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Traffic System Studies at Median U-Turn in Baghdad City Employing U-SIM Model

Dr. Hussein Jassim Shihan
Ph.D. in Statistics
Ministry of Higher Education and Scientific Research, Baghdad, Iraq

Asst. Lect. Hussein Kariem Mohammed
M.Sc. in Civil Engineering
Ministry of Higher Education and Scientific Research, Baghdad, Iraq

Abstract

The current research utilizes the simulation model U-SIM to investigate the performance of range of analysis parameters at median U-turn sites in Baghdad City. The study subjects the U-SIM model to hypothetical sets of input parameters, and monitoring the effect of these parameters on the performance of the model through the selected measures of effectiveness.

The studied parameters were:

- ***Gap-acceptance behavior.***
- ***Gap-forcing behavior.***
- ***Effect of opposing and advancing turning flow.***
- ***Difference between left turn and U-turn behavior.***
- ***Median storage lanes.***

The effect of each above parameter will be studied and discussed with the aid of the figures and tables. Finally, conclusions and recommendations are drawn.

الخلاصـــــــة

يَستعملُ البحثُ الحاليُ نموذجُ المحاكاةَ U-SIM لتَحرّي الأداء لمجموعة من عوامل تحليلِ في مواقع الإستدارة المرورية للوراء في الجزرات الوسطية في مدينةِ بغداد. تُخضعُ الدراسةُ نموذج U-SIM إلى مجموعاتِ إفتراضيةِ مِنْ عوامل الأدخال ويُراقبُ تأثيرَ هذه العوامل على أداءِ النموذجِ من خلال قياسات التأثيرِ والعوامل المدروسة كَانتْ:

- *سلوك قبولِ الفجوةِ.*
- *سلوك الإجْبار للفجوةِ.*
- *تأثير التدفقِ المُنعطف المتقدّمِ والمعاكس.*
- *الاختلاف بين سلوكِ الانعطاف لليسارِ و الإستدارة للوراءِ.*
- *تأثير ممرات الخزنِ في الجزرات الوسطية.*

تأثير كل من هذه العوامل سَيَتمُ دراسته ومناقشَته بمساعدة الأرقام والجداول وأخيراً يتم تقديم الاستنتاجات والتوصيات بصدد الموضوع.

1. Introduction

One of important tasks of the traffic engineer is to evaluate traffic operation of turning movements. There are number of important factors in the traffic existence regarding turning movements at the U-turn median openings and affects on the performance and characteristics of the traffic networks. U-turn movement at median openings is highly complex and risky. It is felt that these locations cause an important effect on the traffic characteristics of networks. Normally the speed of conflicting traffic stream is relatively high and the turning vehicle must wait and then turn under low speed level [1,2]. Therefore, the turning vehicle needs large gap in the conflicting stream before performing the U-turn.

An effort was made to estimate traffic characteristics of U-turn movement at median openings.

2. Background

Hussein K. [3] developed general computer simulation model based on the observed traffic behavior, and evaluated the performance of the median U-turn. The first stage formulated the required equations and sub-models to develop the comprehensive model. Second, the developed model was incorporated into a general simulation program, U-SIM, to facilitate the running of the model on digital computers with minimum hardware computing requirements. A micro-simulation process followed to describe the vehicles movement along the roadway that contains median U-turns.

Following that two sites representing a range of location, vehicle behavior, and geometric conditions at Baghdad City were selected for data collection. The data were collected using video-recording technique. The required data were abstracted using an auxiliary programs developed for this purpose.

The model U-SIM [3] can be used to conduct range of applications for analysis and geometric design, not only at the median U-turn but also at the roadway link contains these median U-turns, and studying the effect of the median U-turn on the performance of the advancing and opposing link-streams.

3. Scope and Objective of the Study

Geometric delay and safety is mainly attributes to the geometric design of the U-turn median opening. Therefore, the decision to select a U-turn system at a particular site under a given set of condition, and to adopt a particular geometric layout as well, need detailed analysis that considers the effect of these conditions and determines the optimum analysis and design strategy according to defined criteria.

The basic objective of the current research is to investigate the traffic performance characteristics at the median U-turn and studying the effects of ranges of the following analysis parameters on the performance by utilizing the simulation model U-SIM in performing a range of applications.

3-1 General Analysis Parameters

In assessing the performance of median U-turn, different parameters may be included in the analysis.

Information was presented briefly regarding the following aspects:

1. Median U-turn characteristics:
   - Gap-acceptance models.
   - Gap-forcing behavior.
   - Effect of opposing and advancing turning flow.
   - Median U-turn average total delay.
   - Difference between left-turn and U-turn behavior.
2. Geometric layout:
   - Median storage lanes.

4. Gap Acceptance Behavior

Turning vehicles from the advancing stream oblique to the priority rules and give way to vehicles on the opposite controlling approach. The driver alone must decide when it is safe to enter the opposing stream. Therefore, the driver must perceive distances and velocities of other vehicles on the controlling stream and he/she must have a feeling for his/her own car performance. The group of gap acceptance models describes this process of perception and decision.

4-1 Site-1 [3]

4-1-1 Raff Method

Raff and Hart [4] defined the critical lag, L, as the size lag for which the number of accepted lags shorter than L is the same as the number of rejected lags longer than L.

Raff graphical method is illustrated in **Figs.(1)** and **(2)**. Then critical gap values for approaches 1 and 2 occur at 3.80 and 3.75 sec respectively. (Approaches 1 and 2 is for site-1 [3]).

4-1-2 Logit Method

When the dependent variable is an indicator variable (i.e., either the acceptance or rejection of a gap), the shape of the response function will frequently be curvilinear and can be approximated using a logit function (1). The mean response is a probability when the dependent variable is 0 or 1 (accept or reject) indicator variable. The logit function is given as:

$$\log_e \frac{p}{1-p} = \beta_0 + \beta_1 X \quad \text{.......... (1)}$$

where:

P = probability of accepting a gap

β_0, β_1 *= regression coefficients.*

A logit equation for approach 1 is given as:

$$\log_e \frac{p}{1-p} = -4.459 + 1.158_1 X \quad \text{.......} \quad (2)$$

For approach 2 is given as:

$$\log_e \frac{p}{1-p} = -3.25 + 0.86X \quad \text{.......} \quad (3)$$

The time gap for a 50 percent probability can be determined by substituting 0.5 for P in equation (1).

In approaches 1 and 2 fifty percent of the drivers accepted a gap of 3.85 and 3.78 sec. respectively; and 85 percent accepted a gap of 5.35 and 5.79 sec. respectively. (Approaches 1 and 2 is for site-1 [3]).

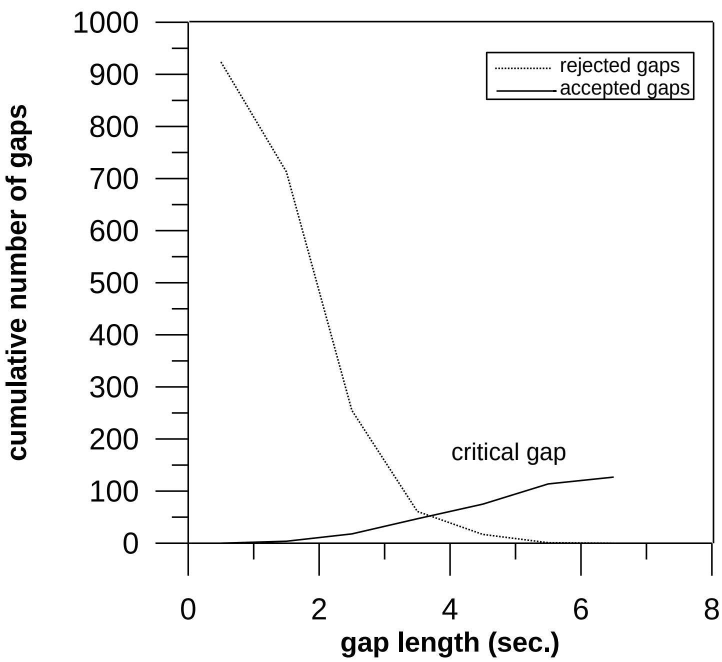


Figure (1) Raff plot approach 1, site-1

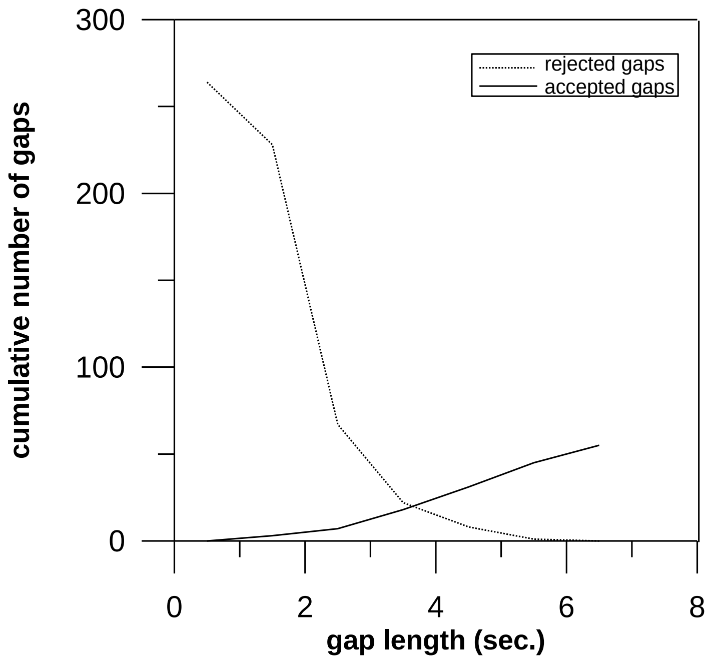


Figure (2) Raff plot approach 2, site-1

4-2 Site-2 [3]

4-2-1 Raff Method

Raff graphical method is illustrated in **Figs.(3)** and **(4)**. The critical gap values for the two approaches occur at 4.5 and 3.45 sec. respectively.

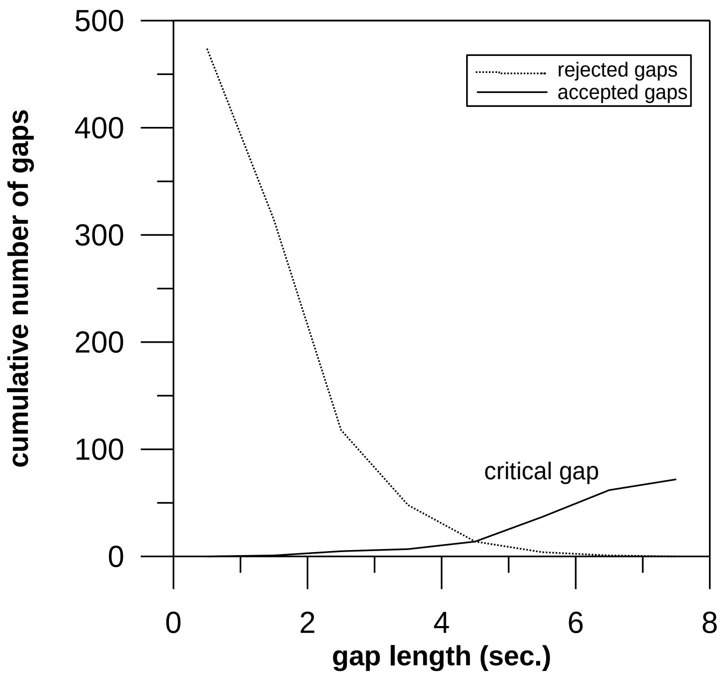


Figure (3) Raff plot approach 1, site-2

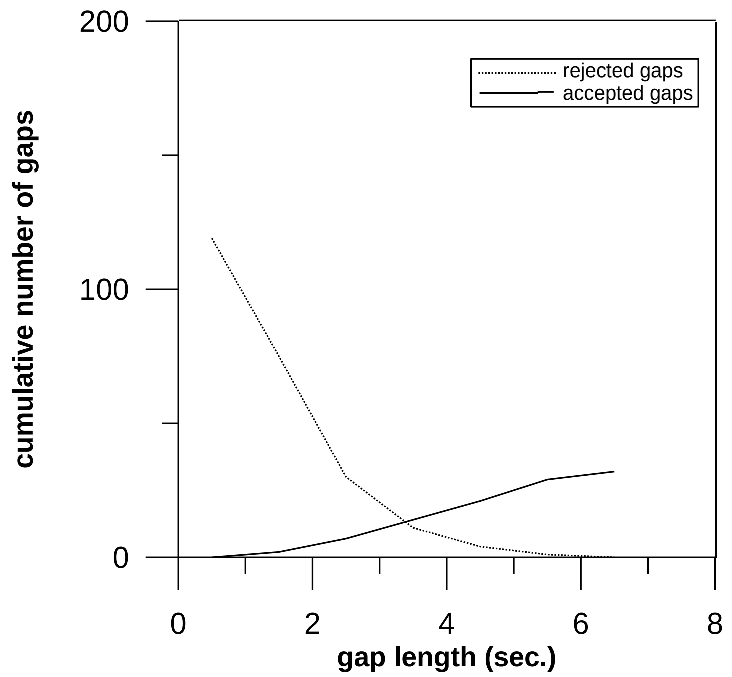


Figure (4) Raff plot approach 2, site-2

4-2-2 Logit Method

A logit equation for approach 1 is given as:

$$\log_e \frac{p}{1-p} = -11.283 + 2.426X \quad \text{.......... (4)}$$

For approach 2 is given as:

$$\log_e \frac{p}{1-p} = -3.334 + 0.901X \quad \text{.......... (5)}$$

The time gap for a 50 % probability can be determined by substituting 0.5 for P in equation (1).

In approaches 1 and 2 fifty percent of the drivers accepted a gap of 4.65 and 3.70 sec. respectively; and 85 percent accepted a gap of 5.36 and 5.62 sec. respectively.

5. Effect of Gap-Forcing Behavior on Delay of Turning Flow

Gap-forcing driver behavior was considered in the U-SIM model [3] due to effects of this behavior on some traffic flow parameters such as delay and queue length. It has a considerable effect on delay at U-turn median opening. **Figure (5)** shows the effect of the gap-forcing behavior with different gap-forcing percentages starting from 0.0 to 20 %.

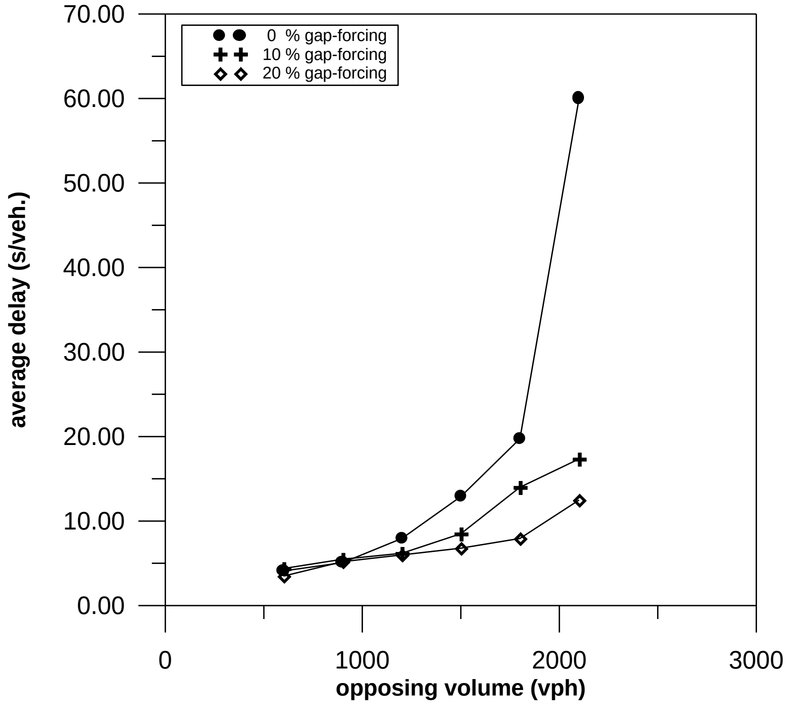


Figure (5) Effect of gap-forcing percentage on delay of U-turning flow

Increasing the gap-forcing percentage from 0.0 to 20% decreased the average turning delay from 8.0 to 6.0 sec. at 1200 vph, and from 19.75 to 7.95 sec. at 1800 vph, i.e. 60%.

It is clear that the average delay increases with increasing the opposing volume, and the average delay decreases obviously with increasing the gap-forcing percentage.

6. Effect of the Opposing Turning Flow on the Delay Values at Median U-turn

One of the significant traffic movement characteristics of the median U-turn is that when the waiting vehicle in the advancing stream waits to accept a gap, the volume of turning vehicles in the opposing stream causes some effects on the available gap in the opposing stream. For no deceleration or storage lanes, the turning vehicle blocks the through movement in the opposing stream, and increases the gap availability to accept. The longer the turning volume in the opposing stream increases the conflicting time and decreases the average delay and queue length in the advancing stream. This median U-turn characteristic was considered in the U-SIM model.

As shown in **Table (1)**, as a result of this situation, at flow equal to 900 vph, increasing the turning flow from 30 to 240 vph in the opposing stream decreased the average delay for the turning vehicles in the advancing stream from 10.9 to 7.5 sec. While at traffic flow equal to 1800 vph turning flow from 60 to 480 vph caused a decrease in the average delay of the turning vehicles in the advance stream from 21.7 sec. to 10.8 sec, i.e. 50% decrease.

Table (1) Simulated delay values showing the effect of the opposing turning flow

Major opposing flow (vph)		Major advancing flow (vph)		Av. delay for advancing app. (sec/veh)
Total	Turn for two lanes	Total	Turn for two lanes	
450	16	450	90	7.3
450	30	450	90	7.5
450	46	450	90	7.6
450	60	450	90	7.4
450	76	450	90	7.6
450	90	450	90	7.2
450	106	450	90	7.0
450	120	450	90	6.9
900	30	900	180	10.9
900	60	900	180	9.6
900	90	900	180	8.3
900	120	900	180	8.7
900	150	900	180	8.0
900	180	900	180	8.6
900	210	900	180	7.7
900	240	900	180	7.5
1800	60	1800	360	21.7
1800	120	1800	360	17.6
1800	180	1800	360	14.6
1800	240	1800	360	12.8
1800	300	1800	360	13.2
1800	360	1800	360	12.6
1800	420	1800	360	10.8
1800	480	1800	360	10.8
3600	120	3600	720	62.2
3600	240	3600	720	59.7
3600	360	3600	720	46.7
3600	480	3600	720	41.9
3600	600	3600	720	40.5
3600	720	3600	720	35.9
3600	840	3600	720	35.5
3600	960	3600	720	27.5

7. Left Turn and U-turn Gap Acceptances

The driver at stop-controlled approach must observe the gap in the opposing traffic stream(s) and determine whether the gap is adequate to complete the crossing or turning maneuver. After accepting a gap, the driver should be able to complete the desired maneuver and comfortably join or cross the major road traffic stream within the length of the gap.

For left turn movement from major approach the driver must cross the conflicting stream and accepts gap needed for crossing movement; this gap is widely lower than that needed to accomplish turning maneuver at the U-turn median opening.

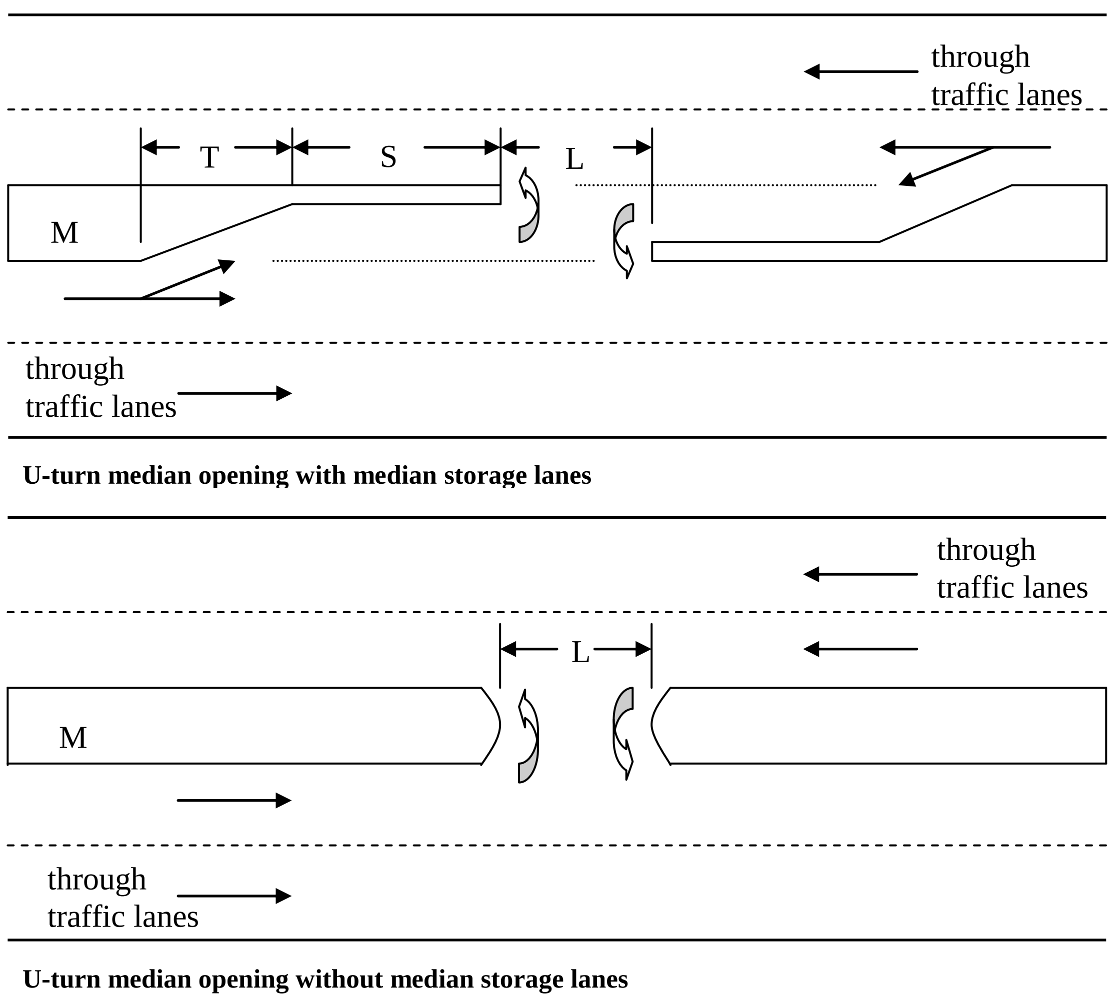
Table (2) showed comparison of gaps needed for left-turn and U-turn movements.

Table (2) Gap and lag acceptance for left-turn and U-turn movements

Site	Gap (sec)		Lag (sec)	
	mean	std. dev.	mean	std. dev.
T-intersection [5] left-turn (2-lanes)	2.788	1.515	2.880	1.492
U-turn site-1 (2-lanes)	3.902	0.992	3.225	2.128
U-turn site-2 (3-lanes)	4.564	1.111	2.424	1.399

8. Median Storage Lanes

In order to study the effect of this geometric factor on median U-turn performance, the simulation model U-SIM was used to simulate delay values for two cases, U-turn with median storage lane, and U-turn without median storage lane. Diagrams of the two layouts are given in **Fig.(6)**.



M=median width *L=length of median opening* *S=storage length* *T=taper*

Figure (6) U-turn median openings with and without left-turn median storage lanes

The relative impact of this factor increases with the increase in the percentage of U-turning movements, and the opposing flow as shown in **Tables (3)** and **(4)**.

Table (3) Simulated average delay values at U-turn without median storage lanes

Flow on the opposing approach (vph)	Average delay for different U-turn percentages (sec/veh)				
	10%	**20%**	**30%**	**40%**	**50%**
600	0.35	0.64	1.09	1.66	1.92
900	0.34	0.77	1.30	2.09	3.13
1200	0.36	0.94	1.43	2.69	3.63
1500	0.39	0.93	1.71	2.53	4.22
1800	0.47	1.06	2.59	4.28	8.22
2100	0.57	1.47	3.53	6.72	12.15

Table (4) Simulated average delay values at U-turn with median storage lanes

Flow on the opposing approach (vph)	Average delay for different U-turn percentages (sec/veh)				
	10%	**20%**	**30%**	**40%**	**50%**
600	0.34	0.63	1.06	1.59	1.89
900	0.33	0.75	1.25	1.96	2.89
1200	0.34	0.89	1.35	2.42	3.29
1500	0.37	0.86	1.61	2.32	3.89
1800	0.45	0.98	2.16	3.69	7.40
2100	0.5	1.27	3.02	5.84	11.11

Gap and lag acceptance input data were used from observations of site-1.

The opposing flow was varied from 600 to 2100 vph and the percentage of turning vehicles was varied from 10% to 50% in order to obtain delay values for wide range of traffic conditions.

In general, the inclusion of median storage lane decreases the average total delay for the advancing approach. The reason for this decrease in delay is that the storage lane provides storage space for turning vehicles. As a result of this, through vehicles on the major road are no longer conflicted by U-turning vehicles.

The blocked time percentage of the advancing lane during design hour was employed as criterion for providing storage lanes at U-turn median opening [3]. A proper geometric design and the necessary calculations of the median storage lane were provided in the U-SIM program [3].

9. Conclusions

The main conclusions obtained from the present study are summarized below:

1. An increase in the U-turning percentages of the opposing approach was accompanied by decrease in the delay time of U-turn vehicles in the advancing approach.
2. Gap forcing driver behavior may occur at the median U-turn. This behavior noticed to have important effects on the traffic simulation and driver behavior at this location at design peak hours, which affects on safety, and traffic performance. Gap forcing sub-model was found to be important to consider in the U-SIM model. Turning delay values and queue length for gap forcing flow reduced with increasing the percentage of gap forcing flow in the advancing U-turn approach that generate and increases forced delay for the through vehicles in the opposing priority lanes.
3. The total delay, the average delay and average queue length per vehicle increased non-linearly with increase in flow levels.
4. The U-turn maneuver is more sophisticated than the left turn maneuver and the driver need more gap acceptance values to accomplish the U-turn movement.

10. Recommendations for Further Work

In view of the above conclusions and within the constraints of the present research, the following recommendations were formulated:

1. Many locations needs construction of U-turn median opening to improve the traffic operations and maneuvers, thus using the developed (U-SIM) model [3] for analyzing, evaluation and improvement the U-turn sites with the observation of critical acceptable gaps is very important and necessary.
2. There are still many factors that influence the traffic performance of U-turn movements along the road links, such as considerations of heavy vehicles, effect of pedestrian movements, environmental conditions. The structure of the developed model (U-SIM) is wide flexible to consider these factors.
3. Further work is required for considering wide range of (U-SIM) model applications.

11. References

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