Model Development of U-turn Capacity Using Simulation and Empirical Approaches

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Abstract:

In this study, both empirical and simulation approaches were used to estimate capacity of U-turn movement at median openings of divided arterials. The empirical approach using regression analysis was adopted to estimate the best form of the predictive equation for the U-turn capacity and investigate the effect of different relevant factors that might affect the estimated capacity. Simulation approach was used also to calculate capacity on the basis of the U-SIM model; this model represents the traffic performance at U-turn median openings and calculates the number of turning vehicles with respect to a different conflicting traffic stream. The results of both approaches were compared and presented in this study. A linear model was also recommended as a relationship between the average total delay of the U-turning vehicles and the conflicting traffic flow.

Keywords : *Traffic engineering; Capacity*

1.Introduction:

The major purpose of capacity modeling of U-turn median opening is to develop useful relationship between capacity and set of traffic and geometric characteristics. The developed model should be easy for practical applications and predictive under different traffic conditions. It should be mentioned that intersections are provided to facilitate traffic turning movements. As part of traffic management to improve intersection operation, some traffic movements are not permitted at some intersection locations, especially along divided arterial (1)(2). In most cases, such minor movements are accommodated at separate U-turn median openings. Compared with turning movements at intersections, U-turn movement at median openings is highly complex and risky. Normally, the speed of conflicting traffic stream is relatively high and the turning vehicle must wait for accepted gap and then turn under low speed level. Therefore, the turning vehicle needs large gap in the conflicting stream before performing the U-turn.

In fact, the little studies which contain procedures and models for estimating capacity and delay for different movements at unsignalized intersections, do not provide specific guidelines for estimating capacity and delay of U-turn movement at median openings. For this reason, an effort was made to estimate capacity and delay at U-turn median openings.

However, the operation can be considered as an interaction of drivers on the minor or stop-controlled turn with drivers on the oncoming approach of the major street in two directions simultaneously. Although the U-turn movement is more complex than right-or left-turning movements at unsignalized intersections, the general concepts and procedures developed for analyzing capacity at priority unsignalized intersections are very crucial in this respect.

2.Background:

Very little studies were available for traffic operation at U-turn median openings. Using the empirical and gap acceptance approaches, AL-Masaeid (1) identified specific guidelines for estimating capacity and delay models of U-turn movements at median openings. He found that, the capacity and delay were significantly influenced by the conflicting traffic flow, that the predictive capacity model had linear form, while the delay relationship had an exponential form. A wide difference obtained by AL-Masaeid (1) between the gap acceptance and the empirical approaches for capacity estimation.

Kimber and Coombe (3) using the empirical approach, concluded that the capacities of the nonpriority streams at T-intersections depend linearly on the flow in the relevant priority streams.

3.Methodology:

To accomplish the objective of this study, three median openings located in Baghdad City were selected. These median openings are located along divided suburban arterials and operated at capacity during peak periods . At capacity condition is defined, as the condition in which there is continuous queue of turning vehicles in the approach of the turning lane.

In this study, both empirical and simulation approaches were adopted to estimate capacity of U-turn median openings. In the empirical approach, multiple regression analysis was performed to develop an empirical relationship for estimating capacity and identifying variables that affect the estimated capacity, while in the simulation approach results of U-SIM program (4) (a micro-simulation followed to describe the vehicles behavior along the roadway that contains median U-turns), were used to calculate the capacity of

U-turn at median openings. Finally, performance of both approaches was compared. The general logic of the U-SIM model (4) starts with arrival time of vehicles generated at two streams in each lane from a headway distribution function at the time headway sub-model. The generated vehicles move along the roadway link with a predefined speed, acceleration/deceleration and lane change activities according to flow-sim and lan-chng sub-models. Assignment of turning movements of the flow generated at the advance stream occurs by the turn sub-model, with gap acceptance values representing the driver behavior generated randomly at the acc-gap sub-model. Turning vehicles will decelerates and stops according to the acceleration/deceleration sub-model at the U-turn, waiting for availability of acceptable lag/gap time values on the opposing stream. These lag/gap times are calculated according to the arrival time of each vehicle on each lane of the opposing stream. When the critical gap acceptance value for the turned vehicle is lower than the available lag/gap, then turning vehicle will accept this lag/gap according to the simulation model and exit will occur to the opposing stream according to the vehicle departure sub-model, then acceleration occurs, otherwise, turning vehicle waits to accept gap on the opposing stream. The previous is true for turning vehicles on the opposing stream in the opposing direction and representing U-turns from the two directions simultaneously. Simulation is applied per each lane for each stream in both directions.

4. Data Collection:

For the purpose of this study, data set was collected to develop an empirical relationship for estimating capacity of U-turn at median openings. The data set included 116 observations on capacity of turning stream, conflicting traffic flow and average total delay. These data were observed at one-minute intervals. The observations were taken with stable queuing in the left turn lane (at capacity operation).

It was decided to adopt recording technique using an automatic video camera to collect the field data. Video tapes are then played back in the laboratory to process the collected data, as required. The total delay for the turning vehicles was measured directly from the videotape. All selected sites were at least 500 meters from the nearest signalized intersection, thus no spillback problems or abnormal bunched arrivals were observed during data collection. Characteristics of the collected data are summarized in Table 1.

Table (1) Openings size and locations of Slabs.					
Variable	No. of observation	mean	standard deviation	min.	max.
Conflicting traffic flow (pcu/hr)	116	1625.21	639.63	700	3060
Capacity of U-turn (pcu/hr)	116	440.81	211.39	60	780
Average total delay (s/pcu)	116	27.45	10.01	10	50

5. Model Development:

A: correlation analysis was undertaken to identify the factors that affect U-turn capacity. The analysis indicated that U-turn capacity had strong correlation with conflicting traffic flow and the average total delay. For illustration, Figure (1) shows the scatter plot of U-turn capacity and conflicting traffic flow for the investigated median openings. Also, the conflicting traffic flow had high correlation with the average total delay, Figure (2).
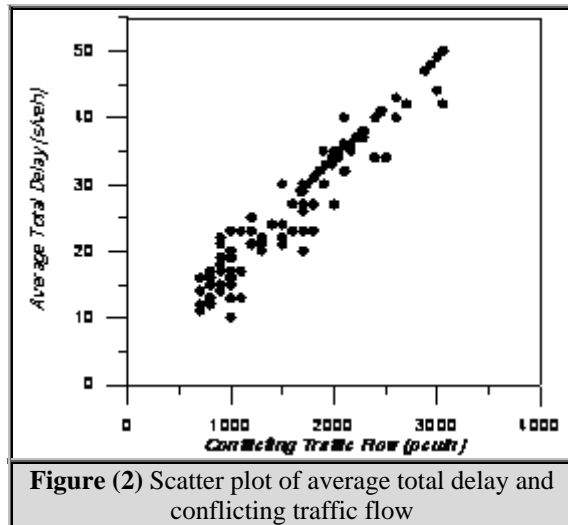

Figure (1) Scatter plot of U-turn capacity and conflicting traffic flow
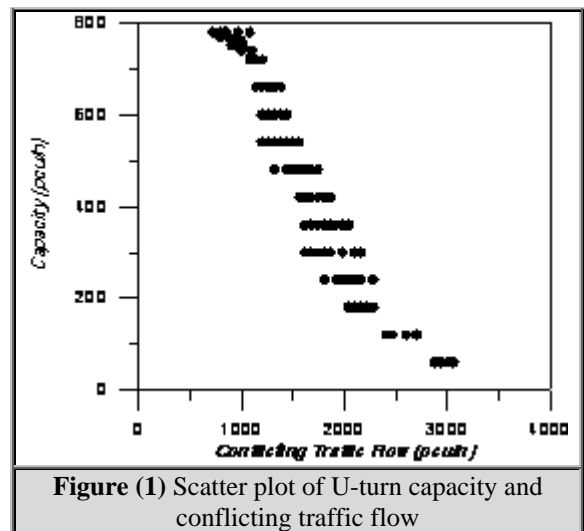
Figure (2) Scatter plot of average total delay and conflicting traffic flow

Regression analysis was carried out to determine the best form of the predictive equation for the U-turn capacity. Since conflicting traffic flow and average total delay were found to be strongly correlated, the average total delay was not included in the modeling analysis. Based on the analysis, the following regression equation was obtained:

$$C = e^{-0.001176\,q} * 2642.76 \qquad \boxed{1}$$

were:

C = capacity of U-turn movement (pcu/hr)
q = conflicting traffic flow (pcu/hr)

Equation (1) was found to be significant at 95% confidence level. $R^2=0.9158$ and N=116.

The conflicting traffic flow q in equation (1) represents the opposing flow.

As mentioned before, each arterial has two through traffic lanes; and vehicles using these lanes conflict with the turning vehicle. Thus, it is more logical to estimate the capacity of U-turn movement as a function of conflicting flow irrespective of the number of the through lanes.

B: Furthermore, the analysis conducted in this study revealed that there is a relationship between the average total delay and the conflicting traffic flow (see figure 2). Analysis showed that linear and exponential forms are suitable to describe the relationship. The linear form was found to have the best statistical characteristics.

The developed regression equations were as follows:

$$TD = 0.0143025\,q + 5.18927 \qquad \boxed{2}$$

$$TD = 0.0124736\,q + 3.02272 \qquad \boxed{3}$$

Were TD represents the average total delay for the turning vehicles (s/veh), and q represents the conflicting traffic flow (veh/hr). The relationship was found to be statistically significant at 95% confident level (N=116, $R^2=0.964$) for equation (2), which represents the average total delay for
the U-turning vehicles from the first turning lane closest to the median , and (N =116,
$R^2=0.929$) for equation (3) which represents the average total delay for the second U-turning lane. Because significant difference obtained between the average total delays for the two U-turning lanes, two models were recommended.
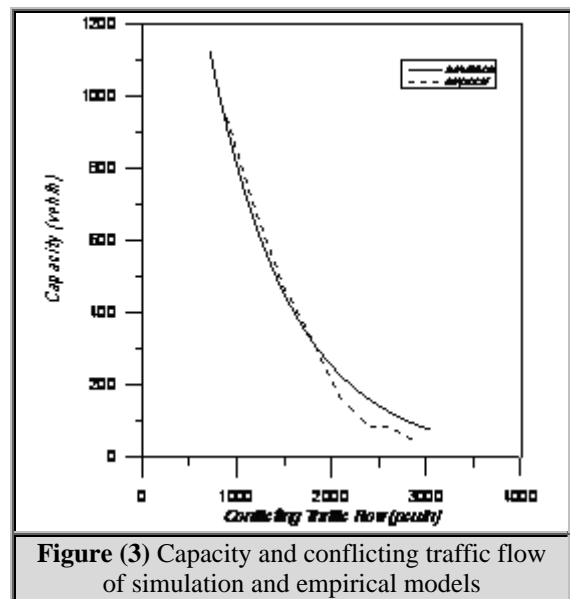Both empirical and simulation capacities are presented in figure (3).

Figure (3) Capacity and conflicting traffic flow of simulation and empirical models

Kyte et al (5) indicated that both conflicting traffic flow and arrival rate of subject approach had linearly influenced the average total delay; however, analysis conducted in this study did not confirm the effect of arrival rate of turning traffic on the average total delay. A higher arrival rate would probably be needed to explore the effect of arrival rate on average total delay.
Simplified flow of the simulation model U-SIM (4) is presented in figure (4).

6. Conclusions:

The results of both empirical and simulation approaches were compared. Based on the results of this study, the following points were concluded:

Figure (4) simplified flow of the simulation model **U-SIM**[(4)]
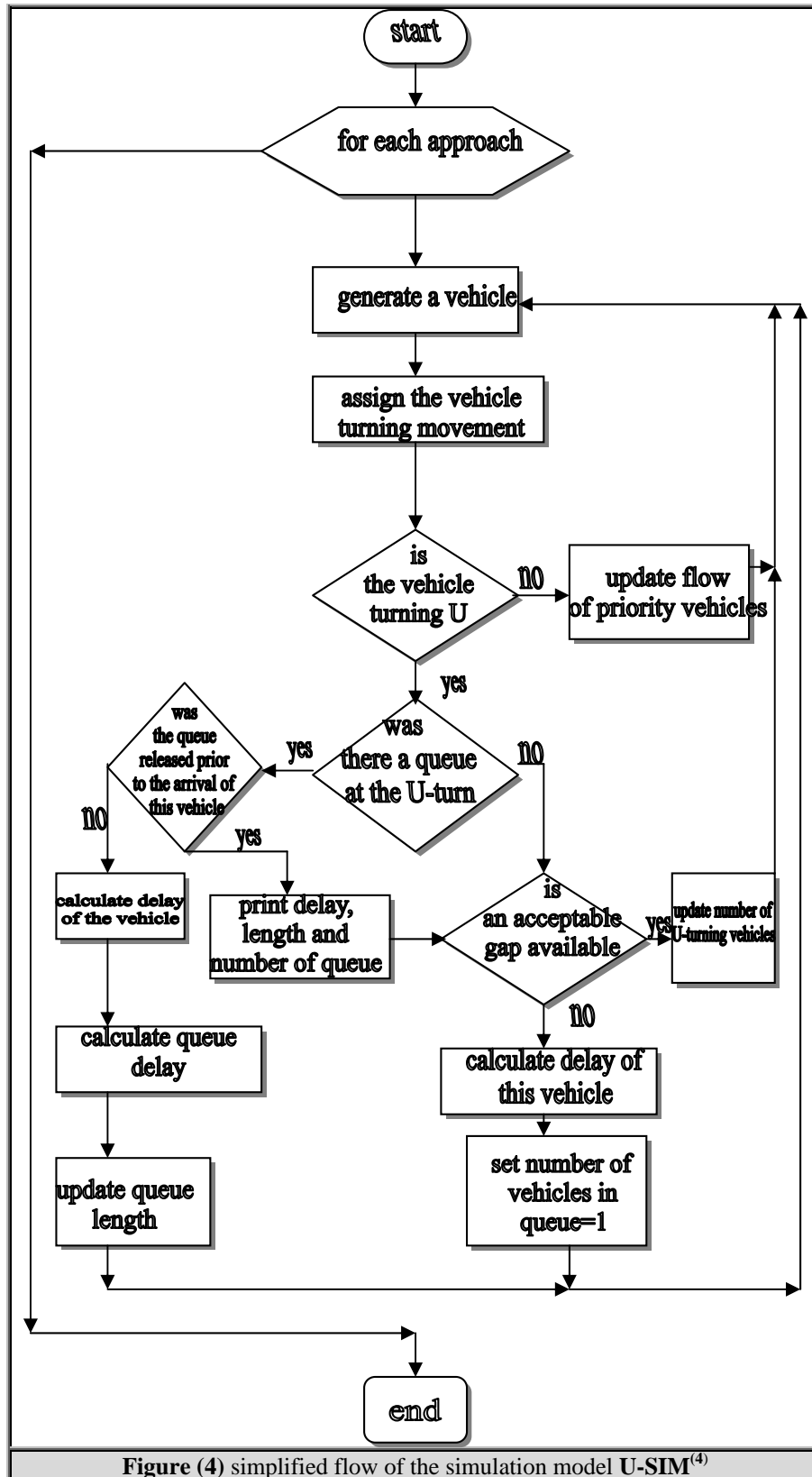
Capacity and average total delay models for U-turn movements at median openings were found to be significantly influenced by the conflicting traffic flow.

The best predictive capacity model had an inverse relationship (exponential form) with the conflicting traffic flow, while linear relationship obtained between

the average total delay and the conflicting traffic flow at U-turn median openings.

Compared with results of the empirical model, the simulation model provides good and reasonable results.

7. References:

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تطوير نظام لسعة الإستدارة المرورية للوراء بتطبيق النظرتين التجريبيةِ والمحاكاة

حســـــين كريـــم مـــحمـــد
ماجســـــتير هندســـة مدنيـــة

الخلاصة:

في هذه الدراسةِ، النظرة التجريبية ونظرة المحاكاةِ تُستَعملُ لتَخمين السعةِ في حركةِ الإستدارة للـــوراء فـــي الجزرات الوسطية للطرق الشريانية المقسمة . تحليل إنحدار بإستعمال النظرةِ التجريبي اســـتعمل فـــي هـــذة الدراسة لتَخمين سعة حركةِ الإستدارة للوراءِ ويَتحرّى تأثيرَ العوامل ذات الصلةِ المختلفةِ الذي قَدْ يُؤثّرُ علـــى السعةِ المُخَمَّنةِ . نظرة المحاكاةِ إستعملتْ أيضاً لحِساب السعةِ على أساس نموذج U-SIM (نمـــوذج محاكـــاةِ يمثل الأداء المروري في فتحات الإستدارة للوراءِ ويحسب عدد المركبات المستديرة نسبة الى تدفقات مرورية مختلفة في الأتجاة المعاكس). نَتائِج كِلتا النظرات قُورنتْ وقُدّمتْ في هذه الدراسةِ.

نموذج اخر أيضا" استنتج في هذة الدراسة يمثل العلاقة الخطية بين معدل التأخير للمركبات المستديرة والتدفق المروري المعاكس.

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