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 midblock 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

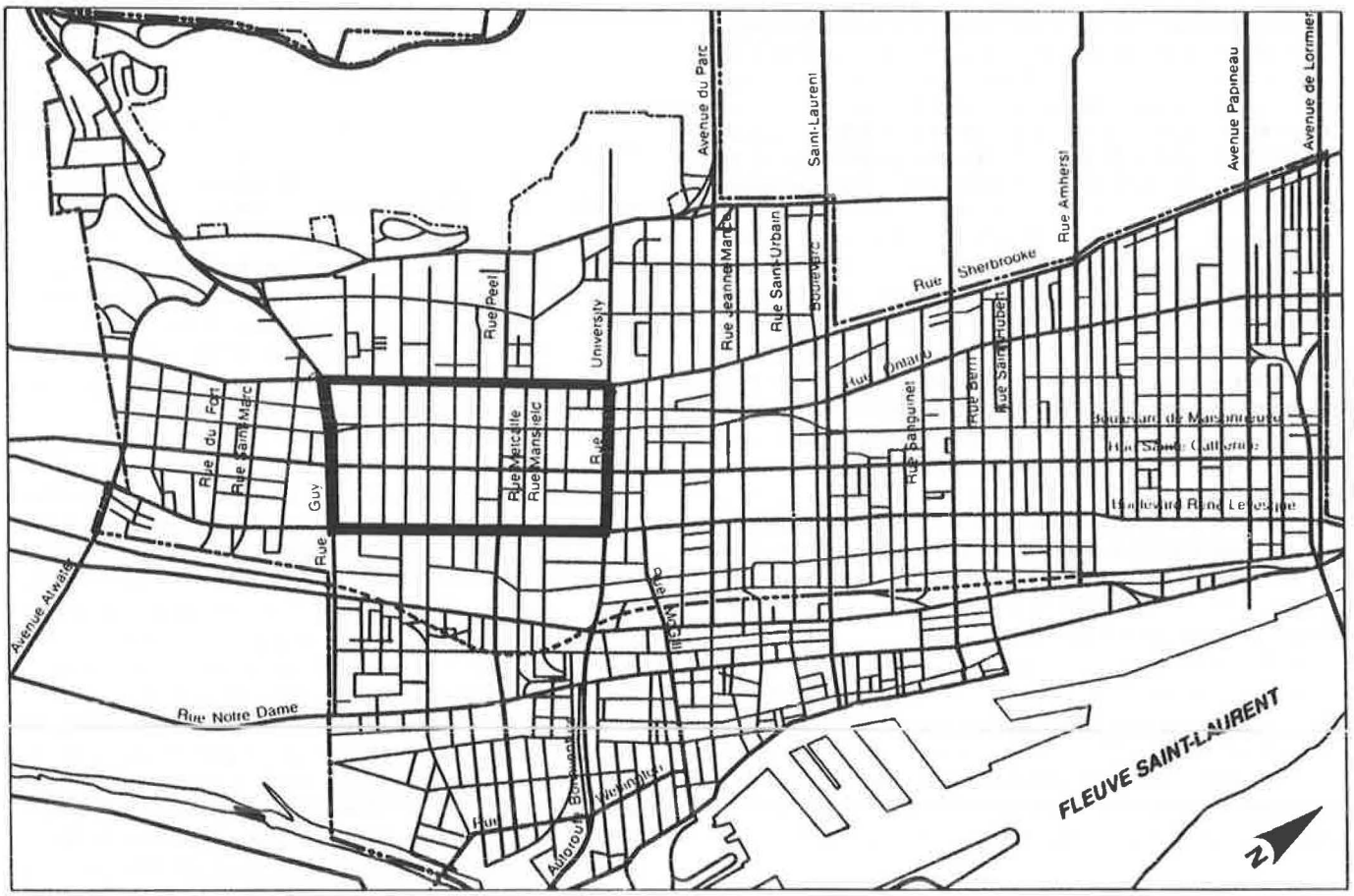

FIGURE 1 Study area within the Montreal CBD.

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.

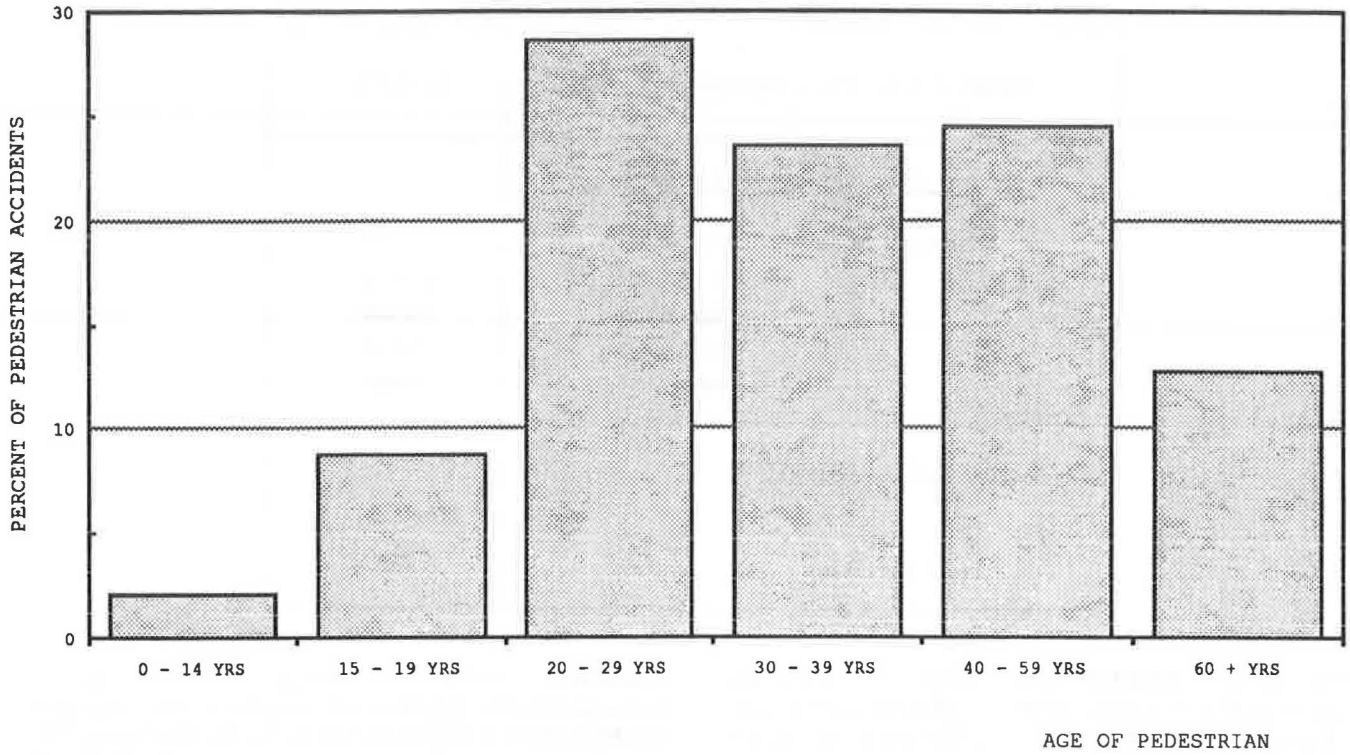

FIGURE 2 Percent of pedestrian accidents by age group (1985–1987).

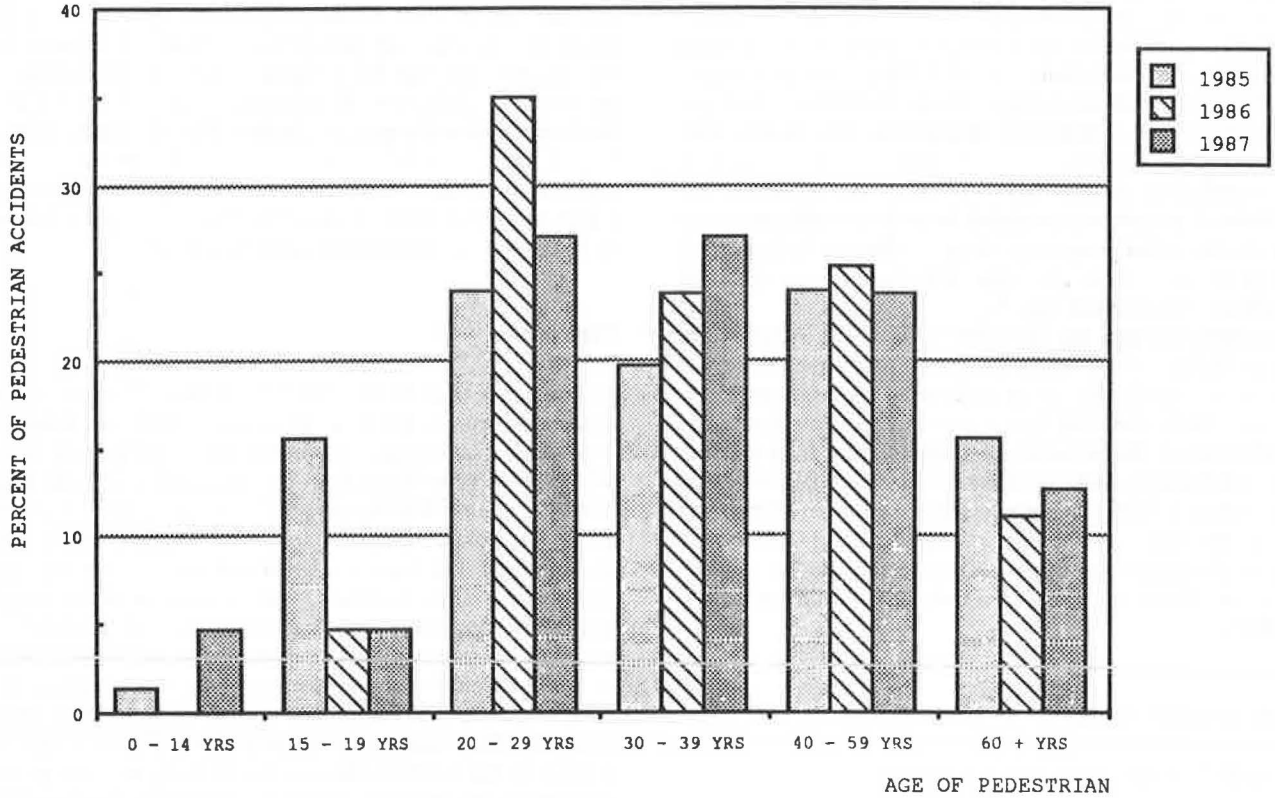

FIGURE 3 Percent of pedestrian accidents by age group.

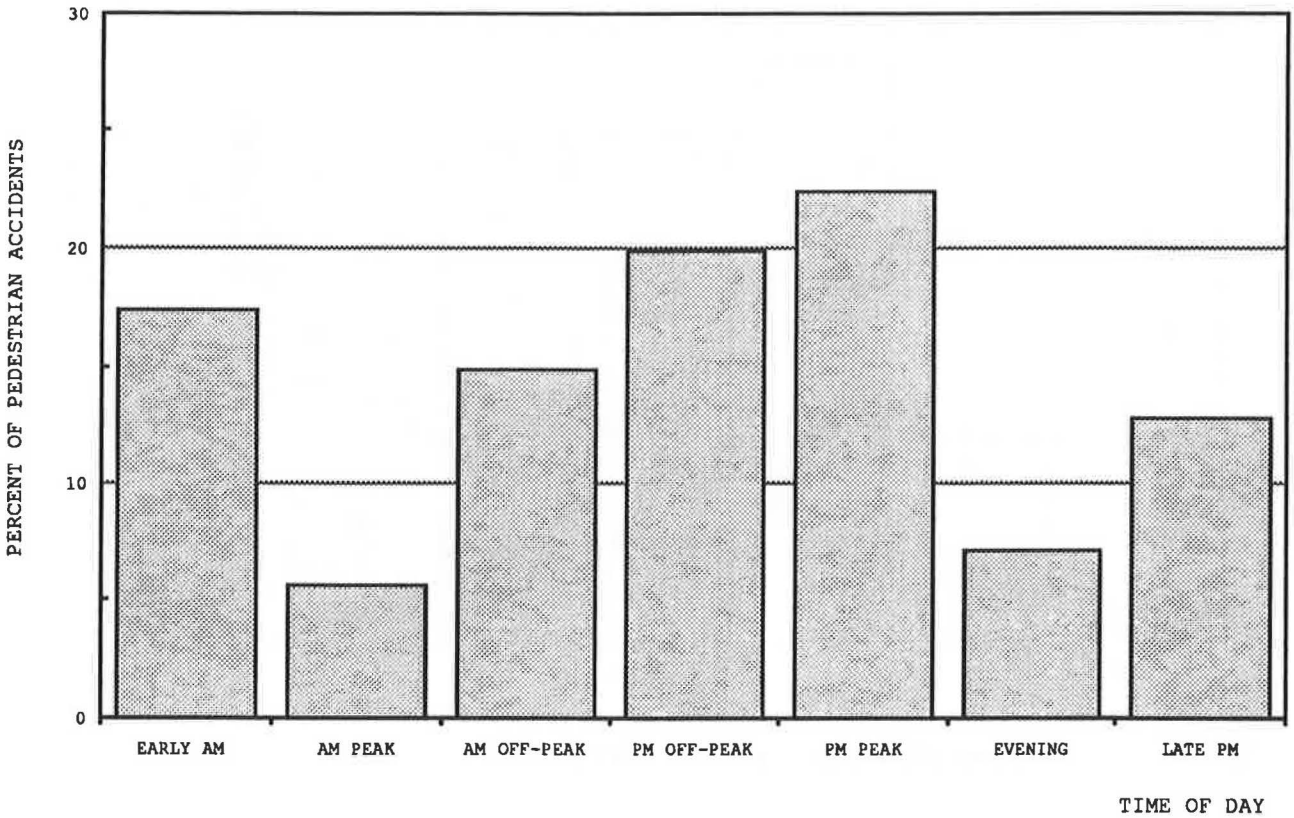

FIGURE 4 Percent of pedestrian accidents by time of day (1985–1987).

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

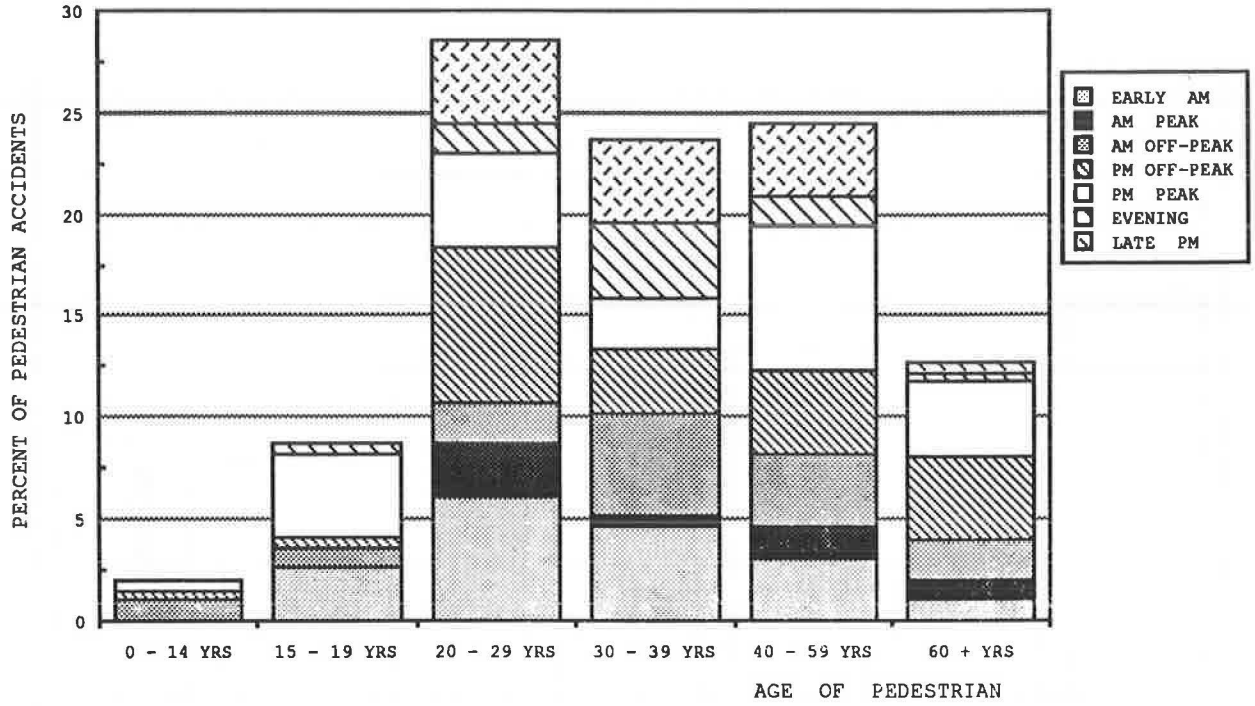

FIGURE 5 Percent of pedestrian accidents by age groups and time of day (1985–1987).

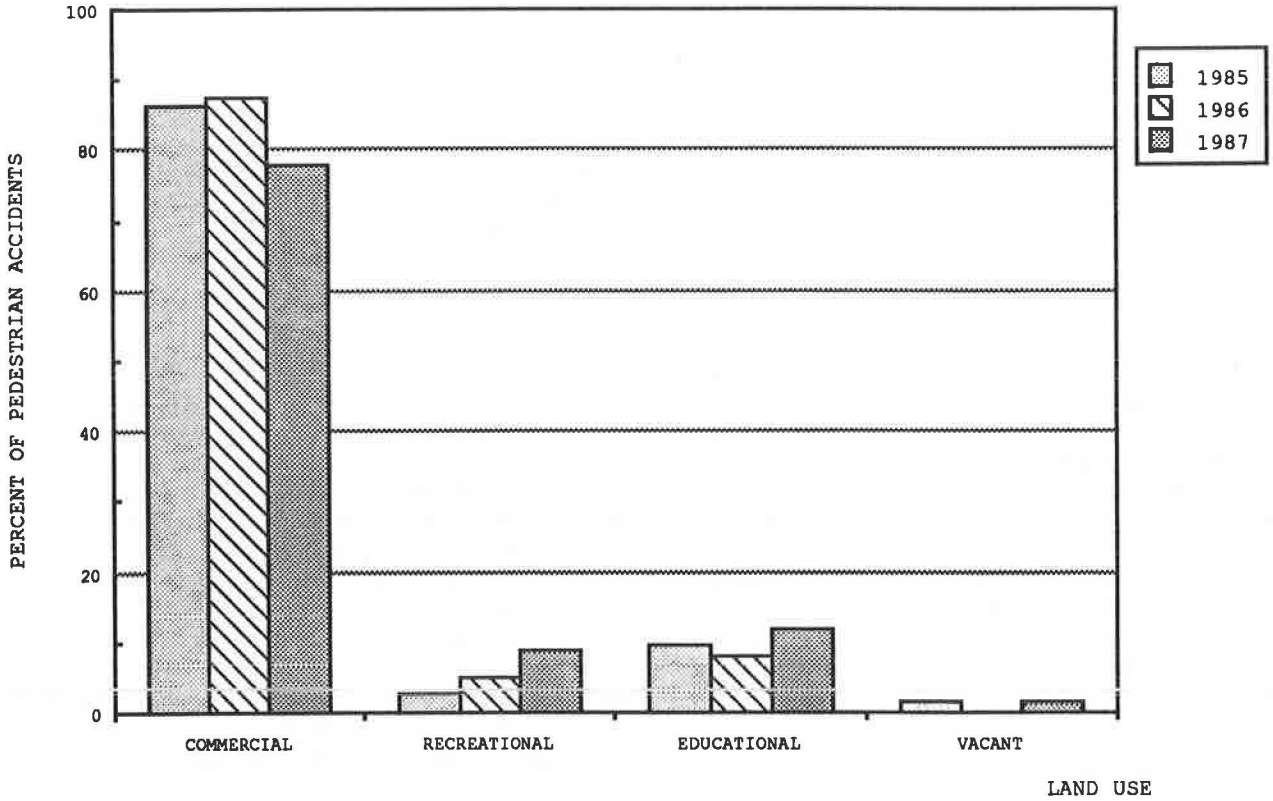

FIGURE 6 Percent of pedestrian accidents by land use type.

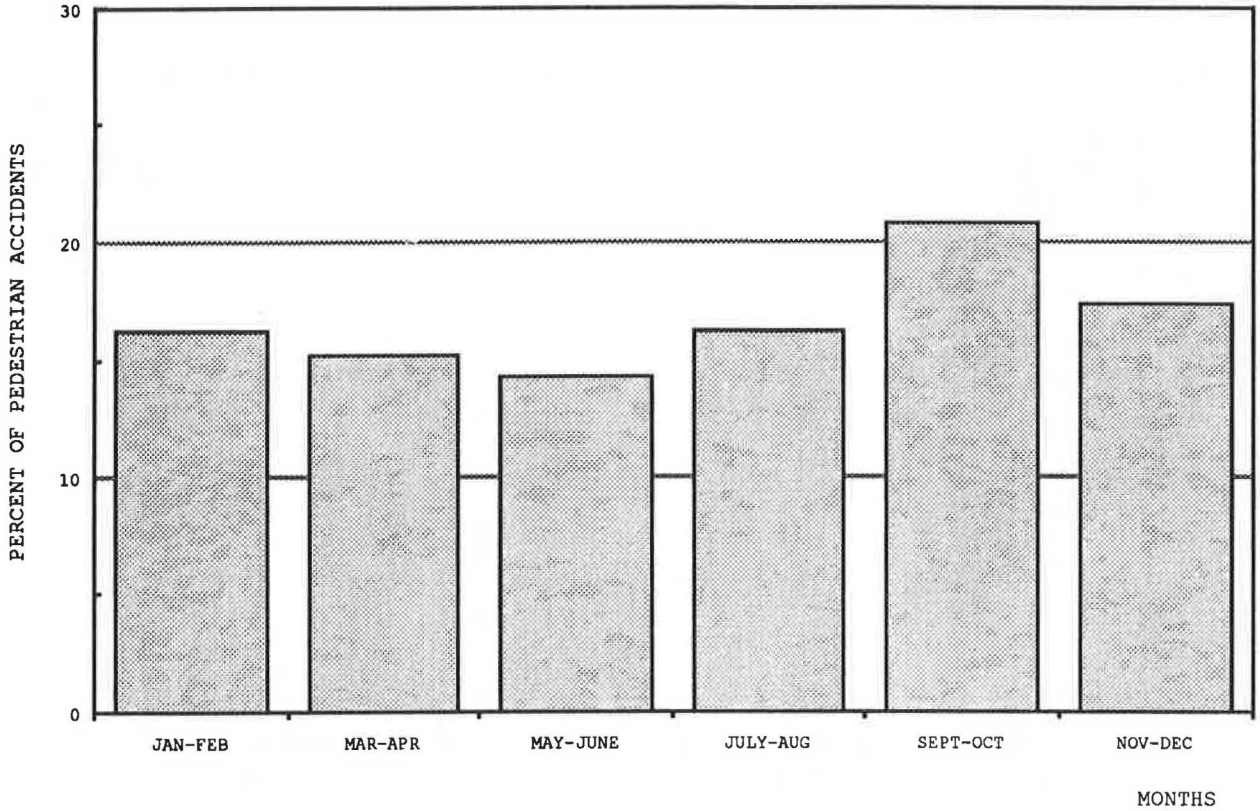

FIGURE 7 Percent of pedestrian accidents by time of year (1985–1987).

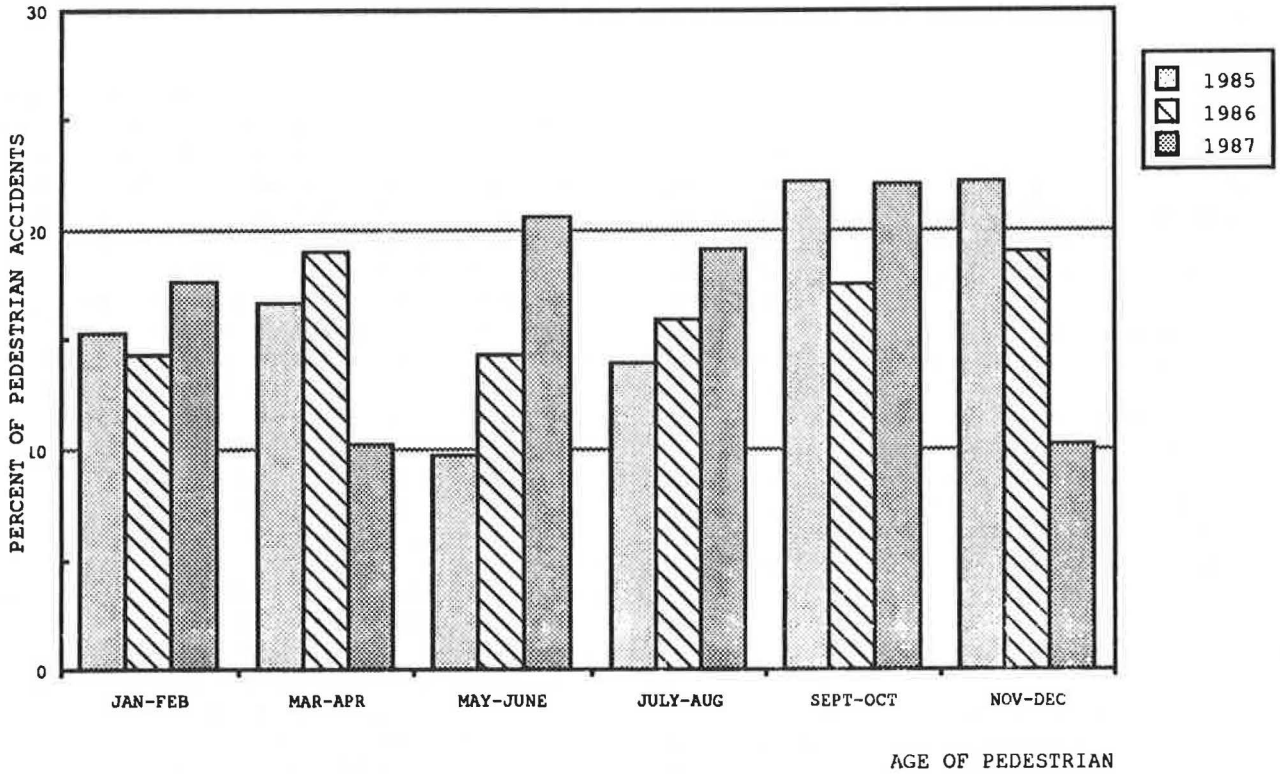

FIGURE 8 Percent of pedestrian accidents by time of year.

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

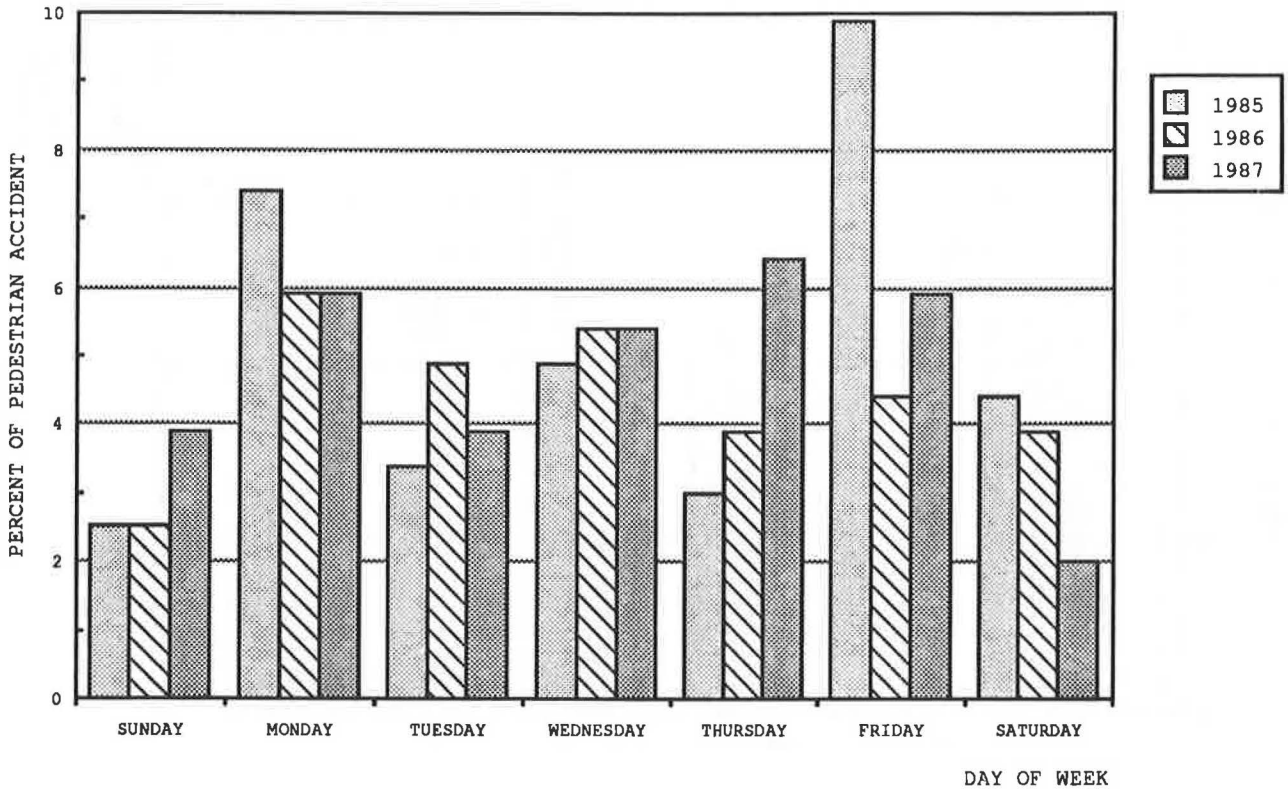

FIGURE 10 Percent of pedestrian accidents by day of week.

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

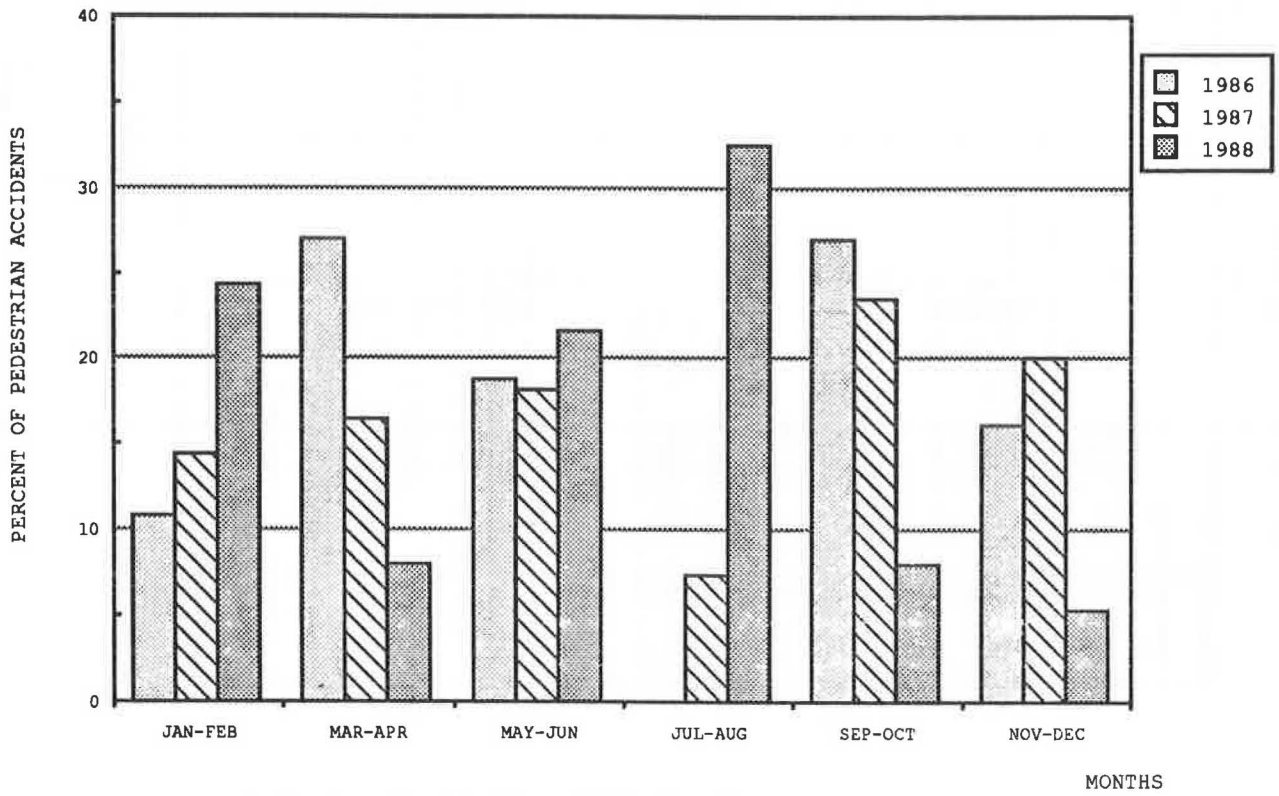

FIGURE 11 Percent of pedestrian accidents in Calgary CBD by time of year.

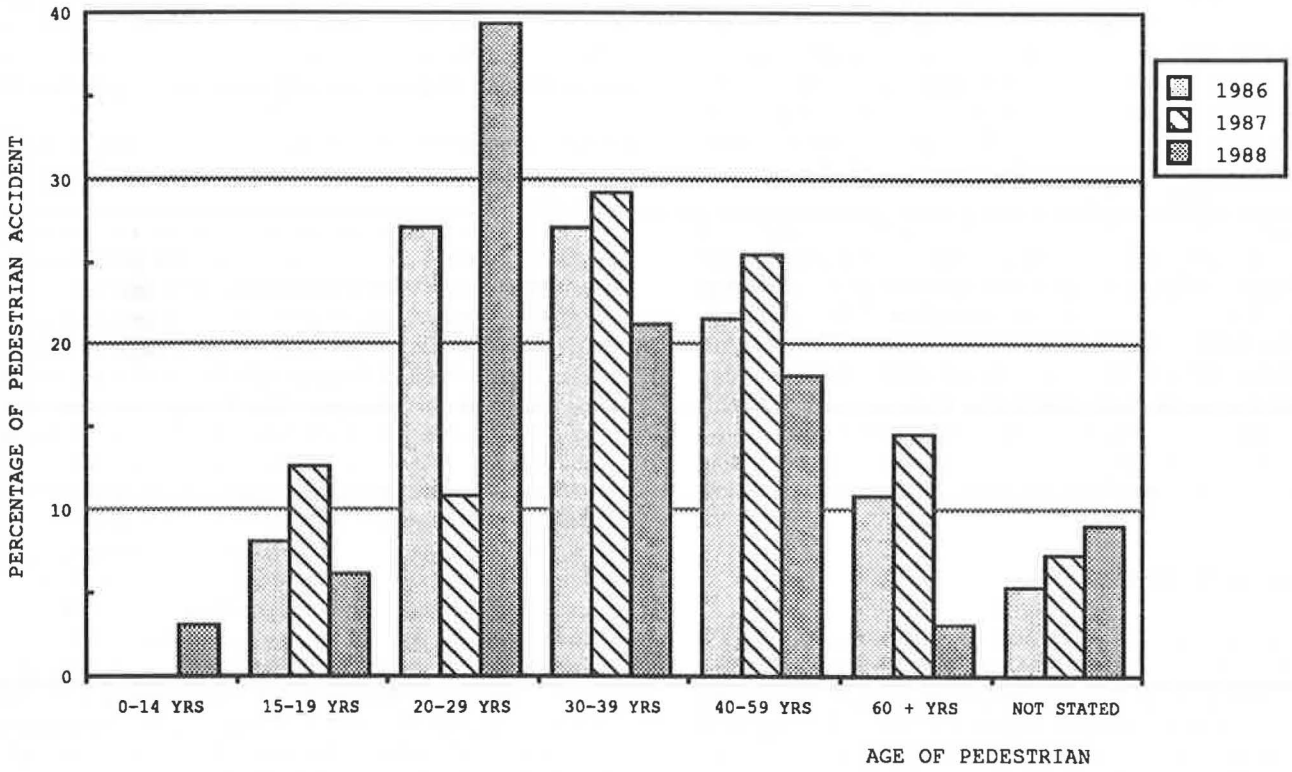

FIGURE 12 Percent of pedestrian accidents in Calgary CBD by age.

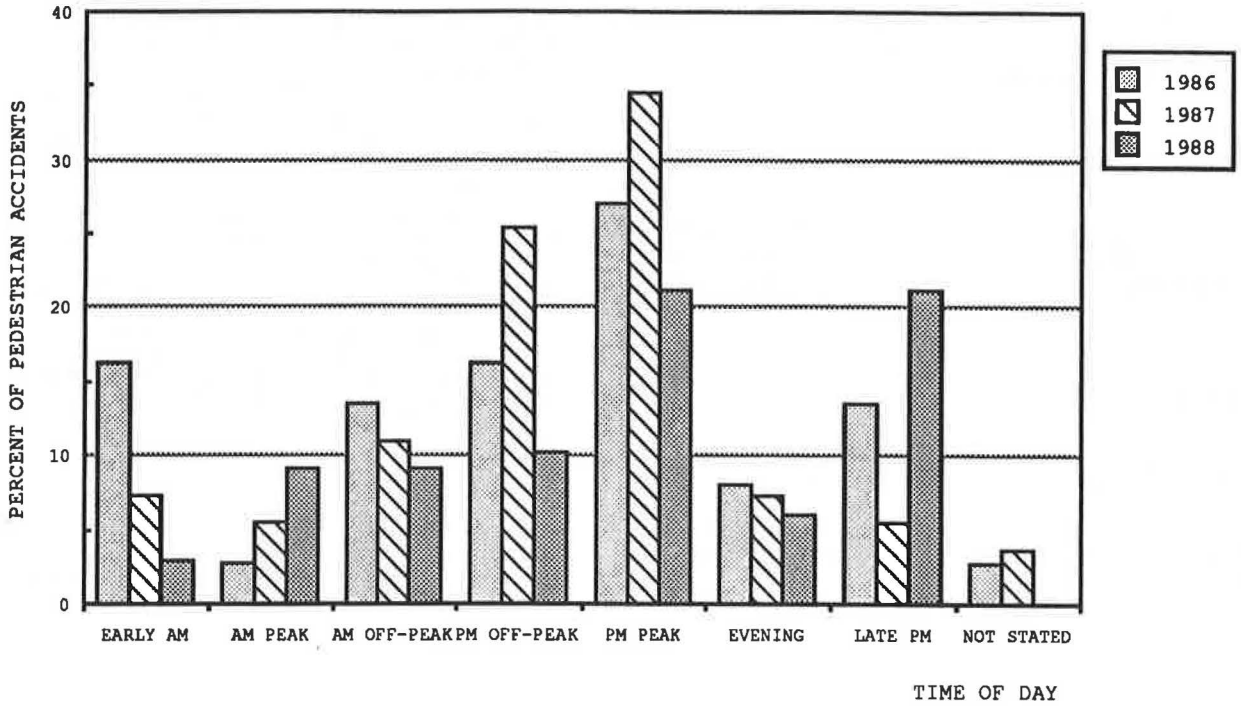

FIGURE 13 Percent of pedestrian accidents in Calgary CBD by time of day.

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.

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