Analysis of Pedestrian Conflicts with Left-Turning Traffic

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The interaction between pedestrians and left-turning vehicles at signalized intersections are examined using the traffic conflict technique. Paramount was a comparison of the safety of left turns at two types of intersections: T-intersections and X-intersections (cross-intersections). Previous research has indicated that T-intersections are more dangerous to pedestrians. In preparation for the comparison several traffic conflict definitions and their applications to pedestrians were evaluated. Use of a laptop computer for data collection was tested. Eight sites taken from intersections in Hamilton, Ontario, Canada, were selected. A conflict recording methodology was developed for T-intersections and X-intersections that consisted of recording data at various times along the paths of pedestrians and left-turning vehicles, and recording traffic conflicts. Two computer programs were written for the data collection process; one for vehicles and one for pedestrians. Several statistical tests were performed to relate traffic conflicts and the expected number of accidents were performed. These tests indicate that a positive correlation between traffic conflicts and expected number of accidents exists; they also suggest that T-intersections have a higher traffic conflict rate than X-intersections.

The primary objectives of the described study are (a) to examine the interaction of left-turning vehicles and pedestrians at two types of signalized intersections using traffic conflicts; (b) to compare several traffic conflict techniques; and (c) to test the use of a laptop computer to record the traffic conflicts.

Four sections describe the study. The first section reviews the literature on pedestrian accidents and traffic conflicts, concentrating on accidents between left-turning vehicles and pedestrians, various traffic conflict definitions, and the validity of the traffic conflict technique. The second section describes the methodology developed to record traffic conflicts according to the different definitions and the data collection process. Results of the study are presented in the third section, which also examines the conclusions of Quaye et al. (1) and the relationship between conflicts and the expected number of accidents. The fourth section concludes with a discussion of the questions the study sought to answer.

LITERATURE REVIEW

A driver making a left turn at an intersection often has to keep track of several traffic elements simultaneously, including opposing traffic flow, traffic lights, and pedestrians crossing. According to various studies left-turning traffic generally constitutes about 20 percent of the approach traffic in urban areas; however, the proportion of accidents involving pedestrians and left-turning vehicles at intersections is slightly higher (20 to 30 percent of all pedestrian accidents in intersections), as shown in Table 1.

One-way intersections reduce the complexity of turning left by removing the opposing traffic flow, thus allowing drivers to concentrate on the pedestrians in the crosswalk and the traffic lights. Two studies, one each conducted by Habib (2) and Fruin (3), have examined pedestrian accidents at signalized intersections on a one-way grid system (Manhattan, New York). They discovered that vehicle left turns were approximately four times more dangerous to pedestrians than through movements.

In a more recent study, Almuina (4) examined accidents involving left-turning vehicles and pedestrians at signalized intersections in Hamilton, Ontario, Canada, between 1983 and 1986. He found that about 32 percent of the pedestrian accidents involved left-turning vehicles. Almuina further analyzed pedestrian accidents by dividing intersections into three types: one-way–one-way, one-way–two-way, and two-way–two-way. He demonstrated that, with the exception of pedestrian accidents with straight-through vehicles, accidents involving left-turning vehicles had the highest proportion of accidents for all intersection types.

Previous research has indicated that the most important factors in increasing the likelihood of pedestrian accidents are pedestrian and vehicle flows (5,6). Accordingly, numerous relationships between accident frequencies and traffic flows have been examined. The most recent studies, such as Hauer et al. (7), assess the safety of intersections by using the product of vehicular traffic flows raised to a power. They suggest that other circumstances such as highway-rail grade crossings and accidents on two-lane highways support the “product-of-flows-to-power” relationship. Studies by Zegeer et al. (8), Hauer and Persaud (9), and Mengert (10) have reached similar conclusions.

Quaye et al. (1) specifically examined the safety of pedestrians by using the product of pedestrian and vehicular flows raised to a power. Their research relied on accident and flow counts during 15-min periods from Monday to Friday for the years 1983 to 1986 in Hamilton. The multivariate accident prediction model was given as follows:

\[
E(m) = b_0 \times F_1^{b_1} \times F_2^{b_2}
\]

where

\[ F_1, F_2 \] = vehicle and pedestrian flows, respectively;

\[ b_0, b_1, b_2 \] = parameters to be estimated;

\[ m \] = entity (signalized intersection);

\[ E(m) \] = mean of such \( m \)'s for different intersections with flows \( F_1 \) and \( F_2 \); and

\[ \hat{m} \] = estimate of \( E(m) \).

Because the safety of pedestrians at an intersection is influenced by its geometry, Quaye et al. separated fixed-cycle signalized intersections as well as the models into two categories.
### TABLE 1  Pedestrian Accidents and Left-Turning Traffic (4)

<table>
<thead>
<tr>
<th>Study</th>
<th>Fruin</th>
<th>Habib et al.</th>
<th>Zogeer et al.</th>
<th>Robertson &amp; Carter</th>
<th>Israel</th>
<th>Almunia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of left-turning accidents</td>
<td>31%</td>
<td>25%</td>
<td>22%</td>
<td>17%</td>
<td>13%</td>
<td>32%</td>
</tr>
<tr>
<td>Number of signalized intersections</td>
<td>32</td>
<td>45</td>
<td>1297</td>
<td>62</td>
<td>520</td>
<td>306</td>
</tr>
</tbody>
</table>

* Only 54 intersections were signalized

### Left-Turns at T-Intersections (Category 1)

Approaches with left-turning vehicles that face no opposing vehicle traffic were selected for Category 1. The purpose of this category is that left-turning vehicles, when turning, face no opposing vehicle traffic. As a result the left-turning maneuver is not complicated by conflicting vehicles. Three-legged intersections or one-way streets on the opposing approach are examples of such intersections. The model and expected number of accidents per day are given for this category by Equation 2:

\[
\hat{E}[m]_T = (2.61 \times 10^{-7}) \times F_1^{1.5} \times F_2^{0.931} \]

(2)

### Left-Turns at X-Intersections (Category 2)

All approaches with left-turning vehicles that face opposing vehicle traffic were selected for Category 2. At X-intersections (cross-intersections) left-turning vehicles must yield to conflicting vehicles coming from the opposite approach during the entire or part of the green phase. The model and expected number of accidents per day are given by Equation 3:

\[
\hat{E}[m]_X = (7.34 \times 10^{-7}) \times F_1^{0.410} \times F_2^{1.867} \]

(3)

Quaye et al. evaluated the relative safety of pedestrians crossing at T- and X-intersections. For the same vehicle and pedestrian flows on a hypothetical intersection, X-intersections were generally found to be safer than T-intersections for a vehicle flow above 100 vehicles per hour.

### TRAFFIC CONFLICTS

Accident data are often used to analyze the safety of intersections. However, evaluations of safety based only on accidents have many drawbacks. For example, reliable estimates of safety require a large number of accidents. Furthermore, not all accidents are reportable, and the ones that are reportable are not always reported. Pedestrian collisions that result in injuries would most likely be reported.

Such drawbacks have led to the development of a surrogate safety measure known as traffic conflicts. In general, a traffic conflict is an event in which two road users (pedestrians, vehicles, and bicycles) would have collided had their paths, speeds, or both remained unchanged on an element of a transportation system (intersection, road section, ramp, and so forth). In the described study a total of four traffic conflict definitions were employed to analyze the safety of pedestrians at signalized intersections. The first one is known as the U.S. traffic conflict technique. This technique originates from a study conducted by Perkins and Harris (11) that consisted of examining evasive actions or sudden braking. Glauz and Migletz (12) further developed the U.S. definition by stating that the action of the first user is atypical in that it is not an action that every road user would perform under the same circumstances, although it need not necessarily be an infrequent or extreme action. The second definition is called classification by severity (CS). This definition classifies conflicts according to the severity of the evasive actions such as in the German (13) and French (14) definitions. The conflicts are judged subjectively by the recorder according to a predetermined severity scale. For example, the German severity scale (13) classifies traffic conflicts into three categories: light, moderate, and serious. The third definition, called the post-encroachment time (PET) is the only one not based on evasive maneuvers. Cooper (15) defined PET as the time difference between the moment an offending vehicle passes out of the area of potential collision and the moment of arrival at the potential collision by the conflicting vehicle possessing the right of way. The fourth definition is called time-to-collision (TTC). The Swedish traffic conflict technique (16) is one of the techniques that is based on this definition. TTC uses the speed and the distance between the two road users at the time of evasive action. A TTC is then computed by dividing the distance by the speed. According to Hyden (16), conflicts under this definition could be considered dangerous by two means: a fixed TTC below 1.5 sec or a speed-dependent TTC.

Several studies have examined correlations between accidents and conflicts and, in many cases, results have been diverse and contradictory (17). This is partly due to the difference in conflict definitions, location, road user behavior, and so on. The lack of consensus on the relationship between accidents and conflicts has surprisingly fostered only few complementary analyses of pedestrian-vehicle conflicts. From these, some included only conflicting situations with through vehicles (18,12), whereas others described the interaction of pedestrians and left-turning vehicles (19–21). In general, the studies of the correlation between conflicts and accidents arrive at divergent conclusions or are often inconclusive because of data problems.

### METHODOLOGY AND DATA COLLECTION

The study population included all fixed-cycle intersections drawn from the Hamilton data base. The approaches of each intersection were examined to determine whether left-turning vehicles had their maneuvers obstructed by oncoming vehicles. Accordingly, all approaches or sites were divided into two categories: left-turns at T-intersections and left-turns at X-intersections. Then the expected number of accidents involving left-turning vehicles and pedestrians was computed for each site according the category. Equations 2 and 3, developed by Quaye et al., were employed to calculate the expected number of accidents. A sample of eight sites were selected, four from each category. Each approach categorized as an X-intersection was matched with an approach categorized as a T-intersection according to level of exposure. The matched sets were separated into four groups:

- **Group 1**: high vehicle and low pedestrian flows,
- **Group 2**: high vehicle and moderate pedestrian flows,
- **Group 3**: low vehicle and low pedestrian flows, and
- **Group 4**: moderate vehicle and high pedestrian flows.
Table 2 shows the expected number of accidents for each of the eight sites.

The relative safety of sites included in the T-intersection and X-intersection categories can be calculated using Equation 4 (1):

\[ R = 0.075 \times \frac{F_{1.065}^{0.415}}{F_{2.415}^{0.415}} \]  

(4)

Relative safety is defined as the number of times a site in the X-intersection category is safer than a site in the T-intersection category with the same level of exposure; the R-value represents the relative risk. Therefore, for any combination of pedestrian and vehicular flows a relative risk can be computed. Equation 4 leads to the series of curves shown in Figure 1. This figure shows the four groups according to the respective pedestrian and vehicular flows, as well as the curves for five relative risks. It should be noted that Group 2 is located between the curves \( R = 4 \) and \( R = 3 \), whereas Group 3 is located close to the curve \( R = 0.5 \). In other words, a site in the X-intersection category for Group 2 is expected to be three to four times safer than a site in the T-intersection category. On the other hand, a site in the X-intersection category for Group 3 is expected to be more or less twice as dangerous as a site in the T-intersection category.

A site survey of all selected intersections was undertaken to verify that each intersection shared similar characteristics, such as the correct pedestrian and vehicular flows in the same group and the intersection geometry, and that each intersection had pedestrian traffic lights (Walk and Don’t Walk) and painted crossing delineation.

Every method of conflict identification primarily seeks to identify what happens when pedestrians and vehicles approach each other in space and time. In the described study the primary observational task was to record the time at different points along the path of a left-turning vehicle and along the path of a walking pedestrian. The path of the vehicles and pedestrians was not fixed, but was observed on site. The observational procedure was divided into two recording strategies depending on the geometry of the intersection. The first recording strategy was for T-intersections, and the second was for X-intersections. A conflict area was identified according to the PET conflict definition, to simplify the work with the analysis. The conflict area boundaries consisted of the painted lines of the crosswalk and the path of the left-turning vehicle (i.e., width of a vehicle). An example of the second recording strategy is presented in Figure 2.

The location of the conflict area was not fixed and was dependent on the path of the left-turning vehicle. In short, for each evasive maneuver or sudden braking the approximate location and the time of the event would be recorded.

To carry out the data collection with the methodology described above two computer programs were written, for the pedestrian and left-turning movements, respectively. Both programs are based on a program developed by Jones (22,23). The computer programs allowed for the automatic recording of traffic phases without connection to the intersection controller, as well as the recording of the various times along the path of a pedestrian and a vehicle and the recording of traffic conflicts.

The equipment used to gather data included two laptop computers, a measuring tape, a string, chalk, spray paint, a pen, and a notebook. Paint marks were placed inside the intersection to help indicate the time when each road-user passed certain points. Each site was recorded for two days, from 2:00 pm to 6:00 pm. A trained assistant collaborated with the researcher during the data collection process. The laptop computers were used to record the events. Because the computers’ internal clocks ran at different speeds the laptops were synchronized at the beginning of the recording so that the data from each could be time-adjusted for further analysis.

Data collection included all elements needed for four different conflict study methods: U.S., TTC, CS, and PET. The TTC definition was divided into two components according to type of TTC employed. The first TTC definition (TTC1) is characterized by the use of a fixed TTC, whereas the second (TTC2) is characterized by use of a speed-dependent TTC. A conflict was recorded at the instant when a vehicle had to brake or perform an evasive maneuver (pedestrian evasive actions were also included) because of pedestrian activity on the crosswalk. Each conflict was recorded as a U.S. conflict (because that definition is the least restrictive) and was then analyzed to examine whether it also fell under another conflict definition. A PET conflict was added to the count for each instance of a vehicle entering the conflict area less than 3 sec after a pedestrian.

### RESULTS AND ANALYSIS

Table 3 reveals that the number of conflicts for sites in the X-intersection category is about half that of sites in the T-intersection category according to the U.S. and the TTC1 definitions. Low speeds at the instant of the evasive action account for the lack of conflicts falling under TTC2. Indeed, the speed of left-turning vehicles seldom surpassed 30 km/hr. Likewise, no conflicts were
categorized as serious according to the CS definition, as none of the vehicles left skid marks or made its tires squeal. Conflicts could not be recorded accurately enough for further analysis of Sites 1 and 6. Therefore, only conflicts categorized in the U.S. definition are used for further analysis, because that definition encompasses all conflicts categorized in the other definitions and also includes all eight sites. The number in parentheses in the PET column in Table 3 indicates the number of conflicts that can be categorized under both this definition and the U.S. definition.

To determine at what time during the green phase (for vehicle traffic) conflicts occurred, the phase was divided into segments and is represented graphically in Figures 3 and 4. These figures also show the times at which pedestrians left the curb. For the T-intersection category close to 71 percent of conflicts happened below 60 percent of the green phase, and about 21 percent of the conflicts occurred during the last 10 percent of the green phase. On the other hand, close to 85 percent of the conflicts for the X-intersection category occurred during the second half of the green phase. The time-of-departure histograms in Figure 3 show that a higher proportion of pedestrians in the T-intersection category start crossing at the end of the red phase (0 percent column). This figure underscores the conclusion that the earlier a pedestrian starts crossing at an approach categorized as a T-intersection, the greater chance there is of a conflict. In contrast, there is a greater risk of conflict for a pedestrian crossing at a site categorized as an X-intersection if that person waits to cross.

TABLE 3 Conflict Counts (2 Days) by Definition

<table>
<thead>
<tr>
<th>T-intersection Category</th>
<th>U.S.</th>
<th>TTC(^1)</th>
<th>TTC(^2)</th>
<th>CS(^3)</th>
<th>PET(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1 (Group 1)</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>9 (n/a)</td>
</tr>
<tr>
<td>Site 2 (Group 2)</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Site 3 (Group 3)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Site 4 (Group 4)</td>
<td>12</td>
<td>5</td>
<td>0</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

X-intersection Category

| Site 5 (Group 1)        | 0    | 0       | 0       | 0       | 0       | 0       | 1 (0)   |
| Site 6 (Group 2)        | 1    | n/a     | n/a     | n/a     | n/a     | n/a     | 2 (n/a) |
| Site 7 (Group 3)        | 6    | 3       | 0       | 4       | 1       | 0       | 12 (2)  |
| Site 8 (Group 4)        | 6    | 3       | 0       | 4       | 1       | 0       | 18 (1)  |
| Total                   | 13   | n/a     | n/a     | n/a     | n/a     | n/a     | 33 (n/a) |

\(^1\) First Time-to-Collision definition - TTC fixed (1.50 sec.)
\(^2\) Second Time-to-Collision definition - TTC speed dependent
\(^3\) Classification by Severity definition
\(^4\) Normal Path
\(^5\) Moderate
\(^6\) Serious
\(^7\) Foot Encroachment Time definition (The number in parentheses indicates the number of conflicts entering both this definition and the U.S. definition.)
\(^8\) Decided subjectively by the author
The relative safety of sites in the two intersection categories was examined in conflict counts as presented in Table 4. As has been mentioned, the site in the X-intersection category for Group 2 was found to be between three to four times safer than its matched site, whereas for Group 3 the T-intersection was expected to be about twice as safe. Table 4 reveals that, for Group 2 the X-intersection site has an $R$-value varying from 5 to 8, depending on the definition. TTC1 was the closest to the theoretical values of $R = 4$ or $R = 3$. On the other hand, for Group 3 no result could be demonstrated because in all cases $R = 0$. However, the site in the X-intersection category used for Group 3 was more dangerous than the site in the T-intersection category because it had a higher conflict count, which is confirmed by the theoretical value below unity ($R = 0.5$).

One purpose of the study was to examine whether those intersections predicted to be dangerous in the models developed by Quaye et al. are indeed dangerous. The sites are ranked from the most dangerous to the least dangerous according to the accident prediction models and the U.S. traffic conflicts alone as shown in (Table 5). The approaches in italics represent the sites in Category 2. It can be inferred from this table that the rankings of the sites for the expected number of accidents and the conflict counts are almost identical. The use of conflicts appears to support the accident prediction models.

In a verification of the findings shown in Table 5 two tests were used to correlate traffic conflict counts to the predicted number of accidents. The results of the two tests are presented in Table 6. The first test computed a weighted linear regression coefficient between traffic counts and the expected number of accidents. No regression coefficient was computed for the PET definition because the points were too scattered. The second test used was the Spearman rank correlation test, which determines the rank correlation between two sets of data.

Table 6 shows that two of the three traffic conflict definitions produced a strong positive correlation between conflicts and the expected number of accidents using the weighted linear regression analysis; the U.S. definition had the highest correlation coefficient with a value of 0.59. The PET definition had no correlation and was discarded from further study. The two remaining definitions were tested for significance because only eight or six sites, depending on the definition, were used in the analysis. Use of the F-test reflected the low number of conflict counts. The two definitions were found to be statistically significant and highly correlated for the Spearman ranking test. A correlation between conflict counts and the expected number of accidents may be inferred from this. Finally, the validation study also supports the accident prediction models.

The relationship of exposure (accident-risk), as measured by the cross product of traffic flow, and the number of conflicts was tested. Exposure was obtained by taking the square root of the product of the traffic flow of pedestrians and vehicles as shown in Table 7. Again, the approaches in italics represent the ones in Category 2.

The ranking for accident risk nearly coincides with the expected number of accidents; once more, the T-intersection approaches

<table>
<thead>
<tr>
<th>Approach</th>
<th>U.S.</th>
<th>TTC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-int</td>
<td>Site 6</td>
<td>1</td>
</tr>
<tr>
<td>(R = 4)</td>
<td>T-int</td>
<td>Site 2</td>
</tr>
<tr>
<td>R = 8</td>
<td>T-int</td>
<td>Site 3</td>
</tr>
</tbody>
</table>

- * assume it enters this definition
appear to be more dangerous than the X-intersection ones, with the exception of Site 3. The accident risk data also corroborates the data presented in Table 5. Overall, the two tests and the accident risk method appear to correlate well with the models developed by Quaye et al.

DISCUSSION AND CONCLUSION

The study involved (a) an examination of the interaction of left-turning vehicles and pedestrians at signalized intersections using traffic conflicts, (b) an exploration of the validity of the traffic conflict technique, and (c) the use of a laptop computer for data collection.

Findings concur with the accident prediction models developed by Quaye et al. The two tests used in the analysis ranked the approaches similarly to their models. The sites in the T-intersection category were determined to be more dangerous than the sites in the X-intersection for traffic flows over 100 vehicles per hour. One explanation for the lower rate of conflicts in Category 2 might be that the majority of pedestrians start crossing at the beginning of the green phase, and that while the first left-turning vehicle is waiting to find a gap long enough to turn the majority of the pedestrians has had sufficient time to cross. As a result the number of conflicts for the approaches in the X-intersection category could also be a function of the number of the vehicles coming from the opposite approach. As can be seen in Figure 3, about 30 percent of pedestrians in the T-intersection category start crossing before the green light appears; it is possible that the first few drivers making left turns might not expect a pedestrian to be so soon in his or her pathway. Over one-half of the conflicts in this category occurred during the first half of the green phase.

Several conflict definitions were examined. Because other studies have already discussed this subject extensive critical analyses of the definitions were not made; instead their applicability to pedestrian conflicts was assessed. It can be concluded from the analysis that categorization of a conflict at the instant of the evasive maneuver appears to be the most appropriate method. Not all traffic conflicts were classified as dangerous; no conflicts were classified under TTC2 or CS. Either of the two remaining conflict definitions can be used to evaluate the safety of pedestrians at intersections; the U.S. definition has the highest correlation and Spearman coefficients. The U.S. definition may be a good candidate, because it does not require extensive data collection (such as the use of a camera, for example). However, according to Brown \( (24) \) support of the TTC definition appears to be gaining more general acceptance in the research community.

A laptop computer proved to be sufficiently accurate for recording all other information, such as the times of travel along both the path of a pedestrian and a vehicle. One positive aspect of the use of the computer was the huge amount of information that could be entered directly and analyzed on a spreadsheet. The programs could be used in the following ways: individually to measure pedestrian counts; to examine when pedestrians start their crossing actions; and to estimate the walking speeds of pedestrians. They may also be used for similar information on left-turning vehicles.

The use of a laptop computer to record traffic conflicts proved to be laborious and difficult. Because traffic conflicts are usually sudden or unpredictable events it was not possible to record conflicts accurately in many cases. A wrong key would often be pressed due to the suddenness of the event, thus disrupting recording. On many occasions it was necessary to predict a potential conflict by looking at the paths of the pedestrian and the vehicle. Sometimes a conflict would occur with a second vehicle following the first; because the first vehicle was being recorded the second could not be. As a result the exact location of the conflict and the vehicle speed had to be estimated from notes taken on site.

The study was the first to attempt correlating traffic conflict rates with the expected number of accidents; all previous studies relied on accident counts alone. One major problem was the rarity of pedestrian accidents, a total of three pedestrian accidents with left-turning

| TABLE 6 Traffic Conflict Definitions and Validation Study |
|-------------|---------|-------|-------|
| Linear Regression \( (r^2) \) | 0.59 | 0.44 | -- |
| Spearman ranking \( (r_s) \) | 0.93 | 0.90 | 0.23 |
| F-test | 20.38 | 15.60 | -- |
| \( F(V_1, V_2) (p=0.05) \) | 5.14 | 6.94 | -- |
| Significant | yes | yes | -- |

| TABLE 5 Ranked Sites by Conflicts |
|-------------|---------|------|-------|
| Rank | Predicted Accidents | Approaches* | Count | Approach* |
| 1 | 16.4 | Site 8 (Gr 4) | 6 | Site 8 (Gr 4) |
| 2 | 5.2 | Site 7 (Gr 3) | 5 | Site 7 (Gr 3) |
| 3 | 4.5 | Site 6 (Gr 2) | 1 | Site 6 (Gr 2) |
| 4 | 4.4 | Site 3 (Gr 3) | 0 | Site 3 (Gr 3) |
| 5 | 1.6 | Site 5 (Gr 1) | 0 | Site 5 (Gr 1) |

* The sites in italic represent the ones in the X-intersection category
vehicles for the eight approaches observed occurred between 1983 and 1986. As a result validation would be inconclusive. Finally, even though a high correlation existed between the number of conflicts and the expected number of accidents, further studies using the expected number of accidents in other circumstances and with more conflict counts should be attempted.

Recommendations for further research include the analysis of traffic conflicts between vehicles and a validation study with the expected number of accidents. Moreover, a validation study with the technique developed by Hauer and Gårder (25) could be attempted. A laptop computer could still be used to record the events, but it should be combined with a video camera. Finally, a higher number of intersections for the analysis of the traffic conflicts is suggested.

REFERENCES


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