Suggested Safe Design for U-turn under Different Levels of Flow

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Abstract

Nowadays, a lot of accidents occur at U-turn spreading at different types of roads in Al-Najaf city. Moreover, the most sever congestion also has been seen in these U-turn during peak hours. Therefore, this study has focused on studying the characteristics of these U-turns in terms of flow for different movements for each site. The manufactured vantage point has been made to capture the weaving movement along these sections using video camera. Simulation model called S-Paramics has been used after calibrating it with filed data collected from several U-turn sites. The simulated model has been used to select the best location for the U-turn regarding to the nearest access point. The results show that the distance should be not less than 300m in order to avoid congestion. In addition, new improvements have been suggested to correct violated behaviors of drivers.

Keywords: U-turning vehicles, S-Paramics, Capacity U-turn, Driver behavior.

الخلاصة

مؤخرا عدد من الحوادث تحدث في الاستدارة نوع U المنتشرة في انواع مختلفة من الطرق في مدينة النجف الاشرف. علاوة على ذلك اغلب الازدحامات القاسية قد شوهدت في تلك الاستدارة خلال ساعات الذروة. لذلك هذه الدراسة قد ركزت على دراسة الخصائص هذه الاستدارة بمصطلح الجريان لكل موقع. نقطة مراقبة مصنعة تم عملها للحصول على الحركات المتماوجة باستخدام الكاميرا الفيديويه. برنامج محاكاة يدعى برامكس قد تم استخدامه بعد معايرته ببيانات حقليه من تلك المواقع حيث استخدم البرنامج في فحص اختيار افضل موقع بالنسبة للاستدارة من موقع اقرب طريق فرعي. النتائج اظهرت ان هذا الموقع يجب ان يكون على مسافة لاتقل عن 300 متر وذلك لتجنب الازدحامات وكذلك تقليل احتمالية الحوادث. كما تم اقتراح معالجات لسلوك السائق غير الصحيح في الاستدارات.

الكلمات المفتاحية: المركبات المستديرة في U، S-Paramics ، سعة U-turn ، سلوك السائق.

1. Introduction

(Al-Masaedi, 1999) developed an empirical model to find the capacity and average delay of U-turn which is located at median openings. The author developed the regression models for that purpose. In addition, he investigates the effect of various relevant factors that might affect the estimated capacity and delay.

(Kim *et.al.*, 2006) performed some simulation studies for three different cases of superstreet which is similar to median U-turn. In the first case one left turn lane and two through lanes on the major road was considered, the second case considered one left turn lane and three through lanes on the major road and the third case considered two left lanes and three through lanes on the major road. For each case microscopic traffic simulations were conducted for various traffic volumes and their performance was compared to the conventional design option. The first case was simulated for high, medium and low traffic scenarios and the remaining two cases were studied for high volumes as their application was mainly intended for sites operating under heavy traffic conditions. A 400 ft offset was assumed in the superstreet design. The traffic signal required only two phases instead of four or more phases. Phase one allowed the major road through movement and phase two allowed the major road left turn movement and the minor road through and left movements. The Simulation Surrogate Safety Assessment tool was used to perform some safety evaluations.

Unconventional intersection designs have been discussed for urban and suburban arterials by different researchers such as (Hummer, 1998; Liu *et.al.,* 2007). They found that these alternatives serve increasing through capacity and reducing conflict point and delay.

(Shihan and Mohammed, 2009) studied the effect of some factors on the performance of U-turns such as gap acceptance, opposing flow, and U-trun flow using U-SIM simulation model in Baghdad city. However, the effect of speed of opposing flow was neglected and no obvious procedure of collecting field data.

(Al-Taei, 2010) conducted empirical study on eight U-turn locations in Iraq under different flow and speed conditions. He found that these locations were characterized by high delay and accident rates. The author also investigated the gap acceptance for left turning vehicles. However, this study has several limitations such as absence of clear methodology of collecting field data and the information of these data.

Pirdavani *et.al.,* 2011) reported that simulation models were adopted to test different scenarios of using unconventional intersections using RTUT. These studies have concluded that unconventional intersections are better than signalized intersections in terms of reducing delay and conflicting points.

(Al-Jameel, 2014) conducted field observation to some U-turns in Al-Najaf city. The field results have been employed to calibrate and validate the S-Paramics model, simulation model. This model indicates how high effect of opposing flow on the U-turning flow is. Moreover, he measure the distance between the U-trun location and the access location. The author showed that these distances were not suitable. However, he did not suggest the optimum distance for each case in his study.

2. Method of data collection

There are different methods of collecting data ranging from manual methods to more sophisticated methods using loop detectors and intelligent cameras.(Garber and Hoel, 2009) reported the most important methods for data collection using the most modern methods is important; however these methods, such loop detectors, are absent from our system here in Iraq. In addition, some traffic facilities need special methods, such as U-turn, looking for more specific data. For U-turn, there is a specific technique to capture more traffic characteritics such as class, flow, through vehicles, left-turning vehicles and geometric design for such facility.

In light of the above, video camera has been adopted; however, there is no suitable vantage points such as footbridge and bridge. Therefore, a manufactured vantage point has been made consisting from steel structure with 4m height carrying by single truck as indicated in Figures 1. This provides vantage point with 5m in height.

This manufactured vantage point provides more flexibility in collecting data from different sites as indicated in the figure. Moreover, the security permission obtaining from different security agents plays important role in facilitating data collection stage.

3. Selected sites for data collection

According to the nature of our study, several sites have been selected in Al-Najaf city. These sites have been selected according to the type of roads under study. Five sites have been chozen, see Figure 2, as following:

1. U-turn infront of main Gate of Kufa University.
2. U-turn infront Al-Adala quarter.
3. U-turn facing Al-medina Al-Maaya
4. U-turn opposing new Al-Najaf studim.

Figure 1 Manufactured vantage point.

3. 1 U-turn infront of main Gate of Kufa University

This U-turn is from the congested U-turn in Al-Najaf city. It is located on Kufa-Najaf road in front of main gate of Kufa University as demonstrated in Figure3. The main movements in this U-turn as demonstrated by Figure 3. The peak hour volume is about 3400 veh/hr just per Najaf-Kufa direction. Whereas, the Kufa-Najaf direction volume is 3700 as indicated in Table 1. This could be attributed that most of trips coming from Al-Najaf direction (i.e. 70% from all trips coming towards Kufa University) as reported by (Al-Jameel and Kamel, 2016).

Figure 2 U-turn selected sites under study.

According to field observations, long queue of vehicles in the direction of Najaf-Kufa due to high flow of turning vehicles (Movement No.3 as indicated in Figure 3) in this turn in addition to high flow of pedestians (students) crossing this road. In addition to long queue which may reach up to 400m, the turnning vehicle may occupy two lanes which block the through vehicles.

Figure 3 U-turn movements in fornt of Kufa University gate.

Table 1 Data for Kufa University site.

Time (AM)	Flow No.1	Flow No.3	Flow No.4
07:00-07:15	1384	344	1928
07:15-07:30	1444	360	2388
07:30-07:45	2052	780	2896
07:45-08:00	2276	1100	2572
08:00-08:15	2344	956	2080
08:15-08:30	2260	916	2232
08:30-08:45	2428	664	1852
08:45-09:00	2244	688	2228

Figure 4 demonstrates the relationship between the turning flow with the opposing flow (i.e. Flow No.3 and Flow No. 4). However, this flow indicates floactuting in turning flow with the opposing and can n't give clear picture for this relation.

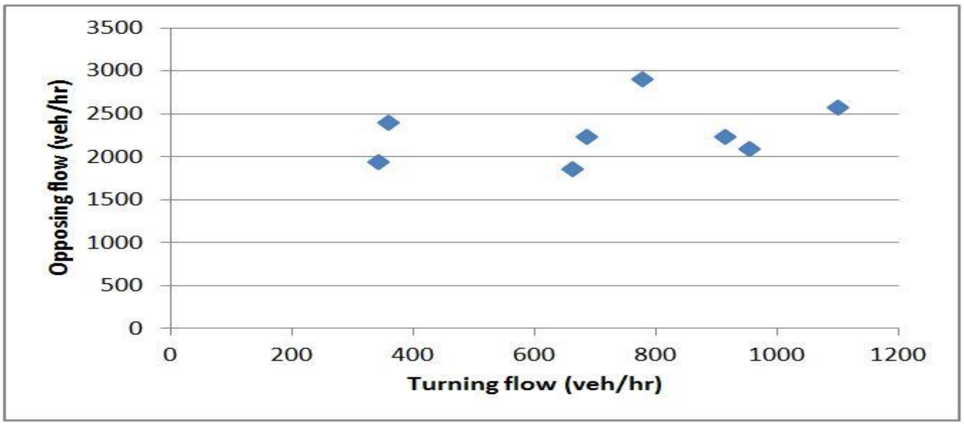

Figure 4 Comparison opposing flow with turning flow in U-turn.

3. 2 U-turn infront of Al-Adala quarter.

This site has been characterised by locating on main road with traffic flow up to more than 4000 veh/hr and design speed about 120km/hr. This U-turn is from the heaviest U-turn in traffic because most of vehicles coming from Al-Gadeer, Al-Forat and Al-Adala quarters going to the Kufa university mainly use this U-turn (see Figure 5). This figure indicates the U-turn movement which has been captured through this study. The absence as mentioned above leads to use the manufactured vantage point.

This road consists of two direction; each direction consists of three lanes. The width of each lane is 3.65m with median width of 3m. The Airport road (ring road) suffers from high congestion especially in the morning peak along the year except in Summer. This is due to the effect of Kufa university which attract a lot of trips coming from Al-Najaf city. The data have been collected for 90minutes from 7:30 AM to 9:00 AM during the peak hour on 22 March in 2017. This was on Wednesday. The collected data has been demonstrated in Table 2 for the movements as indicated in Figure 5.

Figure 5 Al-Adala U-turn movement.

According to collected data from this U-turn, the peak hour of this site starts at 7:30 to 8:30 AM. The combination of both movement 1 and 2 is up to 4450 veh/hr which is the most cogested case at this road. The queue at this case may reach up to more than 100m in length.

One of the important issues which could be noticed clearly from the field data is the existence of MTR and Motorcycle as indicated in Tables 2. The characteristics of such vehicles are unsafe and slow than other traffic mix. Traffic police reports that these vehicles my involve directly or indirectly in the traffic accidents.

Table 2 Data for Al-Adala U-turn.

Time	Flow No.1	Flow No.2	Flow No.3
07:30-07:35	1884	516	2676
07:35-07:40	2016	720	3492
07:40-07:45	2388	720	3456
07:45-07:50	2712	1008	3540
07:50-07:55	2268	1080	3612
07:55-08:00	2544	1008	4200

08:00-08:05	2880	1104	3660
08:05-08:10	2544	1296	3912
08:10-08:15	3012	1416	4032
08:15-08:20	2856	1572	3252
08:20-08:25	2772	1152	3744
08:25-08:30	2664	1092	3060

Figure 6 shows that the maximum turning flow could be up to 1400 veh/hr with opposing flow reaches 4000 veh/hr. However; long queue could be seen in the direction of turning vehicles.

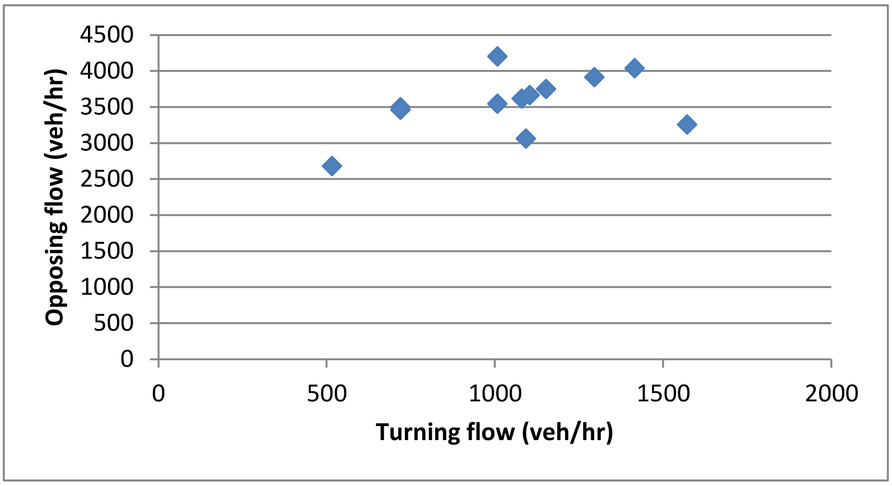

Figure 6 Comparison opposing flow with turning flow in U-turn.

3. 3 U-turn facing Al-medina Al-Maaya

This U-turn is located on major road (Al-Hizam Al-Akter) as indicated in Figure 7. Data have been included four movements as shown in Figure 7. This site also represents another congested U-turn location as demonstrated in Figure 8. Long queue of vehicles has been observed in the field leading to occupying two lanes from the three-lane section at which this U-turn is located.

This road consists of three lanes in each direction. The duration of this video recording is 120 minutes as indicated in Table 3. The most congested U-turn case has been selected. The time from 1:15 PM to 3:00PM has been selected as the time of survey for such traffic congestion on 28th March in 2017. The day of survey was Wednesday.

Figure 7 Al-medina Al-Maaya U-turn movements

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Figure 8 Al-medina Al-Maaya U-turn congestion case.

Table 3 Data for Al-medina Al-Maaya U-turn.

Time	Flow No.1	Flow No.2	Flow No.3	Flow No.4
1:45-1:50	1008	1656	1056	72
1:50-1:55	1068	1632	1356	60
1:55-2:00	876	1632	1404	60
2:00-2:05	1068	1608	1044	24
2:05-2:10	1320	1884	948	60
2:10-2:15	996	1824	888	48
2:15-2:20	1032	1800	996	60
2:20-2:25	1140	1836	1008	24
2:25-2:30	888	2004	960	48
2:30-2:35	1020	1440	1272	12
2:35-2:40	1104	1584	1140	36
2:40-2:45	948	1692	1476	36

In addition, Figure 9 indicates how the influence of turning flow on the opposing flow and vice versa. As turning flow increases up to 2000 veh/hr, the maximum opposing flow couldn't exceed 1000veh/hr.

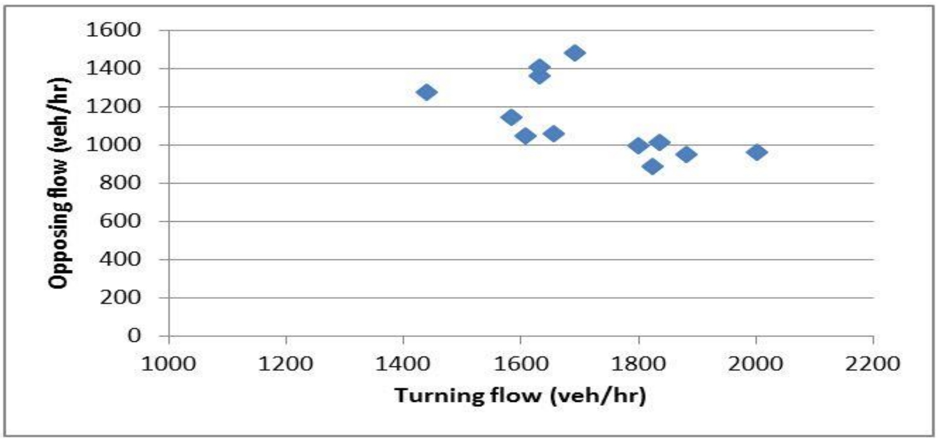


Figure 9 Comparison opposing flow with turning flow in U-turn.

3. 4 U-turn opposing new Al-Najaf studim.

This site is located on Najaf-Kerbala road close to new Al-Najaf studim. Figure 10 shows the location of this U-turn. The geometric design of this road could be summarized by three lanes in each direction with median as indicated in Figure 10. Data have been collected using video camera for 60 minutes starting from 10:00 AM to 11:00 AM on 28 March in 2017 as shown in Table 4.

Figure 10 Movements of U-turn opposing new Al-Najaf studim.

Table 4 Data for U-turn opposing new Al-Najaf studim

Time	Flow No.1	Flow No.2
10:00-10:05	408	1956
10:05-10:10	396	1884
10:10-10:15	444	1800
10:15-10:20	540	2076
10:20-10:25	564	1716
10:25-10:30	444	1932
10:30-10:35	360	1860
10:35-10:40	420	2088
10:40-10:45	360	2004
10:45-10:50	396	1920
10:50-10:55	348	1800
10:55-11:00	420	1908

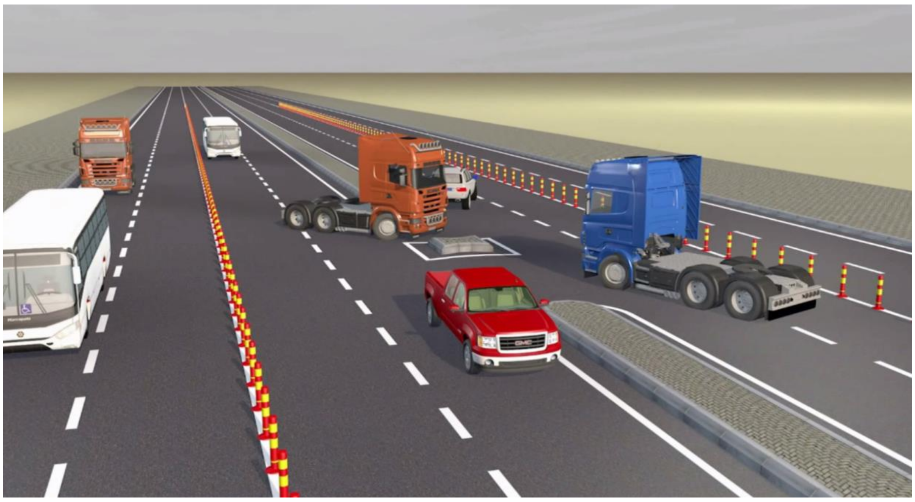
3.5 Wrong turning

Through comprehensive observations within the city, it was found that wrong turning movements which are the turning from the most right lane to the left through U-turn. These turning vehicles were observed in three lanes, blocked the through vehicles in both first and second lane as indicate in Figure 11. This phenomenon has been observed on most U-turn here in Najaf city and other cities. This behavior creates long queues and blocks the road completely.

To solve such problem, there are several methods of solving ranging from regulation such as penalizing violated drivers by charging them. Another method is regarding to the geometric design such as putting plastic cub for more than 100m as indicated in Figure 12.

Figure 11 Turning vehicle from right lane (lane no.1) to do left turning.

a. plastic barrier for turning vehicles.



b. plastic barrier for through vehicles.

Figure 12 Suggested plastic barrier to mitigate congestion.

4. S-Paramics program

S-Paramics is a microscopic simulation model. This model has been proved to represent the traffic characteristics more realistic. It is a micro-simulation model which has been proved to be the most effective tool to represent different traffic facilities such as merging, weaving and intersection (Al-Jameel, 2016).

4.1 Building model

From the important step of simulation is to build the model. The first step of building the model of U-turn facility could be summarized as selecting the suitable nodes and then connecting them by suitable links. These links have some characteristics should be determined accurately such as the type of road and the geometric design for these links. Finally, the origin-destination matrices have been achieved in line with what has been observed from the collected field data. Figure 13 indicates the features of S-Paramics. This figure indicates modeling one of the current U-turn (Adal U-turn). In this figure also the three dimensional vehicles appear in the animation of this program.

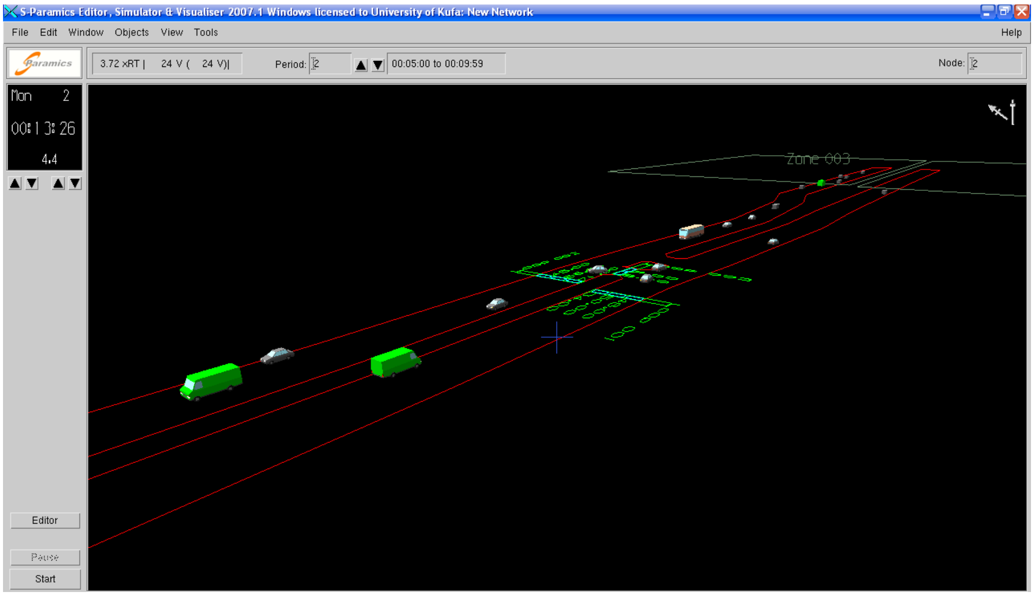


Figure 13 Graphical representations of S-Paramics.

4.2 Model calibration

Calibration is the process of adjusting the parameters utilized in the model to make sure that it reflects the input data (SIAS, 2009). The main important thing of calibration is to mimic the reality. This could be achieved by the similarity between graphical representations between the input data from field data with the output with model for the same data as indicated in Figure 14 for one direction flow of Alada U-turn. The figure shows good consistency between simulated and field data.

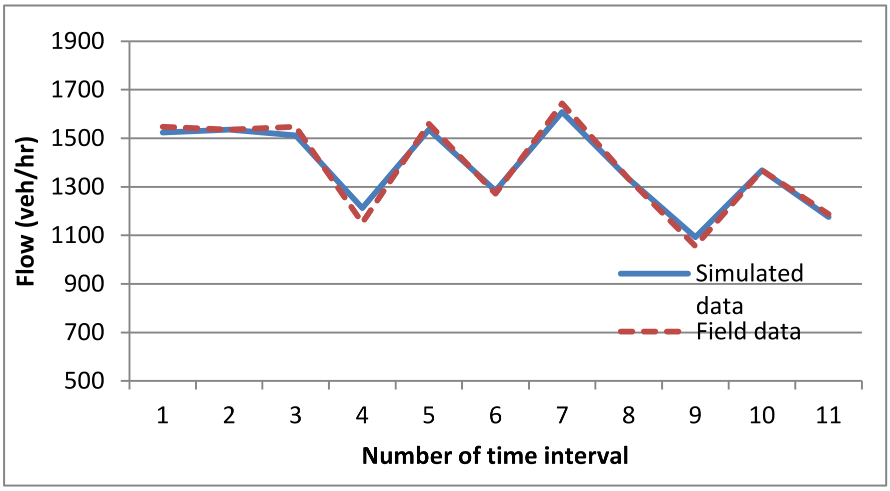


Figure 14 Comparsion between simulated and field data.

4.3 Model applications

After testing the validaty of the model, different scenarios could be implemented because it represents the reality. A lot of scenarios could come up with someone who could image and know how drivers behave in reality. Referring to the observations for several days in the field and long time for the videos capturing from these sites one could conclude that the huge number of turning vehicles always creating bottleneck for the through vehicles for both directions connecting by U-turn. Therefore one of the suggested solution or scenario is to separe the turning vehicles from the through vehicles by either plastic separation cones or even by concrete kerb as indicated in Figure 15.

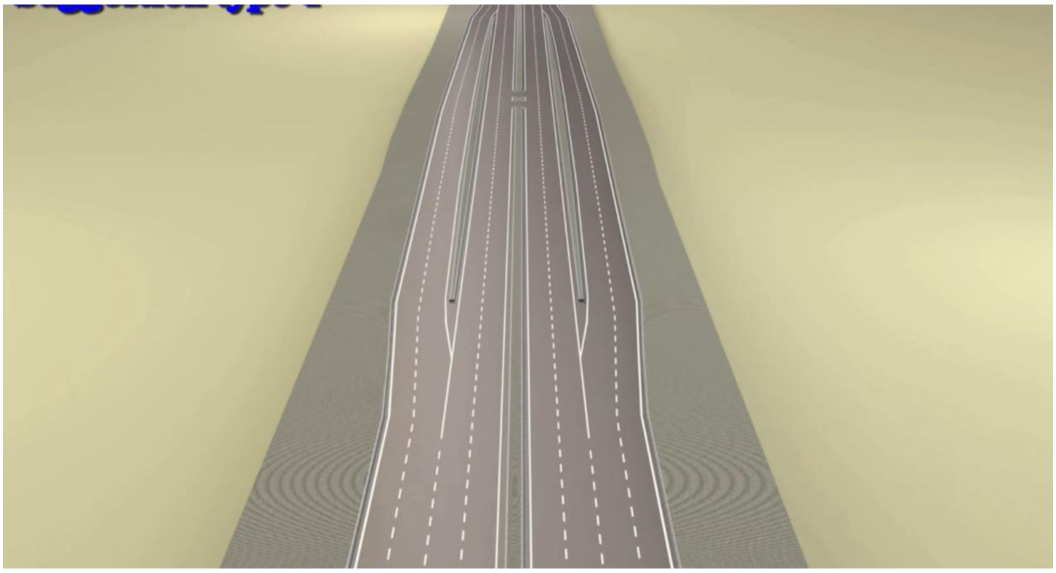


Figure 15 Suggested new design for U-turn.

The main advantage of this figure is to prevent through vehicles from blocking by turning vehicles. The dimension of the tapered shape is about 150m for each direction from the middle of shape or from the widest point of taper section. After modeling the above case using S-Paramics, the results show that using such scenario leads to increasing both flow and speed for the direction coming from airport toward Kerbalaa as indicated in the figures below.

Figure 15 demonstrates how flow increasing with improved design than the current design. This could be attributed to separate through vehicles from turning ones. Similarly, the difference between speeds for improved and current design indicates at Figure 16. Consequently, this improvement for geometric design in terms of applying simulation model provides high flow with high speed, i.e increasing the capacity of the U-turn facility. The same for other improved movements has been found through the output of the simulated model and through visualizing the animation case.

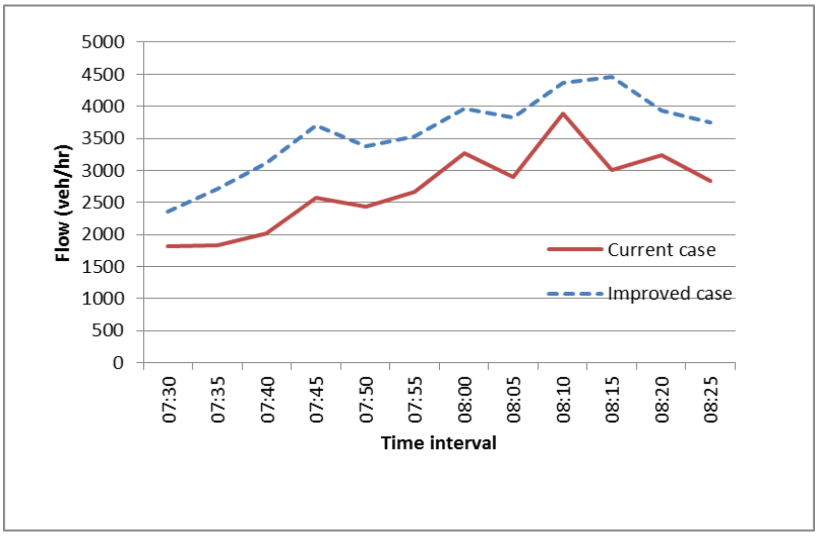


Figure 15 Comparison between flow in current and improved cases.

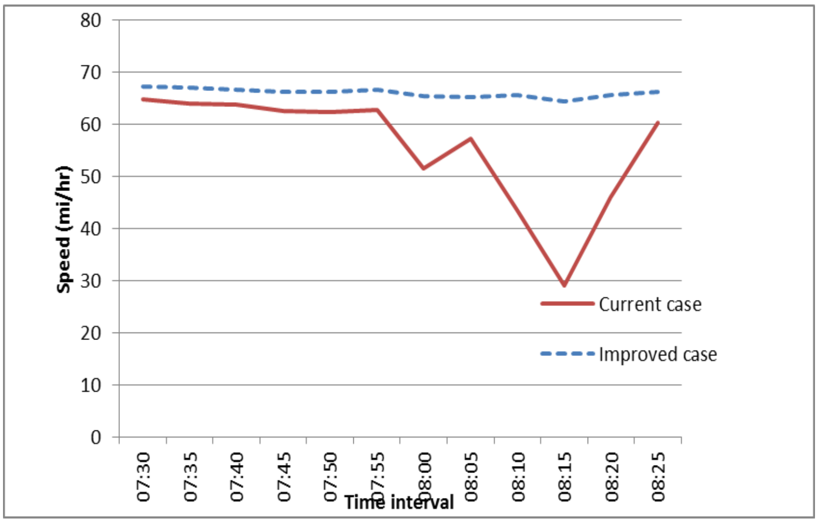


Figure 16 Comparison between average speed in current and improved cases.

4.4 Select the optimum location for U-turn

Another important scenario has been implemented by S-Paramics. This scenario could be summarized by changing the distance between the location of U-turn and the access point starting from 50m to 350m as indicated in Figure 17.

After building the model of this scenario using the S-Paramics package as indicated in Figure 17, seven scenarios have been selected. These include using different distance between the access point and U-turn with the same flow in major road, the data taken from the field of Aladal U-turn, and 500 veh/hr flow for the access point each five minutes. Moreover, the locations of loop detectors which have been installed to collect data from the simulation model are still with same location for all cases.

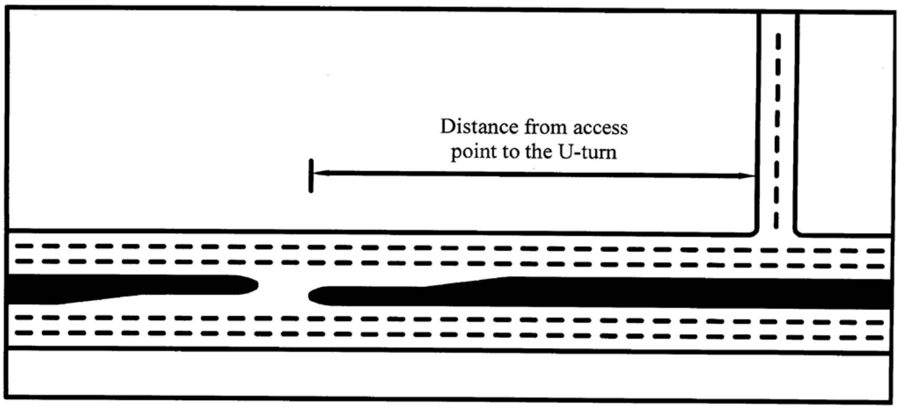


Figure 17 Distance from access point to the U-turn.

The results indicate that as the distance increases, the flow increase too as demonstrated in Figure 19. Generally, the distance with 50m is the lowest value of flow and the 350m distance represents the highest flow. The effect of this distance is so clearly appears in both 50m and 100m as shown in Figure 18 but this effect is less in the distance of 150m and the above values up to 350m. This could be attributed to high interaction at 50m and 100m. This interaction leads to high impedance for the traffic stream in the major road by turning vehicles coming from the access points in addition to the turning vehicles coming already from the major road. Those drivers strive to find the suitable gap in the major road not only to cross one road but to cross three lanes in order to make their turning.

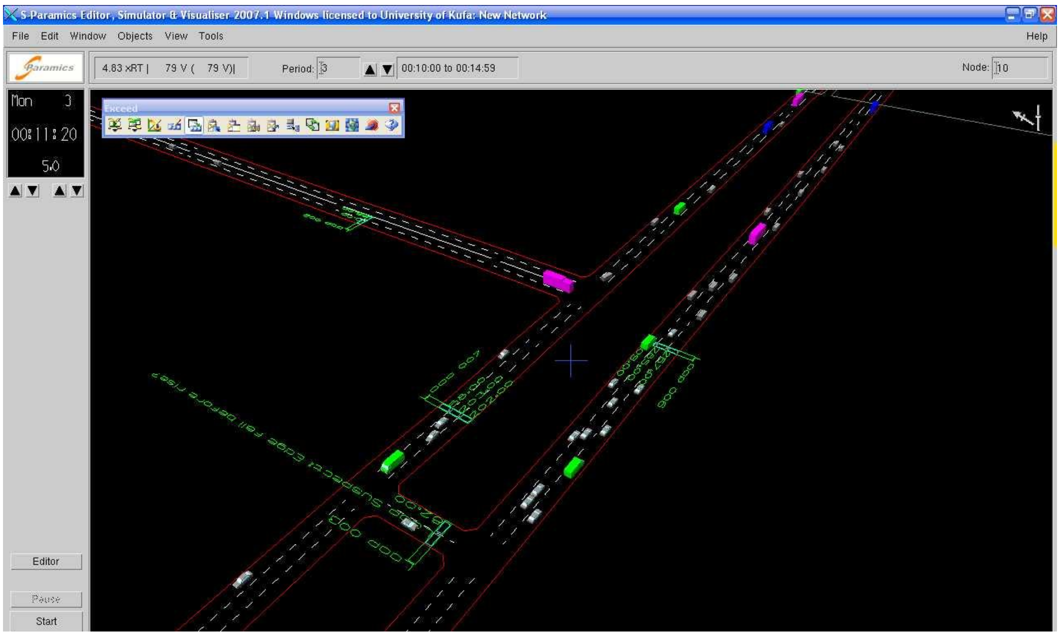


Figure 18 Building U-turn model using S-Paramics.

On the other hand, another characteristic has been also tested by the simulation model which is the speed at different distances, too? However, the speed doesn't show significant effect of speed on changing distance as indicated in Figure 20.

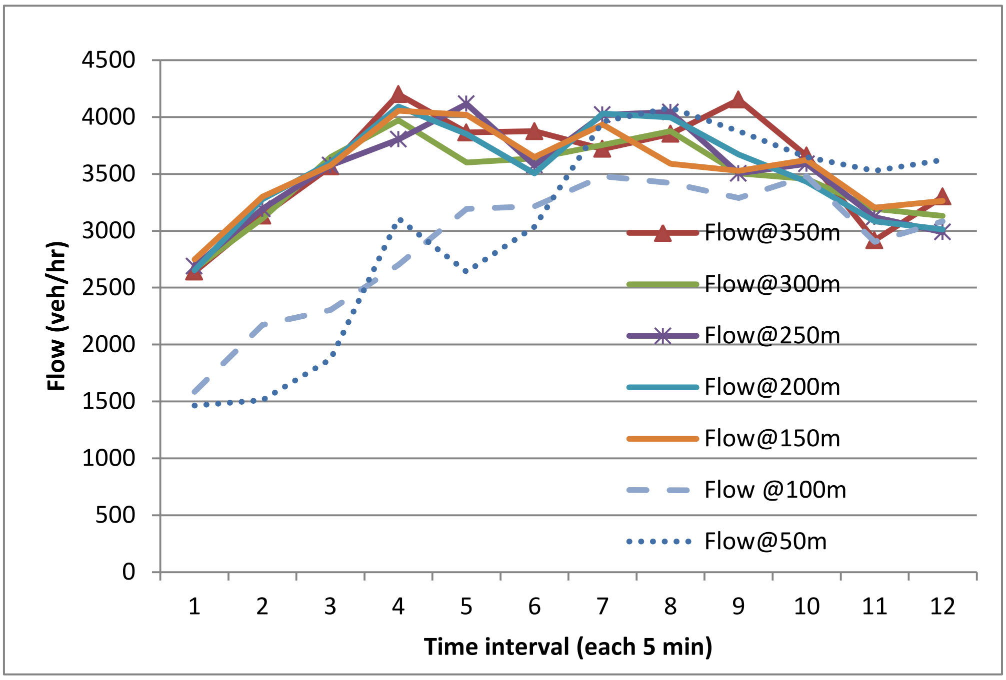


Figure 19 Effect of changing distance of access point on the flow of major road with U-turn.

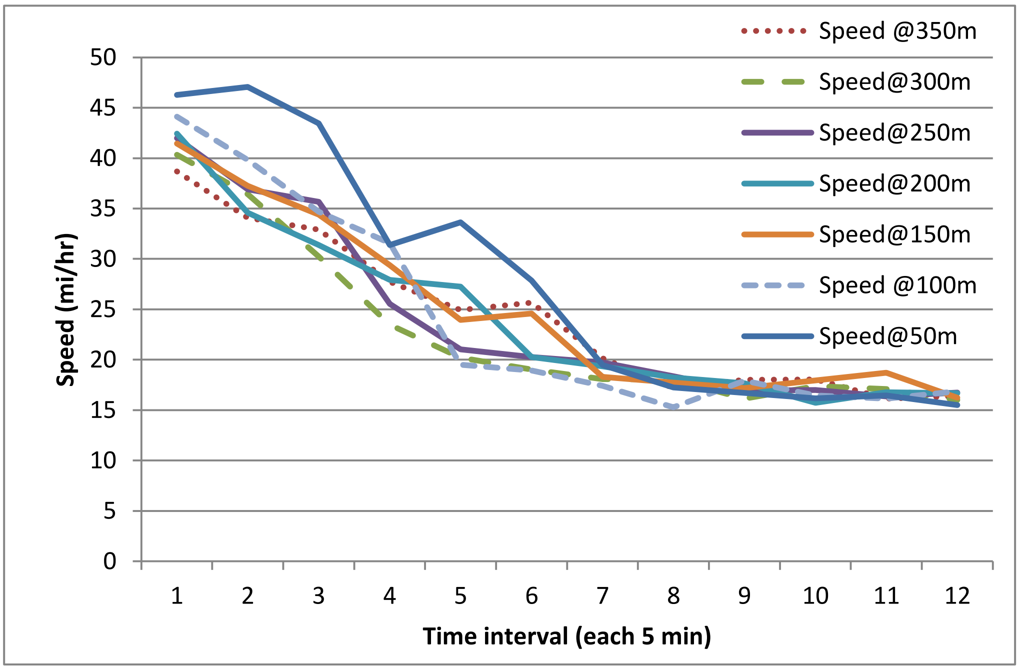


Figure 20 Effect of changing distance of access point on the speed of major road with U-turn.

5. Conclusions and Recommendations

The main conclusions that have been come up with this study could be summarized in the following main points:

1. The collected data indicate that high turning vehicles in the existing U-turn creating bottleneck along all road with different road types. Data have been collected from U-turn in major urban road, arterial and collector roads.
2. U-turns in Al-Najaf city are one of the high accident frequencies even there is no accurate documentation for the traffic accident through the whole city. This study

indicates that about 30% of drivers don't use the left light signal during the turning.
3. The use of simulation model (S-Paramics) in such traffic facility helps more in studying driver behavior in more details to investigate the applicable solutions.
4. The results of using improved design show high capacity for this section than the current design. This could be attributed to high average speed and average flow as indicated in the output of the S-Paramics.
5. The optimum location for the U-turn is 350m away from the access point for road with average speed of 100km/hr or more.
6. It was observed violated turning behavior from the right lane or the slowest lane. Therefore, this study suggests using plastic barrier to mitigate congestion.
7. The main recommendation of this study is to extend this study to include other different types of U-turn. Moreover, there is a need for accurate system to record the accident in these U-turns.

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