tools/software have been developed to analyze and model the existing or proposed signalized intersections which were available both in simulation or analytical approaches at the three different levels of modeling as discussed previously.

The microscopic simulation software has become the most popular tool for traffic engineer or planners in analyzing signalized intersections (Nigarnjanagool and Dia, 2004; Jones and Anderson, 2004; Brian et al, 2006). This is due to the apparent advantages that offered by the microscopic simulation model especially on the ability to model relatively large intersections to sufficient details and enable operational outputs at the link by link level. At the same time, the micro simulation also provides a powerful visual representation and graphical user interface where this is a great advantage especially when the result is to be communicated to non-technical persons.

However there is still a doubt on the accuracy of micro simulation models in representing the real life traffic behavior as well as the generated outputs used to analyze signalized intersections. This is especially true when the models are used without proper calibration and validation. Moreover, it must be noted that micro simulation modeling are stochastic models whose results vary depending on the random seed number used. Therefore multiple runs must be performed in order to ensure an accurate estimate of the various performance measures. Therefore, it is important to quantify the reliability of simulation model output in analysis the performance of signalized intersections.

2. METHODOLOGY

Study Location

An isolated signalized intersection at South Road and Henley Beach Road in Mile End (TS054) was selected to serve as a case site study. It is located around two kilometers west from Adelaide CBD. This intersection is a four-leg signalized intersection which is operated as a fixed time signal control and has five signal phases. A pedestrian signal was operated at this intersection. However it is being omit for the modeling and analysis in this study due to very less observed pedestrian movements during peak periods. The layout diagram of this intersection is shown in Figure 1 as in the following.

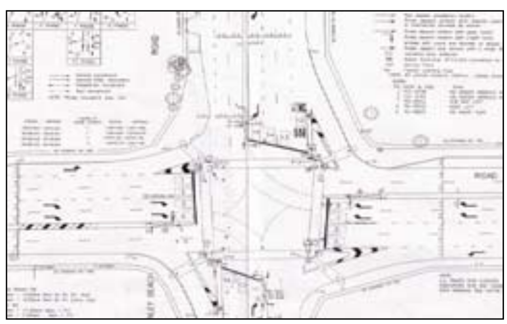

Figure 1: Signalized Intersection Layout

Data Collection

In developing both analytical and simulation models for the intersection the data requirements are extensive. In this study, following data was collected such as traffic count, intersection geometry and signal controller settings.

This intersection has vehicles detectors embedded underneath the road surface in each lane and operated by Sydney Coordinated Adaptive Traffic Systems (SCATS) which this can help to ease the job in data collection of traffic count. Therefore, the traffic count data were quoted from Transport System Center, University of South Australia. In intersection geometry survey, the basic geometry features of road elements such as number of lanes, width of travel lanes, length of slip lanes and short lane for turn right and others was collected. These elements are necessary as a data input in developing the models for the intersection. Meanwhile for signal controller settings, the optimum cycle time, operating signal phasing and timing data was determined. The data gathered is then be used to develop both CUBE Dynasim and aaSIDRA models. Thus, the signalized intersection plan for both models is identical.

2.1 Model Development

a) Micro Analytical Model: aaSIDRA

All the input data that gathered during the field observation was inserted in Road Intersection Data Editing System (RIDES) that included in the aaSIDRA software packages. RIDES are a graphic based, highly interactive program that reflects the design process of actual condition of the intersection. In RIDES operation, it involved several stages of group to insert the data such as basic parameter, intersection geometry, approaches, lanes, volumes and others. The RIDES program then will run all the input data to develop the base model. There are some input data that set by default in this program such as the basic saturation flow, practical degree of saturation, flow parameters and others.

b) Micro Simulation Model: CUBE Dynasim

In developing the CUBE Dynasim model, it involves several stages begin with the development of network scenarios, traffic flow scenarios, signal scenarios and public transport scenarios. In CUBE Dynasim package allows of a set of imported background map as an aid for coding. It gives a greater flexibility by accepting formats in DXF CAD files or BMP image files. As in this study, the selected signalized intersection has been drawn in CAD format and exported to CUBE Dynasim in DXF extension.

Model Verification and Calibration

Calibration and validation is the process where the developed model is producing results that are as close as possible against the actual field's condition. If there is no different made from the results obtain by the develop model to the actual field condition, imply that the model develop are said to be calibrated and validated.

Some basic calibration parameters has been selected to be used in this study which were the road geometry condition, vehicle driving speed and the traffic control system that included the traffic signal setting and priority management that control vehicles priority. As in this study, give ways control priority was used.

Result Analysis

The outputs generated by both models have been compared to assess for their consistency in evaluating the performance of a signalized intersection. The comparison was made based on measures of effectiveness (MOE's) which were delays and Level of Service.

a) Delays

Delays are among the major performance measures which are commonly used in evaluating signalized intersection studies. As been stated by Olszewki (1993), delays can reflect well the inconvenience caused by traffic signals to the road users and can even be converted to monetary value as it can estimate the fuel consumption, noise, and exhaust emissions.

However, the most important, delays are used to determine the level of service (LOS) in the fields of traffic engineering (Mousa, 2002; Darma et al, 2005; Akungor & Bullen, 2007). Basically delay could be defined as the time spent in the system while being unable to move their vehicles due to certain conditions such as the traffic signalization and queues. In order to calculate the delay in simulation models and the analytical models, different methodologies was used.

As in this study the analytical models that represent by aaSIDRA provide a direct measure for the delay outputs. aaSIDRA produce outputs for delay in three categories which are average control delay, average geometry delay and average stop line delay. According to Akcelik (2004), control delay is the summation of the geometry delay and the stop line delay, geometric delay is the delay experienced by a vehicle going through the intersection in the absence of other vehicles while for stop line delay is includes the queuing delay and the major stop start delay but excludes the geometric delay.

Meanwhile in CUBE Dynasim, it doesn't have the ability to produce a direct measure for delay. However there is an alternative on how to measure the delay in this model by using a basic equation in traffic engineering and this is known as average total delay. It could be calculated by subtracting the free flow time from the average travel time as shown in *equation 1* as in the following:

[Equation 1]

$$\text{Average Total Delay} = \text{Measured Travel Time} - \text{Free Flow Travel Time}$$

The free flow travel time was measured by dividing the approach distance by the speed limit proposed at the intersection network. While for the distance was obtained by the relationship of *speed (v), distance (d) and travel time (t)* as presented in *equation 2* as the following:

[Equation 2]

$$v = \frac{d}{t}$$

These speed and travel time could be generated from the CUBE Dynasim outputs. With all the parameters available, the average total delay was calculated for each movement on each approach as presented in Table 1.

Table 1: CUBE Dynasim Average Total Delay

Approach	Movement	Travel Time (s)	Travel Speed (km/hr)	Distance (m)	Free Flow Travel Time (s)	Average Total Delay (s)
South	SW	38.91	48.33	522.37	31.34	7.57
	SN	70.36	31.16	609	36.54	33.82
	SE	104.75	21.85	635.77	38.14	66.61
East	ES	41.15	45.73	522.71	31.36	9.79
	EW	83.39	27.04	626.35	37.58	45.81
	EN	96.46	23.33	625.11	37.51	58.95
North	NE	46.19	41.95	538.24	32.59	13.6
	NS	63.35	35.1	617.66	37.06	26.29
	NW	125.43	18.82	655.72	39.34	86.09
West	WN	62.84	31.78	554.73	33.28	29.56
	WE	74.13	29.56	608.68	36.52	37.61
	WS	71.37	30.76	609.82	36.59	34.78

It is important to recognize that some of the conceptual different between them especially regarding on the definitions and measurements methods used for traffic performances variables. Since CUBE Dynasim produce the average control delay, the same type of delay obtained from aaSIDRA will be used as a comparison. These are tabulated in Table 2 as shown in the following.

Table 2: Comparison of Average Total Delay

Approach	Movement	Delay (s)		Differences (%)
		aaSIDRA	CUBE Dynasim	
South	SW	10	7.57	24.3
	SN	36.1	33.82	6.32
	SE	69.7	66.6	4.45
East	ES	13.8	9.79	29.06
	EW	51.1	45.81	10.35
	EN	67.6	58.95	12.8
North	NE	16.2	13.89	14.26
	NS	29.9	26.29	12.07
	NW	73.3	86.09	-17.45
West	WN	38	29.56	22.21
	WE	42.6	37.61	11.71
	WS	39.8	34.78	12.61

From the comparison above, it was found that only movement on SN and SE were generally simulated fairly well consistent average total delay between modelled and observed which is varied in less than 10%. Meanwhile, all others movement tended to diverse more than 10 % from the observed average total delay. The average total delay on ES movement shows a significant different which was about 29% to the observed value. The reason for this condition probably is due to the stop start delay condition in the simulation model which vehicles took more than 2 seconds to move when received the green light. This could be observed by carefully watching the simulation animations during the calibration procedure. Large number of vehicles in turning movement and in the adjacent traffic stream also may be give effect in the simulation model where each vehicle need an acceptable gap acceptance to proceed with the movement. Thus the capacity of the intersection decreases and this make delay as well as number of stopped vehicles increases as shown in the simulation results in Table 2.

b) Level of Service

According to the US Highway Capacity Manual (2000) stated that the level of service is defined as a quantitative stratification of quality of service. It is a quality ranking on the operational conditions that denoted as A to F where LOS A is the best operating service condition while for LOS F is the worst condition of operating service.

There are some methods proposed to determine the level of service by using aaSIDRA which are based on delay only, delay and degree of saturation or degree of saturation only. According to Pretorius et al (2004), it is a common practice in the field of traffic engineering to use average total delay as the Measure of Effectiveness (MOE's) in the establishment of the Level of Service (LOS) of a signalized intersection.

Table 3: LOS thresholds for signalized intersection (HCM method)

LOS	Delay
A	<10
B	10-20
C	20-35
D	35-55
E	55-80
F	>80

As in this study, both CUBE Dynasim and aaSIDRA average total delay as being discussed previously has been used to determine the level of service (LOS). For the simulation modelled, the level of service (LOS) thresholds for signalized intersection obtained from Highway Capacity Manual were used as an indication to classify the level of service (LOS) of the average total delay for each movement at the intersection. This is shown in Table 3 as shown preceded.

Meanwhile for the analytical model, the LOS could be generated directly from the outputs as depicted in the Figure 2 in the following.

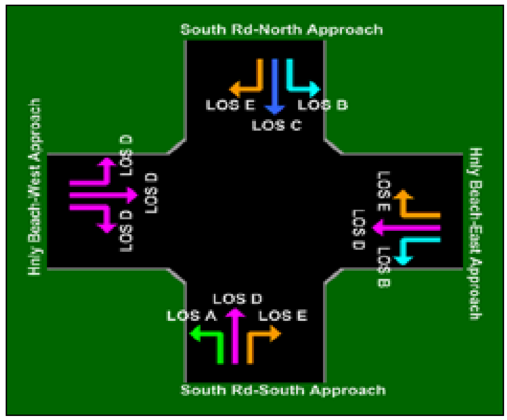

Figure 2: aaSIDRA LOS based on Average Control Delay

Then, the comparison of the level of service (LOS) between CUBE Dynasim and aaSIDRA could be made and tabulated in Table 4 as in the following. From the table, it could be noted that the LOS for both modeled and observed were fairly well consistent except for some approach such as for ES and WS.

Anyhow, the differences were observed to be in a marginal class of the LOS. As for example, for the ES approach the observed LOS was 13.8s (LOS B), while in simulation model the LOS was 9.79s (LOS A) where this is very close to 10s and it could be in LOS B as well. Same goes to WS approach which aaSIDRA generated LOS about 39.8s (LOS D), meanwhile CUBE Dynasim produced 34.78s (LOS C) where this number is so close to 35s and can be consider as LOS D.

Table 4: Comparison of LOS

Approach	Movement	Delay (s)		LOS (aaSIDRA)	LOS (CUBE Dynasim)
		aaSIDRA	CUBE Dynasim		
South	SW	10	7.57	A	A
	SN	36.1	33.82	D	C
	SE	69.7	66.6	E	E
East	ES	13.8	9.79	B	A
	EW	51.1	45.81	D	D
	EN	67.6	58.95	E	E
North	NE	16.2	13.89	B	B
	NS	29.9	26.29	C	C
	NW	73.3	86.09	E	F
West	WN	38	29.56	D	C
	WE	42.6	37.61	D	D
	WS	39.8	34.78	D	C

3. Conclusion

The used of microscopic simulation model has become very popular tools for traffic engineer or planners in analyzing and designing transportation system in particular signalized intersection. This is due to its capability to model a realistic modelling transportation system in a fast and cost effective.

However, there is one issue involved in using the microscopic simulation models which is on the variation of the simulation result in representing the real life traffic behaviour. Thus, this study was conducted to assess the consistency of the results generated by the micro simulation models in analysis the performance of signalized intersection.

To achieve this study, a micro analytical model by means of Cube Dynasim has been used alongside the micro simulation model (aaSidra) where it was considered valid. The outputs generated by both models have been compared to assess for their consistency in evaluating the performance of a signalized intersection. The comparison was made based on measures of effectiveness (MOE's) which were the delay and level of service (LOS).

Based on the comparison, it was found that only movement on SN and SE were simulated the average total delay fairly well consistent which was differ in less than 10%. Meanwhile, all others movement tended to diverse more than 10 % from the aaSIDRA average total delay which ES movement shows a significant different which was about 29 % to the actual field value.

There was also some different noted between the Cube Dynasim models to the aaSIDRA value when compared the level of service (LOS). However, the differences were observed to be in a marginal class of the LOS. As for example, for the ES approach the aaSIDRA LOS was 13.8s (LOS B), while in CUBE Dynasim the LOS was 9.79s (LOS A) where this is very close to 10s and it could be in LOS B as well.

As for the conclusion of this study, it can be said that the output results demonstrated by CUBE Dynasim micro simulation model with basic verification and calibration efforts simulates the signalized intersection system in a manner that is reasonably consistent with aaSIDRA micro analytical model.

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