1210

TRANSPORTATION RESEARCH RECORD

Safety Issues

Pedestrians, Law Enforcement, Seat Belts, Elderly Drivers, and Economics

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Transportation Research Record 1191

page 130

Figure 14 was printed incorrectly. The correct Figure 14 is given below.

page 131

Figure 15 was printed incorrectly. The correct Figure 15 is given below.

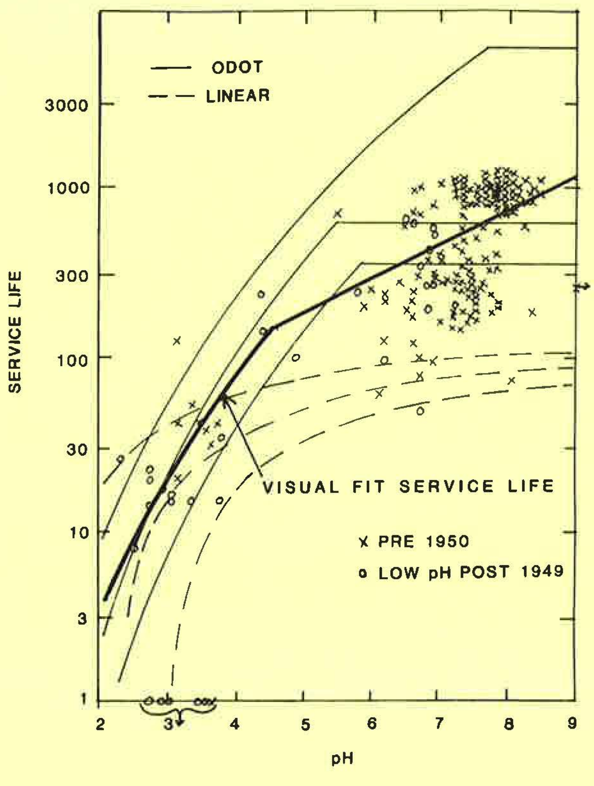

FIGURE 14 Linear projected visual fit service life for inspected culverts.

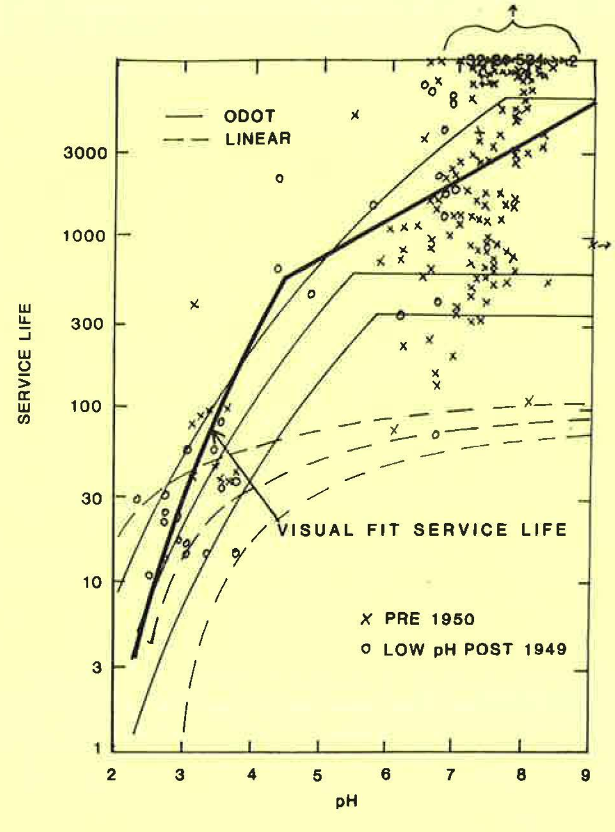

FIGURE 15 Log-linear projected visual fit service life for inspected culverts.

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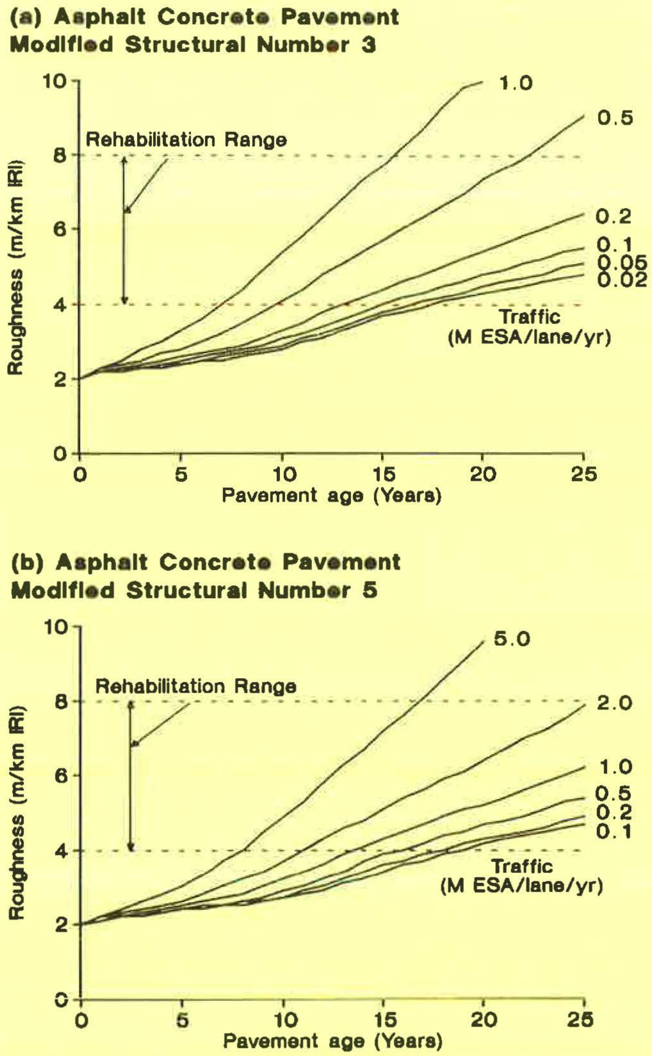
page 12

Change item (c) in the abstract to "(c) the overwhelming majority of children involved in accidents were unaccompanied. . . ."

Transportation Research Record 1215

page 80

Replace Figure 5 with the following:



Note: Maintenance comprised patching of all potholes in the year in which they appeared.
Source: Equation (3) applied through Road Deterioration and Maintenance Submodel of HDM-III.

FIGURE 5 Roughness progression prediction curves for a maintenance policy of patching all potholes.

Transportation Research Record 1231

See the attachment to these errata.

Transportation Research Circular 352

Pages 5 and 6 are reversed.

NCHRP Report 311

page 17, second complete paragraph, last sentence
Insert "below" after "15 dB."

page 20

Figure 8(a) shows only one road (interrupted flow); Figure 8(b) shows two roads (interrupted plus cruise).

page 25

Figure 18(a) is for two roads (both interrupted); Figure 18(b) is for four roads (two interrupted, two cruise).

page 32, Table 7

Table is incorrect; substitute values from Table C–5 on page 88 for those published in Table 7.

In the second footnote, add "(or the end of the queue for unsignalized intersections)" after "point of stop."

page 87, Table C-4

Add "Multiplier" after "AZOI" in the heading of the third column.

page 88, Table C-5

In the second footnote, add "(or the end of the queue for unsignalized intersections)" after "point of stop."

page 88, Table C-6

Change the MT speed for ZOI(2) for the 0 to 55 mph case (sixth row, ninth column) from 40 to 49.

NCHRP Report 325

pages 52 and 53

Tables are reversed (table headings are correct). Material noted under Table 25.3.1A heading (page 52) for *natural rubber* should be Table 25.3.1B (*neoprene*), and material provided under Table 25.3.1B heading (page 53) should be Table 25.3.1A.

Attachment

Transportation Research Record 1231

The third discussion of the paper by Potter and Ulery was omitted. The discussion appears below.

DISCUSSION

JOHN O. HURD
Ohio Department of Transportation,
25 South Front St., Columbus, Ohio 43215.

I commend the author for providing heretofore unpublished information on the structural performance of corrugated steel pipe and reinforced concrete pipe subjected to large vehicle live loads. However, additional elaboration on the structural performance and failure modes of corrugated steel pipe and reinforced concrete pipe is required for the reader to fully benefit from the information provided. The elaboration is given here.

The author cites only deflection as a failure mode for corrugated steel pipe. Because it was not clearly indicated, the reader must assume that the measured deflections were due to elliptical deformation, as in accepted deflection theory (*1*). This failure mode methodology would not be applicable if deformation were not elliptical. Deflection is actually but one of four failure modes that must be checked (*2,3*). The others are wall crushing, buckling, and seam failure.

For thin-walled, small-diameter pipes with well-compacted select side fill, seam strength is of much greater concern than deflection (*4*). Because no measurements of strains or stresses in the wall around the seams were reported, the reader cannot know what factor of safety existed for seam failure. The reader cannot assume that the large factor of safety against failure implied by the measured deflections is the factor of safety against failure in some other failure mode that might be governing.

If seam failure was not imminent, it appears that the test installation covers are reasonable minimums for properly installed corrugated steel pipe for the loading condition. This assumes that the reported roadway surface condition measured above the pipe is acceptable to the users of the facility.

The author cites cracking as the accepted criterion for failure of reinforced concrete pipe. This criterion is only for testing—not performance. In reinforced concrete structure design it is not intended that the concrete carry tension loads. This is the requirement of the reinforcing steel (*5*). In the case of reinforced concrete pipe, failure might occur when the reinforcing steel can no longer withstand the tensile stresses created by bending moments in the pipe wall. A hairline crack in the pipe wall indicates that the tensile stresses have surpassed the tensile strength of the concrete and that the steel is carrying all of the tensile load. The rather wide 0.01-in. crack used to define reinforced concrete pipe strength in the three-edge bearing test occurs at much less than the ultimate load-carrying capacity of the pipe in both the test and in service. The Ohio Department of Transportation requires that the ultimate strength of Class IV reinforced concrete pipe in the test be at least 1.5 times the load that produces the 0.01-in. crack (*6*). Cracks much larger than 0.01 in. can occur before a reinforced concrete structure is judged to have failed (*7*).

In the paper, it was reported that a "barely visible" crack was observed in the 18-in. concrete pipe and that "hairline" cracks were observed in the 24-in. concrete pipe. However, it does not appear that the actual widths of the cracks were measured or estimated or that measurements of reinforcing steel strains were taken. No attempt was made to correlate the loads at crack inception, and subsequently larger cracks, with the ultimate load-carrying capacity of the pipe during laboratory tests. Therefore, the reader cannot know how close the field-tested reinforced concrete pipes were to actual "failure." Based on the description of cracks given in the report, it appears that the pipes were loaded to less than one-half the load to cause failure.

Placing pipes on a flat bedding, as done in this study, is not recommended for either corrugated steel pipe or reinforced concrete pipe (*8,9*). However, because of the bending moment induced failure mode of reinforced concrete pipe, the use of this type of bedding has a more severe effect on the structural performance of that material. The concrete pipe design bedding factor for a flat bedding is 1.1, whereas that for the recommended shaped bedding is 1.9. The use of a flat bedding reduces the load-carrying capacity of the concrete pipe to 58 percent of that of a properly bedded pipe.

Based on these observations, I can see no justification for the minimum cover for properly installed reinforced concrete pipe to be increased (as recommended by Table 5) to greater than the test installation covers for the loading condition.

Considering the installation methods, the reported condition of the roadway surface, and the pipes, both types of pipe material appear to have performed acceptably.

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Contents

Pedestrian/Vehicle Conflicts: An Accident Prediction Model

Scott E. Davis, H. Douglas Robertson and L. Ellis King

Traffic conflicts have been used to define the potential for traffic accidents. However, conflicts defined by vehicle and pedestrian interactions have not produced reliable techniques to explain pedestrian/vehicle accidents. This study was conducted to determine the relationship between pedestrian/vehicle conflicts and accidents in order to develop a reliable model to predict the occurrence of pedestrian accidents. Accident group models were developed using discriminate analysis for the cities of Washington, D.C., and Seattle. Along with counting the conflicts that were used to define these accident groups, exposure measures such as pedestrian volume, vehicle volume, number of lanes, and type of traffic control aided in the explanation of pedestrian accident variance. Further research was recommended to investigate refined variable definitions along with the use of a larger accident data base.

Traffic conflicts have been used as a measure of the potential for traffic accidents. A traffic conflict occurs when a driver has to take some evasive action, that is, a change in direction, speed, or both, in order to avoid a collision. Several studies (*1–3*) have been conducted to determine the relationship between traffic accidents (vehicle/vehicle and vehicle/fixed object) and conflicts and to develop conflict analysis techniques. However, very little research has been conducted to establish a relationship between pedestrian/vehicle conflicts and accidents. Because of this lack of research, reliable pedestrian/vehicle conflict analysis techniques have not yet been developed.

In recent studies (*4, 5*), the concept of "exposure to risk" has been used to define possible hazards to the pedestrian. Still, relating conflicts to accidents in order to define exposure to risk has not yet produced adequate and sensitive analysis techniques or methods. Along with the lack of research in this area is the difficulty of defining conflict measures that would provide accurate indicators of potential accidents. With well-defined conflict measures, it may be possible to establish a relationship between pedestrian/vehicle conflicts and accidents. Then the ability to identify or predict sites where pedestrian accidents would occur would allow preemptive actions to be taken to avoid these types of accidents. In 1985, the Federal Highway Administration sponsored a study to investigate this relationship (*6*).

The objectives of this study were to synthesize existing information on pedestrian/vehicle conflicts, determine the relationship of pedestrian-related conflicts to pedestrian accidents, and develop methods to obtain reliable pedestrian conflict data.

The study was concerned with a thorough examination of the various methods and techniques of measuring vehicle/pedestrian conflicts. Traffic conflict techniques were identified and evaluated in terms of their potential usefulness in defining and developing pedestrian/vehicle conflicts; data requirements; data collection procedures; cost-effectiveness; uses of data; and other evaluation criteria such as accuracy of data, ease of data collection, and feasibility of methodology. In addition, behavioral and exposure measures were investigated in terms of their usefulness in defining pedestrian/vehicle conflicts and developing accident-potential criteria, respectively.

A literature review was conducted to identify methods of measuring vehicle and pedestrian conflicts. The literature search concentrated on locating and reviewing studies that involved the use of the following:

- Traffic conflict techniques,
- Pedestrian/vehicle conflicts,
- Risk and exposure, and
- Accident-conflict relationships.

RESEARCH METHODOLOGY

Most studies from the literature review dealt with vehicle/vehicle conflicts and accidents. Some studies considered the pedestrian/vehicle conflict only as a vehicle hindrance whereas others acknowledged it only in passing. In contrast, this study's primary objective was to examine pedestrian/vehicle conflicts.

The pedestrian conflict measures used by Robertson et al. (*7*) and Zegeer et al. (*8*) primarily dealt with pedestrian behaviors. Conflict-behavior measures were used in before-and-after-type studies to determine pedestrian behavior responses to different pedestrian signalization alternatives. Therefore, their research objectives did not address the accident prediction problem.

Cynecki (*9*), on the other hand, used his pedestrian/vehicle conflict measures as accident-potential indicators. He used conflicts to determine specific locations within an intersection that presented hazards to the pedestrian. In a sense, Cynecki had an objective similar to this study but one more narrowly focused.

Exposure measures have been used to define high-risk locations for pedestrians. Exposure was seen by Cameron et al. (*5*) as the product of pedestrian volume (*P*) and vehicle vol-

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ume (V), $P \times V$. They stated that pedestrian accident risk cannot occur where both pedestrian and vehicle volumes do not exist. Robertson (*10*) used a $P \times V$ exposure measure but added turning volume (T). The introduction of turning volumes, as explained by Mackie and Older (*4*), into a $P \times V$ exposure strengthens the accident-exposure measure relationship.

Pedestrian and vehicle violations were used in the studies of Cynecki (*9*) and Zegeer et al. (*8*). Cynecki used both violations as conflict measures (violations that produced conflicts) whereas Zegeer et al. recorded only pedestrian violations. Neither study discussed risk or the accident-violation relationship.

The first approach of this study was to investigate the pedestrian/vehicle conflict-accident relationship in two cities. Some of the studies (*7, 9*) described in the state-of-the-practice used several states or cities to produce their data bases. The purpose of using several states or cities probably was to increase accident variation and total number of accidents since pedestrian accidents are rare occurrences. However, the use of this type of data did not consider differences that may exist in each state or city between pedestrian and vehicle (driver) behaviors, patterns, volume variations, controls, and laws. This study recognized those differences. Some cities may be highly urbanized, resulting in a relatively greater number of pedestrian and vehicle volumes, violations, and conflicts. In cities that are less densely populated, volumes, violations, and conflicts may be lower. An intersection in either type city may experience one accident in 3 years but under quite different environments.

The second approach was to consider stratified accident data. The poor correlations found in past research between pedestrian/vehicle or vehicle/vehicle conflicts and accidents may be attributed to the lack of accident variation. Stratified or grouped accident data ensure the user of obtaining a broader range of accidents, thus optimizing accident variation. However, as shown in Figure 1, the use of stratified accident data in the analysis of individual accidents versus their respective data eliminates the use of common parametric analysis techniques. The accidents of this study are considered to be grouped ordinal data, and techniques such as Pearson correlations and regression could not be used since both require nominal data.

Keeping in mind the accident data base characteristics that were possible, alternative analysis techniques for handling these types of data were considered. Thus, stratifying the accident data allowed for pre-examination of applicable analysis techniques.

DATA COLLECTION

The data collection effort consisted of three parts: (a) a trial field test, (b) the collection of pedestrian/vehicle conflict data, and (c) the collection of accident data. Each part is discussed below in terms of measures of effectiveness, site selection, sampling plan, and data collection procedures.

Trial Field Test

A sample of pedestrians crossing at three intersections in Washington, D.C., was recorded on videotape during the morning, midday, and afternoon peak hours. Key members of the research team viewed the tape together and collectively evaluated the occurrence of nine conflict measures used in previous studies (*6*). On the basis of this evaluation and input from a Technical Advisory Panel, three of the nine conflict measures were modified and selected for use as measures of effectiveness in the field data collection effort. The conflicts are listed in Table 1.

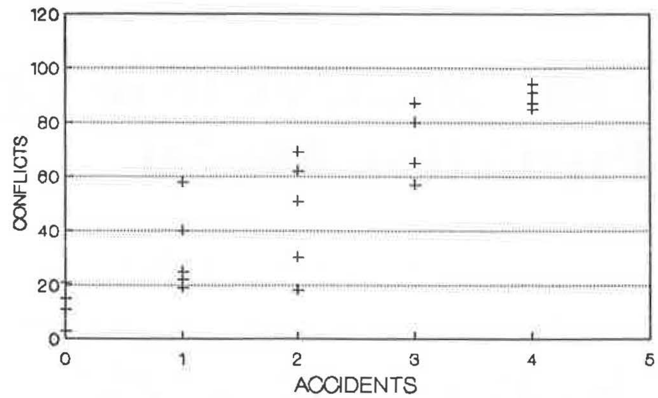

FIGURE 1 Example of grouped accident data.

Collection of Pedestrian/Vehicle Conflict Data

The primary goal of this study was to determine if a relationship exists between pedestrian/vehicle conflicts and accidents. This determination was made through the analysis of empirical and historical data. The historical data were gathered from city agencies involved with traffic and highway programs and the empirical data were collected on site by trained observers during data collection periods.

Intersection characteristic data were obtained for the total population of four approach intersections (signalized and unsignalized) in Washington, D.C., and Seattle. Data on pedestrian and traffic volumes were also obtained for these intersections. A sample of intersections was drawn from the population in accordance with the sampling plan described below. The volumes at the sampled intersections were checked to ensure that there was both pedestrian and vehicle activity present. Each site in the sample was visited and checked to ensure that no unique or unusual characteristics existed that could bias the test results.

The intersections samples were stratified with respect to type of control and pedestrian accident frequency. Noting that several past studies have shown some relationship between pedestrian accidents and volume, the sample was not stratified by pedestrian or vehicle volume in order to avoid a possible duplicate control.

The procedure used to stratify the population was as follows:

1. All intersections in the population were divided into three groups (high, medium, low) on the basis of pedestrian accident frequency, where

High = 3 or more pedestrian accidents in 3 years,
Medium = 1 to 2 pedestrian accidents in 3 years, and
Low = 0 pedestrian accidents in 3 years.

TABLE 1 PEDESTRIAN/VEHICLE CONFLICTS SELECTED FOR FIELD DATA COLLECTION

Code	Definitions
(TV)	Through Vehicle Conflict - Where the projected paths of a through vehicle and a pedestrian cross and either the pedestrian or the vehicle or both must change direction and/or speed to avoid a collision.
(RT)	Right-Turn Vehicle Conflict - Where the projected paths of a right-turning vehicle and a pedestrian cross and either the pedestrian or the vehicle or both must change direction and/or speed to avoid a collision.
(LT)	Left-Turn Vehicle Conflict - Where the projected paths of a left-turning vehicle and a pedestrian cross and either the pedestrian or the vehicle or both must change direction and/or speed to avoid a collision.

2. Each accident group was subdivided into two subgroups with respect to type of control, that is, signalized or unsignalized.
3. From each of the 6 sub-subgroups, 48 intersections were drawn at random, 24 in each city.

In Seattle, 13 signalized and 11 unsignalized intersections were selected and in Washington, D.C., 16 and 8, respectively. A higher number of signalized intersections were chosen because of low-accident frequencies that existed in the nonsignalized intersection group.

Data were collected manually using field observers provided with push-button-type counting devices. Because accidents occur in all types of weather, no attempt was made to avoid poor weather conditions during scheduled data collection. The observers were positioned at a vantage point that offered a clear view of the crosswalk and approaches. For low- to moderate-volume intersections, one observer was used, whereas high-volume intersections required two observers operating as a team.

Each crosswalk (and approach) was observed for one signal cycle per 5 min at signalized intersections or for a 5-min period at unsignalized intersections. The data collected included conflicts, pedestrian and vehicle counts, and compliance. Thus, each approach was sampled at least three times during each data collection hour. At high-volume intersections, one observer coded conflicts and noncompliance, which included walking against the signal and vehicles running the red signal or stop sign, whereas the second observer counted pedestrians and vehicles. This procedure was similar to that used in previous studies where intercoder reliability was found to be high. Data were collected at each intersection on weekdays only for 6 hr per day from 7:00 a.m. to 9:00 a.m., 11:00 a.m. to 1:00 p.m. and 4:00 p.m. to 6:00 p.m. Approximately 2½ wk of data were collected for each city for three seasons (6 hr per season per site): spring (March, April), summer (July, August), and autumn (October, November).

Collection of Accident Data

Accident data served two purposes in this project. First, the data were used as a (stratification) criterion for site selection, and second, in conjunction with the conflict data to establish the relationship between conflict measures and accidents.

The primary measure was pedestrian accident frequency. A secondary measure was pedestrian accident rate. The calculation of rates required volume data, which were obtained either directly from the city if available, or computed from the counts made during field data collection. Pedestrian accident data were obtained from city department of transportation records at each site for a period of 3 yr before the start of data collection and continuing for the duration of data collection. Data elements of interest included type of accident, (i.e., object struck), time of day, day of week, month of year, and severity. There were approximately 50 to 60 pedestrian accidents in each city's data base.

DATA ANALYSIS

Different pedestrian and vehicle volume magnitudes and distributions exist between weekdays and weekends. Therefore, the conflict data were collected for weekdays only, and accidents that occurred on weekends were deleted from each intersection data base. In addition to removing weekend accidents, the accidents that occurred outside of the 6-hr data collection period were initially removed. Winter accidents that occurred in January and February were removed because the data collection effort encompassed spring, summer, and autumn months.

Tables 2 and 3 present 24-hr (7-day), 12-hr (7:00 a.m. to 7:00 p.m.), and 6-hr data collection period accident frequencies for each intersection in both cities. In reviewing the 6-hr accident variation, large groupings of 0- and 1-accident intersections were noted. Thus, to increase the number of accidents

TABLE 2 ACCIDENT FREQUENCIES FOR WASHINGTON, D.C.

Intersection	Accidents 24-hr.	12-hr.	6-hr.
14th & K, NW	10	8	7
8th & H, NE	10	5	5
14th & P, NW	7	4	4
Benning & Minnesota, NE	6	3	3
4th & Independence, SW	5	4	2
7th & Independence, SW	2	2	2
17th & H, NW	3	2	2
3rd & K, SE	3	1	1
8th & E, SE	2	1	1
17th & Pennsylvania, NW	1	1	1
Connecticut & Morrison, NW	1	1	1
12th & U, NW	3	1	1
Wisconsin & Warren, NW	2	1	1
15th & H, NW	1	1	1
18th & Massachusetts, NW	1	0	0
4th & E, SE	1	0	0
Garrison & Wisconsin, NW	0	0	0
3rd & C, SE	0	0	0
Ellicot & Connecticut, NW	0	0	0
1st & D, SE	0	0	0
13th & G, NW	0	0	0
17th & Constitution, NW	0	0	0
6th & Maryland, SW	0	0	0
5th & G, NW	0	0	0

TABLE 3 ACCIDENT FREQUENCIES FOR SEATTLE

Intersection	Accidents 24-hr.	12-hr.	6-hr.
NE University & 45th	7	4	3
S 1st & Lander	5	5	4
N 5th & Broad	5	1	1
E 18th & E Cherry	3	2	2
12th & E Spring	3	2	1
21st & E Cherry	3	1	1
Broadway & E Pike	2	2	2
9th & E Madison	2	2	1
S Rainier & Cloverdale	2	1	1
S 14th & Cloverdale	2	1	1
Fremont & N 35th	1	1	1
SW 26th & Roxbury	1	1	1
NE Brooklyn & 47th	1	1	1
S 12th & S King	1	1	1
NW 8th & Market	3	2	0
Western & Virginia	1	1	0
N Coaliss & 45th	2	1	0
W 2nd & Roy	1	0	0
W 34th & W Dravus	1	0	0
Western & E Spring	0	0	0
8th & NW 85th	0	0	0
3rd & NW 85th	0	0	0
NE Brooklyn & 40th	0	0	0
Olive Way & E Boren	0	0	0

and still have the 6-hr conflict data representative of the pedestrian/vehicle accidents, the 12-hr accidents for each intersection were used in the data analysis.

The conflict data included through, right-turn, and left-turn conflicts as defined in the data collection section; pedestrian and vehicle violations; pedestrian volumes; and left-turn, through, and right-turn vehicle volumes.

From the state-of-the-practice, two computed exposure measures were selected for use in the analysis: (a) the product of pedestrian volume and vehicle volume ($P \times V$) and (b) the pedestrian and vehicle volume product divided by percentage of vehicle turns ($P \times V/\%T$). These exposure measures were computed on the basis of sum of 1-hr products. These two measures, along with the additional data collected in this study, are presented in Tables 4 and 5. Conflicts, violations, and volumes are computed on the basis of 6-hr seasonal averages.

The cities of Washington, D.C., and Seattle were analyzed separately because of the differences in their accident frequencies, conflict occurrences, and pedestrian and vehicle volumes. In a comparison between the two cities' data bases, the intersections sampled in Seattle had fewer accidents and conflict events and lower volumes.

The analysis effort was directed toward group modeling because correlating the stratified accident data with the collected data would not have produced usable results.

Discriminate analysis was chosen because it models groups by use of discriminating variables. The groups that were used in this analysis were the three accident groups previously given in the data collection section. As for the discriminating variables, past research had to be investigated to aid in locating potential variables to be used in the modeling effort.

The state-of-the-practice study showed that conflicts have been used in defining potential pedestrian and vehicle accident sites and that exposure measures, such as pedestrian and vehicle volumes and distance or time traveled, have been used to define risk. Therefore, the variables collected or computed in this study for use in the modeling effort were total number of intersection approach lanes, pedestrian/vehicle conflicts, pedestrian volumes (P) and vehicle volumes (V), and the products of $P \times V$ and $P \times V/\%T$. In addition to these variables, type of traffic control and vehicle and pedestrian violations were also used.

Because both pedestrians and vehicles have to exist at the same time at a given location in order for a conflict or accident to occur, these two variables were entered into the modeling effort first. Table 6 was generated from the discriminate analysis procedure. The column labeled "Number" is the number of observations assigned to the expected group based on the equations derived in the discriminate analysis process. Using Group 1 (0-accident intersections) as an example, a total of 10 intersections belong to this group. From the equations based on pedestrian and vehicle volumes for each group, seven intersections fell into Group 1, one intersection fell into group 2, and two into group 3. Thus for the equations based on pedestrian and vehicle volumes, 70 percent of the intersections were placed into the appropriate Group 1. Overall, 15 of the 24 intersections (62.5 percent) were placed into the correct groups.

It was apparent that pedestrian and vehicle volumes explained a substantial amount of variation in Groups 1 and 3. However, these two variables did not aid in predicting Group 2 accidents. Another variable had to be selected that would help explain the variation in Group 2. The next variable entered was total conflicts.

For Group 3 in Table 7, the accuracy of the prediction was reduced from 80 to 60 percent with the addition of conflicts into the model. This type of occurrence is a result of the negative effect of conflicts in Group 3. When variables are added to the models (Groups 1, 2, and 3), the first inclination is that these variables will produce a positive effect, thus increasing the group model accuracy. However, this is not always the case because some variable values are found in more than one group. Therefore, one or two intersections in Group 3 were best defined (by conflicts) to reside in Groups 1 and 2 because conflict similarities of these intersections existed with the conflict counts of Groups 1 and 2.

The classification matrix for the variables of conflicts and pedestrian and vehicle volumes is given in Table 7. The addition of conflicts into the model aided both Groups 1 and 2 and the model improved its overall predictive accuracy from 62.5 percent to 70.8 percent.

The process of adding, deleting, and replacing variables continued until the best model was found. The final model classification and equations for Washington, D.C. are given in Tables 8 and 9. By introducing type of traffic control and pedestrian violations, the model produced the best accuracy, 83 percent.

To use the three-group model given in Table 7, substitute the respective raw data into each equation in Table 9. The largest value indicates the proper group classification. Discriminate equations *do not* predict actual accident frequency because the dependent variable coefficients are not slope values (as produced in regression modeling). In addition, the signs of the coefficients *do not* indicate the relationship (positive or negative) between the dependent variable and the accident group number. However, the coefficients define a variable's magnitude in describing its particular group.

From the analysis procedure, the best groupings for the Seattle data were produced using pedestrian and vehicle volumes, conflicts, and number of lanes. Refer to Table 10 and the following table, which gives equations for the model based on conflicts, number of lanes, and pedestrian and vehicle volumes for Seattle

Group 1: $G1 = 0.0943C + 0.0023P - 0.0047V + 1.6625L - 9.4869$

Group 2: $G2 = 0.0533C + 0.0058P - 0.0065V + 2.0950L - 14.0488$

Group 3: $G3 = 0.0675C + 0.0155P - 0.0058V + 2.4968L - 27.3187$

where

L = number of lanes.

Since Group 3 (3-accident or more intersections) for both Washington, D.C., and Seattle had a small number of observations, the reliability of the model's accuracy for this group was questioned. Thus, the next step in the modeling process investigated the use of two groups: Group 1 with zero accidents and Group 2 with one or more accidents.

The final two-group models developed by use of the three-

TABLE 4 PEDESTRIAN/VEHICLE DATA AND VARIABLES FOR WASHINGTON, D.C.

Intersection	Type of Control*	12-Hour Accidents	Number of Lanes	Conflicts TV	Conflicts RT	Conflicts LT	Conflicts Total	Pedestrian Violations	Vehicle Violations	Pedestrian Volumes	Vehicle Volumes L	Vehicle Volumes T	Vehicle Volumes R	Vehicle Volumes Total	P x V	P x V/%T	Group Number
4th & Indep.	1	4	28	1.666	48.33	9.333	59.3	46.3	24	778.3	113.3	2289	419.6	2822	361012.6	18965.54	3
4th & E St.	1	0	16	5.333	21.66	13.66	40.6	183.	72.6	508.6	188.6	599	138.3	926	80770.88	2295.245	1
1st & D St.	1	0	12	2	26	17.33	45.3	206	25.3	717.6	114	454.3	157	725.33	84210.66	2336.289	1
13th & G St.	1	0	20	11.66	109.3	71	192	219	93	2797.	232.6	1152	318.6	1703.3	798610.7	24446.89	1
5th & G St.	1	0	12	1.333	28.66	11.66	41.6	48	17.6	630	138	748.6	267	1153.6	117007.1	3312.970	1
17th & Const.	1	0	24	4	66.33	22.66	93	25.6	104.	556	104.3	3939	646	4689.3	421297.2	25175.60	1
6th & Md.	1	0	16	0.333	35.66	17	53	72.6	12	586	141.6	596	192.6	930.33	88060.22	2441.392	1
14th & K	1	8	28	6.333	133.3	43.33	183	220	257.	2114	358.3	2559.	337	3255	1132983.	53578.83	3
15th & H	1	1	12	12	175.6	57	244.	437.	133.	1938.	190.6	1470.	394.6	2055.6	642908.3	22430.32	2
18th & Mass.	1	0	12	7	62	26.33	95.3	102.	30.3	929	173.3	1729.	227	2130	332996.2	17704.58	1
Benning & MN	1	3	20	5	84	44	133	229.	107.	813.3	631	1840	502	2973	409770.5	10783.97	3
17th & H	1	2	20	13.33	235.6	88.66	337.	281	218.	2484	358.6	1672.	407.3	2438.6	1010272.	32615.17	2
8th & H St.	1	5	15	8.333	42	12	62.3	53	6.66	613.6	74.33	1690.	178.3	1943.3	200624.8	16389.11	3
7th & Indep.	1	2	28	7.333	111.3	54.33	173	82.3	227.	1207	330.3	2564.	521.3	3416	705366.7	28218.60	2
14th & P	1	4	18	2	15.33	7.666	25	31.3	19.6	374.6	150.6	1561	212	1923.6	121039.2	6500.976	3
17th & Penn.	1	1	24	19	189.3	39.33	247.	160.	126.	2385.	229.3	2773	562.6	3565	1407803.	63173.27	2
8th & E	0	1	12	8.666	5.666	6	20.3	112.	1	452.3	41.66	339	58	438.66	34450.44	1533.144	2
Garrison & WI	0	0	16	17.33	15.66	8.333	41.3	92.6	0.66	308.3	56.33	1134.	66	1256.6	65469.55	6830.590	1
CT & Morrison	0	1	16	15.33	9.666	5.333	30.3	13.6	8.33	263.6	48.33	1119.	67.33	1235.3	53346.66	6137.030	2
12th & U	0	1	12	19.66	7.333	0.666	27.6	7.66	1	167	17.66	432	32.33	482	14647.22	1545.013	2
CT & Ellicott	0	0	16	1.333	2	1.666	5	2	0.66	89	314.3	1355.	30	1700	26302.22	1376.892	1
WI & Warren	0	1	16	21.66	11.33	5.666	38.6	69	0.66	257	50	1248.	40.33	1338.6	56483.88	8578.183	2
3rd & K	0	1	8	3.333	3.666	2.333	9.33	28.6	2	129.3	15.33	147.3	27.66	190.33	4203.111	188.3855	2
3rd & C	0	0	8	5.666	5.666	5.666	17	46	8	271.3	87.66	192	102.6	382.33	17269.33	349.7424	1

* 1 - Signal Control

0 - Stop Control

TABLE 5 PEDESTRIAN/VEHICLE DATA AND VARIABLES FOR SEATTLE

Intersection	Type of Control*	12-Hour Accidents	Number of Lanes	Conflicts				Pedestrian Violations	Vehicle Violations	Pedestrian Volumes	Vehicle Volumes				P x V	P x V/$T	Group Number
				TV	RT	LT	Total				L	T	R	Total			
Univ. & 45th	1	4	18	5.666	69.66	0	75.3	43	11.3	.1544	5	1516.	187.6	1709	470142.	40313	3
1st & Lander	1	5	22	0	1	2	3	9.66	23	47	445	1135.	411.3	1991.66	15879.6	370.59	3
5th & Broad	1	1	22	0.333	5.333	2	7.66	26.3	13	347.6	217.6	1603.	98	1919.33	110340.	6510.6	2
18th & Cherry	0	2	10	13.33	4	3	20.3	0.66	3.33	134	41.66	460.6	102	604.333	13533.6	567.94	2
12th & Spring	0	2	12	3.666	0.666	1	5.33	0	0.33	76.66	25	943	57.33	1025.33	12935.5	1617.4	2
21st & CHerry	0	1	15	0.666	0	0	0.66	0	0	16.66	23.66	456.3	44.33	524.333	1568.44	122.54	2
Broadway & Pike	1	2	20	0.666	8	4	12.6	20.6	27.3	191	137.3	1346.	196	1679.66	53446.2	2686.9	2
9th & Madison	1	2	18	3.333	1.333	3.666	8.33	16.6	15.6	228	138	1013.	216.6	1368.33	52424.4	2087.6	2
Rainer & Clov.	1	1	19	0.333	1	1	2.33	8	12.3	44	89.66	1090	78.33	1258	9799.33	723.86	2
14th & Clover.	1	1	16	0.333	0.333	2	2.66	7	17.3	54.33	305.6	707.3	288	1301	11403.4	249.19	2
Fremont & 35th	1	1	20	0	0	0	0	10.6	17	89	340	649	195.6	1184.66	17996.4	392.30	2
26th & Roxbury	1	1	19	0.666	1.666	1	3.33	1.66	2.33	28.66	117	966.6	142.3	1226	5925.44	282.31	2
Brooklyn & 47th	0	1	16	1.333	0.666	0	2	0.33	1	154	71.66	228.6	80.66	381	10938.8	266.63	2
12th & King	0	1	17	3	0.333	1	4.33	1	0	26	123.3	682.6	144	950	4189.55	151.23	2
8th & Market	1	2	19	0.333	6.666	1.333	8.33	7.33	91.3	81.66	255	1516.	212.3	1984	28777.6	1246.1	2
Western & VA	0	1	11	1.333	0.333	0.333	2	10.3	0.33	527.3	461.6	396.6	190	1048.33	106334.	1593.6	2
Coaliss & 45th	0	1	12	4.333	1.666	0.333	6.33	0.66	6.33	75	41.33	531.3	236.3	809	10962.5	318.91	2
2nd & Roy	0	0	10	5	2	0	7	8	4.33	82	160.3	170	105	435.333	5938	97.975	1
34th & Dravus	0	0	10	0	0	0	0	0	0	13.66	7	221	11.33	239.333	552.555	101.35	1
West. & Spring	0	0	10	57.33	12	16.33	85.6	43.3	7	419.6	114	610	112.6	836.666	59326.4	2156.4	1
8th & 85th	1	0	17	0	4	0.333	4.33	1.33	6.33	26.33	257	1259	193	1709	7633.44	291.55	1
3rd & 85th	1	0	15	1.333	2.666	1	5	3.66	14.6	76.66	261.3	1269.	136.3	1667.33	21859.7	914.13	1
Brooklyn & 40th	0	0	11	8	2.666	4.666	15.3	14.3	10.6	246.3	54.33	260.3	54.66	369.333	15425.7	534.67	1
Olive & Boren	1	0	18	0	1	1.333	2.33	7.66	16.6	130	76.33	1311.	184	1571.66	34845	2107.7	1

* 1 - Signal Control

0 - Stop Control

TABLE 6 CLASSIFICATION MATRIX BASED ON THE VARIABLES OF PEDESTRIAN AND VEHICLE VOLUMES FOR WASHINGTON, D.C.

Group*	Expected Group	Number	% Correct
	1	7	
1	2	1	70
	3	2	
	Total	10	
	1	5	
2	2	2	22
	3	2	
	Total	9	
	1	1	
3	2	0	80
	3	4	
	Total	5	
	Overall (all 3 groups)		62.5

*Group 1: 0-accident intersections
Group 2: 1-and 2-accident intersections
Group 3: 3-or-more-accident intersections

TABLE 7 CLASSIFICATION MATRIX BASED ON THE VARIABLES OF CONFLICTS AND PEDESTRIAN AND VEHICLE VOLUMES FOR WASHINGTON, D.C.

Group	Expanded Group	Number	% Correct
	1	9	
1	2	0	90
	3	1	
	1	3	
2	2	5	56
	3	1	
	1	1	
3	2	1	60
	3	3	

TABLE 8 CLASSIFICATION MATRIX BASED ON THE VARIABLES OF CONFLICTS, PEDESTRIAN AND VEHICLE VOLUMES, TYPE OF CONTROL, AND PEDESTRIAN VIOLATIONS FOR WASHINGTON, D.C.

Group	Expected Group	Number	% Correct
	1	6	
1	2	2	60
	3	2	
	1	0	
2	2	9	100
	3	0	
	1	0	
3	2	0	100
	3	5	

TABLE 9 EQUATIONS FOR THE MODEL BASED ON CONFLICTS, PEDESTRIAN AND VEHICLE VOLUMES, TYPE OF CONTROL, AND PEDESTRIAN VIOLATIONS FOR WASHINGTON, D.C.

```
group 1:  G1 = -0.0829C + 0.0041P + 0.0026V + 3.4671S
               + 0.0222Vp - 3.3074

group 2:  G2 = -0.0099C + 0.0006P + 0.0016V - 1.0553S
               + 0.0127Vp - 1.5951

group 3:  G3 = -0.0989C + 0.0045P + 0.0037V + 4.8675S
               + 0.0254Vp - 6.1205

where:
        C = conflict
        P = pedestrian volume
        V = vehicle volume
        S = type of control (1-signal, 0-stop)
       Vp = pedestrian violations
```

group model procedures for Washington, D.C., and Seattle are presented in the tables below.

The following classification matrix is based on the variables of pedestrian and vehicle volumes, conflicts, type of control, and number of lanes for Washington, D.C.

Group	*Expected Group*	*Number*	*% Correct*
1	1	8	80
	2	2	
2	1	4	71
	2	10	

The following equations are for the model based on pedestrian and vehicle volumes, conflicts, type of control, and number of lanes for Washington, D.C.

$$\text{Group 1: } G1 = 0.0139C - 0.0019P - 0.0029V + 2.0773S + 0.8544L - 4.7114$$

$$\text{Group 2: } G2 = 0.0475C - 0.0045P - 0.0038V + 0.6226S + 1.1048L - 6.9865$$

The following classification matrix is based on the variables of pedestrian and vehicle volumes, conflicts, and number of lanes for Seattle.

Group	*Expected Group*	*Number*	*% Correct*
1	1	6	86
	2	1	
2	1	3	82
	2	14	

The following equations are for the model based on pedestrian and vehicle volumes, conflicts, and number of lanes for Seattle.

$$\text{Group 1: } G1 = 0.0934C - 0.0013P - 0.0052V + 1.5888L - 8.5028$$

$$\text{Group 2: } G2 = 0.0505C + 0.0024P - 0.0070V + 2.0441L - 13.4090$$

The Washington, D.C. model produced a 75 percent accuracy whereas Seattle model's accuracy was 83 percent.

CONCLUSIONS AND RECOMMENDATIONS

The modeling effort produced significant results in predicting potential pedestrian/vehicle accident or nonaccident intersections. By use of the discriminate analysis modeling technique, 3- and 2-group models were developed for the cities of Washington, D.C., and Seattle. The three-group models consisted of the following: Group 1, zero-accident intersections; Group 2, one- and two-accident intersections; and Group 3, three-or-more-accidents at three or more intersections. In Washington, D.C., the variables of pedestrian and vehicle volumes, conflicts, type of control, and pedestrian violations best explained the groups that had three accidents or more with a model accuracy of 83 percent. For the Seattle three-group model, pedestrian and vehicle volumes, conflicts, and number of lanes best explained the accident groups with a model accuracy of 75 percent.

Because of the limited amount of accident data for Group 3 (accidents at three or more intersections), with only five such intersections in Washington, D.C., and only two in Seattle, the models from both cities were reduced to two groups: Group 1, zero-accident intersections, and Group 2, accidents at one or more intersections. Basically, the two-group model predicts an intersection's potential for having or not having an accident. The three- and two-group models are presented in Table 11.

In both cities it was evident that pedestrian and vehicle volumes and pedestrian/vehicle conflicts were the primary variables in defining pedestrian/vehicle accident occurrences. In contrast, neither the pedestrian volume and vehicle volume product ($P \times V$) nor that product divided by the percentage of turning vehicle volume [$(P \times V)/\%T$], measures that represent both pedestrian and vehicle volumes and potential conflicts, performed well in the modeling analysis. These two exposure measures may not represent, in one aspect, the true value of their product. For example, there may exist 20 pedestrians and 20 vehicles at a given location in a given time frame. Their $P \times V$ product is 400 pedestrian–vehicles, which indicates 400 potential conflict events. There may also exist a location with 2 pedestrians and 200 vehicles. Again the $P \times$

TABLE 10 CLASSIFICATION MATRIX BASED ON THE VARIABLES OF CONFLICTS, NUMBER OF LANES, AND PEDESTRIAN AND VEHICLE VOLUMES FOR SEATTLE

Group	Expected Group	Number	% Correct
	1	6	
1	2	1	86
	3	0	
	1	3	
2	2	11	73
	3	1	
	1	0	
3	2	1	50
	3	1	

TABLE 11 3- AND 2-GROUP MODELS FOR WASHINGTON, D.C. AND SEATTLE

Washington, DC 3-group model

group 1: $G1 = -0.0829C + 0.0041P + 0.0026V + 3.4671S + 0.0222V_p - 3.3074$

group 2: $G2 = -0.0099C + 0.0006P + 0.0016V - 1.0553S + 0.0127V_p - 1.5951$

group 3: $G3 = -0.0989C + 0.0045P + 0.0037V + 4.8675S + 0.0254V_p - 6.1205$

Seattle, WA 3-group model

group 1: $G1 = 0.0943C + 0.0023P - 0.0047V + 1.6625L - 9.4869$

group 2: $G2 = 0.0533C + 0.0058P - 0.0065V + 2.0950L - 14.0488$

group 3: $G3 = 0.0675C + 0.0155P - 0.0058V + 2.4968L - 27.3187$

where,

G1 = 0-accident intersections
G2 = 1-and-2-accident intersections
G3 = 3-or-more-accident intersections

Washington, DC 2-group model

group 1: $G1 = 0.0139C - 0.0019P - 0.0029V + 2.0773S + 0.8544L - 4.7114$

group 2: $G2 = 0.0475C - 0.0045P - 0.0038V + 0.6226S + 1.1048L - 6.9865$

Seattle, WA 2-group model

group 1: $G1 = 0.0934C - 0.0013P - 0.0052V + 1.5888L - 8.5028$

group 2: $G2 = 0.0505C + 0.0024P - 0.0070V + 2.0441L - 13.4090$

where,

G1 = 0-accident intersections
G2 = 1-or-more-accident intersections

where,

C = conflicts
P = pedestrian volume
V = vehicle volume
S = type of control
V_p = pedestrian violations
L = number of lanes

V product indicates a 400 conflict potential, but obviously not in the same sense. Thus, treating pedestrian–vehicle volumes and conflicts as single variables did not distort their value or relationship. The pedestrian and vehicle volumes indicated the presence of activity with respective magnitudes, whereas the conflicts defined their actual accident potential interaction, not their maximum conflict potential.

The use of type of traffic control as a variable was also an indicator of pedestrian and vehicle activity. A stop-control intersection usually indicates low pedestrian and vehicle volumes whereas a signalized intersection usually indicates either high pedestrian or high vehicle activity or both. Therefore, the use of this variable may be of some importance when defining accidents.

The Washington, D.C. 3- and 2-group models used type of traffic control to define accident groupings whereas the Seattle models did not. Because of the pedestrian and vehicle volume differences between the two cities, the use of the traffic control variable may have been more representative of the potential pedestrian/vehicle interaction that occurred in Washington, D.C. In reviewing both cities' data sets, the stop-control intersections of Washington, D.C., had low pedestrian volumes and moderate vehicle volumes when compared with the signalized intersections. In Seattle, however, several stop-control intersections had high pedestrian volumes and moderate vehicle volumes when compared with the signalized intersections. Thus, type of control was not distinctive when compared with pedestrian and vehicle volumes.

The Seattle three- and two-group models and the Washington, D.C., two-group model contained number of lanes as a variable. The number of lanes on the intersection approaches gives an indication of the time or distance that the pedestrian must traverse or the number of conflict locations defined as the number of places where the pedestrian and vehicle can interact. These places are in the travel lanes. In both cities, the occurrence of accidents increased as the number of lanes increased.

Differences in pedestrian behaviors between the two cities were apparent when comparing pedestrian violations. In Washington, D.C., where numerous pedestrian violations occurred, the violations were found to be indicators of accident groupings; however, in Seattle, the opposite was true. Pedestrian violations in Seattle may be of little importance when compared to the pedestrian and vehicle volumes that existed. A pedestrian may walk against the pedestrian signal or not cross inside of 50 ft of the intersection in Seattle but because of lower vehicle volumes, a car may not be near the area. However, Washington, D.C., pedestrian and vehicle volumes were greater in magnitude, and a violation by a pedestrian may have been more meaningful in defining accidents.

Finally, vehicle violations were not useful in defining accident groupings. Vehicle violations of running a red signal or stopping in the crosswalk would not endanger a pedestrian if the pedestrian signal indicated "Don't Walk" and pedestrians complied. Therefore, many of the vehicle violations recorded may not have been violations that would have caused or been representative of pedestrian and vehicle interactions (i.e., true conflicts).

Research is recommended to investigate pedestrian and vehicle violation variables that define the types of violations that lead to true conflicts. Variables of this type may better aid in defining accident occurrences because some violations rarely endanger the pedestrian.

Additional research using a larger intersection data base with a single accident frequency defining each group would improve the utility of the model. As was shown in this study, the three-group models were reduced to 2-group models because of the small number of intersections that were in Group 3 (three or more accidents).

In conclusion, developing a pedestrian/vehicle accident-prediction model using pedestrian and vehicle volumes and conflicts shows promise. With additional research, the relationship between pedestrian accidents and conflicts and various variables would better refine an accident prediction model in order to identify potential pedestrian accident intersections.

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Traffic Accidents Involving Accompanied and Unaccompanied Children in the Federal Republic of Germany

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Investigated in this study are accidents involving accompanied or unaccompanied children in road traffic. The study is based on 3,716 accident reports by the police on children involved in traffic accidents in the state of Hessen, Federal Republic of Germany. The term "children" refers in this study to all persons under 18 years of age. A literature review showed that children are involved with road traffic with the consent of their parents at a relatively young age, and often without being accompanied. Some of the findings of this research that were noted are as follows: (a) Children become road traffic users at an early age, often without any surveillance by adults; (b) in all observed age groups and accident severity classes, the accident involvement of boys was significantly higher than that of girls; (c) the overwhelming majority of children involved in accidents were accompanied; (d) the degree to which accident-involved children are accompanied by an older person correlates with the age of the children; (e) children who are involved in traffic accidents are far more likely to be active than passive traffic participants; and (f) the frequency of injuries suffered by unaccompanied children involved in traffic accidents is significantly higher than that of accompanied children.

The involvement of children in traffic accidents is a critical issue in the Federal Republic of Germany. As Table 1 indicates, the Federal Republic of Germany has the highest casualty rate (per 100,000 children) and one of the highest fatality rates (per 100,000 children) in Western Europe.

Between 1976 and 1986, the Federal Republic of Germany experienced a reduction in this casualty rate for the age group under 6 but a slight increase for those 6–14 (see Table 2).

Analysis of accident statistics indicate countermeasures that could help reduce the risk for children in road traffic. However, research experience has shown that investigations dealing with accidents involving children lie mostly between two extremes: the investigation is based either on a large accident data base provided by governmental agencies or on a small sample size of accidents obtained, for example, from questionnaires.

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In the first case, large data bases are usually available, but the data are highly summarized; thus, from these data bases only simple questions can be addressed and answers to more profound questions are not often achievable.

In the second case, considerably more parameters for identifying possible accident causes can be investigated. But because of the small accident sample sizes used in these investigations, it is often impossible to achieve statistically reliable results.

To adopt a middle course between the two extremes, a research study of accidents involving children (*3*), on which this paper is based, was conducted in the state of Hessen, Federal Republic of Germany. For this research study, a large sample of accidents involving children was obtained. The study was based on original accident reports provided by the police, which constitute, in a less detailed form, the basis for the federal government accident statistics. Overall, 3,716 police reports on children involved in road traffic accidents were considered.

LITERATURE REVIEW

Comparative analyses of traffic accident characteristics in the United States and Western Europe have been conducted by the authors for approximately a decade (*4–9*). These investigations mostly identified the involvement of different age and road user groups in road traffic accidents.

Available reports on the involvement of children in road traffic accidents are largely based on highly summarized (i.e., few parameters to describe accident causes) data bases. Therefore, relying on these reports to identify probable causes of accidents involving children may not result in a comprehensive and complete picture. This is especially true for the question of whether children who are involved in traffic accidents were "alone" or "accompanied" at the time of the accident.

A study conducted by Grayson (*10*) reported that less than half of the children in his study who were involved in road traffic accidents were alone on the road at the time of the accident. Grayson indicated that children under 6 generally are accompanied by adults.

An investigation by Schulte (*11*), based on interviews with parents of 2,990 young children under 18, revealed the obvious: that with increasing age, children, often unaccompanied, participate in road traffic. For instance, Schulte found that on

TABLE 1 CASUALTIES AND FATALITIES FOR CHILDREN UNDER 15 YEARS OF AGE FOR DIFFERENT EUROPEAN COUNTRIES (*1*)

	DK	D	A	F	GB	NL	CH	S
Casualties per 100,000 Children	156	508	386	243	442	218	230	115
Fatalities per 100,000 Children	6.1	5.9	5.7	5.7	5.0	4.7	4.6	3.2

Legend:

Casualties: Injured and Fatally Injured Children

DK: Denmark; D: Federal Republic of Germany; A: Austria;

F: France; GB: Great Britain; NL: The Netherlands;

CH: Switzerland; S: Sweden

TABLE 2 NUMBER OF CASUALTIES AND CASUALTY RATES FOR CHILDREN IN THE FEDERAL REPUBLIC OF GERMANY (*2*)

	Age	1976	1980	1984	1985	1986
Casualties	0-5	14,233	12,181	11,011	10,548	10,930
	6-14	52,528	47,751	37,472	33,077	33,727
Casualty Rate (Dif. Age Groups)	0-5	360	345	308	295	296
	6-14	589	623	628	585	617

the way to playgrounds, kindergarten and sports activities, 62 percent of children up to 6 were escorted by adults, 13 percent were accompanied by other children, and 24 percent were unaccompanied. On the way to and from school, 58 percent of children between 7 and 12 were accompanied by other students; however, only 12 percent of children in this age group were accompanied by adults to playgrounds and sports. Schulte summarizes the accompanying of children while playing and on their way to playgrounds, related to high-volume and low-volume roads, as follows:

	Percent Accompanied by Type of Road					
	High Volume			*Low Volume*		
Age (years)	*Not*	*Adults*	*Children*	*Not*	*Adults*	*Children*
Up to 6	26	56	18	50	19	31
7 to 12	41	5	54	47	5	48

Schulte also indicated that most children in the first grade are escorted to and from school by adults.

Wittenberg et al. (*12*) repeated the study conducted by Schulte 10 yr earlier. Their findings confirmed his results.

Note that the above percentages may not be comparable with United States figures. One reason for this is that because of shorter travel distances in Europe, children typically walk or bicycle. Children in the United States, because of longer travel distances, often are occupants of cars or school buses.

Even though accompanying children in road traffic may provide a feeling of security, many parents in the Federal Republic of Germany believe that their young children are mature enough to participate alone in road traffic. An investigation by Guenther (*13*), based on questionnaires to parents with preschool children, revealed that 70 percent believed that full-time surveillance of their youngsters was unnecessary. Furthermore, half of the sampled parents did not insist on keeping their children away from road traffic, and a majority of the parents thought that being near traffic routes does not endanger children under 6. In conclusion, Guenther indicated the following: "In many ways, parents' attitude toward providing security for their children in road traffic has to be evaluated as unreliable."

A study by Kueting et al. (*14*) of children riding bicycles determined that nearly half of the children were unaccompanied in road traffic. When children were accompanied, it was not by experienced adults, but mostly by friends, brothers or sisters.

Hohenadel (*15*) summarizes the experiences gained in Europe as follows:

> Parents are often unable to educate their children (3 to 8 years of age) about the possible danger of being involved in road traffic. This is especially true for parents in the Federal Republic of Germany, who are obviously little concerned about when, where and how their children come into contact with road traffic. . . . Therefore, these parents should be considered as accessories in the occurrence of accidents involving children. This is especially true for young children who are involved in traffic accidents.

DATA COLLECTION AND REDUCTION

Police reports on accidents involving children from September 1, 1977, to February 28, 1978, were obtained by official decree from the Minister of the Interior, State of Hessen, Federal Republic of Germany. The time period could not be extended because of personnel, economic, and especially legislative constraints, although the authors are aware that a time period of a full year might have reduced the chance of a biased sample. The half-year period covers a typical school-year term without long vacation times.

Police reports are used in this study as the only source of accident information. It is well known that police reports of accidents may be biased, particularly for pedestrian, bicycle, and motorcycle accidents, which represent the main categories related to accidents involving children (*7,9*). Despite these reservations, it should be noted that the present data base is unique concerning the issue of accompanied or unaccompanied children in road traffic accidents, and the German accident reporting system regarding personal injuries appears to be very accurate. For example, Table 1 reveals a high proportion of casualties versus fatalities in the Federal Republic of Germany as compared with other European countries, which cannot be explained by the actual differences in accident severities alone.

Furthermore, the state of Hessen, in the center of the Federal Republic of Germany, which represents about 10 percent of its population, is considered representative of German conditions and is often selected for case studies in different research fields, accident characteristics included. In many ways, the state of Hessen is comparable with the state of Ohio with its large urban, suburban, and industrialized areas on the one hand and, on the other hand, with its extended rural areas. Because of the above discussed considerations, the present data base appears to be useful for the following investigations.

With the exception of the internal research report to the Minister of the Interior (*3*), the results of this investigation were not made public for approximately a decade because of data protection laws. (Today, a study of this kind could not be conducted because of new data protection laws that do not allow direct examination of police accident reports by researchers.) However, the results are still of great interest to traffic safety because more recent official yearly statistics in Germany show that the involvement of children in traffic accidents has not improved markedly, and the rate has even increased over the years (see Table 2).

As mentioned earlier, 3,716 police reports on fatal, injury, and property damage accidents involving children under 18 were obtained for this study. For every child involved in an accident, 22 parameters were identified to describe the child's age and sex, the accident type, the accident location, traffic participation, and other relevant information.

Contrary to many accident investigations, the analysis conducted in this study is not based on exposure units, accidents per million entering vehicles (for spots) or accidents per million vehicle miles (for sections), but rather on absolute numbers and percent distributions. This is because the study is based on children under 18, for whom exposure data are not available in the Federal Republic of Germany, especially data concerning accompanied or unaccompanied children in road traffic.

OUTCOME OF THE ANALYSIS

Of the 3,716 children who were involved in traffic accidents, 37 suffered fatal injuries (death within 30 days), 941 suffered serious injuries (more than a day in a hospital), 2,016 suffered light injuries (one day or less in a hospital), and 722 were unharmed. Of all these children, 24 percent were pedestrians, 19 percent were bicyclists, 41 percent were riders of light powered two-wheelers (e.g., mopeds) or motorcyles, and 15 percent were passenger-car occupants. Note that 60 percent of these children were riders of powered and nonpowered two-wheeled vehicles. The results showed that the mean age of children involved in traffic accidents was 9.6 years for pedestrians, 12.3 years for bicyclists, 16.6 years for riders of light powered two-wheelers or motorcycles, and 13.1 years for passenger-car occupants.

Male children are more likely to be involved in traffic accidents (*4,5*) than female children. For instance, Table 3 reveals that the percentage of male children under 14 greatly outnumbers female children as traffic accident victims; for children between 15 and 17, the percentage of male involvement in traffic accidents is dramatically higher than that for females.

Comparing the active traffic participation of children (as pedestrians or riders of bicycles or mopeds) to the passive traffic participation (as passengers of two-wheelers or cars) clearly shows that the overwhelming majority of accident-involved children actively participated in road traffic (see Table 3).

The conclusion was reached that in all age groups observed, male children are significantly more involved in accidents than female children. Children who are involved in traffic accidents are far more likely to be pedestrians or two-wheeled operators (active) than to be passengers (passive).

In all severity classes, distinct differences between active and passive traffic participation by male and female children were also noted from the data base (see Table 4). In all classes, actively participating male children were significantly more involved in accidents than female children.

Table 4 reveals that 90 percent of the male children who were involved in traffic accidents actively participated in road traffic. The comparable figure for female children was 70 percent. These statements are more or less true for the accident-severity classes light injury, serious injury, and fatal injury. *T*-test results indicated for most of the observed cases that the differences were statistically significant at the 95 percent level of confidence.

The active traffic participation of male and female children is mainly related to their being pedestrians, bicyclists, moped operators, and motorcycle operators. On the other hand, passive traffic participation is predominantly confined to being passenger-car occupants, which accounts for about 75 percent; only 13 percent of children's passive traffic participation is as passengers of mopeds and motorcycles.

It was concluded that in all observed accident severity classes, the accident involvement of male children is significantly higher than that of female children. Both male and female children involved in accidents are likely to be active rather than passive participants in traffic; this is especially true for males.

To evaluate the accident situation involving children, it is important to learn whether or not the children were alone or accompanied by adults or older children at the time of the accident. An overview of percent distributions of children who

TABLE 3 ACCIDENT PERCENT DISTRIBUTIONS, SUBDIVIDED BY SEX AND BY ACTIVE AND PASSIVE TRAFFIC PARTICIPATION

	Age Groups			
	0 - 5	6 - 9	10 - 14	15 - 17
Male	62.1	61.8	64.0	81.1
Female	37.9	38.2	36.0	18.9
Active	64.1	85.0	86.2	86.0
Passive	35.9	15.0	13.8	14.0

Legend:

Active: Pedestrian or Vehicle Operator

Passive: Occupant

Male children represent in all age groups about 51% of the population.

TABLE 4 ACCIDENT SEVERITY DISTRIBUTIONS, SUBDIVIDED BY SEX AND BY ACTIVE AND PASSIVE TRAFFIC PARTICIPATION (*3*)

	Accident Severity Class					
	none	light	serious	fatal	all	percent
Male	624	1,372	663	26	2,685	100
Active	611	1,196	587	22	2,416	90
Passive	13	176	76	4	269	10
Female	94	626	272	11	1,003	100
Active	87	397	208	6	698	70
Passive	7	229	64	5	305	30

TABLE 5 ACCIDENT PERCENT DISTRIBUTIONS, SUBDIVIDED BY ROAD USER GROUP AND WHETHER CHILDREN WERE ACCOMPANIED OR NOT IN ROAD TRAFFIC (*3*)

	Road User Groups					
Accompany	Pedest.	Bicycl.	Moped.	Motorcyc.	Car*	Total
No	81.2	91.3	90.1	83.2	13.9	75.0
Same Age	12.0	7.1	8.0	12.7	5.4	9.7
Older Children	1.8	0.7	1.2	3.5	24.1	5.2
Adults	5.1	1.0	0.7	0.5	56.7	10.2

* Includes Other Motor Vehicles, e.g., Agricultural Vehicles.

were involved in traffic accidents subdivided into different road user groups and classified as accompanied or unaccompanied in road traffic is provided in Table 5. This table clearly indicates that between 80 and 90 percent of the children were unaccompanied at the time of the traffic accident. These results mostly refer to all road user groups with the exception of car passengers. Children in the latter road user group are usually accompanied by adults or older persons, because a driver's license is only issued to those over 18 in the Federal Republic of Germany. Therefore, children in passenger cars usually are passive traffic participants.

In conclusion, the overwhelming majority of children involved in accidents for the different road user groups were unaccompanied at the time of the accident.

A corresponding overview of percent distributions of children who were involved in traffic accidents subdivided into different age groups and classified as accompanied or unaccompanied in road traffic is provided in Table 6.

The degree to which accident-involved children are accompanied by adults or older children in road traffic strongly correlates with the age of the children. Table 6 indicates that between 50 and about 80 percent of the children were unaccompanied at the time of the traffic accident in the different age groups. It is interesting to note that in the group up to age 5, about 45 percent of the children were involved in traffic accidents despite the fact that they were accompanied by an older person. Table 6 also reveals that in the same age group about 50 percent of the children involved in traffic accidents were unaccompanied and that in the 6–9 age group, the corresponding percentage increased to about 64 percent.

These findings may support the results of the literature review that revealed parents in the Federal Republic of Germany as believing that accompanying their children at relatively young ages is not necessary.

It may be concluded that the degree to which accident-involved children are accompanied by adults or older children in road traffic strongly correlates with the age of the children. It appears that parents in the Federal Republic of Germany believe that accompanying children in road traffic in general is only important during the preschool ages.

Finally, with regard to the severity of accidents, Table 7 indicates that unaccompanied children in road traffic accidents suffer about 2.5 times more from light and serious injuries than do accident-involved children who are escorted. Although these differences are significant at the 95 percent level of confidence, one should not conclude that a lack of surveillance by parents is the only reason for this significant difference. For instance, there may be a correlation between the age of the children and their participation in road traffic. It is nearly impossible for parents to supervise their children constantly once they have reached the age when they can ride bicycles, mopeds, or motorcycles.

The conclusion was reached that the frequency of light and serious injuries suffered by unaccompanied children involved in traffic accidents is significantly higher than that of accompanied children involved in traffic accidents.

CONCLUSIONS

This case study is based on 3,716 police accident reports on children involved in traffic accidents in the State of Hessen, Federal Republic of Germany. The term "children" refers in this study to all persons under 18 years of age.

For every child involved in an accident, 22 parameters were identified to describe the individual, the accident location, the accident type, traffic participation, and other relevant information, including whether a child involved in an accident was accompanied or not at the time of the accident.

The literature review clearly showed that children participate in road traffic with the consent of their parents at a relatively young age, and often without being accompanied.

In general, the following conclusions were drawn:

1. Children become road traffic users at an early age, often without any surveillance by adults.
2. In all observed age groups male children were found to be more involved in accidents than female children.
3. Children who are involved in traffic accidents are far

TABLE 6 ACCIDENT PERCENT DISTRIBUTIONS, SUBDIVIDED BY AGE GROUP AND WHETHER CHILDREN WERE ACCOMPANIED OR NOT IN ROAD TRAFFIC (*3*)

	Age Groups				
Accompany	0-5	6-9	10-14	15-17	Total
No	49.2	63.9	75.6	78.4	75.0
Same Age	5.7	22.0	9.9	9.9	9.7
Older Children	2.9	0.9	2.9	7.7	5.2
Adults	42.2	13.3	11.6	4.0	10.2

TABLE 7 NUMBER OF ACCIDENTS INVOLVING CHILDREN, SUBDIVIDED BY SEVERITY CLASS AND WHETHER CHILDREN WERE ACCOMPANIED OR NOT IN ROAD TRAFFIC (*3*)

	Accident Severity Class		
Accompany	Light	Serious and Fatal	Total
No	1,417	720	2,137
Yes	591	252	843

more likely to be active traffic participants than to be passive traffic participants.

4. In all observed accident severity classes, the accident involvement of male children was significantly higher than that of female children.
5. The overwhelming majority of children involved in traffic accidents for different road user groups were unaccompanied (the obvious exception is children in cars).
6. The degree to which accident-involved children are accompanied by older persons in road traffic correlates with the age of the children.
7. The frequency of light and serious injuries suffered by unaccompanied children involved in traffic accidents is significantly higher than that of accompanied children involved in traffic accidents.

On the basis of these conclusions, it seems logical that any future safety work regarding children has to begin with parents before their children reach school age. As long as the majority of parents are not committed to the questions of when, where, and how their children participate in road traffic, the success of any safety measures will remain incomplete.

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Characteristics of Pedestrian Accidents in Montreal Central Business District

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Pedestrian trips constitute a substantial portion of the total daily intra-central business district (CBD) journeys. As a consequence, conflicts between pedestrians and vehicles continue to be a major concern for transportation planners and engineers. CBDs are expected to expand in terms of persons employed and persons entering the area for business and social activities. Despite crackdowns on jaywalking and extensive traffic management schemes, the number of pedestrian accidents in the Montreal CBD has remained virtually unchanged between 1985 and 1987. Analysis of available data pertaining to the Montreal CBD suggests that more pedestrians involved in accidents are in the 20- to 29-yr-old category than in any other age group considered in the study. Over 40 percent of the accidents occur during the 12–6 p.m. period and 80 percent are within commercial land use areas. Very similar characteristics are evident in the accident statistics for the Calgary CBD. The fact that almost 40 percent of the CBD pedestrians in Calgary are in the above age category, and that they walk the farthest but always choose the shortest path, partly explains the higher rate of involvement of this age group in accidents. The data available in Montreal are sufficient for reporting but not for planning. The research suggests that further detailed studies are required to determine movement patterns and identify the highly involved groups and their need to travel as pedestrians. Means of obtaining and analyzing such information are suggested.

In many cities, over 70 percent of daily intra-central business district (CBD) journeys are made on foot. As pointed out by Bondada (*1*), this figure may indeed be higher, depending on the availability of public transit services, climatic conditions, and density of land development. The primary purposes of the journeys are dependent on the time of day. During the mornings and the early evenings, the journeys are primarily work-based as area residents and people arriving in the area by various modes usually walk from transportation terminals and parking facilities to their places of work, and vice versa. On the other hand, during the midday period, many journeys are for recreational or social purposes, with people walking to and from shops, restaurants, and recreational areas.

Depending on the time of day and the trip purpose, the length of the journeys have been found by Seneviratne and Morrall (*2*) to range anywhere from a few hundred feet to over one mile. Thus, the level of exposure or the potential for conflicts between pedestrians and motor vehicles is higher in the CBDs than in other areas. Unfortunately, some of these conflicts end in fatalities and many cause serious injuries to pedestrians. Compared to 1.4 percent of the injured car occupants who die in a given accident, Moore and Older (*3*) have observed that 3.8 percent injured pedestrians are fatal cases. In spite of these alarming figures, the general attitude of transportation agencies toward pedestrian needs and the approaches to managing pedestrian safety have not changed sufficiently in the last two decades. The same could be said of the research efforts. On the safety side, the main emphasis of research has been on risk and identification of hazardous sites. For example, over a decade ago Jacobs and Wilson (*4*) proposed the classification of roadway sections according to the level of risk, defined as the ratio of accidents in 2½ years to 12 minute pedestrian flow. The ratio is designed to identify the relative safety of different pedestrian facilities such as zebra crosswalks, signalized crosswalks, etc. However, according to the definition, the accidents would have occurred prior to the period in which pedestrian volume counts are taken. Thus, the appropriateness of the ratio for evaluating relative risk is questionable.

The more recent work [Grayson (*5*) and Jonah and Engel (*6*)] is quite similar to that of Jacobs and Wilson (*4*). The primary focus has been on identifying target groups and comparing risk levels. For instance, Jonah and Engel (*6*) examined the relationship among pedestrian crossing frequencies, walking distances, time spent on the streets, and a ratio defined as relative risk. While this type of ratio is appropriate for evaluating relative risk in large populations and useful for identifying target groups or hazardous locations in these populations, the practical insight provided at the micro-level seems negligible. In other words, in calculating risk, the authors assume that the level of exposure to conflict (i.e., the instances in which pedestrians actually cross the path of moving vehicles) is similar for every trip and every location.

An understanding of the hazards and the high risk groups or sites is an important requirement for formulating safety management schemes. However, unless the factors influencing risk or risk-taking behavior are clearly evident from the risk analysis, this knowledge and information alone is unlikely to provide the insight needed to formulate effective schemes. For this reason, one needs to understand pedestrian travel patterns and circulation needs. In this article, we discuss a study of pedestrian accident characteristics in the CBD of Montreal, Quebec, Canada. An attempt is made to identify certain trends or significant factors that have contributed to the occurrence of accidents over a 3-yr period and to determine whether such information could be used to plan appropriate remedies. We also discuss the database as well as the presently used data acquisition technique. Based on the Montreal experience and pedestrian accident characteristics of two other Canadian cities, we suggest certain issues that we feel are important in planning for pedestrians.

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CHARACTERISTICS OF STUDY AREA AND METHOD OF DATA COLLECTION

Urban Montreal, with a population of approximately 2 million, is the second largest metropolis in Canada. It is a highly cosmopolitan region subdivided into several municipalities. The City of Montreal is one of these municipalities with a CBD that occupies an area of 6 square miles (1,570 hectares).

The number of pedestrian accidents in the Montreal CBD has remained high and virtually unchanged over the last 3 yrs. In 1986, for example, pedestrian accidents constituted 48 percent of all accidents and 52 percent of fatal accidents within the City of Montreal. If this trend is allowed to continue without immediate action to understand and correct the potential conflict situations, the City's long term plans (7) to revitalize the CBD and make it an attractive place to live and work could be undermined.

The area outlined in Figure 1 was chosen for analysis. It consists of 50 intersections and is approximately 173 acres (70 hectares). Travel patterns and demographics of the study area are classified in Table 1 according to 1986 census data.

The physical characteristics of accident sites were recorded during field visits; the accident information was extracted from records maintained by the City of Montreal. The primary source of information for the City is police accident report forms. It should be noted that accidents occurring at mid-block are assigned to the nearest intersection. Thus, the numbers represent reported pedestrian accidents in the entire road network in the study area.

The records contained the following information for each of the 203 accidents that occurred in the study area during the analysis period from January 1, 1985 to December 31, 1987:

1. Age of pedestrian;
2. Time and day of accident;
3. Date of accident;
4. Direction of travel of vehicle;
5. Severity of accident (fatal or otherwise); and
6. The approach leg of the intersection on which the accident occurred.

In terms of physical characteristics, we recorded the availability of pedestrian signal phases (i.e., walk/don't walk signs), the predominant land use in the vicinity of the intersection, the number of signal phases, delays at intersections, and features that induce conflicting behavior.

The Statistical Package for Social Sciences (SPSS) was used to analyze the data. Thus, characteristics of the pedestrian as well as times and accident site details were classified as described below.

In order to examine the characteristics of pedestrian groups that are more susceptible to accidents, the involved persons were first classified according to age. Five age groups, which

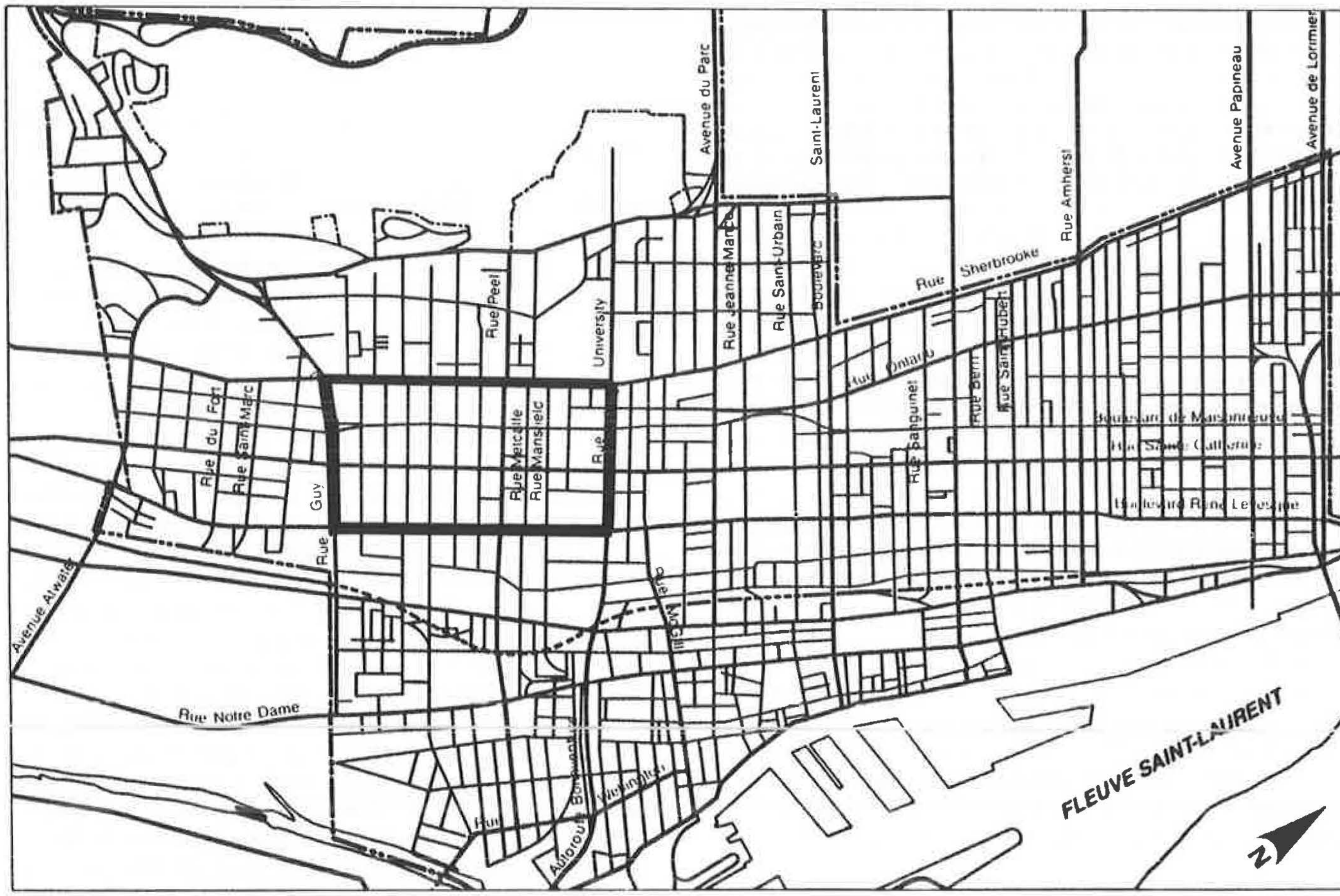

FIGURE 1 Study area within the Montreal CBD.

TABLE 1 CHARACTERISTICS OF MONTREAL CBD AND STUDY AREA

Greater Montreal Urban Area Population (1986)	1,752,582
CENTRAL DISTRICT (CITY OF MONTREAL)	
Number of people entering for work	135,000
for study	20,000
for leisure	25,000
for shopping	40,000
other	28,000
REGION UNDER STUDY	
Area	70 hectares
Population (1986)	2,015

were expected to reflect different lifestyles, were chosen. The times of accident occurrence were divided into seven intervals.

In addition, accidents were classified into four general types according to the direction of travel of the vehicle. These included a) "direct hits," or conflicts that occurred when a pedestrian crossing a street was hit by a vehicle moving straight through; b) "left-turn hits;" c) "right-turn hits;" and d) "reverse hits," or vehicles backing up from parking spots and driveways.

Only two physical characteristics of the accident site (adjacent land use and the availability of pedestrian signals) seemed to provide even a minimum of insight. The intersections were, therefore, classified according to the most dominant land use types, defined as commercial, residential, educational, recreational (open spaces), industrial, parking space, or mixed. As for pedestrian signals, sites were grouped according to the existence of exclusive pedestrian walk/don't walk phases as well as concurrent pedestrian phases. Where pedestrians had to depend on the vehicular indication, the site was classified as lacking in pedestrian signals.

Accident statistics for the CBD of Calgary, Alberta and City of Halifax, Nova Scotia were used to examine the existence of any similarities in the pedestrian accident characteristics in CBD areas. The data were obtained from the traffic departments of the two cities. The manner in which the data were summarized made it difficult to isolate CBD accidents from outside-CBD accidents in Halifax. However, Halifax has a relatively small CBD compared to Montreal or Calgary and it is not clearly distinguishable from the neighboring residential areas. Therefore, we consider the data for the entire city of Halifax.

ANALYSIS OF DATA

Age of Pedestrian

The crosstabs function of the SPSS was able to highlight the relative susceptibility to accidents of the different age groups. From Figure 2, when data are aggregated over the 3-yr period, it is apparent that approximately 28 percent of the accidents in Montreal involved pedestrians in the 20–29 category. The 30 to 39 and 40 to 59 groups were also involved in a significant number (~24 percent each) of accidents. Conversely, the 0–14 category was the least involved group within the study.

As expected, the involvement of 20 to 60 yr olds in approximately three quarters of all pedestrian accidents is due to the fact that the majority of the people who are present in the study area for different purposes (see Table 1) fall into this age bracket. As seen from Figure 3, the low percentage of involvement of the 0 to 14 category in accidents is likewise the result of their low presence in the CBD. However, a closer look at the age profile is necessary to estimate the relative risk, except in the case of the over 60 group who are clearly a high risk group on the basis of the 5 percent representation in the pedestrian population in the study area.

Time of Day

It is apparent from Figure 4 that more than 22 percent of all accidents occur in the p.m. peak (3:00–6:00 p.m.) and 20 percent occur in the p.m. off-peak (12 noon–3:00 p.m.) periods. Of the 20 percent of accidents that occurred during the p.m. off-peak, almost 40 percent were between 12 noon and 1:00 p.m. This could be attributed to the large number of journeys generated around noon for lunch and other social and recreational purposes. Similarly, both pedestrian and vehicular traffic flows during the p.m. peak period are more pronounced compared to the a.m. peak period. This leads to more interaction between the two modes and, therefore, explains the difference between the number of a.m. peak and p.m. peak accidents. Moreover, it is apparent from Figure 4 that 13 percent of the accidents that occurred during the 3-yr period were during the late p.m. (9 p.m. to 12 midnight) period while 17 percent occurred in the early a.m. (12 midnight to 7:00 a.m.) period.

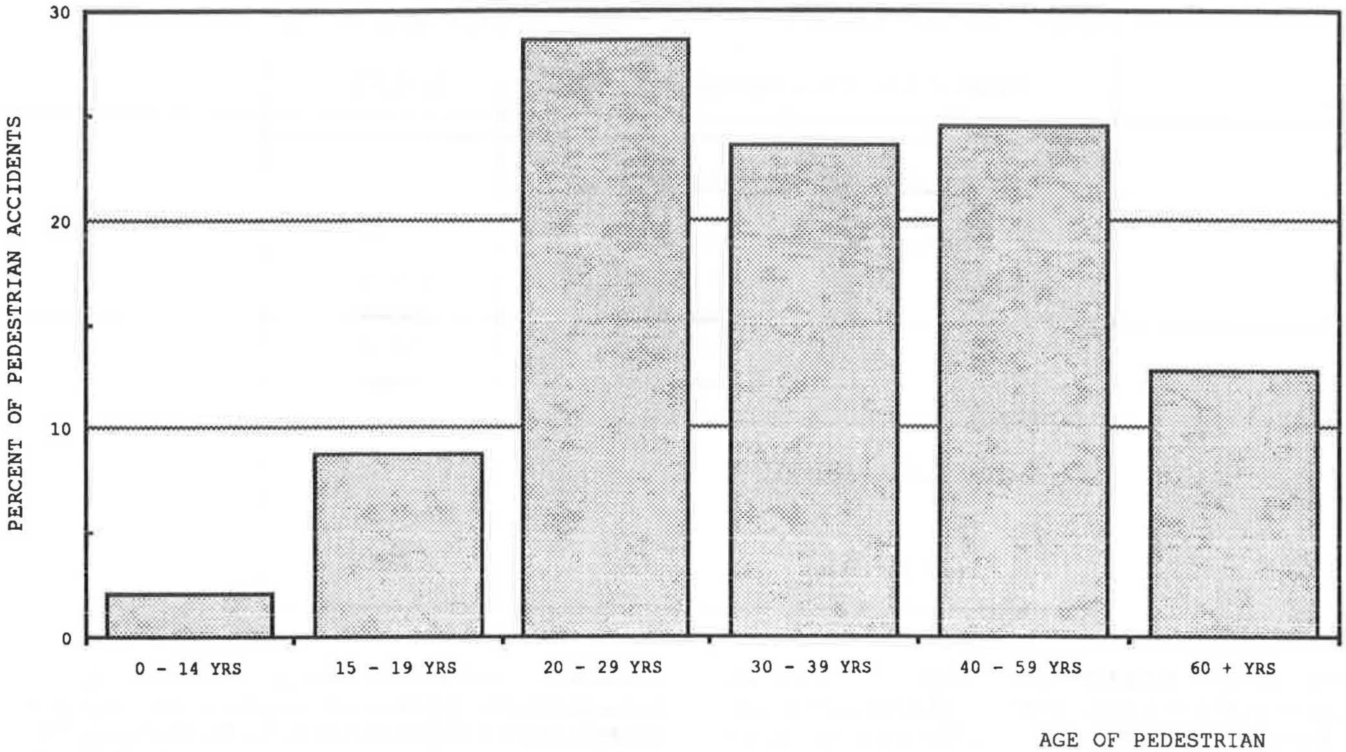

FIGURE 2 **Percent of pedestrian accidents by age group (1985–1987).**

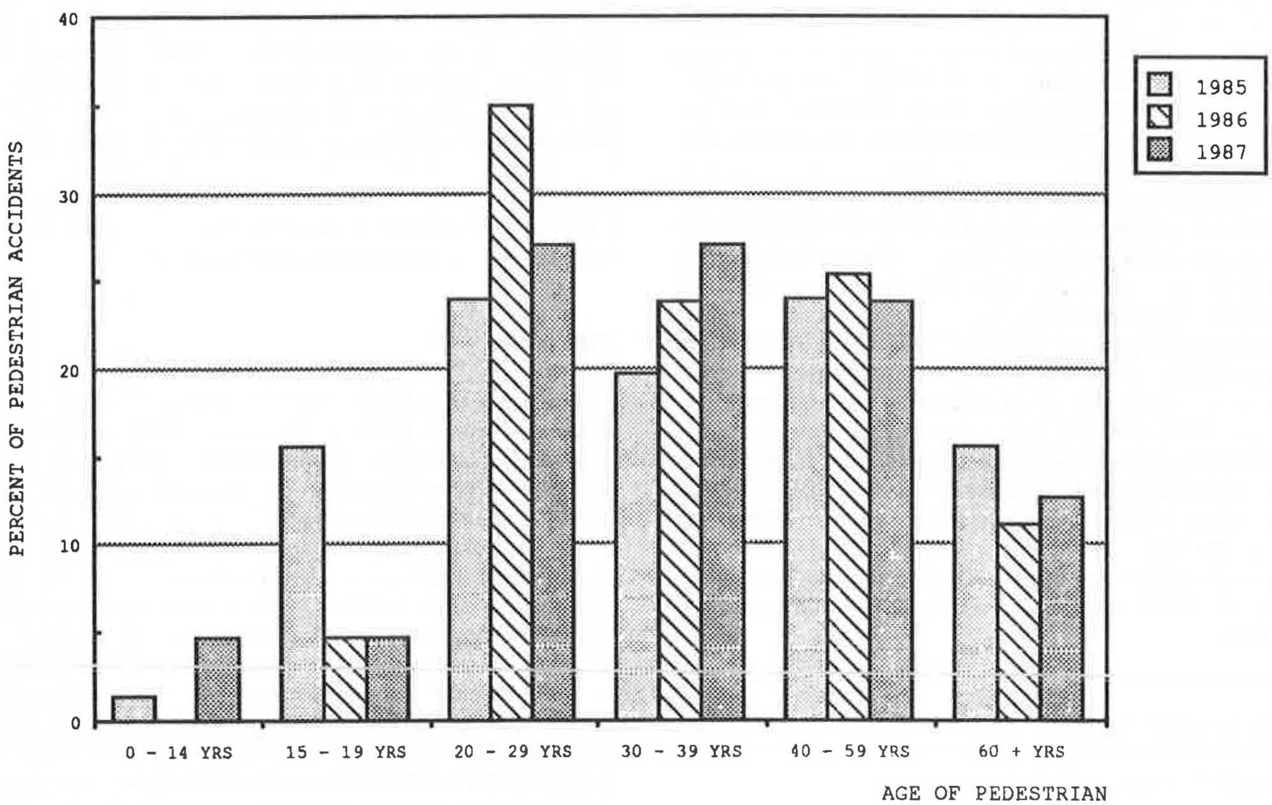

FIGURE 3 **Percent of pedestrian accidents by age group.**

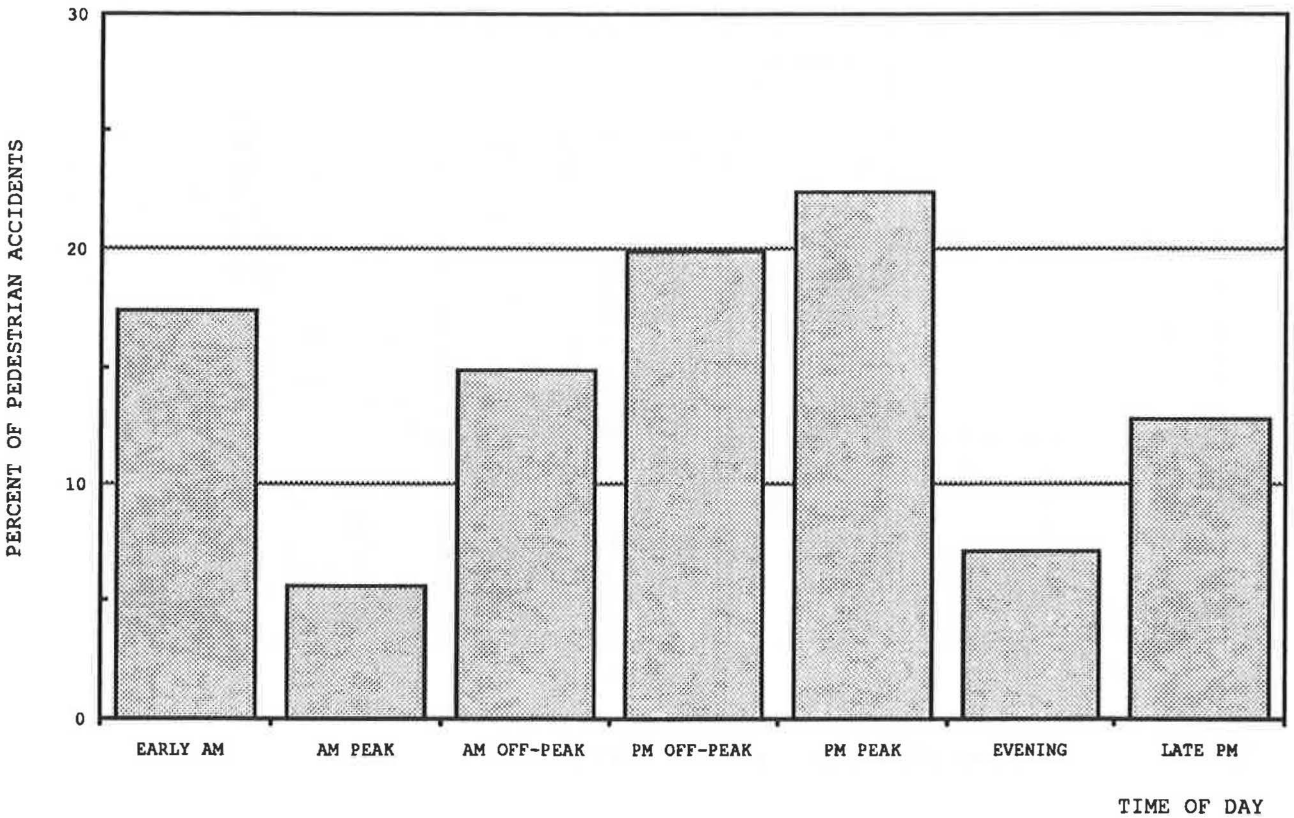

FIGURE 4 Percent of pedestrian accidents by time of day (1985–1987).

As evident from Figure 5, during the late p.m. period, the majority of accidents involved an equal number of people in the age groups of 20s, 30s and 40 to 50s. Whereas during the early a.m. period, the 20 to 29 yr olds who are more likely to remain in the city for social and other engagements are involved in 35 percent of the accidents that occurred during that period.

Land Use

It seems that every year at least 80 percent of the accidents occurred at intersections located in predominantly commercial surroundings, which make up approximately 80 percent of the land use in the study area. Figure 6 indicates that, on the average, 10 percent of the accidents occurred in the neighborhood of the two universities, which are also major generators of pedestrian trips during the day. The land area occupied by the universities is less than 8 percent of the study area. However, in the absence of details on pedestrian volumes or trip generation rates, one cannot make definitive conclusions regarding the relationship between land use and accidents.

Time of Year

Early fall (September to October) appears from Figure 7 to be the period during which most accidents occurred. The portion of accidents that occurred during the remaining months, as shown in Figure 8, seems to be different from one year to another. Although data collected between 1981 and 1985 for another purpose indicate that the early part of fall usually experiences the highest vehicle volumes, as well as the fact that pedestrian volumes would be higher because of students returning to school, the existing data are inadequate to make a definitive conclusion.

Pedestrian Signals

Traffic flow through a large portion of the 50 intersections in the study area is one-way, and 8 percent of the intersections had walk/don't walk phases. Furthermore, right turns (right and/or left when it is one-way) on red are not permitted. Although it is difficult to judge without knowing the exact position of the accidents within the intersection, Figure 9 shows that the portion of accidents that occurred while a vehicle was turning are much less compared to the direct hits, which averaged about 70 percent over the 3-yr period. However, the proportion of left-turn accidents doubled from 14 percent in 1985 to 28 percent in 1987. The average share of reverse accidents remained relatively unchanged at about 5 percent, and right-turn accidents declined from 14 percent in 1985 to 5 percent in 1987. At first, the high percent of direct hits appeared to be the result of the absence of walk/don't walk signs or other warnings for pedestrians and drivers. However, over 14 percent of the total accidents occurred at the four intersections that had pedestrian walk/don't walk signals. Thus, if the ratio of the number of accidents to the number

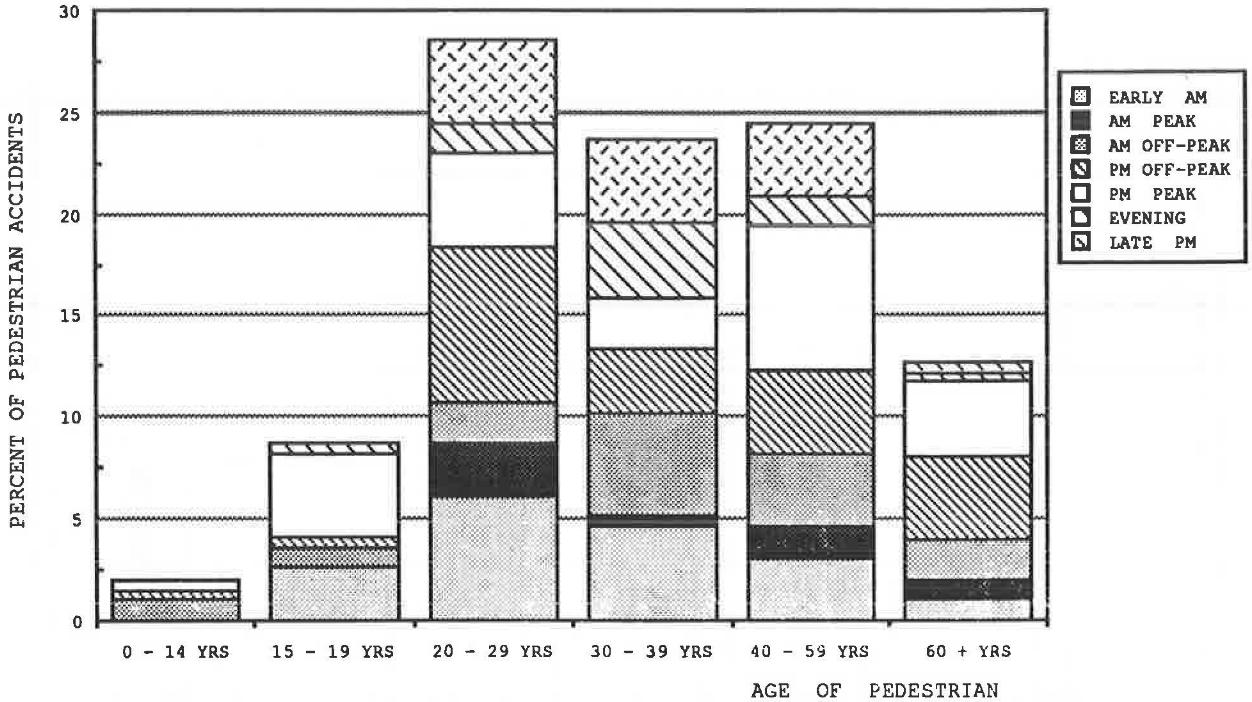

FIGURE 5 Percent of pedestrian accidents by age groups and time of day (1985–1987).

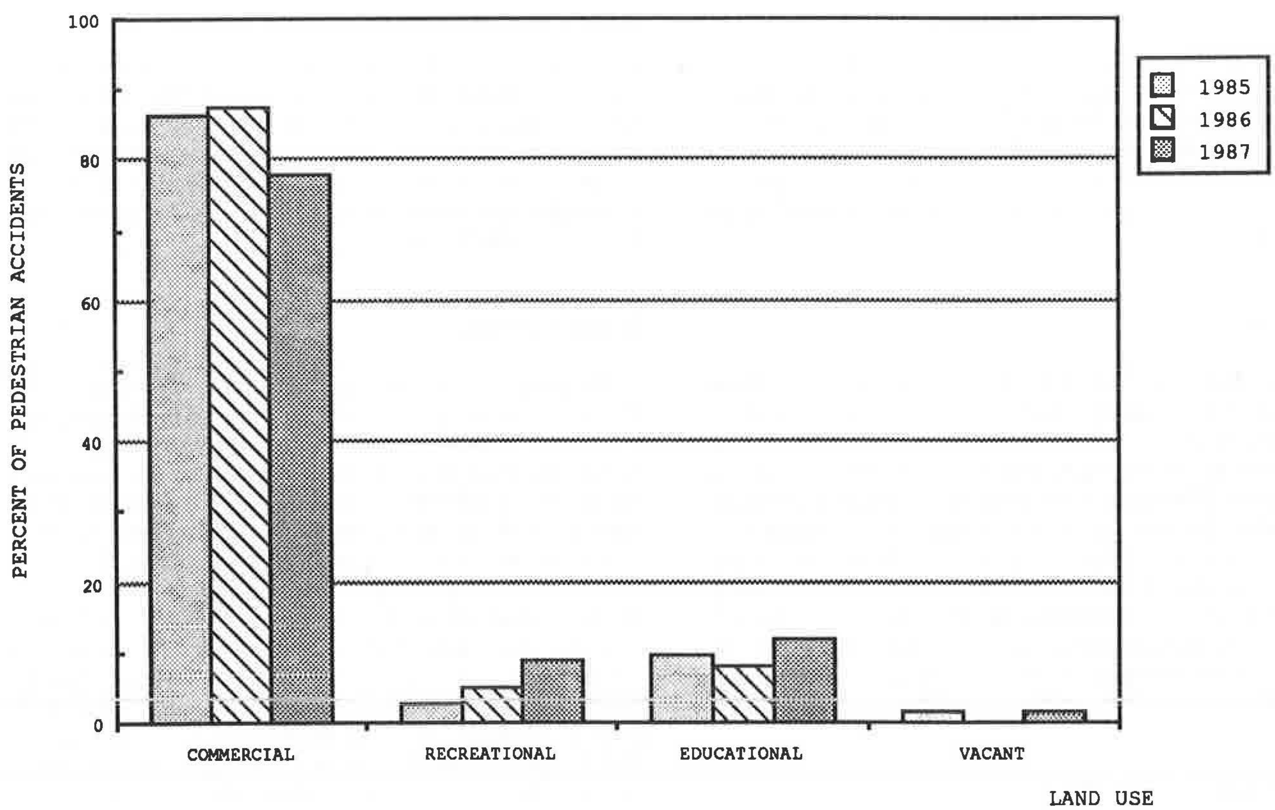

FIGURE 6 Percent of pedestrian accidents by land use type.

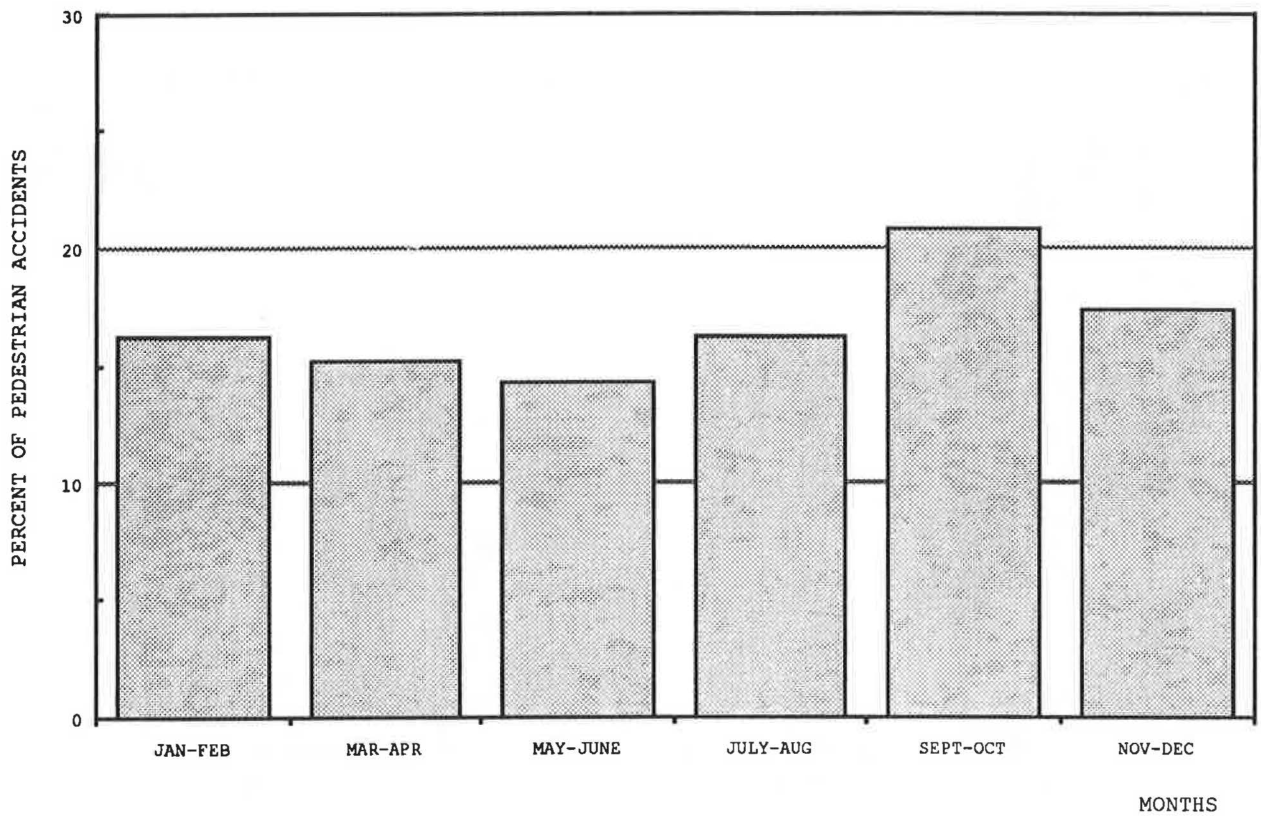

FIGURE 7 **Percent of pedestrian accidents by time of year (1985–1987).**

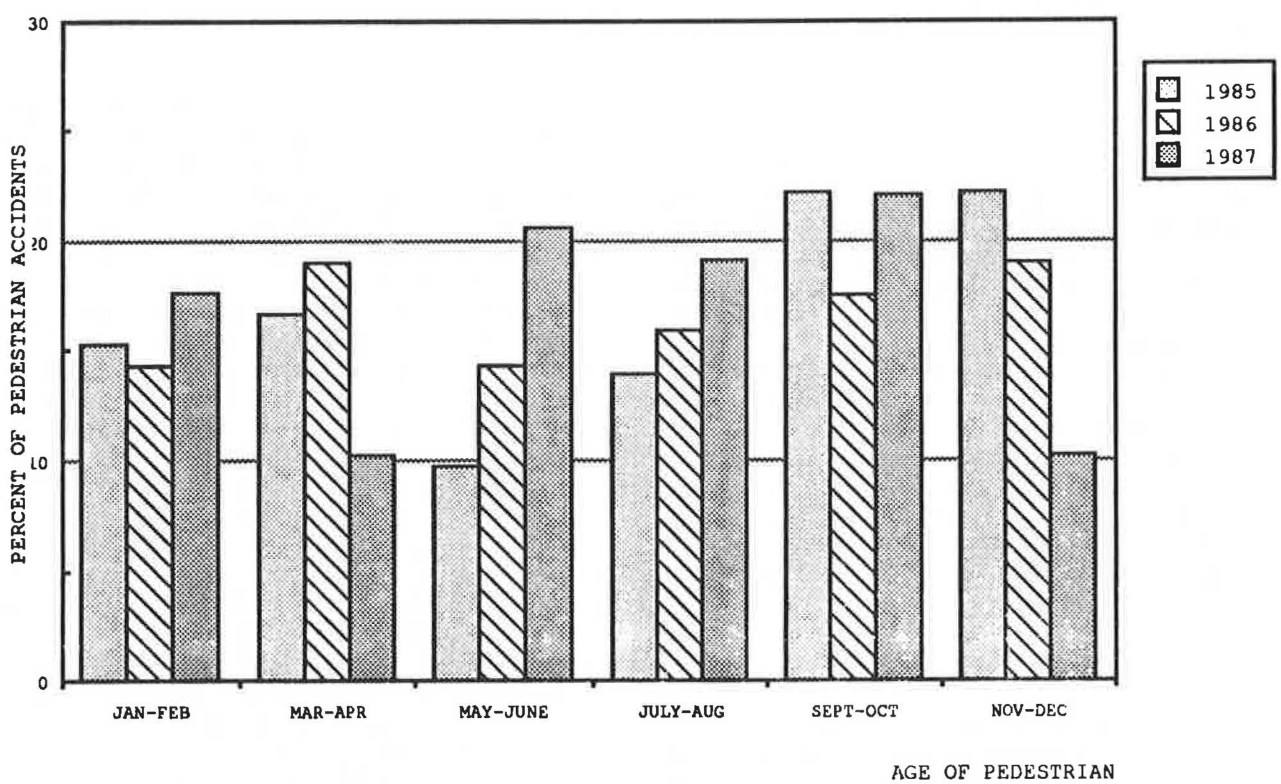

FIGURE 8 **Percent of pedestrian accidents by time of year.**

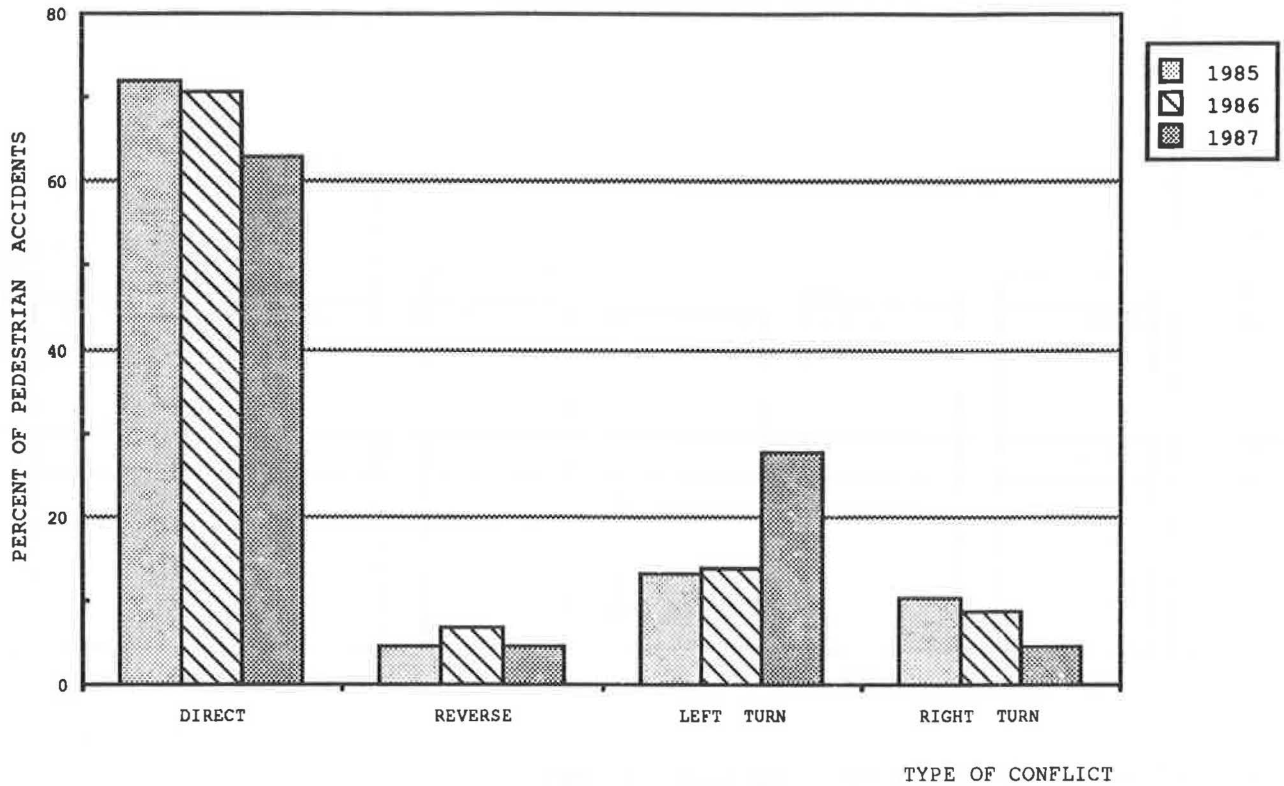

FIGURE 9 Percent of pedestrian accidents by direction of travel of vehicle.

of sites in each category is considered, the intersections with pedestrian signals seem more hazardous. Nevertheless, more information about pedestrian and traffic volumes is needed to confirm or reject the hypothesis.

Location

In 1985, accidents were clustered at a few intersections within the study area. For example, eight accidents occurred at the intersection of de la Montagne and Ste-Catherine, while seven occurred at Peel and Ste-Catherine. In contrast, most other intersections experienced less than three accidents. Over the next two years (1986 and 1987), when no changes to the physical characteristics were made, accidents were more evenly distributed, with the maximum number occurring at any one location in the sample (including the high accident intersections mentioned above) being only four.

Incidentally, even though it spans only 25 percent of the accident sites, Ste-Catherine Street experienced 35 percent of the 203 accidents. The larger portion of accidents may be explained by the relatively higher level of vehicular and pedestrian movement on this primary artery at all times of the day.

Day of Week

The number of accidents that occurred during weekdays was only slightly greater than during weekends. The exception was Monday and Friday, when the number of accidents was twice as great as Saturday or Sunday, as shown in Figure 10. This indirectly indicates the difference in the level of exposure during weekdays and weekends.

Conflict

In order to permit comparisons of safety levels at different locations, we defined two simple measures. First is conflict, which we define as the ratio of pedestrian crossings per unit time to vehicles crossing the path of pedestrians during the same period of time. In other words, the ratio of the number of pedestrians crossing while vehicles are attempting to turn or proceeding straight through to the number of vehicles attempting to turn or proceeding straight through during the time periods when pedestrians have the right-of-way. The second is an accident rate, defined as the ratio of the number of accidents during a given time period to the product of the number of vehicles and pedestrian crossings (defined the same way as in exposure) during the same interval.

Partial pedestrian and vehicle counts were performed in July 1988 at two intersections in the study area. One was at the intersection of de la Montagne and Ste-Catherine where there were 12 accidents in the 3 years. The other was at the intersection of Guy and de Maisonneuve where 8 accidents occurred during the same period. From these data and expansion factors obtained from partial counts at adjacent locations, the expected conflicting volumes during the time of accidents were derived for the two locations. In addition, we observed pedestrian and driver behavior.

During the p.m. peak period, pedestrians at the latter intersection were law abiding and crossed with the right-of-way

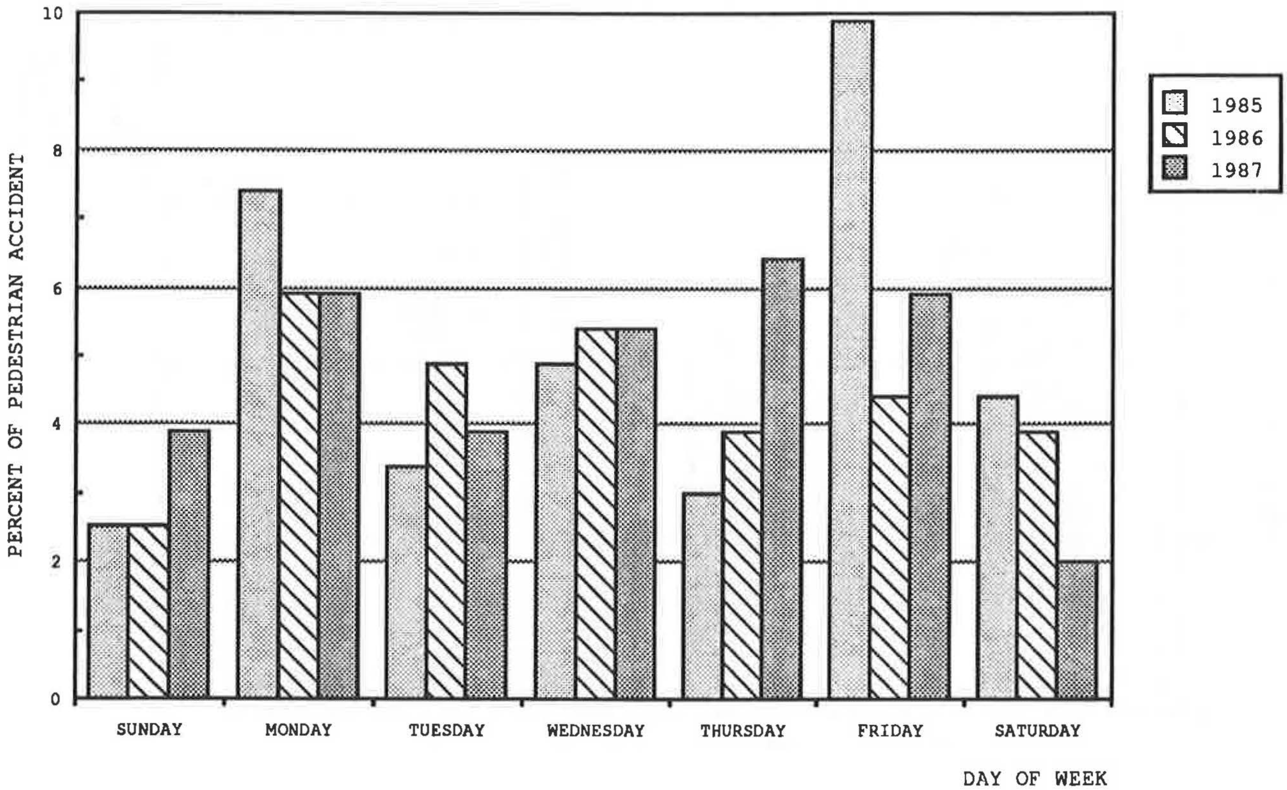

FIGURE 10 Percent of pedestrian accidents by day of week.

even though the average delay computed from 10-sec arrival rates was about 67 percent of red time. The exception was approximately 2 percent who crossed against traffic and away from the intersection. The conflict during this interval was 7.2×10^{-2}, but only one accident had occurred at this time over the period of 3 years. Therefore, the accident rate during this interval was found to be 2.2×10^{-4} accidents per pedestrian per 1,000 vehicles.

Conversely, noon hour observations at the intersection of de la Montagne and Ste-Catherine, which experienced similar pedestrian volumes to the former site and averaged waiting times of 50 percent of red time, showed over 13 percent crossing the traffic stream without the right-of-way. However, the exposure of 6.1×10^{-2} is lower than that of the former case where the north-south approaches were two-way. This site also experienced only one accident during the noon hour over the same period, but the accident rate during the noon hour was 1.0×10^{-4} accidents per pedestrian per 1,000 vehicles.

DISCUSSION OF RESULTS

Several common characteristics became evident from the comparison of the three databases. For example, in Halifax, the largest percentage of accidents also occurred during the months of September and October, whereas Calgary CBD experienced the second largest share of pedestrian accidents during the same period (approximately 20 percent) averaged over the 3 years (1985–1987). The largest share was in the May–June period, although the difference is negligible as seen from Figure 11. Also, the age groups of most individuals involved were similar among the three cities. The percentages of the 30 to 60 yr olds involved in Montreal, Calgary (see Figure 12) and Halifax were approximately 47 percent, 41 percent, and 49 percent, respectively. Also, in Calgary, 33 percent (from 1985–1987) of the accidents occurred during the p.m. peak period (see Figure 13) as opposed to 20 percent in Montreal.

On the basis of this information and information on pedestrian travel patterns [Seneviratne and Morrall (*2*)], it can be reasonably concluded that the higher level of exposure is the primary factor influencing 30 to 60 yr olds to be involved in a relatively larger share of accidents. For example, the walking distance distributions for Calgary indicate that this age group walks farther on the average (~995 ft) than any other age group. Furthermore, when selecting routes, the pedestrians in the same category were found to select the quickest path, which is likely to result in more crossings of conflicting vehicular traffic. What may also be inferred from this is that, since pedestrians wish to gain access by the quickest (shortest) path, satisfying this criterion while minimizing conflicts is likely to be more effective than simply reducing conflicts through median barriers, rerouting pedestrians, and grade separation. Such measures may reduce exposure, but add to the walking distance, inconvenience the elderly and the handicapped, and may sometimes shift the conflicts to a much more complicated site. It also works against the force attempting to provide equal priority and space for pedestrians.

Observations at two sample sites (de la Montangne and St. Catherines and Guy and de Maisonneuve) between 3:00 and

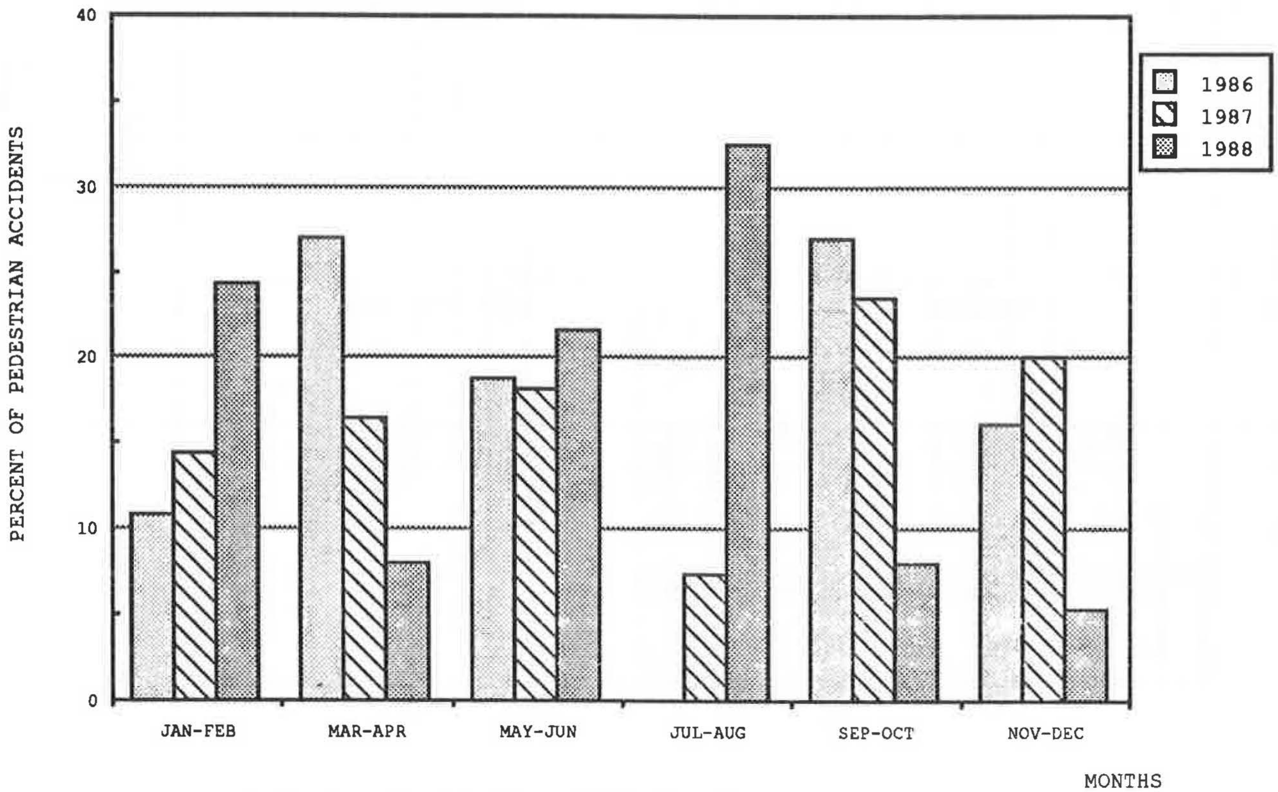

FIGURE 11 Percent of pedestrian accidents in Calgary CBD by time of year.

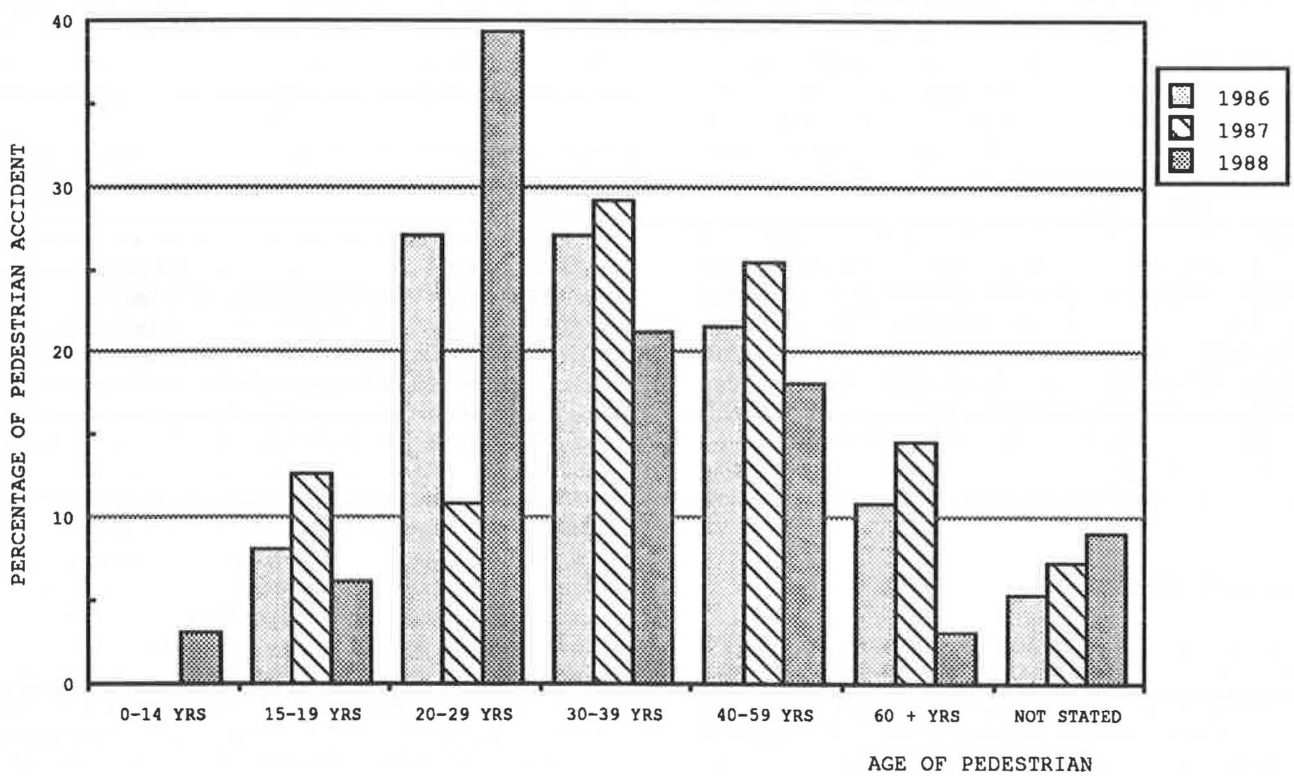

FIGURE 12 Percent of pedestrian accidents in Calgary CBD by age.

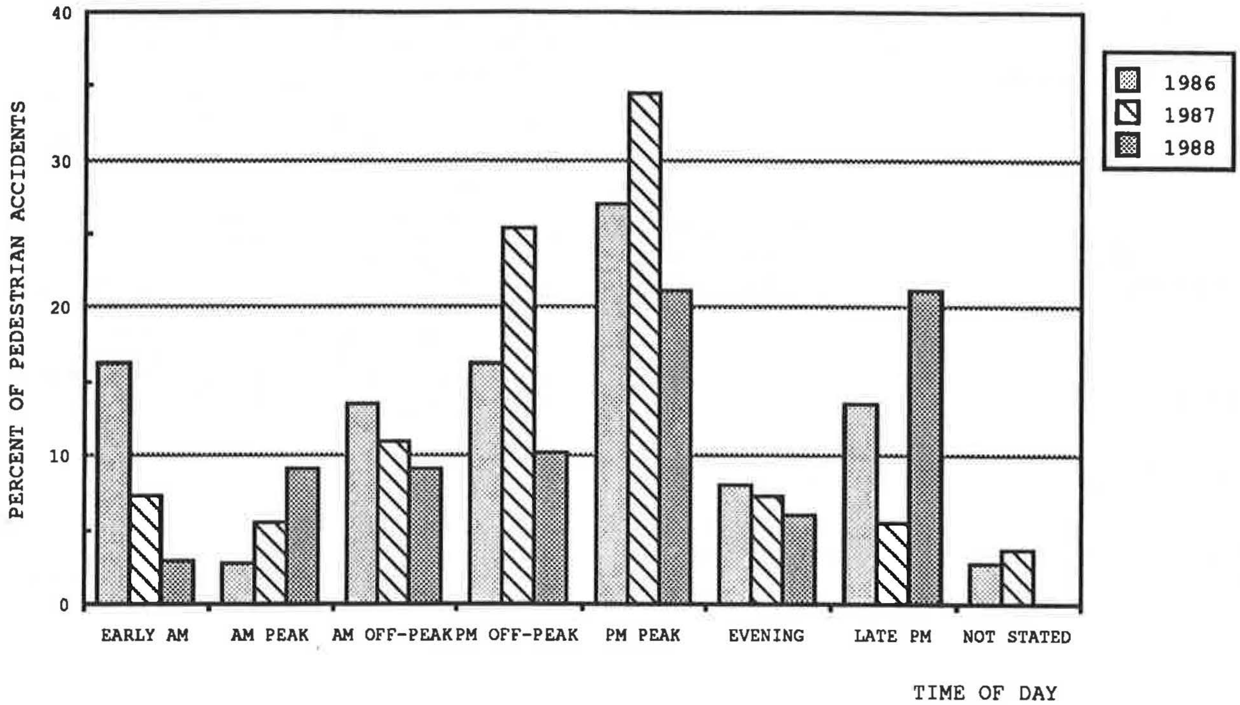

FIGURE 13 Percent of pedestrian accidents in Calgary CBD by time of day.

6:00 p.m. showed close to 17 percent of the eastbound vehicles on St. Catherines Street running the red light. Moreover, 6 percent stopped for the red light across the pedestrian crosswalk (ahead of the stop line) and 14 percent failed to yield to pedestrians while turning on green. While this small sample is insufficient to make a final conclusion, it suggests that the large number of direct-hit and turning accidents in Montreal could be as equally attributable to aggressive driving habits as to inattentive pedestrians. This observation also suggests that exposure should be defined in terms of actual conflicts as opposed to general ratios made up of the total number of vehicles on the road, number of street crossings, or total number of pedestrians. Such macro-level ratios cannot provide much insight to planners and engineers.

CONCLUSIONS

It was found that the 20 to 29 yr age group is involved in a disproportionately larger share of accidents within the study area. Furthermore, most accidents seem to occur between 3:00 p.m. and 6:00 p.m. These two pieces of information imply a strong relationship between pedestrian volume and traffic volume. In other words, during the p.m. peak period the study area pedestrian volume consists of a large portion of persons in the 20 to 29 yr age category, and traffic volume is at its highest during this period.

In order to develop proposals for effective management of pedestrian flow and safety, it is essential that up-to-date information concerning pedestrian volumes; walking distances; and travel patterns by time of day, trip purpose, and under different weather conditions, as well as corresponding vehicular volume data are carefully considered. In the absence of such information, it is difficult, if not impossible, to make inferences or increase our knowledge about the true factors that lead to a high level of conflicts. As is indeed the case in many other cities, adequate information of this nature is unavailable in Montreal and, therefore, the ability of authorities to design effective countermeasures is limited.

Several extensive surveys are usually needed to acquire specific information. For example, an attitudinal survey and a volume survey should highlight some of the deficiencies in the pedestrian network that require adjustments. Such surveys are expensive and time consuming. Nevertheless, the benefits that accrue from efficient adjustments have been found (*8*) in several areas to far outweigh the costs. The forms of adjustments made in these instances range from the creation of traffic-free zones to pedestrian/transit malls as well as the establishment of time-dependent traffic management schemes to balance pedestrian and vehicular space in existing areas.

The task of information acquisition should be a continuous and ongoing process. However, extensive surveys are not required for this information updating. It can be achieved by systematic sampling at a minimal cost. Such sampling can be used to establish growth factors, trends, and alterations in user needs.

Furthermore, the presently used accident data management methods are not the most efficient and user friendly. The information contained in standard police accident report forms is primarily geared to assist in legal proceedings rather than to provide details for urban planners. Even the little information that is of use is obscured by current data maintenance procedures. An effective database management system to store the information in a format that could be querried according to user needs can, nevertheless, be easily created using any database package. Such a system can provide more accurate and helpful statistics related to the existing information. Similarly, information updating and future survey data can be stored and effectively analyzed.

ACKNOWLEDGMENTS

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Calibration of an Infrared Pedestrian Counting System for Shopping Malls

GEOK K. KUAH

Riverwalk Shopping Mall is a festival marketplace located in New Orleans. As part of the pedestrian counting system, photoelectric sensors were installed at the mall entrances to record pedestrian flows entering and exiting the mall. This paper describes the system and presents a nonlinear model that correlates manual pedestrian counts with the corresponding sensor data. Two types of sensor data were recorded: (a) number of sensor breaks and (b) number of busy cycles. The number of sensor breaks was found to be a better explanatory variable than the number of busy cycles, which depends on the size and speed of the object that crosses the sensor beam. Issues relating to model development include simultaneous crossings of the beam by multiple shoppers and the effect of varying entrance widths on model parameters. The nonlinear relationship between actual pedestrian counts and their associated sensor data accounts for simultaneous crossings, and hypothesis testing revealed that the model is invariant under varying entrance widths.

This paper describes a pedestrian counting system and presents the calibration of the counting device for estimating pedestrian flows at Riverwalk Shopping Mall in New Orleans. Riverwalk is a festival marketplace center that consists of apparel shops, specialty retail shops, and a large concentration of food offerings.

DESCRIPTION OF THE PEDESTRIAN COUNTING SYSTEM

The mall has nine entrances. Entrances C through I encompass the retail portion of the mall while Entrances A and B are at the fountain area of the mall. Photoscanners (sensors) were installed at four of the busiest entrances (A, B, C, and I) and connected to a personal computer located in the mall management office. These traffic sensors are designed to record the movements of pedestrians crossing at the entrances. The sensors record the number and duration of infrared beam interruptions caused by pedestrians during every 15-min period.

The sensors (Warner Photoscanners) are high intensity, two-part photoelectric controls that consist of a modulated light-emitting diode light source in one housing and a receiver in the other housing. The receiver is designed with a phototransistor amplifier and output circuity. The light source is modulated and the receiver is tuned to that frequency, making it virtually immune to ambient light. The light source operates in the infrared spectrum and is invisible to the human eye. Depending on the response of the photoelectric controls, the device is capable of sending beams at a rate of over 1,500 cycles per min. By placing the source and receiver side by side at a height of 4–12 in. above the floor at entrances free from obstructions, the device can be used to measure pedestrian flows. However, the sensors cannot distinguish the inflows from the outflows.

CHARACTERISTICS OF PEDESTRIAN FLOWS AT THE MALL

To calibrate the counting system, actual pedestrian inflows and outflows were counted at all entrances. Data were collected from January 28, 1988 to January 30, 1988, between 10:00 a.m. and 6:00 p.m. at 15-min intervals. The 15-min peak mall occupancy for Thursday (January 28, 1988) was 1,449 shoppers; it was 1,663 for Friday. Both the Thursday and Friday peaks occurred between 12:30 p.m. and 12:45 p.m. The Saturday peak occurred between 1:45 p.m. and 2:00 p.m.

Table 1 shows the total number of pedestrians entering the retail portion of the mall for each survey day. On Thursday this was 7,739; 10,219 on Friday; and 17,166 on Saturday. The combined percentage of trips entering through Entrances C and I on each survey day was 74 percent, 75 percent and 66 percent, respectively. The actual count data also revealed that the inflow and outflow at each entrance remain approximately equal.

MODEL CALIBRATION

To develop a model for estimating pedestrian flows at mall entrances, a strong correlation must exist between the sensor data and the actual pedestrian counts. Two types of data were generated from the sensors: sensor breaks and busy cycles. Sensor breaks determine the number of times the sensor beams were blocked during a given time period, while the number of busy cycles measured the amount of time (duration) that the beams were blocked during the same time period. Thus, the number of busy cycles is dependent on the speed and size of the crossing object. Therefore, we would expect a model using the number of sensor breaks to perform better than one using busy cycles.

The second issue of model development was simultaneous crossings of the entrances. For example, two or more pedestrians may pass through an entrance with only one pedestrian blocking the sensor beams. In this case, the multiple crossings that take place simultaneously will be recorded as a single break. Thus, a nonlinear relationship could exist between the

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actual number of crossings and the associated number of sensor breaks. Multiple crossings at the entrances were further complicated by the varying widths of entrances.

Linear regression was used to relate the actual pedestrian flows to the corresponding sensor data. Three model forms were calibrated:

Linear: $y = a + bx$

Multiplicative: $y = ax^b$

Exponential: $y = \text{Exponent}\ (a + bx)$

where y is the two-way pedestrian count by 15-min intervals, and x is the number of sensor breaks by 15-min intervals.

Two types of independent (explanatory) variables were considered: number of sensor breaks and number of busy cycles by 15-min intervals. Table 2 summarizes the results of model performances as measured by the R^2 values. As expected, models with number of sensor breaks as the explanatory variable performed consistently better than those using number of busy cycles as the explanatory variable.

Comparing the R^2 values among models, it was found that the multiplicative model outperformed all the others except

TABLE 1 TOTAL NUMBER OF PEDESTRIANS

Day	Date	(1) Total Entered Mall (A to I)	(2) Total Entered Retail Portion (C to I)	(3) Total Entered Through C & I	(4) (3) as a Percentage of (2)
Thur	01-28-88	10,982	7,739	5,706	73.7%
Fri	01-29-88	15,371	10,219	7,690	75.3%
Sat	01-30-88	25,090	17,166	11,363	66.2%

TABLE 2 MODEL PERFORMANCE: THE VALUES OF R-SQUARED

Independent Variable	Model Form *	Entrance Locations A	B	C	I	All
Number of Sensor Breaks by 15-min. intervals	L	0.85	0.80	0.69	0.92	0.83
	M	0.86	0.85	0.65	0.93	0.87
	E	0.82	0.81	0.67	0.88	0.81
Number of Busy Cycles by 15-min. intervals	L	0.73	0.79	0.03	0.91	None
	M	0.84	0.81	0.06	0.92	None
	E	0.64	0.77	0.001	0.88	None

* L = Linear, M = Multiplicative, and E = Exponential

TABLE 3 APPLICATION OF THE MODEL

	Sensor Data from Special Day				Estiamted 2-Way Volumes			
	Sensor				Entrance			
Time	A	B	C	I	A	B	C	I
10:00-10:15	22	19	25	17	130	110	150	97
10:15-10:30	20	11	24	19	117	60	143	110
10:30-10:45	23	12	23	13	136	66	136	72
10:45-11:00	26	17	35	8	156	97	217	42
11:00-11:15	19	17	28	20	110	97	170	117
11:15-11:30	28	20	42	19	170	117	266	110
11:30-11:45	27	26	50	41	163	156	323	259
11:45-12:00	44	35	66	42	280	217	440	266
12:00-12:15	41	36	71	83	259	224	477	567
12:15-12:30	51	32	69	105	330	197	462	736
12:30-12:45	62	41	74	83	410	259	499	567
12:45-13:00	66	51	83	87	440	330	567	597
13:00-13:15	56	53	87	95	366	344	597	659
13:15-13:30	72	47	107	90	454	156	529	492
13:30-13:45	56	47	87	70	309	156	484	388
13:45-14:00	68	26	78	73	454	156	529	492
14:00-14:15	48	26	72	59	309	156	484	388
14:15-14:30	55	27	75	49	359	163	417	273
14:30-14:45	57	34	69	42	373	210	462	266
14:45-15:00	43	26	65	43	273	156	432	273
15:00-15:15	53	27	63	43	344	163	417	273
15:15-15:30	45	28	69	35	287	170	462	217
15:30-15:45	56	24	57	39	366	143	373	245
15:45-16:00	46	27	57	39	294	163	373	245
16:00-16:15	43	17	46	22	273	97	294	130
16:15-16:30	50	25	67	25	323	150	447	150
16:30-16:45	47	18	63	29	301	104	417	176
16:45-17:00	44	23	59	27	280	136	388	163
17:00-17:15	72	29	57	26	484	176	373	156
17:15-17:30	47	17	54	30	301	97	352	183
17:30-17:45	41	20	50	21	259	117	323	123
17:45-18:00	45	20	44	23	287	117	280	136

for the Entrance C model using number of sensor breaks as the explanatory variable. The high R^2 values of some of the models indicated a strong correlation between the actual counts at the entrances and their corresponding sensor data. The poor performance for the Entrance C models was due to bad sensor data at that location. At Entrance C, the traffic sensor was installed too close to the door; therefore, whenever the door was opened, the beams were blocked. The parameters of the multiplicative model using number of sensor breaks as the explanatory variable are given below:

	Entrance Location			
Parameter	*A*	*B*	*I*	*A + B + I*
ln *a*	1.422	1.455	1.468	1.432
b	1.119	1.100	1.098	1.111

These parameters are consistent and in the same order of magnitude for Entrances A, B, and I, which have varying widths. The results revealed that the width of an entrance may not have any effect on the model parameters.

HYPOTHESIS TESTING

To test whether entrance width has any effect on model parameters, a statistical test approach based on the "extra sum of squares" principle (*1*) was used. The test postulates that the model parameters, a and b, are invariant over various data sets, which are characterized by the width of the entrance. The procedure is to develop a model for each individual data set (unrestricted model) and to develop a common model for the pooled data set (restricted model). The ratio of the difference in residual sum of squares between the restricted and the unrestricted models relative to the residual sum of squares of the unrestricted model follows an F distribution. The F-ratio for the test of invariance of parameters a and b was calculated to be equal to 0.369 and, therefore, highly insignificant. The hypothesis of a common value of a and b cannot be rejected. That is, the model parameters are invariant relative to the width of the entrance. The recommended model developed using the pooled data from entrances A, B, and I is a nonlinear model as follows:

$$y = \text{Exponent}[1.432 + (1.111) \ln(x)] \quad (1)$$

where

y = two-way pedestrian flow volumes during a 15-min interval, and
x = the associated number of sensor breaks for the same interval.

APPLICATION

A hypothetical example is developed to illustrate the use of the model. Assume that the mall management has launched a special marketing effort on a Friday and they would like to know the percent increase in the number of shoppers resulting from the effort.

Table 3 shows the sensor data recorded on the event day and the two-way pedestrian flow volumes estimated by the model. For example, for Entrance I during the interval 10:00 a.m.–10:15 a.m., the two-way pedestrian flow volumes were calculated as follows:

$$y = \text{Exponent}[1.432 + (1.111) \times \ln(17)] = 97$$

If each pedestrian crosses a sensor twice, the number of one-way pedestrian crossings at Entrances C and I would be 21,933/2 = 10,966. Comparing 10,966 pedestrians that use Entrances C and I with only 7,690 pedestrians (see Table 1) using the same entrances during the survey day (Friday, January 29, 1988), there would be an increase of 3,276 pedestrians (or 43 percent) as a result of the special event.

CONCLUSIONS

A pedestrian counting system for shopping malls was described and a model for estimating pedestrian counts at shopping mall entrances was presented using sensor data obtained from photoelectric sensors. The sensor records two types of data: (a) the number of sensor breaks and (b) the number of busy cycles. The number of sensor breaks was found to be a better explanatory variable than the number of busy cycles, because sensor breaks are not dependent on the size and speed of the object crossing the beam. The nonlinear relationship between the sensor data and pedestrian crossings of the model addresses the issue of simultaneous crossings by multiple shoppers. The hypothesis test showed the model is invariant under changing entrance widths.

ACKNOWLEDGMENTS

The author gratefully acknowledges the comments of Blount Hunter and Ken Cusick of the Rouse Company. Funding for this project was provided by the Rouse Company.

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Publication of this paper sponsored by Committee on Pedestrians.

Guidelines for Utilization of Police Officers in Traffic Control and Enforcement on Urban Freeways

JOHN M. MOUNCE AND R. QUINN BRACKETT

Presented in this paper are general guidelines for the use of uniformed police officers in highway maintenance, construction, and other traffic management activities, such as incident management and the operation of high occupancy vehicle facilities. The guidelines distinguish between traffic control and enforcement roles for uniformed police officers. The traffic control and enforcement guidelines are discussed in terms of: (a) objectives of using uniformed police officers; (b) requirements for implementing the guidelines; and (c) measuring the effectiveness of guideline use. Examples of possible applications of the guidelines are given for illustrative purposes. Because of the large number of variables, site characteristics, and transportation agencies involved, the guidelines presented in this paper are necessarily broad and general in nature. However, the paper outlines some recommendations regarding procedures for reviewing and refining the guidelines for possible adoption, dissemination, and implementation by those agencies responsible for enforcement and traffic control activities on freeway systems.

The construction, maintenance, and operation of transportation facilities are vitally dependent upon effective utilization of police personnel for safe and efficient control of traffic and enforcement of traffic regulations. However, traffic law enforcement and safety are only a part, albeit an important part, of an urban enforcement agency's responsibilities.

Although many states have police agencies highly competent in traffic control, the trend for law enforcement administrators has been to separate themselves from this activity because it is not traditional police work. Likewise, there has been considerable reluctance on the part of engineers to accept and involve enforcement agencies in the processes of planning and implementing transportation systems. Two factors have brought about the need for increased cooperation between these two groups.

First, legislation at both the federal and state levels has induced unprecedented levels of construction, reconstruction, and maintenance of the highway network. The work zones associated with construction and maintenance activities are susceptible to becoming locations of high accident frequency and/or sources of considerable traffic delay. The effective use of police officers in these areas should enhance safety and expedite traffic movement.

Second, growth in traffic demands has exceeded the development of the transportation infrastructure in many areas. Innovative techniques in traffic system management (TSM) have been introduced to move more people faster on existing systems. Examples include priority facilities for high occupancy vehicles (HOV), ramp meter control, commercial vehicle routing, special speed zones and lane restrictions, and shoulder usage. Many of these techniques require a significant level of regulation compliance. Active enforcement by police personnel to insure acceptable compliance to these special regulations is essential for sustained and successful operation.

To safely and efficiently accommodate traffic movement on urban freeways in future years, an increasing presence and/or enforcement by police agencies will be required. The necessity for cooperation and mutual advisement between agencies responsible for transportation and law enforcement to effect this is obvious. The intent of this paper is to document guidelines for the utilization of police officers to optimize traffic control and enforcement under atypical roadway situations (work zones, incidents, etc.) or special transportation management strategies (HOV, ramp control, restrictions).

OBJECTIVES

The purposes of this paper are to (a) acquaint law enforcement agencies and officers with some of the unique characteristics of work zones and TSM projects and to attempt to define the role of law enforcement in traffic management; (b) provide guidelines to both transportation and law enforcement officials concerning the numbers and placement of personnel for traffic management and control in various work zone configurations; (c) provide guidelines concerning the levels of enforcement and the techniques necessary for obtaining motorist compliance with TSM regulations; and (d) provide transportation and law enforcement officials with information concerning implementation procedures and issues.

The guidelines presented in this paper have been categorized as traffic control or enforcement. *Traffic control* guidelines relate to those situations occurring on urban freeways in which a uniformed officer is needed to reinforce an existing traffic control plan for optimum vehicular movement. The officer functions as an authority figure with the capability of citation; however, for the purposes of traffic control, only the threat of citation is necessary.

The second category of guidelines, *enforcement*, refers to those transportation facilities or techniques which require unique or special restrictions to operate successfully. Com-

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pliance with these restrictions is dependent upon the level and effectiveness of active enforcement.

The guidelines and other information presented are based on an extensive literature review (*1*), field observations, and interviews conducted with numerous enforcement officers and traffic engineers.

TRAFFIC CONTROL GUIDELINES

Maintenance and Construction Work Zones

The requirements for traffic control in maintenance and construction zones will vary from site to site. Choice of the appropriate technique and manpower requirements will depend on the type of work being performed, the length and duration of the work, and the time of day during which the work is being conducted. Each situation on urban freeways with the potential to utilize police officers for traffic control or enforcement must be considered independently. In all cases, the *Manual on Uniform Traffic Control Devices* (MUTCD) (*2*) should be adhered to for work zone traffic control devices, and police officer traffic control should be implemented in concert with these standards.

Table 1 summarizes the goals, objectives, and measures of effectiveness for traffic control strategies which may be used in conjunction with maintenance and construction activities.

Urban freeway traffic can be managed adequately through many construction and maintenance projects by following an effective traffic control plan utilizing competent flagmen. However, under conditions of high traffic demand, stressful geometrics, unprotected and/or unusual work activity, or nighttime operations, the support and authority conveyed by a uniformed police officer at the work site facilitates safe and efficient traffic control. Specifically, officers may be most effective in speed control.

Figure 1 shows an example of minimal utilization of police officer support for traffic control in work zones. The project site is adjacent to freeway mainlanes. No transition, constriction, or blockage of the freeway lanes is required. An active flagman located off the roadway prior to the work zone should provide adequate warning, protection, and control of any potential traffic encroachment. But, if any of the mitigating factors cited previously exist at the site causing a degradation in safety or operations, the utilization of a uniformed police officer is recommended either in place of or in conjunction with the flagman.

For construction or maintenance work sites that physically close one freeway lane, as shown in Figure 2, a flagman or police officer should be positioned just before the delineated point of transition. The transition may be from multiple full-width lanes to an equal number of narrow lanes or from multiple lanes to a single lane. In either case, the flagman or officer should reinforce the advisements of other traffic control devices and physically provide demarcation of the point necessary for driving adjustment. The decision to use a police officer for traffic control authority at this location should reside with the project engineer, with the concurrence of the police agency under jurisdiction.

Additional flagmen and police support may also be necessary in advance of the transition for speed control and/or immediately adjacent to the exposed site if no other physical

TABLE 1 GOALS, OBJECTIVES, AND MEASURES OF EFFECTIVENESS FOR URBAN FREEWAY MAINTENANCE AND CONSTRUCTION TRAFFIC CONTROL STRATEGIES UTILIZING POLICE OFFICERS

Urban Freeway Goal	Traffic Control Objectives	Enforcement Strategies	Measures of Effectiveness
Insure safety of the work zone	• Maximize safety	• Maximize visibility of site and personnel • Provide advance position of personnel and warning of work zone to insure prior speed reduction • Position personnel and traffic control devices immediately adjacent to conflict points	• Accidents (personal injury and property damage) • Accidents rates • Conflicts
Maintain acceptable traffic flows through the work zone	• Minimize motorist delays	• Active traffic control by police personnel in cooperation with the supervising project engineer	• Travel times • Speeds • Length of queues • Flow rates

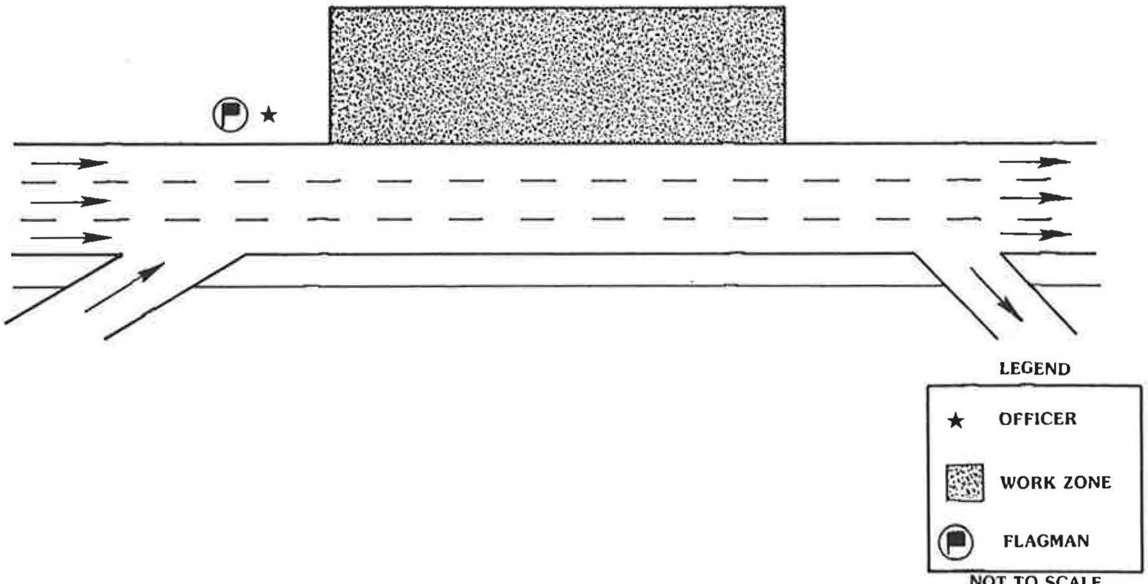

FIGURE 1 Work zone adjacent to freeway.

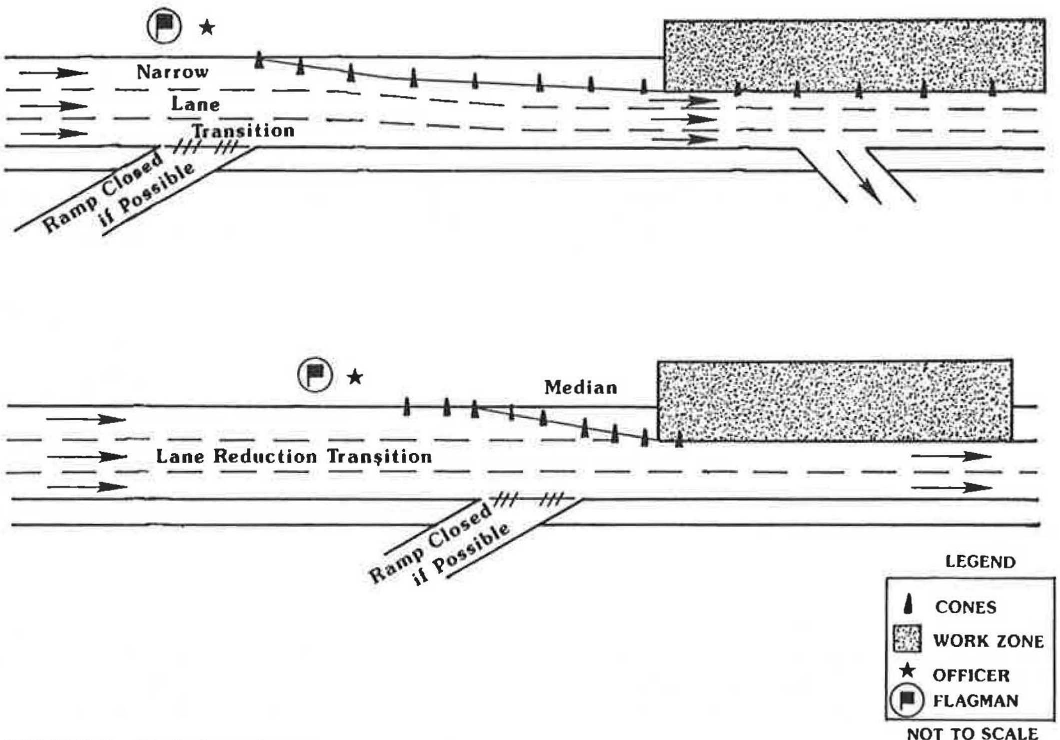

FIGURE 2 Single lane closure.

protection is provided to equipment and work personnel. This decision should be at the discretion of the project engineer based on safety and operational considerations and in concert with local enforcement officer advisement.

For those locations where construction or maintenance activities reduce the capacity of heavily congested freeways or where work must be conducted during peak commuter periods, excessive queueing and delay may result. As illustrated in Figure 3, one option to minimize delay may be to divert a portion of the mainlane traffic to parallel frontage roads. This is only possible if the work site is contained within the limits of an exit-entrance ramp pair. Officers should be at locations indicated to intercept, expedite movement, and reroute onto the freeway beyond the work zone. Each site should be considered unique as to utilization of police support in this regard.

Figure 4 provides two examples of more extensive and major work sites necessitating the closure of two or more lanes on a multilane freeway facility. A flagman or police officer should be located before the first point of physical transition. Addi-

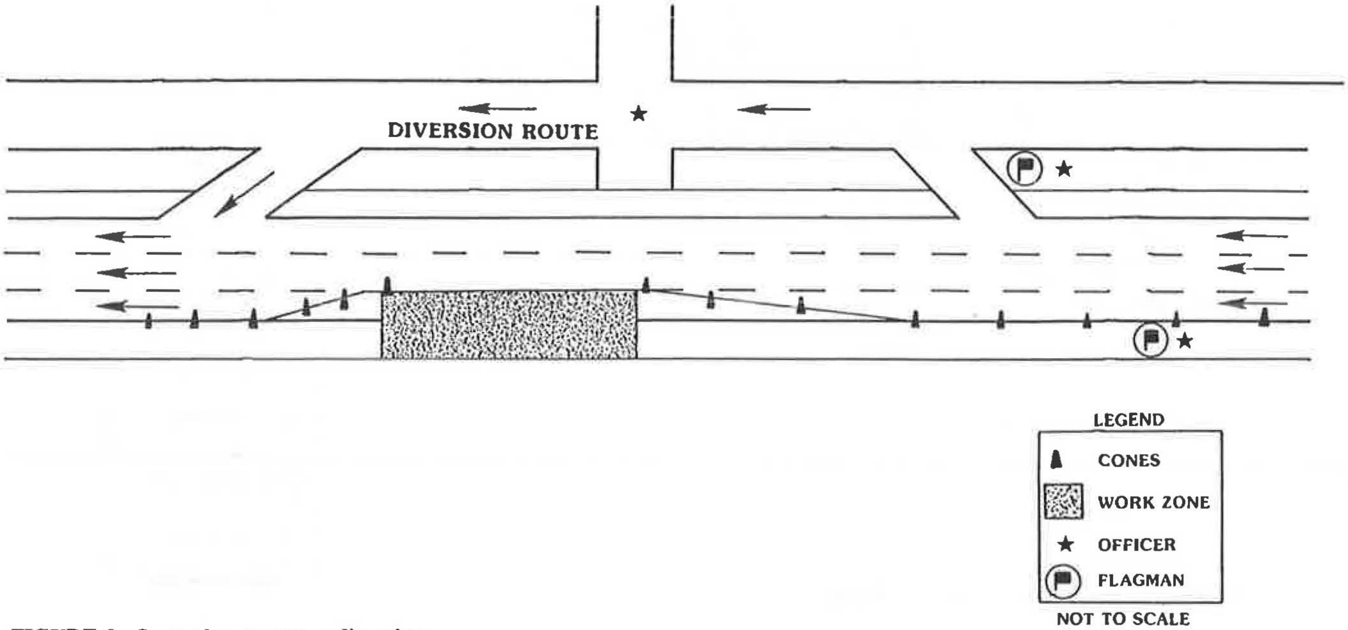

FIGURE 3 Lane closure queue diversion.

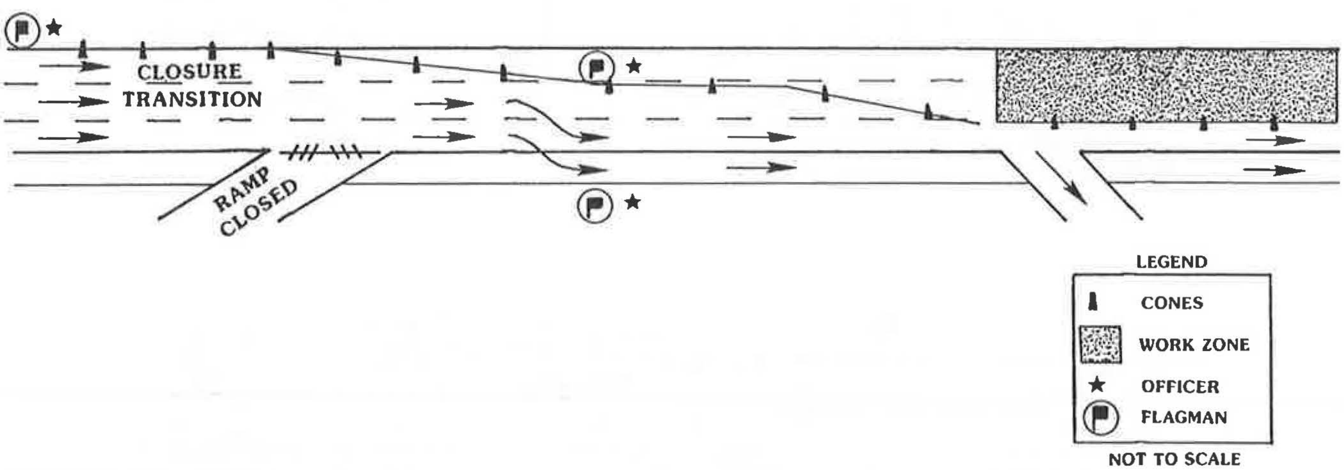

FIGURE 4 Lane closures with diversion.

tional flagmen or officers may be required in advance of the transition itself to reinforce the signing advisements and to positively effect the desired merge maneuvers. Other flagmen or officers may need to be positioned at the secondary transition or adjacent to the work site itself. All of these possible locations using police officer support for traffic control are shown in Figure 4.

The decision to use police support at any or all of these positions to optimize traffic flow and safety within the work zone should be made by the project engineer in consultation with the local police commander. Where several officers are used for a long period of time, provisions should be made for breaks and specified officers should be designated as supervisors.

Maximum use of uniformed police officer support occurs under conditions of a complete freeway closure due to major construction or maintenance operations. Freeway traffic would be intercepted at some point before the work site, transitioned off the freeway, diverted along a parallel route around the project area, and directed back onto the freeway. Obviously, extensive signing and delineation would be employed for warning, advisement, and routing. Flagmen or uniformed police officers, or both, would be used to reinforce traffic communication in advance of the closure. Flagmen or officers, or both, positioned at all transition points would enhance timely and appropriate traffic maneuvers for diversion. Police personnel would also be desirable for authority support at all locations (intersections) requiring manual traffic control.

Figure 5 shows two possible scenarios of freeway closure and locations of police officers for traffic control support. One scenario involves work activity closing the freeway between exit/entrance ramp pairs such that the ramps serve as the diversion route links to and from the frontage road. The second scenario involves diverting traffic off the freeway by an

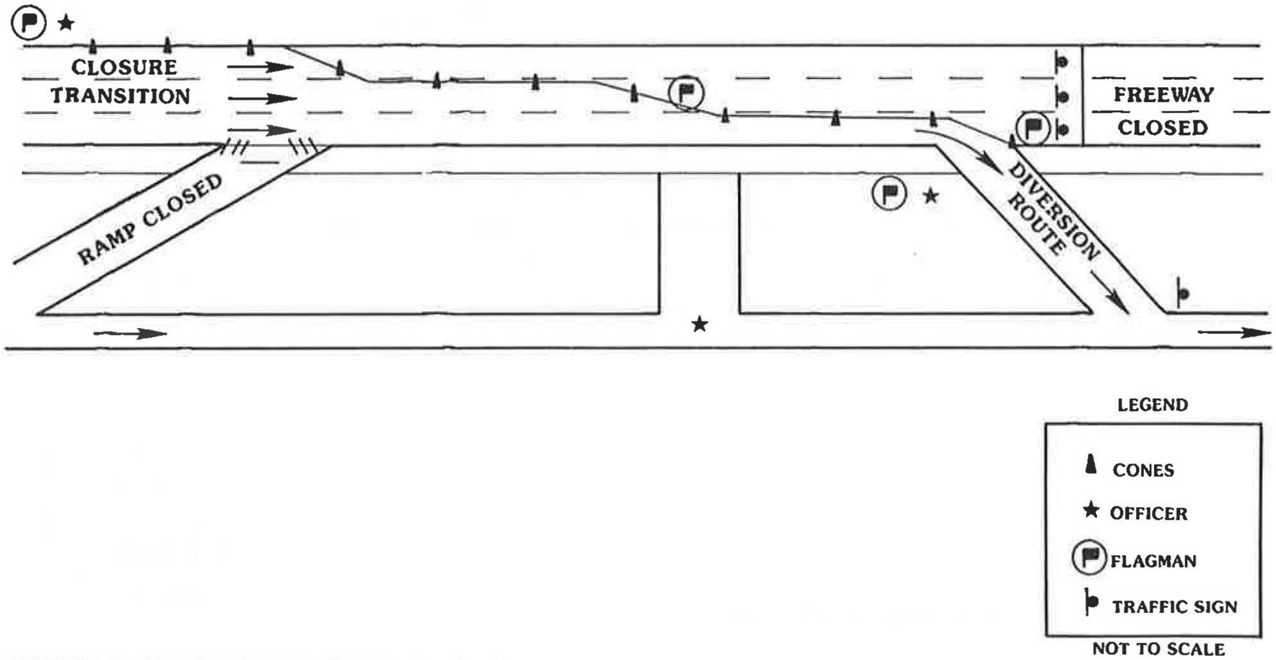

FIGURE 5 Complete freeway closure and diversion.

TABLE 2 GOALS, OBJECTIVES, AND MEASURES OF EFFECTIVENESS FOR MAJOR FREEWAY INCIDENT TRAFFIC CONTROL STRATEGIES UTILIZING POLICE OFFICERS

Goal	Objectives	Strategies	Measures of Effectiveness
Protect the incident site	• Minimize secondary incidents • Insure emergency vehicle access	• Maximize visibility of incident site • Provide advance warning	• Accidents • Accident rates • Emergency vehicle response time
Maintain traffic flow and clear incident	• Minimize motorist delay • Maximize safety	• Use of shoulders • Manually-controlled merging • Contraflow diversion • Advance warning signs • Off-freeway diversion • Pre-planning (types and location of equipment and personnel)	• Travel times • Speeds • Accident rates • Emergency vehicle response time • Time required to return to normal operations

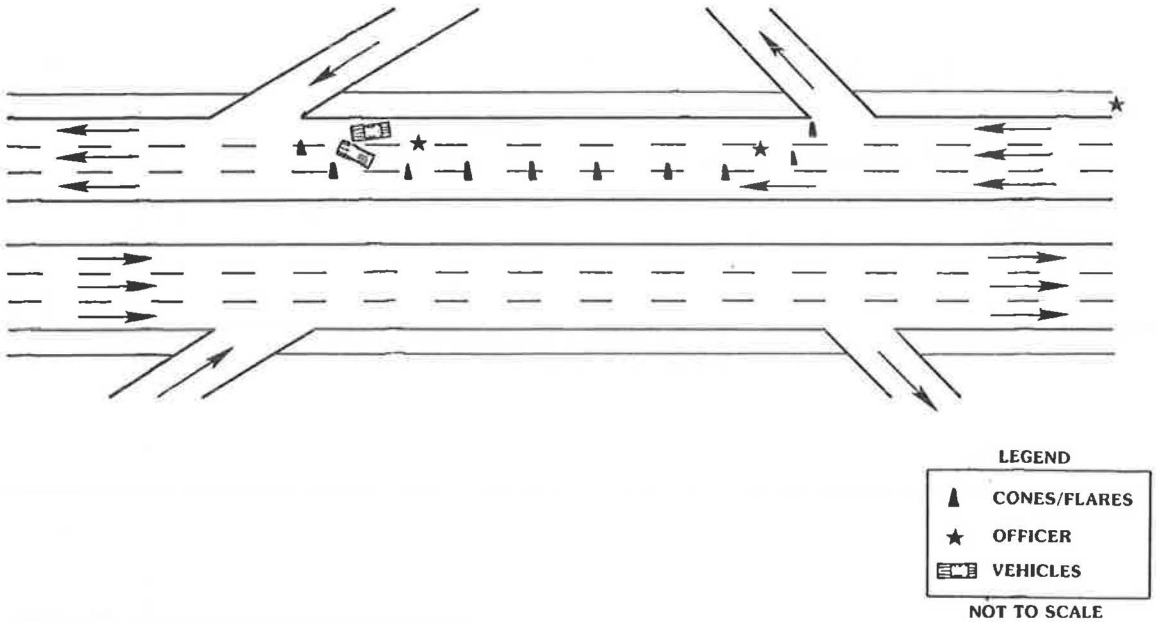

FIGURE 6 Freeway incident: Manual merge.

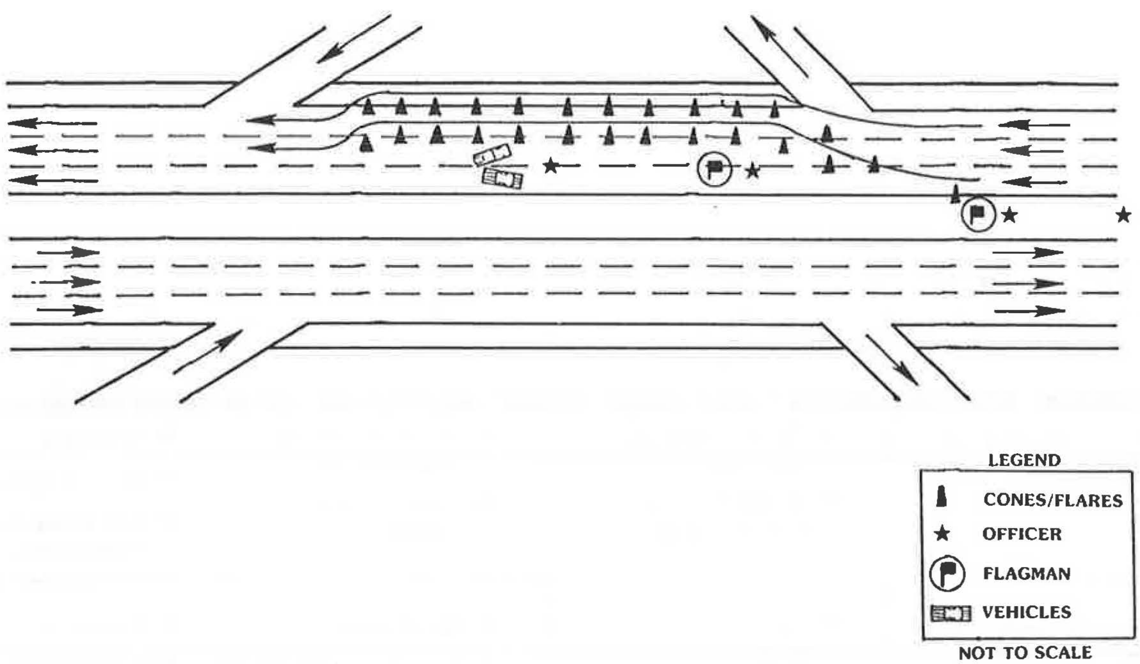

FIGURE 7 Freeway incident: Shoulder usage.

exit ramp and onto a nearby parallel arterial. Either scenario involves several officers and additional support as indicated for traffic control. These same scenarios for complete diversion and example applications of police utilization could follow from a major incident (accident, breakdown, emergency, weather, etc.) closing the freeway.

It should be noted that Figures 1 to 5 are simple illustrations to provide reference positions of flagmen/officers relative to a type and location of construction and maintenance work area. Signing and delineation details of the traffic control plan associated with a particular work site are not included. In all cases, the MUTCD for work zone traffic control devices should be adhered to and police officer traffic control implemented in concert with these standards.

Major Incident Response

A major incident is defined as one that cannot be effectively managed by a single patrolman or patrol vehicle. General guidelines for two incident management strategies (techniques for increasing capacity and techniques for managing demand) are presented. Techniques for increasing capacity in the vicinity of an incident include use of freeway shoulders, merging

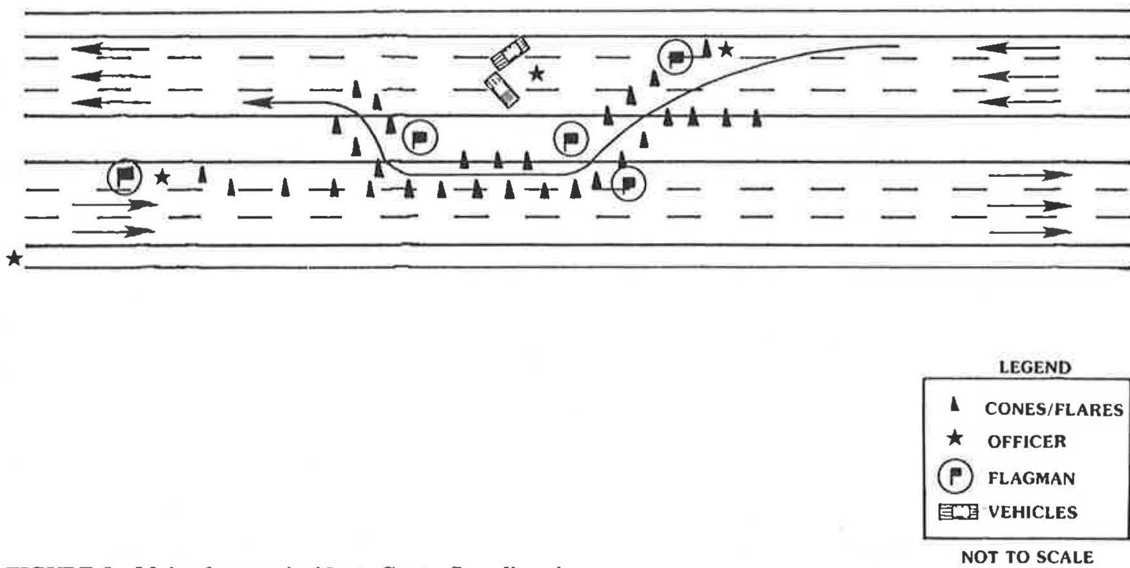

FIGURE 8 Major freeway incident: Contraflow diversion.

techniques, and contraflow operations. Demand management strategies include off-freeway division and advance warning signs.

Because the primary objective of incident management is to restore freeway traffic services as quickly and as safely as possible, the effectiveness of incident management techniques using police officers should be measured in terms of how quickly the incident can be cleared and normal traffic services restored, and how effective the techniques are in preventing or minimizing secondary incidents. The data in Table 2 summarize freeway incident management traffic control strategies in terms of goals, objectives, and measures of effectiveness.

Figures 6 to 8 show typical applications of freeway incident management techniques utilizing police officers. Figure 6 shows an incident requiring patrolmen to effect a manual merging of traffic into the remaining open freeway lane. One patrolman should always be positioned to protect the incident site while other officers are responsible for traffic control associated with the merge transition (or division), if necessary. Transportation agency personnel, as available, should provide assistance with traffic control device placement, flagging support, and other traffic management support. Flagging support should be of a traffic-direction approach carried out by specially trained personnel.

Figures 7 and 8 provide two examples of freeway incident management to make maximum use of available lane capacity. Figure 7 presents a freeway incident blocking the inside lanes. Police officers are used to transition traffic into the remaining open lane and along the shoulder for an additional lane. Figure 8 indicates a major incident closing the freeway. Patrolmen or flagging support, or both, are located to transition traffic to take advantage of capacity in the opposite direction. Obviously, this scenario would only be possible where there was no physical median obstruction.

In either case of shoulder use (Figure 7) or contraflow diversion (Figure 8), extensive delineation and flagging support is needed in addition to uniformed officers. The exact requirements for both police and other support depend on the duration of blockage, the location of the incident, and the time of day (peak, off-peak).

ENFORCEMENT GUIDELINES

Priority Treatment Facilities

The objectives of police enforcement on priority treatment facilities (transitways, concurrent flow lanes, contraflow lanes, HOV bypass ramps) are to maintain the operational integrity and safety of the facilities. Consequently, a strict and active enforcement program is necessary. Detection and apprehension, issuance of citations, and effective prosecution of violators is essential (*3*).

For priority treatment facilities that do not have full access controls and/or are not physically separated from the general use freeway lanes, tandem enforcement at strategic locations along the facility may be applicable. In this technique, one officer detects violators and a second officer stationed downstream apprehends and cites violators. The data in Table 3 summarize the goals, objectives, and measures of effectiveness for priority treatment enforcement techniques.

Figures 9 to 11 show several examples of enforcement on priority treatment facilities. Figure 9 indicates officer locations on two types of priority entry ramps. The patrolman must be in a position for good visibility on the ramp to assess priority restrictions with sufficient time to restrain violators. It is critical to have a refuge area adjacent to the priority ramp for this purpose and to issue citations.

Figure 10 shows possible enforcement strategies for either contraflow or concurrent flow lanes. Detection and apprehension of priority violators may employ "catchment pairs" of patrolmen or routine line patrol procedures. Again, refuge areas for citation are essential.

Figure 11 shows the possible need for additional officers for enforcement on physically separated, controlled access, priority treatment facilities (transitways) with multiple entry/exit points. Violations must be controlled to maintain the priority authorization of the facility.

Enforcement on priority treatment facilities may come from local police agency personnel or it may be the responsibility of the operating transit authority. In this case, special transit police may enforce (detect, apprehend, cite) violations on

TABLE 3 GOALS, OBJECTIVES, AND MEASURES OF EFFECTIVENESS FOR PRIORITY TREATMENT ENFORCEMENT STRATEGIES

Goal	Objectives	Strategies	Measures of Effectiveness
Maintain operational integrity	• Minimize travel times • Maximize vehicle occupancy levels • Minimize violation rates	• Strict enforcement of occupancy requirements • Clear communication of nature of facility • High visibility of enforcement officers • Swift, safe removal of violators	• Violations • Violation rates • Travel times
Maintain safe operation	• Minimize accidents • Minimize incident response and clearance times	• Strict enforcement of authorization requirements • Clear communications of nature of facility • Swift, safe removal of violators	• Accidents • Accident rates • Incident response and clearance times

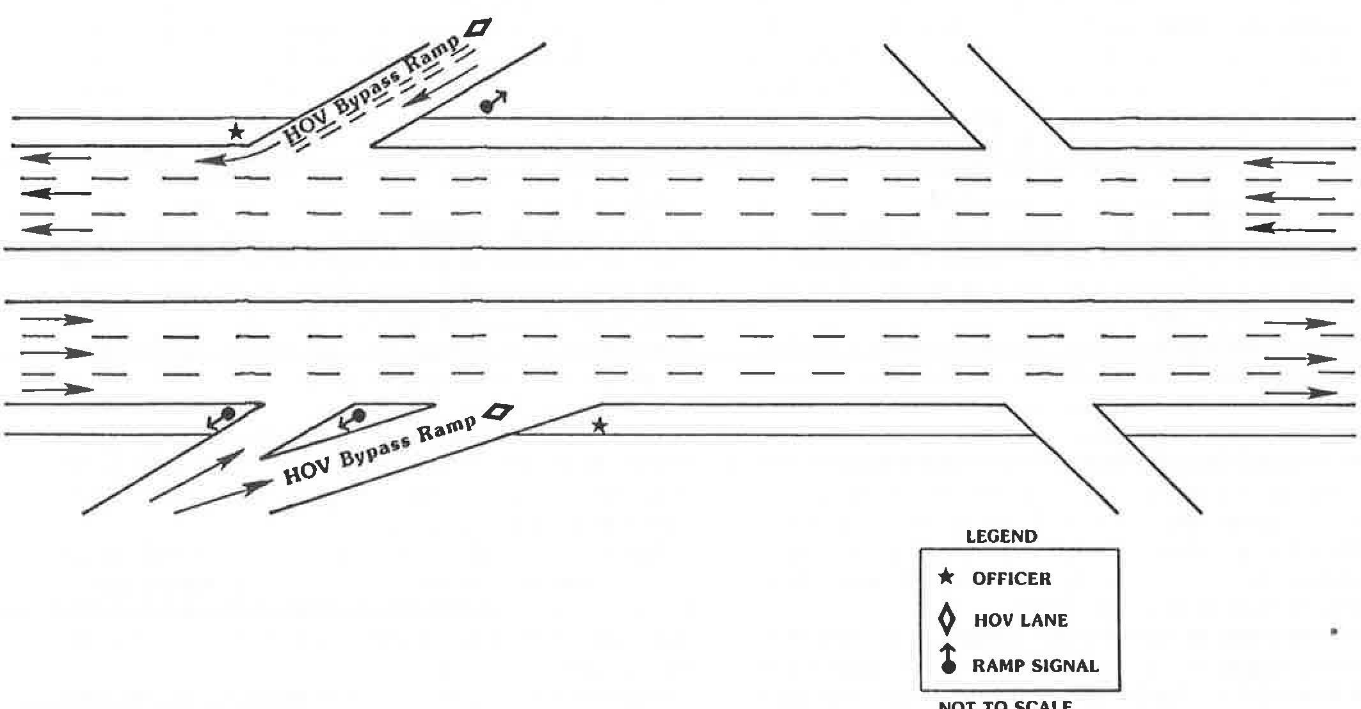

FIGURE 9 Priority entry ramps.

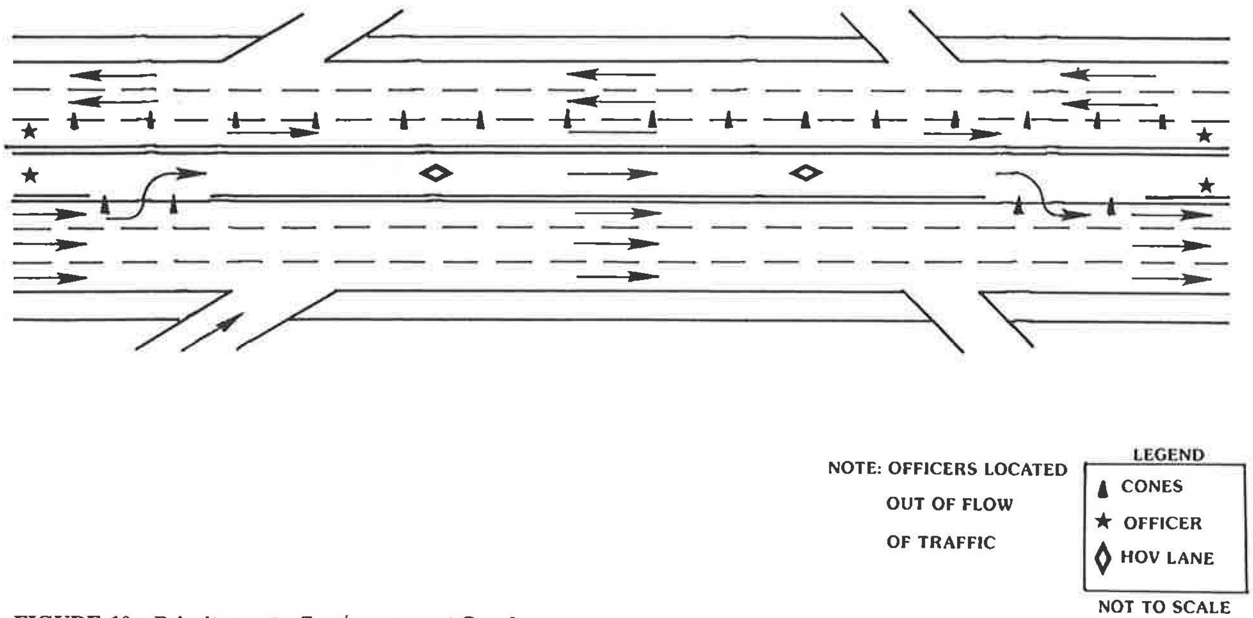

FIGURE 10 Priority contraflow/concurrent flow lanes.

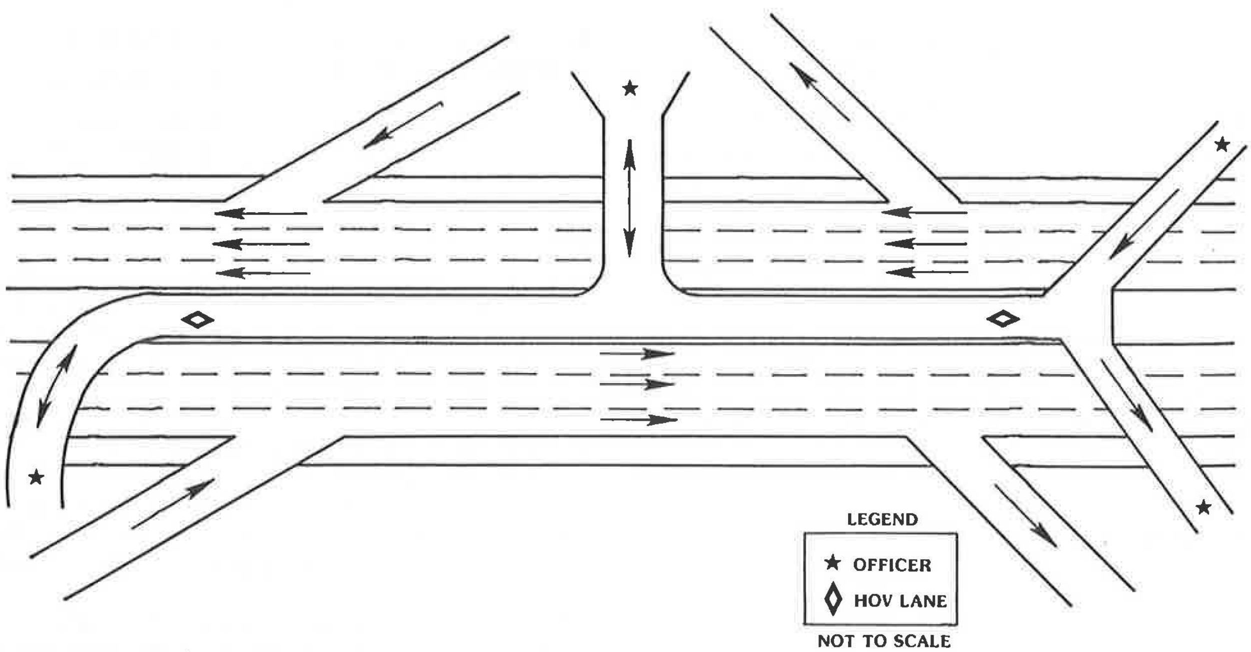

FIGURE 11 Median transitway.

these types of priority facilities. This somewhat insures consistency in enforcement due to more day-to-day facility operating experience by the transit police personnel.

Transportation System Management Operations

Transportation system management (TSM) strategies are actions or groups of actions intended to produce shifts in the supply-demand equilibrium of the transportation system. Many of these strategies involve a rearrangement of physical facilities and/or operating practices, requiring users to face new situations and to learn new rules. Consequently, the success of many TSM strategies, such as ramp metering, commercial vehicle routing, speed zoning, lane restrictions, and shoulder usage, depends on the effectiveness of the enforcement program which accompanies them.

There are three basic enforcement strategies that may be used in conjunction with TSM projects: (a) routine enforcement; (b) special enforcement; and (c) selective enforcement. Specific enforcement procedures for TSM projects may include one or more of the following apprehension and citation procedures: (a) standard; (b) stationary; and/or (c) signaling. Line and stationary patrols with standard or stationary appre-

TABLE 4 GOALS, OBJECTIVES, AND MEASURES OF EFFECTIVENESS FOR SELECTED TSM PROJECT ENFORCEMENT STRATEGIES

System Goal	Transportation Management Objectives	Enforcement Strategies	Measures of Effectiveness
Manage system demand	• Meter freeway input (ramp metering) • Reduce commercial vehicle congestion (commercial vehicle routing) • Segregate vehicle types (lane restrictions) • Reduce incidents and conflicts (e.g., speed zoning)	• Strict enforcement of ramp metering • Strict enforcement of truck/commercial vehicle route regulations • Strict enforcement of lane restrictions • Strict enforcement of speed limits • High visibility of enforcement officers • Institution of selective enforcement programs	• Violations • Violation rates • Travel times
Increase system capacity	• Maximize capacity (shoulder usage) • Minimize travel times	• Institution of selective enforcement programs	• Travel times • Accident rates • Flow rates

hension and citation methods are the most commonly used enforcement procedures associated with TSM improvement projects.

As with priority treatment facilities, the effectiveness of TSM enforcement activities may be evaluated in terms of compliance with posted restrictions and regulations. Table 4 summarizes the goals, objectives, and measures of effectiveness for selected TSM project enforcement strategies.

RECOMMENDATIONS

The guidelines presented provide a framework for assessing the need for using uniformed police personnel for a large range of activities. Although formulated from field observations and expert consultation, these guidelines require evaluation for further refinement. It is the intention of the guidelines to supplement the required traffic control devices and traffic control plans with skilled persons who can command the attention of the motorists and receive compliance with their directives to achieve acceptable levels of operations and safety.

For the guidelines to be effective, they must be able to be implemented. Many issues and problems must be resolved if wide-scale application of the guidelines is to be achieved. The issues can be categorized as: (a) institutional, or dealing with the internal and external orientation and relationships of law enforcement agencies; (b) legal; and (c) economic, or related to manpower and funding.

Institutional

Law enforcement personnel, by virtue of their training, are oriented toward apprehending people who violate laws. They are much more familiar with this aspect of their responsibility than they are with preventing violation or using their authority to control behavior. Because of this orientation, it is not surprising that some officers, when asked to control traffic through work zones, resort to citing violators. This form of institutional resistance is usually compounded by transportation personnel who are not sure of the role law enforcement officers are to play when they are assigned to work zones and to whom they are responsible.

This enforcement orientation is not as prevalent during the occurrence of major incidents because of the requirements to secure the scene from a safety standpoint and because these incidents are usually of short duration. However, the attention of responding officers is on resolving the incident rather than managing the traffic problems that develop. In some cases, the number of officers dispatched to the scene of a major incident is insufficient to handle both the incident management and traffic control roles. During these incidents, many agencies may respond, which may result in confusion over control authority and conflicts of purpose.

The basic institutional issues that should be addressed in assessing enforcement needs are those of enforcement philosophy and interagency cooperation. Most enforcement agencies consider traffic enforcement measures primarily as a means to reduce accidents or improve the safety of a specific facility. This basic philosophy needs to be expanded to encompass the effective use of enforcement strategies in achieving an efficient traffic movement. Early involvement of the enforcement agency in project planning, or additional enforcement agency training programs, may be needed to broaden the enforcement philosophy.

Enforcement agencies tend to be institutionally isolated from those agencies responsible for transportation planning. Typically, police officials are not members of, and do not attend meetings of, formal transportation groups. Police involvement in transportation planning is usually on a project-by-project basis. A significant factor in achieving a successful enforcement program appears to be early involvement in the planning process by representatives of the enforcement agencies affected.

Legal

The primary legal issue that results from the use of law enforcement personnel to control traffic through work zones is the disparity between the job they are contracted to perform and their sworn duty to uphold the law. In order to effectively manage traffic, officers cannot divert attention to the time-consuming activity of stopping and citing violators. However, officers are obligated and trained to take action against drivers committing infractions. This dilemma is further compounded by the restriction against using funds dedicated for construction and maintenance to pay for enforcement activities. These funds, however, can be used to pay for traffic control. In this regard, the primary responsibility of the officer is to the specific task set by the contractor; other enforcement activities become secondary.

Legal issues that should be considered in assessing enforcement needs and procedures include not only the legality and enforceability of a particular strategy, but the responsibility for enforcement as well. In terms of the legality of the enforcement guidelines suggested in this study, the following specific legal issues should be researched with respect to state and local law.

- *HOV priority treatment facilities*: Lane restrictions for HOV facilities may be enforced by state, local, or special (e.g., transit authority) enforcement agencies. Local and/or state ordinances may need to be revised to clarify enforcement responsibilities for such facilities.
- *Work/construction zone speed restrictions*: Work and construction zones typically have lower speed limits than those sections of the roadway on either end of the zones. However, given the current practice of allowing a 5–10 mph leeway in enforcing speed restrictions, the potential effectiveness of these speed restrictions may be diminished. Legislative changes may be necessary to clarify procedures for establishing speed limits and to permit more stringent enforcement of speed limits in construction work zones. Paradoxically, enforcement personnel must balance the need to enforce speed limits with the need to maintain efficient traffic movement in such zones.
- *Use of innovative enforcement procedures*: Various alternatives to standard enforcement procedures have been suggested. A number of legal issues have been raised regarding the employment of some of this advanced technology, especially when it involves photography. Most of the concerns raised to date about the systems have been found not to present formidable legal barriers to their employment in the United States. The major exception is the liability problem, which arises with photographic systems when only the vehicle owner can be identified (through the license plate), and not the driver (*5*).

Economic

The main economic issue is that of allocation of scarce resources. Enforcement agencies are notoriously undermanned and are consequently reluctant to dedicate manpower to areas other than those of the highest priority. In most urban areas, crime prevention and criminal investigation take precedence over traffic law enforcement. Within the realm of traffic law enforcement, traffic control assumes a lower priority than active traffic law enforcement, and the probability of having manpower consistently available for traffic control is small. Consequently, there is a need for funds to hire off-duty personnel on a supplemental basis. Since active enforcement is not desired and since a clear-cut accident problem usually does not exist, selective traffic enforcement, or STEP, funds would not be appropriate. This suggests that funds set aside by contractors for traffic control may be the best source, provided the institutional and legal difficulties can be overcome.

Many police agencies no longer have a special division for traffic. Consequently, traffic enforcement and any other transportation-related activity must compete with the other responsibilities of a police agency. This means that either police enforcement for traffic management functions may not be available on a consistent basis or that alternative means of enforcement and/or funding may be needed.

In the case of scheduled enforcement activities (e.g., construction/maintenance and HOV facility enforcement) enforcement costs could be included as a line item in the project budget. For nonscheduled enforcement activities (e.g., incident management) additional funds will be needed if these activities are to be effectively managed. At this point, it is not clear what source(s) may be available to fund these enforcement activities.

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This paper is based on a study conducted by the Texas Transportation Institute sponsored by the Texas State Department of Highways and Public Transportation entitled "Guidelines For Utilization of Police Officers in Traffic Control and Enforcement on Urban Freeways." The contents of this report reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas State Department of Highways and Public Transportation. This report does not constitute a standard, specification, or regulation.

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Safety Belts and Turn Signals: Driver Disposition and the Law

JON D. FRICKER AND RANDY J. LARSEN

One of the more interesting behavioral issues in traffic safety is the use of safety belts. Engaging in this behavior involves a good deal of personal choice by the driver, given that most statutes call for secondary enforcement of mandatory use laws. A similar situation exists with respect to turn signal use, where drivers are rarely cited for failure to use turn signals except as secondary to an accident or some other violation. Because the use of safety belts and turn signals involves a great deal of personal choice by drivers, it was thought that these behaviors reflect certain aspects of a driver's disposition and should, therefore, be positively correlated. From this rationale, it was hypothesized that there would be a significant and positive relationship between the tendency to use safety belts and the tendency to use turn signals. Field observation of driver behavior supported this hypothesis in two separate studies conducted before and after the enforcement of Indiana's mandatory use safety belt law. Even though the use of safety belts increased after the law went into effect, those drivers who did not use safety belts still tended not to use turn signals. Finally, a discussion of the policy implications of these findings draws upon the growing body of literature in areas that may offer useful analogies—motorcycle helmet laws, drunk driving legislation—in an attempt to focus the promotion of safety belt use.

As of the end of 1988, 31 states and the District of Columbia had laws requiring safety belt use by drivers and front seat passengers in motor vehicles (*1*). Activity in state legislatures on this topic continues. Among the 44 state legislatures that convened in regular session during 1988, 29 considered legislation to enact, amend, or repeal safety belt use laws (*2*). The most significant results were (a) Georgia enacted a mandatory safety belt use law with secondary enforcement; (b) Oregon repealed its law, which had primary enforcement; (c) Oklahoma and Louisiana extended the law to cover vans and light trucks; and (d) Hawaii increased its fine from $15 to $20 (*1*).

No longer is the effectiveness of safety belts the major issue. A previously popular rationale for not using a restraint system—"It's generally safer to be thrown clear of the accident"—has been thoroughly discredited. The number of fatalities and serious injuries that occurred after the dates each mandatory safety belt use law took effect was significantly below the number forecasted in the absence of such laws (*3,4*). The major issue now is freedom of personal choice—even to do something unwise—versus the extra costs to society as a consequence of unwise individual behavior.

Perhaps as a consequence of this philosophical conflict, most mandatory safety belt use laws are not particularly strong. Fines are modest, typically $10–$50. In 23 states and Washington, D.C., the safety belt use law provides for only secondary enforcement (*1*). In Indiana's safety belt use law (Indiana Code 9-8-14-3), "secondary enforcement" means that a motorist cannot be "stopped, inspected, or detained solely to determine compliance with this chapter." The practical meaning of such a law is that personal choice remains largely uninhibited, except to the extent that the existence of a law—even if rarely enforced—exerts a moral influence on a portion of the public.

A similar situation exists with respect to turn signal laws. Although turn signal laws are not truly subject to secondary enforcement, drivers are rarely cited for failure to use turn signals as the sole violation. Even though a turn signal law was enacted by Indiana in 1939, it is rarely enforced except as a contributing factor in accidents or along with other violations.

Because safety belt and turn signal laws are rarely enforced, they do not engender strong pressures for compliance in all drivers. The practical implication of these traffic safety laws is that personal choice to comply remains largely up to individual drivers. Many psychologists have suggested that, in situations where an individual has a good deal of personal choice, those choices will often reflect aspects of the person's disposition or personality (*5*). This implies that the choice to comply with or disregard safety belt and turn signal laws may be determined, in part, by the general disposition of the driver.

DISPOSITION THEORY

In developing this theory, it is assumed that the choice to disregard turn signal use and safety belt use are both behaviors that reflect a single underlying disposition to engage in nonconforming, risk-taking behaviors in general. Such behaviors appear to fall into a category of behaviors summarized by the personality disposition called "sensation seeking." A great deal of research has been conducted on the sensation seeking disposition (*6*), and a well-developed theory has been advanced to explain why certain people frequently engage in nonconforming, risk-taking behaviors (*7*). Briefly, the theory holds that certain people have a biological need to achieve a higher level of arousal than other people. Consequently, the sensation seeker develops a lifestyle that is geared to avoid boredom and routine, and to seek out stimulating activities and

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arousing situations. Sensation seekers often develop a disregard for social mores and a generally impulsive and nonconforming attitude toward the law (*8*). In addition, sensation seeking correlates positively with gambling, physical risk taking, and poor self-control (*6*).

The failure to use safety belts and turn signals both imply a disregard for social mores and laws. Both of these poor traffic safety behaviors are likely to be related to personal risk taking, lack of self-control, and, in a sense, gambling. An example is the driver who refuses to wear a safety belt and states, "I'd rather take my chances." Finally, both of these behaviors (the failure to use safety belts and turn signals) are likely to be exhibited by the impulsive, nonconforming individual.

The "sensation seeking" behavior described here is not necessarily of the sort manifested by those who drive at extremely high speeds or deliberately drive the wrong way on a one-way street. The behavior is often subtle and subconscious, although the actions at issue here—use of safety belts and turn signals—involve personal choice. Moreover, these choices are often made by default. To many drivers, the operation of a motor vehicle has become so familiar that the activity no longer commands a significant degree of conscious effort. Such drivers devote little more than the minimal mental effort needed to operate a motor vehicle. If a driver never took (or no longer takes) the driving task seriously enough to develop (or maintain) good habits, even those that affect the safety of one's self and others, then risk taking is present.

This line of reasoning leads to the suggestion that the failure to use safety belts and the failure to use turn signals are reflections of the same underlying disposition. If this is true, then we should find that drivers who fail to use safety belts also fail to use turn signals and, conversely, those drivers who conscientiously wear safety belts should also conscientiously use turn signals. Based on this rationale, the major hypothesis of this study was that a significant positive relationship would consistently be found between safety belt use and turn signal use.

DATA COLLECTION

To test the hypothesis, data on driver behavior were collected by 32 observers at 29 sites in September 1986. This was during the 1-yr phase-in period for the Indiana safety belt use law (Indiana Code 9-8-14-1). During the period 1 July 1986 and 1 July 1987, only warnings could be issued to violators. Use of safety belts was at that time still completely a matter of personal disposition (i.e., without penalty), although the law's passage and its upcoming effective date had received much publicity. The field personnel observed and recorded whether each driver passed through a study location (a) was wearing a shoulder safety belt, and (b) used turn signals in a situation where the law (or a reasonable, practical, and consistent interpretation of it) called for them.

Each study location consisted of a lane or lanes of traffic in which use of turn signals would be required by law. A preliminary reconnaissance of candidate sites not only led to the selection of the 29 sites used in September 1986, but also indicated which sites (because of traffic volumes or geometrics) required more than one observer and helped the personnel choose the best points from which to make their observations. A wide variety of sites were selected: signalized, stop-controlled, and uncontrolled intersections; exclusive and shared turn lanes; bridge offramps; and entry/exit driveways at shopping centers and apartment complexes. Furthermore, the observations were made on various days of the week and at different times of the day.

TABLE 1 SEPTEMBER 1986 OBSERVATIONS AT 29 SITES

	Signal Used	Signal Not Used	Missed	Row Totals
Belt used	871	287	4	1,162
Belt not used	1,660	844	4	2,508
Missed	179	88	2	269
Totals	2,710	1,219	10	3,939

It was surprisingly easy to detect whether a shoulder safety belt was in use or not, but observers were also urged to record as "missed" those drivers whose safety belt use could not be determined with certainty rather than guess at the observation. Uncertainty usually occurred for older pickup trucks, where only a lap belt may be available, and where the chrome buckle of an unused shoulder belt could not be seen over the driver's left shoulder. Of the 3,939 observations summarized in Table 1, only 277 (or 7 percent) involved "misses." To test the reliability of the observed data, a car-by-car analysis was made of the data sheets submitted by two individuals who observed 107 vehicles at the same site at the same time. There was differences in judgment on belt use for only four vehicles and on turn signal use for only two vehicles.

The data from the 3,662 complete observations at the 29 sites were used to test the following hypothesis: A driver's use of safety belts is related to his/her use of turn signals.

DATA AND STATISTICAL ANALYSIS

From Table 1, the proportion p of drivers wearing safety belts (event B) in September 1986 can be calculated as

$$p(\mathrm{B}) = 1{,}158/(1{,}158 + 2{,}504) = 0.316, \text{ or } 31.6 \text{ percent},$$

which is very close to a 1987 estimate of 0.308 for Indiana (*9*). Likewise, the proportion of drivers observed using turn signals (event T) when they are called for by law was

$$p(\mathrm{T}) = 2{,}531/(2{,}531 + 1{,}131) = 0.691, \text{ or } 69.1 \text{ percent}.$$

This is lower than the 80 percent figure reported in a self-report survey conducted by the AAA Hoosier Motor Club (*10*), but self-report surveys always overestimate desirable behavior. Therefore, both values from our data are consistent with data collected by others.

With respect to the Disposition Theory proposed for this study, the proportion of drivers who use their turn signals among those who wear safety belts, $p(\mathrm{T}|\mathrm{B})$, was

$$p(\mathrm{T}|\mathrm{B}) = 871/(871 + 287) = 0.752 \text{ versus } p(\mathrm{T}) = 0.691 \text{ overall},$$

and the proportion of drivers who wear safety belts among those who use their turn signals, $p(B|T)$, was

$$p(B|T) = 871/(871 + 1660)$$
$$= 0.344 \text{ versus } p(B) = 0.316 \text{ overall.}$$

These data suggest that a driver who wears a safety belt is more likely to use turn signals, and a driver who uses turn signals is more likely to wear a safety belt. To investigate whether these differences are significant enough to claim a relationship, a contingency analysis was conducted. The chi-square test (*11*) was used to determine whether the chance of an observation being in column 1 of Table 1 depended on the row in which the observation fell. A 2 × 2 contingency table has 1 degree of freedom (*df*) and a typical level of significance (α) for such a test is 5 percent, so the critical test parameter value is

$$\chi^2_{df,\alpha} = \chi^2_{1,.05} = 3.841.$$

The chi-square value calculated from the Table 1 data, $\chi^2 = 29.53$, exceeds the critical value of 3.841. This means that the relationship shown in Table 1 would occur by random chance less than 5 percent of the time. These chi-square test results, together with the $p(T|B)$ versus $p(T)$ and $p(B|T)$ versus $p(B)$ values shown earlier, support the safety belt-turn signal dependence proposed by the Disposition Theory.

UPDATED ANALYSIS

The Indiana safety belt use law has resulted in an increase in safety belt use. The most recent statewide survey indicates a 46 percent use rate (*12*) after secondary enforcement had commenced. As a follow-up to our September 1986 survey, data were collected at three sites in June and July 1988 to:

a. confirm the higher safety belt use rate, $p(B)$, and
b. determine the impact of the law, as reflected in the higher $p(B)$, on our Disposition Theory hypothesis.

The first two of these three sites were actually sites 12 and 21 from the September 1986 survey. They were chosen because of their proximity to our offices, not because of any special results found in September 1986. In fact, site 21 was among those sites whose 1986 data did not support the Disposition Theory hypothesis. At these two sites, safety belt use had risen from 34.2 percent during the phase-in period of the Indiana law to 50.2 percent (130 of 259 in Table 2) one year after secondary enforcement began. The contingency analysis indicates that the Disposition Theory still has merit: the calculated $\chi^2 = 23.763$, which is larger than the critical value of 3.841.

The selection of any site or set of sites introduces the possibility of biased data. However, a site-by-site search for factors that would influence the outcome of contingency tests—such as intersection controls, exclusive turn lanes, or adjacent land use—yielded no detectable pattern among our 29 original sites.

The third site chosen in 1988 was one not used in September 1986, but it had some desirable features. From a single observation point, three different situations calling for use of turn signals can be observed: turning onto a state highway, changing lanes, and turning left across the northbound (NB) lanes of the highway. The site (illustrated in Figure 1) is a segment of two southbound (SB) lanes on a state highway (SR 43) in a built-up area with a two-way volume of 12,000 vpd. The site is entered at point 1 either by traffic already on SB SR 43 or by vehicles turning right from Robinson. The use of turn signals by traffic from Robinson was recorded (Yes or No), but this observation was not applicable ("n/a" in Figure 2) to SB traffic already on SR 43. Much of this SB traffic was destined to make left turns to the Harrison Bridge (point 3) over the Wabash River or to the Levee Plaza Shopping Center (point 4). Both turns are served by separate left turn lanes. Whether a driver used turn signals in making a turn at point 3 or 4 and whether a lane change in section 2 involved use of turn signals were also recorded. In Figure 2, "n/a" under "Point 2" means that a vehicle did not make a lane change in that section and, under "Point 3 or 4," "n/a" means that no left turn was made.

During 2 hrs at this site (99 vehicles) in June 1988, only turn signal use was observed. In Figure 2, one can see evidence of a tendency to use (or not use) turn signals. The "16 Yes-15 n/a-10 Yes" branch of the event tree indicates that of the 16 vehicles that used turn signals at point 1, 15 did not change lanes at point 2, and 10 of those 15 used turn signals at point 3 or 4. Thus, only 1 of the 16 vehicles that entered the site at point 1 with proper use of turn signals failed to use them at point 3 or 4. Of the 56 vehicles that entered the site on SB SR 43, 9 used turn signals while changing lanes at point 2 and

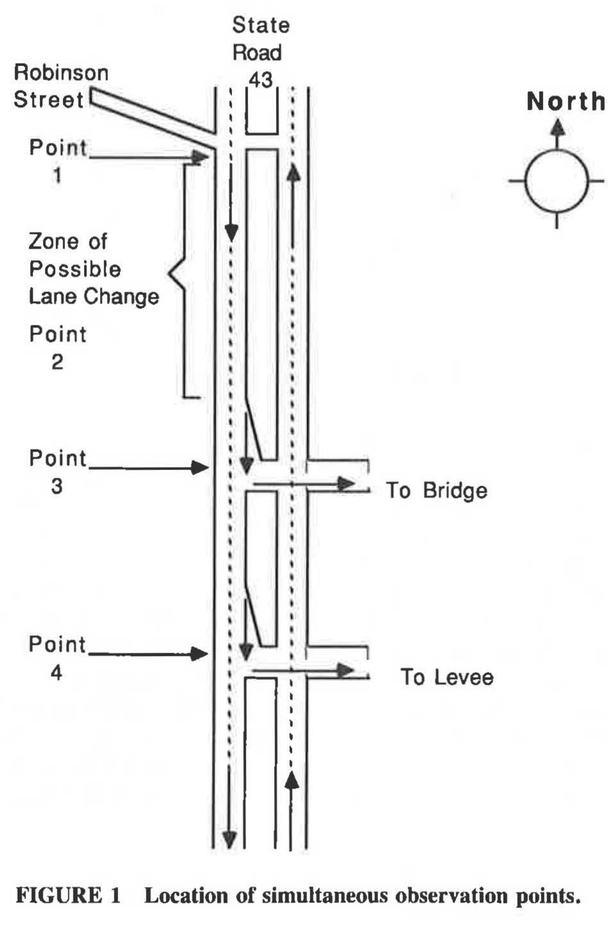

FIGURE 1 Location of simultaneous observation points.

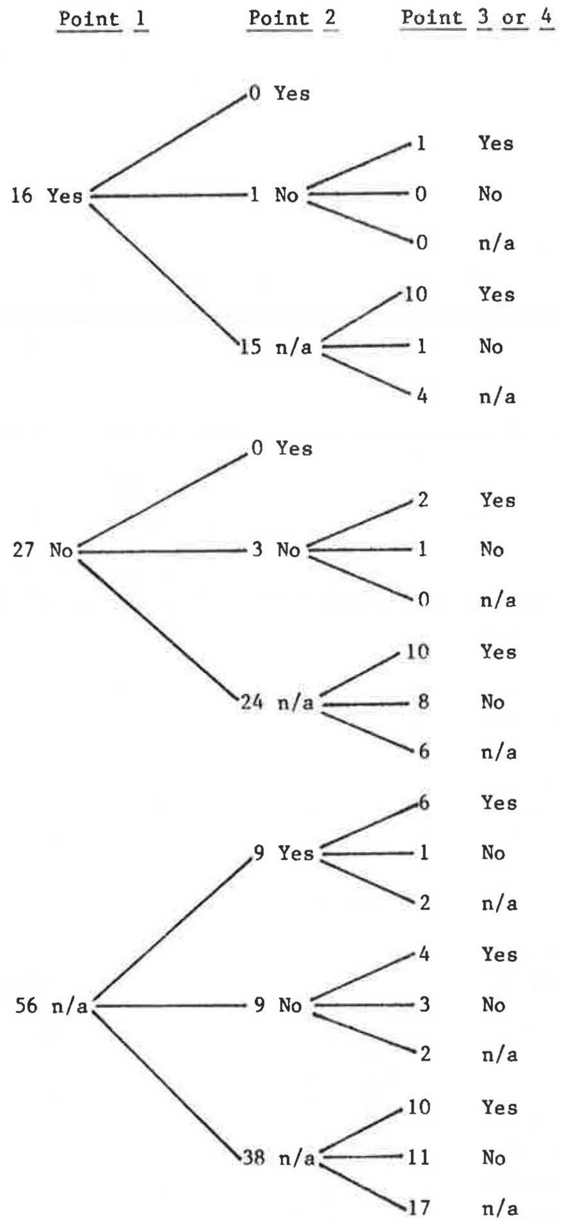

FIGURE 2 Event tree for turn signal use.

9 did not. Among the 9 that did, only 1 out of the 7 that turned left at point 3 or 4 failed to use turn signals; among the 9 that did not use turn signals at point 2, 3 of 7 also failed to use them at point 3 or 4. These chains of events are found along the branches that begin with "56 n/a-9 Yes" and "56 n/a-9 No" in Figure 2. There were 25 cases in which turn signals were used at point 1 or 2—see the branch beginning with "16 Yes" under point 1 and the branch beginning with "56 n/a-9 Yes." These branches end with a total of 17 "Yes" entries, 2 "No" entries, and 7 "n/a" entries under "Point 3 or 4." If the use of turn signals at either point 1 or point 2 is denoted as the event "T12," and if "T34" is defined as use of turn signals at point 3 or 4, one key lesson from Figure 2 is

$$p(\text{T34}|\text{T12}) = \frac{17}{25} = 0.68, \text{ and } p(\text{T34}) = \frac{34}{68} = 0.50.$$

If a turn signal has been used upstream (i.e., at point 1 or 2), it is more likely to be used downstream (at point 3 or 4). This is further evidence of the validity of our Disposition Theory, suggesting that people are consistent as to whether they adopt traffic safety behaviors.

In July 1988, data on safety belt use were collected at the SR 43 site shown in Figure 1. Of the 217 drivers observed, 128 (59 percent) were wearing a safety belt. At this point in the analysis, an attempt was made to identify personal characteristics in the observed driver population that would lead to groups to focus on in a program to promote safety belt use. A significant relationship (calculated $\chi^2 = 5.316$) was found between belt use and sex of driver. Seventy-five of 113 women drivers (66.3 percent) were wearing seat belts, while only 53 of 104 men drivers (51 percent) had seat belts on. Seat belt use by age category was

$$p(\text{B}|\text{young}) = 0.578,\ p(\text{B}|\text{mid-aged}) = 0.566, \text{ and } p(\text{B}|\text{older}) = 0.644.$$

The authors (who were also the observers) defined "young" to be drivers with apparent age 25 years or younger and "older" to be age 50 and up. These age boundaries were chosen not only to make it easier to make judgments, but also with the idea of the target population for education and promotional ads in mind.

POLICY IMPLICATIONS

An increased awareness of traffic safety issues among the general public has been taking root. In addition to the "don't drink and drive" advertisements, a variety of ads that promote safe driving behavior and safety belt use have appeared in the media. Nationwide, safety belt use increased from 11 percent in 1982 to 42 percent in 1987—52 percent in states with belt use laws versus 27 percent in states without such laws (*13*).

The results of the current study suggest that poor traffic safety behaviors tend to occur together. That is, some individuals are more likely to disregard *both* safety belt use and turn signal use. It is interesting to note that turn signal use rose from 68.8 percent before the mandatory safety belt use law took full effect (Table 1) to 80.3 percent afterwards (Table 2). This increase was almost entirely due to belt users. Turn signal use among drivers not wearing safety belts went from 66.3 percent to 68.2 percent, while those wearing belts had their turn signal use rate climb from 75.2 percent to 92.3 percent. Furthermore, the study of turn signal use reported here indicates that individual driver behavior is consistent, even under different specific conditions (e.g., turns and lane changes) where its use is called for.

TABLE 2 JUNE 1988 OBSERVATIONS AT THREE SITES

	Signal Used	Signal Not Used	Row Totals
Belt used	120	10	130
Belt not used	88	41	129
Totals	208	51	259

Another interesting aspect of this study is that the turn signal use rate is generally higher than the safety belt use rate. This appears contrary to logic, since the decision to use a safety belt (a) takes place only once per trip and (b) has clearly demonstrated benefits to the user. Meanwhile, the decision to use a turn signal (a) occurs repeatedly during a trip and (b) has benefits that quite often are greater for *other* vehicle operators in the traffic situation. More investigation into the risk perception and habit aspects of this otherwise irrational behavior appears to be called for. The Disposition Theory suggests that nonusers of safety belts or turn signals likely engage in other high-risk traffic behavior as well. Further data collection efforts are needed to identify groups in need of education with respect to traffic laws and the consequences of high-risk behavior.

Highway safety is something that affects us all directly, and yet many misconceptions and much carelessness persist among the driving public. In many ways, the philosophical and political issues surrounding mandatory safety belt use laws are the same as those for mandatory helmet use by motorcyclists. At one point, 47 states had mandatory helmet laws, but 26 states have repealed or weakened their laws since 1976. The argument has been made that motorcyclists have a right to put themselves at risk, if they choose to do so. However, not only does not wearing a helmet greatly increase the risk of death and serious injuries, but 63.4 percent of motorcycle injury medical costs are paid for by public funds (*14*). Injuries to motorcyclists are being subsidized by the state. A similar case is being built regarding the absence of effective safety belt use laws. One study (*3*) concluded that mandatory safety belt use laws had saved about 1,300 lives through mid-1987, and that the saving of lives would have been greater if enforcement was tougher and/or compliance with safety belt use laws was more widespread. Another study (*15*) estimates a reduction of 1,100 severe or fatal accidents each year in North Carolina since that state's mandatory belt use law (with primary enforcement) went into effect. Besides saving lives, improved traffic safety behavior would undoubtedly save a percentage of state funds that currently subsidize the medical costs of traffic injuries. An evaluation of 1,364 motor vehicle accident victims in the Chicago area indicated that "safety belt wearers had a 60.1 percent reduction in severity of injury, a 64.6 percent decrease in hospital admissions, and a 66.3 percent decline in hospital charges" (*16*). Furthermore, the "findings demonstrate the significant societal burden of nonuse of safety belts in terms of morbidity and the costs of medical care."

A recent study (*17*) of the impacts of raising the minimum drinking age in Tennessee has some interesting findings of possible application to the safety belt use issue. The Tennessee study included a discussion of the relative contributions to decreased drunk driving among various age groups made by stiffened driving under the influence (DUI) laws, the drinking age law, and extensive anti-DUI publicity and social pressure. Since the true risk of detection and apprehension for DUI is estimated to be less than one in 1,000 (*17*) and application of even strict DUI laws can be uneven (*18*), the latter two influences are important elements in combating drunk driving. Just as we have seen a reversal of the general public's view of the smoking habit lead to a steady decrease in the fraction of our population that retains it, so has society's decreasing tolerance of excessive drinking brought about an improvement in the problem of drunk driving. In the Tennessee study, denying 18 to 20 years olds unrestricted access to alcohol was found to be a clearly superior alternative to allowing that age group to "decide" whether to make responsible decisions. At the same time, groups such as Students Against Drunk Driving and publicity given to DUI convictions offer low-cost options to reach appropriate target groups.

The preceding comments offer ideas for the promotion of safety belt use, even in states where enforcement is minimal or no belt use laws exist. This paper attempts to identify one underlying cause for nonuse of safety belts. The results suggest that multi-behavior educational efforts could be developed. That is, instead of advertisements that target a single behavior (e.g., just safety belt use), perhaps a more effective campaign would target multiple safety behaviors within single educational advertisements. What needs to be changed is a general disposition to take risks while driving, which is in itself made up of a variety of safety behaviors that are interrelated. The data in this paper provide evidence of a possible behavioral basis for different traffic safety-related habits or dispositions on the part of drivers. By identifying target groups for educational efforts and encouraging the general public to realize that nonuse of safety belts is an unwise choice, not a declaration of personal freedom or an acceptable manifestation of sensation seeking, the personal risks and societal costs of such behavior can be reduced.

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Highway Accident Patterns in Michigan Related to Older Drivers

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Discussed in this paper are age-group comparative research analyses for trunkline highway accidents in the state of Michigan. Statistics are presented on the frequency and severity of highway accidents and the factors responsible for the types of violations cited in these highway accidents are examined.

Differences in the metric used to indicate exposure to accidents have resulted in considerable debate concerning the relative driving safety of older drivers. In this research, age 60 was taken as the threshold for the definition of the older driver because it was shown that in most instances accident overinvolvement begins to occur between ages 60 and 65. As a result of research conducted in Michigan related to the accident patterns of older drivers (*1*), comparative highway accident data on the state trunkline system based upon several exposure metrics may be developed. Detailed study of these records leads to an identification of several of the factors which differentiate between the accident patterns of younger, middle-aged, and older drivers.

LICENSING TRENDS AND TRAVEL STATISTICS

Licensing data for Michigan indicate that in the period from 1981 through 1986 there were an average of 6.3 million licensed drivers per year in the state. During this period, the total number of licensed drivers increased by only about 1 percent. However, the number of licensed younger drivers, those between age 16 and 24, decreased by 14.6 percent and in 1986 represented about 18.7 percent of the licensed drivers. The number of older drivers, those aged 60 and above, increased by about 14.0 percent over this period and in 1986 represented about 18.1 percent of the licensed drivers in the state (*2*). These data clearly show that the decrease in younger drivers in the state is being offset by an equivalent increase in older drivers. Perhaps more significant is the fact that the number of licensed drivers of age 70 or more increased by 32.2 percent over this period, and in 1986 this group represented 7.3 percent of the driving population in the state.

Data representing the number of vehicle-miles of travel by drivers of different age groups show that drivers age 60 and over are responsible for about 11.4 percent of the vehicle-miles of travel in this country. Both licensing and travel data are typically utilized as measures of exposure in order to estimate the relative safety of drivers on highways in this country.

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Highway Accident Statistics

Depending upon the measures used, older drivers may be considered to be either relatively safe or relatively unsafe drivers. The number of reported interstate and noninterstate multivehicle accidents on the state trunkline system in Michigan during the period from 1983 through 1985, the most recent period for which complete data are available, is shown in Table 1 by age group.

As may be seen, the total number of reported accidents increased over this period by 40.5 percent. Interstate accidents, which represented 13.0 percent of the reported accidents in 1985, increased by 62.9 percent and non-interstate accidents, which represented 87 percent of the reported accidents in 1985, increased by 37.7 percent. The reasons for the disproportionate changes in interstate and noninterstate accidents is thought to represent the effect of improved economic conditions and stable fuel prices, which results in greater vehicle-miles of travel. The relative involvement of each of the age groups in total accidents remained relatively stable over this period.

Comparative Accident Involvement Measures

The proportion of age group involvement in reported accidents in 1983 may also be compared to the proportion of the number of vehicle-miles of travel and the proportion of licensed drivers in each age group as shown in Table 2. If the proportion of vehicle-miles of travel and the proportion of licensed drivers are considered measures of accident exposure, then a group is underrepresented or underinvolved in accidents if the ratio of the proportion of accidents to the respective exposure metric is less than 1.0. If the ratio is greater than 1.0, the group is over-represented or over-involved in accidents. Underinvolvement infers more safety in driving and overinvolvement infers less safety in driving. A ratio of 1.0 indicates the rate of involvement in accidents is equal to the rate of exposure to accidents.

As may be seen in Table 2, the ratio of the percentage of accidents to the percentage of vehicle-miles of travel indicates that younger drivers are involved in accidents at a rate of more than twice their exposure, older drivers are involved in accidents at a rate slightly above their exposure, and middle-aged drivers are involved in considerably fewer accidents than their rate of exposure. When the ratio of the percentage of accidents to the percentage of licensed drivers is used, younger drivers are significantly overinvolved in accidents, older drivers are considerably underinvolved in accidents, and middle-

TABLE 1 REPORTED TRUNKLINE MULTIVEHICLE ACCIDENTS IN MICHIGAN, 1983 AND 1985 (*4*)

Driver Category	Interstate		Non-Interstate		Total	
	1983	1985	1983	1985	1983	1985
Younger	2,073	3,514	20,080	28,315	22,153	31,829
Middle-aged	4,366	7,132	28,210	38,748	32,576	45,880
Older	580	787	7,082	9,174	7,662	9,961
Total	7,019	11,433	55,372	76,237	62,391	87,670

aged drivers are somewhat underinvolved in accidents. Both vehicle-miles of travel and the number of licensed drivers are valid exposure metrics that have legitimate applications to various types of travel studies. Since most data indicate that the drivers in each age group do not drive the same amount of mileage or operate under driving conditions with the same degree of difficulty (*5*), more credibility in accident analysis is usually attached to the first exposure metric based on vehicle-miles of travel. If this interpretation is used here, it is also apparent from these data that driver safety increases with increasing age between younger drivers and middle-aged drivers but also decreases with increasing age between middle-aged drivers and older drivers. The accident ratio for older drivers is 51.3 percent higher than that for middle-aged drivers. For drivers of age 70 and above, Michigan data indicate that the rate of accident involvement approaches that of the younger driver.

The rate of accident occurrence is often stated in terms of the number of accidents per licensed driver or the number of accidents per vehicle-mile of travel. These data have been analyzed for the period from 1983 to 1985 on the state trunkline system and the average annual accident rates are shown in Table 3. As may be seen from these data, the average accident rate for all drivers on the state trunkline system was 11.8 accidents per thousand licensed drivers and 1.15 accidents per million vehicle-miles of travel. The accident rate of younger drivers is significantly higher than the average for both exposure metrics; whereas, the accident rates for middle-aged and older drivers are slightly less than the average for both exposure metrics. Again, the accident rate for older drivers is higher than that for middle-aged drivers by 23.9 percent based upon the vehicle-miles of travel exposure metric.

As a result of this research, a measure of the exposure of drivers of different ages to accidents was derived from the records for trunkline system accidents in the state. This measure of exposure has been discussed in the literature (*1*). It is based upon the relative frequency of driver involvement in multivehicle accidents in which the driver was not cited on the accident record for committing a hazardous action contributing to the accident, that is, Driver 2. This is termed the "innocent victim" concept of exposure to accidents. The Driver 2 percentage in all multivehicle accidents in Michigan in 1983 for drivers age 60 and over was found to be 10.2 percent (*2*). A relative accident involvement ratio was derived for use in this research. This ratio was defined as the ratio of the relative frequency of multivehicle accident involvement in which a driver was cited for committing a hazardous action contributing to the accident, Driver 1, to the relative frequency of multivehicle accident involvement in which the driver was not cited for a hazardous action contributing to the accident, Driver 2. If the ratio is less than 1.0, accident involvement is less than accident exposure, or an underinvolvement in accidents, which is interpreted in this research as indicating greater driver safety. If the ratio is greater than 1.0, accident involvement is greater than accident exposure, or an overinvolvement in accidents, which is interpreted in this research as indicating less driver safety.

This measure of relative accident involvement is similar to that developed by Cerrelli (*6,7*) in which drivers were divided into those responsible and not responsible for multivehicle accidents to develop a relative exposure index, a liability index, and a hazard index for drivers of various age groups. The principal difference between Cerrelli's work and this research is that an examination of many different types of multiple vehicle accidents was undertaken to discover, for example, the relative accident involvement ratio on interstate and non-interstate highways, both at interchanges and intersections. Most of the work of others, for example, Carlson (*8*), Haight

TABLE 2 COMPARISON OF PROPORTION OF AGE GROUP REPRESENTATION IN MULTIVEHICLE ACCIDENTS, VEHICLE-MILES OF TRAVEL, AND LICENSED DRIVERS FOR ALL REPORTED TRUNKLINE ACCIDENTS IN MICHIGAN, 1983 (*2–4*)

Driver Category	Percentage of			Ratio of Percentage of Accidents to Percentage of	
	Acc	VMT	Lic	VMT	Lic
Younger	35.5	16.0	20.3	2.22	1.75
Middle-aged	52.2	72.7	62.6	0.72	0.83
Older	12.3	11.3	17.1	1.09	0.72
Total	100.0	100.0	100.0		

TABLE 3 ANNUAL AVERAGE TRUNKLINE MULTIVEHICLE ACCIDENTS, LICENSED DRIVERS, VEHICLE-MILES OF TRAVEL, AND ACCIDENT RATES FOR THE MICHIGAN TRUNKLINE SYSTEM, 1983 THROUGH 1985 (*2,4*)

Driver Category	Total Accidents	Licenses (Thousand)	VMT (Million)	Accidents per Licenses (Thousand)	Accidents per VMT (Million)
Younger	26,570	1,310	12,125	20.3	2.19
Middle-aged	38,443	3,890	43,841	9.9	0.88
Older	8,667	1,026	7,972	8.4	1.09
Total	73,680	6,226	63,938	11.8	1.15

(*9,10*), Koornstra (*11*), and Thorpe (*12*), sought to formulate measures of induced exposure from accident records related to both single and multivehicle accidents and, in some cases, from licensed drivers [for example, Wasielewski and Evans (*13*)]. This research did not seek to derive exposure from these accident records but defined exposure based upon the innocent victim in a multiple vehicle accident. This approach is similar to that used by Carr (*14*) and Hall (*15*) in the assigned responsibility model. A comparison of the results of the research reported herein with that of others was reported earlier (*1*).

Using this relative accident involvement ratio, it can be shown that older drivers are more likely to be involved in highway accidents than other drivers when the innocent victim concept is used as a measure of exposure to highway accidents. Table 4 shows the designation of Driver 1 and Driver 2 for state trunkline multivehicle accidents for the period from 1983 through 1985. These data indicate that in about 221,000 multivehicle accidents over this period, older drivers were cited as the driver at fault in 11.8 percent of the accidents and were considered the innocent victim in 9.9 percent of the accidents. Therefore, older drivers are over-involved in accidents with a relative accident involvement ratio of 1.19. This over-involvement ratio is similar to that of younger drivers who have a relative accident involvement ratio of 1.21, but it is 38.4 percent higher than middle-aged drivers who have a relative accident involvement ratio of 0.86.

TYPES OF ACCIDENTS

Because of the significantly higher occurrence of non-interstate accidents, analyses were performed on the accident data to try to gain some knowledge of the accident patterns of older drivers. When the accident data are tabulated into single and multivehicle non-interstate trunkline accidents, as shown in Table 5, older drivers tend to be involved in multivehicle accidents to a greater extent than other drivers. That is, given that an older driver is involved in an accident, there is an 83.1 percent chance that it is a multi-vehicle accident; whereas, for all drivers there is only a 75.4 percent chance that it is a multivehicle accident. These data suggest that there is a greater chance for older drivers to involve other drivers in accidents than there is for the driving population at large.

The noninterstate multivehicle accidents were then broadly categorized into rear-end, head-on, angle, and side-swipe type accidents. These data show that older drivers are slightly more susceptible to head-on accidents than either younger or middle-aged drivers and significantly more prone to angle type accidents than either of the other driver groups.

Older drivers have a greater chance of being cited for a violation when they are at fault in an accident than do other drivers. Data show that in 16 percent of the head-on accidents in which younger drivers were at fault and 21 percent of the accidents in which middle-aged drivers were at fault, no violation of traffic laws was cited in the accident record as contributing to the accident. However, only in about 12 percent of the accidents in which older drivers were at fault was no violation cited. Typically, older drivers are cited for failure to yield the right-of-way and illegal turns to a greater extent than other drivers for head-on accidents. In rear-end accidents, older drivers are more frequently cited for failure to yield the right-of-way, illegal turns, and improper lane usage than other drivers. Failure to yield the right-of-way is the major violation for all drivers in angle accidents at intersections, but the incidence of this violation is proportionately higher for older drivers.

TABLE 4 RELATIVE ACCIDENT INVOLVEMENT RATIO FOR MULTI-VEHICLE ACCIDENTS ON THE STATE TRUNKLINE SYSTEM, 1983 THROUGH 1985 (*4*)

Driver Category	Driver 1 Number	Driver 1 Percent	Driver 2 Number	Driver 2 Percent	Relative Accident Involvement Ratio
Younger	79,709	36.0	68,329	29.7	1.21
Middle-aged	115,329	52.2	138,746	60.4	0.86
Older	26,001	11.8	22,674	9.9	1.19
All	221,039	100.0	229,749	100.0	

TABLE 5 SINGLE AND MULTI-VEHICLE NON-INTERSTATE TRUNKLINE ACCIDENTS IN THE STATE OF MICHIGAN, 1983 THROUGH 1985

Driver Category	Number of Accidents		Multivehicle Percentage
	Multivehicle	Single Vehicle	
Younger	71,128	21,192	77.0
Middle-aged	98,102	37,048	72.6
Older	23,912	4,877	83.1
All	193,142	63,117	75.4

FACTORS RESPONSIBLE FOR ACCIDENTS

The accident reporting form completed by the investigating officer at the scene of an accident is converted into a computerized record that lists items which may be indicated as contributing circumstances to the accident. The contributing circumstances for non-interstate trunkline accidents show that for each age group both skidding and driving under the influence are the major contributing circumstances for such accidents. There is little difference in the percentage of accidents attributed to skidding among the age groups, each age group having slightly over 30 percent of its accidents due to this contributing circumstance. The incidence of driving under the influence as a factor in about 32 percent of the accidents for drivers in the age group from 25 to 59 is not unexpected. However, the fact that about the same percentage of accidents, 22 percent, have driving under the influence as a factor for both the younger and older age groups was somewhat surprising given the frequency of younger driver involvement in alcohol-related accidents. It was expected that older driver involvement in such accidents would be considerably less than younger drivers. It is thought that the relatively high proportion of leisure time available to older drivers may contribute to this phenomenon.

Perhaps more significant is the relative percentage of accidents due to illness, fatigue, or inattention and due to obscured vision for older drivers relative to other drivers. These two contributing circumstances are more significant for older drivers than they are for the other driver groups. This tends to confirm suggestions that physical limitations or mental distractions play a significant role in contributing to multi-vehicle accidents involving older drivers. The type of visual obstruction is also noted on the accident record. These data show that slightly more than 60 percent of the visual obstructions for each age group are physical obstructions outside the vehicle. Each of the other types of visual obstructions, except glare, seem to follow expected patterns. In the case of glare, the older driver is affected by this factor to a greater extent than other drivers. This likely follows from the fact that there is a significant decrease in visual acuity for older drivers.

ACCIDENT SEVERITY

An examination of non-interstate accidents for severity was also undertaken. Accident severity is indicated on the accident record as a fatality, incapacitating injury, non-incapacitating injury, possible injury, or no injury. The data were analyzed for all such accidents during the period from 1983 through 1985 and the results show that 28 percent of the fatalities are younger drivers, 50 percent are middle-aged drivers, and 22 percent are older drivers. However, there is a higher incidence of a fatality occurring than each of the other types of accident severities for an older driver involved in an accident.

The fatality rate for older drivers is the highest of any of the driver categories by either exposure metric. It is 33.7 percent higher than the average rate for all drivers using thousands of licensed drivers as the exposure metric, and it is 81.3 percent higher than the average rate for all drivers using the millions of vehicle-miles of travel metric. These data indicate that there is a greater chance for an older driver to be a fatality in an accident than there is for other drivers.

SUMMARY

This paper has shown that the accident records of older drivers are not nearly as good as those of middle-aged drivers. In some cases, the accident records of older drivers are similar to those of young drivers. A new exposure metric based upon the "innocent victim" concept was introduced and the relative safety of various driver groups computed on the basis of this exposure method compares favorably to accident rates based upon the vehicle-miles of travel exposure measures.

Trends in the licensing of drivers in the state indicate that younger drivers are being replaced by older drivers in the population in a virtually one-to-one ratio. Accident data in Michigan indicate that older drivers are more likely to be involved in a multi-vehicle accident than other drivers and that older drivers have a greater proneness for head-on and angle-type accidents on non-interstate highways than other drivers. Older drivers are cited for violations related to failing to yield the right-of-way, illegal turns, and improper lane use to a greater extent in the accidents in which they are involved than are other drivers. Glare seems to affect older drivers more than other drivers, which may be due to diminished visual acuity. The fatality rate of older drivers is considerably higher than that of all drivers.

It is expected that the findings summarized above are applicable to the study of the driving safety of older drivers throughout the country.

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Short-Term Effects of Safety-Related Recalls on New Vehicle Purchase Decisions: An Empirical Analysis

PATRICK S. MCCARTHY

Since passage of the National Traffic and Motor Vehicle Safety Act, the federal government has played an active role in regulating vehicle safety. In addition to mandating that vehicle manufacturers equip new vehicles with a variety of accident prevention and crash protection devices, the federal government requires manufacturers to report any defects that may develop. To date, much of the research in this area has concentrated on the highway safety effects of accident prevention and crash protection regulations. On the other hand, there has been relatively little research on government recall campaigns and the effect these may have upon the demand for new vehicles. Although it is known that well-publicized recalls of a major defect (e.g., the gas tank problem in the Ford Pinto or the recent accelerator problem in the Audi 5000) will have an immediate effect on current demand for the recalled vehicle, there are other questions whose answers are less clear. Will such campaigns affect contemporaneous demand only or will there be lingering effects on future demand? Do recall campaigns of a less serious nature have any effect upon new vehicle purchase decisions? The purpose of this paper is to develop and estimate an economic model that addresses the short-term effects of recall campaigns upon consumer behavior.

In 1966, Congress passed the National Traffic and Motor Vehicle Safety Act, which empowered the federal government to set national safety standards for motor vehicles. Section 151 of this act requires that if a manufacturer:

> (1) obtains knowledge that any motor vehicle or item of replacement equipment manufactured by him contains a defect and determines in good faith that such defect relates to motor vehicle safety; or
>
> (2) determines in good faith that such vehicle or item . . . does not comply with an applicable Federal motor vehicle safety standard prescribed . . . ; [then] he shall furnish notification to the Secretary [of Transportation] and to owners, purchasers, and dealers . . . and he shall remedy the defect or failure . . . .

In an effort to distribute this information, the National Highway Traffic Safety Administration (NHTSA) publishes quarterly summary reports on safety-related recalls conducted by domestic and foreign manufacturers.

Reflecting the significant amount of private and public resources devoted to ensuring that new motor vehicles satisfy government-mandated regulations, much of the research in this area has focused upon the highway safety effects of the regulations [Lave and Weber (*1*), Peltzman (*2*), Arnould and Grabowski (*3*), Graham et al. (*4*), and Crandall et al. (*5*)]. On the other hand, surprisingly little research has been undertaken on the effects of motor vehicle recall campaigns upon new car purchase decisions.

The purpose of this paper is to develop and estimate a model that identifies the effects that a recall campaign will have upon new car purchase decisions. All else held constant, a safety-related recall for a particular make/model may affect the expected benefits associated with the recalled vehicle. To the extent that it does, one would expect the recall campaign to alter the relative choice probabilities of the available set of new vehicles.

In the following section, the theoretical effects of a safety-related campaign will be discussed. Following this, the sources of data and development of an estimation data set will be outlined. The estimation results are then presented followed by a summary of the paper and concluding comments.

THEORETICAL CONSIDERATIONS

In economic theories of consumer behavior, individuals are generally assumed to be wealth or economic welfare maximizers. This implies that individuals will continue to consume a commodity up to the point at which the marginal benefit of one more unit equals the marginal cost of obtaining one more unit. Equalizing marginal costs and benefits typically characterizes individual consumption of a good that can be altered in small amounts, that is, a divisible good. If the good in question is discrete rather than divisible, then it is not possible to increase or decrease the consumption of the good in response to a change in existing economic circumstances. Rather, the consumer will simply switch from one good to another. In the case of discrete commodities, an individual has a set of alternatives available to him/her and will select that alternative that provides the greatest level of economic welfare. Suppose, for example, that an individual is in the market for a new car and that, all else held constant (including the prices of other new vehicles), the price of a particular make/model vehicle increases 10 percent. Because the individual has not yet purchased an automobile he will not respond by consuming a little less of the vehicle. The increase in price will, however, decrease the *probability* that the consumer will purchase this particular make/model. For discrete commodities, then,

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changing economic circumstances or other factors that affect the expected benefit derived from the good will alter the probability of selecting the good.

To be more explicit, assume that individual n is in the market for a new car and has J_n mutually exclusive and exhaustive make/model alternatives available. Each available make/model alternative provides the individual with some level of economic welfare, $U_{in}(x_{in},t_n)$ $i \varepsilon J_n$, where x_{in} is a set of variables that characterizes vehicle i and t_n represents attributes specific to individual n.

Included in x_n is not only the capital and operating costs of the vehicle but myriad other factors that influence an individual's choice of one vehicle over another, including (but not exclusive to) acceleration, vehicle comfort, styling, safety, and passenger/cargo space. All else held constant, an increase (decrease) in any attribute of a given make/model which would increase (decrease) the level of economic welfare associated with this vehicle would increase (decrease) the frequency with which the vehicle is purchased.

The second set of variables, t_n, corresponds to all characteristics of individual n relevant to his/her vehicle choice decision. These include such factors as household size, household income, preferences for imported versus domestic vehicles, and life cycle stage.

If make/model i provides individual n with the highest level of economic welfare, then

$$U_{in}(x_{in},t_n) > U_{jn}(x_{jn},t_n) \; i,j \, \varepsilon \, J_n; \; i \neq j \qquad (1)$$

In order to examine fully the effects of safety recalls on consumer choice, two aspects of the process will be identified: the impact of announced recalls on one make/model when a manufacturer has no history of producing defective automobiles; and the screening effects associated with a manufacturer that has a history of producing defective vehicles.

EFFECT OF A SAFETY-RELATED RECALL IN THE CURRENT MODEL YEAR

To isolate the effect that vehicle recalls have on new car purchase decisions, suppose that one manufacturer annually produces all new vehicles sold. Then, in any given year, an individual in the market for a new vehicle will purchase that vehicle that maximizes his level of economic welfare. Note that included in the vector of vehicle attributes, x_{in}, is vehicle reliability. Initially, because each vehicle is new and produced by the same manufacturer, there is no reason to believe, a priori, that one model will be any more or any less reliable than any other model. In effect, an individual is assumed to have equal uncertainty about the future reliability of each model in the new vehicle market so that, at the margin, this attribute is irrelevant to one's decision.

Suppose this assumption is relaxed. In particular, assume that until the current model year no defective vehicles in previous production years were produced. However, in the current model year, all production units of a given model have a safety-related defect. Before a purchase decision, the problem is identified by the government and a recall campaign for that model is announced. All else held constant, the expected benefits of the recalled model will fall relative to all other vehicles offered, which lowers the probability of an individual purchasing the vehicle. In this case, the identified problem increases the uncertainty regarding future performance of the recalled vehicle relative to the rest of the market. This result is true notwithstanding that the identified problem is corrected prior to one's purchase. Assuming that identified safety-related defects cannot be solved through engineering design changes in the current model year production, ad hoc procedures employed to fix a safety-related defect will still reduce a recalled vehicle's expected benefits relative to non-recalled vehicles on the market.

EFFECT OF A SAFETY-RELATED RECALL IN PRIOR MODEL YEARS

The above conclusion rests upon the assumption that the identified problem occurs in the current model year. Alternatively, assume that with the exception of the previous model year production no vehicles produced by the manufacturer were defective. In the previous model year, a given model was subject to a safety-related recall. As concluded above, the recall in the previous year would have a negative contemporaneous effect upon the probability of purchasing that model. However, there are two potential effects on *current* model year consumption. First, if the recall is indicative of declining production quality, the uncertainty associated with the model's expected performance would increase and the probability of purchase would decrease, all else held constant. This is not a likely result, however, since the model has posited a one-time recall occurrence. That is, the manufacturer has not exhibited a history of defective production. Second, a profit maximizing manufacturer has an economic incentive to correct problems identified in a previous model year production. In order to minimize the direct costs of a recall as well as liability costs, the less costly procedure, when possible, for fixing a safety-related defect is through vehicle redesign rather than employing ad hoc procedures.

Thus, all else held constant, a consumer in the current model year will have greater certainty regarding the vehicle's performance on that attribute which was subject to recall in the previous year. By increasing the expected benefits of that model, the probability of purchase would increase.

Suppose, on the other hand, that the only safety-related recall occurred two years prior to the current model year. Again, since the manufacturer does not exhibit any historical pattern of defective production, this will not have an adverse effect upon the probability of purchase in the current model year. But it may again increase the probability of purchase since this information reduces a consumer's uncertainty in the present period. Moreover, if recent information is valued more than distant information, the effect on the probability of purchase will be less in this case than when the recall occurred in the immediately preceding year.

In general, economic theory suggests that recalls which occur in previous years will increase the probability of purchasing current year models, all else held constant. But this effect will be greater the more recent the recall.

SCREENING BEHAVIOR

In the preceding analysis, it was assumed that all vehicles were produced by a single manufacturer with no history of producing defective vehicles. Suppose, alternatively, that there are two producers each of which manufactures multiple vehicle models. In addition, assume that one firm consistently produces vehicles not subject to recalls and the second firm has had its models recalled in the previous model years. In the current model year, neither the firm nor the purchaser knows which, if any, of its models will be recalled. This suggests that a consumer uses a manufacturer's past recalls to screen models produced in the current year. For firm two, then, expected reliability of *all* current models is lower. This reduces the economic welfare associated with firm two vehicles, which reduces the probability of purchase, all else held constant.

If the manufacturer of less reliable vehicles experiences a recall in the current model year, the effect on the probability of purchase reinforces the screening effect. Consequently, a recall in the current model year will lead to the same qualitative results for both the "safe" and the "unsafe" producers, although one would expect to see a stronger effect for the "unsafe" producer.

The effect of previous year recalls upon current model demand leads to ambiguous effects in the presence of screening effects. Although, as discussed above, prior year recalls increase the probability of purchase in the present year (all else held constant), a history of government recall actions reduces, if not completely offsets, this effect. Thus, the effect of prior year recalls upon the likelihood of current model purchases is expected to be positive for the "safe" manufacturer and ambiguous for the "unsafe" producer.

DATA

Data for this analysis came from three sources. In July 1985, J.D. Powers and Associates conducted a nationwide survey of new 1985 vehicle buyers who had taken delivery in February/March 1985. A total of 68,825 surveys were mailed and 30,306 returned 5 yielding a 45 percent response rate. For each of the 143 vehicle models produced in 1985, a stratified random sample was used to obtain approximately 200 usable observations per model. The survey obtained information on multiple facets of new vehicle purchase decisions, including a description of the new vehicle purchased, purchasing and financing arrangements, source of sales by make and market segment of vehicle, owner loyalty, and socioeconomic characteristics of the principal purchaser and household.

A second source of information was the Automobile Club of Southern California. Since 1984, the Automobile Club has had a Target Car program in which it evaluates currently manufactured four passenger vehicles on various design characteristics, including crashworthiness potential, fuel economy, luggage capacity, size, ride quality, entry and exit, interior noise, and interior size. Cost information and performance characteristics for each vehicle are also collected.

A third data source was NHTSA, which provided detailed information on safety-related recalls for 1984 and 1985 model year vehicles.

Although the national survey of households provided purchase information on each of the 143 make/models produced in 1985, the usable data set included a smaller number of make/models. This reflected two factors. First, the Target Car program did not test each of the new vehicles but annually evaluated a subset of vehicles based upon the following criteria: four passenger vehicle; significant new design; vehicle not tested in the previous year; enclosed cargo/luggage area; and similar vehicles not tested. Specifically excluded from the testing program were sports cars (e.g. Porsche) and "sporty" cars (e.g., Ford Mustang, Chrysler Laser). And second, Ford, Chrysler, and General Motors have "sister" cars; that is, automobiles that are structurally similar. For example, Tempo and Topaz for Ford; Reliant and Aries for Chrysler; and Toronado, Riviera, and Eldorado for General Motors are, respectively, in the same family line. In the event that a given make/model was not tested by the Automobile Club but a "sister" car was evaluated, the specifications for the sister car were used. Thus, from the 143 make/models produced in 1985, the set of included make/models numbered 68.

In addition to the smaller number of included make/models, a second factor that reduced the size of the usable sample was absence of relevant data. Thirty percent of the surveyed households were eliminated as a result of missing data on a number of important variables (e.g., household income and household size).

The usable data set containing all of the relevant socioeconomic and vehicle data comprised 4,902 observations. Since this was too large for estimation purposes, a sample was drawn from the usable data set under the constraint that the sample proportion of each of the 68 make/models represented in the usable data set equaled the proportion in which each of these are represented in the population. This procedure guarantees that the estimated parameters of the model will be consistent [Ben-Akiva and Lerman (*6*)]. This sampling strategy resulted in a random sample of 726 observations. Comparing the mean values on a large number of vehicle and socioeconomic characteristics revealed that the random sample was representative of the larger sample.

Finally, before estimating the model, it was necessary to define the alternative choice sets for each individual in the sample. Since the Automobile Club and the J.D. Powers data contained 68 new car make/models, 14 randomly selected vehicles were drawn from the set of feasible make/models and assigned to each of the 726 observations in the estimation sample. These 14 assigned alternatives combined with an individual's chosen alternative give each observation a choice set of 15 make/models. McFadden (*7*) has shown that this sampling-of-alternatives technique satisfies a uniform conditioning property, which ensures that the coefficient estimates will be efficient. For a more comprehensive discussion of the data development, see McCarthy (*8*).

ESTIMATION RESULTS

Conditional logit analysis was used to estimate the effect that recall campaigns have upon new car purchase behavior. Table 1 identifies the relevant vehicle attributes and household socioeconomic factors that determine an individual's choice of vehicle. The expected effect of most variables upon new car purchase behavior is straightforward. All else held constant, it is expected that each of the cost-related attributes will decrease the likelihood of purchase. Also, assuming that increased vehicle performance is associated with lower slalom

TABLE 1 VEHICLE ATTRIBUTES AND HOUSEHOLD SOCIOECONOMIC FACTORS

Variable	Definition
Cost-Related Attributes	
Price share	Purchase price of vehicle divided by annual household income.[a]
Operating cost	Per mile fuel cost, defined as the average gasoline price in respondent's home state divided by the EPA's fuel economy for city driving.
Performance-Related Attributes	
Slalom	Time required to complete a slalom test course (seconds).[b]
Comfort-Related Attributes	
Front/rear leg room	The sum of front and rear leg room (inches).[c]
Front/real shoulder room	The sum of front and rear shoulder room (inches).[d]
Interior noise level	Interior noise level at 30 mph (decibels).
Entry/exit	Ease of entry and exit from the vehicle. Entry/exit takes on a value from 1 to 10 where 10 is the best.[e]
Door sill height	Door sill height (inches).
Safety-Related Attributes	
Crashworthy index	Dummy variable which equals 1 if vehicle is identified as one of the most crashworthy vehicles in the 1985 model year, 0 otherwise.[f]
Vehicle weight	Vehicle weight (pounds).
Cargo Carrying Attributes	
Trunk size	Size of cargo space specified in the EPA fuel economy guide (cubic feet).
Vehicle Reliability	
Recall (1984)	Total number of recalls associated with the 1984 model year of make/model.
Recall (1985)	Total number of recalls associated with the 1985 model year of make/model.
Recall date (1984)	Number of months, before purchase, of latest recall for 1984 model year make/model.
Recall date (1985)	Number of months, before purchase, of latest recall for 1985 model year make/model.
Technical service index	An index representing the frequency and quality of routine maintenance and repair work by a dealer on a newly purchased vehicle. A higher index number is associated with improved performance on this dimension.[g]
Other Attributes	
Brand loyalty	Dummy variable that equals 1 if new vehicle purchased is of the same make as the respondent's previous vehicle, 0 otherwise.
American motors	Dummy variable that equals 1 if vehicle is manufactured by American Motors Corporation, 0 otherwise.
Chrysler	Dummy variable that equals 1 if vehicle is manufactured by Chrysler Corporation, 0 otherwise.
Ford	Dummy variable that equals 1 if vehicle is manufactured by Ford Motor Company, 0 otherwise.
Foreign	Dummy variable that equals 1 if vehicle is manufactured in a foreign country, 0 otherwise.

[a]The purchase price is defined as the manufacturer's base vehicle price, adjusted for engine option, transmission option, freight, and California emission system.

[b]Based upon a test developed by Motor Trend Magazine, the test course is 800 ft long and 100 ft wide. Each variable is tested three times on the course. Slalom is an average of the three test scores. Other measures of performance, including acceleration from 0 to 60, 40 to 60 (seconds), and net horsepower were tried. Slalom time led to the best model fit.

[c]Front leg room is measured from the accelerator pedal heel point up over the lower seat cushion to the seat back. Rear leg room is measured from the rear of the front seat back, horizontally to rear seat lower cushion, down the lower cushion to the intersection of the rear seat back and rear lower cushion.

[d]Front (rear) shoulder room is measured laterally across the width of the vehicle at a height of 18 in. vertical from the intersection of the front (rear) seat back with the lower seat cushion.

[e]The procedure was developed by the Automotive Engineering Department of AAA with the assistance of Man Factors, Inc., a human engineering research company. The primary concern of the procedure is with entry/exit into the rear seat area.

[f]See *The Car Book* by Jack Gillis, 1985 Edition. For each size class of vehicle, a crash test index is calculated that is based on occupant protection in a frontal crash at 35 mph.

[g]The Technical Service Index was developed by J.D. Powers and Associates for 1985 make/models. The index reflects consumer satisfaction on a variety of reliability dimensions, including type and frequency of repair problems, cost of repairs, and quality of dealership servicing.

times, the coefficient of slalom is expected to carry a negative sign. With the exception of interior noise level, increases in each of the comfort-related variables enhances the vehicle's comfort, all else held constant, and is expected to have a positive coefficient. Interior noise level is expected to carry a negative sign since higher decibel levels are associated with less comfort. Each of the vehicle safety variables is expected to carry a positive sign, indicating that safer vehicles are preferred to less safe vehicles, all else held constant.

Trunk size is expected to carry a positive sign, all else held constant. However, the fact that other vehicle size measures are incorporated in the estimating equation (interior roominess and vehicle weight, which is highly correlated to length of vehicle), larger trunk capacity may come at the cost of smaller dimensions in other areas. Its overall effect, therefore, is ambiguous. Because the effect of trunk size is expected to differ by size of family, this variable was interacted with two family size variables: households with 3 or fewer members and households with 4 or more members.

Brand loyalty is expected to have a positive sign. And the criterion for including the manufacturer/foreign dummy variables is the effect upon overall fit of the model.

With respect to vehicle reliability, the technical service index is expected to carry a positive sign. And from the theoretical model discussed above, it is expected that recall (1984) and recall (1985) will have a positive and negative sign, respectively. Although data on recalls was not available prior to the 1984 model year, month of recall for the 1984 and 1985 model years was available and was used to test the hypothesis on the value of information over time. Date of recall is a number that varies from 0 (corresponding to a recall in the month the car was purchased) to 20 (indicating that the latest recall occurred 20 months prior to purchase). Assuming that more recent recalls provide more information, and hence are of greater value for new car purchase decisions than more distant recalls, recall date (1984) and recall date (1985) are expected to carry positive signs.

The data in Table 2 summarize the estimation results, which for the most part are consistent with a priori expectations. Cost, performance, vehicle comfort, and safety-related attributes all have their expected signs and are significantly different from 0 at the .05 level (most are significantly different from 0 at the .01 level). Trunk size is significant for smaller households and its negative sign indicates that, all else held constant, a larger trunk volume decreases the probability of purchase. Somewhat unexpectedly, the coefficient for trunk size was larger in absolute value for smaller relative to larger families.

As expected, brand loyalty was positive and significantly different from 0. And, among the manufacturer/foreign dummy variables, only that for Chrysler was significantly different from 0. Its positive sign indicates that, all else held constant, an individual prefers a Chrysler to a non-Chrysler made vehicle.

Focusing on vehicle reliability, it is seen in Table 2 that the technical service index, as expected, carries a positive sign and is significant at the .01 level. In addition, each of the recall variables has its expected sign. Recall (1984) is positive and significant, consistent with the hypothesis that recall in a previous year make/model reduces uncertainty in purchasing the given make/model in the current year, all else held constant. On the other hand, recalling a make/model in the current model year increases consumer uncertainty, which reduces the probability of purchase. This is consistent with the sign and significance on recall (1985). When considering the time of recall, recall date (1984) and recall date (1985) both carry positive signs, although only recall date (1985) is significantly different from 0. Thus, even for current year make/models, more recent recalls, which correspond to a decrease in recall date (1985), decrease vehicle choice probabilities.

ELASTICITY MEASURES

In order to investigate the sensitivity of consumer demands to vehicle attributes, elasticity measures were calculated for a variety of representative vehicles and are reported in Tables 3 and 4. In Table 3, there are several interesting facts to note. First, the elasticity of choice with respect to the cost variables shows an increasing trend with size of vehicle, a result consistent with standard theory. Goods which make up a larger proportion of one's budget will have higher price elasticities of demand. Second, vehicle choices are very sensitive to interior noise levels—a 1 percent increase in the interior noise level reduces the probability of choice by 4–5 percent. New car vehicle choices are also sensitive to vehicle performance and safety (to the extent that weight reflects vehicle safety).

Table 4 provides elasticity measures for the recall variables included in the analysis. The results indicate that choice behavior is inelastic with respect to recall campaigns. However, as reflected by the measures for 1984 and 1985 recalls, vehicle choices are twice as sensitive to recall campaigns associated with current model year vehicles than with previous model year vehicles.

OTHER CONSIDERATIONS

The results presented in Table 2 reflect the short-term effects of vehicle recalls upon new car purchase decisions. Table 2 does not incorporate information as to whether a given manufacturer has a history of producing vehicles subject to a recall. As noted in the theoretical section, this would reinforce the contemporaneous effects of a recall but lead to ambiguous effects of recalls that occurred in prior years. Although it is not possible in the present study to estimate a dynamic vehicle choice model, it is possible to gain some insight into this issue. Over the past few years, there has been considerable discussion regarding the quality of American-produced vehicles relative to their foreign counterparts, particularly the Japanese [see, for example, Crandall et al. (*5*) and Mannering and Winston (*9*)]. Assuming that the quality of the vehicle is inversely related to the incidence of recall campaigns, then the hypothesis that the United States produces poorer quality vehicles can be tested by interacting the recall (1984) and recall (1985) variables with a dummy variable reflecting country of origin.

Estimating the model in which recall (1984) and recall (1985) were disaggregated by country of origin (domestic and foreign) yielded results that were virtually identical to those presented in Table 2. Moreover, the coefficient estimates for the interacted recall variables were consistent with the hypothesis

TABLE 2 EFFECT OF RECALLS ON NEW VEHICLE PURCHASES

Independent Variable	Coefficient Estimate	Asymptotic t-statistic
Price Share	- 4.587	- 8.85
Operating Fuel Cost	- .256	- 2.35
Slalom	- .258	- 1.69
Front/Rear Leg Room	.0570	2.91
Front/Rear Shoulder Room	.0575	3.66
Interior Noise Level	- .0847	- 3.90
Entry/Exit	.250	3.84
Door Sill Height	.182	6.18
Crashworthy Index	.443	3.14
Vehicle Weight	.000609	2.80
Trunk Size (Household size ≤ 3)	- .0414	- 6.71
Trunk Size (Household size > 3)	- .0071	- 1.02
Technical Service Index	.0112	4.71
Recall (1984)	.256	2.06
Recall (1985)	- .956	- 2.88
Recall Date (1984)	.00926	.72
Recall Date (1985)	.276	3.05
Brand Loyalty	2.068	16.98
Chrysler	.788	4.28

Number of households: 726

Number of observations: 10,890

Log-likelihood at 0: 1966.0

Log-likelihood at convergence: 1576.7

$\chi^2 = 778.7$

$\chi^2_{.05}(19) = 30.14$

$\rho^2 = .198$

TABLE 3 CHOICE PROBABILITY ELASTICITY MEASURES—VEHICLE ATTRIBUTES

Market Segment	$E_{Pr,Price\ Share}$	$E_{Pr,Operating\ Cost}$	$E_{Pr,Slalom}$	$E_{Pr,Noise}$	$E_{Pr,Weight}$
Subcompact					
Ford Escort	- .91	- .87	-2.11	-5.12	1.17
Honda Accord	- .92	- .86	-1.84	-4.77	1.09
Compact					
Chrysler Lebaron	-1.25	-1.04	-2.23	-4.81	1.49
Mazda 626	-1.20	-1.04	-2.34	-4.95	1.49
Intermediate					
Buick Regal	-1.26	-1.36	-2.50	-4.64	1.76
Nissan Maxima	-1.51	-1.33	-2.14	-5.11	1.76
Large					
Cadillac Eldorado	-2.17	-1.48	-2.14	-4.61	1.96
Oldsmobile 98	-1.58	-1.23	-2.16	-4.58	1.74

that the quality of American-manufactured vehicles is lower than vehicles produced outside of the United States, all else held constant. All recall variables had their expected signs. For 1985 recalls, the coefficient for domestic vehicles was uniformly greater (in absolute value) than the coefficients for foreign-produced vehicles. This is consistent with the notion that recalls associated with domestically produced vehicles involve greater uncertainty regarding expected reliability. Similarly, previous year recalls for domestic vehicles had a larger effect upon the probability of purchasing current year make/models relative to their foreign-produced counterparts. However, these results should be viewed as tentative since a likelihood ratio test of the hypothesis of equal coefficients for domestic and foreign-produced vehicles could not be rejected at the 0.05 level.

SUMMARY AND CONCLUSION

Since the seminal research of Peltzman (*2*), there has been a considerable amount of effort devoted to the role and the effects of the federal government's regulatory efforts to promote vehicle safety. One aspect of this issue that has received little attention is the effect of government-sponsored recall campaigns upon the purchase of new vehicles. Economic theory suggests that recall campaigns will alter the probability of purchasing a recalled vehicle, all else held constant, but that the direction of the effect will depend upon the model year of the vehicle recalled. By increasing the uncertainty associated with a recalled vehicle's expected reliability, a recall occurring in the current model year will adversely affect the probability of an individual purchasing the vehicle. Alternatively, if the recall corresponds to a prior model year, it will act to reduce the uncertainty of the vehicle's expected reliability in the current model year; hence, it will increase the probability of purchasing the current make/model. This effect, however, will be less the more distant the recall from the present period.

To test this hypothesis, detailed household socioeconomic and vehicle attribute information was obtained from a national survey of new car buyers and the Automobile Club of Southern California, respectively. This was supplemented with Department of Transportation data on new car vehicle recalls during the 1984 and 1985 model years. The data were used to estimate a conditional logit model of new vehicle type choice and the results were consistent with the underlying hypotheses.

The main conclusion from this analysis is that recall campaigns have predictable short-term effects upon individual choices of new vehicles. In particular, the number of recalls as well as the timing of the recall significantly influence the demand for new vehicles. Moreover, there was limited evidence to support the hypothesis that recall campaigns have more pronounced effects on manufacturers that are perceived to produce lower quality vehicles. Although this latter result is not conclusive, it does imply the need for further research in this area. In the longer term, a history of poor quality production will affect market demand and be capitalized into the price of the vehicle, all else held constant. A more accurate, albeit more complex, model would incorporate the inter-

TABLE 4 CHOICE PROBABILITY ELASTICITY MEASURES—RECALL VARIABLES

Market Segment	$E_{Pr,Recall}$ 1984	$E_{Pr,Recall}$ 1985	$E_{Pr,Recall}$ Date 1984	$E_{Pr,Recall}$ Date 1985
Subcompact				
Ford Escort	.45	-	.04	-
Compact				
Chrysler Lebaron	-	-.85	-	-.49
Toyota Camry	.21		.12	
Intermediate				
Buick Regal	.47	-	.04	-
Chevrolet Celebrity	-	-.75	-	1.08
Large				
Cadillac Eldorado	.24	-	.11	-

[a]A dash in the table indicates that the particular make/model was not subject to a recall in the specified year.

action between government recall actions, market demand, and the resulting influence on capital cost.

The primary policy implication is that there are potential benefits from increased dissemination of recall information to the public. Although this analysis does not provide any insight into the net benefits of the recall program, it does indicate that these campaigns are relevant to one's decision making.

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