# Performance Analysis of Roundabouts at Bandar Maharani Bandar Di Raja, Johor, Malaysia

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***Abstract:*** ***Roundabout is one of road facilities that has been used to intentionally reduce the speed as well as conflicting points among vehicles. Therefore, roundabout is a safer option for an intersection and may also increase capacity and smoothness of traffic flow. The aim of this study was to determine the level of service of three main roundabouts in Bandar Maharani Bandar Di Raja, Muar namely roundabout of Jalan Bakri, roundabout of Jalan Sulaiman and roundabout of Jalan Abdul Rahman. Hence, the traffic pattern was identified by analyzing the commuter data at Jalan Khalidi. In this study, 12-hour of manual counting was carried out manually and then, the turning movements at roundabouts was determined by using videotaping method via drone. The flying and recording durations were 20 and 15 minutes, respectively. Data were extracted from the video to obtain flow rate using the derivation of peak hour factor formula. The traffic pattern analysis showed that the morning peak 15-minute were at 7.00 to 7.15 a.m. These 15-minute times were used to obtain flow rates of movements at roundabout through a simple peak hour factor analysis for determination of level of service. In the performance analysis, the overall level of service of Jalan Bakri /Jalan Sulaiman/Jalan Abdul Rahman roundabouts during morning and evening peak hour were D/F/E and B/F/F, respectively. In `the contrary, as expected, the level of service of these three roundabouts during off-peak hour were A, D and A. These outcomes are expected to be benefited by the Majlis Perbandaran Muar for better traffic management of Bandar Maharani.***

***Index Terms:*** ***Delay, Level of Service, Roundabout, SIDRA Intersection 8.0***

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## I. INTRODUCTION

Traffic congestion is one of the major problems that challenge developed countries around the world. As a result of traffic congestion intersections in Malaysia, delays and long queues are observed repeatedly during peak hours due to poor strategies of road network especially at the Centre Business District (CBD). The increasing number of vehicle cause traffic congestion, resulting in slower travel speed [1].

Roundabout has been introduced to reduce traffic congestion at with function of reducing the crossing conflicts points. Roundabout also being solutions that ensure high levels of fluidity, capacity, road safety and having advantages in terms of pollutant emissions [2]. There are two fundamental elements that can distinguish roundabout from traffic circle, which is yield at entry for entering vehicle and the deflection of approaches and exit. In Malaysia, the movement of roundabout is in clockwise circulating movement. At the entry of roundabout, signs usually direct traffic entering the circle to slow down and give the right of way to drivers already in the circle [3].

The Signalized Intersection Design and Research Aid (SIDRA) Software is used as an aid for design and evaluation of individual intersections and networks of intersections. SIDRA INTERSECTION allows modelling of separate Movement Classes (Light Vehicles, Heavy Vehicles, Buses, Bicycle, Large Trucks, Light Rail / Trams and two user Classes) with different vehicle characteristics [4].

## II. BACKGROUND OF STUDY

According to the Federal Highway Administration (FHWA), mini roundabout, single lane roundabout and multi-lane roundabout can be classified into 5 characteristics which are maximum design speed at the entry of roundabout that vehicle can applied, maximum number of vehicle entering lanes per approach, diameter of circle, central island of roundabout and volume that roundabout can approximately support [5]. This study was carried out at Jalan Bakri, Jalan Sulaiman and Jalan Abdul Rahman multilane roundabouts with diameter more than 50 metres and up to two circulatory lanes.

The necessary elements in roundabout which are entry section of roundabout, circulatory roadway width, Central Island, entry curves, exit curves, inscribed circle diameter and splitter island [3]. Roundabout user consists of motorists, pedestrians, bicyclists and emergency vehicle. Capacity levels of roundabout depends on the conflicting volume or circulating traffic, vehicle rate on roundabout in front of the approach and approach geometry especially entrance width. The less conflicting traffic, the greater capacity is for a given geometry, and the wider the approach, the more capacity the approach has for a given conflicting volume [6]. Capacity levels are calculated and compared for different gap acceptance parameters, including local parameters and different traffic flow scenarios [7].

Volumes to Capacity ratio (v/C) referred to degree of saturation, represents the sufficiency of an intersection to accommodate the vehicular demand. A v/c ratio less than 0.85 indicates that vehicle is not expected to experience significant queues and delays and if v/c ratio approaches 1.0 traffic flow may become unstable, delay and queue. For design purposes, a v/C ratio in between 0.85 to 0.95 is used for the peak hour of the horizon year [8].

The key feature of roundabouts is approach to delay reduction [6]. Control delay is the time that a driver spends queuing and the waiting for an acceptable gap in the circulating flow while at the front of the queue [5]. On the other hand, the field-observed queue lengths were measured by counting the number of vehicles in the queue at the time [9].

Level of Service (LOS) of traffic facility is a concept introduced to relate the quality of traffic service to a given flow rate. Six LOS letters are defined by the United States Highway Capacity Manual, namely A, B, C, D, E, F, where A denotes the best quality of service and F denotes the worst. Typical measure of effectiveness include speed, travel time, density and delay [10].

The benefits of roundabouts are traffic safety, operational performance, aesthetics, access management (reduce left U-turn movements), traffic calming and pedestrian safety [5]. SIDRA Intersection software is an advanced micro-analytical traffic evaluation tool that employs lane by lane and vehicle drive-cycle models coupled with an iterative approximation method to provide estimates of capacity and performances of delay, queue length and stop rate [11]. The purpose of this study is to analyse the performance of existing roundabouts at Bandar Maharani, Muar using a modified data collection method.

## III. METHODOLOGY

Figure 1 shows flowchart of overall study.

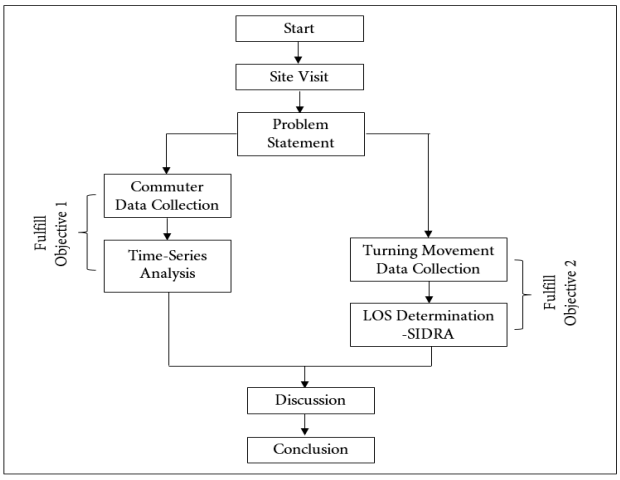


**Fig. 1 Flowchart of overall study**

Referring to Figure 1, site visit was carried out at Muar town to identify the proper study location. The commuter data count was done for 12 hours to know the peak and off-peak hours along Jalan Khalidi in order to fulfill the first objective. The turning movement data were used to identify the total of vehicles that passing through the roundabouts and to determine the level of services. Drone was used to obtain the aerial footage of roundabouts traffics in 15 minutes. The reason for using the drone is to gain overall coverage of the roundabout large circumference. Although 15 minutes data were obtained, the modified peak hour factor (PHF) equation was used to calculate the flow rate of every movement. Equation 1 is the original PHF calculation.

$$PHF = \frac{Q}{V_{15\,\min(\max)} \times 4} \qquad (1)$$

Where, Q is maximum flow rate, $V_{15min(max)}$ is the peakiest 15-minute volume. Equation (2) was derived using Equation (1).

$$Q = PHF \times V_{15\,\min(\max)} \times 4 \qquad (2)$$

The maximum flow rate data were used to analyze the performance of roundabout in order to fulfill second objective. The conclusion was made at the end of this study to clarify whether the two objectives are achieved or not.

## IV. RESULT AND DISCUSSION

### A. Time Series Analysis

The traffic flow rate for every 15-minute interval with classification of class 1 (motorcycles), class 2 (cars), class 3 (vans & medium trucks) and class 4 (heavy trucks & buses) was recorded in commuter data count for 12 hours along Jalan Khalidi. Figure 2 shows time series analysis from the commuter count data.

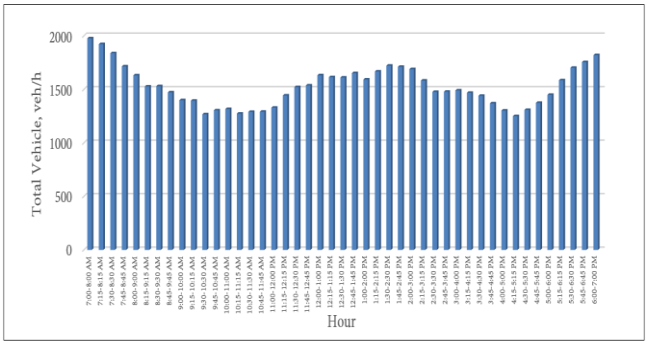


**Fig. 2 Time series analysis of commuter data count**

Referring to figure 2, the morning peak hour along Jalan Khalidi was at 7.00 am to 8.00 am. The total vehicle during this hour was the highest with 1977 veh/hr. The evening peak hour was at 6.00 pm to 7.00 pm with total vehicle of 1820 veh/hr. The minimum flow rate was 1250 veh/hr at 4.15 pm to 5.15 pm. The most peak of 15 minutes volume was 515 during morning peak hour. Therefore, the PHF value is calculated using equation (1) as follows.

$$PHF = \frac{Q}{V_{15\min(\max)} \times 4} = \frac{1977}{515 \times 4} = 0.96$$

This PHF value of 0.96 was then used in the calculation of maximum flow rate at every approach in the intersection.

### B. Performance analysis of study locations

The performance analysis consists of LOS, delay, degree of saturation and queue distance. LOS in the case study is range from A to F as mentioned in the background study. Figure 3 shows an example of LOS, delay, v/c ratio and queue distance results at roundabout of Jalan Bakri during morning peak hour.

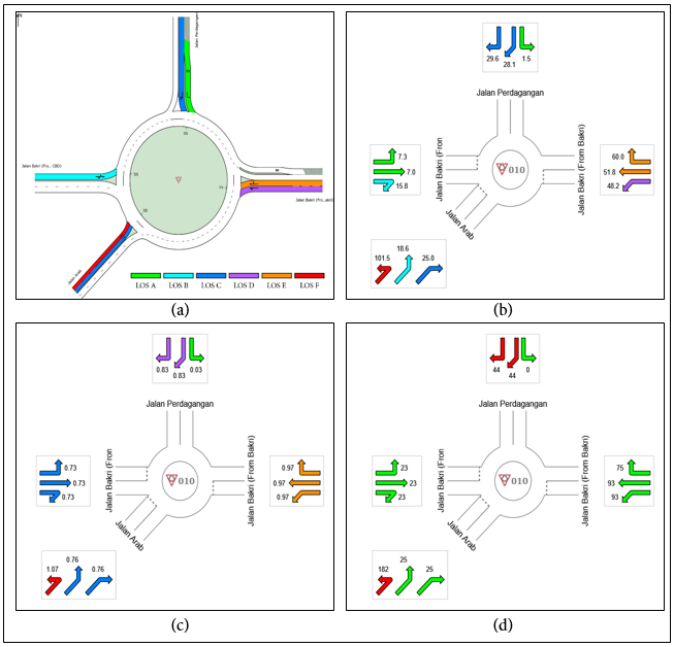


**Fig. 3 Performance analysis at roundabout at Jalan Bakri during morning peak hour; (a) LOS, (b) Delay, (c) v/c ratio, (d) queue distance**

Table 1 shows the results of LOS, delay, v/c ratio and queue distance for roundabout of Jalan Bakri (R001), roundabout of Jalan Sulaiman (R002) and roundabout of Jalan Abdul Rahman (R003) during morning peak hour.

**Table. 1 Results for morning peak hour**

| Roundabout | Morning Peak | | | |
|---|---|---|---|---|
| | LOS | Delay (s) | V/C | Queue (m) |
| R001 | D | 47.1 | 1.07 | 182 |
| R002 | F | 354.9 | 2.03 | 763 |
| R003 | E | 62.3 | 1.17 | 223 |

Referring to Table 1, the worst LOS was at R002 with LOS F. This result was achieved based on delay, v/c ratio and queue distance highest values. R002 is in the middle of another two roundabouts and possess five approaches. The total number of vehicles are increased during the morning peak hour due to active connection between two roundabouts. Therefore, this roundabout is the busiest among the roundabouts. For R001 and R003, even though the LOS were quite poor with LOS D and LOS E but the delays were only up to 1 minute. Table 2 shows the results of LOS, delay, v/c ratio and queue distance for R001, R002 and R003 during evening peak hour.

**Table. 2 Results for evening peak hour**

| Roundabout | Evening Peak | | | |
|---|---|---|---|---|
| | LOS | Delay (s) | V/C | Queue (m) |
| R001 | B | 14.1 | 0.84 | 39 |
| R002 | F | 116.3 | 1.36 | 248 |
| R003 | F | 174.0 | 1.44 | 844 |

Referring to Table 2, LOS at R001 is the finest among three roundabouts with LOS B. At R001, there is two alternative routes without entering the roundabout, from Jalan Arab to Jalan Bakri (Muar CBD) and Jalan Perdagangan to Jalan Bakri (Bakri). People rather use alternative route than roundabout because they can avoid congestion and saves time. The evening peak is at 6.15 pm until 6.30 pm and for R002 and R003 the total number of vehicles are increased during this hour because the workers are on their way to go home. Near R001, there are many offices and workers went home around 5.30 pm to 6.00 pm but on the contrary to R002 and R003, the office is far from the roundabout and workers usually reached the roundabout during evening peak hour. Moreover, R001 has wider circulating multilane of 3.4 metres/lane so that the delay was shorter. However, when the delay is longer, the queue will also be long. The greater the number of lanes, the least of delay happened at every approach. The more the delay happened at the roundabout, the degree of saturation is increased. R001 has the shortest queue because of

short delay.

Table 3 shows the results of LOS, delay, v/c ratio and queue distance for R001, R002 and R003 during off-peak hour.

**Table. 3 Results during off-peak hour**

| Roundabout | Off-Peak | | | |
|---|---|---|---|---|
| | LOS | Delay (s) | V/C | Queue (m) |
| R001 | A | 7.3 | 0.51 | 12 |
| R002 | D | 38.8 | 1.23 | 149 |
| R003 | A | 6.2 | 0.64 | 20 |

Referring to Table 3, R001 and R003 have LOS A that is optimum as expected during off-peak hours. When the LOS is A, traffic volume is low, and the drivers will be having the complete freedom to choose their desired speed. However, the number of vehicles at R002 was not decreased even during off-peak hour. LOS on R002 is D and this may due to the present of shortcut route from R003 (Jalan Abdul Rahman (Muar CBD) approach) to R002 (Jalan Ibrahim approach). As the queue depends on delay, R001 and R003 has the shortest queue but R002 has the longest queue but not as longer as during peak hour.

## V. CONCLUSION

The performance of roundabouts was evaluated in terms of LOS, delay, degree of saturation (v/c ratio) and queue. Table 1, Table 2 and Table 3 provide the results of performance evaluation. In summary, the following conclusions can be drawn from this study.

i. The morning peak hour for Jalan Khalidi was 7.00 am to 8.00 am while the evening peak hour was 6.00 pm to 7.00 pm. For off-peak hour was 4.15 pm to 5.15 pm.

ii. The LOS in the morning peak hour was better than the evening peak hour, which means that the volume of traffic flows in the evening more than the morning peak hour.

The current performance of roundabouts can be useful for the local authority to plan for future development in Bandar Maharani, Muar so that the traffic congestion can be controlled.

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