A STUDY OF TRAFFIC SAFETY AT FOUR-LEG SIGNALIZED INTERSECTIONS USING TRAFFIC CONFLICT TECHNIQUE+

Hussein A. Ewadh* **Sahar S. Neham****

Abstract

With the absence of reliable accident record, traffic conflict technique is a suitable alternative aid to conduct a study of traffic safety. This research aims to conduct such study at four leg- signalized intersections using traffic conflict technique.

Surveys include traffic conflict, volume data, spot speed and some geometric characteristics at four sites in Baghdad city. Rate quality control and cluster analysis are used to identify the hazardous approach and the abnormal conflict types respectively.

Developed models show that, linear relationships are significantly appropriate to explain the relation between hourly traffic conflict and hourly approach traffic volume with coefficient of determination ranging between 0.701 and 0.884. Although this finding agrees with the literatures, exponential relationship introduces higher coefficient of determination between 0.759 and 0.897. This might be due to extra increase in conflicts at high traffic volume. Further, a model of multiple linear is appropriate to explain the relation between conflict rates and some of geometric characteristics with coefficient of determination ranging between 0.580 to 0.969. Identification of hazardous approach shows that, the lower rank in geometric characteristics among all approaches is the most hazardous one. This agrees with the finding in the developed model. In order to enhance traffic safety, the study proposes suitable countermeasures such as creating left turn lane, providing special phase for left-turn traffic.

المستخلص

في غياب سجلات حوادث ذات مصداقية فأن تقنية التصادمات المرورية تعد بديلا مناسبا لدراسة حالة السلامة المرورية في منظومة الطرق. يهدف البحث إلى أجراء مثل تلك الدراسة في التقاطعات الرباعية والتي تعمل بالإشارة الضوئية وذلك باستخدام تقنية التصادمات المرورية.

عملية المسح المروري شملت عدد التصادمات بأنواعها والأحجام والسرع وبعض الخصائص الهندسية في أربع مواقع من مدينة بغداد. تم استخدام طريقة نسبة السيطرة النوعية وطريقة التحليل التجميعي لتحديد الطريق الخطر في التقاطع ونوع التعارض السائد.

في هذا البحث، وجد أن العلاقات الخطية مناسبة لتوضيح العلاقة بين التصادمات المرورية والحجوم المرورية وبمعامل تغير يتراوح بين(0.701 إلى0.884). مع اتفاق ذلك مع أدبيات سابقة فان العلاقات

+Received on 16/1/2006 Accepted on 1/7/2007

Asst. Prof. Road & Traffic Engineering, Commission of Technical Education *

MSC. Road & Bridges Engineering, Commission of Technical Education **

الأسية أعطت تمثيل أفضل لمعامل التغير والذي يتراوح بين (0.750 إلى 0.897) وذلك يعزى إلى زيادة عالية في التصادمات مع ازدياد الحجوم المرورية. من جهة أخرى وجد أن العلاقات الخطية المتعددة مناسبة لتوضيح العلاقة بين معدل التصادمات و الخصائص الهندسية للطرق المؤدية للتقاطع وبمعامل تغير يتراوح بين(0.580 إلى 0.969). بينت طريقة تمييز الطريق الخطر أن الطريق ذا الخصائص الهندسية ذات الدرجة الأقل بين باقي الطرق هو الأخطر وذلك يتوافق مع نتائج الموديل الرياضي المستحدث. فضلا عن ذلك أوصت الدراسة ببعض الإجراءات المناسبة لتحسين السلامة المرورية منها؛ توفير خط مساعد لاستدارة اليسار وتوفير طور خاص لاستدارة اليسار.

Introduction

In most of the countries states, the traffic environment is getting more and more complex. In consequence, deficiencies in road-traffic safety represent a worldwide problem. Iraq is one of the developing countries in the Middle East, and traffic accidents are increasing continuously leading to more fatalities and considerable social economic cost losses. According to the statistics of traffic accidents for the period from 1995 to 1999, there were about 248 fatalities and 803 injuries per 1000 accidents and about six traffic accidents per 1000 vehicles [1]. A deficient situation is identified in traffic culture of drivers concerning traffic signs and marking, existence of traffic operation features, and maintenance works of the roadway network [2].

The above situations make it useful to conduct a traffic safety studies among the highway system in Iraq. Signalized intersections are chosen to represent the most hazardous sites in the way high system. In this research, traffic conflict technique (T.C.T) is used as accidents measure alternative because of the problems associated with the unreliability of traffic accident records and time required waiting for adequate sample size.

Traffic Conflict

Traffic conflicts, like traffic accidents, are produced by interaction between components of traffic system; road users, vehicle, and road environment. The main feature of traffic conflicts and accidents is that, they are always preceded by a critical combination of circumstances in traffic [3]. The original definition of traffic conflicts introduced by Perkins and Harris of the General Motors (GM) Research Laboratory 1967 is as follows "A traffic conflict is an evasive action, such as braking or weaving, taken by a driver to avoid a collision" [4].

The (NCHRP) defines the traffic conflict as " a traffic event involving two or more road users, in which one user performs some typical or unusual action, such as a change in direction or speed that places other users in jeopardy of collision unless an evasive maneuver is undertaken " [5]. Table (1) shows the main elements of operational definition for traffic conflict approved by the most credited organizations.

Table (1) Definitions of Traffic Conflict by Operational Elements

Name of organization	Type of activity
Federal Highway Administration (FHWA)	• Evasive action
Transport and Road Research Laboratory (TRRL)	• Severity scale
Lund Institute of Technology (LIT)	• Time to Accident
Canada Ministry of Transport (CMT)	• Time Measured to

	Collision
National Organization for Road Safety(NOFRS)	• Severity scale
National Center of Highway Research Program (NCHRP)	• Evasive action

The objective evidence of a traffic conflict by the (NCHRP) definition is the evasive action which is indicated by a brake-light or a lane change affected by the offended driver. This criterion makes it simple in observing and analyzing intersection conflict situations as well as, it is shorter than the period recommended by FHWA.

Since the development of the traffic conflict technique by Perkins and Harris, various studies have adopted this technique to evaluate safety issues of various highway elements. These elements include; construction zones, freeway acceleration lanes, freeway weaving areas, pedestrian facilities and, signing and traffic signals [6], [7], [8], [9] and [10].

In general, fourteen intersection conflict situations appear to be potentially useful in pinpointing operational or safety deficiencies. Five types of conflicts observed in signalized intersections are; left turn same direction, slow vehicle same direction, lane change, right turn same direction and right turn cross traffic from left.

Conflict Measurements

There are two main procedures to count different types of traffic conflicts. First is the recording technique and the other is observing procedure. The recording technique requires human observers to analyze conflict events recorded by video. Hence, all information of interest can be collected due to the playback facility, which makes it possible to review conflicts more than one time. In summary, Table (2) shows different measurement procedures of traffic conflict. It can be seen that, the duration of counting T.C ranges between one and five days. Also, the number of hours also ranges between one and fourteen hours for all approaches in a day.

As recommended by (FHWA 1980) [11] and (NCHRP1980) [5], the recording period is defined in terms of one-hour blocks. A typical one-hour block is divided into two recording periods and two breaks. The location of observers is in a range of 30-90 meters upstream of the intersection depending on the available space for observation purposes [6]. The fifteen-minute periods of observation are adjusted to represent one-hour period. The adjustment process consists of estimating the number of conflicts by type that occurs during the non-observation period [6].

Table (2): Measurement Procuderes in Reviewed Literature for Traffic Conflicts

Source	**Intersection Type**	**Duration**	**Counting Procedure**	**Team**	**Measurement procedure**
Perkins&Harries (1968) U.S [12]	Signalized & unsignalized intersections	3 days,12 hrs per day	Alternate sampling per direction	* * *	Observation procedure
Baker(1972) U.S[12]	Different types of intersection	1 day	15 min sample on each approach	Two-persons	Recording procedure
NCHR (1980) [5]	Signalized	4 days, 4 hrs/day	15 min	Two observers for conflict	Observation procedure
Brian L. Bowman & Robert L. (1995) [13]	Signalized & mid block location in CBD & suburban areas	* * *	* * *	Using video camera	Recording procedure
Katamine (1998) Jordan [14]	Signalized with three & four legs	Off 9 peak hrs (9-12) Am & (3-5) Pm during weekdays (Saturday - Wednesday)	20 min – two group alternate between the approach every half hour	Four persons, two of them for conflict	Observation procedure

(* * *) Unreported in the literature.

Relationships between Traffic Conflicts and Traffic Volume

Most of related literatures show that traffic conflicts have a high positive association with traffic volume. Table (3) demonstrates a summary of key finding for some literatures about the relation between traffic conflict and traffic volume.

On the other hand, some statistical models were developed to relate traffic conflicts and traffic volumes are as follows:

- **(**Katamine 2000) reported that, the traffic entering volume is significantly correlated with total conflicts of all grades and the coefficients of determination for various relationships ranged between 0.370 to 0.960 [15].

- (Shbeeb 1992) showed linear relationships between traffic conflicts of different levels and total approach volumes [16]. The coefficients of determination for various relationships ranged between (0.620) and (0.920).

Table (3) : Summary of Relationships between Traffic Volumes and Traffic Conflict

Author	Type of Intersection	Key Finding
Ghrair 1985 [17]	Signalized intersections with three & four legs	The relationships between traffic conflicts and traffic volume indicate that counting conflicts alone does not reflect traffic volume.
Yan and Sheng 1985 [18]	Different types of Intersections.	For both kinds of intersections , signalized and unsignalizeds, the number of conflicts increases with increase in traffic volume.
Katamine 1998 [14]	Signalized intersections	Significant statistical correlation exists between total volume and total number of conflicts.
Glennon et.al [19]	Signalized intersections	Conflicts have a high positive association with traffic volume

- Ghrair (1985([15] developed a model that explains the relationship between total conflict and traffic volume at signalized four leg intersections, this model is as follows:

$$Y=1.46 + 0.106X \quad (R^2=0.886) \quad (1)$$

where:

Y= total conflicts per 15 minutes, X= total traffic volume per15minutes.

Relationships between Traffic Accidents and Traffic Conflicts

Traffic conflict technique has been developed to evaluate accident potential and safety problem [20]. The traffic conflict technique may be useful for solving problems at individual intersections [21]. Many studies are conducted to detect the relations between traffic accidents and traffic conflicts. Table (4) shows a summary of these relations at different sites of signalized intersections.

Table (4) Summary of Relationships between Traffic Conflicts and Traffic Accidents

Author	Study Site	Key finding
Spicer 1973 [22]	-Signalized intersections	-There is high and significant correlation between accidents and serious conflicts.
NCHRP 1980 [5]	-Signalized intersections	-Linear relationships between traffic accident and traffic conflicts.
Glauz& Migletz 1982 [23]	-Signalized & unsignalized intersections four-legs & three-legs	-Traffic conflict data should be viewed as supplements to, not replacement of, accident data. - When accidents of certain types are compared with conflicts of analogous types , better relationships are obtained. - Opposing left-turn accidents and cross-traffic accidents, particularly, yields significant correlation with analogous conflicts.

Models of Traffic Conflicts in Relation with Geometric Characteristics

To evaluate the traffic safety, some researchers used T.C. as a measure in place of accident records. Some of local studies are reviewed as follows:

- Al-Isa *et al* (1988) applies T.C.T at different types of intersections. The procedure of this study includes many independent variables such as speed, traffic volume, number of lanes and stopping sight distance[24]. The main conclusions of points in this study are :
  - The average number of conflicts for rear-end sideswipe causing accidents is much higher for major arterial at signalized intersections than those for collector and local streets.
  - No relationship between traffic conflict and sight distance is established for signalized intersections.
- AL- Kubaisy (2002) has developed models for uncontrolled intersections relating the traffic volume and geometric characteristics, to

traffic conflicts by linear regression relationship with coefficient of determination ranging from 0.998 to 0.96 [25].

Identification of Hazardous Approach

Evaluation of traffic safety at a study site of highway is based on identification of hazardous spot or approach among others. The rate quality control method is applied in the present study to determine the hazardous approach at the study site. Rate quality control method utilizes a statistical test to determine whether the conflict rate at a particular approach is significantly higher than the critical rate for approaches of similar characteristics.

Accident patterns are determined using a suitable summary of accident data. Cluster analysis is used to identify any abnormal occurrence of a specific accident type by rate in comparison with other types of accidents at a specific site [26]. In the present study, cluster analysis is used to identify any abnormal rate of conflicts at the hazardous approach of the study sites. The rate of conflict used in this analysis represents the number of conflicts divided by the generating traffic volume that involves such type of conflicts.

Methodology and Data Collection

Site Selection

To collect the required data according to the objectives of the study, a general reconnaissance in selection of sites is carried out covering the area of Baghdad City. Four signalized intersections are selected as being the most suitable over the others for the purpose of this study. Extensive fieldwork is conducted at four leg-signalized intersections located in Baghdad City. The general guidelines that are considered in site selection are as follows [5, 11]:

- Minimal pedestrian traffic.
- No appreciable grade (down grades produce more brake-light application).
- Minimum volume at intersection must be equal to 1000 vehicle per day.
- No parking restrictions.

According to the above guidelines and criteria, the following signalized intersections are selected to conduct the present study:

1. Al-Akadimyah intersection
2. AL-Sarafiyah Intersection
3. Baratha Mosque Intersection
4. AL-Kasrah intersection

Procedure of Data Collection

The procedure of data collection consists of three stages; Geometric characteristics, traffic conflict data, and traffic data. Level instrument and cloth tape was used in the site observation. Period of data collection was extended from 4 April to 5 March 2004. Due to failure of electricity source, several times data were collected at low enforcement and traffic signal was operated by the police officer according to the cycle and green time operated at the intersection.

Traffic Conflict Data

The traffic conflict data are collected due to the definition of NCHRP [5] using the recording procedure technique. The traffic conflict data are collected at each of the observed intersections during a weekday (Sunday, Monday, Tuesday and Wednesday) on peak at A.M and P.M period. Table (5) shows a sample of a schedule adopted for observing the events at AL- Akadimyah Intersection by using a camera (Sony/video digital, 700x/zoom, high quality, USB streaming) for the A.M period. The observing period is carried out for 15 minutes at each approach followed by a break of 15 minutes for four legs signalized intersection [6].

Table (5) :A Sample of Peak Period (On Peak A.M)

Conflict Observation Schedule at AL- Akadimyah Intersection

Step No.	Time	Type of Activity
1	6:55-7:25	• Preparation at site and setup the camera
2	7:25-7:40	• Observe all conflict types and volumes on approach No.1 and No. 4
3	7:40-7:55	• Move to the second location of observation and setup the camera
4	7:55-8:10	• Observe all conflict typesand volums on approach No.2 and No. 3
5	8:10-8:25	• Move to the first location and setup the camera again
6	8:25-9:25	• Repeat steps No. 2 to step No.5
7	9:25-10:25	• Repeat step No. 6

The conflicts are estimated for one-hour period for each approach at an intersection. The adjustment process assumes that conflicts occur during the non-observation periods are under similar conditions to the conflicts that occur during the corresponding observation periods [6].

The traffic conflict data are then collected compiled and presented in a format suitable for analysis. The data collection sheet includes details of all the effective conflict types at signalized intersections, traffic volume and general condition for intersection.

Table (6) demonstrates the conflict types considered in the present study and their abbreviations. These abbreviations are used in the developing models for relation of conflict types as dependent variables.

The following equation is used to determine the minimum sample for conflict numbers [27]:

$N=P*q*K^2/E^2$…………………………………………………………….….….. (2)

where: N minimum sample size, P, q = proportion of the vehicles involved and not involved in specific traffic conflict for the observed flow of traffic respectively, K= constant corresponding to the desired confidence level, E= permitted error in the proportion estimate of traffic conflicts.

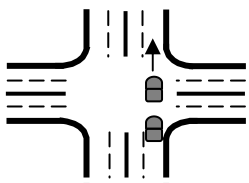
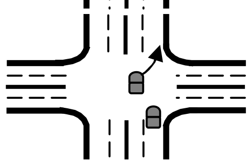
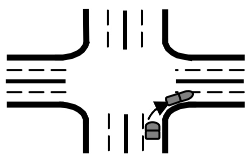
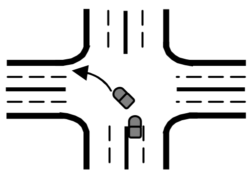
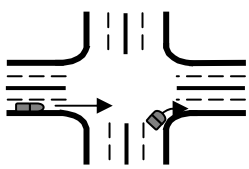
The equation for sample size should be checked for each movement and each type of traffic conflict. The traffic data are collected for the observed intersections at 90% confidence level and 10% percentage of permitted error. Traffic data include the following items:

<u>Traffic Volume Data</u>

Traffic capacity studies show that 15 minutes intervals are not fully adequate to establish the peak hour and that five minutes count are preferable [27]. In the present study, five minute intervals are used to count traffic volume at location upstream of the intersection to determine the hourly volume at each approach. Cycle by cycle counts are used to determine the percentage of through, left turn and right turn movements [27].

The traffic conflict data as well as the traffic volume are recorded according to the classified movement left turn, right turn and through movements. The peak hour is identified firstly. Then, the traffic volume data is collected and the traffic conflicts are counted at the peak hour at the same time and procedure.

Table (6) List of the Codes Used for Conflict Types

Code	**Conflicts types ***	**Conflict Configurations***
C_1	Slow vehicle : Slow vehicle, same direction conflict situation occurs when an instigating vehicle slows while approaching or passing through an intersection, thus placing a following vehicle in jeopardy of a rear-end collision.	
C_2	Lane change : Lane change conflict situation occurs when an instigating vehicle changes from one lane to another, thus placing a following, conflicted vehicle in the new lane in jeopardy of a rear-end sideswipe collision.	
C_3	Right turns same direction : A right turn same direction conflict situation occurs when an instigating vehicle slows to make a right turn, thus placing the conflicted vehicle in jeopardy of rear-end collision.	
C_4	Left turns same direction : A left turn, same direction conflict situation occurs when an instigating vehicle slows to make a left turn placing a following conflicted vehicle in jeopardy of rear-end collision	
C_5	Right turns cross traffic from left : The right turn, cross traffic from left conflict situation is rather unusual . It occurs when an instigating vehicle	

approaching from the left makes a right turn across the centre of the road way and into an opposing lane, thus placing a conflicted vehicle in that in jeopardy of ahead-on collision.

$C_6= C_4+ C_5$	Total same direction
$C_7= C_1$ To C_4	Total rear-end conflict
C_8	Total conflict type

*: Extracted from reference [5]

Speed Data

A spot speed study is conducted at each site to determine the unknown design speed. The spot speed surveys are carried out at the studied approaches by using manual method. Two painted signs are used to assign the course length across the pavement at the start and end of the measured course. The position of the course is selected beyond the queue approach. Speed data are measured at the same condition in which conflict and volume data are collected Summery of course length is shown in Table (7). The following equation can be used to determine the minimum sample size for the normal distribution of spot speed data [27]:

$$N=(S*K/E)^{2} \quad \text{...(3)}$$

where: N: minimum sample size, S: estimated sample standard deviation, K: constant corresponding to the desired confidence level, E:permitted error in the speed estimate .

The permitted error (E) may range from ± 8kph to ± 1.5kph or even less depending on the purpose of the study [27]. However, in this study a value of ±2 kph has been used to compensate for a possible error in measurement.

Table (7) Summery of Used Course Length at Observed Intersections

Intersection Name	**AL- Akadimyah Intersection**				**AL- Sarafiyah Intersection**				**Baratha Mosque Intersection**				**AL-Kasrah Intersection**			
App. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Course Length (m)*	50	50	50	50	50	50	50	50	50	25	50	50	50	50	50	25

***: Course Length (m)=25m , 50m and 75m when average speed of traffic stream below 40 kph, 40 kph to 65 kph and above 75 kph respectively.**

Analysis and Discussion of Results

Summery of data collected is shown in Table (8); different stages of analysis are performed in the following articles:

.Analysis of Collected Spot Speed Data

Chi-Square Goodness of Fit Test is used to check the normality distribution of the observed speed data. The estimated design speed is obtained according to the 85%

of collected spot speed data from the cumulative frequency curve for all approaches. Goodness of fit test shows that: it can not be rejected that the speed data follows a normal distribution for a 5 % degree of significance. Hence, consistencies of speed are introduced and drivers drive as it is expected at each site.

Regression Analysis to Relate Hourly Traffic Conflicts to Hourly Traffic Volume

The resulting statistical analysis of regression (by STATISTICA software) between hourly traffic conflicts and hourly traffic volume is shown in Table (9). It can be seen that, linear relationships are significantly appropriate to explain the relation between hourly traffic conflict and hourly approach traffic volume with coefficient of determination ranging between 0.701 and 0.884 at (0.0002) level of significance. This result agrees with the reported findings in Table (3) considering that traffic conflicts of all types are highly correlated to the traffic volume.

Table (8) Summery of collected data (Hourly Traffic Volume by Movement, Hourly Traffic Conflicts and Geometric Characteristics)

Intersections Name	App. No	Traffic Volume by Movement (vph) *1			HTV (vph) *2	Hourly Traffic Conflicts (C_i) *3					Geometric Characteristics *4				
		L	Th	R		C_1	C_2	C_3	C_4	C_5	LW	MW	DS	PASD	AALL
AL-Akadimyah Intersection	1	749	676	392	1817	16	12	6	15	6	3.5	2.5	48.0	69.8	2
	2	524	622	586	1732	15	11	5	14		3.5	15.0	49.4	*	1
	3	653	970	373	1996	17	8	3	15	7	3.5	2.0	50.0	64.1	3
	4	794	803	414	2012	18	13	7	17	7	3.5	11.5	49.8	67.7	1
AL-Sarafiyah Intersection	5	411	1381	872	2664	50	42	20	49	10	2.5	2.0	50.2	57.4	1
	6	326	724	130	1180	12	13	7	15	6	2.8	11.5	45.3	55.5	1
	7	739	1764	319	2822	38	41	18	51	11	2.5	2.0	40.7	58.2	1
	8	259	628	429	1316	13	10	8	16	5	2.8	11.5	48.4	47.8	1
Baratha Mosque Intersection	9	1100	1222	292	2614	33	28	17	34	N.A	2.5	2.5	48.5	*	1
	10	361	1174	725	2260	22	16	13	23	8	2.8	20.5	35.4	58.7	1
	11	597	635	208	1440	14	10	8	13	6	2.8	3.5	45.2	51.6	1
	12	566	1447	139	2152	20	15	9	18	8	3.2	22.2	44.3	59.	1

														5	
AL-Kasrah Intersection	13	350	733	317	1400	13	10	6	12	6	3.0	2.3	50.2	48.5	2
	14	713	1142	491	2340	23	17	14	26	N.A	2.8	2.0	46.7	*	1
	15	430	618	712	1760	16	12	6	15	N.A	3.4	2.5	44.3	*	1
	16	**758**	**1465**	**320**	**2543**	**24**	**18**	**14**	**22**	**N.A**	**2.9**	**2.0**	**38.4**	*****	**1**

*1- L: Left turns movement, Th: Through movement, R: Right turns movement.

*2- HTV: Hourly traffic volume.

*3-C_i: Conflict coding with reference to Table (6).

*4 : LW:Lane Width, MW:Median Width, DS:Design Speed, PASD:Percentage Available Sight Distance[PASD=(ASD/RSD)% where ASD: available sight distance are measured in the site ,RSD: Required Sight Distance are calculated according to procedure explained in reference[28], AALL=Availability of Auxiliary Lane Length= 3: if approach has adequate auxiliary lane length,=2:if approach has not adequate auxiliary lane length,=1:if approach has not auxiliary lane.

*: Approach has no right turn on red.

Table (9) Linear Models Developed Relating Hourly Traffic Conflict to Hourly Traffic Volume

Conflict Types C_i	**Model development $C=ß+ ß_1 V$**		**R**	**R^2**	**P-value**	
	ß	**$ß_1$**			**ß**	**$ß_1$ ***
C_1	-12.91	0.02	0.842	0.709	0.050	4.3 E-05
C_2	-22.27	0.02	0.837	0.701	0.013	0.0002
C_3	-5.60	0.01	0.858	0.737	0.06	4.2 E-05
C_4	-18.72	0.02	0.840	0.705	0.03	8.99 E-05
C_5	1.17	0.003	0.94	0.884	0.001	1.68 E-05
C_6	-29.83	0.03	0.843	0.710	0.02	8.02 E-05
C_7	-55.82	0.06	0.843	0.710	0.03	8.04 E-05
C_8	-72.76	0.07	0.854	0.730	0.02	9.97 E-05

C_i= Hourly traffic conflicts (dependent variable), coding in reference to Table (6), ß = Intercept, $ß_1$ = Slope,

V = Hourly traffic volume vph (independent variable).

R = coefficient of correlation, R^2 = coefficient of determination.

Referring to Table (9); It can be seen that right turn cross traffic from left conflict (C_5) introduces the highest correlation with hourly traffic volume (R^2= 0.884). On the other hand, Figure (1) shows exponential relationships as appropriate alternative to the linear ones between hourly traffic conflict and

hourly approach traffic volume with coefficient of determination rangins between 0.759 and 0.8968. This may be interpretive due to extra increase in traffic conflict at high traffic volume.

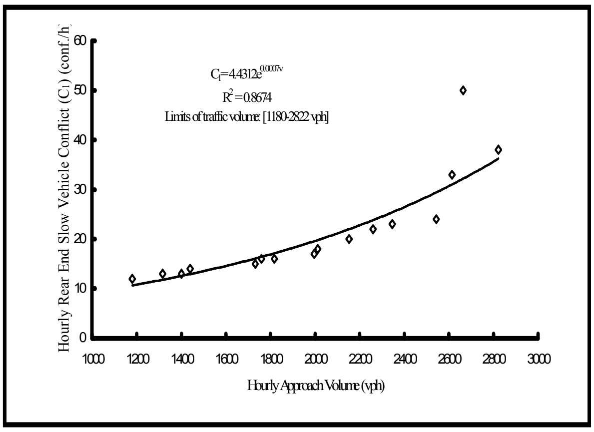


Figure (1-a) Rear End Slow Vehicle Conflict

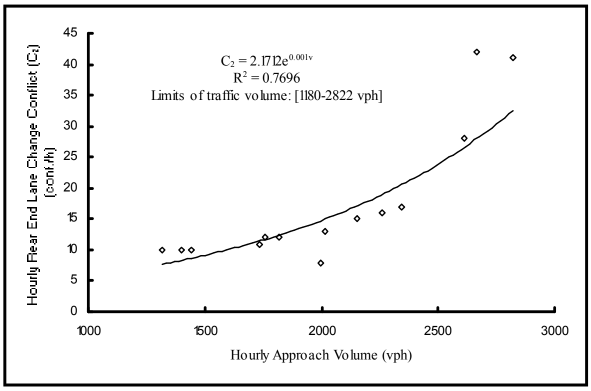


Figure (1-b) Rear End Lane Change Traffic

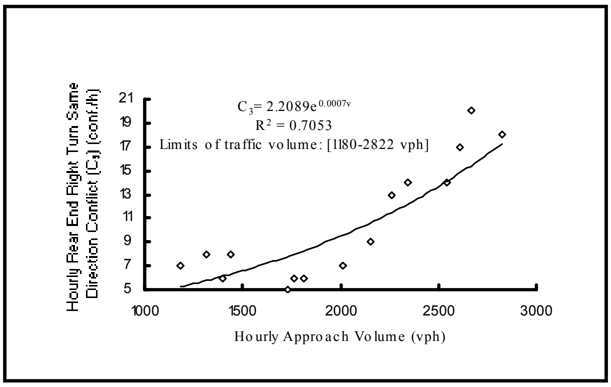


Figure (1-c) Hourly Rear End Right Turns Same Direction

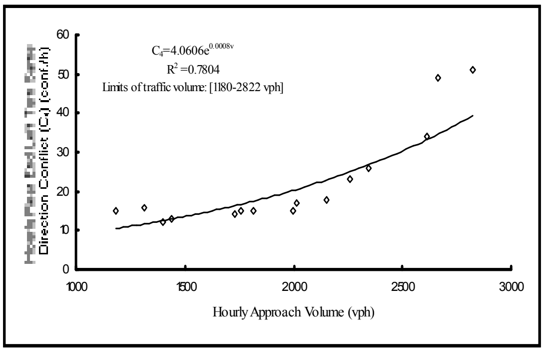
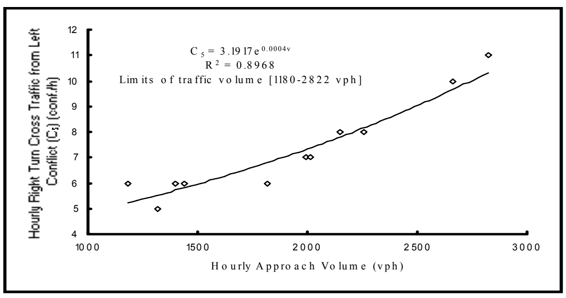


Figure (1-d) Hourly Rear End Left Turns Same Direction



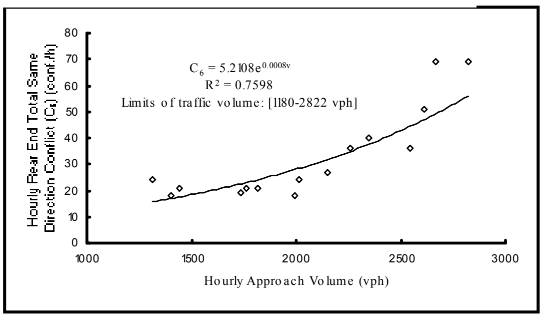
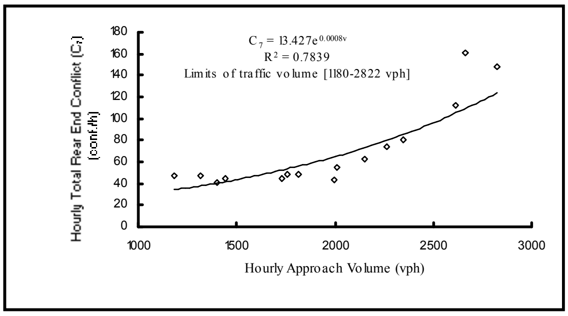


Figure (1-e) Right Turns Cross Traffic from Left

Figure (1-f) Total Same Direction



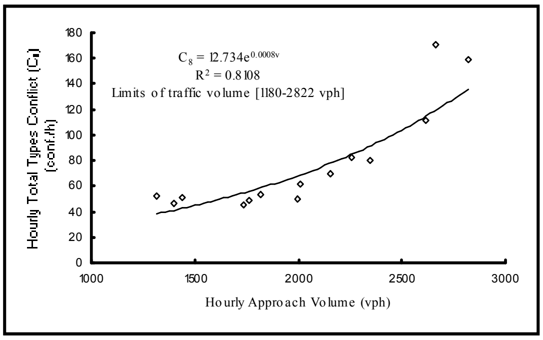


Figure (1-g) Total Rear End

Figure (1-h) Total Types of Traffic

Figure (1) Exponential Relationship between Different Types of Hourly Traffic Conflict & Traffic Volume

9.3 Models Developed to Relate Traffic Conflict Rates to Geometric Characteristics

Table (10) represents a summary of multiple linear regression analysis to relate conflict rates with some geometric characteristics observed at signalized intersections. It can be seen that, a model of multiple linear is appropriate to explain the relation between conflict rates and some of geometric characteristics with coefficient of determination ranging between 0.580 and 0.969 at level of significance from 0.0001 to 0.02. According to the developed models, increase is; lane width, median width, percentage available sight distance, and availability of auxiliary lane length, involves a decrease in conflict rates. On the contrary, increase in design speed results in an increase of conflict rates.

Table (10) Summary of Models Developed to Relate Different Types of Traffic Conflicts Rates with Some Observed Geometric Characteristics

Types of Conflict Rate	Developed Model (1) $C_{ri}= a_o+a_1LW+a_2MW+a_3DS+a_4PASD+a_5AALL$ Intercept (a_o)	Parameters for Independent Variables a_1	a_2	a_3	a_4	a_5	R	R^2	P-value(4)
C_{r1}	17.71	-0.71	-0.10	0.31	N.I (3)	-0.11	0.761	0.580	0.01 **
C_{r2}	21.02	-0.71	-0.09	0.20	N.I	-0.18	0.782	0.612	0.02 **
C_{r3}	16.44	-0.86	-0.03	0.04	N.I	-0.23	0.984	0.969	0.006 **
C_{r4}	26.38	-0.82	-0.03	0.21	N.I	-0.28	0.824	0.678	0.004 ***
C_{r5}	5.51	-0.13	-0.10	N.I	-0.98	-0.09	0.929	0.863	0.009 **

C_{r6}	**42.82**	**-0.87**	**-0.03**	**0.16**	**N.I**	**-0.14**	**0.911**	**0.830**	**0.0001 *** **
C_{r7}	**81.55**	**-0.81**	**-0.07**	**0.22**	**N.I**	**-0.15**	**0.856**	**0.732**	**0.002 *** **
C_{r8} (2)	**85.77**	**-0.86**	**-0.03**	**0.23**	**N.I**	**-0.03**	**0.833**	**0.693**	**0.003 *** **
	108.41	**-0.60**	**-0.22**	**N.I**	**-0.35**	**-0.23**	**0.853**	**0.728**	**0.004 *** **

(1): C_{ri} = coding with reference to table (4-4), LW= lane width (2.5m-3.5m), MW= median width (2m- 22.2m), DS= design speed (35.4kph- 50.2kph), PASD= percentage available sight distance (47.82%-69.75%), AALL= availability of auxiliary lane length (1-3).

(2): Design Speed (DS) or Percentage of Available Sight Distance (PASD) is included in separate models to avoid dependency between these variables.

(3): N.I= not included in model.

(4): ** = 0.05 degree of Significance, *** = 0.005 degree of Significance.

9.4. Identification of Hazardous Approach

Table (11) shows that: at confidence level of 95 % approach number 5 at AL- Sarafiyah intersection has a priority of rank (1) in the hazardousness condition and thereby a first need of safety improvement. In addition, approach number 7 at AL- Sarafiyah intersection and approach number 9 at Baratha mosque intersection are of rank 2 and 3 respectively.

On the other hand, it can be seen that: at confidence level of 90 % approach number 5 at AL- Sarafiyah intersection has a priority of rank (1) in the hazardous condition and approach number 7 is of rank 2. This may result from some hazardous aspects in geometric characteristics of the approach No. 5 at AL-Sarafiyah intersection as follows:

- Approach number 5 has a lane width of (2.5 meters) which is the minimum lane width among all approaches at the study site.
- Approach number 5 has minimum median width of (2 meters) among all approaches at the study site. Although this width is within the recommended limit of (AASHTO 1994) [28] (1.2m–24m) it provides a least separation between opposing movements and hence affects conflict occurrence.
- The design speed of approach No. 5 is the maximum (50.2 kph) among all approaches at the study site. The avoidance of accidents as well as conflict

depend on the judgment capabilities and the response of the individual driver.

- Approach No. 5 has percentage of available sight distance of (57.37%). The ability to see traffic that approaches from a cross street is dependent on obtaining a clear diagonal line of sight. When blocked by buildings as in the hazardous approach the sight line may be insufficient to permit a vehicle from stopping in time to avoid colliding with side street traffic.
- Approach number 5 has no auxiliary lane (left turn lane). Hence, there is no permission for the traffic with major operational differences to separate and thus avoid drastic differentials in speed and delay characteristics.

Table (11) Identification of Hazardous Approach at the Study Sites.

Intersection Name	**App. No.**	**HTV (veh.)**	**$R_{observed}$ (conflict/10^3 veh.)**	**$R_{critical}$ (H)*** Confidence Level	
				95 % *1	**90 %*2**
AL-kadimyah Intersection	1	1817	29.72	42.83	44.5
	2	1732	25.55	42.99	44.66
	3	1996	25.47	42.54	44.10
	4	2012	30.46	42.52	44.07
AL-Sarafyah Intersection	5	2664	64.42	41.74 (H)[1]	43.09(H)[1]
	6	1180	44.42	44.57	46.40
	7	2822	56.29	41.60 (H)[2]	42.91(H)[2]
	8	1316	40.15	43.95	45.87
Baratha Mosque Intersection	9	2614	42.72	41.79 (H)[3]	43.15
	10	2260	36.46	42.18	43.65
	11	1440	35.44	43.62	45.45
	12	2152	32.15	42.32	43.82
AL-Kasrah	13	1400	33.43	43.72	45.58

Intersection	14	2346	34.00		42.08	43.52
	15	1760	27.52		42.94	44.60
	16	2543	30.51		41.86	43.24

HTV: Hourly traffic volume.

$R_{observe}$: The total conflict rate at the approach (conflict/10^3 veh).

$R_{critical}$: Critical conflict rate for a spot (conflict/ 10^3 veh.),
$(H)^*$: H= Hazardous approach, * = priority ranking.

Finally, approach No.5 is the most hazardous approach and simultaneously, has the lower rank in the geometric characteristic of all approaches in the study site. Hence, it can be concluded that the procedure of identification of hazardous approach based on traffic conflict data used in this study is valid. Also, a conclusion can be drawn that there is a significant correlation between geometric characteristics of approaches at four leg-signalized intersections and the conflict rate at that approach. In reference to the developed models in article 9.3, there is a good agreement between the finding of this process and the trend of developed models. On the other hand, according to the pecuniary specification the strategy improvement is executed, when pecuniary specification is limited to two projects (strategy No.2) (approach No. 5 and approach No. 7 at AL-Sarafiyah intersection) have the first priority. Also, when the pecuniary specification is sufficient to achieve (strategy No.1) (approach No. 5, approach No. 7 at AL-Sarafiyah intersection and approach No. 9 at Baratha Mosque intersection) are carried out.

Cluster analysis for the hazardous approach (approach number 5 at Al-Sarafiyah intersection by priority ranking) is summarized in Table (12). It can be seen that: the left turn same direction and slow vehicle conflict rate by generating volume have abnormal occurrence at the hazardous approach according to the priority ranking. In addition, the conflict types of abnormal occurrence at approach No. 7 at Al- Sarafiyah intersection (the second priority in hazardousness) are left turn same direction and right turn same direction. Also, right turn same direction and left turn same direction are the predominant conflict types at approach No. 9 at Baratha Mosque intersection (the third priority in hazardous).

Table (12) Conflict Patterns at the Hazardous Approach (No.5-SB) of AL-Sarafiyah Intersection

Conflict Type (C_i)	**G.V (veh.)**	**C_{rgi} (Conflict/10^3)**	**P.R**
C_1	1381	36.2	2
C_2	1792	23.4	3
C_3	870	22.9	4
C_4	411	119.2	1
C_5	1596	6.3	5

(C_i): Coding with reference to Table (6). G.V: Generating volume.
C_{rg}: Conflict rate of specific conflict type due to generation volume.
P.R: Priority ranking.

To alleviate the identified safety deficiencies, Table (13) is a list of suitable countermeasures at the hazardous approach of the study sites according to the abnormal conflict patterns with possible causes.

Table (13) Proposed Countermeasure for the Predominant Conflict Types at the Hazardous Approaches.

Types of Conflict	Probable Cause	General Countermeasure/ Approach
-Left turn same direction	-Slippery surface	- Overlay pavement. (All approaches) - Reduce speed limit. (All approaches)
	-Large number of turning vehicle	- Create left turn lanes (Approach No. 5 at AL-Sarafiyah intersection, and Approach No. 9 at Baratha Mosque intersection) - Provide special phase for left turning traffic. (Approach No. 5 at AL-Sarafiyah intersection, and Approach No. 9 at Baratha Mosque intersection)
-Slow vehicle	-Slippery surface	- Overlay pavement. (All approaches) - Reduce speed limit. (All approaches)
	-Poor visibility of signals	- Add additional signal heads(All approaches) - Remove obstacles. (Approach No. 5, No. 7 at AL-Sarafiyah intersection, and Approach No. 9 at Baratha Mosque intersection) - Reduce speed limit.(All approaches)
-Right turn same direction	-Large number of turning vehicle	- Create right turn lanes. (Approach No. 7at AL-Sarafiyah intersection, and Approach No. 9 at Baratha Mosque intersection)

Conclusions

On the basis of the research findings, the following conclusions can be drawn:

1. Goodness of Fit test of the speed data shows that: the speed data follows normal distribution for a 5 % degree of significance. Hence, consistencies of speed are introduced and drivers drive as it is expected at each site of the study.
2. Linear relationships are significantly appropriate to explain the relation between hourly traffic conflict and hourly approach traffic volume with coefficient of determination ranging between 0.701 and 0.884 at (0.0002) level of significance.
3. Exponential relationships is significantly appropriate to explain the relation between hourly traffic conflict and hourly approach traffic volume with higher coefficient of determination ranging between 0.759 to 0.897 than the linear relationships. This may be interpretive due to extra increase in traffic conflict at high traffic volume.
4. A model of multiple linear are appropriate to explain the relation between conflict rates and some of geometric characteristics with coefficient of determination ranged between 0.580 and 0.969 at (0.0001 to 0.02) level of significance. The developed models show that:
   a. conflict rates of all types decrease in case of increase in; lane width median width and design speed.
   b. conflict rates of all types decrease when approaches have sufficient auxiliary lane length.
   c. right turn cross traffic from left conflict rates decreases when percentage available sight distance increases.
5. The rate quality control method shows that: the lowest rank in the geometric characteristics in reference with the recommended characteristics of

(AASHTO 1994) [28] is the most hazardous approach. A good agreement can be concluded between this finding and the developed model.

6. The cluster analysis used to identify the abnormal conflict type shows that: the left turns same direction and slow vehicle rear end conflict is over represented at the hazardous approach. No auxiliary left turn lane and bad driver behavior may be the reasons for that pattern of traffic conflict.
7. Procedures that are based on traffic accident data such as, rate quality control method and cluster analysis can be sufficiently used in studies based on traffic conflict data. Hence, traffic conflict technique can be used efficiently in evaluating traffic safety at four leg-signalized intersections when accident data are not reliable or not available.
8. A suitable countermeasure (such as, overlay pavement, creating left turn lane and providing special phase for left turning traffic) can be considered based on finding of the result of the process to identify hazardous approaches using traffic conflict technique.

References

1. Republic of Iraq. Commission of Planning. Central Dep. Of Transportation and Communications, *Statistics of Traffic Accidents in Iraq*, Baghdad. Iraq, 1999.
2. Mohammed, N.K. "Towards A Comprehensive National Campaign To Increase Traffic Culture". *Proc. Fourth Scientific Conference: Ministry of Housing & Construction.* Baghdad. Iraq, pp. 26-42, 2001.
3. Erik A., *Joint Intersectional for the Calibration of Traffic Technique*, Director Institute for Road Safety Research SWOV, Netherlands, 1983.
4. Brown, R.J., "A Method for Determining the Accident Potential of an Intersection". *Traffic Engineering and Control*, No. 12, pp.648-651, 1981.
5. National Center Highway Research Program (NCHRP), *Application Traffic Conflict Technique at Urban Intersection*, *Transportation Research Record* No.776, USA, 1980.
6. Parker,M.R., and Zegeer, C.V., *Traffic Conflict Technique for Safety and Operation. FHWA-IP-88-026*, Federal Highway Administration, USA, 1989.
7. Zimolong, B.1980. "Traffic Conflict at Urban Junction". *Transport and Road Research Laboratory*, SR557, pp.130-139, 1980.
8. Zegeer, C.V.,and Deen, R.C., "Traffic Conflict as a Diagnostic Tool in Highway Safety"., *Transportation Research Record*, No.667, pp.48-55, 1978.
9. Tanvir, I. Q., *Validity and Use of Traffic Conflict Technique Study in the Kingdom of Saudia Arabia*. MSc. thesis, University of Petroleum and Minerals, KSA, 1983.

10. Glauz, W. D., and Migletz, D.J., "Traffic Conflict Techniques for use at Intersections", *Transportation Research Record*, No.770, pp. 21-29., 1982.
11. FEDERAL HIGHWAY ADMINISTERATION (FHWA). *Safety Design and Operational for Street and Highways*. FHWA. Technology Sharing Report: 80-228, U.S. Department of Transportation, Washington D.C. U.S, 1980.
12. Hauer, E., "Design Considerations of Traffic Conflict Survey", *Transportation Research Record*, No. 667, pp.55-65, 1978.
13. Brian, L., and Robert, L., "Pedestrian Walking Speeds and Conflicts at Urban Median Locations", *Transportation Research Record*, No. 1438, pp.67-73, 1995.
14. Katamine, N.M., "The Effects of Signalized Intersections Types and their Approaches on the Correlation between Volume and Conflicts", *Safety on Roads: an International Conference*. Amman. Jordan, pp.181-188, 1998.
15. Katamine, N.M., "Various Volume Definitions with Conflicts at Unsignalized Intersections", *Journal of Transportation Engineering*, Vol.126, No1, pp.18-35, 2000.
16. Shbeeb, L.I., *The Usage of Traffic Conflicts Technique at Intersections*, MSc Thesis, University of Jordan, Amman, Jordan, 1992.
17. Ghrair, M.A., *Traffic Conflicts at Rotary Intersections in Amman*, MSc Thesis, Yarmouk University, Irbid, Jordan, 1985.
18. Yan, X., and Sheng, S., *Conflicts and Delay Studies at Unsignalized Intersections*. Institute of Highways, China, pp.237-247, 1985.
19. Glennon, J.C., Glauz, W.D., Sharp, M.C., and Tnorson, B.A., "Critique of the Traffic Conflict Technique", *Transportation Research Record*, No. 630, pp. 32-38, 1977.
20. Glaus, W.D., "Discussion Paper on Design Consideration of Traffic Conflict Survey", *Transportation Research Record*, No. 667, PP.65-66, 1978.
21. Williams, M.J., "Validity of the Traffic Conflicts Technique", *Accident Analysis and Prevention*, Vol.13, pp.133-145, 1981.
22. Spicer, B.R., *A Study of Traffic Conflict of Six Intersections*, Transportation and Road Research Laboratory TRRL, Report SR 551, USA, 1973.
23. Glauz, W. D., and Migletz, D.J., "Traffic Conflict Techniques for use at Intersections" *Transportation Research Record*, No.770, pp. 21-29, 1982.
24. AL- Isa M., Gokmen E., Al-Senan N., and AL- Zabrani A., "Development of a Hazardous Index for Urban Intersections", *Proceedings of the third international road federation IRF, Middle East Regional meeting*, Riyadh, kingdom of Saudi Arabia, 1988.
25. AL- Kubaisy, Y. A., *Development of Hazards Index at Urban Uncontrolled Intersections*. MSc Thesis, AL-Mustansiriya University, Baghdad, Iraq, 2002.
26. Garber, N.J., and Hoel, L.A., *Traffic and Highway Engineering*, 2nd edition, PWS Publishing Company, USA, 1988.
27. Box Paul, C. and Oppenlander J.C., *Manual of Traffic Engineering Studies*, Institute of Transportation Engineers. Virginia, USA, 1976.
28. American Association of State Highway and Transportation Officials (AASHTO), *A policy on Geometric Design of Highways and Street*, Washington D.C., USA, 1994.