Traffic Conflict Technique: A Tool for Traffic Safety Study at Three-leg Signalized Intersections

تقنية التعارضات المرورية:
أداة لدراسة السلامة المرورية على التقاطعات الثلاثية المسيطر عليها بإشارات ضوئية

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Abstract:

Traffic accident data are the principal tool for identifying degree of safety at traffic system. In situation of no reliable accident record, traffic conflict technique TCT is a suitable alternative aid. This paper aims at studying the traffic safety at three-leg signalized intersections using TCT.

Three different sites of three-leg signalized intersections are selected according to specified criteria. The data concerning; traffic volume, traffic conflict, are collected using video camera. Spot speed and some of the geometric characteristics (lane width, median width, and availability and length of auxiliary left lane), are determined and measured due to observation at site.

A developed model shows that, an extra increase of traffic conflicts can be represented by negative exponential trend in relation with approach traffic volume. That negative exponential model shows a better explanation rather than linear model. On the other hand, developed models are introduced to indicate the traffic conflict rate in relation with some geometric characteristics. Further, a statistical analysis of extracted data of previous works in sites of four-leg signalized intersections reveals that no significant dependency of traffic conflict occurrence, in relation with approach traffic volume, with the type of signalized intersection (three or four legs). In addition, it is found that, linear relation explains increasing variation (97.8%) of total hourly traffic conflict in relation with total stopped delay time. This may reveals that the potential conflict increases when drivers argue from unacceptable delay introduced due to the traffic operation at the intersection.

المستخلص:

تمثل بيانات الحوادث المرورية الأداة الرئيسة في تشخيص درجة السلامة على منظومة المرور. في حالة عدم وجود تسجيل حوادث بشكل موثوق فان تقنية التعارضات المرورية أداة بديلة مناسبة. هذه الورقة تهدف الى دراسة السلامة المرورية على التقاطعات الثلاثية المسيطر عليها بالأشارات الضوئية باستخدام تقنية التعارضات المرورية.

تم اختيار ثلاث مواقع لتقاطعات ثلاثية مسيطر عليها بالأشارات الضوئية وفقا لمعايير محددة. تم جمع بيانات الحجوم والتعارضات المرورية باستخدام كاميرا فيديو. أما سرعة المركبات وبعض الخصائص الهندسية للتقاطعات (عرض المسرب،عرض الجزرة الوسطية، توفر وطول مسرب الأستدارة لليسار) فقد تم احتسابها استنادا لمشاهدات موقعية.

يبين النموذج الإحصائي المستحدث بان هناك زيادة اضافية للتعارضات المرورية وبمنحى أسي سالب بالعلاقة مع الحجم المروري للطريق المؤدي للتقاطع. يبين البحث بان تلك العلاقة الأسية السالبة توضح نسبة اكبر من التغير في التعارضات المرورية بالمقارنة مع العلاقة الخطية. من جانب آخر، فان البحث يقدم نماذج إحصائية مستحدثة للعلاقة بين معدل التعارضات المرورية وبعض الخصائص الهندسية. فضلا عن ذلك فان التحليل الإحصائي لبيانات البحث وأخرى مأخوذة من بحوث سابقة على تقاطعات رباعية يبين بأنه لا يوجد اعتماد معنوي لعلاقة التعارضات مع الحجوم المرورية، مع طبيعة ذلك التقاطع (ثلاثي أو رباعي). كذلك يبين البحث بان (97.8%) من التغير في التعارضات المرورية يمكن توضيحه بالعلاقة الخطية مع زمن تأخير التوقف على التقاطع. وذلك يبين بان احتمالية التعارض تتزايد حينما يتعرض السائقين الى تأخير غير مقبول ناتج من عمليات المرور على التقاطع.

1. INTROUDUCTION:

Traffic accidents are not a good measurement for describing the traffic safety condition because it has many problems. One of these problems is that the number of accidents at a specific site is usually small; many years have to be included to get a good picture of the situation, this means that many extraneous factors are changed during the period of observation. Another problem is that many

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accidents are never reported to the police. A third problem is that often a countermeasure is introduced at a site because the number of reported accidents there has been large.
The conflicts do not only reflect the number of accidents well, but also their nature. A negative aspect of conflict technique is the severity (fatality, injury, and property damage only) involved, which cannot be well explained by traffic conflicts.
The process of a conflict is almost identical to that of a compatible accident. Therefore, the observations can be used as a basis for explaining how these situations occur. Analytical study of traffic conflicts may avoid the social economic effects of a potential traffic accident that can be diminished by a proper countermeasure.

2. BACKGROUND

Perking and Harris have used the traffic conflict technique since 1967[1]. Table (1) shows summary of authors adopted this technique and their contributions to evaluate traffic safety conditions at different types of intersections.

3. Relationships between Traffic Conflicts and Traffic Volume

Most of the previous studies at intersection sites concluded that a linear relation with different coefficients of determination may explain traffic conflict in reference to traffic volume. Table (2) demonstrates a range of 37% to 99% of variation in traffic conflicts can be explained by the linear relationships with traffic volume.

4. Site Selection

The data for this research are collected at 3-leg signalized intersections located in Baghdad city in 2003. All intersections have no pedestrian facilities , no appreciable grades, no markings are present at the intersection area, and had entering traffic volume more than 1000 vehicles per day as recommended by NCHRP and FHWA [4,15]. According to this guidelines, the signalized intersections selected to conduct the present study are:

1. Abu-Talib Intersection.
2. Ras AL- Hawash intersection.
3. AL- Emam AL-Adham intersection.

5. Data Collection

The main data concerning this research are classified into; traffic conflict data, traffic volume data, and geometric characteristics. Due to failure of electricity source, several times data are collected at low enforcement and traffic signal is operated by the police officer according to the designed cycle and green time.

5.1. Collection of traffic conflict data

The data are collected due to the definition of NCHRP (traffic conflict as" an 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") [4]. The recording procedure is achieved by a Sony video digital, 700x / zoom,
high quality USB streaming, to calculate the traffic conflict data. 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 observations is in a range of 30-90 meters upstream of the intersections depending on the available space for observation purposes [16].
Four weekday (4-hour minimum) traffic conflict study are conducted at each intersection on peak at A.M and P.M period. The data collection procedures include; a 10 minutes set-up the camera before the start conflict study followed by data collection for 20 minutes then moves to the second location of

observation and starts to set-up the camera again [16]. Four types may occur at the observed three-leg signalized intersections and their abbreviations [4]:

a- Slow vehicle Conflict (C_1):

Slow vehicle, same direction conflict situation occurs when an instigated vehicle slow while approaching or passing through an intersection, thus placing a following vehicle in jeopardy of a rear-end collision.

b- Lane Change Conflict (C_2):

Lane change conflict situation occurs when an instigated 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- Right Turn Same Direction Conflict (C_3):

A right turn same direction conflict situation occurs when an instigated vehicle slows to make a right turn, thus placing the conflicted vehicle in jeopardy of rear-end collision.

d- Left Turn Same Direction Conflict (C_4):

A left turn, same direction conflict situation occurs when an instigated vehicle slows to make a left turn placing a following conflicted vehicle in jeopardy of rear-end collision.

5.2. Collection of traffic volume data

The peak hour is identified firstly at A.m and P.M period. The peak hour and hourly traffic volume at each approach are identified due to,five minute intervals of counting upstream the intersection. On the other hand, cycle by cycle counts is used to determine the percentage of through, left turn, and right turn movements. Table (3) shows a summary of all types of conflicts collected as well as hourly traffic volume .

5.3 Geometric Characteristics

The most influent geometric characteristics are measured at the selected intersections. Design speed as an indication of geometric design is extracted from spot speed study achieved at the study sites. Availability of auxilary lanes indicates the possibilty of left turn movement and the avilable lane for that movement. Widths of lanes and medians are measured at the sites using tape measuring. Table (4) demonstrates the geometric characterics prepared for the statistical analysis.

6. Analysis of Relationships between Conflicts and Traffic Volumes

Two types of relation are studied to investigate the correlation between traffic conflict as a dependent variable with the traffic volume as independent. Table (5) shows that, the exponential model describes a range of variation (77.7% - 94%) in different types of traffic conflict due to the relation with traffic volume with a significance of 0.09 or less. Further, exponential model introduces a less standard error than the linear model. Hence, exponential model is the best alternative to explain the relation between traffic conflict and traffic volume.

Figures (3-a to 3-e) demonstrate the exponential relation between the traffic conflict and traffic volume. It can be seen that, exponential model reveals that extra increase in traffic conflict may be resulted due to further increase in traffic volume.

7. Influence of Intersection Type on Correlation between Traffic Conflicts and Volumes.

The developed correlation between traffic conflicts and volumes is tested for validation to prediction of conflicts in reference to extracted data of four-leg intersections from Neham 2005 [17]. The Chi-square (χ^2) test is employed to check whether the difference between the observed conflicts and predicted conflicts from the developed relation is significant or not as reported in Table (6).

It can be seen that, χ^2 tabulated is more than all values of χ^2 calculated. Hence, it can be concluded that, the predicted values of different types of conflicts using the developed model of three-leg intersections, are not significantly different from those observed at the four-leg intersections. Hence, the correlation between traffic conflicts and volume is independent of the type of the signalized intersections (three or

four legs). In consequence, the data of three-leg intersections and that of four-leg intersections can be dealt at once as one set of data without serious effect on the safety analysis at the sites.

8. Correlation between Conflict Rates and Some Geometric Characteristics

Fifty percent of accidents occur at intersections therefore understanding the problem may lead to better improvement strategy [18]. The severity of accidents is related to types of accidents, geometric condition, and traffic control, at signalized intersections. Due to unreliable accident records and the time required to collect adequate sample sizes, the traffic conflict technique can still be very useful tool to identify the relation between safety condition and some geometric characteristics at the signalized intersections.

Statistical models are developed to detect the effect of four geometric characteristics: lane width: median width: design speed :and availability of auxiliary lanes as shown in Table (7). Intercept in models introduces less residual than the case of no intercepts, even of the higher percentage of explanation of the model shown in models without intercepts. In addition, exponential model shows less percentage of explanation and higher residual errors. Hence, it is intended to consider the multiple linear model with intercept to represent the variation of traffic conflicts in relation with some geometric characteristics.

In reference to P-values of the multiple linear model, there is no significant relation between left turn same direction conflict and some observed geometric characteristics while there are in case of other types of conflicts.

It can be seen that the width adequacy of lane and median, and the availability of auxiliary lanes decrease the conflict rates at signalized intersections. On the other hand, the design speed shows a contrary effect with less contribution. This may be attributed to the fact that the high design speed does not match the geometric characteristics at the observed sites. In consequence, the expectancy of drivers is affected resulting in potential conflicts and thereby accidents.

9- Traffic Conflict and Delay at Intersections

The assumption behind the correlation of traffic conflicts and total stopped delay time is that the potential conflict increases when drivers argue from unacceptable delay introduced due to the traffic operation at the intersection. This paper highlights a promising study of any probable relation, in order to use conflict technique as an aid to represent level of service as well as level of safety. A software of HCS 2000 is used to analyze the traffic operation at the different studied intersections to compute total stopped delay. Linear relation explains increasing variation (97.8) of total hourly traffic conflict in relation with total stopped delay time as shown in Figure (2). Linear relation represents relatively less percentage of variation.

10. Conclusions

1. The exponential model describes a range of variation (77.7% - 94%) in different types of traffic conflict due to the relation with traffic volume with a significance of 0.09 or less. Further, exponential model introduces a less standard error than the linear model. Hence, exponential model is the best alternative to explain the relation between traffic conflict and traffic volume.
2. Exponential model reveals that extra increase in traffic conflict may be resulted due to further increase in traffic volume.
3. The correlation between traffic conflicts and volume is independent of the type of the signalized intersections (three or four legs). In consequence, the data of three-leg intersections and that of four-leg intersections can be considered as one set of data without serious effect on the safety analysis at the sites.
4. There is no significant relation between left turn same direction conflict and some observed geometric characteristics while there are in case of other types of conflicts.

5. The width adequacy of lane and median, and the availability of auxiliary lanes decrease the conflict rates at signalized intersections. On the other hand, the design speed shows a contrary effect with less contribution.
6. Linear relation explains increasing variation (97.8 %) of total hourly traffic conflict in relation with total stopped delay time. This may reveals that the potential conflict increases when drivers argue from unacceptable delay introduced due to the traffic operation at the intersection.

11. References

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Table (1) Review Summary about Traffic Conflict Technique at Intersections

Author	Type of Intersection	Key Finding
Spicer 1973 [2]	Signalized intersection	There is high and significant correlations between accidents and serious conflicts.
Glennon et.al 1977 [3]	Signalized intersections	Conflicts have a high positive association with traffic volume
NCHRP 1980 [4]	Signalized intersection	Linear relationships between traffic accidents and traffic conflicts.
Glauz& Migletz 1982 [5]	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 were compared with conflicts of analogous types , better relationships were obtained. - Opposing left-turn accidents and cross- traffic accidents, particularly, yielded significant correlation with analogous conflicts.
Yan and Sheng 1985 [6]	Different types of Intersections.	For both kinds of intersections , signalized and unsignalized, the number of conflicts increases with increase in traffic volume.
Ghrair 1985 [7]	Signalized intersections with three & four legs	The relationships between traffic conflicts and traffic volume indicate that counting conflicts alone does not reflect traffic volume.
Al-Isa et al (1988) [8]	different types of intersections	- 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.
Katamine 1998 [9]	Signalized intersections	Significant statistical correlation exists between total volume and total number of conflicts.

Table (2) Proposed linear Relationships between Traffic Conflicts and Traffic volume at Intersection Sites

Author	R^2	Type of study area
Ghrair 1985 [7]	0.87	Signalized intersections (four and three legs)
Shbeeb1992 [10]	0.63-0.92	Unsignalized intersections (four - legs)
Salman and AL-Maita 1993 [11]	0.43-0.75	Unsignalized intersections (three legs)
Katamine 1998 [9]	0.28	signalized intersections (four and three legs)
Katamine 2000 [12]	0.37-0.96	Unsignalized intersections (four and three legs)
Katamine 2000 [13]	0.95	Unsignalized intersections (four - legs)
AL-Kubaisy 2002 [14]	0.89-0.99	Unsignalized intersections (four and three les)

Table (3) Hourly Conflict Counts at The Studied Intersections

Intersections Name	App.No	HTV (vph)	Hourly Traffic Conflicts (C_i)*				
			C_1	C_2	C_3	C_4	C_5
Abu-Talib Intersection	1	1135	9	17	N.A.	8	34
	2	1767	12	19	20	3	54
	3	2215	19	35	35	N.A.	89
Ras AL- Hawash intersection	4	1659	12	18	N.A.	4	34
	5	1644	12	19	21	9	61
	6	2158	17	29	32	N.A.	78
AL- Emam AL-Adham intersection	7	2351	23	38	N.A.	26	87
	8	1439	11	17	17	2	47
	9	1342	11	17	18	N.A.	46

* C_1= Slow vehicle Conflict , $C_{2=}$ Lane Change Conflict , $C_{3=}$ Right Turn Same Direction Conflict , $C_{4=}$ Left Turn Same Direction Conflict . $C_{5=}$ All types of conflict.
N.A.= not avilable type of confict at that site.

Table (4) Geometric Characteristics at The Studied Intersections

Intersections Name	App. No	Geometric Characteristics *			
		LW (m)	MW (m)	DS (kph)	AALL
Abu-Talib Intersection	1	3	2	36.8	2
	2	3.6	5.76	37.8	1
	3	3	2	34.2	1
Ras AL- Hawash intersection	4	3.5	4.28	33.4	3
	5	3.5	3.19	30.1	1
	6	3.2	2	31.4	2
AL- Emam AL-Adham intersection	7	2.8	1.8	38.5	1
	8	3.5	3.09	28.7	1
	9	3.4	2.42	36.6	1

*: LW= Lane width, MW= Median width, DS= Design Speed, 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 no auxiliary lane.

Table (5) Linear & Exponential Models Developed Relating Hourly Traffic Conflict to Hourly Traffic Volume

Model	parameter	C_1	C_2	C_3	C_4	C_5
Linear $C= \beta+ \beta_1 v$	β	-4.07	-8.91	-11.23	-18.35	-21.76
	β_1	0.01	0.02	0.02	0.02	0.05
	R^2	0.886	0.836	0.909	0.536	0.825
	P-value (β)	0.14	0.15	0.11	0.23	0.17
	P-value (β_1)	0.000	0.001	0.003	0.090	0.001
	Std. Err.	1.66	3.65	2.59	6.81	9.54
Exponential $C= \beta*e^{\beta 1* v}$	β	3.92	6.11	5.50	0.73	14.28
	β_1	0.001	0.001	0.001	0.001	0.001
	R^2	0.940	0.869	0.926	0.304	0.777
	P-value (β)	0.05	0.02	0.09	0.03	0.06
	P-value (β_1)	0.001	0.000	0.0011	0.001	0.000
	Std. Err.	0.004	0.003	0.000	0.004	0.007

* β = Intercept, β_1= Slope. V= Hourly traffic volume vph (independent variable)., R^2= Coefficint of determination.

* C_1= Slow vehicle Conflict , $C_{2=}$ Lane Change Conflict , $C_{3=}$ Right Turn Same Direction Conflict , $C_{4=}$ Left Turn Same Direction Conflict . $C_{5=}$ All types of conflict.

Table (6) Validation of Conflict Data at Four-Leg Intersections in The Developed Model by Chi-square (χ^2) Test

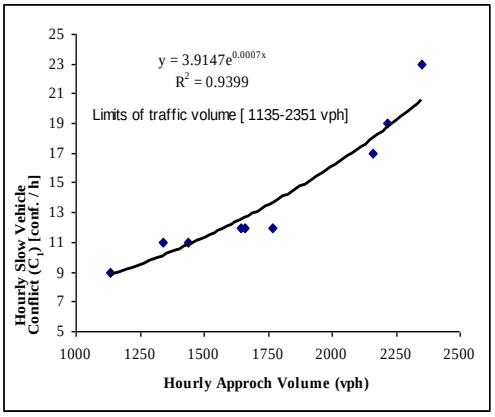
HTV* (veh/hr)	C_1 Obs..	C_1 Pred.	C_2 Obs..	C_2 Pred.	C_3 Obs..	C_3 Pred.	C_4 Obs..	C_4 Pred.
1817	16	15.81	12	13.36	6	7.88	15	17.37
1732	15	14.90	11	12.27	5	7.43	14	16.23
1996	17	17.92	8	15.98	3	8.93	15	20.05
2012	18	18.12	13	16.24	7	9.03	17	20.31
2664	50	28.60	42	31.16	20	14.26	49	34.21
1180	12	10.12	13	7.07	7	5.04	15	10.44
2822	38	31.95	41	36.50	18	15.92	51	38.82
1316	13	11.13	10	8.09	8	5.549	16	11.64
2614	33	27.62	28	29.64	17	13.77	34	32.87
2260	22	21.56	16	20.81	13	10.74	23	24.76
1440	14	12.14	10	9.16	8	6.05	13	12.85
2152	20	19.99	15	18.68	9	9.96	18	22.71
1400	13	11.81	10	8.80	6	5.88	12	12.44
2346	23	22.89	17	22.67	14	11.41	26	26.53
1760	16	15.19	12	12.62	6	7.57	15	16.60
2543	24	26.28	18	27.61	14	13.10	22	31.05
χ^2 calculated		19.57278	21.62		12.99		20.25	
χ^2 tabulated d.o.f =15,α= 0.05		24.996						

* HTV : Hourly traffic volume

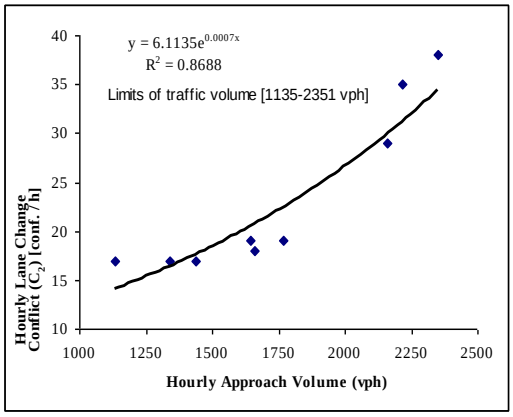
- C_1= Slow vehicle Conflict , $C_{2=}$ Lane Change Conflict , $C_{3=}$ Right Turn Same Direction Conflict , $C_{4=}$ Left Turn Same Direction Conflict .

Table (7) Developed Models to Relate Traffic Conflict Rates to Observed Geometric Characteristics at Studied Three leg Signalized Intersections

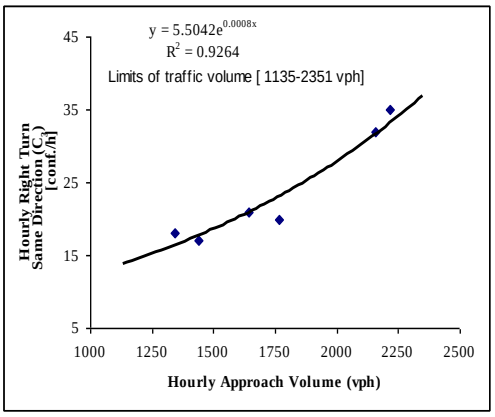
Conflict Type	Developed Model (1) $Cei=a_o+a_1 LW+a_2 MW+a_3 DS+a_4 AALL$					R	R^2	P-value Of (R^2)
	Intercept (a_o)	Parameters for Independent Variables / (P-values)						
		a_1	a_2	a_3	a_4			
1	13.20	-0.54 (0.016)	-0.33 (0.038)	+0.14 (0.091)	-0.21 (0.062)	0.915	0.837	0.0700
2	35.15	-0.88 (0.004)	-0.12 (0.040)	+0.01 (0.090)	-0.13 (0.010)	0.992	0.984	0.0008
3	33.04	-0.79 (0.040)	-0.25 (0.060)	+0.10 (0.090)	N.A.	0.982	0.965	0.0500
4	22.50					0.931	0.866	0.5000



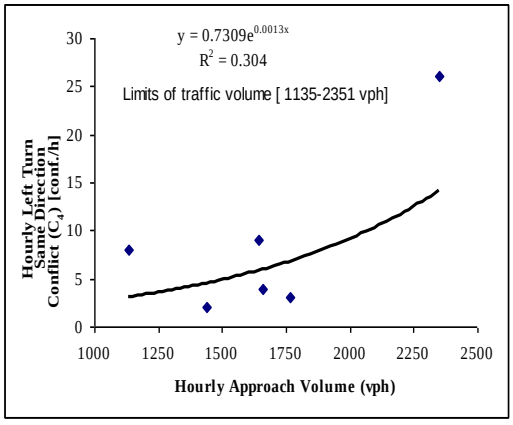
a- Slow Vehicle Conflict



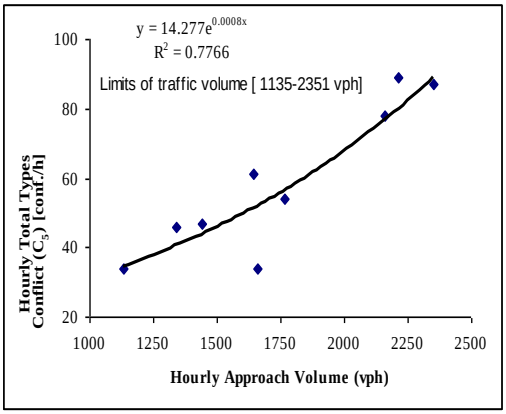
b- Lane Change Conflict



c- Right Turn Same Direction Conflict



d- Left Turn Same Direction Conflict



e- Total Types of Conflict

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

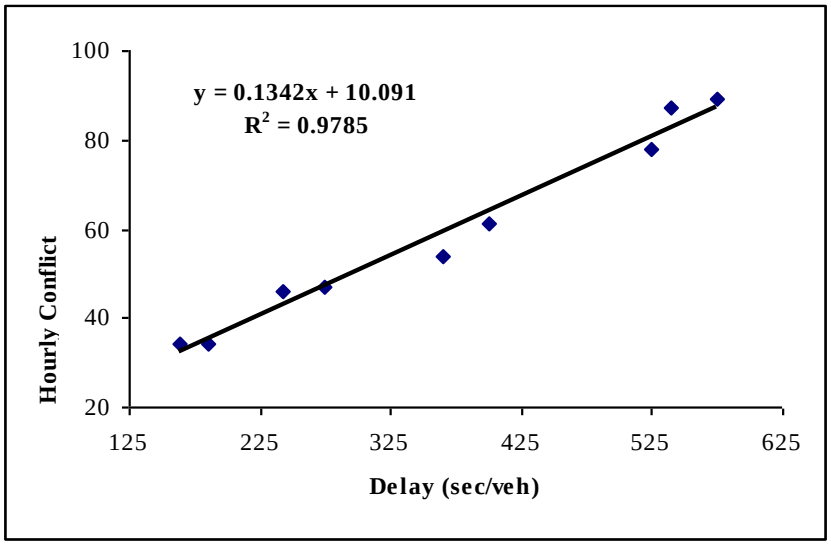


Figure (2) Correlation of Hourly Traffic Conflict with Total Stopped Delay.