Effect of Police Control on U-turn Saturation Flow at Different Median Widths

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U-turn at the midblock median opening is risky and sometimes controlled by police, especially during peak periods. This research investigated the effect of police control on u-turn saturation flow. The u-turn movement, when the conflicting traffic stopped with and without police control, was compared in terms of saturation headway and flow rate. The saturation headway data were collected at four u-turn sites on the same highway with different median widths. The results showed that the u-turning vehicle moved with less headway when police controlled the junction. The u-turn saturation flow rate was 10 % higher due to police control. The effect of median width was also investigated. When the median width was comfortably sufficient, the wider median leaded to higher saturation headway. Consequently, the saturation flow decreased as the median width increased. However, too narrow median leaded to uncomfortable u-turn and reduced the saturation flow rate. Moreover, the efficiency of police control was diminished at the u-turn site with too narrow median width.

Key Words : *u-turn, police control, median width, saturation headway, saturation flow*

1. INTRODUCTION

U-turn facilities at midblock median opening can be found on urban arterials in the developing countries. This is to facilitate the access to/from the local residential area and roadside developments. The proper street network planning, following the road hierarchy, can accommodate the traffic movements without providing u-turn at midblock median opening.

The u-turn movement at uncontrolled midblock median opening is based on the gap acceptance process. When the vehicle arrives at the median opening, its driver faces the gaps of the conflicting through traffic, waits for an acceptable gap, and then makes a u-turn. However, when the conflicting traffic volume is high, it is very difficult to find a large enough gap for the u-turn movement. The police will present and control the u-turn junctions. This is to facilitate the u-turn traffic movement, avoid through traffic blockage by u-turn queue, and prevent unsafe forcing u-turn behavior.

This research evaluates the effect of police control at the median opening u-turn on its saturation flow, comparing to the normal traffic operation when there is no police control. To conduct a fair comparison, the effect of conflicting traffic volume was neglected. The saturation flow was calculated based on the inverse of the saturation headway. In case of no police control, the headway of u-turning traffic was measured in the situation that conflicting traffic stopped for u-turn or no conflicting traffic. The objectives of this study can be listed as follows:

(i) to evaluate the effect of police control at median opening on u-turn saturation flow;

(ii) to investigate the effect of median width on u-turn saturation flow and u-turn maneuver.

The u-turning vehicles in this research focused only on passenger car, which included all kinds of vehicle with passenger car equivalent (PCE) of 1.

The results showed that the police control could increase the u-turn saturation flow. The saturation flow decreased as the median width increased. However, the too narrow median reduced the saturation flow rate and reduced the effeciency of police control at u-turn.

2. LITERATURE REVIEW

The capacity of the uninterrupted traffic can be determined by the inverse of the saturation headway. For interrupted traffic facilities with major-minor traffic priority system, the capacity is based on gap acceptance process. According to the previous research, the gap acceptance model is found reasonable for estimating u-turn capacity at median openings[1), 2), 3)]. The recent Highway Capacity Manual 2010 has included the u-turn movement in the methodology for the Two-Way Stop-Control (TWSC) intersection[4)].

Traffic police occasionally controls traffic operation; in case of special events, evacuation, and incidents[5)]. In developing countries, traffic police are often utilized to control the traffic operation during peak periods. There is a study evaluating the efficiency of a police controlled roundabout comparing to a pre-timed traffic signal controlled intersection, in term of dynamic delay. The police is necessary to be provided to control the roundabout during peak periods. This gives better chances for mass crossings of traffic and better control on queue length. The relationship between delay and queue length as the vehicle joins the queue has been developed. It shows that the roundabout cause less delay when the queue length less than 80 m and cause greater delay as the 80 m queue length criterion is exceeded[6)].

The provision of midblock median openings for u-turn between intersection can reduce the number of turning maneuvers at the adjacent intersections. Since the conflict points are less, the accident rates at midblock median openings are lower than at three- or four-leg median openings[7)]. However, the u-turning vehicles may delay full-speed conflicting through traffic. In addition, narrow medians may not provide enough space for larger vehicles to negotiate a u-turn maneuver. To accommodate the u-turn maneuver at median opening, the width of median nose (refer to median at u-turn location) and receiving driveway should be wide enough. For the design vehicle "P" (passenger car with length of 5.7 m), AASHTO recommends the median nose width of 9 m, 5 m, and 2 m for the u-turn maneuver from inner lane to inner lane, to outer lane, and to shoulder lane, respectively, for 4-lane divided highway[8)].

3. METHODOLOGY

Generally, the u-turn capacity model is based on gap acceptance process. The capacity of u-turn depends on the volume of conflicting traffic volume, headway distribution, and u-turn gap acceptance characteristics. The higher conflicting traffic volume, the lower u-turn capacity due to less chances for entering to the through traffic stream. The smaller value of either critical headway or follow-up headway for u-turn, the greater u-turn capacity.

This research intends to compare the u-turn movement between when there is police control and no police control. The effects of conflicting traffic characteristics are neglected. For comparison purpose, the saturation headway of u-turn movement in both situations are determined. The saturation headway is the movement headway when the subjected movement is in queued condition. In case of police control, it is the headway of the u-turn movement when the police blocks the conflicting traffic. In case of no police control, it can be measured in the situations that the conflicting traffic stop and allow the queued u-turn traffic to enter into the traffic stream continuously. The saturation flow rate of the u-turn movement, when there is no conflicting traffic, is determined by the inverse of the saturation headway;

$$S = \frac{3600}{h} \tag{1}$$

where S is the saturation flow rate (veh/hr) and h is the saturation headway (s).

In this study, the saturation headway and flow rate of u-turn movement are compared between control strategy at each site. In addition, the comparisons of the results from all sites are conducted to check the effect of median width.

4. DATA COLLECTION

(1) Site selection

To fulfill the research objectives, the selected u-turn sites should be operated for both with and without police control. In addition, the major through traffic should frequently stop to allow u-turn traffic to move. The physical geometry characteristics of all sites should be similar. The site locations should be in the same area to get the similar driver behavior, i.e. same driver population.

Consider the above criteria, four midblock median openings were selected for data collection. Those sites are located on the same six-lane divided street (three lanes in each direction). The roadway section at one site has been expanded to eight-lane divided roadway (four lanes in each direction). There is an exclusive storage lane for u-turn in both directions at 3 sites while the site with 4 lanes in each direction has no u-turn bay. Therefore, the lane arrangement at

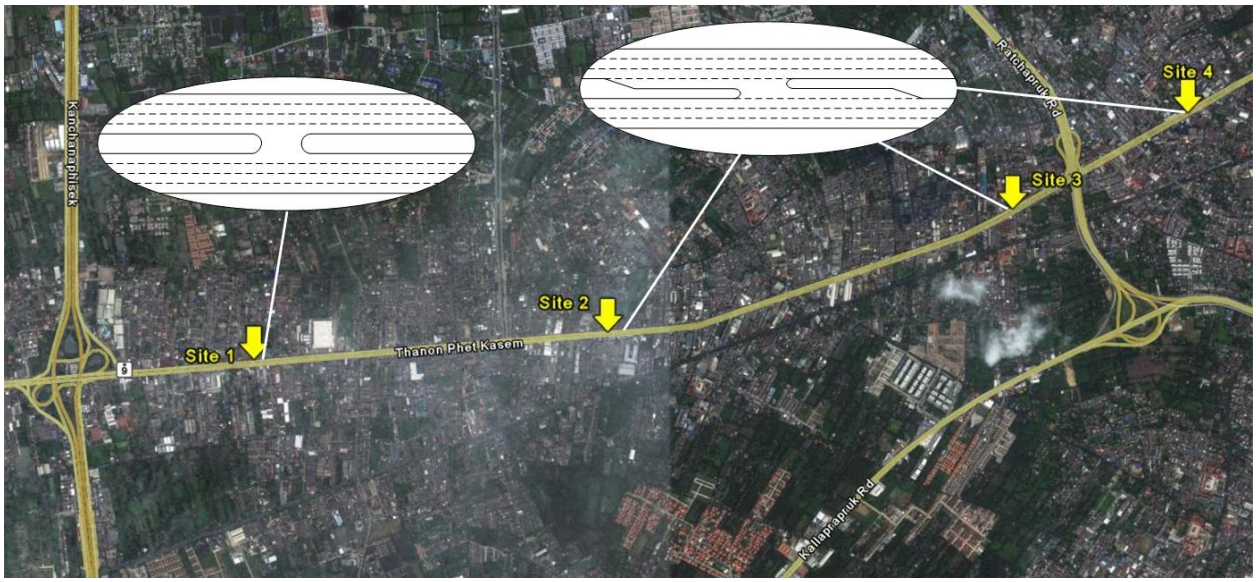

Fig. 1 Location and typical layout of the selected u-turn sites

u-turn section at all sites are similar; one u-turn lane and three through lanes in each direction. The width of median nose and receiving roadway is sufficient for u-turn maneuver at all sites. The site location and typical u-turn layout were shown in **Fig.1**.

(2) Collected data

The field data collection was conducted by video recording. A video camera was set at the nearby pedestrian bridge at each site to record the traffic movement during morning peak, afternoon peak, and off-peak periods. The video data was collected on two days at each site to get more and sufficient data for further analysis.

The video data were reviewed to collect useful information in the laboratory. The first step was to identify the periods of continuous u-turn movement when the through traffic stopped, for both police control and no police control. After that, the time headway data were collected for all applicable periods. The headway data were analyzed separately for each site at each control condition.

(3) Data screening and analysis

To avoid the possible error from the inconsistent driver behavior, outliers were excluded from the data analysis. In this study, the outlier is any data point that is at least 1.5 times interquartile ranges (IQR) less than the lower quartile (Q1) or greater than the upper quartile (Q3). In other words, the data points used for analysis were between Q1-1.5*IQR and Q3+1.5*IQR.

Data analysis applied the basic statistical process. The descriptive statistics were calculated to explain the characteristics of data. The statistics got from the data sets included mean or average, standard error of mean, standard deviation, median, minimum, and maximum, as shown in **Table 1**.

Table 1 Descriptive statistics of saturation headway data

Site	Median Nose Width (m)	Case	No. of Sample	Mean (s)	Standard Error of Mean (s)	Standard Deviation (s)	Median (s)	Mini-mum (s)	Maxi-mum (s)
1	5.8	No Police	544	2.84	0.02	0.43	2.9	1.5	3.7
		With Police	823	2.59	0.02	0.44	2.6	1.5	3.6
2	3.2	No Police	553	2.64	0.02	0.45	2.6	1.4	3.7
		With Police	373	2.39	0.02	0.39	2.4	1.4	3.3
3	2.7	No Police	389	2.64	0.02	0.47	2.6	1.5	3.8
		With Police	334	2.49	0.02	0.42	2.4	1.3	3.7
4	3.8	No Police	830	2.67	0.01	0.38	2.7	1.5	3.7
		With Police	569	2.41	0.02	0.40	2.4	1.2	3.3

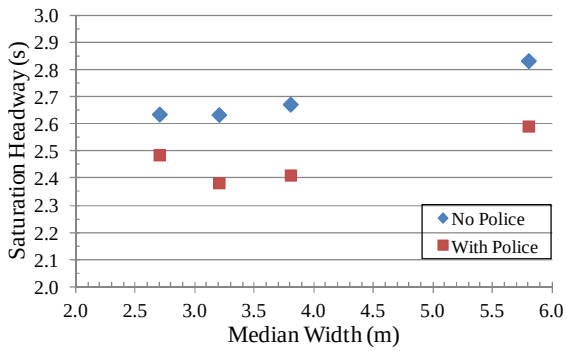

Fig. 2 Effect of police control and median width

Table 2 Saturation flow increase by police control

Median Nose Width	Case	Saturation Flow Rate (veh/hr)	% Increase of Police Control
2.7 m	No Police	1,365	6%
	With Police	1,447	
3.2 m	No Police	1,365	11%
	With Police	1,509	
3.8 m	No Police	1,346	11%
	With Police	1,491	
5.8 m	No Police	1,270	9%
	With Police	1,388	

5. RESULTS AND DISCUSSIONS

(1) Effect of police control

From the statistical analysis results (**Table 1**), the comparison of average saturation headway at different median widths on different control strategies was illustrated in **Fig. 2**. The mean headway values of u-turn movement in case of police control were lower than those in case of no police control at all sites. This could indicate that the police control at u-turn could increase the u-turn saturation flow, even comparing with the same situation that the conflicting through traffic stopped. When the u-turn junction was controlled by police, the drivers were more confident to make u-turn quickly. Based on the field observation, the policeman who controlled the junction sometimes rushed the u-turn movement by his hand sign as well. On the contrary, when the through traffic stopped without police, the u-turn drivers still concerned on the conflicting traffic action, whether to let u-turn go or not.

The behavior of driver is subjective, difficult to predict, and different from place to place. In some places, the u-turning traffic might move quicker in case of no police control than in case of police control. The reason is that when there is police control, the drivers do not need to rush to make u-turn while the drivers need to rush for their movement when there is no police control. Nevertheless, the results from this study confirmed that the u-turn traffic moved quicker with less headway when there was police control.

The amount of saturation flow increase due to police control was summarized in **Table 2**. The saturation flow was increased at approximately 10% at all sites except the site with the narrowest median (2.7 m), which the saturation flow increase was only 6%. The median width might affect the saturation flow increase since the u-turn maneuver required the sufficient driveway space.

(2) Effect of median width

The effect of median width on saturation headway could be seen in **Fig. 2**. Except the narrowest median of 2.7 m, the wider median nose leaded to the greater headway, and consequently the lower saturation flow rate of u-turn movement. The raised median might be considered as an obstacle for u-turning vehicle. The drivers have to carefully control their vehicles when making a u-turn at a wide median. Therefore, the wider median nose at u-turn, the larger headway to follow the leading vehicle. Since the width of median nose and roadway was sufficient for u-turn maneuver at all sites, there was no limitation of space for u-turn maneuver.

In case of normal gap acceptance u-turn, on the contrary, the u-turning vehicle prefers the wide median to narrow median. Since the u-turn maneuver needs large space to turn back, the wide median can compensate the required space. The u-turning vehicles can turn into the inner lane (close to median). The conflicting traffic is only the through vehicles on that lane. Therefore, the less conflicting traffic, the easier to make u-turn and the higher u-turn capacity. For narrow median, the u-turning vehicles have to conflict with 2 or more traffic lanes, making more difficult to complete the u-turn maneuver.

The median nose width of 2.7 m seemed quite narrow for comfortable u-turn maneuver. The u-turning vehicles could not use smaller saturation headway for their movement. The turning radius might not be sufficient for normal u-turn maneuver and the drivers had to turn steering wheel tightly. So, there would be a minimum median nose width for comfortable u-turn maneuver. Based on the result and comparison of 4 sites, the median nose width of 3.2 m could be the comfortable minimum width. However, the more site investigation should be conducted to find the exact relationships. The sites having median nose wider than 2.7 m and narrower

than 3.2 m should be observed for saturation headway data collection.

For comfortable median width, the police control could improve the saturation flow at the same level (about 10%). Nevertheless, the contribution of police control was less at the site with uncomfortably narrow median.

6. CONCLUSIONS

This research evaluated the effect of police control and median nose width on u-turn saturation flow by collecting the saturation headway at different sites. The conclusions could be listed as follows:

- the saturation headway was less when police controlled the traffic operation at u-turn;
- the police control could increase the saturation flow rate of about 10%;
- the saturation flow rate was less at the sites with the wider median;
- the median nose width at u-turn should be wider than a critical minimum width for comfortable u-turn maneuver; and
- With too narrow median, the saturation flow rate was less and so was the efficiency of police control.

For design purpose, if a u-turn at midblock median opening were designed to be fully controlled by traffic signal, the median width would be minimum but still provide comfortable u-turn maneuver. On the contrary, for uncontrolled u-turn junction, the median should be as wide as possible to give more chances for gap acceptance u-turn due to less interference to the conflicting traffic stream.

The limitation of this research was the number of study sites. The more data collection at other u-turn sites having median nose width in a range of 2.7- 3.2 m would be useful in order to determine the minimum preferable median width. In addition, the swept path analysis should be conducted to get better understanding of the u-turn maneuver in traffic engineering point of view.

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(Received August 3, 2012)