International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Four-Legged Unsignalized Intersections Capacity Derived by Conflict Techniques

Israa Mohsin Turki[1, a)] Khawla H. H. Shubber[2, b)]

Submitted: 31/01/2023 **Accepted:** 02/04/2023

Abstract: Almost world countries, the complexity of traffic environment is becoming increasingly over time, so any shortcoming that may face traffic safety in roads, especially intersections, could constitute a global problem. Iraq is considered among these developing countries in the Middle East, and traffic accidents are growing in it, which leads to danger fatalities and economic and social losses in the country. Current research aims to provide a revision on analyze the capacity of a four-legged unsignalized intersection by means of traffic- conflict technique. It has been proven that this method is simpler dealing than the theory of gap- acceptance. In order to avoid many of the complexities facing the gap- acceptance theory, which is in a certain circumstances are far from reality. The traffic conflict technique represents the ideal solution for analyzing safety situations in terms of traffic events that can be observed more than accidents one of the best technologies so far. The current article provides a trial on review of previous research and literature regarding the traffic conflict technique. In order to obtain an answer to traditional questions related to the meaning of traffic conflict, the roles of the traffic conflict technique that are make them ideal guides to the accident record, the methodology of collect traffic conflict data. Finally, advantages and disadvantages are clarified in answering these questions based on methodological and scientific foundations.

Keywords: *Conflict Methods, Unsignalized Intersections, Capacity, TWSC, AWSC, Safety.*

1- Introduction

An intersection is a complex traffic facility, usually a node in traffic flow in highway networks. Intersection capacity can affect the total capacity of highway networks because of all kinds of turning maneuverings. A great deal of effort has been spent for capacity analysis of unsignalized intersections. The acceptance gap theory is a traditional method for finding the capacity of unsignalized intersections of two types of control (TWSCA and AWSC) i.e. TWO WAY STOP CONTROL and ALL WAY STOP CONTROL based on many researches the gap theory mainly depend on Harder, Siegloch, and Grossman methodology found in [HCM 2000]. On the other side, the researcher (Wu), 2001, introduced a movement- based model to calculate capacity at intersections (AWSC) based on the basis of conflict flow theory [Wu N. Brilon W.,2001]. While, previous theories have given little or no consideration to non-motorized traffic (pedestrians, cyclists), and the traffic characteristics at non-lighted intersections with homogeneous conditions (vehicle traffic only) differ from those with heterogeneous conditions. Both of motorized and non-motorized traffic movement's consequence, new theories has been developed to calculate the capacitance of the unsignalized intersections of both types (TWSCA and AWSC) based on the field data source and conflict theory. Current research present a comparison review between classic method of estimating unsignalized intersection capacity i.e. gap acceptance method and conflict technique that, recently depended due to some advantages and simplicities of application.

2. Gap Acceptance Technique

Unsignalized intersections do not give positive signals or control to the driver. So, only the driver adopts when the intersection is safe to enter. The driver searches about a suitable and safe time space (gap) in the opposite flow to go into the intersection space. This theory is known as "gap acceptance techniques". The gaps in this technique are measured within the appropriate time and equal progress. At the intersections not controlled with traffic signal, it is necessary to respect the priority of other drivers for the driver, because in some cases there may be other vehicles that have priority over the driver who wants to enter the intersection [1].

Capacitance estimates according to the gap acceptance technique are widely dependent on the accuracy used in calculating the critical gaps, conflict traffic flow and follow-up time. Although both conflicting flow and follow-up time is collected from field data, it is possible to calculate the critical gap based on acceptable and

[1]M.Sc. student, [2]Prof. Dr. Civil Engineering Department / Engineering Faculty/ University of Kufa/ Iraq.
[b)] Corresponding author: khawla.shubber@uokufa.edu.iq
[a)] asraamohsen412@gmail.com

unacceptable gaps and on the basis of the delays at the intersection. Over these years, researchers have organized several theories to measure and estimate the critical gap. But, drivers are not expected to strictly adhere to the rules of priority in the case of homogeneous traffic, so it loses its applicability to heterogeneous [2]

A traditional intersection such as the four- Legged intersections is shown in Fig.1. Data was collected during a period not less than daylight hours to include both peak and off-peak periods [2]. From recorded video that was recorded, information about accepted and rejected gaps was extracted by each vehicle category, number of traffic volumes and occupancy time occupancy time means the time it takes for the vehicle to evacuate the conflict zone at the intersection, i.e. "the time from the moment of front bumper of the car reaches the edge of the conflict zone until the moment the rear bumper exits the conflict zone" [2].

Fig.1: Four-legged intersection

At the site, traffic volume surveys include collecting the number of vehicles of all types that pass through the selected intersection. Studying the number of traffic volumes and their classifications obtained from surveys aimed at understanding the factors that are necessary to establish the highway network used by vehicles of different types, and the volume of traffic during peak hour. Data are calculated from the collected video recordings. Acceptable and unacceptable gaps are taken from a digital video by stratified sampling technique for capacitance analysis and critical gaps [3].

3- Capacity Estimation by HCM Method

The theory of gap acceptance mainly depends on the distributions of the main flow gaps and the arrival of vehicles that do not have priority at the intersection. Based on the accepted gap techniques, the main flow gaps, the follow-up time and the driver's verdict in choosing the gaps are the main indicators on which the capacity of movement depends [3]. In simplest words, this theory assumes that all movements within the intersection must be consistent and homogeneous, and this is not possible in reality, so an understandable formula was reached to express the potential amplitude of a movement that does not have priority within a non-light intersection in equation [1]:- [4].

$$C_{p,x} = V_{C,X} \cdot \left(\frac{e^{-[v_{c,x} \cdot t_{c,x}/3600]}}{1 - e^{-[v_{f,x} \cdot t_{f,x}/3600]}} \right) \quad \text{.... [1]}$$

Where:-

$C_{P,X}$:-Minor movement potential capacity (vph)

$V_{C,X}$:-Movement conflicting flow rate (vph)

$t_{C,X}$: - minor movement critical gap (s)

$t_{f,X}$: - minor movement follow up time (s)

4. Traffic Conflict Technique

The idea of near misses by vehicles or traffic conflict techniques has had a long history in traffic safety research .The actual establishment of the Traffic Conflict Techniques (TCT) was proposed by many researchers [5] . Their goal was to find a technique to study the actions that can be clearly observed and closely related to traffic accidents, instead of referring to accident data that is sometimes difficult to be available or incomplete data. Due to the movement of specific user at the intersection, the another user has to do an elusive maneuver to avoid the risk of collision [6].

There is a different set of maneuvers that the first driver has to follow at the beginning, which are:

1- The driver should turn from the intersection into the path of the passing driver.

2- To turn left from the passing vehicle exactly when the passing vehicle driver enters the intersection.

3- Because of the slowness of the driver while turning at the intersection, which leads to the exposure of the vehicle traveling behind him to the risk of collision from behind or rear.

Intersection conflicts can lead to collisions between drivers. When a conflict take place, one user must be on a collision course with another user (i.e. they share the same path and the same time) [6]. A traffic conflict can be defined as [a traffic obstacle that occurs between two road users, where one of them makes unusual movements such as increasing the speed of his car or changing its direction, which leads to the other user being at risk of collision unless an elusive maneuver is made] [7].

4-1 conflict study Problems

Basically, the majority of the problems associated with the technology of traffic conflicts are caused by three main and interrelated principles:

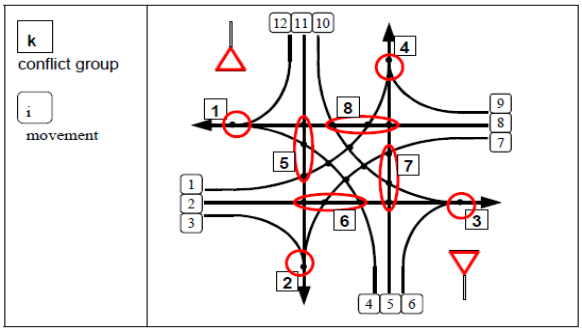


Fig. 2: Unsignalized Intersections Conflict [10].

1- The validity of the conflict concepts.

2- Consistency in recognizing traffic conflict.

3- Accuracy of measuring traffic collisions.

Main parts of the research work deal directly or indirectly with some issues related to early conflict experiences. In order to obtain smooth and understandable theories to explain the events that cause traffic conflicts , researchers are interested in providing the best methods for identifying conflicts or more stringent ways to substantiate the correctness of the work of the traffic conflicts technique in order to reach accurate accounts of the conflicts [8]

Using video recording technology, data on traffic disputes is collected. Traffic conflict data and traffic volume of the specified intersection are collected during one day of the week. This is done during the peak hours for the morning and evening periods during the day, depending on the movements classified when turning in the left and right directions and during the movements, and that is done by determining the peak hour at the beginning[8] .

The method used in the analysis is the quantitative method and it consists of a group of stages: the preparation stage; which includes discussion of the preliminary surveys, the data collection stage and the analysis stage; which includes processing and analyzing the collected data. A real field survey is conducted at the intersection in order to obtain important information such as the engineering and environmental characteristics of the intersection (road width, side barriers, and average island width), vehicle speed, traffic movements, and traffic conflict data based on on-site observations [9]. These observations are performed for one day, each using a heavy traffic approach. Figure 2 shows potential points of conflict in the four- legged unsignalized intersection.

In order to analyze the conflict approach technique, each part of the intersection must be observed in order to obtain the predominant type of conflict. According to the video surveillance at the intersection, vehicles are classified into two categories, heavy and light vehicles [11]. Figure 3 illustrates four movements of conflict. Here it must apply a hierarchy of priorities that resembles conflict arrangements at unsignalized intersection [12]. Generally, as shown in Fig. 4 the typical conflicts that can occur in a four-legged intersection [13] are:

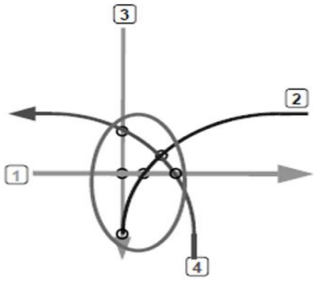


Fig. 3: Conflicts of Four Movements (10) .

1. (straight in the same trend):-This type can occur while the first vehicle is moving in a upright line and slowly. This leads to a possible collision from the front and the back, so the other vehicle must press the brakes and change its direction to the right or left.

2. (Turn right in the same trend):-This type can occur due to the slow movement of the first vehicle, in the event of a risk of front and rear collision, this leads to the movement of the second vehicle to the rear, so the second vehicle must press on the brakes and variation its course to the right or left.

3. (Straight turning to the right):- The movement of the second vehicle heading towards the right is interrupted due to the movement of the first vehicle in a straight line. As a result of these movements, the risk of lateral and head passing between both vehicles is likely to occur.

4. (Merging):- It is a conflict that occurs as a result of two movements with two different directions that converge in one direction, which leads to the risk of collision between them. When a movement occurs between vehicles coming from the right and straight vehicles as a result, the vehicle heading to the right at the intersection must press the brakes or change the direction of its movement to avoid a collision.

5. (Secondary conflict):- As a result of a conflict between two vehicles, which leads to friction between other vehicles at the intersection.

This technique is applied to the four movements of the struggle [Fig. 3], it is possible to obtain the capacity for rank 4 conflict moves.

$$C_4 = \left[\frac{3600 - \left(Q_1.t_{B,1} + Q_2.t_{B,2} + Q_3.t_{B,3}\right)}{t_{B4}}\right]$$

$$= C_{max4} \cdot (1 - (B_1 + B_2 + B_3)) \quad \dots [2]$$

$$= C_{max4} \cdot P_{0(1/2/3)}$$

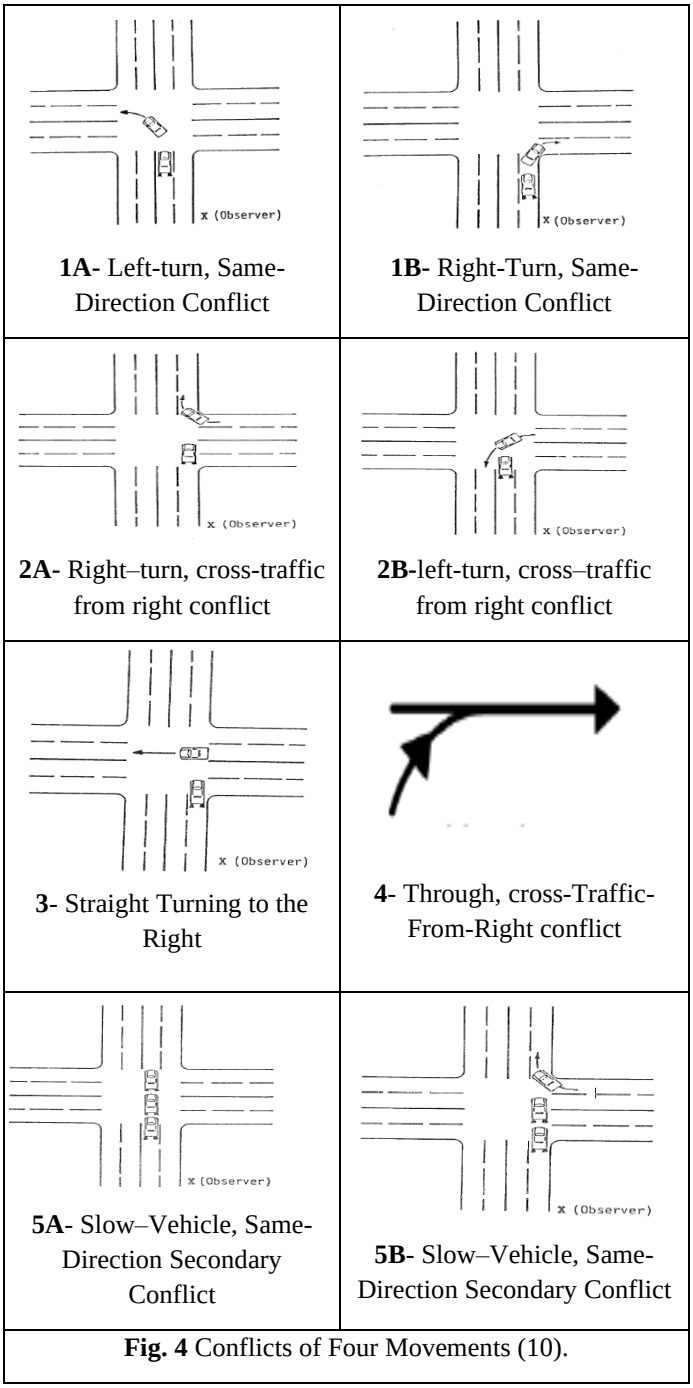
Where:-

$P_{0(1/2/3)}$: - $\{1 - [B_1 + B_2 + B_3]\}$ = Represents the probability that the vehicles are from the stream (1, 2, and 3) doing not occupy the conflict area at the intersection.

4-2 Pedestrian

Another type of conflict points must be taken into account when pedestrian traffic is permitted accepted at the selected intersection (Fig. 3) as additional elements in conflict groups [1, 2, 3, and 4] at intersection exits. Furthermore, it is of great importance at intersection entrances [10]. Pedestrian traffic has priority over vehicular traffic, and that is based on the traffic rules that were stipulated in the German code for highways [14].

As a result, according to the usual practices of road users, such rules are not applied in the field, for each individual case, there are special rules to be followed by pedestrians and drivers. Some initial studies [15] have shown that in the event of a conflict, the pedestrian takes precedence over the movement of the vehicle in a certain percentage of cases.



1A- Left-turn, Same-Direction Conflict

1B- Right-Turn, Same-Direction Conflict

2A- Right–turn, cross-traffic from right conflict

2B-left-turn, cross–traffic from right conflict

3- Straight Turning to the Right

4- Through, cross-Traffic-From-Right conflict

5A- Slow–Vehicle, Same-Direction Secondary Conflict

5B- Slow–Vehicle, Same-Direction Secondary Conflict

Fig. 4 Conflicts of Four Movements (10).

The capacity of vehicles at the intersection without neglecting the impact of pedestrian traffic:

$$\mathbf{C_{i,p} = C_{max,i,p} . \prod_{each\ k}[1 - \sum_{j=a}^{f}(\frac{A_j}{100} . B_{k,j})]}$$ **..[3]**

Where:-

$C_{i,p}$ Movement capacity (i) including the pedestrian movements effect. (vph);

$A_j = 100$ if j is a vehicle movement, and

$A_{k,f,i}$ for a pedestrian movement.

$B_{k,j}$: Conflict group (k) with movement (j). [$B_{k,j} = \frac{Q_j . t_{B,j}}{3600}$]

Q_i : movement of volume (j) vph

$T_{B,j}$: The average service time that vehicles or pedestrians would take while in motion.

j:- blockage time period rational by pedestrian or one vehicle. [s]

4-3 Queue length and discharge:

A classical approach can be used to calculate the average delay. For non-steady traffic (which usually occurs in the field) it is possible to apply the formula derived from [16] , and implied in [4]. The average delay [$\mathbf{d_i}$] for movement [i] of the vehicles is calculated [10] :

$$\mathbf{d_i = \frac{3600}{C_1} + 900 . T\left[X_1 - 1 + \sqrt{(X_1 - 1)^2 + \frac{\frac{3600}{C_1} X_1}{450.T}}\right]...}$$

[4]

According to the rule little's it is possible to calculate the average length of the queue

$$N_1 = Q_1 . d_1 \qquad \dots [5]$$

Equation 3 can only be applied in steady traffic conditions. In the case of unsteady traffic conditions (excessive saturation), the relationship will be as follows:

$$N_1 = (d_1 - \frac{3600}{C_1}) . X_1 \qquad \dots [6]$$

5. Comparison between Gap and Conflict Techniques:

A briefly comparison between gap acceptance and conflict Techniques provided in table 1 below, based on main features depended in both techniques according to long and continuous effort of researchers and concerned institutions.

Table -1 Element of Gap Acceptance and Conflict Technique Comparison

Gap acceptance Technique	***Conflict Technique***
This method includes four major concepts: 1- The traffic streams at the intersection are in relative priority. 2- Distribution (availability) of gaps in higher priority areas. 3- Usefulness of gaps in vehicle production (acceptance). 4- Queue discharge.	includes four basic elements: 1- Number of lanes in the approaches. 2- Traffic volumes Distribution for each approach. 3- Pedestrians number for each approach. 4- Flared areas in the approaches.
Two major considerations that must be estimated are 1. Follow-up time 2. critical gap	$t_{B,i}$ - The service time taken by the movement [i] at the intersection(These values are only parameters in the model)
Follow-up time and Critical Gap Estimation Methods many methods such as Siegloch method (1973)	Different methods are used to calibrate the $t_B -$ values of a model parameter.
The data collection process takes place in two separate stages. 1- Video depicting the flow of traffic and the behavior of drivers. 2- The second stage involves manually extracting data from the video and encoding it for analysis.	Methods for traffic conflict data collection: 1. Field observation 2. Computer vision technique 3. Naturalistic driving
The gap acceptance technique is likely to lose its applicability when applied to the movement of pedestrians and cyclists (non-motorized movements) at the specified intersection.	Include pedestrian movements in the analysis

6. Conclusion

It is possible for the traffic volume and critical gap to change with monitoring time, hence the intersection capacity is considered to be random in nature. Addendum to the classic methods used to analyze non-photonic intersections (experimental regression method - gap acceptance method), the new method is clearer and simpler to understood than the gap acceptance method. Moreover, based on the rules stipulated in the German code, it is possible to simulate the behavior of real-life users who do not respond with the principles of the road simply and flexibly. Hence, in this method it is very simple to counting for the so-called limited priority impacts. The new concept of calculating the capacity is foreseeable to have the ability to replace the gap acceptance technique to a large range, principally when taking pedestrian traffic into account in the analysis .The new method provides great advantages that are compatible with all types of motorized and non-motorized road movements.

Reference

[1] Luttinen, R. T. (2003). Capacity at Unsignalized Intersections.

[2] Mohan, M., & Chandra, S. (2019). Capacity Estimation of Unsignalized Intersections under Heterogeneous Traffic Conditions. Canadian Journal of Civil Engineering.

[3] M.Satya Deepthi, A. Ramesh. (2019).A Model for Estimation of Capacity and Critical Gap at Unsignalized Intersections in Hyderabad city.

[4] HCM (2000) Highway Capacity Manual. TRB, National Research Council, Special Report 209: Washington, D.C., Edition 2000, chapter 17th.

[5] Perkins, S. R., and J. I, Harris.(1967). "Traffic Conflict Characteristics; Accident Potential at Intersections," General Motors Research Publication GMR-718.

[6] Parker Jr, M. R., & Zegeer, C. V. (1989). Traffic conflict techniques for safety and operations: Observers manual (No. FHWA-IP-88-027, NCP 3A9C0093). United States. Federal Highway Administration.

[7] National Center Highway Research Program (NCHRP), Application Traffic Conflict Technique at Urban Intersection, Transportation Research Record No.776, USA, 1980.

[8] Chin, H. C., & Quek, S. T. (1997). Measurement of traffic conflicts. Safety Science, 26(3), 169-185.

[9] Rifai, A. I., Surgiarti, Y. A., Isradi, M., & Mufhidin, A. (2021). Analysis of Road Performance and the impact of Development in Pasar Minggu, Jakarta: Case Study of Jalan Lenteng Agung-Tanjung Barat. ADRI International Journal of Civil Engineering, 6(1), 68-74.

[10] Wu, N., & Brilon, W. (2001). Capacity at unsignalized intersections derived by conflict technique. Transportation Research Record, 1776(1), 82-90.

[11] Thankappan, A., Tamut, Y., & Vanajakshi, L. (2010). Traffic stream modeling under heterogeneous traffic conditions. In Traffic and Transportation Studies 2010 (pp. 401-411).

[12] Kurek, A., & Macioszek, E. (2021). Impact of parking maneuvers on the capacity of the inlets of intersections with traffic lights for road traffic conditions in Poland. Sustainability, 14(1), 432.

[13] Fu, C., & Sayed, T. (2022). Bayesian dynamic extreme value modeling for conflict-based real-time safety analysis. Analytic methods in accident research, 34, 100204.

[14] StVO. (1998) Strassenverkehr sordnung (German Highway Code), latest edition: 1998.

[15] Czytich, D., & Boer, M. (1999). Untersuchung des Fußgaengerverkehrs an vorfahrtgeregelten Knotenpunkten in staedtischen Gebieten (Investigation of pedestrian traffic at unsignalized urban intersections). Ruhr-University Bochum, Germany, Study Thesis.

[16] Akçelik, R., & Troutbeck, R. (2021). Implementation of the Australian roundabout analysis method in SIDRA. In Highway capacity and level of service (pp. 17-34). Routledge.