Traffic Conflicts and Level of Service at Four-Legged, Signalized Intersections in Sacramento

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Introduction

This study analyzes the relationship between traffic conflicts and traffic delay at four-legged, signalized intersections. The purpose of the study is to explore if traffic conflict techniques can be applied to predict or estimate delay, which is used to determine level of service (LOS). Delay has been used as a measure of effectiveness (MOE) in signalized intersection analysis since 1985 (Zhang and Prevedouros, 2003).

This paper consists of four major sections. The first section, the background section, presents definitions of terms and concepts including the history of traffic conflict techniques, types of conflicts, and types of level of service. While studies exploring the relationship between delay and the number of conflicts were limited, a review of the literature pertaining to the application of traffic conflict techniques in the safety and operations of roadway systems was conducted. The methodology and data collection section discusses the study area site selection, the data collection procedures, and the analytical instruments employed. The analysis and discussion section presents the analytical techniques employed and the major findings of this study.

Background

For many years, traffic engineers have made observations of traffic movements at hazardous locations in an effort to identify operational and roadway characteristics contributing to perceived safety problems. Traffic events such as near misses, sudden stopping, and swerving to avoid rear-end collisions were often noted and sometimes documented. In a sense, anyone who has made these observations has conducted a traffic conflict study (Parker and Zegeer, 1989a).

In 1967, two researchers with the General Motors Research Laboratories developed a set of formal definitions and procedures for observing traffic conflicts at intersections (Parker and Zegeer, 1989a). The researchers identified traffic conflict patterns for over 20 corresponding accident types. The procedure became known as the "Traffic Conflict Technique" (Parker and Zegeer, 1989a). Because each traffic conflict was based on a related accident type, the technique was considered to be a measure of accident potential.

The traffic conflict study technique has been used since the 1960s. Traditionally, a traffic conflict study is performed by a trained observer stationed along one approach of an intersection. Conflicts are collected for 20 to 25 minutes in each 30-minute segment for an 11-hour period. Conflicts and events are most often quantified in terms of units of conflicts per hour or conflicts per 1,000 entering vehicles. The latter is used to normalize conflict and event rates for different traffic volume conditions (Noyce et al., 2000).

A traffic conflict is an event involving two or more road users (e.g. vehicles), in which the action of one user causes the other user to make an evasive maneuver to avoid a collision (Parker and Zegeer, 1989a). The action of the first user could include a variety of maneuvers such as: 1) turning left across the path of a through vehicle just as the through vehicle is entering the intersection; 2) turning from the cross street into the path of a through vehicle; or 3) slowing to turn at the cross street, placing a following vehicle in danger of a rear-end collision. Conflicts can lead to collisions. For a conflict to occur, a road user must be on a collision course (i.e., users must be attempting to occupy the same space at the same time) (Parker and Zegeer, 1989a).

Traffic conflicts are normally categorized by the type of maneuver and are discussed in detail by Parker and Zegeer (1989b). Generally, there are 14 types of conflicts, which are categorized as being 1) "same direction" conflicts, 2) "opposing left turn" conflicts, 3) "cross traffic conflicts, right turn on red" conflicts, and "pedestrian" conflicts. For the purpose of this study, however, only the first category of conflicts, "same direction" conflicts, were observed for this study simply because of their ease of observation, and they are discussed below:

1. ***Slow Vehicle (SV)*** conflict occurs when the first vehicle slows while approaching or passing through the intersection, placing a second, following vehicle in danger of causing a rear–end collision.

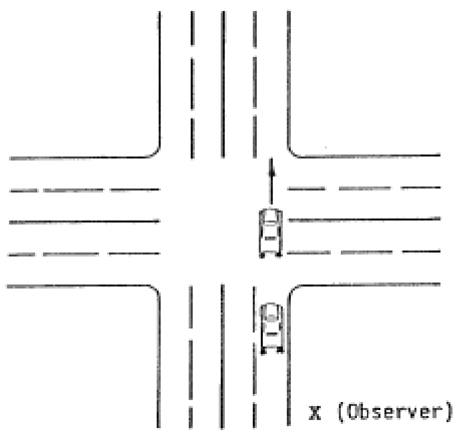

Figure 1: Slow-Vehicle Same Direction Conflicts (Parker and Zegeer, 1989b)

2. ***Lane Change (LC)*** conflict occurs when the first vehicle changes from one lane to another, thus placing a second, following vehicle in the new lane in danger of causing a rear–end or sideswipe collision.

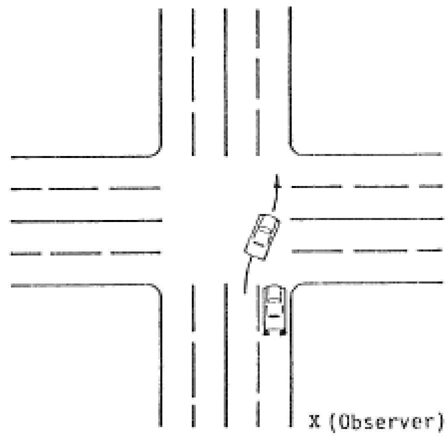

Figure 2: Lane Change Conflicts (Parker and Zegeer, 1989b)

Right Turn, Same Direction (RTSD) conflict occurs when the first vehicle slows to make a right turn, thus placing a second, following vehicle in danger of causing a rear–end collision.

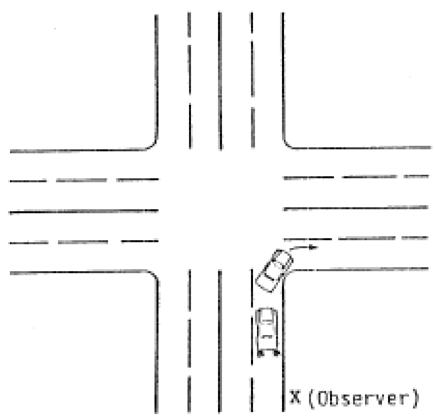

Figure 3: Right Turn, Same Direction Conflicts (Parker and Zegeer, 1989b)

3. ***Left Turn, Same Direction (LTSD)*** conflict occurs when the first vehicle slows to make a left turn, thus placing a second, following vehicle in danger of causing a rear–end collision.

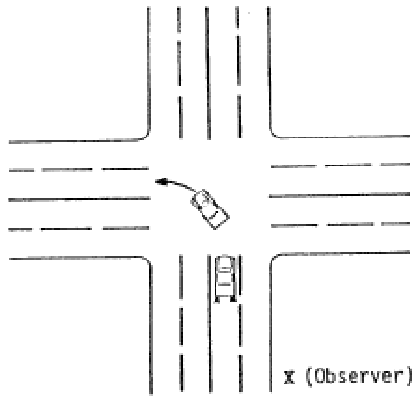

Figure 4: Left Turn, Same Direction Conflicts (Parker and Zegeer, 1989b)

Signalized Intersection Level of Service

Level of service (LOS) refers to quantitative classification of performance measures or procedures that related to quality of service. From a traveler's point of view, the best condition may be "LOS A," and the worst would be "LOS F." For several reasons, highways are not generally designed to provide the best level of service. Cost, environmental considerations, and other influences such as the difference between demand at peak and off-peak hours, roads are designed with a lower LOS to arrive at a balance between what is ideal and what is practical or cost-effective (Transportation Research Board, 2010).

For signalized intersections, it is possible to determine the LOS not only for the whole intersection itself, but also for each approach of the intersection and for each lane group within each approach. Only the single measure of control delay is used to determine the overall LOS for the entire intersection or for an individual approach to the intersection (Transportation Research Board, 2010). Both volume-to-capacity ratio and control delay are used to depict the LOS for any lane group (Transportation Research Board, 2010). Control delay can be used to calculate the increase in travel time caused by traffic signal control. Typically, because an increase in time to a destination generally means an increase in driver dissatisfaction, control delay can also be used to estimate fuel consumption and driver distress and discomfort. Table 1 indicates the criteria of LOS for signalized intersections; as prescribed in the 2010 *Highway Capacity Manual*.

Table 1: Signalized Intersections - LOS Criteria*

Level of Service (LOS)	Control Delay (seconds/vehicle)
A	≤10
B	>10 – 20
C	>20 – 35
D	>35 – 55
E	>55 – 80
F	>80

* If volume-to-capacity ratio exceeds 1.0, LOS is F.

(Source: Transportation Research Board, 2010, pp. 18–6)

Literature Review

The literature review focuses on showing how traffic conflict techniques are utilized in different studies to determine the various safety and operational traffic service characteristics when crash data are not available. There are no studies which have directly correlated number of conflicts with intersection level of service. This section is intended to draw guidelines, methodologies, and results from previous research to assist in determining the analysis of traffic conflicts and the level of service at four-legged, signalized intersections.

A study by Parker and Zegeer in 1989 produced step-by-step guidelines on the collection and analysis of conflict data for engineers. The guidelines included determination of sample sizes, the type of conflicts that needed to be observed, training methods for observers, methods of conflict analysis, and conflict definitions. The paper followed study guidelines set by Parker and Zegeer (1989a) pertaining to data collection and analysis.

A report, titled "A Study of Traffic Safety at Four-Leg Signalized Intersections Using Traffic Conflict Technique," provided useful results regarding the relationship between traffic conflicts and traffic volume, and traffic conflicts in relation to the geometric characteristics of the roadway system (Ewadh and Neham, 2008). The study showed further that traffic conflicts of all types have a high correlation with traffic volume. In this study, conflict rates were found to decrease with an increase in: 1) lane width, 2) median width, 3) sight distance, and 4) auxiliary lanes. The results also indicated that an increase in design speed resulted in increased conflict rates. The study concluded that in the absence of reliable crash data, or when there were no data at all; traffic conflict techniques can be applied effectively to evaluate traffic safety at four-legged signalized intersections.

Another report titled, "Conflict Technique Applied to Traffic Safety on the Model Corridor of Ha Noi," used traffic conflict techniques together with interviews of the drivers and inhabitants to identify hazardous road intersections after three to five days of conflict studies (Anh et al., 2005). The study then recommended countermeasures to help minimize the dangers of road intersections without having to wait three to five years (or more) to acquire a larger set of cumulative crash data.

A study titled, "Conflict Analysis for Prediction of Fatal Crash Locations in Mixed Traffic Streams," showed that the use of traffic conflict techniques in heterogeneous traffic situations does not provide the same results as those in homogeneous traffic situations due to differences in the behavior of roadway users involved in the two contrasting environments (Tiwari et al., 1998). Moreover, the authors of the study concluded that their analyses did not show a strong correlation between conflict and fatal crash rates, which affirms a previous study (Kulmala, 1993). The result indicated that conflict data alone is insufficient to predict crash rates. Conflict data may, however, serve as a surrogate measure of safety when crash data are incomplete or absent.

Another study titled "Traffic Conflict Technique: A Tool for Traffic Safety Study at Three-legged Signalized Intersections" found a high correlation between the number of traffic conflicts and total stopped delay based on the assumption that the number of potential conflicts increase when drivers stop to verbally argue from unacceptable delay, (which can occur often in less developed countries) which is introduced due to the traffic operation at the intersection (Ewadh and Neham, 2008). The authors called for further study to show that conflict techniques can be used to assess level of service as well as assess level of safety.

Data Collection

Site Selection

The following section provides the identification of the study intersections, the development of the data collection procedures, the collection of data, and the summarization of the collected data. All the selected study areas were signalized intersections located in Sacramento and were identified based on the following criteria:

- Four-legged approaches: all selected intersections had four approaches.
- No unusual sight distance restrictions: the selected intersections were free of obstructions that block a driver's view of potentially conflicting vehicles or pedestrians entering the traveled way.
- No unusual signal timing or phasing: all the selected intersections operated under actuated signal timing.
- No appreciable grade: the intersections selected for this study had level intersection approaches with no recognizable uphill or downhill grade difference.
- No turn restrictions: there were no turn restrictions such as no right turn on red or no U turn, and all the intersection approaches were two-way streets.

Data Collection

Data were collected in three stages: 1) traffic conflict data collection; 2) traffic volume data collection; and 3) acquisition of the geometric characteristics of the intersection and signal timing. Data collection took place from March 3, 2013 to May 2, 2013. Table 2 shows the specific locations and dates of the data collection schedule. Figure 5 below shows the location of each intersection on a map.

Table 2: Signalized Intersection Study Sites

	Intersection	Day	Date
1	Howe Avenue and El Camino Avenue, Sacramento, CA 95821 (city operated)	Monday	03-18-2013
2	Arden Way and Morse Avenue, Sacramento, CA 95825 (county operated)	Thursday	03-21-2013
3	65th Street and Elder Creek Road, Sacramento, CA 95824 (city operated)	Tuesday	04-02-2013
4	65th Street and Fruitridge Road, Sacramento, CA 95820 (city operated)	Monday	04-29-2013
5	Florin Perkins Road and Florin Road, Sacramento, CA 95828 (city operated	Tuesday	04-30-2013
6	Florin Perkins Road and Elder Creek Road, Sacramento, CA 95828 (city operated)	Wednesday	05-01-2013
7	Florin Perkins Road and Fruitridge Road, Sacramento, CA 95826 (county operated)	Thursday	05-02-2013

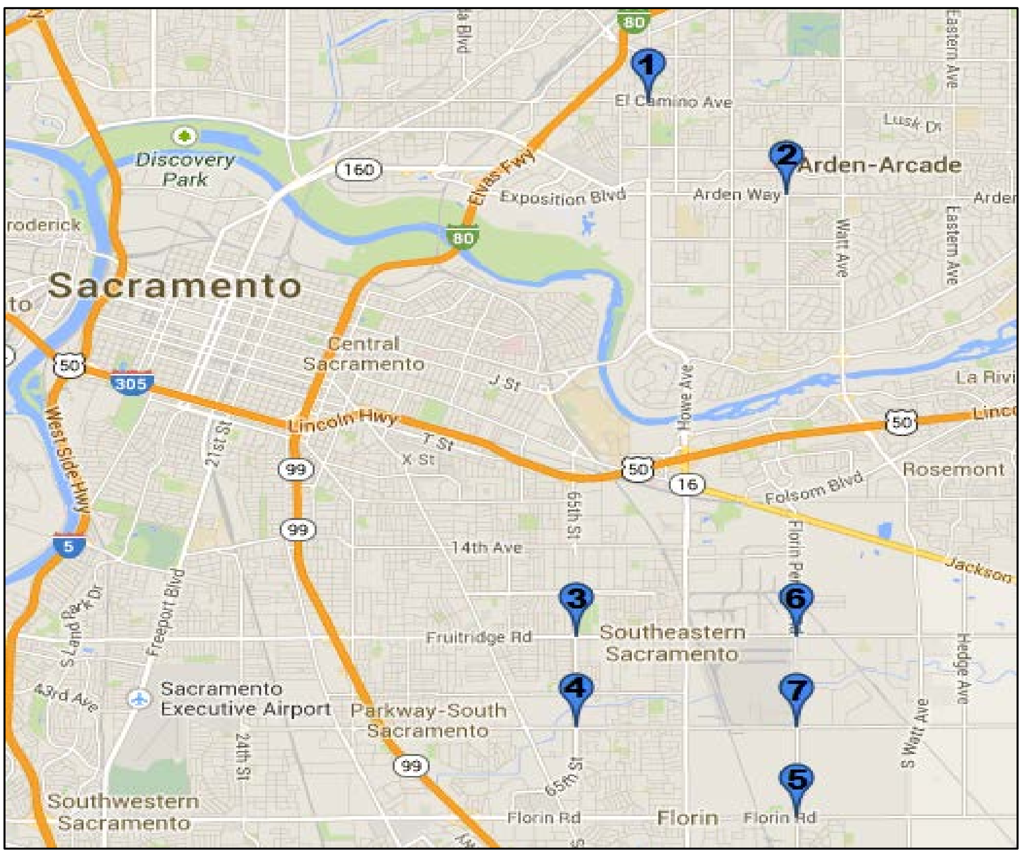

Figure 5: Signalized Intersection Study Sites in the Sacramento Area

Conflict Count Data: Conflict counts were done according to FHWA guidelines, procedures, and techniques (Parker and Zegeer, 1989b). The conflict counts were done for all selected intersections through direct observation and through the use of a video camera. Traffic count data were collected during the morning peak hours from 6:30 to 10:00 a.m., weekdays from Monday through Thursday, to avoid unexpected traffic behavior. No occurrences of traffic breakdowns (signal failure or crashes) or weather conditions were experienced which inhibited data collection. A location of approximately 200 feet to 300 feet from the intersection on the right side of the approach was selected for each leg, depending on the availability of clear space. The observer stood at locations carefully selected so as not to attract or distract drivers with cameras set up in the same manner. Conflict count s were done for 20 minutes at each approach with a five minute intermission to change locations and setup the camera again. The conflict counts were done for the "same direction type of conflicts mentioned earlier in this paper. Besides direct observation, the recorded video was reviewed for precision and consistency with conflict data collection methods outlined above.

Conflicts were estimated for a one-hour period at each approach of an intersection. The conflict data at each approach was collected for two 20-minute periods. The conflict data from the two 20-minute periods were converted into one-hour conflict data based on the assumption that similar numbers and types of conflicts occur in the non-observation periods under similar conditions as in the periods immediately before and immediately after the observation periods (Parker and Zegeer, 1989a).

Volume Count Data: Volume counts were done with the help of a JAMAR handheld Traffic Data Collector (TDC) simultaneously with the collection of conflict data by a second person. The Traffic Data Collector (TDC) was set on one- minute intervals and the volume counts were done in synchronization with the conflict counts but without any interruption from the beginning to the end of the conflict data collection time. The person conducting volume counts stood on the south corner of the intersection facing north and did not change positions during the entire data collection period. The volume counts were then uploaded to a computer for analysis.

Geometric Characteristics: The geometric characteristics of the intersections were acquired from Google Earth by measuring each lane width and length of left and right turn lanes.

Signal Timing: All of the intersections had actuated signal controls. The signal timing and phasing data were obtained from the departments of transportation (DOTs) from both the County of Sacramento and the City of Sacramento, as indicated back in Table 2. .

Data Summary

After the data collection tasks were completed, the 20-minute conflict data were projected for one-hour periods for each approach at each intersection by multiplying the number of conflict by three. As mentioned earlier, the adjustment method assumes that conflicts occur under similar conditions in the immediate periods both before and after the observation periods. The total number of hourly conflicts was calculated for each conflict type, and the total number of hourly conflicts was then compared with the delay time of each turning movement.

Because the traffic volume data were collected for the whole three and half hour period, the peak one-hour traffic volume data were identified from the total traffic data and presented in Table 3. As Table 3 shows, the maximum average volume count observed on northbound through movements. The lowest average volume count observed on southbound left-turn movements. In the individual movements maximum volume count observed on the westbound through movement at Arden Way and Morse Avenue and the lowest count was observed on eastbound right-turn movement at 65th Street and Elder Creek Road. However, the westbound through movement at Arden Way and Morse Avenue volume count was extremely high when compared with the other movements (see Table 3), which affected the delay (312 seconds per vehicle). As a result, the westbound through movement at Arden Way and Morse Avenue was considered as an outlier and removed from the analysis.

Table 3: Peak One-Hour Traffic Volume Data of Each Intersection by Movement

	Northbound			**Southbound**			**Eastbound**			**Westbound**		
Intersection	**R**	**T**	**L**	**R**	**T**	**L**	**R**	**T**	**L**	**R**	**T**	**L**
Howe Ave. and El Camino Ave.	83	243	175	88	424	99	218	690	85	26	847	129
Arden Way and Morse Ave.	69	139	75	53	112	74	37	675	77	59	1507	54
65th Street and Fruitridge Rd.	169	960	102	121	588	115	65	464	201	195	483	89
65th Street and Elder Creek Rd.	75	657	36	96	338	173	12	447	172	173	482	114
Florin Perkins Rd. and Florin Rd.	55	720	147	111	183	25	74	310	254	257	538	83
Florin Perkins Rd. and Fruitridge Rd.	107	822	191	74	399	51	93	209	102	88	285	134
Florin Perkins Rd. and Elder Creek Rd.	97	1012	106	74	304	46	85	249	152	87	235	89
Average	**94**	**650**	**119**	**88**	**335**	**83**	**84**	**435**	**149**	**126**	**625**	**99**

Note: R - Right Turn (veh/hr), T - Through (veh/hr), L - Left Turn (veh/hr)

Analysis and Results

Synchro traffic analysis software was used to determine the average stopped delay for all approaches in the study intersections by using geometric characteristics, traffic volumes, and signal timing data as inputs. The relationship between the average stopped delay and the hourly traffic conflict was explored through linear regression analysis of each approach. Table 4 shows the summarized data of hourly traffic conflict and delay (seconds per vehicle) for all approaches.

Table 4: Summary of Hourly Traffic Conflicts and Delay

Intersection	App.	Hourly Traffic Conflicts (#/hr)					Delay by Movement (sec/veh)				LOS
		LTSD	RTSD	SV	LC	Total	Left	Through	Right	Total	
Howe Ave. and El Camino Ave.	NB	20	3	5	0	28	1078.3	28.8	4.7	1111.8	F
	SB	12	0	6	2	20	769.2	36.5	4.6	810.3	F
	EB	3	6	9	5	23	36.7	27.2	6.9	70.8	C
	WB	3	2	6	2	13	40.2	38.4	0	78.6	D
Arden Way and Morse Ave.	NB	3	5	5	0	13	287.3	18.5	0	305.8	F
	SB	0	0	2	0	2	447.7	19	0	466.7	F
	EB	5	0	8	0	13	46.2	22.3	7.3	75.8	C
	WB	8	12	0	0	40	43.8	0	0	355.9	F
65th Street and Fruitridge Rd.	NB	0	3	12	2	17	58.1	132	12.4	202.5	F
	SB	0	0	5	0	5	55.9	35.4	10.9	102.2	C
	EB	2	2	9	0	13	177.7	31.1	0	208.8	E
	WB	0	2	8	0	10	48.6	30	5.4	84	C
65th Street and Elder Creek Rd.	NB	0	2	9	0	11	39.2	56.4	0	95.6	E
	SB	5	3	3	0	11	156.7	24.2	0	180.9	E
	EB	5	0	8	2	15	104.8	31.6	0	136.4	D
	WB	2	11	6	0	19	51.2	31.8	6.6	89.6	C
Florin Perkins Rd. and Florin Rd.	NB	2	0	8	0	10	935.9	36.3	5.5	977.7	F
	SB	2	0	8	0	10	64.4	23.7	4.5	92.6	C
	EB	5	0	6	0	11	404.1	17.6	0	421.7	F
	WB	0	3	5	2	10	60.9	27.7	0	88.6	C

Intersection	App.	Hourly Traffic Conflicts (#/hr)					Delay by Movement (sec/veh)				LOS
		LTSD	**RTSD**	**SV**	**LC**	**Total**	**Left**	**Through**	**Right**	**Total**	
Florin Perkins Rd. and Fruitridge Rd.	NB	2	18	17	3	40	151.7	47.5	13.4	212.6	E
	SB	2	0	8	0	10	41.4	30.9	6.7	79	C
	EB	3	0	2	0	5	51	20.7	0	71.7	C
	WB	2	0	2	0	4	75.5	27.6	0	103.1	D
Florin Perkins Rd. and Elder Creek Rd.	NB	0	3	11	3	17	247.1	44.1	8.9	300.1	E
	SB	0	0	3	0	3	54.6	20.6	5.2	80.4	C
	EB	2	2	2	0	6	561.9	20.4	4.8	587.1	F
	WB	2	0	3	0	5	265.7	19.8	4.6	290.1	E
Average		3.2	2.8	6.2	1	13.7	227	32.1	4.01	263.1	

As Table 4 above showed, the average delay time of the left movement was 227 seconds per vehicle, indicating LOS F. Compared to the maximum threshold for the signalized LOS F, this extremely high average delay likely indicates a breakdown of vehicular flow. Unlike the left turning movement, the average delay time for right turning movement was only 4 seconds per vehicle, which corresponds with LOS A and implies little delay. The high level of service for the right turning movements can partly be attributed to the absence of restrictions (e.g. right turns on red) and low traffic volumes. Finally, the average delay time of through movements was 32.1 seconds per vehicle which is equivalent to LOS C and indicates traffic proceeds smoothly or the traffic signal cycle length is moderate. Cycle failures may occur at this level so that some queued vehicles may not get through the intersection until the next cycle.

The average conflicts observed for each movement type include approximately three vehicles for the left and right turn, as well as about seven and one vehicles, for slow vehicle and lane change respectively. For the overall average number of conflicts, seven vehicles per hour was the highest rate for slow vehicle movements. One vehicle per hour was the lowest rate for lane change movements.

Linear regression was employed to further investigate the relationship between conflict and delay, assuming the number of conflicts is an independent variable and traffic delay is the dependent variable. Figure 6 shows the relationship between left turn conflicts and the resulting delay. The coefficient of determination (R^2) value is a measure of the proportion of variability explained by the regression model. The R^2 value suggests that 37 percent of the total variation in left movement delay is explained by left movement conflicts. This relationship was statistically significant with an F-test value of 15.59 (p-value = 0.0005) which indicates that a significant proportion of the total change in delay is caused by the relationship between left movement delay and left movement conflicts. The model also shows that the parameter estimate for the explanatory variable was 41.11, which indicates that an increase of one left conflict per hour will result in an average increase of approximate 41 seconds per vehicle of left turn delay.

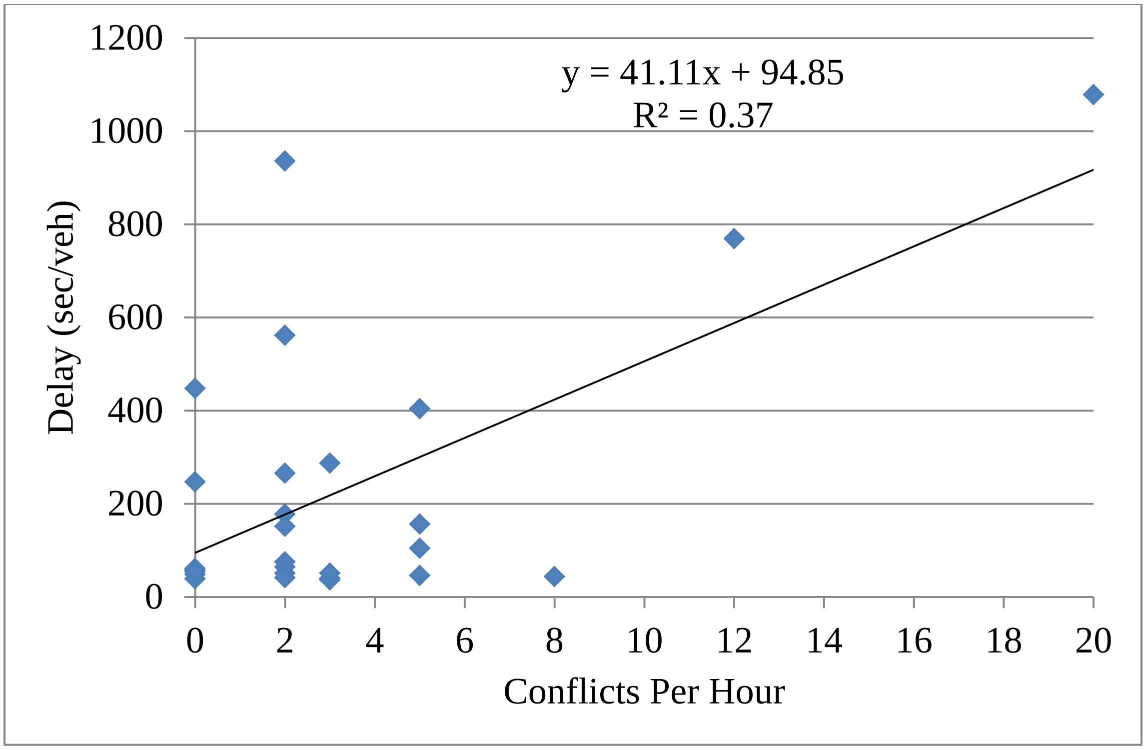

Figure 6: Left Turn Conflicts and Delay Relationship (All Approaches)

Figure 7 shows the relationship between the through movement delay and slow vehicle traffic conflicts. The R^2 value of 0.35 indicates that 35 percent of the variability observed in through movement delay was due to changes in slow vehicle conflict. The R^2 value was statistically significant with an F-test value of 14.31 (p-value = 0.0008). This result suggests that there is a correlation between the number of slow vehicle traffic conflicts and through traffic movement delay. The model shows that the parameter estimate for the explanatory variable was 3.64, which indicates that an increase of one slow vehicle conflict per hour will result in an average increase of 3.64 seconds per vehicle of through movement delay.

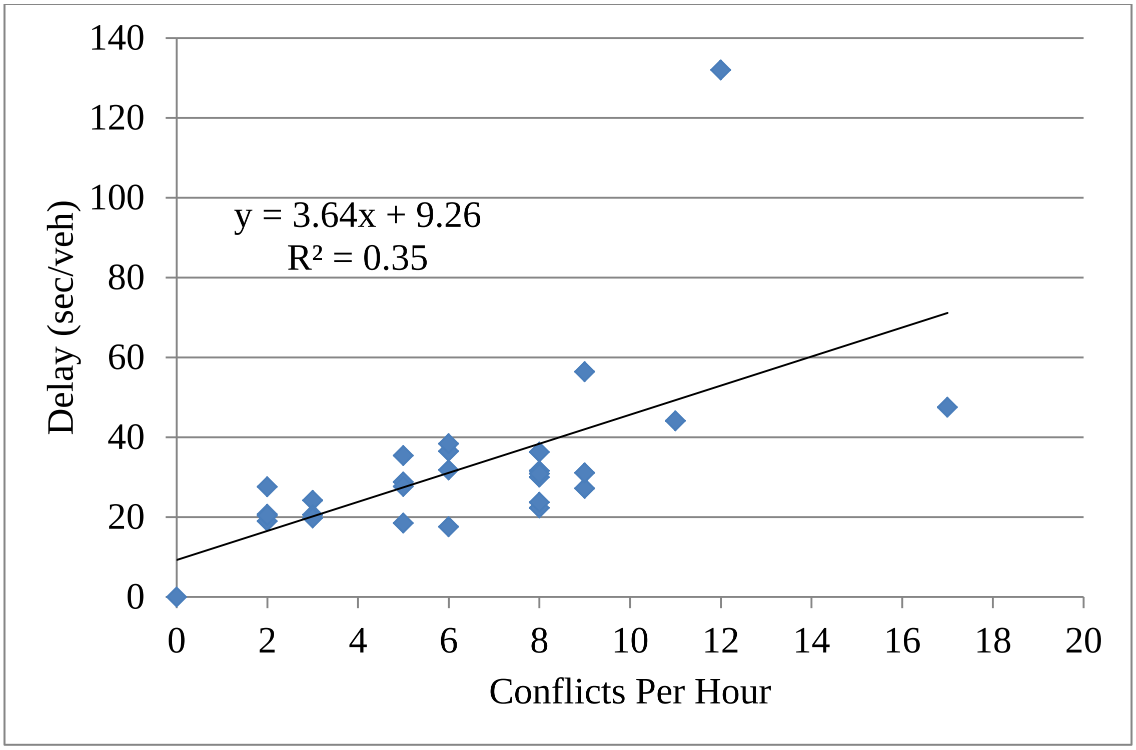

Figure 7: Slow Vehicle Conflicts and Through Movement Delay Relationship (All Approaches)

The relationship between right-turn conflicts and right-turn delay is shown in Figure 8. The linear regression results of the right movement delay time against the right movement conflict shows that only 9 percent (R^2 = 0.089) of the changes in right movement delay were explained by changes in right movement conflicts. The R^2 value was not only weak but was statistically insignificant as well with an F-test value of 2.56 (p-value = 0.1220). This result suggests that a relationship between right turn movement conflicts and right turn movement delay is not strong.

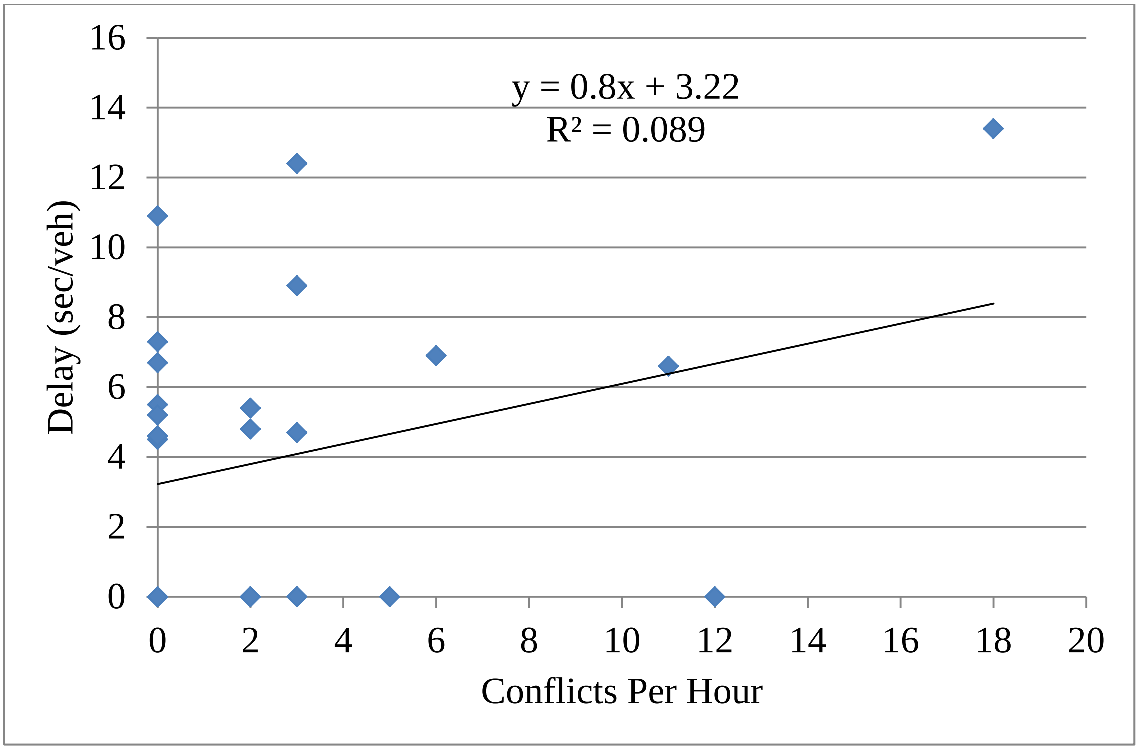

Figure 8: Right Turn Conflicts and Delay Relationship (All Approaches)

The relationship between lane change conflicts and the resulting delay on through movements was statistically insignificant with an F-test value of 3.30 (p-value = 0.08). The R^2 suggests that the model explains 11 percent (R^2 = 0.11) of the total variation in through movement delay is explained by lane change conflicts (plot not shown). This result suggests a weak relationship between lane change conflicts and through movement delay.

The overall relationship between total conflicts and total delay shows that the model explains only four percent (R^2= 0.04) of the total variation in delay explained by changes in conflict (plot not shown).

Conclusions

The study examined the effects of traffic conflicts on traffic delay using linear regression analysis. The linear regression analysis suggests that 37 percent (R^2 = 0.37) of the total variation in left movement delay is explained by left movement conflicts; this relationship was statistically significant with an F-test value of 15.59 (p-value = 0.0005). Meanwhile, 35 percent (R^2 = 0.35) of the changes observed in through movement delay were due to slow-vehicle conflicts, and this relationship was statistically significant with an F-test value of 14.31 (p-value 0.0008). Only 11 percent (R^2= 0.11) of the total variation in through movement delay is explained by lane change conflicts, and the relationship was statistically insignificant. Only 9 percent (R^2 = 0.09) of the changes in right movement delay were explained by changes in right movement conflicts and the relationship was statistically insignificant. The total traffic delay is correlated against the sum of all conflicts (left, right, slow vehicle and lane change); the result is a weak and statistically insignificant correlation (R^2 = 0.05 and F-stat = 1.25).

In contrast, as discussed in the review of related literature, a 2008 study (Ewadh and Neham) found a high correlation between traffic conflicts and stopped delay time. It is worth mentioning that the above study was conducted by observing three-legged signalized intersections and was based on the assumption that traffic conflicts increase when drivers stop to verbally argue due to the unacceptable delay introduced by the traffic operation at the intersection. The difference in the geometry of the intersection (three-legged against four-legged) and other factors such as: 1) differences in the study area, 2) the difference in the study assumptions between conflict and delay, and 3) design of roadway and the behavior of the road users may account for the difference in study findings.

This study found statistically significant relationships between left movement conflicts and left movement delay, and slow vehicle movement conflicts and through movement delay. In contrast, the study revealed statistically insignificant relationship between right movement conflicts and right movement delay, and lane change movement conflicts and through movement delay.

The overall conclusion of the study is that traffic conflict techniques alone cannot be used effectively to determine the delay (and therefore LOS) of four-legged signalized intersections. Other contributing factors that may play important roles in determining the operational performance of four-legged signalized intersections could include: the characteristics of the drivers, the characteristics of vehicles, as well as roadway or weather condition.

Traffic conflict technique is one of the important tools available to identify the safety of an intersection. By observing the possible conflicts on an intersection can provide a remedial countermeasures that improve the safety of the intersection before accidents happen. Therefore, this study was trying to see the applicability of traffic conflict techniques in determining the level of services of an intersection; because with the help of traffic conflict techniques it is possible to identify safety issues of an intersection.

Limitations and Future Research

Although this study has benefited from the efficiencies of contemporary data collection devices and analytical software (JAMAR Technologies hand-held traffic data collector and Synchro 8 traffic analysis software), it also has many limitations. 1) Although data collection in this type of study normally requires continuous (eleven hour) observation (per recommendation by Parker and Zegeer, 1989a), resource constraints dictated that only 3.5 hours of data were collected per intersection. 2) It is assumed that similar conflicts occur during the non-observational hours. 3) Even if there are fourteen conflict types observed in an intersection this study only focused on four kinds of conflicts. 4) It is assumed that delay times is function of the number of conflicts, while other factors potentially affecting delay time such as driver and vehicle characteristics, were ignored. 5) Data may not have been completely independent as multiple data points were obtained from same intersection. In other words, traffic behavior at one approach may be similar to that of another approach within the same intersection. The study is geographically limited to selected signalized intersections in Sacramento County, which could have similar driver or signal characteristics.

As indicated earlier, the scope of this study was limited to four-legged, signalized intersections. Resource constraints also dictated that the recommended observation time of conflicts be reduced from 11.0 hours to 3.5 hours. To state definitively, the use of traffic conflict technique in determining the level of service of an intersection, it is recommended that: a) to conduct a similar study using traffic conflict technique at unsignalized intersections, b) to replicate the same study at signalized intersections using the recommended 11.0 hours of conflict observation time.

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