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Relationship Between Delay, Accepted Gap and Circulating Flow at Roundabout

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Relationship Between Delay, Accepted Gap and Circulating Flow at Roundabout

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Abstract. Capacity and delay are critical parameters to evaluate roundabout performance. This paper is attempted to investigate the influence of circulating traffic flow and gap acceptance on roundabout delay. All the data related to the analysis were gathered at a three-leg roundabout located at Kulai in Johor using video camera technique. The data were analyzed using a regression analysis technique: simple regression and multi-linear regression. The simple regression results show there is an exponential relationship between the delay and circulating flow and a power relationship between the accepted gap and delay as well as between accepted gap and circulating flow. The result of the multi regression between the delay, circulating flow and accepted gap gives high R-value. Despite the high R-value, the p-value of the circulating flow and accepted gap were found higher than 0.05 at 95% confident level; due to the high correlation between circulating gap and the accepted gap. This result can be used as a basis in developing a delay model for the roundabout in Malaysia, taking into account the influence of the drivers' behavior

1. Introduction

The roundabout is capable of increasing traffic safety, reducing traffic emission, and reducing delays [1–3]. Vehicles in the roundabout have only to stop for circulating vehicles; thus the driver's idling times and delays are decreased and ultimately leads to a reduction in vehicular emission as well as fuel consumption compared to normal junction [1]. Many researchers compared roundabout with different types of the intersection, and the results showed that the emissions from the roundabout are less [4–7]. Delay is known as the difference between actual travel time experienced by the driver and free-flow travel time. Highway Capacity Manual 2000 defines control delay as “the total elapsed time from the time a vehicle stops at the end of the queue to the time the vehicle departs from the stop line. The control delay includes initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay” [8].

Both an empirical approach or an analytical approach are used to analyze roundabout delay. The empirical approach depends on field observation for a different number of sites, so that regression analysis can be conducted to obtain an equation to calculate delay. The analytical theory is based on either queuing theory or gap acceptance theory; this approach is based on the driver's behavior. These approaches were used to develop a delay equation in most countries, depending on the local conditions. Thus these equations need to be calibrated to transfer to other countries. Using equations from guidelines created outside of Malaysia may overestimate or underestimate the assessment of



roundabout delay because these methods have been created in other nations where traffic features, driver behavior and geometric intersection differ from those in Malaysia. Therefore, there is a need for a delay model that describes the Malaysian roundabout performance based on the local conditions. This paper illustrates the relationship between the delay, circulating flow and the accepted gap, which will be the base of model development in the future.

2. Methodology

The chosen site is located at Kulai, Johor. Figure 1 shows the map of the selected roundabout. The roundabout is considered small roundabout; the inscribed diameter is 46 m (is less than 50 m and more than 20 m). This roundabout is the intersecting point of three roads, which are; Jalan Persiaran Indahpura 2, Jalan Persiaran Indahpura Utama northeast, and Jalan Persiaran Indahpura Southwest. Jalan Persiaran Indahpura Utama Northeast and Jalan Persiaran Indahpura Southwest are the major roads, and there are consisting of three lanes. While Jalan Persiaran Indahpura 2 is the minor road, which consists of two lanes. The roundabout geometric were measured using Google Earth and Auto CAD software, and the parameters measured were listed in Table 1.

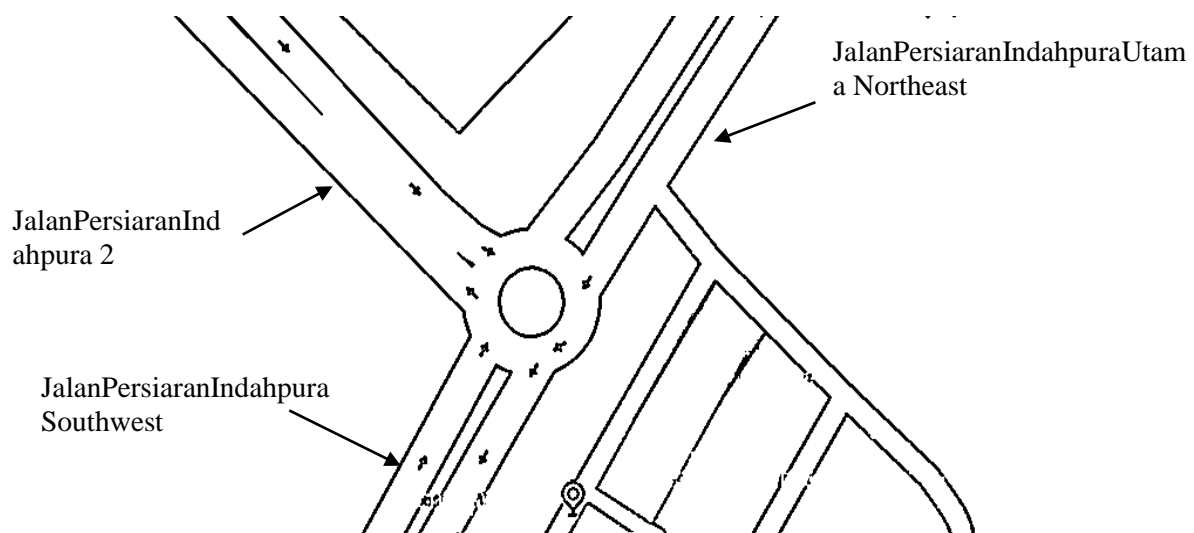


Figure 1. Roundabout map

Table 1. The geometric parameters for Kulai roundabout

Parameters	Jalan Persiaran Indahpura 2	Jalan Persiaran Indahpura Utama North east	Jalan Persiaran Indahpura South west
Inscribed diameter	46	46	46
No of entry	2	3	3
Entry width (m)	10.5	14.3	14
Circulating width	9.4	9.3	9.4
No of	2	2	2

3. Data collection and Analysis

Traffic flow parameters of the roundabout were obtained using video camera. Two video cameras were installed inside the roundabout; one is heading towards Jalan Persiaran Indahpura 2 and the other one towards Jalan Persiaran Indahpura southwest. The data was recorded for two days on weekdays in the morning from 7:00 am to 10:00 am (3 hours).

Then, in the lab, the recorded videos were played several times using the VLC media player. The data were extracted using a microscopic extraction method. The stop line at each roundabout entry was selected as a reference line, so the followings were recorded;

- i. Vehicle type
- ii. The time vehicle joins the queue
- iii. The time the vehicle reaches the service line and the time leave the reference line
- iv. For each vehicle stopped at the reference line at the entry, the arrival time of each circulating vehicle at the conflict point was recorded.

3.1. Estimating traffic parameters

From the recorded time events mentioned above, four traffic parameters were determined which are; traffic composition, circulating flow, accepted gap and delay.

3.1.1. Traffic composition.

The vehicles were categorized into three main groups based on visual assessment, which are light vehicles (i.e., car, taxis, and vans), heavy vehicles (lorries, large trailers, and buses), and motorcycles.

3.1.2. Estimating circulating flow rate.

The circulating traffic flow was estimated for each vehicle at each entry leg separately, as illustrated in Equation 1[9-12].

$$\text{Circulating flow rate} = \frac{n}{t_n - t_0} \quad (1)$$

Where: t_0 the arrival time of entry vehicle at the reference line, n is the number of observed circulating vehicles for the entry vehicle, and t_n is the time of arrival of circulating vehicle number n^{th} after the vehicle at the reference line depart the reference line.

3.1.3. Accepted gap.

Both the accepted gap and lag was used in the analysis. The gap was recorded as an accepted lag if the driver at the entry accepts the first gap between him and the circulating vehicle. In contrast, accepting the following gap is recorded as an accepted gap. Any gap greater than 13 s was excluded as it is regularly accepted by the drivers.

3.1.4. Delay.

The measured delay was the control delay, which starts from the time the vehicle joins the back of the queue until departing the stop line at the entry.

3.2. Data analysis and results

First of all, the roundabout traffic composition was calculated as illustrated in Figure 2, and it was found that 80% of the traffic composition was light vehicles, 14 % motorcycles, and 6 % heavy vehicles.

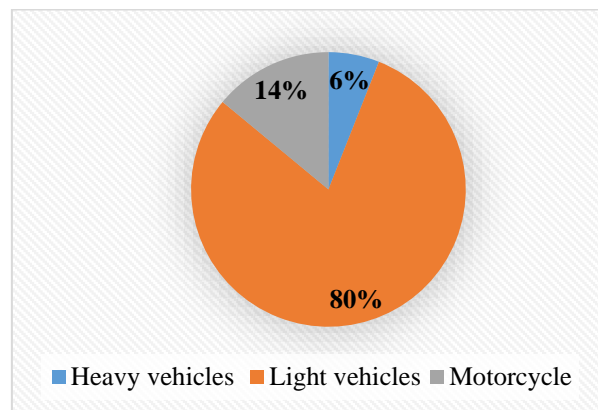


Figure 2. Traffic composition

The statistical analysis using both simple regression and multilinear regression was conducted after extracting all the necessary data (circulating flow, accepted gap, and delay). The simple regression was used to determine the relationships between each parameter with another (delay, circulating flow, and the accepted gap). Then, multilinear regression was conducted to determine relationship between delay and combination of circulating flow and accepted gap.

Figure 3 depicts the relationship between the accepted gap and circulating flow. A power relationship between the two parameters was found for the left, right, and middle lane. When the circulating traffic flow increases, the accepted gap decreases, this means that as conflicting flow increases the drivers tend to take what is an available gap in front of him/ her, although the available gap size is smaller than what he/ her desire.

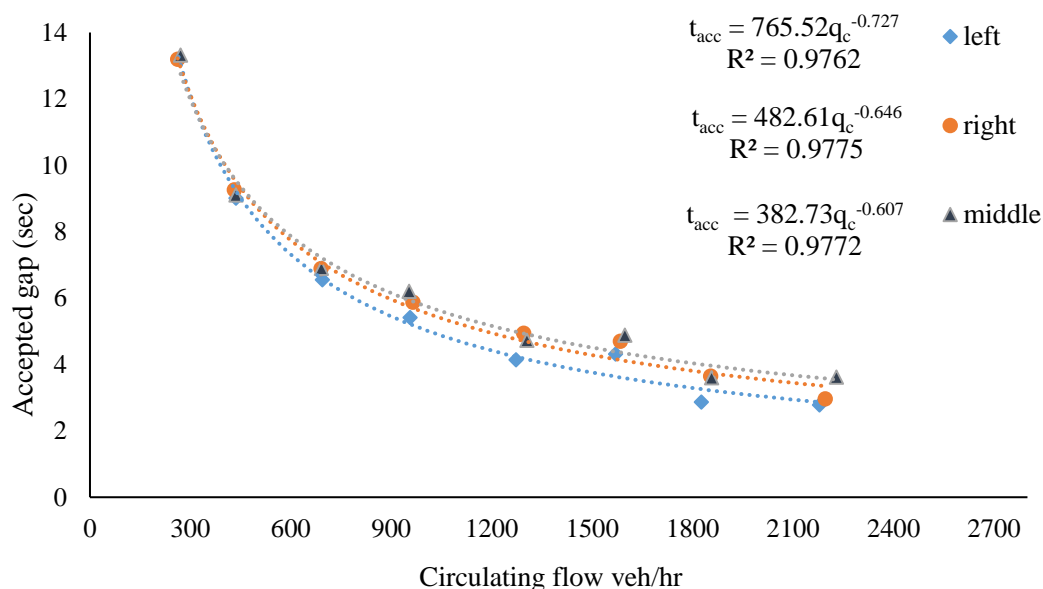


Figure 3. The relationship between the accepted gap (t_{acc}) and circulating flow (q_c)

A power relationship between delay and the accepted gap is shown in Figure 4. It has been noticed that as the control delay increases, the accepted gap decreases; this means as waiting time increases the drivers become more aggressive, taking the risk to accept shorter gaps. This result was confirmed by the relationship between accepted gap and the circulating flow in Figure 3 as mentioned earlier.

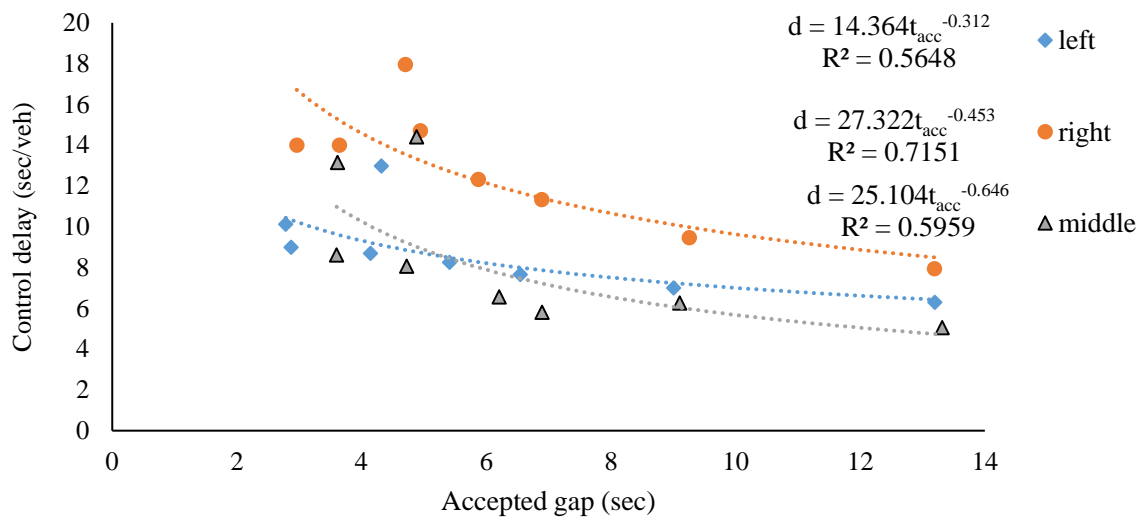


Figure 4. The relationship between delay (d) and the accepted gap (t_{acc})

Figure 5 shows an exponential relationship between the delay and the circulating flow, the increase of the circulating flow leads to an increase in the control delay. As the number of vehicles on the circulating lane increases, it becomes harder for a vehicle at the stop line to enter the roundabout due to the insufficient gap for him/ her; this leads him/ her to wait longer until the acceptable gap found.

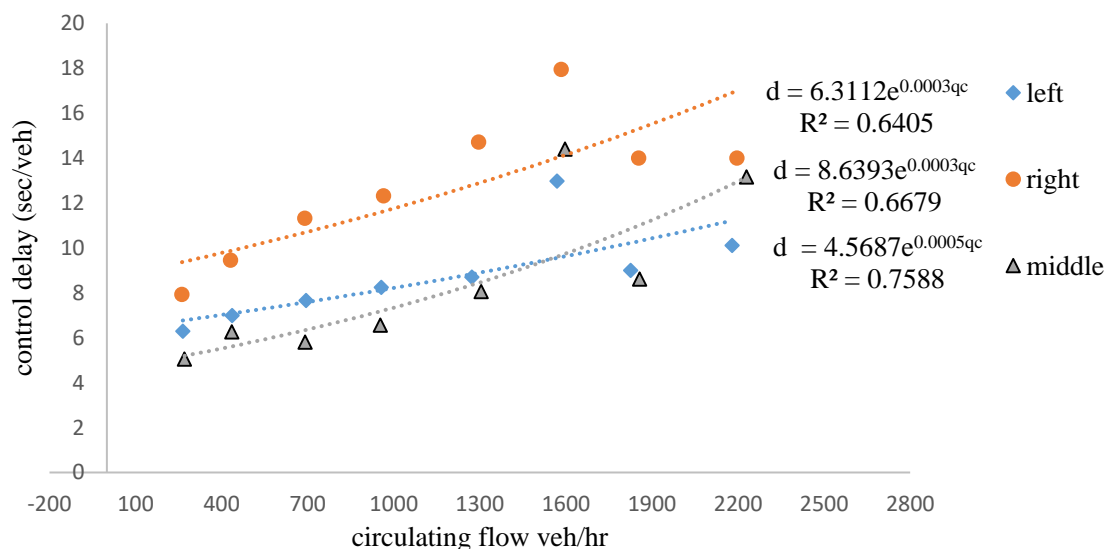


Figure 5. The relationship between delay (d) and the circulating flow (q_c)

Then, a multi-linear regression was used to examine the relationship between these three parameters: the delay, the accepted gap, and the circulating flow. Table 4 and Table 5 list the results of the regression analysis. Despite the high value of R ; however, the p -value of the circulating flow and accepted gap are greater than 0.05; that can be a result of collinearity between circulating flow and accepted gap as shown in Figure 3. The collinearity is phenomenon when the independent variables are highly correlated to each other.

Table 4. The Relationship between the delay, the accepted gap, and the circulating flow

Lane	Equation	R	F
Left	$d=6.993+0.00193q_c-0.0753t_{acc}$	0.74	0.133
Right	$d=15.439+0.00098q_c-0.6t_{acc}$	0.84	0.0497
Middle	$d=0.44+0.0051q_c+0.292t_{acc}$	0.88	0.02645

Table 5. Multi-linear regression parameters

Lane		P-value
Left	Intercept	0.1824
	circulating flow	0.379
	accepted gap	0.852
Right	Intercept	0.059
	circulating flow	0.723
	accepted gap	0.314
Middle	Intercept	0.934
	circulating flow	0.054
	accepted gap	0.529

4. Conclusion

This paper discussed the relationship between delay, accepted gap, and circulating flow at the roundabout. A relationship between delay and circulating flow was found, as well as between delay and the accepted gap. The drivers become more aggressive when entering roundabout if the circulating flow increases or they wait for too long. The relationship between the control delay and the circulating flow was found to be significant as the R square value for the left, right, and middle lane was 0.64, 0.67, and 0.76 respectively. A multilinear regression was performed, to check the influence of both the circulating flow and the accepted gap on the delay. The result reveals that the relationship is not significant because the circulating flow and accepted gap are highly correlated, causing collinearity problems.

As a result of the absence of a delay equation for the roundabout in the guideline in Malaysia, the engineers have to use other equations that were developed in other countries to assess the roundabout performance, which may not represent the actual conditions. Therefore, the outcome of this paper is a step forward towards the development of a roundabout delay model in Malaysia, taking into account the influence of the drivers' behavior. For developing a reliable and accurate model more data from different roundabouts with different geometric parameters are needed to overcome the shortage in the Malaysian guideline.

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