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Performance Analysis of Jalan Senawang 2 and Jalan Berlian Intersection, Seremban, Negeri Sembilan: A Case Study

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Abstract: Traffic congestions and long queues were always being observed at the signalised intersection of Jalan Senawang 2 and Jalan Berlian, Seremban, Negeri Sembilan. Hence, this study was conducted to analyse the level of service (LOS) of the intersection based on the delays, queue length, and degree of saturation. In addition, this study also aimed to propose suitable improvements for the study location. A pilot study was carried out to observe the intersection and identify the critical peak period of the intersection. The video filming technique was applied to collect most of the required data. The video was recorded on a sunny Tuesday during the evening peak (5.30 p.m. – 7.30 p.m.). SIDRA Intersection 8.0 was employed in this study as a tool to analyse the performance of the intersection. The results showed that the study location has low LOS (LOS E) with long delays (70 s/veh), long queues (179m) and a high degree of saturation (0.98). An improvement was proposed to enhance the performance of the study location, which was adding extra lanes. As a result, the performance of the study location improved from LOS E to LOS C with a reduction in delays, queue lengths and degree of saturation.

Keywords: Signalised Intersection, LOS, Delay, Queue Length, Degree of Saturation

1. Introduction

Planning policies in transportation and land use cause long-term effects on the urban form, particularly in the street network which serves as the backbone of the city and influences the flow and pattern of movement [1]. Research has shown that Malaysia has experienced a tremendous rise in demand for vehicles in recent decades, with the total number of registered motor cars reaching 15 million [2].

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Unfortunately, the development of infrastructure in Malaysia nowadays could not satisfy the rapid urbanization. As a result, serious traffic congestion has become a major problem in many cities around Malaysia. Traffic congestion is a status of the traffic movement that creates sluggish speeds, lengthier journey time, and cropping vehicles queuing under high traffic volume at peak hours that decelerates the traffic speed and results in jamming [3]. Traffic congestions cause negative impacts on human health in terms of the emission of toxic gases from vehicles. The traffic-related air pollutants (TRAPs) exposure is a public health concern as it causes many diseases each year in Malaysia [4]. TRAPs also bring negative environmental impacts, such as air pollution and the greenhouse effect. On the other hand, traffic congestions also cause financial losses to society. Furthermore, the fuel consumption of vehicles will be increased as the travel journey become longer. Wear and tear of the vehicle, such as frequent usage of accelerator and brakes, as well as idle traffic need repairs and maintenance frequently [5].

The objective of this study was to analyse the level of service (LOS) of the selected signalised intersection based on the delay, queue length and degree of saturation. Moreover, this study also proposed suitable improvements for the intersection. The study location had chosen one of the congested signalised intersections in Seremban, Negeri Sembilan, which was the intersection of Jalan Senawang 2 and Jalan Berlian. Traffic congestions and long queues are always being observed at the study location especially some specific periods so called peak periods, such as morning peak, afternoon peak and evening peak. In this study, the evening peak (5.30 p.m. – 7.30 p.m.) has been identified to be the critical peak period at the study location through the pilot study. In addition, video filming technique was applied to record the traffic flow and traffic movement on a sunny working Tuesday during the peak hours. SIDRA Intersection 8.0 was used in this study to analyse the performance of the selected signalised intersection in terms of delays, queue length, and degree of saturation. SIDRA software established by Australian Road Research Board (ARRB) to serve as an aid to intersection timing, capacity and performance analysis [6]. The data were extracted and inputted into SIDRA software for simulation and analysis. The main data extracted from the video were the vehicle volume and traffic movement. The vehicles that need to be counted were classified in four classes as shown in Table 1. However, Class 1 vehicle, which is motorcycles are not taken into account. The motorcycles are less likely to contribute to the analysis of intersection performance, such as the delay and queue length.

Table 1: Vehicle classes

Class	Type of vehicle
1	Motorcycles
2	Passenger cars
3	Vans and Medium trucks
4	Heavy trucks and Buses

2. Methodology

Methodology indicates the process and method used to carry out the study. In this chapter, the pilot study, data collection, and data analysis are discussed in detail.

2.1 Pilot Study

Before collecting the required data for the performance analysis of the intersection, a pilot study is necessary to observe the traffic flow and traffic movement at the study location. In this study, the pilot study is essential to determine the critical peak hours at the study location. Several field visits were conducted to observe the traffic conditions at the study location. The field visits were carried out during the normal weekdays and avoided any public holidays, raw weather conditions, as well as natural traffic conditions such as accidents. Based on the field observations, among the three peak hours, the most congested traffic flow and the longest queue is in the evening peak, from 5.30 p.m. to 7.30 p.m. Furthermore, the traffic phases at the study location were observed to have four phases, each phase only allows movement of one lane. Meanwhile, the traffic signal timing at the study location is observed to be actuated traffic signal timing, where the cycle length is different for every cycle.

2.2 Data Collection

Before determining the LOS of intersection using SIDRA software, there are some parameters or data that need to be inputted. Some of the data can use the default values in SIDRA software, but some parameters or data need to be collected in the field. First and foremost, the intersection geometry, which also can be defined as the dimensions of lanes and approaches at the intersection. The intersection geometry is needed to be collected and measured to ensure the simulated intersection in SIDRA is similar to reality. Some intersection geometries can be determined based on the observations, such as the lane type, lane configuration, and lane control. However, some parameters need to be measured manually in the field or measured using the applications. For instance, the approach length, lane length, lane width and others.

Next, the vehicle volume or vehicle count. To obtain vehicle volumes, the video filming technique was used in this study to record the traffic flow and movement at the study location. Class 2 to Class 4 vehicles were considered in this study. Then, the vehicles were classified into two types, which are light vehicles and heavy vehicles. Last but not least, the traffic phasing and timing. Traffic phases indicate the movement of vehicles under the control of traffic signals. The traffic phases of the intersection were identified by observations at the study location. Moreover, the cycle length was determined manually using the stopwatch at the study location. At least five cycles should be recorded to identify the traffic signal setting.

2.3 Data Analysis

SIDRA Intersection 8.0 was used as a tool to analyse the performance of the study location. SIDRA software presented the performance of the intersection in terms of LOS, delay, queue length and degree of saturation. Figure 1 shows the summarised procedures of SIDRA Intersection 8.0.

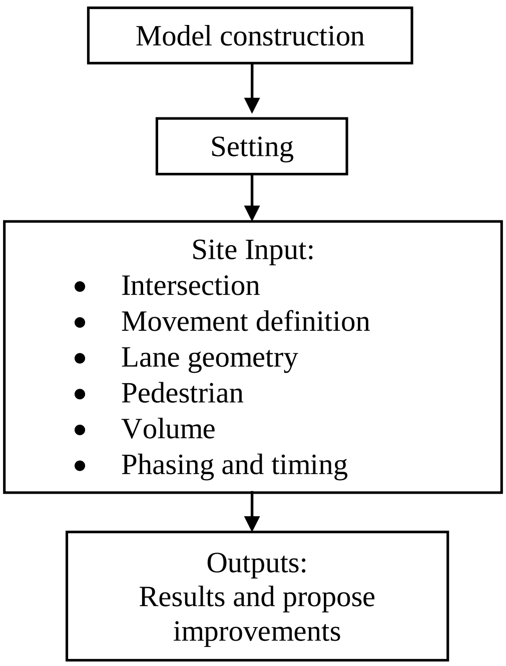

Figure 1: Summarised procedures of SIDRA Intersection 8.0.

3. Result and Discussion

The analysis results from SIDRA software are discussed in this section, such as the vehicle volume, LOS, delays, queue length and the degree of saturation.

3.1 Vehicle Volumes

The volumes were extracted from the video and inputted into SIDRA software. Table 2 shows the vehicle volumes of each approach per hour. Based on the table, most of the light vehicles from the South and North approaches are tended to have left turns at the intersection, which have 268 and 189 veh/hr respectively. However, for the East and West approaches, the light vehicles are most likely to go straight, which have 270 and 230 veh/hr accordingly. At the same time, most of the heavy vehicles from the East and North approaches go straight, which have eight and five veh/hr respectively. Moreover, for the West and South approaches, most of the heavy vehicles turn left, which have seven and eight veh/hr accordingly. Moreover, the South approach had the highest total vehicle volumes (600 veh/hr) while the North approach had the lowest total vehicle volumes (400 veh/hr).

Table 2: Vehicle volumes for each approach per hour.

Approach	**Flow/Turn**	**Vehicles (veh/hr)**		**Total**
		Light	**Heavy**	
East	**Left**	137	5	142
	Straight	270	8	278
	Right	53	3	56
			Total	**476**
West	**Left**	20	7	27
	Straight	230	4	234
	Right	136	5	141
			Total	**402**
South	**Left**	268	8	276
	Straight	157	4	161
	Right	162	1	163
			Total	**600**
North	**Left**	189	4	193
	Straight	167	5	172
	Right	34	1	35
			Total	**400**

3.2 Level of Service (LOS)

The average LOS for each approach of the intersection is shown in Table 3. The West and North approaches have an average LOS F, while the East approach has an average LOS E. Besides that, the South approach has the best average LOS among the approaches, which is LOS D. The LOS of the intersection is as expected, which is poor LOS. The results can be concluded that the study location is facing the issue of traffic congestion.

Table 3: Average LOS of the approaches.

	Approaches			
	East	**West**	**South**	**North**
LOS	E	F	D	F

3.3 Delay

The results of the delay from SIDRA software are presented in Table 4. The North approach has the longest delays with 95.4 s/veh since the approach only has one lane for all different flows of vehicles, whereas the South approach has the shortest delays with 46.6 s/veh. Moreover, the East approach has 56.4 s/veh of delays and 90.2 s/veh of delays for the West approach.

Table 4: Average delays of each approach.

	Approaches			
	East	**West**	**South**	**North**
Delay (s/veh)	56.4	90.2	46.6	95.4

3.4 Queue Length

Table 5 represents the average queue length of each approach. Among the approaches, the North approach has the longest queue length at 179m, while the South approach has the shortest queue length (94m). Besides that, the East and West approach has 129m and 167m of queue length respectively. The queue length analysed by SIDRA software can be concluded that the vehicles have to experience long queues at the study location.

Table 5: Average queue length of each approach.

	Approaches			
	East	**West**	**South**	**North**
Queue length (m)	129	167	94	179

As to verify the results, a manual calculation has been conducted to determine the queue length at the study location. The vehicle counts have been conducted at the study location for five cycles. Then, the critical values of queue length are compared with the results from SIDRA software. The vehicle queues are counted from the centre of the intersection to the centre of the nearest intersection. The average length of the vehicles is used to estimate the queue length at the intersection. For instance, the average length of a passenger car is 4.5m, while the length of vans and mediums trucks is about 5.5m. The total queue length of the approach is equal to the average length of the vehicles multiplied by the vehicle counts as shown in Table 6. Based on the table, the North approach has the longest queue since it has the longest distance between the intersections. Hence, the North approach has a larger capacity compared to other approaches. In addition, by comparing the results in Table 4 and Table 5, there are only slight differences between the queue lengths. Hence, the results from SIDRA are verified and applicable.

Table 6: Average queue length by manual calculation.

Approach	Passenger Cars (4.5m)	Vans & Medium Trucks (5.5m)	Heavy Trucks & Buses (14m)	Total queue length (m)
East	19 85.5	3 16.5	1 14	116
West	21 94.5	4 22	2 28	144.5
South	15 67.5	4 22	0 0	89.5
North	29 130.5	2 11	2 28	169.5

3.4 Degree of Saturation

Table 7 shows the average degree of saturation of each approach. The average degree of saturation is the highest value among the lanes of each approach. The average degree of saturation at the South and West approaches is 0.98. Meanwhile, the degree of saturation at the North and East approaches are 0.97 and 0.87 respectively. The results of the degree of saturation have shown that the traffic flow at the intersection is nearly equal to one, which is saturated traffic flow. Therefore, suitable solutions are needed to reduce the degree of saturation of the study location.

Table 7: Average degree of saturation of each approach.

	Approaches			
	East	**West**	**South**	**North**
Degree of saturation (v/c ratio)	0.87	0.98	0.98	0.97

3.4 Summary

The overall average LOS of the intersection is LOS E as shown in Table 8, which indicated that the performance of the intersection is poor. Based on the table below, the intersection has an average of 70 s/veh of delays, which can be understood as a vehicle having to delay for an average of one minute and ten seconds at the intersection. Moreover, the intersection has an average queue length of 179m, which is a long queue. Besides that, the average degree of saturation of the intersection is 0.98 as a whole, which also explained that the traffic flow at the intersection is saturated. In conclusion, the analysed results by SIDRA software show that the study location is a congested signalised intersection where the vehicles have to experience high delays, long queues and saturated traffic flow.

Table 8: Summary of intersection performance.

Performance Measure	Intersection
Delay	70 s/veh
Queue Length	179 m
Degree of Saturation	0.98
LOS	**LOS E**

4. Conclusion

The findings indicated that there is a lot of dissatisfaction with the performance of the selected signalised intersection. According to the results, the analysed results of the key measure indicators have proved that the performance of the study location is poor. For instance, the average delay at the intersection is 70 s/veh, the queue length is 179m, and the degree of saturation is 0.98, which is nearly equal to one. As a result, the performance of the intersection is LOS E expectedly, which indicated that the intersection is congested with long delays, long queue length and saturated traffic flow. In conclusion, the first objective has been achieved, in which the LOS of the study location has been identified based on the key indicators, such as delay, queue length and degree of saturation. The findings showed that the study location is a congested signalised intersection which brings a lot of negative impacts on society, the environment and the economy. Hence, the issue of traffic congestion at the signalised intersection needs to be solved by suitable improvements.

There are two main strategies to improve the performance of the signalised intersection, which are adjustment of the lane geometry or the traffic signal. The most recommended improvement for the intersection performance in this study is to adjust the lane geometry of the intersection. For instance, adding extra lanes for the lanes that have a long queue. However, the spaces at the site must also be considered. As to prove this recommendation is applicable, the adjusted intersection is analysed with SIDRA software with the existing vehicle volumes, traffic phasing and timing. Overall, the performance has improved from LOS E to LOS C. Moreover, the delay at the intersection has reduced 52.4%, the queue length has reduced to 49m as well as the degree of saturation has drop to 0.52. In a nut shell, the recommendation is proved to be useful in enhance the performance of the study location.

Acknowledgement

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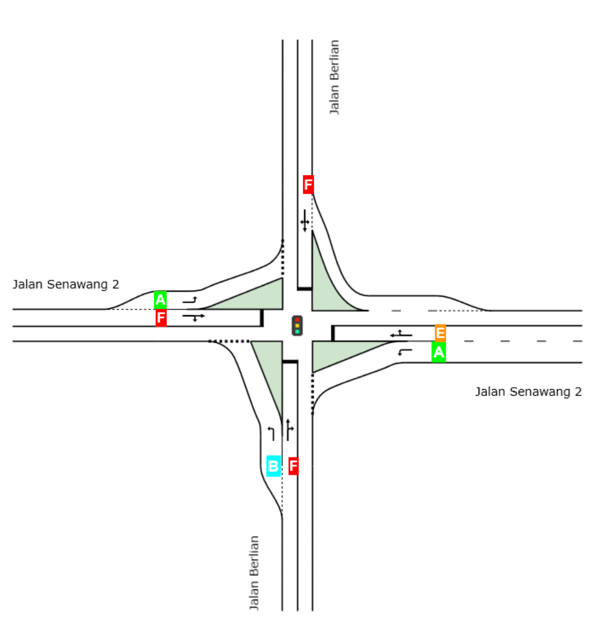
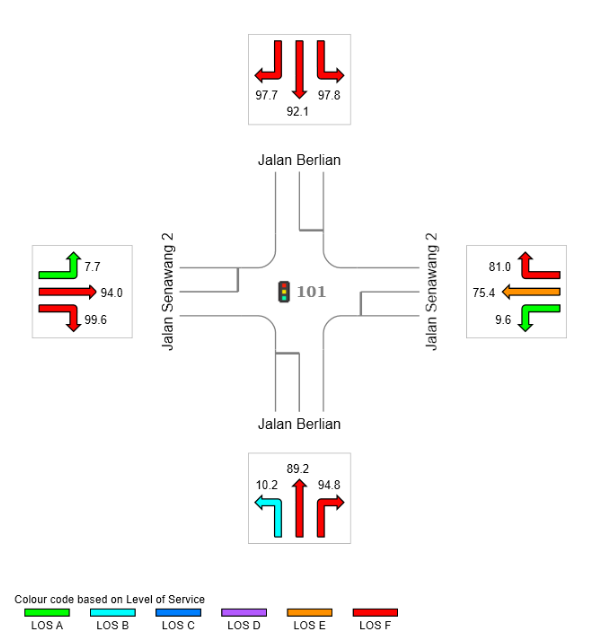
Appendix A

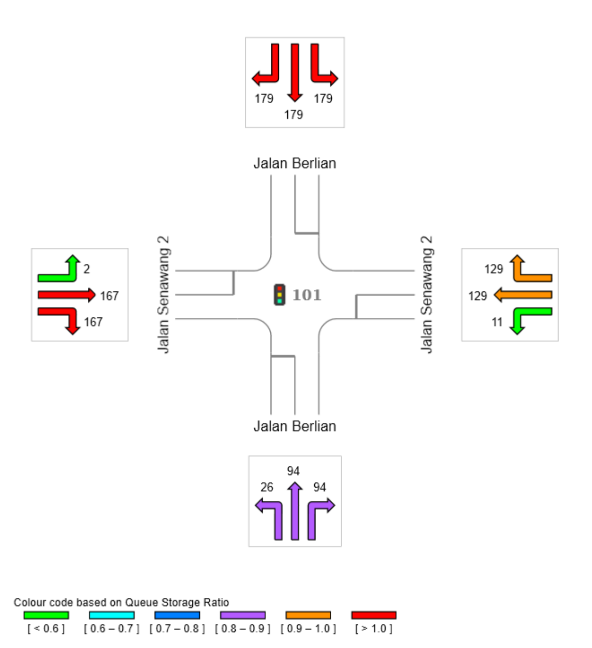
Before improvement:



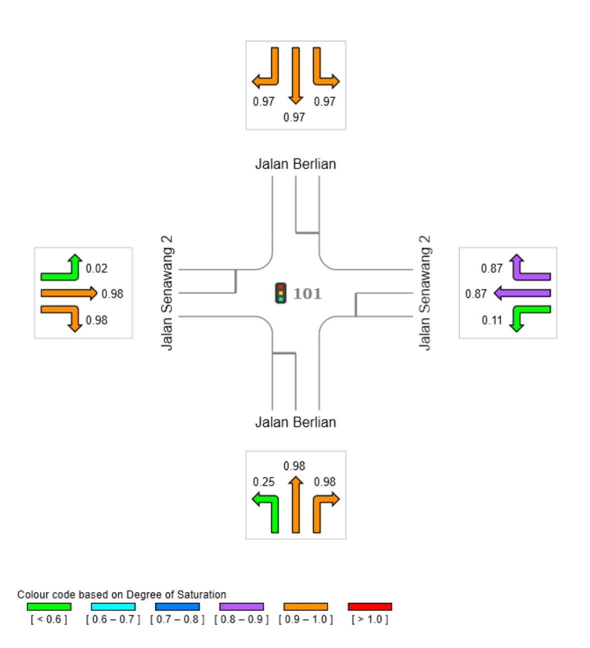
Lane LOS of the approaches



Lane delays of each approach in s/veh



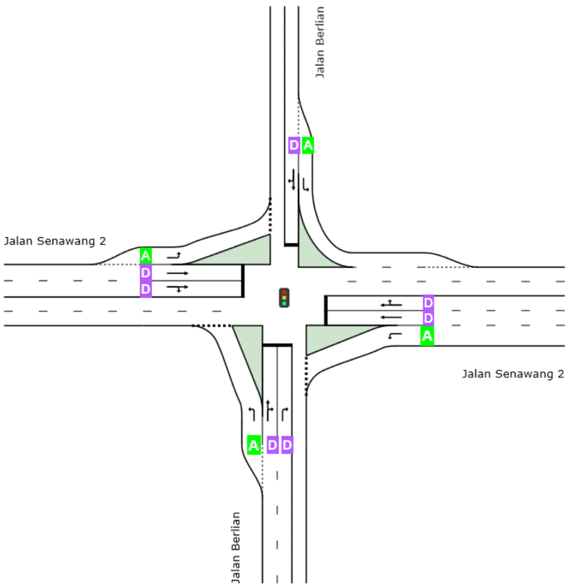
Queue length for each lane of each approach in metres



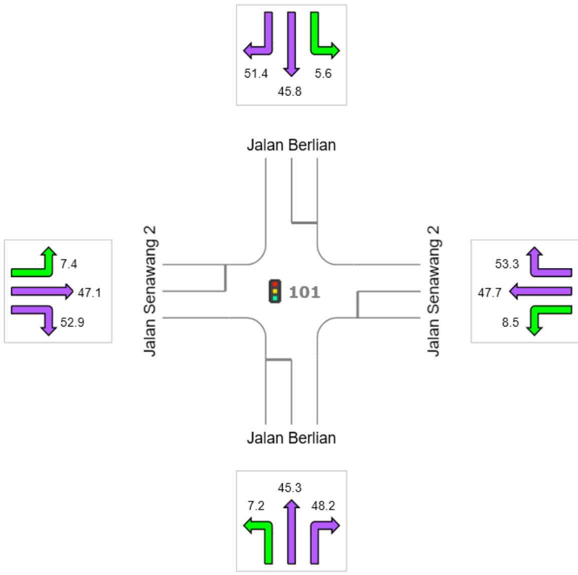
Degree of Saturation for each approach

Appendix B

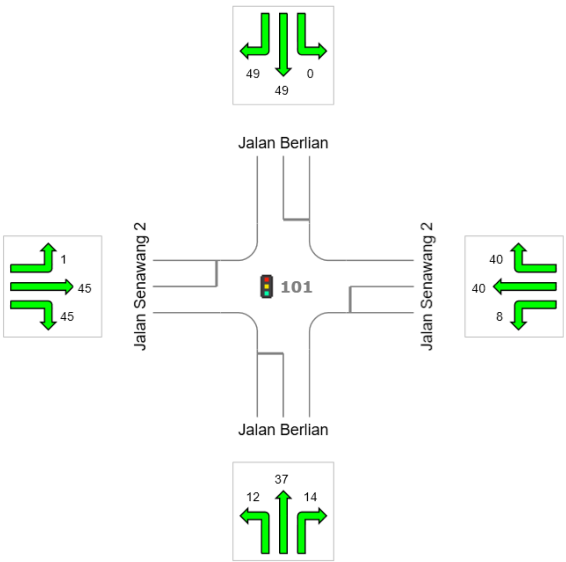
After improvement:



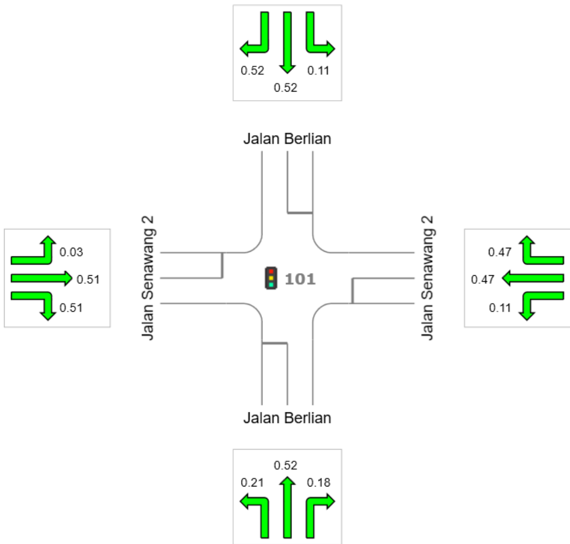
Lane LOS of the approaches



Lane delays of each approach in s/veh



Queue length for each lane of each approach in metres



Degree of Saturation for each approach

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