

Evaluation of Al-Najaf Hospital Intersection Performance Using Simulation model: Case Study

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Abstract

Traffic congestion is a widely spreading problem through the world. It is mainly observed around intersections in urban areas. In this study, Al-Najaf Hospital (Ibn Blal) intersection has been evaluated because it is considered the congested T-intersection on Kufa-Nafa road. This T-intersection suffers from high congestion especially in the morning peak. This could be due to a lot of centers of activities (trip generation and attractive) on that road such as University of Kufa, four hospitals and other facilities. Although the Highway Capacity Manual (HCM) 2000 suffers from several shortcomings and limitations, it is used widely in the evaluation of intersections in Iraq. On the other hand, simulation models have been proved to be accurate tools in the evaluation of intersections. Therefore, a simulation model (S-Paramics model) has been used to assess the performance of the current intersection. Then, the simulation model was calibrated with field data. Data was collected from the intersection using video camera installing over Al-Najaf Hospital building. The results of this study show that the developed model clearly mimics the reality. Then, different alternatives have been implemented using the developed model. Consequently, the construction of an overpass coming from Najaf-Kufa road towards Al-Sahlaa road is the best alternative with protecting U-turn.

Keywords: T-intersection, traffic simulation, protected U-turn.

الخلاصة:

الازدحام المروري هو مشكلة واسعة الانتشار في كل انحاء العالم. غالبا ما يلاحظ الازدحام في التقاطعات في المناطق الحضرية. في هذه الدراسة، تم تقييم تقاطع مستشفى النجف (ابن بلال) كونه من التقاطعات المزدحمة على طريق كوفه-نجف. هذا التقاطع الذي هو بشكل T-intersection يعاني من ازدحام خصوصا في الذروة الصباحية كون طريق الكوفة-نجف يمثل مركز فعاليات كثيرة كجامعة الكوفة واربع مستشفيات ووسائل خدمية اخرى. رغم ان مواصفات الطرق والسعة الامريكية HCM تعاني من نواقص و محددات كثيرة في تقييم التقاطعات الا انها تستخدم بصورة واسعة في تقييم التقاطعات في العراق. من ناحية اخرى، نماذج المحاكاة (Simulation Models) قد اثبتت بانها وسائل كفوءة في تقييم التقاطعات. لذلك تم استخدام نموذج (S-Paramics) في تقييم التقاطع قيد الدراسة. بعد ذلك نموذج المحاكاة (Simulation Model) تمت معايرته باستخدام بيانات حقيقية تم جمعها باستخدام كاميره فيديو وضعت فوق بناية مستشفى النجف الاهلي. نتائج الدراسة اظهرت بان النموذج المطور يمثل الواقع بصورة واضحة. لذا تم دراسة البدائل المختلفة بالنموذج المطور لزيادة كفاءة التقاطع. وكنتيجة لذلك فان انشاء مجسر يربط بين طريق كوفه-نجف وطريق السهلة مع استدارة محمية هو البديل الافضل.

الكلمات المفتاحية: تقاطع بشكل حرف T، نماذج المحاكاة المرورية، الاستدارة المحمية.

1. Background

An intersection is defined as an area shared by two or more roads which may be joined or crossed (Garber and Hoel, 2009). A system of signalized intersection is a critical element in the smooth operation of both arterial and urban street facilities. Unsignalized intersections exist widely in urban traffic system. Traditional procedures such as the HCM were proved to be inadequate to capture the system impacts of queues and oversaturated conditions (Bloomberg and Dale, 2000). The HCM 2000 assumes that the signalized intersections in central business are relatively inefficient as compared to those in other locations. Whereas, Rahman *et. al.*, (2008) study the effect of taxi drivers on the capacity of signalized. The results indicated that the capacity increases by 20% as the proportion of taxi drivers increases from 0 to 100%. This could be attributed for increasing the percent of familiar drivers.

Perez-Cartagena and Tarko (2005) reported that the HCM 2000 suffers from several shortcomings such as there are doubts by some professionals used the HCM about the results produced by this manual. They refer that the source of error may be

due to using default values while equations to calculate delays are too sensitive to these inputs and they amplify the inaccuracies. Cheng et al., (2005) indicate that the optimal cycle length reported by the HCM 2000 is inaccurate which results in the minimal intersection delay.

Wu *et. al.*, (2005) studied the interactions between vehicles on different roads on capacity of T-shaped intersection system using cellular automata model. However, the accuracy of the car-following model which is the core of this simulation package may be unacceptable to a certain limit (Wang, 2006).

Yang *et. al.*, (2012) estimated the operational impacts of left-turn waiting areas at signalized intersections using the VISSIM simulation technique. A procedure was proposed to model capacity of single left-turn lanes with waiting areas in VISSIM. Using data collected from 7 different sites, the VISSIM simulation model was calibrated and validated. The simulation results of the calibrated VISSIM model were compared to field measured capacity, as well as the capacity estimated using the analytical model developed by the same researchers. The calibrated VISSIM simulation model yields a Mean Absolute Percent Error (MAPE) of 8.28% for the exclusive left-turn lanes, indicating that VISSIM provides reasonable capacity estimates for left-turn lanes with waiting areas at signalized intersections. Based on the calibrated VISSIM simulation model, the capacity for left-turn lanes with waiting areas with different storage capacity was compared with the scenario for which the left-turn waiting area is not installed. The results show that the use of left-turn waiting areas could increase the capacity for the left-turn movement, and the capacity gains would increase with the increase in the volume of the left-turn waiting areas.

In the light of above, there is a need for adopting new technique which is less limitations from current mathematical model (i.e., HCM 2000). On the other hand, simulation models have been proved to be the best tools to evaluate the intersection performance (Bloomberg and Dale, 2000, Oricchio, 2007, Cunto and Saccomanno, 2008, D'Ambrogio *et. al.*, 2009 and Ding *et. al.*, 2010). Therefore, this tool has been recently used to evaluate intersection such as S-Paramics. Consequently, this study model has used S-Paramics simulation model to test different alternatives to improve T- intersection. Al-Najaf Hospital Intersection has been used as a case study.

2. Data collection

Data has been collected from field using video camera. This Sony video camera has specific characteristics such high storage capacity (80 GB) with long life battery (battery charging lasts for 10 hours). This camera has been installed over the building of Al-Najaf Hospital. This vantage point provides a good quality for collecting data. With full support from Al-Najaf Hospital' staff Sony camera was installed there. The time of recording started from off-peak (7:00 AM) till another off-peak (10:00 AM) via peak hour period.

More than 5 continuous hours have been collected from this site starting from off-peak period (7:00)AM through peak hour (7:40-8:40)AM till another off-peak (12:00)AM. This data has been collected in the 1st of April 2013. Another set of data was collected in 2012. Figure 1 shows the traffic congestion in Al-Najaf Hospital Intersection.



Figure 1 Traffic congestion in Al-Najaf Hospital (Ibn Blal) Intersection.

3. Data analysis

The HCM 2000 has been used to analyze the data and find the performance of this intersection. The HCS 2000 has been adopted to find the performance of this intersection. Several scenarios were tested such as un-signalized and signalized T-intersection.

The results of analysis show that for both un-signalized and signalized scenarios unacceptable performance, that is, the level of service is F. Therefore, the results indicate that T-intersection could not support this level of traffic even there is a range of inaccuracy in the HCS 2000.

4. Developing and calibrating a simulation model

As discussed in the introduction, simulation models have been proved to be the best tools for evaluating signalized intersection because of complexity of driver's behavior at these locations. Moreover, simulation models mimic the reality and different alternatives without any cost and disturbing the traffic (Wang, 2006). Therefore, in this study, a simulation model was firstly built for Al-Najaf Hospital Intersection. Then, data was collected using video camera. Different types of data were collected from these videos such as through, left and right movements for each approach. Then, data has been extracted from video each 15 minutes for each movement by determining the type of each vehicle such as passenger car, truck and bus.

Simulation model has been used to represent this intersection. Loop detectors have been put in the developed model in order to determine some traffic characteristics such as flow and speed for each link. Moreover, data for each lane could be obtained from the loop detectors. After building the simulation model with all its nodes and links, the simulation model has been verified by visualization. Then, a set of field data has been used to calibrate the simulation model. Two factors have been used for achieving calibration such as time headway and gap space. More iterations have been implemented to get consistency between field and simulated data as shown in Figure 2. The optimum values which have been selected to get close results from simulated model were 0.5 sec as time headway and 1m as minimum gap space. Consequently, the simulation model has been adopted to represent the reality.

After graphical representation between the simulated and field data outputs, another methods of assessing the difference between simulation outputs and field data in terms of calibration, these are statistical tests such as:

- The correlation coefficient (r) is considered a popular goodness-of-fit measure used to give an indication of the strength of the linear association between the simulated and field data as expressed in the following equation (Hourdakis *et al.*, 2003):

$$r = \frac{1}{n-1} \sum_{i=1}^n \frac{(\text{Val}_1 - \overline{\text{Val}_1})(\text{Val}_2 - \overline{\text{Val}_2})}{\sigma_{\text{Val}_1} \sigma_{\text{Val}_2}} \dots\dots\dots(1)$$

Where;

$\overline{\text{Val}_1}$ is the mean value of simulated data.

$\overline{\text{Val}_2}$ is the mean value of observed data.

σ_{Val_1} is the standard deviation for the simulated data.

σ_{Val_2} is the standard deviation for the observed data.

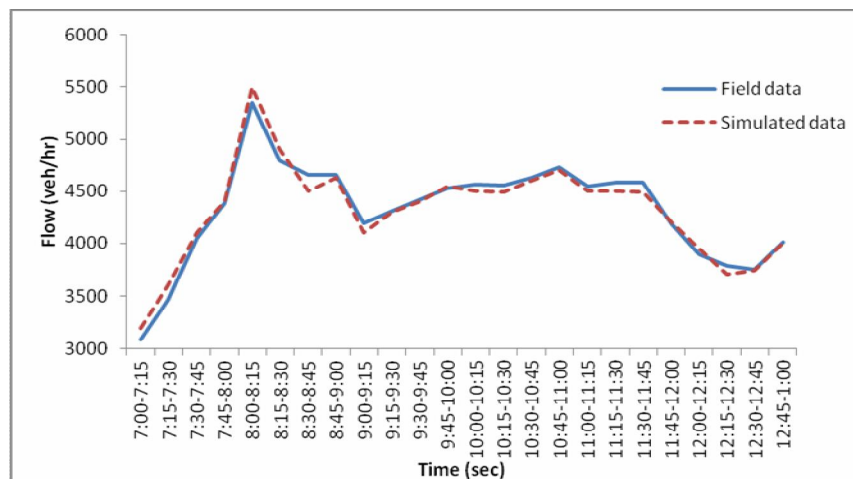


Figure 2 Observed and simulated flow data for Ibn Blal Intersection.

- Theil's Inequality Coefficient has been considered to be more sensitive and accurate than the r. It can be determined by the following equation (Wang, 2006 and Hourdakis *et al.*, 2003):

$$U = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^n (\text{Val}_1 - \text{Val}_2)^2}}{\sqrt{\frac{1}{N} \sum_{i=1}^n (\text{Val}_2)^2 + \frac{1}{N} \sum_{i=1}^n (\text{Val}_1)^2}} \dots\dots\dots(2)$$

Another measure called the bias proportion (U_m), which is a measure of systematic error that can be used to determine consistent over-counting or understanding caused by an excess/loss of vehicles. It has to be obtained from decomposing from Theil's Inequality (Hourdakis *et al.*, 2003).

$$U_m = \frac{n(\overline{\text{Val}_2} - \overline{\text{Val}_1})^2}{\sum_{i=1}^n (\text{Val}_2 - \text{Val}_1)^2} \dots\dots\dots(3)$$

- The variance proportion (U_s). This can be used to measure the simulated measurements' ability to replicate the degree of variability (fluctuations) from the actual measurements (Hourdakis *et al.*, 2003).

$$U_s = \frac{n(\sigma_{Val_2} - \sigma_{Val_1})^2}{\sum_{i=1}^n (Val_2 - Val_1)^2} \dots\dots\dots(4)$$

In light of the above, the U is considered as the best measure because r suffers from not providing any additional information to the analyst as to the nature of error (difference) between real and simulation measurements. Moreover, one could investigate the accuracy of the simulated data by determining the value for each statistical test. If the value of r is close to 1.0, this represents that the difference between simulated and field data is very small. Whereas this difference is very close when the values of U, U_m and U_s approach to zero (Hourdakis et al., 2003).

Table 1 indicates that the values of statistical coefficients (r, U, U_m and U_s) are within the acceptable limits. Consequently, simulated data for current case could represent the field data.

Table 1 Calibration of the developed model with the field data.

Parameters	Flow
r	0.93
U	0.030
U _m	0.087
U _s	0.0118

According to the field data, it was found that the major problem of bottleneck coming from the u-turn down stream of this intersection. Long queue from this u-turn leads to block all movements in this intersection. Therefore, in order to solve the traffic congestion problem in this intersection, there is a need to solve u-turn problems first.

After that, the developed simulation model has been used to test different levels of flow used this intersection. Moreover, downstream u-turn has been improved by adopting new design for this u-turn. This scenario has been tested by the simulation model. It was found that the interchange indicating by Figure 3 is the best solution for this intersection. This solution includes using new type of u-turn called protected u-turn. This could be achieved by blocking all turning movements for T-intersection as shown in the above figure. So the left turn movement will be transferred into right turn and then left –turn. In addition, replacing Direct Left Turn (DLT) by Right Turn plus U Turn (RTUT) lead to reduce delay and travel time for intersections as reported by Pirdavani *et. al.*(2011).

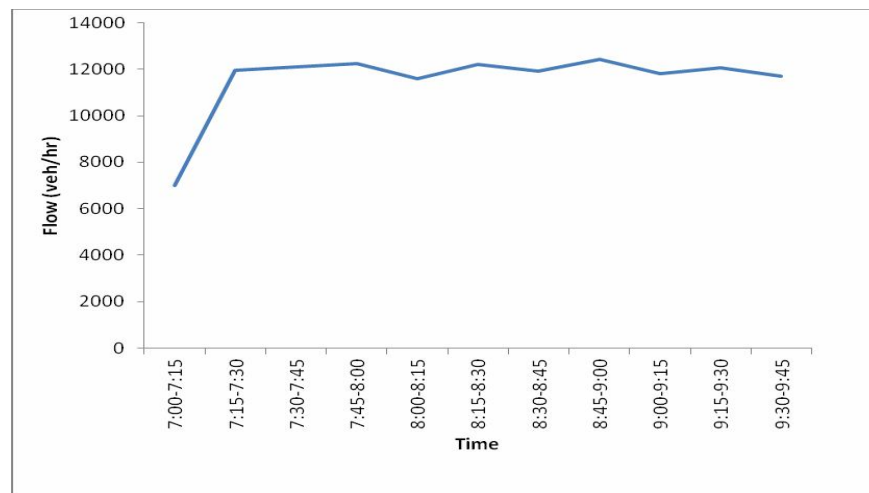


Figure 3 Simulated maximum flow obtained from the suggested overpass.

5. Discussion the results

After calibrating the simulation model of the intersection under study, the simulated model has been used for evaluating the capacity of the proposed interchange. This alternative makes improve the capacity of this intersection from 5000 veh/hr to 12000veh/hr. however, the input flow has been up to 15000 veh/hr, and the capacity did not exceed 12500 veh/hr. This is because the simulation model mimics the reality by taking into consideration the dynamic characteristics for each vehicle and the minimum gap and headway between successive vehicles. Therefore, the simulation model prevents entering vehicles under unsafe conditions such as gap less than minimum gap according to the flow and speed conditions.

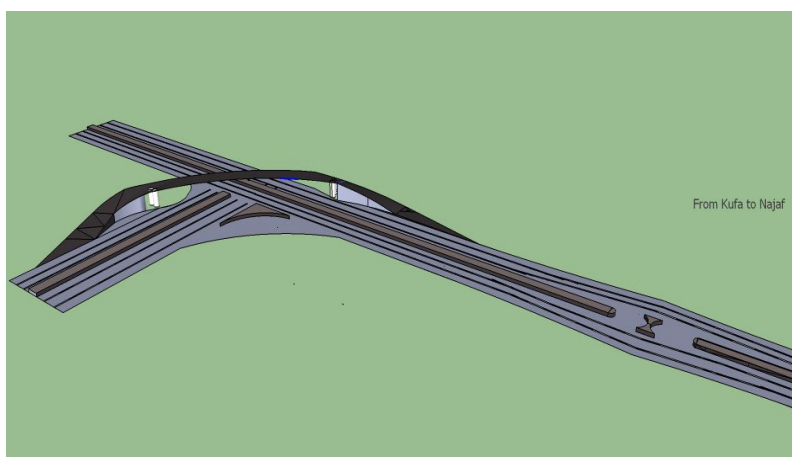


Figure 4 Suggested overpass for Ibn Bilal Intersection.



Figure 5 Simulated suggested overpass.

In the light of above, the main difference between the current method of evaluation adopting by this method and other existing methods such as the HCM 2000 is that this method depends mainly on the methodology used by a simulation model. The methodology of any simulation model could be summarized by building the case under study (T-intersection) using nodes and links. After building that model, the calibration stage could be implemented by comparison the simulation model with field data. Several runs may be needed before reaching acceptable graphical and statistical results. Moreover, the animation of simulation model could also help in the calibration process. Whereas, other methods such as the HCM depend on

deterministic values getting either from specific equations or default values. Therefore, the HCM has several shortcomings as mentioned in the section 1(Background).

6. Conclusions and recommendations

The main points that have been concluded from this study are:

1. According to field data, the capacity of T-intersection is so limited due to complex movements, especially when the intersection is located on main roads with high flow as in Ibn Blala Intersection.
2. According to the preceding studies and current study, a simulation model is the best tool to represent the behavior of the T- intersection.
3. The graphical and statistical results indicate that the S-Paramics model could mimic the reality. This depends mainly on the accuracy of collecting and analyzing field data.
4. Protected U-turn provides a suitable solution for the problem of bottleneck due to conflict movements between turning vehicles and through vehicles in the opposite direction.
5. According to the simulated model, replacing T-intersection by protected U-turn has good results in terms of reducing conflict movements and long queues of turning vehicles.
6. For the case of current T-intersection, the overpass with protected u-turn improves the capacity by three times than T-intersection. Therefore, this study recommends to change the T-intersection into protected U-turn with right and left turns.

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