The effect of elimination the left-turn movements on the intersections Capacity-A simulation study

Tabarak A Al-amedy¹, Jalal Al-Obaedi²
¹ MSc Student, University of Al-Qadisiyah, College of Engineering, Roads and Transport Dept., Iraq
² PhD, Assistant professor, University of Al-Qadisiyah, College of Engineering, Roads and Transport Dept., Iraq.

Abstract. Left-turn movement is an important element to determine the capacity of intersections due to high conflicts points. Therefore, finding the alternatives for such left turn movements may increase the intersection throughput and make it safer. This study discusses the effect of eliminating the left turn movements on the intersection capacity by adding U-turn sections after each approach to apply the left turning away of the intersection. This means that the left turn traffic will pass the intersection using through movements, use the added U-turns and use the intersection again to reach the destination direction using right turns. To apply such scenario, traffic simulation has been applied as a tool using Paramics traffic simulator which is one of the most confident tools over the world. Simulation models have been developed using Paramics considering both signalized and un-signalized intersections with different effective green times. The results suggested that applying such alternatives will significantly increase the intersection capacity. However, further research is needed to examine the geometric layout that would be useful for such alternatives and to confirm the validity of the findings by validation the developed simulation models.

1. Introduction
Traffic simulation models help the traffic engineers by giving the ability to evaluate traffic condition. These models help in suggesting alternatives scenarios and solutions and give immediate results without needing to apply in site and this provide saving time and money [1].

Traffic simulation models are categorized into macroscopic, mesoscopic, and microscopic. Macroscopic model based on deterministic relationships of the flow, speed, and density of the traffic stream without tracking individual vehicles and it collect the description of traffic flow. Microscopic model measures both time and space for individual vehicle and these models are simulating the state of individual vehicles continuously or intermittently based on car-following and lane-changing theories. Mesoscopic models have combined properties of both microscopic and macroscopic [2]. Intersections represent an example of the complicated sections than could be analysed using traffic simulation.

Intersection is an area consisting of two or more roads used to turn to various directions to reach to the required destinations. Intersections represented complex sites on the highway due to all vehicles moving traffic in different directions want to occupy the same area at the same time which producing high number of conflict points. Moreover, pedestrians want the same area to cross. Drivers should make decision in part of a second and this led to an accident if there are a small error in decision [3]. Road users have a bad experience at road intersections because of delay time and exposure to safety hazards. The traffic congestion and delays reduce the intersection capacity and that effect on the performance of transport [4]. There are many alternatives to improve intersections capacity and safety such as the use
of roundabout and adding additional lanes. However, such alternatives have almost limited effectiveness especially at urban areas because the right of way limitations.

One of the promising solutions is that applying of indirect left-turn (IDLT) as an alternative to direct left turn. This is applied by forcing the left-turn movement to make “through” or “right” movements and used the U-turn site near to the intersection to change to the opposing direction and used the intersection again by either through” or “right” movements to reach the destination. Figure 1 shows the IDLT configuration.

Theoretically, this will reduce the conflict points and enhancing traffic safety. Indirect left-turn allow vehicles pass the intersection without cross with other road users [5]. The objective of use indirect left-turn movement makes less stops than conventional intersection [6], and increase throughput compared to conventional intersection [7]. Using the indirect left-turn will eliminate left-turn movement and reduce intersection phases to be two phases with maintaining on green light period with shorter cycle length at signalized intersection [8].

Many authors studied effect of replacement direct left turn with indirect left turn and they focus on the travel time and delay time for example and intersection performance for example, Lu et al. [9] conducted a study to evaluate the effects on the roadway operational performance for ten sites in Florida. The analysis was done by using the CORSIM simulation tool. Results showed that the alternative reduced the total delay and total travel time and give indicate that indirect left turn has effective merits at high traffic volume.

Taha and Abdelfatah [10] evaluated the improvements of replacing the (DLT) manoeuvre with the (RTUT) or (UTRT) manoeuvres. The analysis was performed using the Synchro and VISSIM simulation tool. The results indicated that application of the RTUT or UTRT manoeuvres reduced the total intersection delay.

Maxim A. Dulebenets et al. [11] evaluated the IDLT using the Synchro and VISSIM simulation tool. The study was performed for the Abu Saeed-Khalije Fars intersection, one of the most congested areas in the Tehran metropolitan area (Iran). The results of simulation analysis showed that the alternative treatment not only reduces the total vehicle queue length and the total delay at the considered intersection, but also decreases the total delay of network and the total travel time and increases the number of vehicles entering the network.

In the case of unsignalized intersection there are few studies on the indirect left turn at unsignalized intersection and don’t consider the intersection capacity.

This study uses Quadstone Paramics microsimulation to evaluate the applying of IDLT for both signalized and un-signalized scenarios. Paramics used the car following and lane challenge model to show correlation of numerical data under various conditions [12]. (Robert L. Bertini Roger Lindgren Sutti Tantiyanugulchai) used Paramics simulation at a diamond Interchange [13], and (ElAzzony, Tamer Talaat, Hoda Mosa, Ahmed) using “Quadstone Paramics” to develop model was used to evaluate the operational impacts of different intersection treatments including different U-turn solutions [14].
2. Methodology
As discussed above, this paper uses traffic simulation to test the effect of applying indirect left-turn (IDLT) movement on the capacity of intersections. While there are many traffic simulation tools applied over the world, Quadstone Paramics has been selected in this study since it has been successfully applied for simulation intersections.

The tests include making a comparison for sites with a direct left-turn and indirect left-turn movement for both signalized and un-signalized intersections. The capacity is used as a measure of comparison between the DLT and IDLT for both signalized and un-signalized scenarios. The capacity is defined here as the maximum hourly volume that can pass through an intersection prior to occurring of traffic congestion. [15].

3. Simulation models
Simulation models have been created using Paramics for the following cases shown in Table 1. Figure (2) shows the snapshots for the developed models from Paramics shows before the use of IDLT for signalized and un-signalized intersections.

The intersection layout used for study for both signalized and un-signalized intersections represent a four-leg intersection with three lanes at each approach.

The traffic volumes that used in the testing the above scenarios are assumed to be equal for all intersections approaches. For signal timings, different values of cycles with equal green times among all approaches have been used as will be discussed later in the results section. The cycle lengths of (100,140,180 and 220 seconds) are used for the case of DLT. For the case of IDLT, only two phases are required and therefor, half cycle length than those used for the DLT are applied (i.e., 50,70,90 and 110 seconds). The green times are therefore being 20, 30, 40 and 50 are used with each cycle correspondingly.

The traffic speeds used in approaching the intersection are used as obtained from a real site at Al-Diwaniyah city, Iraq. The speeds were measured using speed gun device of each lane at approach. The average speed that used in this study was 35km/hr as obtained in real site for the main approach (see Figure 3).
Table 1. Paramics simulation cases

| Case No. | Description                                           |
|----------|-------------------------------------------------------|
| 1        | Un-signalized intersection with direct left-turn      |
| 2        | Un-signalized intersection with indirect left-turn    |
| 3        | Signalized intersection with direct left-turn         |
| 4        | Signalized intersection with indirect left-turn       |

Figure 2. Snapshots from Paramics for both type intersections

(a) DLT at signalized intersection  
(b) DLT at un-signalized intersection

Figure 3. Lanes speed (a) for South approach and (b) for West approach

4. Simulation results
To evaluate the effect of indirect left-turn on the intersection capacity, a number of simulation runs were conducted for all cases described above to find the capacity of signalized and unsignalized intersections.
For signalized intersection, four effective green times of 20, 30, 40 and 50 seconds were considered. In general, and for signalized and unsignalized intersections, Figure 4 shows the input traffic volumes and throughput traffic volume obtained from simulation for DLT and IDLT. The figure shows that the capacity of the intersection has significantly improved by applying IDLT. For the case of un-signalized intersection with DLT as shown in Figure 4-a, the throughput volumes became lower than the input volumes for traffic volumes higher than 1700 veh/hr (i.e., traffic congestion started when traffic demand reach 1700 veh/hr) while for the case of IDLT with the same input volumes the throughput volumes became lower than the input volumes for traffic volume higher than 4200 veh/hr which is higher than the case of DLT. Similarly, and for signalized intersection with IDLT as shown in Figure 4 (b-e), the throughput volumes for IDLT are much higher than throughput volumes of DLT for traffic volumes higher than 4500 veh/hr. The capacity of the intersection was found to be increased with the increasing of the cycle length.
Figure 4. Comparing input traffic volume with throughput traffic volume of direct left-turn and indirect left-turn at different green time

5. Conclusion
This study discussed the effect of eliminating the left turn movements on the intersection capacity by adding U-turn sections after each approach to apply the left turning away of the intersection. This means that the left turn traffic will pass the intersection using through movements, use the added U-turns and use the intersection again to reach the destination direction using right turns.

To apply such scenario, traffic simulation has been applied as a tool using Paramics traffic simulator which is one of the most confident tools over the world. Simulation models have been developed using Paramics considering both signalized and un-signalized intersections with different effective green times.

The results suggested that applying indirect left turn as an alternative at signalized intersection will significantly increase the capacity of the intersection for all signalized and un-signalized cases. The capacity of the saturated intersection was found to be increased with the increasing of the cycle length. Further research is needed to examine the geometric layout that would be useful for such alternatives and to confirm the validity of the findings by validation the developed simulation models.

6. References
[1] P. Hidas, “Modeling vehicle interactions in microscopic simulation of merging and weaving,” Transp. Res., C: Emerging Technol., vol. 13, no. 1, pp. 37–62, Feb. 2005.
[2] Sharon Adams Boxill and Lei Yu (An Evaluation of Traffic Simulation Models for Supporting ITS Development) Center for Transportation Training and Research, Texas Southern University, 3100 Cleburne Avenue, Houston, Texas 77004
[3] Tom V. Mathew and K V Krishna Rao, Introduction to Transportation Engineering, NPTEL May 24, 2006
[4] Havrylov E. V., Dolia V. K., Lanovyj O. T. et al. (2005) Systemolohiia na transperti. Orhanizatsiia dorozhnoho rukhu: knyha 4 [Systemology in transport. Organization of traffic: Book 4. Kyiv: Znannya Ukrayiny. (in Ukrainian)
[5] Pauw, Ellen & Daniels, Stijn & Herck, Stijn & Wets, Geert. (2015). Safety Effects of Protected Left-Turn Phasing at Signalized Intersections: An Empirical Analysis. Safety. 1. 94–102. doi:10.3390/safety1010094. (in English).
[6] Rodegerdts, L. A., Nevers, B., and Robinson, B., "Signalized Intersections: Informational Guide." FHWA-HRT-04-091, (2004)
[7] American Association of State Highway and Transportation Officials (AASHTO). A Policy on the Geometric Design of Highways and Streets. Washington, DC: AASHTO, 2011.
[8] Information Guide “Median U-Turn intersection” August 2014
[9] Lu, J., Dissanayake, S., Zhou, H., Yang, X. and Williams, K. (2001) Operational Evaluation of Right Turns Followed by U-Turns as an Alternative to Direct Left turns. Report Submitted to the Department of Transportation, University of South Florida.
[10] Taha, M.A. and Abdelfatah, A.S. (2015) Impact of U-Turns as Alternatives to Direct Left-Turns on the Operation of Signalized Intersections. Journal of Traffic and Logistics Engineering, 3, 12-17.
[11] Maxim A. Dulebenets, Amir M. Rahimi, Arash Mazaheri “Assessing the Effects of Indirect Left Turn on a Signalized Intersection Performance: A Case Study for the Tehran Metropolitan Area” November 2017Open Journal of Applied Sciences 07(11):617-634
[12] “Quadstone PARAMICS User Manual - V.6.9.3 - Paramics Product Suite > Modeller” (nd). 2013
[13] Robert L. Bertini Roger Lindgren Sutti Tantiyanugulchai (Draft Application of PARAMICS Simulation at a Diamond Interchange) research Report PSU-CE-TRG-02-02 April 30, 2002
[14] ElAzzony, Tamer Talaat, Hoda Mosa, Ahmed (Microsimulation approach to evaluate the use of Restricted Lefts/Through U-turns at major intersections — A Case Study of Cairo-Egypt urban corridor) October 2010Conference Record - IEEE Conference on Intelligent Transportation Systems
[15] Highway Capacity Manual 2010. TR B, National Research Council, Washington, D.C.