Walking Speeds of Elderly Pedestrians at Crosswalks

ANN COFFIN AND JOHN MORRALL

Elderly pedestrians are an increasing part of the North American population. Their growing numbers raise the question of the suitability of the assumed normal walking speed used to determine the pedestrian clearance interval. Findings of a study that measured the walking speed of elderly pedestrians at various types of crosswalks are reported. Walking speeds of pedestrians over the age of 60 were recorded at seven locations: six field locations and a seniors club. The field locations included pedestrian actuated midblock crosswalks, crosswalks at signalized intersections, and crosswalks at unsignalized intersections. The field studies included a short interview following the recording of curb-to-curb walking time. Study participants at the seniors club were asked to walk at their normal speed and then their fast speed down a corridor, then they completed a short questionnaire. One of the main findings was that people over age 60 are not a homogeneous group; they possess a range of walking speeds and mobility levels. Elderly pedestrians reported several problems associated with crosswalks, including difficulty in negotiating curbs and judging the speed of oncoming vehicles, discourteous drivers, turning vehicles and confusion with the Walk, flashing Don't Walk, and Don't Walk pedestrian signal indications. At signalized intersections near seniors and nursing homes, where most pedestrians are elderly, a design walking speed of 1.0 m/sec is satisfactory. Suggested design walking speeds of elderly pedestrians at midblock crosswalks and signalized intersections are 1.0 and 1.2 m/sec, respectively.

Walking speeds of pedestrians are used to determine the pedestrian clearance interval of pedestrian signals or, in locations where there are no pedestrian signals, to obtain the minimum green time for concurrent traffic.

In Canada and the United States, pedestrian signals consist of a Walk interval, then a flashing Don't Walk interval, followed by a solid Don't Walk interval. The *Manual on Uniform Traffic Control Devices* (MUTCD) recommends the following for pedestrian intervals and phases (*1*):

1. "The Walk interval should be at least 4 to 7 seconds in length," and
2. The flashing Don't Walk interval (or pedestrian clearance interval)" should be sufficient to allow a pedestrian crossing in the crosswalk to leave the curb and travel to the center of the farthest lane before opposing vehicles receive a green indication." The "normal walking speed is assumed to be 4 feet per second" (1.2 m/sec).

Elderly pedestrians are an increasing part of the North American population. Their growing numbers raise the question of the suitability of the assumed normal walking speed used to determine the pedestrian clearance interval. The purpose of this paper is to report the findings of a study that measured the walking speed of elderly pedestrians at various types of crosswalks (*2*).

A. Coffin, Reid Crowther and Partners, Suite 300, Atrium VII Midpark Way, S.E., Calgary, Alberta, T2X 1P1 Canada. J. Morrall, Department of Civil Engineering, University of Calgary, 2500 University Drive, N.W., Calgary, Alberta, T2N 1N4 Canada.

CURRENT PRACTICE

A letter survey was undertaken by the authors to determine the crossing speeds used by municipalities in North America. Twenty-six municipalities responded to the survey. Eighty-five percent of the respondents replied that they used a walking speed of 1.2 m/sec to calculate pedestrian crossing time at intersections. Almost all of the surveyed jurisdictions replied that they usually made some sort of adjustment to the pedestrian signal timings for the benefit of elderly pedestrians. The most popular walking speeds used for signal timing for the elderly were between 1.0 and 1.1 m/sec.

The lack of a uniformly accepted walking speed for elderly pedestrians is the result of ambiguity in the traffic control manuals. The MUTCD (*1*) states that 4.0 ft/sec (1.2 m/s) is the "assumed" normal walking speed. The *Uniform Traffic Control Devices for Canada* (UTCD) manual does not recommend a walking speed but reports that normal walking speeds vary from 1.1 to 1.4 m/s (*3*). The *ITE Manual of Traffic Signal Design* (*4*) mentions the "normal" speed of 4.0 ft/sec (1.2 m/s) but also says that research has shown the 85th-percentile walking speed to be 3.5 ft/s (1.1 m/s). None of the Canadian (*3*) or American (*1,4,5*) manuals recommends a walking speed for elderly pedestrians; instead, each suggests the use of engineering judgment.

In general, there appear to be two purposes for researching walking speeds: to augment physiological or medical discussions and to measure how people operate in the transportation system.

Most of the reviewed studies demonstrate some connection between age and walking speed. In their study, Imms and Edholm (*6*) suggested that age is a masking variable and that walking speed actually decreases with decreasing mobility level. In their laboratory study, Cunningham et al. (*7*) showed that fitness level is a better indicator of walking speed than age.

Actual walking speeds for Imms and Edholm's study ranged from 0.399 m/s for housebound subjects to 0.931 m/s for subjects with unlimited outdoor activity. Testing was conducted indoors and may have influenced walking speeds. The remaining studies were conducted outdoors and demonstrate higher walking speeds.

Using time-lapse photography and interviews, Wilson and Grayson (*8*) measured the walking speeds of more than 11,000 people over age 15 crossing at a midblock crosswalk. By counting the number of nearside and farside glances made by subjects as they crossed the street, the study indicated a link between increased level of caution and decreased walking speeds. Furthermore, subjects over age 55 appeared to be more cautious than their younger counterparts. The average walking speeds for male and female subjects over the age of 60 was 1.10 and 1.15 m/s, respectively. However, the researchers concluded that age-related differences in road crossing behavior are small and that the elderly should not be considered as a separate group within the population.

Molen et al. (*9*) suggest that trip purpose, location, and the presence of other people might influence the walking speed of pedestrians of all ages. Unfortunately, the researchers could not draw any conclusions regarding walking speed and age.

In an unpublished Japanese study, Shimizu et al. determined the differences between elderly and nonelderly users of a crosswalk, underpass, and an overpass. They reported that the difference between the crossing speeds of elderly and nonelderly users of the signalized crosswalk was smaller than at either of the other two facilities. The researchers concluded that the time limitation at a signalized crosswalk might have caused elderly users to walk faster than their normal speed. The crossing speeds of the elderly and nonelderly users were 1.23 and 1.41 m/s, respectively.

Dahlstedt (*10*) also found that time limitations influenced walking speed; his subjects (age 70 and over) appeared to increase their walking speeds by 0.1 m/s when crossing at a signalized crosswalk versus walking on a paved lot. Dahlstedt also found that walking speeds decreased with age but this relationship was not closely correlated. However, Dahlstedt's results indicate that variability in walking speed decreased with age. The average "fast" walking speeds of his female and male subjects on a paved lot were 1.14 and 1.33 m/s, respectively.

In summary, the literature indicates that age or age-related factors do influence walking speed. As well, factors such as location and crossing time limitations may also influence the walking speeds of elderly pedestrians.

STUDY METHOD

The walking speeds of pedestrians over 60 were recorded at seven locations: six were crosswalks located in Calgary and the seventh was a hallway in a seniors club in Calgary. In all six field locations, no selection procedure was used except that pedestrians had to be older than 60. Furthermore, the subjects were unaware that they were being timed. The purpose of the field study was to examine the influence of environmental factors such as location and crosswalk type on walking speed. The purpose of the indoor study was to understand the influence of gender and functional classification on walking speed.

All of the study participants were given a questionnaire to complete. The questionnaire enabled walking speeds to be matched with information such as age, gender, location, time, and a series of behavioral questions. A pilot study was conducted at the Golden Age Club in Calgary before walking speed measurements made at the Kerby Center, a Calgary seniors club.

INDOOR DATA COLLECTION

Walking speeds of 184 people over age 60 were measured under ideal conditions at the Kerby Center. These participants came from a variety of backgrounds; many were in good physical and mental condition. Some of the participants eagerly took part in the study; others were at first hesitant and uncertain but then participated after observing other participants. The short duration of the timings and the interview—less than 3 min—was also an important factor in their decision to participate.

Participants were asked to walk at their normal speed and then at their fast speed 13 m down a flat, well-lit corridor with a minimum of environmental influences. After the timings, each participant completed a short questionnaire. Their timings, as well as height (including footwear), gender, and age were recorded. Participants were then asked if they had any problems crossing streets in Calgary. After the participant departed, the researcher classified the participant as either "adult" or "senior." Classification was based on an intuitive reaction on the part of the researcher to the interviewee's attitude and alertness. The classification was not based on age, gender or walking speed. Instead, the researchers hoped that it would be a quick summary of a person's functional abilities.

The mean normal walking speed of all women was 1.24 m/s, and the mean fast walking speed was 1.55 m/s. As noted, participants were classified as adult or senior. The mean normal walking speed of senior women was 1.13 m/s, and the mean normal speed of adult women was 1.27 m/s. The mean normal speed of all men was 1.29 m/s. The mean normal speed of senior men was 1.13 m/s, and the mean normal speed of adult men was 1.34 m/s.

The main problems identified by participants concerning crosswalks included being extra cautious because of a mistrust of drivers, fear of turning vehicles, difficulty negotiating curbs, inability to judge vehicular speeds, problems during winter, and annoyance with quick-changing lights. It was also found that many elderly pedestrians do not understand the purpose of the Walk, flashing Don't Walk, and solid Don't Walk lights. This finding was confirmed in the intersection study of elderly pedestrians. This finding is not confined to elderly pedestrians in Calgary, and it is noted that the city of Buenaventura (*11*) has developed a sign to improve the understanding of pedestrian indications at signalized intersections.

FIELD DATA COLLECTION

The six field locations were chosen after a brief evaluation to ensure significant numbers of elderly pedestrians. Four of the six locations were near shopping centers. The field locations consisted of two pedestrian actuated midblock crosswalks, two crosswalks at signalized intersections, and two crosswalks at unsignalized intersections.

The objective was to interview at least 30 elderly pedestrians at each of the six intersections. Fifteen pedestrians were timed in each direction.

The procedure for gathering information consisted of two main steps: timings and interviews. Without their knowledge, pedestrians assumed to be over age 60 were timed starting from where they stepped off the curb until they stepped onto the sidewalk at the other side.

To calculate crossing speed, the measured curb-to-curb distance was divided by the time taken to walk from one curb to the other. The measured distance for each intersection was equivalent to the observed most traveled path of the pedestrians using the crosswalk. Admittedly, not all participants walked the same distance across the intersection. Thus, for the field conditions, the more accurate term of crossing speed was used instead of walking speed.

Once the pedestrians had finished crossing the road, they were intercepted and asked if they had time to answer questions about that particular intersection. If the pedestrians agreed to that interview, they were shown and asked between six and eight behavioral questions, depending on the location. For each question, the interviewee had a choice of five one-word answers ranging from "never" to "always." At the end of the interview, the participants were asked their age discreetly. The behaviorial questions were included in the questionnaire in the hopes that road crossing behavior might be correlated with crossing speed.

In general, most of the pedestrians consented to the short interview. Some who were in a particular hurry did not consent to the interview, and only those persons who consented were included in the study.

FINDINGS

Table 1 contains a brief description of the six crosswalks and the average walking speed of elderly women, men, and total surveyed. The highest crossing speeds were measured at the two signalized intersections. The crossing speeds at both midblock crosswalks were quite close. Surprisingly, the crossing speeds at the unsignalized intersections differed significantly with 90 percent confidence although the crosswalks were geographically only one block apart. In all cases the men had higher walking speeds than the women.

The Chinook and Safeway intersections had the same type of traffic control device: traffic lights with separate pedestrian lights. However, the intersection geometries were quite different: the Chinook pedestrians had to cross a distance of 40.03 m and six lanes of two-way traffic separated by a raised median. Meanwhile, the Safeway pedestrians only had to cross a distance of 16.09 m and four lanes of one-way traffic. There were differences in pedestrian herding, pedestrian signal phasing, and surrounding land use. Fifty percent of the Safeway pedestrians stated that they had walked fast when crossing the intersection but 85 percent of the Chinook pedestrians stated that they had walked fast when crossing. Using the results of the Kerby Center data analysis, which stated that the average fast speed of elderly pedestrians as a group is significantly greater than their average normal speed, the Chinook crossing speed should have been greater than the Safeway crossing speed. Yet, a hypothesis test stated with 80 percent confidence that the two crossing speeds were the same.

One explanation for this contradiction may be fatigue. The crosswalk at Chinook was more than twice the length of the crosswalk at Safeway. Furthermore, although it was not asked, overall trip length for pedestrians at Chinook may have been longer than for those at Safeway because of differences in land use between the two sites. In fact, hypothesis testing indicated that the mean crossing speed for pedestrians returning from Chinook Center was lower than the speed of pedestrians going to Chinook Center.

The difference may indicate that pedestrians are more tired when returning from a shopping center than when they are going to a shopping center. The trend was reversed at the other signalized intersection; the crossing speed of the pedestrians going toward Safeway was lower than the crossing speed of the pedestrians traveling away from Safeway. However, unlike most pedestrians at the Chinook Center, the pedestrians crossing the Safeway intersection appeared to have a variety of trip destinations.

The second pair of statistically similar intersection samples was the Lions Park and Market Mall samples. The samples were found to be statistically similar with an 85 percent confidence interval. There are several possible explanations for this similarity. The most obvious reason is that they shared the same type of traffic control device. Both crosswalks were midblock crosswalks with pedestrian-actuated overhead beacons. Once a pedestrian activated it, the beacon immediately began flashing as warning to drivers. Pedestrians very rarely waited for longer than a few seconds before crossing.

Second, vehicular traffic volumes were similar at both crosswalks. On average, two cars were delayed by each participant at the Lions Park crosswalk and three cars for each participant at the Market Mall crosswalk.

Third, as part of the study, participants at each intersection were asked whether they walked faster when they crossed the respective intersection. Just over 80 percent at the Lions Park crosswalk and 70 percent at the Market Mall crosswalk replied that they did walk faster than normal while crossing.

However, there were a number of differences between the two samples, the biggest being the respective pedestrian herding characteristics. Many more pedestrians were using the Lions Park crosswalk than the Market Mall crosswalk. Yet, because of the nature of the pedestrian-actuated beacons, no pedestrian at either crosswalk waited for very long; arrivals were quickly dispersed. So, although there were not pedestrian herds at either crosswalk, there was a sufficient volume of pedestrians at the Lions Park crosswalk to create a continuous string of pedestrians. Thus, while pedestrians using the Lions Park crosswalk could not take comfort among a pedestrian herd, they could derive a certain amount of security in the knowledge that other pedestrians were in the crosswalk. The frequency of pedestrian arrivals at the Market Mall crosswalk was so low that nearly all pedestrians crossed singly.

As an aside to the preceding discussion of pedestrian crossing strings, it is possible that a pedestrian's position in the string influences walking speed. For example, the flashing beacon lasted longer than 20 sec, and a pedestrian crossing immediately after the beacon

TABLE 1 Average Walking Speeds of Elderly Pedestrians

CROSSWALK			AVERAGE WALKING SPEED (m/s)		
TYPE	LOCATION	WIDTH (m)	WOMEN	MEN	TOTAL
Signalized	Chinook Centre	40.03	1.33	1.41	1.36
	Safeway	16.09	1.37	1.45	1.40
Ped-Actuated	Market Mall	21.98	1.20	1.30	1.23
	Lion's Park	11.92	1.17	1.31	1.22
Unsignalized	Four-Way Stop	13.14	1.26	1.35	1.29
	Two-Way Stop	14.20	1.13	1.19	1.15

had been activated might be confident in the knowledge that he or she had ample time to cross. However, a pedestrian arriving later would not be aware of how much longer the beacon would flash. This later pedestrian has two choices: (*a*) to hurry across or (*b*) to reactivate the beacon and then cross. Therefore, the pedestrian who arrived after the beacon had been activated and who did not reactivate the beacon most likely walked faster than the pedestrian who knew how much time he or she had to cross. Although no formal observations were made, many pedestrians were seen to reactivate the flashing light unless they arrived directly on the heels of the other pedestrians.

The other dissimilarities between these two crosswalks concerned traffic speed and level of aggressiveness. Since the Lions Park light rail transit (LRT) area was a hub of activity, with buses, an LRT station, and mall entrances and exits along with the midblock crosswalk, most drivers appeared to drive slowly and cautiously. Contrary to this scenario, drivers near Market Mall had a wide boulevard on which to travel and few obstructions in their path. Occasionally, pedestrians at the Market Mall crosswalk purposely waited for a gap in traffic before activating the flashing lights.

Despite the dissimilarities, the average crossing speeds were not statistically different. Since the crosswalks share many environmental factors, focusing on one environmental variable to explain the similar crossing speeds is difficult.

The two-way- and four-way-stop crosswalks, although only one block apart, were found to be statistically different with a 90 percent confidence interval. The reasons for the dissimilar mean crossing speeds are likely to be related to the different user characteristics.

First, these two crosswalks do share similar types of traffic control devices. The four-way-stop crosswalks is located at an intersection controlled on all four legs by stop signs. Meanwhile, the two-way-stop crosswalk is located at an intersection controlled on the east-west legs by stop signs. In this instance, the study crosswalk cuts across the north-south street, which is uncontrolled. Drivers were aware that there was a crosswalk at this junction since the crosswalk was signed as an elderly pedestrian crosswalk, as shown in Figure 1. The *City of Calgary Traffic Control Manual* (*12*) contains an elderly pedestrian crosswalk sign that is used at painted crosswalks in areas commonly used by elderly pedestrians such as areas near senior citizens' homes. The sign is used in conjunction with the elderly pedestrian advance warning sign (Figure 1). Both crosswalks are used as access conduits from the immediate residential area to a nearby shopping and service district. Many pedestrians use either crosswalk on their way to or from a shopping plaza located just west of the two intersections. The crosswalks were parallel to each other and had close but not equal crossing distances: 13.14 m for the four-way-stop crosswalk and 14.20 m for the two-way-stop crosswalk.

The reason that the two-way-stop crossing speeds were so much lower than the four-way-stop crossing speeds was probably due to a flaw in the data collection procedure. For instance, at the two-way-stop intersection, pedestrians who were in a hurry probably either crossed midblock or crossed the intersection on a diagonal. These pedestrians were not counted in the study. Thus, the two-way-stop study is biased toward unhurried pedestrians. This bias is illustrated in the answer to the question, "Do you walk faster than normal when crossing?" Sixty-five percent of pedestrians at the two-way-stop crosswalk answered no; 45 percent of pedestrians at the four-way-stop crosswalk answered no. Furthermore,

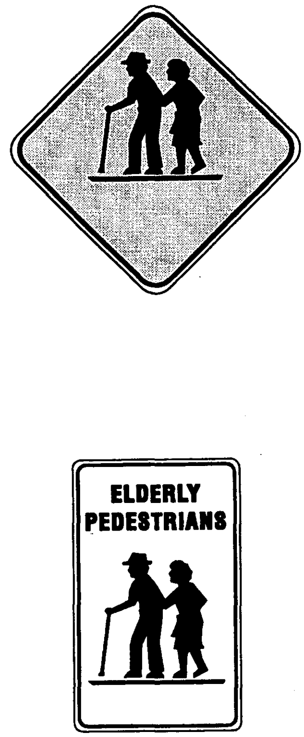

FIGURE 1 Elderly pedestrian crosswalk signs (*12*).

as at other study intersections where traffic volumes changed throughout the day, many participants added that their crossing speed depended primarily on prevailing traffic conditions. The four-way-stop intersection was busier than the two-way-stop intersection. The four-way-stop is more representative of crossing speeds of elderly pedestrians at uncontrolled intersections than the two-way stop.

Hypothesis testing indicated that the walking speeds at the signalized crosswalks could be combined as could the walking speed at the midblock pedestrian-actuated crosswalk. Figure 2 shows the cumulative frequency diagrams for both combined groups and the Kerby Center normal walking speed. Note that the cumulative walking speed diagram at the midblock crosswalk closely matches that of the Kerby Center normal speed. As shown in Figure 2, 15 percent of elderly pedestrians walked slower than 1.0 and 1.2 m/s at midblock and signalized crosswalks, respectively. The 85th percentile is commonly used in transportation engineering as a fair compromise between the needs of the majority and realistic design. Using this principle, the following design crossing speeds are suggested: for midblock crosswalks, 1.0 m/s; for signalized intersections, 1.2 m/s.

CONCLUSIONS

The following conclusions were drawn from this study:

1. It appears that the walking speed of elderly pedestrians varies according to functional classification, gender, and intersection type.
2. Elderly pedestrians reported a range of problems associated with crosswalks, including difficulty negotiating curbs, fear of turning vehicles, inability to judge the speed of incoming vehicles, discourteous drivers, and confusion with the WALK, flashing DON'T

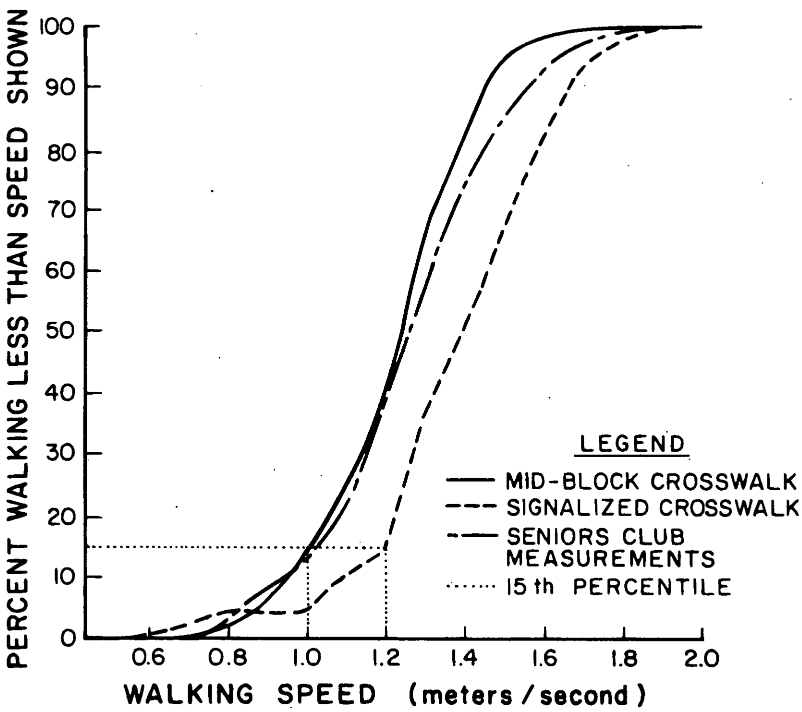

FIGURE 2 Cumulative distribution of walking speeds of elderly pedestrians.

WALK, and solid DON'T WALK pedestrian signal indications. At signalized intersections near seniors and nursing homes, where most pedestrians are elderly, a design walking speed of 1.0 m/s is satisfactory.

3. Suggested design walking speeds for elderly pedestrians at midblock crosswalks and signalized intersections are 1.0 and 1.2 m/s, respectively. At signalized intersections near seniors and nursing homes, a design walking speed of 1.0 m/s is suggested.

ACKNOWLEDGMENT

This study was funded by the Natural Sciences and Engineering Research Council of Canada.

REFERENCES

1. *Manual on Uniform Traffic Control Devices.* FHWA, U.S. Department of Transportation, 1988.
2. *The Walking Speeds of Elderly Pedestrians.* Department of Civil Engineering, University of Calgary, Alberta, Calgary, 1992.
3. *Uniform Traffic Control Devices for Canada.* Transportation Association of Canada, Ottawa, Ontario, 1976.
4. Kell, J. H., and I. J. Fullerton. *ITE Manual of Traffic Signal Design.* Prentice-Hall, Englewood Cliffs, N.J., 1982.
5. Traffic Control Devices Handbook. FHWA, U.S. Department of Transportation, 1983.
6. Imms, F. J., and O. G. Edholm. Studies of Gait and Mobility in the Elderly. *Age and Ageing,* Vol. 10, 1981, pp. 147–156.
7. Cunningham, D. A., P. A. Rechnitzer, and A. P. Donner. Exercise Training and the Speed of Self-Selected Walking Pace in Men at Retirement. *Canadian Journal on Ageing,* Vol. 5, No. 1, 1986, pp. 19–26.
8. Wilson, D. G., G. B. Grayson. *Age-Related Differences in the Road Crossing Behavior of Adult Pedestrians.* TRRL Laboratory Report 933. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1980.
9. Molen, N. H., R. H. Rozendal, and W. Boon. Fundamental Characteristics of Human Gait in Relation to Sex and Location. *Proc., Koninklijke Nederlands Akademie van Wetenschappen,* Series C, Vol. 75, 1972, pp. 215–223.
10. Dahlstedt, S. *Långsamma Fotgängare—Pensionärers Gånghastigheter och Promenadvanor* (in Swedish). Report R2. Swedish Council for Building Research, Stockholm, 1978.
11. Lanalni, N., and B. Baranowski. Reducing Public Confusion About the Use of Pedestrian Signals. *ITE Journal,* Vol. 63, No. 1, 1993, pp. 41–43.
12. *City of Calgary Traffic Control Manual.* Traffic Operations Division, Transportation Department, Calgary, Alberta, Canada 1990.