THE UNIVERSITY OF BRITISH COLUMBIA

DEPARTMENT OF CIVIL ENGINEERING

TRANSPORT SAFETY RESEARCH GROUP

TRAFFIC CONFLICT

PROCEDURE AND VALIDATION

By

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CANADA

TRAFFIC CONFLICT

PROCEDURE AND VALIDATION

For

Road Safety Program

INSURANCE CORPORATION OF THE PROVINCE

OF BRITISH COLUMBIA

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1. BACKGROUND

Individual accidents are, by their very nature and definition, essentially unpredictable. We can only speak of "prediction" in terms of the expected value of a number of future accident occurences.

Past accidents themselves are only moderately successful predictors of future accidents and then only in terms of relatively large numbers. Even so, past accident records of several years' duration would still form the most useful and reliable engineering database for analysising intersection safety but, unfortunately, such information is often not available because the location is a new one or physical changes have been made.

The concept of "Traffic Conflicts" is based on the notion that poor or misguided driver decision-making will lead to visually observable evidence of abnormal vehicular actions. These abnormal actions (typically involving some form of braking or evasive maneuver on the part of one or more vehicles) are recorded as traffic conflicts according to certain commonly utilized classifications. Such conflicts have a distinct advantage over accidents as a source of data since they occur much more frequently, and can be observed in the field, in turn leading to a "non-destructive" test for the safety of an intersection or roadway element.

Conflicts have been shown in many studies (1,5) to be related to accidents within well-accepted levels of statistical reliability. The major advantage of conflicts in understanding accident events lies not in their predictive power "in aggregate", however, but rather in their ability to be sensitive to driver actions on a much smaller scale than the traditional traffic engineering tools. Thus they offer, to a far greater extent than has hitherto been availiable, the potential for true diagnostic evaluation of specific geometric and traffic control features.

Traffic conflicts provide the link between driver actions resulting from combinations of human and environmental conditions, and the occurence of "unsafe traffic situations". Whether or not such an unsafe situation individually results in a collision is largely a matter of chance and the interrelated influence of many factors, but over a period of time an accumulation of such occurences must inevitably give rise to accidents. The observation and recording of traffic conflicts can be seen in this manner as simply a means to quantify subjective impression. This is not a trivial notion since what is percieved by a traffic engineer is often not easily communicated to or understood by an elected official unless it can be reliably and objectively compared to previous obervations or similar results in other jurisdictions.

Such considerations have led to wide-spread acceptance of the traffic conflicts concept in the U.S. and Europe, where much of the developmental work has taken place, as a diagnostic technique for evaluating vehicular safety and pedestrian risk.

2. STUDY OBJECTIVE

The objective of this study is to investigate the operational potential of the Traffic Conflict Technique (TCT) in diagnosing intersection safety. To be operational, the technique will require an observation procedure that can be performed consistently and easily with modest preparation and training time.

3. STUDY APPROACH

The study approach adopted consisted of the following steps:

1) Develop a standard observation form.
2) Develop an observation procedure.
3) Develop an observer training program.
4) Field test the developed procedure.
5) Analyse observed results and deduce the usefulness of the technique as a diagnostic tool.

The first two steps establish the standards for observation in order to achieve consistent results. The third step investigates the type and length of observer training required to achieve the desired reliability. The last two steps tests the procedure developed and determines if there is a significant relationship between conflicts and accidents. The usefulness of this technique as a diagnostic tool is evaluated based on the findings from the study.

4. DEVELOPMENT OF THE OBSERVATIONAL PROCEDURE

In view of the importance of consistency to the successful application of the traffic conflict technique, a set of observation procedures and guidelines were developed for the user to follow.

The observation procedure manual developed is illustrated in appendix A. The objective of this procedure manual is to define the classifications of conflicts and to provide guidelines for the user to follow to achieve consistent observation results. The manual illustrated is designed for use with 4-way intersections, but other types of intersections can be accommodated with minor modifications to the procedure.

4.1 STANDARDIZED FORM

The recording methods used in most past studies involved a check list, recording a conflict under a specific category. These methods were often criticized for their rigidity, and unless a very large number of categories was available, the characteristics of a conflict could not be described. The recording method adopted here records all the important characteristics of a conflict and any significant factors in the environment that may have contributed to the conflict situation. The descriptions of the character of a conflict and the environment conditions give the traffic engineer or the analyst more flexibility in interpreting observed data than before. The observation form adopted in this study is illustrated in Figure A-1.

The adopted form contains a description of the intersection location, the weather condition, the time the conflict occurred, a sketch of the conflict situation, and the classification of the conflict.

4.1.1 CLASSIFICATION OF CONFLICT

Conflicts can be classified according to the following scales:

a) minimum time to collision (TTC) value
   scale - (1) 3.0-2.0 seconds
           (2) 2.0-1.5 seconds
           (3) 1.5-1.0 seconds
           (4) 1.0-0.0 seconds

b) estimated risk of collision (ROC)
   scale - (1) small
           (2) moderate
           (3) high
           (4) very high

c) type of evasive action
   type - (1) braking
          (2) swerving
          (3) accelerating
          (4) combination

d) severity of evasive action
   scale - (1) light
           (2) moderate
           (3) heavy
           (4) emergency

e) proximity of vehicles at end of evasive action
   scale - (1) greater than two cars length
           (2) between one and two cars length
           (3) less than one car length
           (4) near accident

The first two types of classification, minimum TTC value and ROC, describe the severity of the conflict. These two types of classification are used to measure the threshold for traffic conflicts. TTC is the estimated time difference between the first observable reaction of the right of way vehicle being conflicted with and the moment when that vehicle would have reached the potential collision point had it continued with unchanging speed and/or direction.

In urban areas, where through-vehicle travel speeds are in the 50 kph range and manoeuvring is possible without much braking, the critical TTC which governs has generally been chosen as less than 1.5 seconds. In rural areas, the higher through vehicle speeds do not normally permit safe manoeuvring without a substantial amount of prior braking. If the crossing or interfering vehicle thus stops or otherwise blocks the through vehicle path, the later must decelerate to a safe manoeuvring speed - which from an initial velocity of about 80 kph, would take about 3 seconds on normal wet pavement with no vertical gradient. There is no consensus on the ROC thresholds, however, since subjective risk scales have not been used in most of the past studies. Section 7 will describe how a TTC-ROC threshold is selected.

The last three classifications are also useful. These provide a good overall description of the traffic conflict situation. Any doubt about the accuracy of a TTC or ROC observation recorded by an observer can be checked for consistency. In general, conflict situations with lower TTC values also have higher risk and heavier evasive action. Situations in which the classifications are not consistent can be checked by the analyst using the sketch of the conflict situation and the comments made by the observer. For example, a conflict situation recorded with time to collision of less than 1.0 seconds and a very small risk (TTC-ROC of 4-1) with emergency braking may indicate a mistake was made, unless the observer noted some comment on the form to support his or her observation.

Furthermore, the last classification, proximity of road users at end of evasive action, is particularly useful for classifying conflicts for which the TTC value cannot easily be measured. A common situation for which this type of classification is useful is when a pedestrian stops or jumps back to avoid an on-coming vehicle. Other useful applications are for situations where there is no potential collision point directly along the courses projected for the road users.

For any standardization of procedure then, the above categories of conflict should be recorded.

4.2 OBSERVATION PROCEDURE

The observation procedure adopted, as described in appendix A, is simple to follow and defines the approximate location of observers, the types of conflict situation and the area of the intersection that each of the observers will be responsible for.

For simple intersections, such as a two-lane roadway intersecting another two-lane roadway or four lanes intersecting two lanes, two observers stationed on the main opposing legs at a distance of 30 to 50 meters from the intersection would be required (depending on site lines and obstructions).

With complex locations, more observers may be required depending on the volume of traffic and the variety of possible conflict situations. More observers increase the potential for multiple counting, but since each observer will be assigned specific types of conflict situation, any conflict recorded that is outside his or her observation boundary can be marked with a note and checked for accuracy against another observers' remarks.

As road accidents can occur at any time of day, conflicts should ideally be observed for the full 24 hours in order to reflect all normal traffic and lighting conditions. However, this is obviously impractical, and normally only a portion of the day can be observed. The total length of observation time for a particular location can vary depending on the traffic volume which governs the time-rate of conflict occurrence. It is recommended that observation be carried out for a minimum of two consecutive days for 8 hours a day encompassing both the morning and the afternoon peak periods.

5. OBSERVER TRAINING

A training program was developed as part of the study to illustrate successful implementation in the field. The purpose of the training program is to develop a procedure for training inexperienced observers to perform traffic conflict observation.

Effectiveness of the training program was measured by the observers' reliability in observing traffic conflicts. Observers' reliability was evaluated by checking the observers' field results against video tapes taken concurrently with field observations. A study by Kulmala(1) has shown that the reliability of an observer can be improved to a fairly high level (87%) by increasing the number of field observations, however, the rate of improvement in reliability is a decreasing function and such a high level of reliability would take a long training period to achieve.

In terms of user practicality, a relatively short training period that can achieve reasonably high reliability (such as 75%) is desired.

5.1 OBSERVER SELECTION

Unlike vehicle counting, traffic conflict observation requires specially trained observers. For this study, two inexperienced observers were selected for training. One of the observers selected had an initially good conceptual knowledge of the technique, but had no field observation experience. The other observer has no previous knowledge of the technique at all.

5.2 TRAINING PROGRAM

Apart from brief instruction on the concept of the technique, the training program adopted involves successive iterations of field training and video tape reviewing. The program consisted of two stages; I and II.

The purpose of stage I was to familiarize the trainees with the identification of the different types of conflict. The concept of time to collision (TTC) and risk of collision (ROC) were discussed and explained. A 20 minute training film showing different types of conflict was produced by the study team and used to help illustrate the concepts.

Since TTC is an objective measure, the trainees had little difficulty in grasping this concept, however, the subjectivity of risk measurement raised some legitimate concerns. The extreme scales of near accident and small risk were easily understood and were later found to be consistently observed by the trainees, but the mid-scale positions were found to be difficult to distinguish. To overcome any vagueness in recording conflicts of these types, the following guidelines were adopted.

1. The risk of a collision was considered to be moderate or less when the following conditions were satisfied :

a) the vehicle being conflicted with has plenty of roadway to maneuver around the vehicle causing the conflict,
b) the vehicle being conflicted with has plenty of time to react to the conflict situation, and
c) the driver of the vehicle being conflicted with has a clear view of the intersection and the vehicle causing the conflict.

2. The risk was considered as high when any one or more of the above conditions is not satisfied.

The purpose of stage II was to familiarize the trainees with the field observation technique. Field training involved observation in the field and video tape filming concurrently taken from the same position as the observers. Video tape provided a quick check and feed back to the observers.

All field observation sessions were two hours long and were performed during the rush hour periods. Each field session was followed by a video tape reviewing session. During the video tape reviewing session the trainees reviewed all the conflicts observed in the field and noted any discrepancy. Also, mistakes made in classifying the conflicts in the field were identified and discussed.

The availability of video tapes of the field observation allows the performance in the field to be measured. Figure 1 shows the training performance curve for both observers selected for the study.

It can be seen that the reliability of the trainees improves with the number of field observation performed. It would be useful to know what the increased reliability would be if more field observations were done. However, due to limited resources, a reliability of 75% achieved at the end of the training period (a total of 3 days) is considered acceptable. In a similar study by Kulmala(1), it was found that the reliability of a trainee can reach 77% after 5 days of observation and improve slowly to 87% after 11 days. This observed pattern indicates that extensive training periods beyond a few days duration will result in diminsihing marginal returns.

5.3 TRAINING SCHEDULE

A normal training program should cover 3 - 5 days. Based on the experience gained in this study, a minimum schedule and content should be similar to the following:

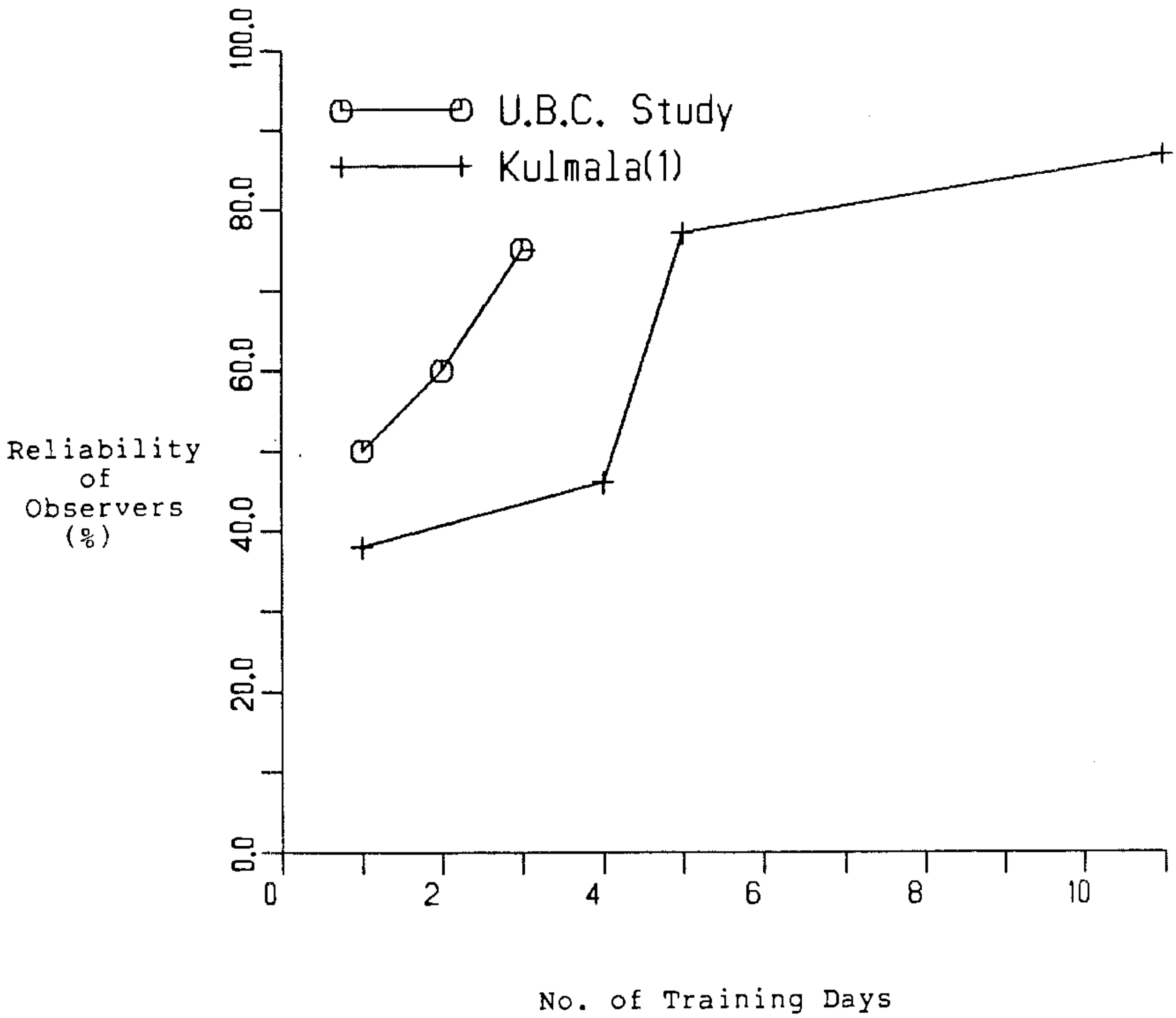


Figure 1 Level of Reliability achieved by Observers during the Training Period

1st day - Instruction on the concept of TCT and the study objective. Introduction of the procedure manual, the severity scale, the classification of conflicts and the technique in completing the observation form. Showing examples of conflicts on video film. First observation on site with moderate traffic volume and moderate number of conflicts. Video taping of the traffic from the same vantage point as the observers' should be undertaken concurrently. Reviewing video tape of first observation period. Identifying and discussing mistakes.

2nd day - Second observation on site with high traffic volume and high number of conflicts, coupled with video taping. Reviewing video tape of second observation period. Identifying and discussing any mistakes. Introduction of the boundary of observation and how to account for multiple counting. Emphasizing the importance of sketch and special comments. Third observation on the same site, coupled with video taping. Practicing team work by separating trainees to ensure good coverage of the intersection. Reviewing video tape of third observation period. Identifying and discussing mistakes.

3rd day - Fourth observation on different site with high volume and high number of conflicts, coupled with video taping, to practice team work. Reviewing video tape of fourth observation period, and discussing any mistakes made by the trainees. Practicing the data reduction process, including elimination of multiple counted conflicts. Selecting and assigning teams for observation.

During this three day period, the performance of the trainees should be monitored by measuring their level of reliability.

6. FIELD STUDY

The objective of the field study was to test the procedure developed and to see if there was a significant correlation between conflicts and safety (as measured by the number of reported accidents that had occurred at the intersection over the last five years).

6.1 INTERSECTIONS STUDIED

Four similar intersections in the city of Vancouver were selected for field study:

(A) Heather Street & 12th Avenue
(B) Granville Street & Drake Street
(C) Main Street & 10th Avenue
(D) Blenheim Street & 41st Avenue

The selection of these intersections was based on the following criteria:

(1) Simple intersections (either two-lane roadways intersecting other two-lane roadways or four lanes intersecting two lanes perpendicularly) with no signal control other than stop signs on the minor approaches.
(2) No significant structural, geometric or intersection control changes for the last five years.
(3) No significant changes in traffic volume for the last five years.
(4) Unobstructed view of vehicle movements at the intersection from observers' position.

6.2 FIELD STUDY PROCEDURE

Field observation was performed in accordance with the observation procedure manual described above and in appendix A. A form was completed for each and every conflict observed by the observer. In addition to the general information recorded, the classification of the conflict, a sketch of the conflict situation and brief remarks on the conflict were prepared. The sketch and the remarks assisted the analyst with the interpretation of the form during subsequent data reduction.

All intersections were observed for two consecutive weekdays during 8 hours per day. The observation day was divided into three periods, 7:30 a.m. to 10:00 a.m., 11:30 a.m. to 2:00 p.m. and 3:00 p.m. to 6:00 p.m., encompassing both the morning and the afternoon peak periods.

6.3 SUMMARY OF STUDY RESULTS

Figure 2.1 to Figure 2.4 summarize the field observations by maneuver types. A total of 44 maneuver types, which represent all possible maneuvers, of which the paths taken by two road users could meet at an intersection, were observed and analysed.

The 44 possible maneuvers at an intersection were aggregated into seven movement types, LTO, LTC, C, RE, RT, W, P, described as follows:

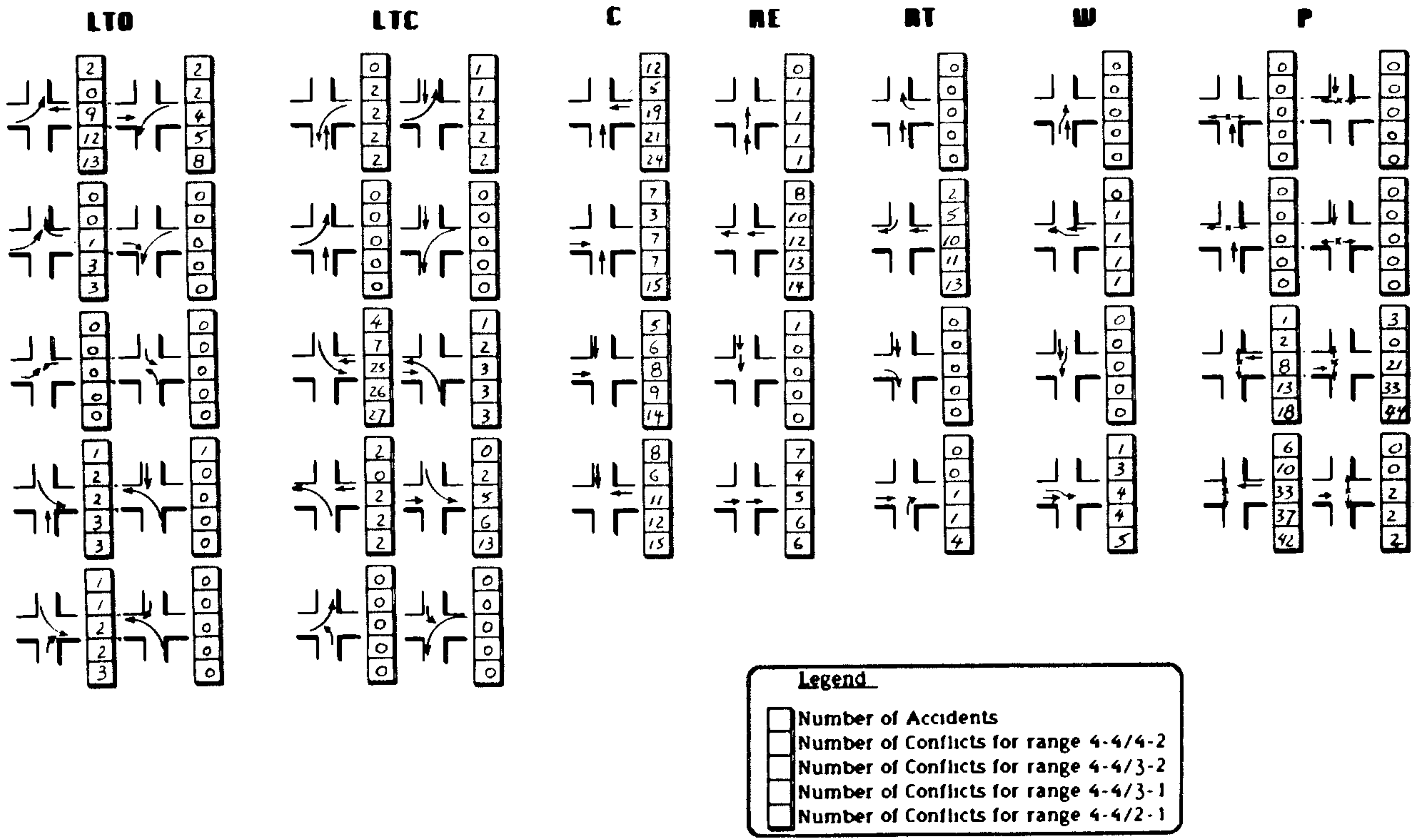


Figure 2.1- Movement Diagrams showing total number of Accidents and Conflicts for Intersection A.

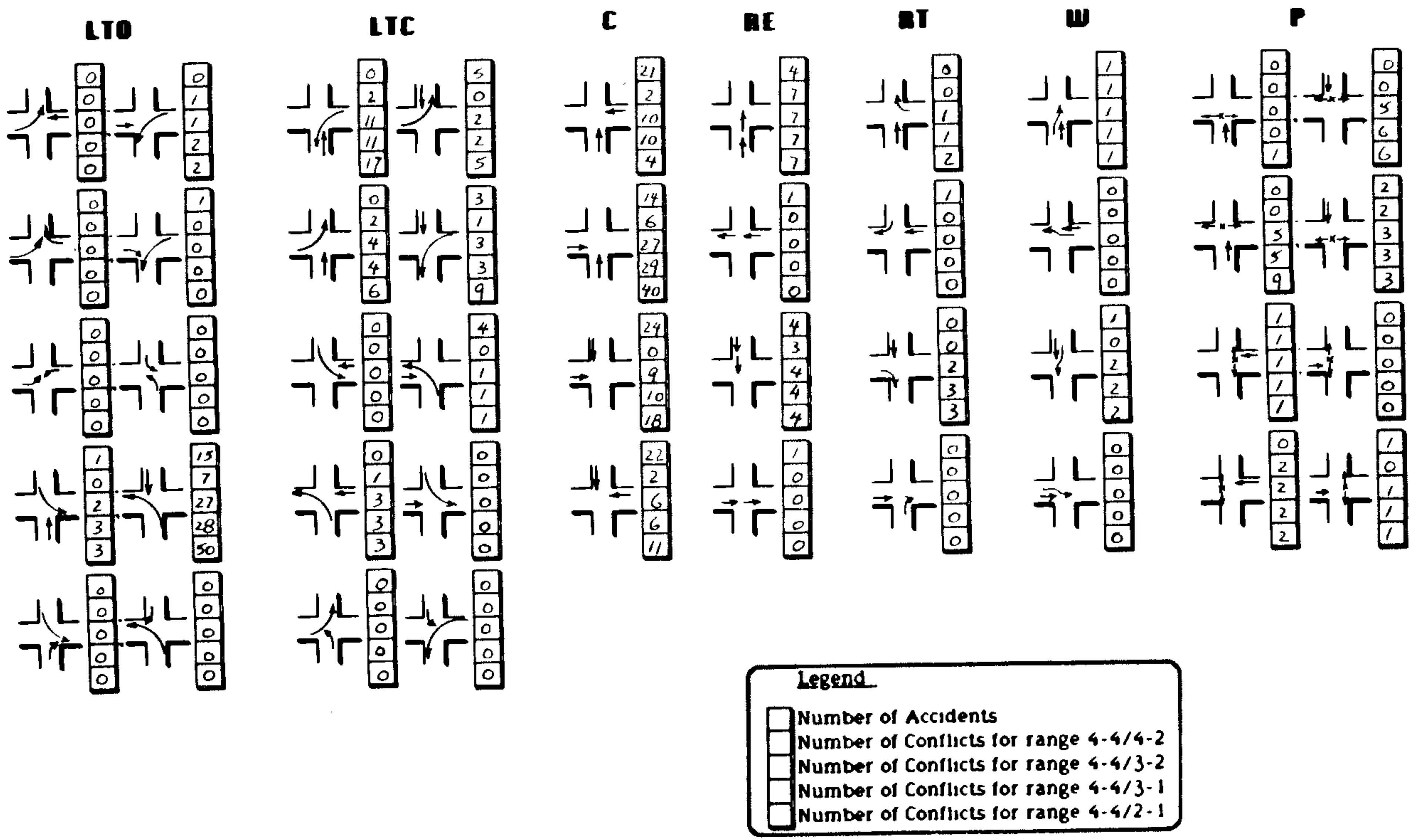


Figure 2.2- Movement Diagrams showing total number of Accidents and Conflicts for Intersection B.

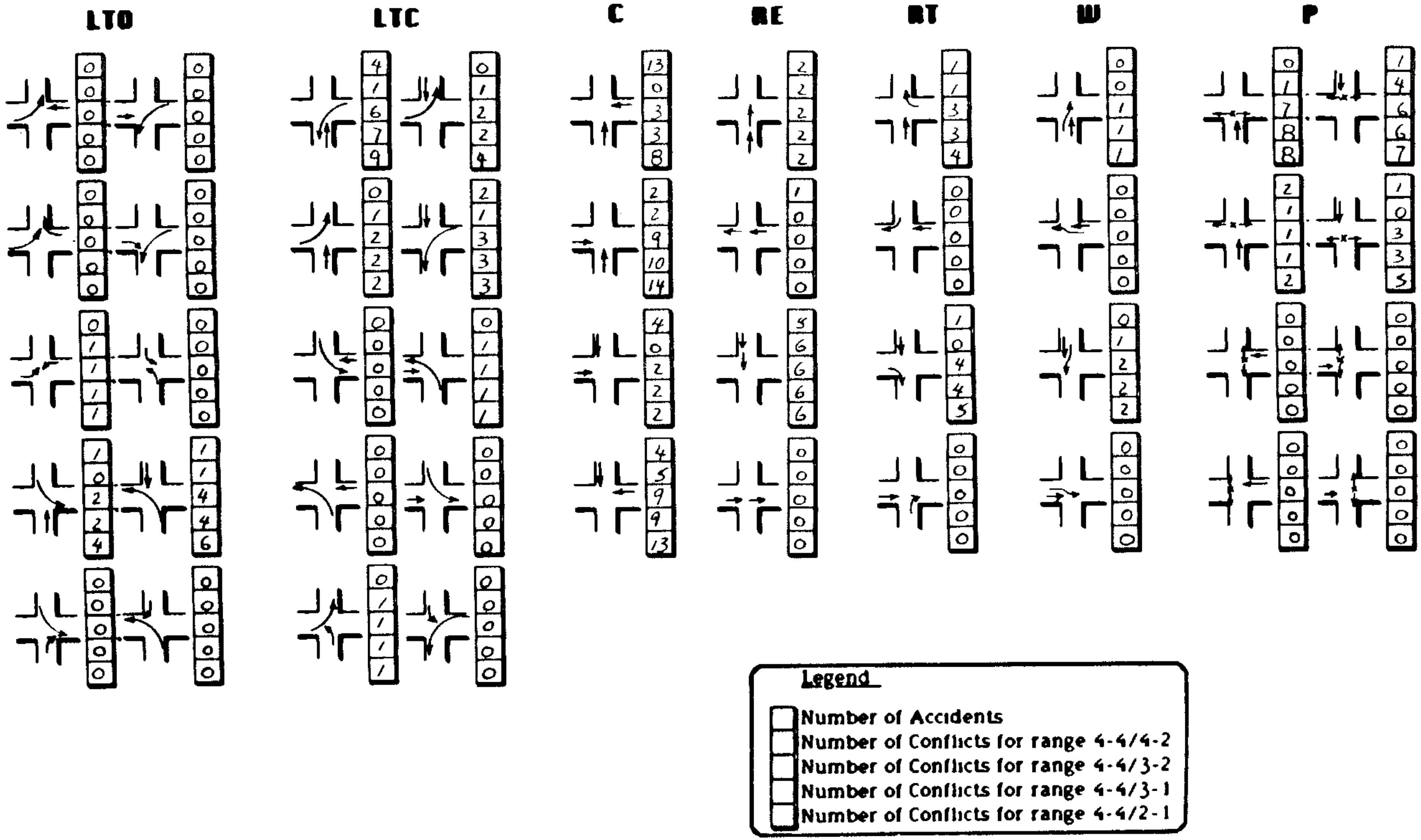


Figure 2.3- Movement Diagrams showing total number of Accidents and Conflicts for Intersection C.

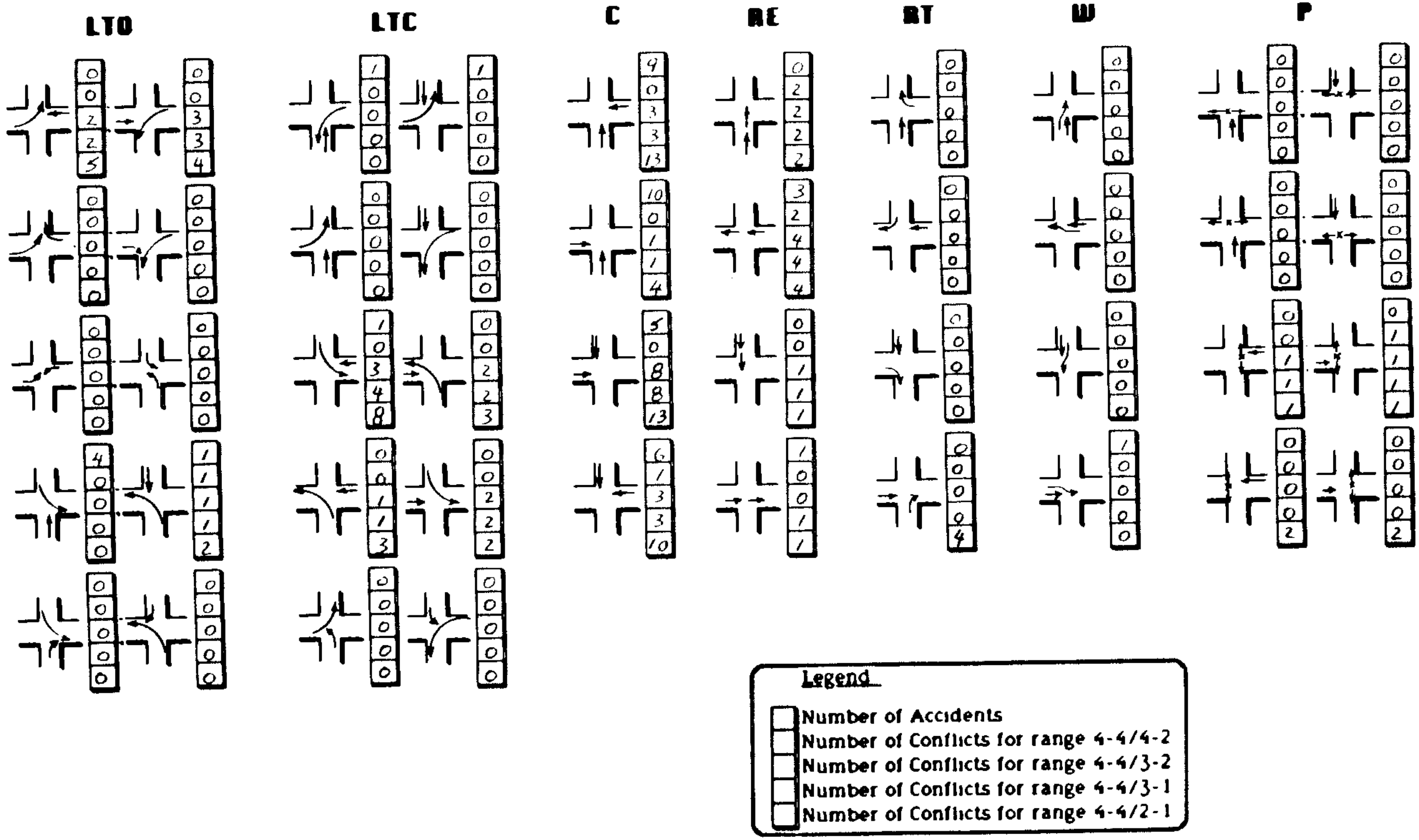


Figure 2.4- Movement Diagrams showing total number of Accidents and Conflicts for Intersection D.

10 LTO - Left Turn with Opposing traffic movement
one road user turning left and the other road user in the opposite direction going through or turning left or right.

10 LTC - Left Turn with Crossing traffic movement
one road user turning left and the other road user going through or turning left in the crossing direction.

4 C - Crossing traffic movement
one road user going through and the other road user going through in the crossing direction.

4 RE - Rear End movement
one road user following the other road user.

4 RT - Right Turn movement
one road user truning right and the other road user going through in the crossing direction.

4 W - Weave movement
one road user swerved or weaved in front of the other road user.

8 P - Pedestrian movement
one road user is a pedestrian crossing the intersection as the other road user arrived at the intersection.

7. ANALYSIS

7.1 METHODS USED

Three types of statistical analysis were performed:

1. Linear Regression;
2. Significance Tests; and
3. Spearman Rank Correlation Tests.

The form of the linear regression equation adopted is:

$$Y = a0 + a1\ X$$

where Y is the total number of accidents in the last five years,
X is the total number of traffic conflicts observed in two days,
a0 is the regression constant, and
a1 is the regression coefficient.

The correlation coefficients (r) obtained from the linear regression analysis are a measure of the reduction in the variability of Y (5-year accident histories) attained by the use of information about X (conflicts). A plus or minus sign is attached to this measure according to whether the slope of the fitted regression line is positive or negative. Thus, the range of r is :

$$-1 <= r <= 1.$$

Absolute values close to 1 indicate strong relationships, zero indicates the variables are independent.

To test if the data supported the linear model, taking into account the small sample sizes the f-statistic (f-stat) was used. The f-stat value is the ratio of MSR (regression mean square) over MSE (error mean square) of each set of data.

The decision rule to determine if the data is supported at the level of confidence $1-\alpha$ is:

$$\text{f-stat} > F\ (1-\alpha, p-1, n-p),$$

where F is the test value,
$1-\alpha$ is the level of confidence,
p is the number of degrees of freedom,
and n is the sample size.

The Spearman rank correlation coefficient (rs) is a measure of the association between ranking the intersections according to number of conflicts and number of accidents. The most convenient formula for computing the Spearman rs is:

$$rs = 1 - \frac{6 \sum_{i=1}^{N} di^2}{N^3 - N}$$

where rs is the Spearman rank correlation coefficient,
di is Xi - Yi, and
N is the number of samples.

7.2 ANALYSIS CATEGORIES

For analysis, the data were categorized by:

1. movement types and severity
2. intersection quadrants and severity.

For each conflict recorded, one level of severity (TTC-ROC scale) was assigned. According to this scale, the data were divided into four severity ranges, and the analysis of the results obtained for each range showed the best TTC-ROC threshold for traffic conflicts in urban areas.

Each TTC-ROC scale was represented by a pair of numbers. The first one corresponded to the time to collision (TTC), the second to the risk of collision (ROC):

Scale	TTC(seconds)	ROC
1	2.0-3.0	very small
2	1.5-2.0	moderate
3	1.0-1.5	high
4	0.0-1.0	very high

And the chosen TTC-ROC scale was:

```
4-4> 4-3> 4-2> 3-4> 3-3> 3-2> 2-4> 4-1> 3-1> 2-3> 2-2> 2-1
High Severity---------------------------------Low Severity
```

Which was divided into the four severity ranges :

a) 4-4 --> 4-2
b) 4-4 --> 3-2
c) 4-4 --> 3-1
d) 4-4 --> 2-1

Besides the TTC-ROC classification, accidents and conflicts were categorized into seven movement types and four zones (quadrant) within the intersection.

The seven movement types selected were:

LTO - Left Turn with Opposing traffic
RT - Right Turn
C - Crossing traffic
W - Weave
LTC - Left Turn with Crossing traffic
RE - Rear End
P - Pedestrians

and the four quadrants were:

```
       !   !   !
       !   !   !
-------+   !   +-------
         1 ! 2
-----------+-----------
         3 ! 4
-------+   !   +-------
       !   !   !
       !   !   !
```

7.3 SUMMARY OF DATA COLLECTED

From the movement diagrams (Figures 2.1 to 2.4) the total number of accidents and conflicts categorized by intersection quadrant and by movement type are summarized and shown in Tables 1 and 2, respectively.

Some difficulties were encountered when categorizing accidents and conflicts by intersection quadrant. These difficulties arose mainly from the lack of precise information, on which quadrants the accidents occured, on the accident record, and from the conflict form adopted which was not equiped to record this type of information. The conflict form can easily be changed to include the classification of conflict by intersection quadrant. However, the accident record cannot easily be changed.

Int>	---[A]---					---[B]---					---[C]---					---[D]---				
Type of Conf	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc
Q 1	28	90	100	112	26	15	47	49	76	42	16	25	25	32	11	2	11	12	31	8
Q 2	19	42	52	61	21	7	32	32	49	23	4	15	16	25	21	2	8	8	18	13
Q 3	11	36	50	66	16	36	3	19	21	38	3	15	15	22	8	1	9	10	15	7
Q 4	13	27	30	52	12	14	39	43	55	24	6	21	23	29	5	2	10	10	21	14
TOT	71	195	232	291	75	72	121	143	201	127	29	76	79	108	45	7	38	40	85	42

Table 1 Summary of Accidents and Conflicts Categorized by Intersection Quadrants

Int>	---[A]---					---[B]---					---[C]---					---[D]---				
Type of Conf	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc	4.4 to 4.2	4.4 to 3.2	4.4 to 3.1	4.4 to 2.1	No. of Acc
LTO	5	18	25	30	7	8	30	33	55	17	2	7	7	11	2	1	6	6	11	5
RT	5	11	12	17	2	0	3	4	5	1	1	7	7	9	2	0	0	0	4	0
C	20	45	49	68	32	10	52	55	83	81	7	23	24	37	23	1	15	15	40	30
W	4	5	5	6	1	1	3	3	4	2	1	3	3	3	0	0	0	0	0	1
RE	15	18	20	21	16	10	11	11	11	10	8	8	8	8	8	4	7	8	8	4
LTC	14	39	41	49	8	6	24	24	41	12	6	15	16	22	6	2	10	11	18	3
P	12	64	85	106	10	5	17	18	23	4	6	17	18	22	4	1	2	2	6	0
TOT	75	200	237	297	76	40	140	148	222	127	31	80	83	112	45	9	40	42	87	43

Table 2 Summary of Accidents and Conflicts Categorized by Movement Type

7.4 ANALYSIS BY INTERSECTION QUADRANT

Table 3 shows the results of the analysis performed considering accidents and conflicts categorized by intersection quadrant.

Except for Intersection A, the results are very poor. The low correlation coefficients and f-stat values attained show that there is no significant correlation between accidents and conflicts when divided according to the zones (quadrants) where they occurred. This is not totally unexpected and can at least partially be explained by the fact that conflicts preceed accidents in time and space and thus, except for very severe conflicts with extremely low TTC, it is unlikely that conflicts and accidents will actually overlap spatially. Apparently the spatially difference is often beyond that expressed by a single quadrant of the intersection.

Int. TTC-Risk	Slope	Y-Int	Corr.	fStat	S. E.
[A] / 4.4-4.2	0.73	5.77	0.92	10.76	2.95
[A] / 3.4-3.2	0.20	9.22	0.91	9.24	3.14
[A] / 2.4-3.1	0.19	7.75	0.93	12.21	2.79
[A] / 2.3-2.1	0.19	4.68	0.85	5.35	3.88
[B] / 4.4-4.2	0.44	23.75	0.58	0.99	9.69
[B] / 3.4-3.2	-0.07	33.99	0.15	0.04	11.72
[B] / 2.4-3.1	0.01	31.22	0.02	0.00	11.85
[B] / 2.3-2.1	0.04	29.95	0.08	0.01	11.81
[C] / 4.4-4.2	-0.11	12.08	0.10	0.02	8.47
[C] / 3.4-3.2	-0.56	21.81	0.39	0.36	7.83
[C] / 2.4-3.1	-0.57	22.55	0.41	0.41	7.76
[C] / 2.3-2.1	-0.29	19.16	0.19	0.07	8.36
[D] / 4.4-4.2	4.67	2.33	0.66	1.58	3.21
[D] / 3.4-3.2	-0.80	18.10	0.29	0.19	4.11
[D] / 2.4-3.1	-1.25	23.00	0.58	1.02	3.50
[D] / 2.3-2.1	-0.08	12.19	0.16	0.05	4.25

Table 3 Linear Regression Values for Analysis Categorized by Intersection Quadrants

7.5 ANALYSIS BY MOVEMENT TYPE

7.5.1 Linear Regression And Threshold Selection

Table 4 shows the linear regression results (including correlation coefficients and f-stat values) obtained for each movement type and TTC-ROC range.

The correlation coefficients obtained are good. For all but one type of movement there is at least one severity range with correlation coefficient above 0.7. The exception is for the Weave type.

Analysis of the total number of accidents and conflicts by intersection (with all 7 movement types combined) give poor correlation results. This can be attributed to the different nature of each type of movement and its independence from the other type of movement.

Comparison of the correlation coefficients and f-stat values shows that the most consistent TTC-ROC range is 4-4 --> 3-2. The TTC threshold for this range is 1.5 seconds, and the ROC threshold is moderate. Thus, a threshold of (TTC-ROC) 3-2 was chosen for all of the analyses that follow.

The disappointing results observed for the Weave type can be attributed partly to the difficulty of identifying weave accidents from the accident records available. Since these records give only the general direction in which each vehicle was travelling (N,S,NW etc.), and since weave conflicts imply changing lanes, weave information is not recorded. Unless accident records that can describe this type of movement are available, the significance of the correlation between conflicts and accidents for weaving cannot be measured.

The f-statistic values are also generally good. Comparing the reference $F(1-\alpha,1,2)$ for different levels of confidence $(1-\alpha)$

$1-\alpha$	=	.500	.900	.950	.975	.990	.995	.999
F	=	.67	8.53	18.50	38.50	98.50	199.00	998.50

with the f-stat values in Table 4 shows that the data support the linear model adopted up to the following levels of confidence:

Type	Level of Confidence (%)
LTO	95
RT	93
C	73
W	0
RE	97
LTC	57
P	98

Type TTC-Risk	Slope	Y-Int	Corr.	fStat	S. E.
LTO / 4.4-4.2	1.87	0.28	0.91	9.41	3.33
LTO / 3.4-3.2	0.55	-0.59	0.95	17.00	2.58
LTO / 2.4-3.1	0.43	0.18	0.88	6.81	3.79
LTO / 2.3-2.1	0.30	-0.30	0.97	27.73	2.06
RT / 4.4-4.2	0.26	0.85	0.66	1.53	0.88
RT / 3.4-3.2	0.19	0.28	0.93	12.27	0.44
RT / 2.4-3.1	0.17	0.26	0.91	9.89	0.48
RT / 2.3-2.1	0.13	0.14	0.78	3.12	0.73
C / 4.4-4.2	0.34	38.28	0.10	0.02	32.43
C / 3.4-3.2	1.11	4.04	0.73	2.32	22.18
C / 2.4-3.1	0.98	6.53	0.71	2.02	23.00
C / 2.3-2.1	1.00	-15.58	0.84	4.69	17.82
W / 4.4-4.2	0.00	1.00	0.00	0.00	1.00
W / 3.4-3.2	0.00	1.00	0.00	0.00	1.00
W / 2.4-3.1	0.00	1.00	0.00	0.00	1.00
W / 2.3-2.1	0.05	0.83	0.16	0.05	0.99
RE / 4.4-4.2	1.09	-0.60	1.00	670.32	0.33
RE / 3.4-3.2	0.97	-1.20	0.97	28.33	1.57
RE / 2.4-3.1	0.82	-0.16	0.93	13.50	2.20
RE / 2.3-2.1	0.75	0.45	0.93	12.82	2.25
LTC / 4.4-4.2	0.30	5.13	0.40	0.39	4.23
LTC / 3.4-3.2	0.17	3.54	0.57	0.96	3.80
LTC / 2.4-3.1	0.15	3.79	0.52	0.76	3.94
LTC / 2.3-2.1	0.19	1.02	0.76	2.67	3.03
P / 4.4-4.2	0.90	-0.92	1.00	241.23	0.46
P / 3.4-3.2	0.15	0.76	0.98	44.26	1.05
P / 2.4-3.1	0.11	1.19	0.96	26.24	1.34
P / 2.3-2.1	0.09	1.08	0.95	20.60	1.50
TOT / 4.4-4.2	0.57	50.71	0.40	0.38	44.03
TOT / 3.4-3.2	0.33	34.93	0.59	1.05	38.85
TOT / 2.4-3.1	0.24	41.93	0.52	0.76	40.87
TOT / 2.3-2.1	0.25	27.05	0.64	1.36	37.06

Table 4 Linear Regression Values for Analysis Categorized by Movement Types

The confidence levels attained are very high, except for types C and LTC (and W, of course). Graphs of accidents against conflicts for both types show that there are outliers, values that seem to be atypical (Intersection D for C type and Intersection B for LTC). When these points were excluded from the analysis the sample sizes were reduced by 25%, and although the correlation coefficients increase, lower levels of confidence were obtained.

For the C type of conflict, for example, the analysis performed without the outlier point (Intersection D) gives a higher correlation coefficient - r=0.93 instead of 0.73 - but the new value for f-stat is only 4.54, which for three points means a level of confidence even lower than the original one.

7.5.2 Pie-Charts For Each Intersection

Figure 3.1 (a to d) shows pie-charts illustrating the distribution of accidents and conflicts by movement type for each of the intersections studied.

Except for Intersection A (r=0.49), the correlation coefficients are good (all greater than 0.80). Again, comparing the reference values of $F(1-\alpha;2,7)$

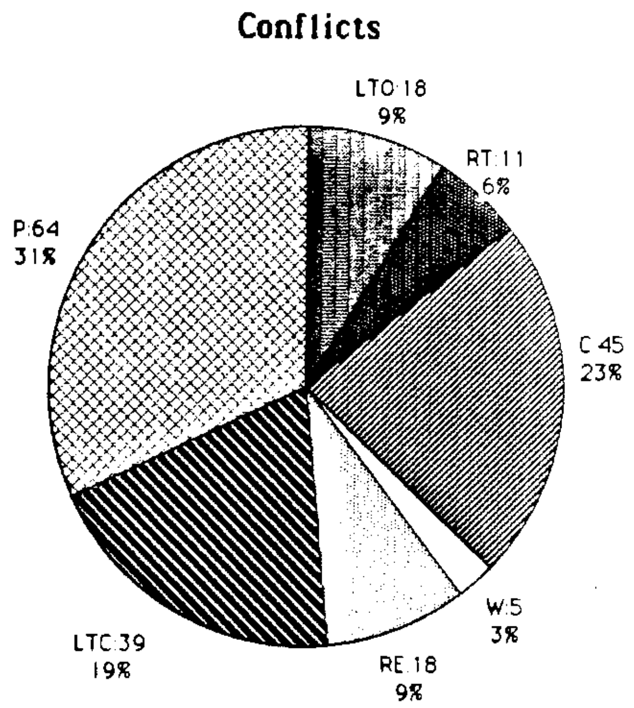
$1-\alpha$ =	.500	.900	.950	.975	.990	.995	.999
F =	.53	4.06	6.61	10.00	16.30	22.80	47.20

with the values obtained for f-stat shows high levels of confidence for three out of the four intersections studied :

Intersection	Level of Confidence (%)
A	73
B	99
C	97
D	98

The values obtained are good, except for Intersection A, where the correlation is not significant mainly because of the discrepancy between the number of accidents and conflicts involving pedestrians. If we ignore P type, the correlation coefficient (r) goes to 0.76, indicating a much better correlation, and f-stat goes to 5.41, which gives a very good confidence level (greater than 90%). The negative effect of including the P type may be attributed to the exceptionally high volume of pedestrian traffic associated with the nearby hospital.

As the figures show, the Spearman Rank correlation values are high (greater than 0.77) for all intersections, at confidence levels greater than 90%. This indicates that there is a strong correlation between ranking critical movements by accidents or conflicts.



- Correlation Coefficient = 0.49
- f - Statistic = 1.57
- Level of Confidence [f] = 0.73
- Spearman Rank Correlation Coefficient = 0.79
- Level of Confidence [SR] = 0.95

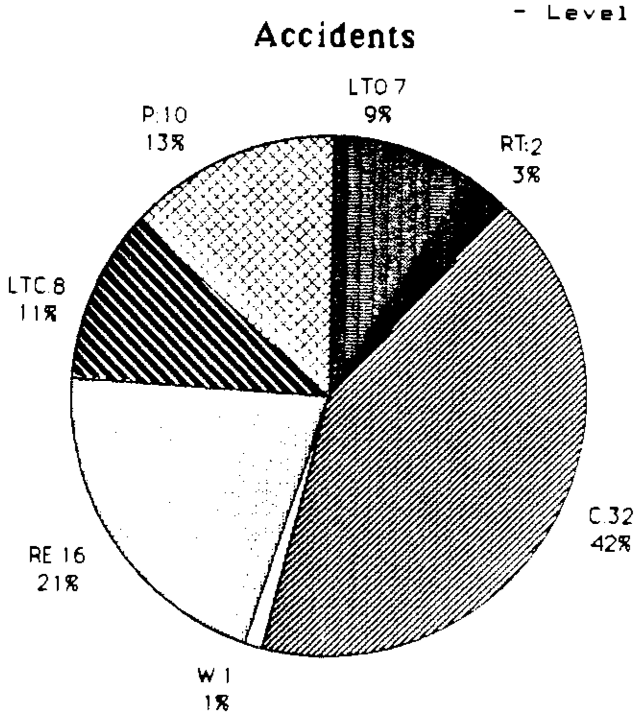
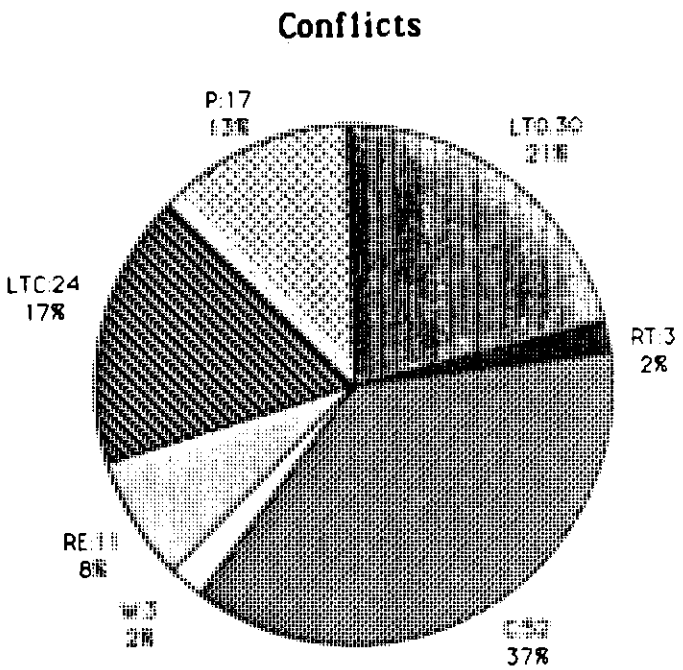


Figure 3.1 (a): Pie-Charts illustrating Conflicts and Accidents by movement type for Intersection A.



- Correlation Coefficient = 0.90
- f - Statistic =21.54
- Level of Confidence [f] = 0.99
- Spearman Rank Correlation Coefficient = 0.96
- Level of Confidence [SR] = 0.99

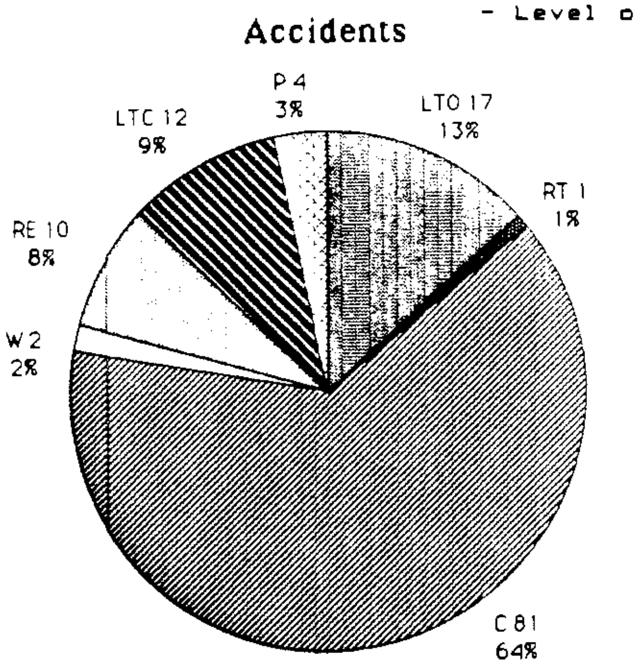
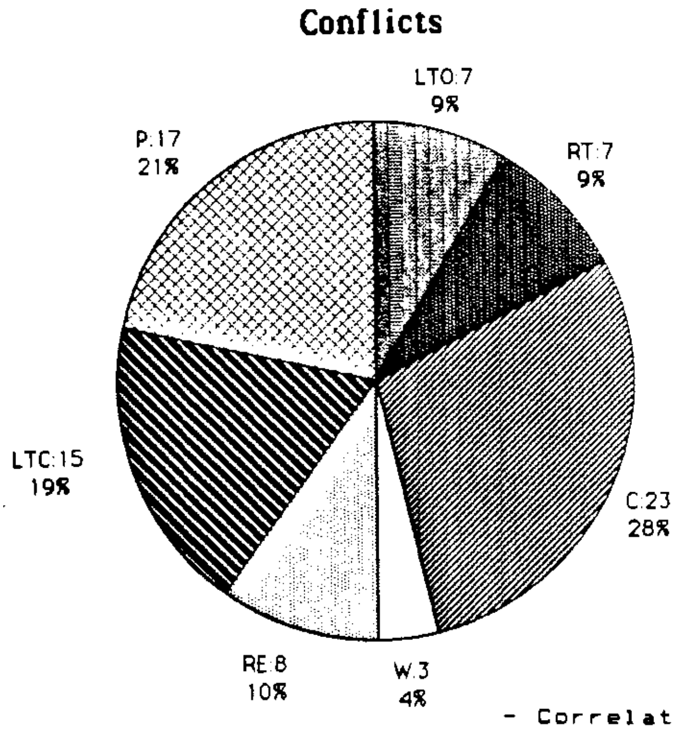


Figure 3.1 (b): Pie-Charts illustrating Conflicts and Accidents by movement type for Intersection B.



- Correlation Coefficient = 0.80
- f - Statistic = 8.99
- Level of Confidence [f] = 0.97
- Spearman Rank
  Correlation Coefficient = 0.85
- Level of Confidence [SR] = 0.95

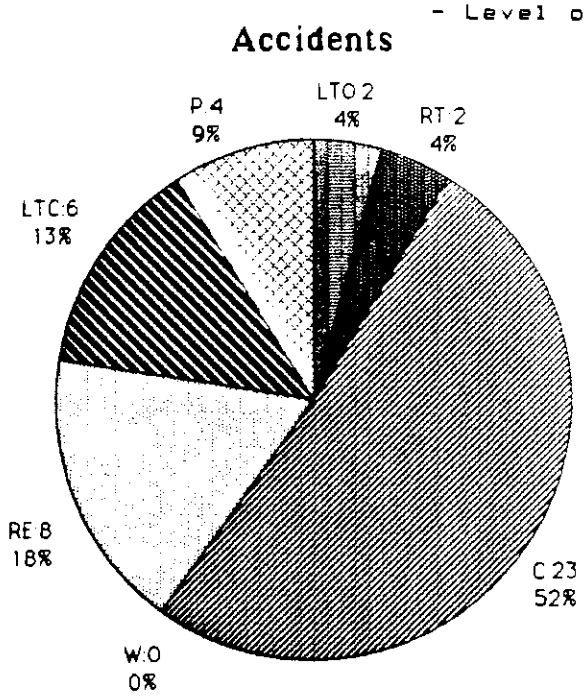
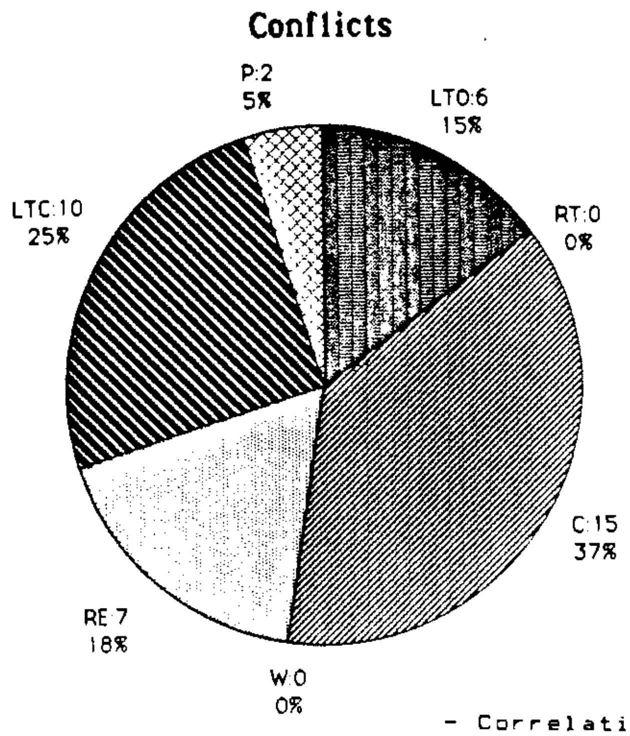


Figure 3.1 (c): Pie-Charts illustrating Conflicts and Accidents by movement type for Intersection C.



- Correlation Coefficient = 0.82
- f - Statistic =10.19
- Level of Confidence [f] = 0.98
- Spearman Rank Correlation Coefficient = 0.77
- Level of Confidence [SR] = 0.95

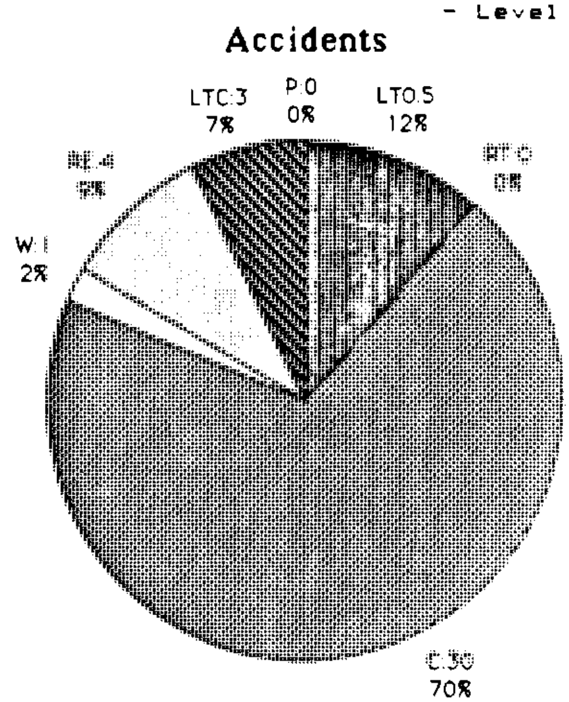


Figure 3.1 (d): Pie-Charts illustrating Conflicts and Accidents by movement type for Intersection D.

7.5.3 Pie-Charts For Each Movement Type

Figure 3.2 (a to g) shows pie-charts illustrating the distribution of accidents and conflicts by intersections, for each movement type.

As discussed in section 7.5.1, the correlation coefficients and f-stat values attained indicate that there is significant correlation between conflict and accident categorized by movement type, except for the W, C, and LTC types.

The Spearman Rank correlation coefficients are very good, except again for the W type. This again indicates that a strong correlation exists between ranking intersections by accidents and conflicts.

8. OUTLOOK ON THE TRAFFIC CONFLICT TECHNIQUE

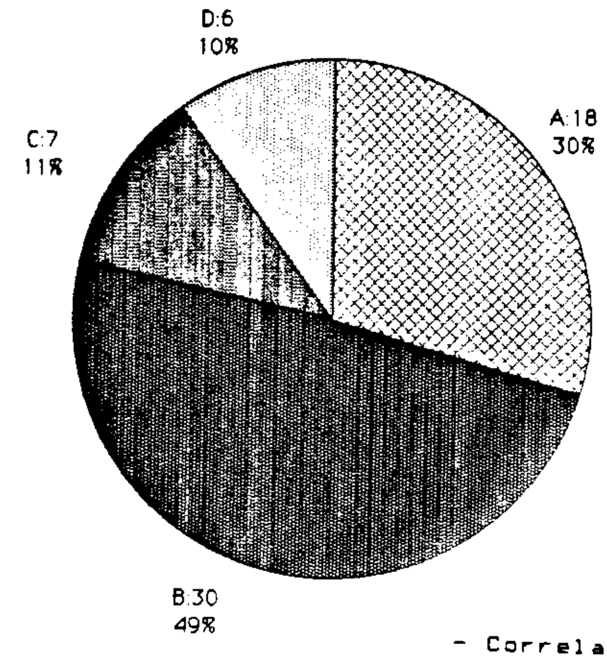
The results of this study indicate that there is a strong and significant relationship between conflicts and accidents where they are classified by the types of movement, with a traffic conflict threshold of 3-2 (1.5 seconds and moderate risk). This illustrates the potential for using traffic conflict counts as a means of evaluating the safety of an intersection -provided that the number of reported accidents is an accurate measure of safety. This type of disaggregation may also be useful to start the development of predictive models of accidents. The results here point to the general usefulness of full scaled studies using data disaggregated by movement type for diagnosis and evaluation of intersection problems.

Three meaningful applications of the traffic conflict technique can be infered from the results of this study. They are:

1. before and after studies to evaluate intersection safety;
2. ranking intersection according to safety;
3. diagnosing critical movement types within an intersection.

The most useful application of the technique is before and after studies to evaluate intersection safety. Current evaluation procedures require a record of accident history which may take many years to accumulate sufficient data. The effect of any changes made to an intersection cannot, therefore, be quickly evaluated. Traffic conflict observation provides an alternative that can be performed shortly after the implementation of changes (until stability is reached) to the intersection. Thus, the effect of any changes can be evaluated quickly.

Conflicts



- Correlation Coefficient = 0.95
- f - Statistic =17.00
- Level of Confidence [f] = 0.95
- Spearman Rank Correlation Coefficient = 0.80
- Level of Confidence [SR] = 0.80

Accidents

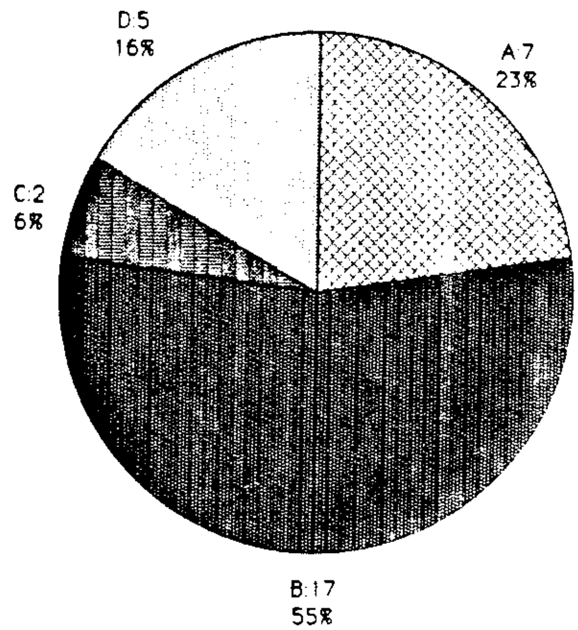
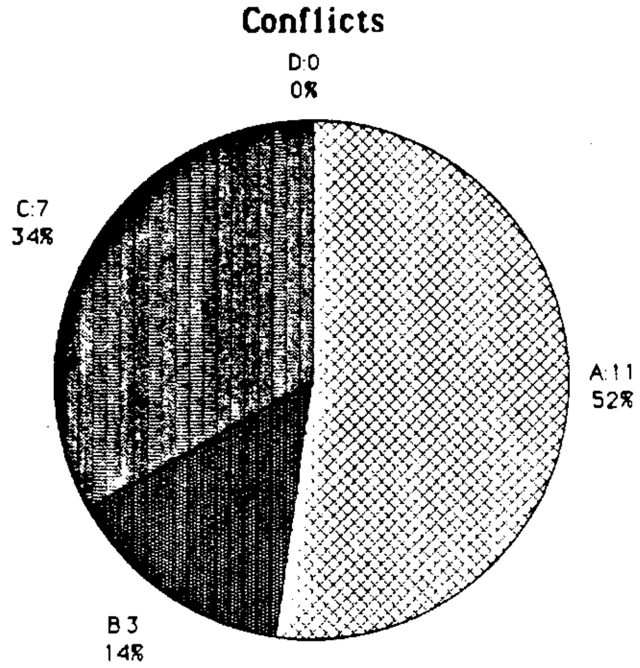


Figure 3.2 (a): Pie-Charts illustrating Conflicts and Accidents by intersection for conflict type LTO.



- Correlation Coefficient = 0.93
- f - Statistic =12.27
- Level of Confidence [f] = 0.93
- Spearman Rank
  Correlation Coefficient = 0.95
- Level of Confidence [SR] = 0.90

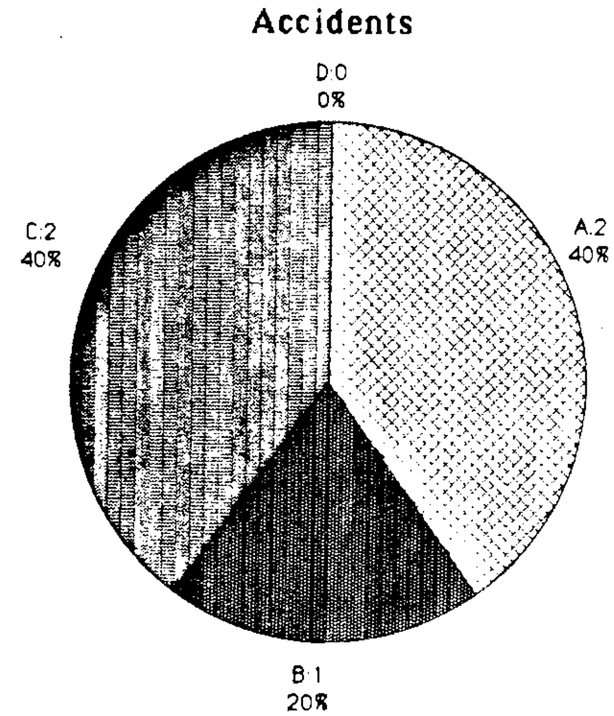
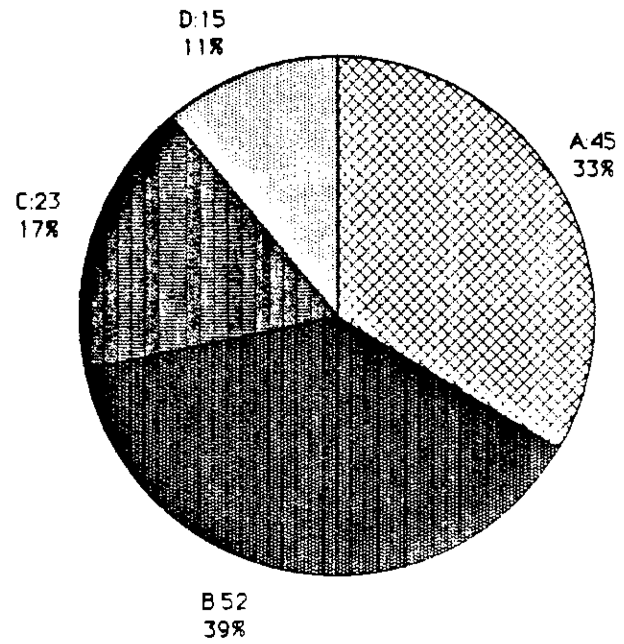


Figure 3.2 (b): Pie-Charts illustrating Conflicts and Accidents by intersection for conflict type RT.

Conflicts



- Correlation Coefficient = 0.73
- f - Statistic = 2.32
- Level of Confidence [f] = 0.73
- Spearman Rank
  Correlation Coefficient = 0.80
- Level of Confidence [SR] = 0.80

Accidents

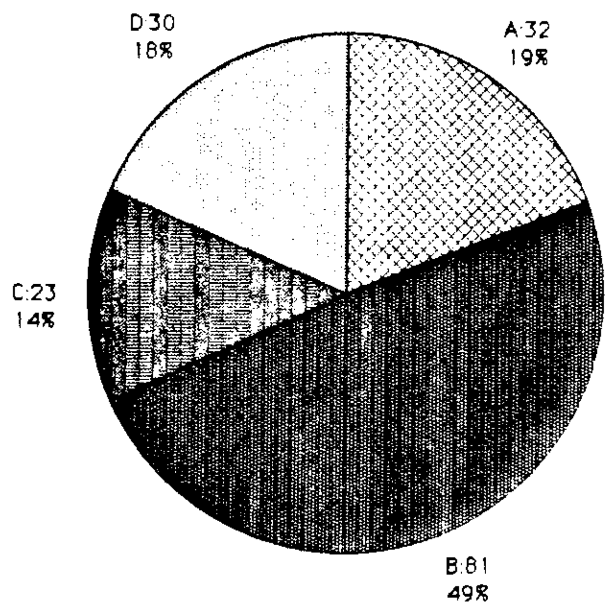
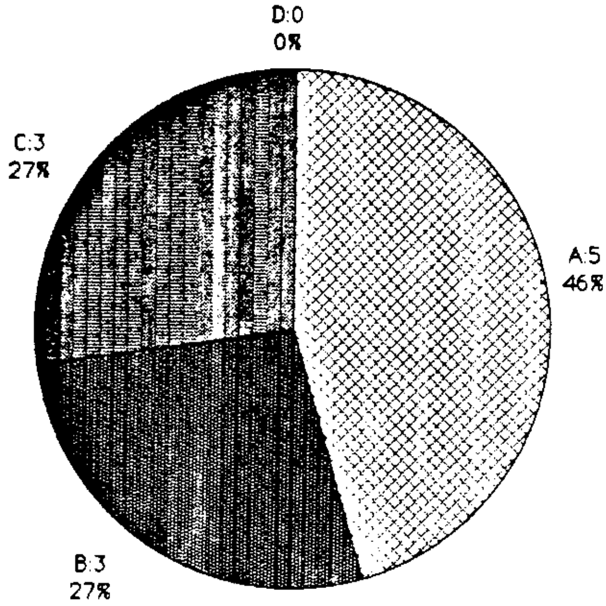


Figure 3.2 (c): Pie-Charts illustrating Conflicts and Accidents by intersection for conflict type C.

Conflicts



- Correlation Coefficient = 0.00
- f - Statistic = 0.00
- Level of Confidence [f] = 0.00
- Spearman Rank
  Correlation Coefficient = 0.00
- Level of Confidence [SR] = 0.00

Accidents

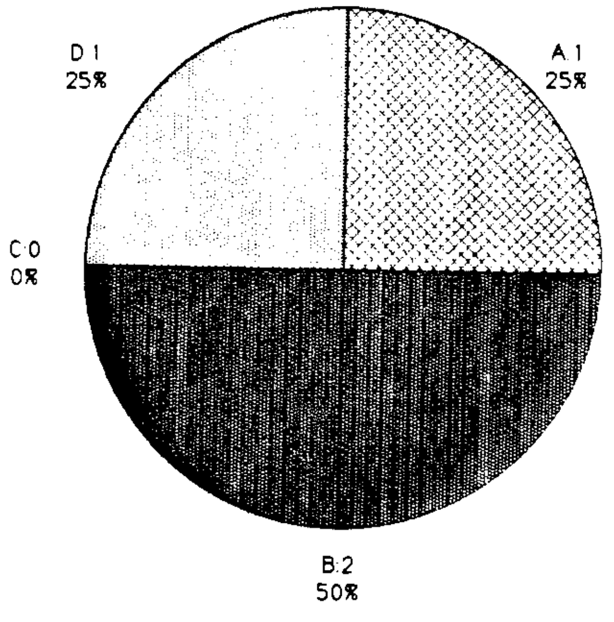
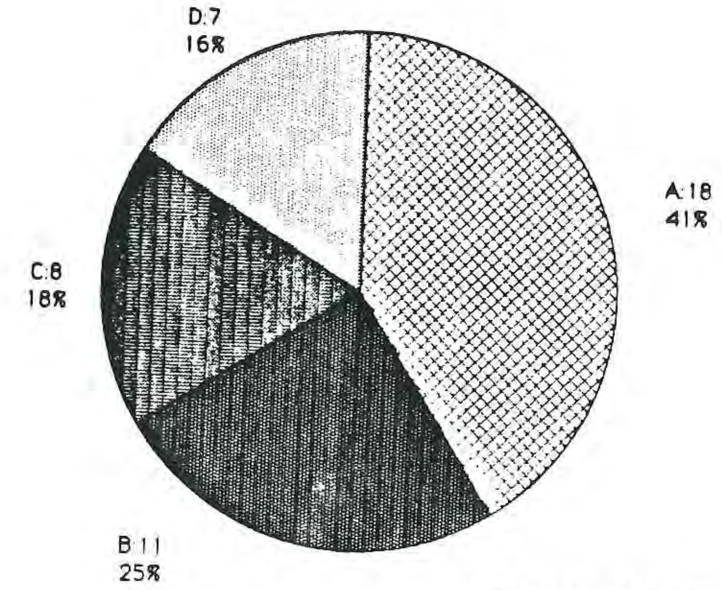


Figure 3.2 (d): Pie-Charts illustrating Conflicts and Accidents by intersection for conflict type W.

Conflicts



- Correlation Coefficient = 0.97
- f - Statistic =28.33
- Level of Confidence [f] = 0.97
- Spearman Rank
  Correlation Coefficient = 1.00
- Level of Confidence [SR] = 0.95

Accidents

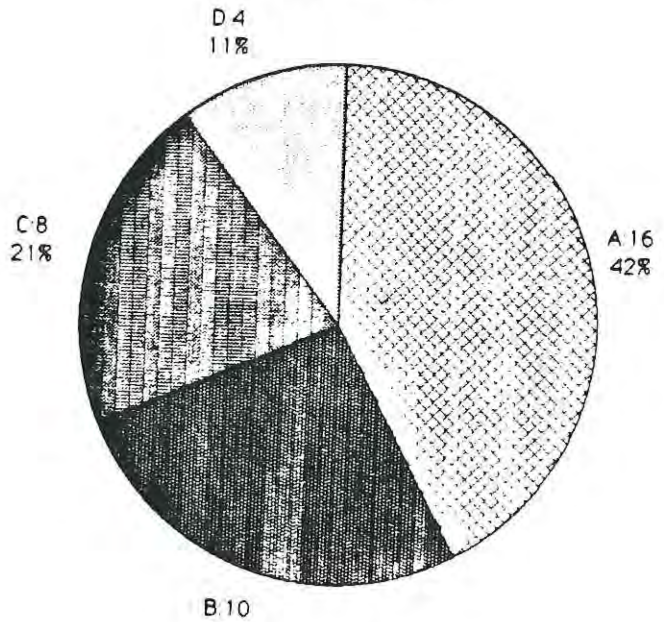
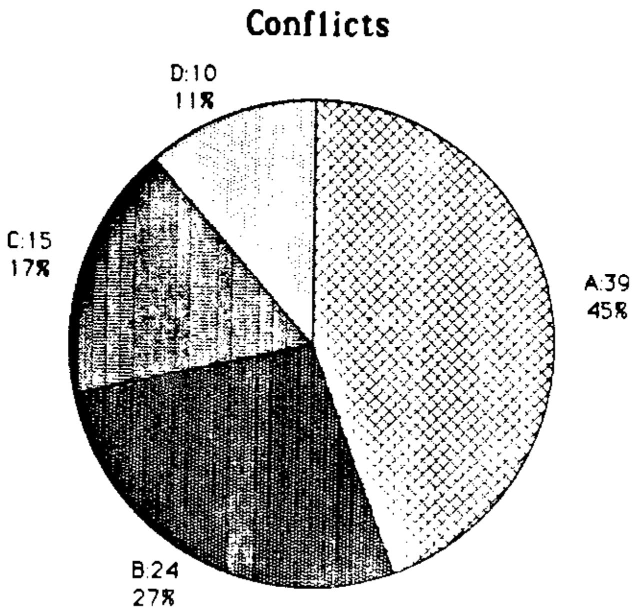


Figure 3.2 (e): Pie-Charts illustrating Conflicts and Accidents by intersection for conflict type RE.



- Correlation Coefficient = 0.57
- f - Statistic = 0.96
- Level of Confidence [f] = 0.57
- Spearman Rank
  Correlation Coefficient = 0.80
- Level of Confidence [SR] = 0.80

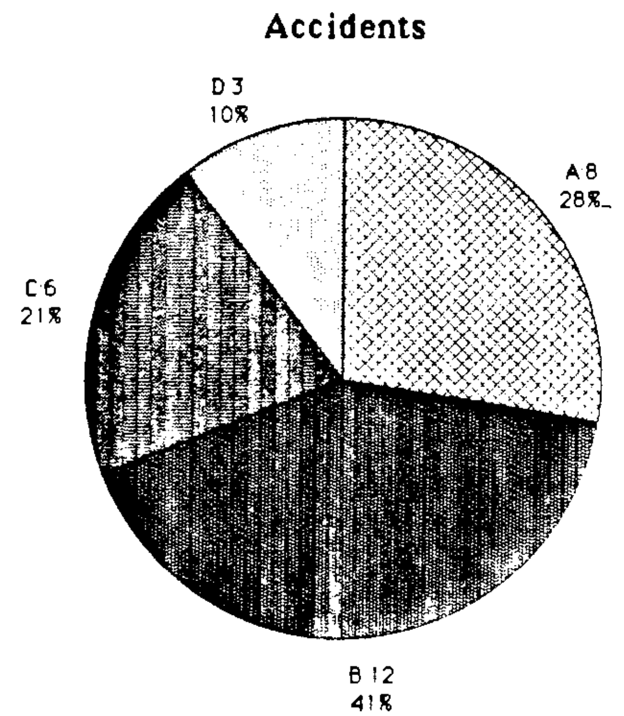
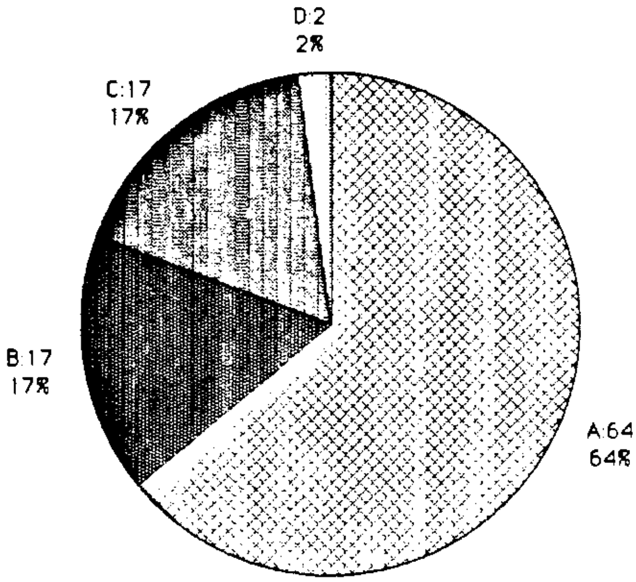


Figure 3.2 (f): Pie-Charts illustrating Conflicts and Accidents by intersection for conflict type LTC.

Conflicts



- Correlation Coefficient = 0.98
- f - Statistic =44.26
- Level of Confidence [f] = 0.98
- Spearman Rank
  Correlation Coefficient = 1.00
- Level of Confidence [SR] = 0.95

Accidents

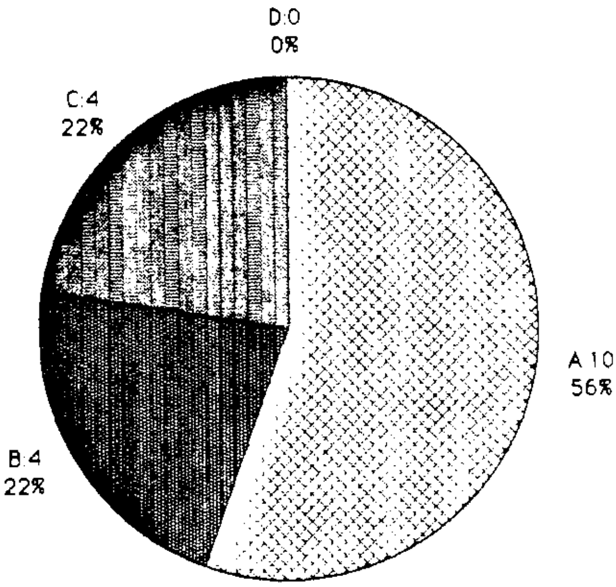


Figure 3.2 (g): Pie-Charts illustrating Conflicts and Accidents by intersection for conflict type P.

APPENDIX

Another useful application of the technique is for ranking intersections for improvement according to their traffic conflict count (safety). Any recent changes to the intersection or to the traffic can be taken into account and a more up-to-date rank order can be determined.

The third useful application of the technique is for diagnosing the highest risk movements at an intersection. The results of a traffic conflict count can provide guidance to the traffic engineer in the selection of improvement strategies for an intersection. This technique falls short of prescribing the actual improvement strategies, however, which should always be a task that requires professional judgement.

It should be noted that the results of this study support the conclusion that there is a significant correlation between conflicts and accidents for the seven general types of movement described. The correlation between conflicts and accidents for a secific maneuver (as shown in Figures 2.1 to 2.4) cannot be determined because of insufficient data within individual cells.

Appendix A-

PROCEDURES MANUAL FOR TRAFFIC CONFLICT OBSERVERS

1. Definition :

A traffic conflict situation is an event involving two or more road users in which the unusual action of one of them places the other(s) in danger of a collision unless an evasive maneuver is taken.

Traffic conflicts do not include vehicle action that result from obeying a traffic control device. For a situation to be considered a conflict, the time difference between the first observable reaction of the right of way vehicle being conflicted with and the moment when that vehicle would have reached the potential collision point had it continued with unchanging speed and/or direction has to be less than or equal to a certain threshold. For urban areas, 1.5 seconds is a critical value. The conflict recording forms, however, allow conflicts with greater TTC'S to be recorded.

2. Classification :

The conflicts are classified according to the following criteria:

(a) Time to Collision (TTC):

1. from 3 to 2 seconds
2. from 2 to 1.5 seconds
3. from 1.5 to 1 second
4. from 1 to 0 seconds

Although the TTC threshold is 1.5 seconds, the classification goes up to three seconds. This enables recording of conflicts that involve significant risk of collision and TTC above the threshold, usually due to high speeds or other atypical factors.

(b) Proximity of Vehicles at End of Evasive Action:

1. greater than two average car length
2. between one and two car length
3. less than one car length
4. collision

The classification according to the proximity of vehicles is useful for some types of conflict where it is difficult to evaluate accurately the time to collision, like conflicts involving pedestrians or conflicts where both vehicles travel in the same direction.

4. Observation Procedures:

```
        A    *-----[1]-----*
        a    *-------------*
30-50 m !    *-------------*
        !    *-------------*
        V    *-------------*
  **********-------------***********
  --------------------*..............
  [3]--------------*...............[4]  minor approach
  -------------*.......................
  **********.............************
             *.............*   a
             *.............*   ! 30-50 m
             *.............*   !
             *.............*   V          major approach
             *.....[2].....*   B
```

For simple intersections - e.g. the intersection of two two-lane roads or a four-lane and a two-lane - the data can normally be collected by two observers (A and B) stationed on the main opposing legs at a distance between 30 and 50 m from the intersection (depending on site lines, obstructions etc., as shown on diagram above).

Observer A records all conflicts which occur on legs 1 and 3 up to the middle of the intersection (pattern "-" on diagram) while observer B does the same for legs 2 and 4 (pattern "."). Overlaps will possibly occur and the same conflict will occasionally be recorded twice, but this can be sorted out during the data reduction process. The diagrams on the following page show which conflicts are which observer's responsibility but the governing rule should always be: when in doubt, record it. Whenever one observer records a conflict that is not strictly within his boundaries, he should make a note on the form indicating the possibility of double recording. More important than the proximity of the observer is the capability of seeing the brake the braking lights, good indicators of the evasive action taken.

With complex locations, such as the intersection of a six-lane road with a four-lane, for example, the volume of traffic and variety of possible conflict situations will usually require four observers, one for each intersection leg. The procedure would be similar to that described above, however, the potential for multiple counting would be somewhat increased.

The total length of count time for a particular location can vary depending on the traffic volume which governs the time-rate of conflict occurrence. In any event, however, it should encompass both peak and off-peak traffic conditions (unless, of course, there are suspected problems associated with specific short time periods to which it is desired to restrict the study).

(c) Evasive Action Type and Severity:

Type	Severity
1. Braking	1. Light
2. Swerving	2. Moderate
3. Accelerating	3. Heavy
4. Combination	4. Emergency

(d) Estimated Risk of Collision:

1. small
2. moderate
3. high
4. very high

This is a subjective classification. It is useful for analysis, as a consistency indicator. For most conflicts, there is a strong relation between the estimated risk of collision and the severity of the evasive action.

3. Types of Conflict :

The conflicts observed are divided into seven different groups, according to the type of movement involved:

1. LTO............Left Turn with Opposing Traffic
2. RT.............Right Turn
3. C..............Crossing
4. W..............Weave
5. RE.............Rear End
6. LTC............Left Turn with Crossing Traffic
7. P..............Pedestrians

5. Filling out the Forms :

Before starting the observation, it is useful to choose references (light poles, signs, lane dividers etc.) and measure the time vehicles take from the references to the beginning and end of the intersection. This procedure enables the observer to evaluate the TTC based on the position of the conflicted vehicle at the beginning and end of the conflict rather than using the chronometer for each conflict.

A good sequence to fill up the forms is:

1. Record the time
2. Sketch the conflict situation
3. Record the TTC, based on the reference points chosen before
4. Record the distance between vehicles (for types P, W and RE)
5. Record type and severity of evasive action
6. Estimate the risk of collision
7. Make the comments, if any.

It is useful to copy on the bottom right corner the TTC and risk of collision scale. This significantly eases reduction of data later. It is also useful to fill out the general data (names of streets, north, conflict number, observer name etc.) before actually recording the conflict.

Figure A-1 Observation Form

CONFLICT RECORDING FORM

Observer	Date	Number	Time

City/Municipality ____________________

Location ____________________

speed limit (kph) ______

north

Weather: sunny ☐ cloudy ☐ rain ☐ snow ☐

Surface: dry ☐ wet ☐ icy ☐

Time Interval 08-10 ☐ 10-12 ☐ 12-14 ☐ 14-16 ☐ 16-18 ☐ other ☐

Road User Type	Road User 1	Road User 2	Secondary Involved
car/light truck	☐	☐	☐
heavy truck/bus	☐	☐	☐
motorcycle	☐	☐	☐
bicycle	☐	☐	☐
pedestrian	☐	☐	☐
	age ___	age ___	age ___
est. speed (kph)	___	___	___

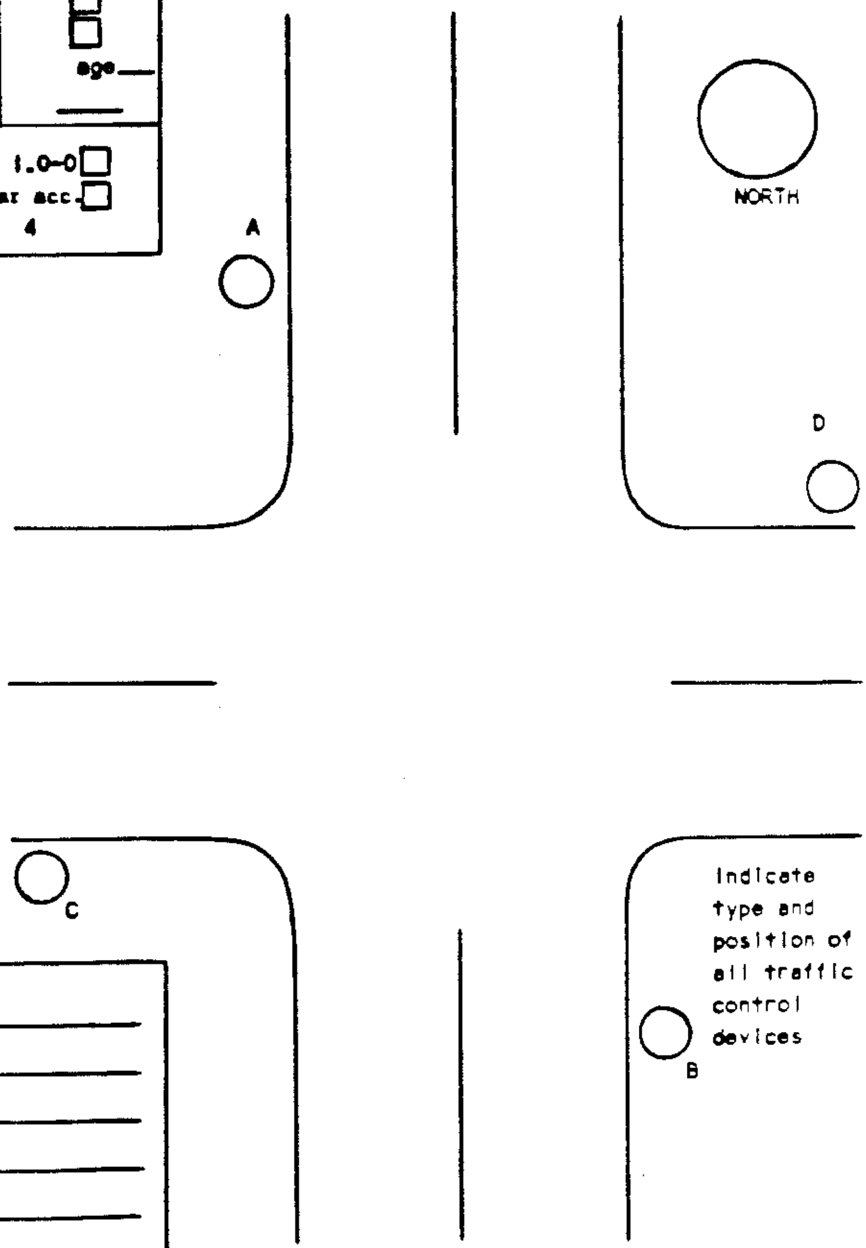
minimum TTC 3-2.1 ☐ 2.0-1.6 ☐ 1.5-1.0 ☐ 1.0-0 ☐

proximity >2 cars ☐ 1-2 cars ☐ <1 car ☐ near acc. ☐

1 2 3 4

Sketch actions of road users involved and mark observer position

conflict type LTO ☐ RT ☐ C ☐ P ☐ W ☐ RE ☐ LTC ☐



Indicate type and position of all traffic control devices

Evasive Action Type and Severity

	light	mod.	heavy	emerg.
braking	1 ☐	2 ☐	3 ☐	4 ☐
swerving	1 ☐	2 ☐	3 ☐	4 ☐
accelerating	1 ☐	2 ☐	3 ☐	4 ☐
combination	1 ☐	2 ☐	3 ☐	4 ☐

Estimated Risk of Collision

small 1 ☐
mod. 2 ☐
high 3 ☐
very high 4 ☐

Written Comments/Description

____

____________________ (continue on back if necessary)

car/light truck/van
heavy truck/bus
motorcycle/bicycle
pedestrian

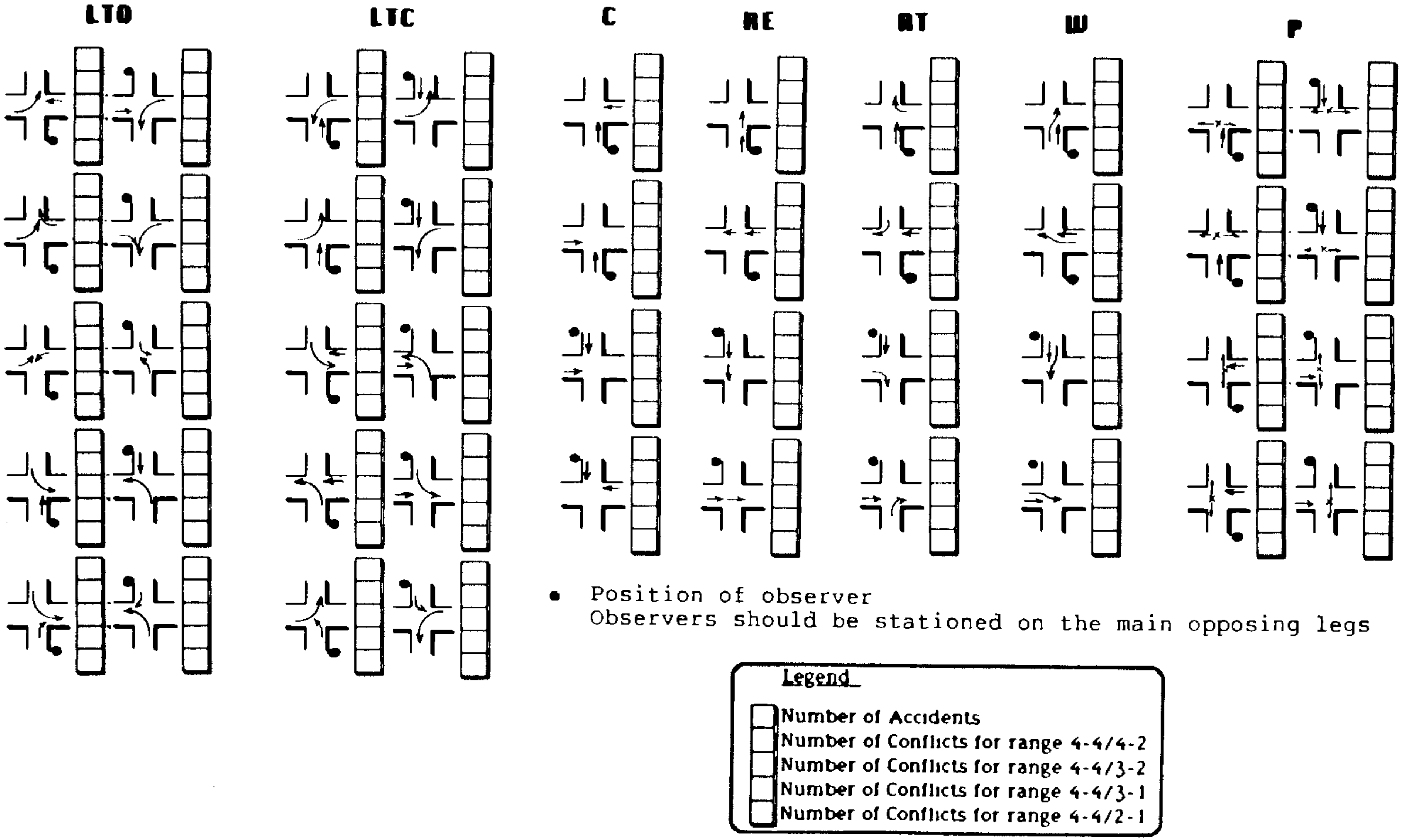


Figure A-2 Stationing of Observers

References:

1. Asmussen E., ed., "International Calibration Study of Traffic Conflict Techniques", NATO ASI Series, New York, 1984.

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