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Contents

Foreword

The first three papers in this Record pertain to pedestrian control. The paper by Zaidel and Hocherman examines three basic pedestrian crossing provisions common at signalized intersections: an uncontrolled crossing at a right-turn filtering lane; a pedestrian crossing phase concurrent with the vehicle phase, thus causing conflicts with turning vehicles; and an exclusive pedestrian phase, completely separating pedestrians from turning vehicles. The relationship between crossing type and the average number of accidents per intersection was tested while factors known to àffect accident level were controlled for. Seneviratne and Fraser deal with issues related to planning for pedestrian needs in central business districts. Planning policies and guidelines that will enable user needs to be better incorporated into the planning process are suggested. The last paper in this group, by Smith and Knoblauch, addresses the need for uniform guidelines for installing crosswalks. The recommended guidelines call for marked crosswalks at all signalized intersections with pedestrian signal heads and unsignalized locations that satisfy specific minimum vehicular and pedestrian volume criteria.

The second group of papers in this Record deals with bicycle transportation. Replogle reviews and summarizes recent research concerning bikes-on-transit from American cities and from foreign sources not readily accessible to North American transportation professionals. He offers recommendations for the further development of bicycle-transit integration as a potentially important strategy for reducing suburban traffic congestion and boosting the performance and productivity of suburban transit services. Kerr investigates the role played by demographics as well as the energy crisis in the resurgence of the demand for bicycles in the United States that has occurred during the last 20 years. Berchem describes a community campaign to increase the use of helmets among bicyclists in Madison, Wisconsin. Field counts showed that helmet use increased from 15.0 percent before the promotional campaign to 19.2 percent after the campaign.

Safety of Pedestrian Crossings at Signalized Intersections

David M. Zaidel and Irit Hocherman

In Israel three basic pedestrian crossing provisions are common at signalized intersections: an uncontrolled (but marked) crossing at a right-turn filtering lane; a pedestrian crossing phase concurrent with the vehicle phase (which may produce conflicts with turning vehicles); and an exclusive pedestrian phase, completely separating pedestrians from turning vehicles. The relative risk of these crossing-turning designs was evaluated through accident analysis. The data base consists of information about geometry, traffic, and operational characteristics of 320 signalized intersections in Tel Aviv, Jerusalem, and Haifa, and details of 5,132 vehicle accidents and 1,310 pedestrian accidents that occurred at those intersections during 1977–1982. The relationship between crossing type and average number of accidents per intersection was tested while factors known to affect accident level—vehicle volume, pedestrian activity, and intersection complexity—were controlled for. Pedestrian accidents were indeed influenced by these factors, but the various crossing types had little effect, if any, on the number of pedestrian accidents, and no effect on the number of vehicle collisions. There was some indication that exclusive and concurrent phases provide different degrees of pedestrian protection in particular combinations of vehicle and pedestrian volumes.

With the ever-increasing demands for improved safety and operational efficiency of signal-controlled intersections, many aspects of intersection and signal design are being critically reexamined *(1–3)*. Provisions for pedestrians crossing at signalized intersections are of particular concern because of the vulnerability of pedestrians and because of the apparent increase in delays and operational and maintenance costs involved in pedestrian signals and other provisions.

Zegeer et al. *(4)* concluded that there was no significant difference in the pedestrian accident experience of standard signal-controlled intersections compared with similar intersections in which pedestrians cross concurrently with vehicles. Robertson and Carter *(1)* reported similar findings. Knoblauch et al *(5)*, on the other hand, report a lower hazard index for intersections equipped with pedestrian signals compared with intersections without special pedestrian indications. A hazard index as estimated in that study is the ratio of accidents to exposure.

It might be expected that an exclusive pedestrian phase would demonstrate a positive safety effect for pedestrians. However, the number of such installations in the United States is not very large, because traffic engineers are reluctant to use them *(1)*. In their data base of 1,300 intersections, Zegeer et al. *(4)* had only 109 intersections equipped with an exclusive pedestrian phase. The arrangement showed a probable safety advantage only at high pedestrian and vehicle volumes.

Concern with pedestrian safety at signalized intersections revolves around vehicle turning movements. This is because in most applications the signal-timing program does not separate crossing pedestrians and turning vehicles [right turn on green (RTOG) and left turn on green (LTOG)]. The right-turn-on-red (RTOR) maneuver adds yet another potential conflict with pedestrians at both ends of the turning movement *(3)*.

Table 1 shows the distribution of pedestrian accidents by direction of vehicle movement as reported in several U.S. studies and in Israel. It can be seen that the majority of pedestrian accidents at signalized intersections involve vehicles going straight ahead (a small percentage involve vehicles backing up). The proportion of accidents related to turning in the U.S. studies and in Israel is 30 to 45 percent. The Israeli figures are based on the total national accident file for 1980–1982. More than 90 percent of the 850 pedestrian accidents at signalized intersections were on urban streets.

Left-turn maneuvers are generally considered more hazardous for pedestrians than right-turn maneuvers *(1)*, a conclusion reflected by the U.S. data in Table 1. When the proportions of turnign vehicles are considered (15 to 25 percent are typical design assumptions), the hazard associated with turning vehicles is higher than that for those going straight ahead *(1, 7)*. However, unlike previous results, Knoblauch et al. *(5)* found similar exposure ratios for left- and right-turning vehicles (7 to 8 percent) and a lower hazard index compared with that for vehicles going straight ahead.

The RTOR maneuver, on the other hand, was found by Knoblauch et al. *(5)* to have a relatively high hazard index—it accounted for a small percentage (1.6 percent) of pedestrian accidents, but for an even smaller percentage (0.5 percent) of turning vehicles in the exposure data.

In Israel the smaller proportion of accidents associated with left-turning compared with right-turning vehicles can be attributed to the provision in the signal program of an exclusive or nonconflicting phase for all left-turning vehicles. During this phase, pedestrians usually face a Don't Walk indication.

How can the conflict between turning vehicles and crossing pedestrians be minimized? Zegeer et al *(8)* and Zegeer and Cynecki *(3)* list numerous design alternatives to enhance clarity of signals, alert pedestrians or motorists, decrease pedestrian delays, and improve compliance. Chadda and Schonfeld *(9)* suggest the use of exclusive right-turn lanes as an engineering

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TABLE 1 PEDESTRIAN ACCIDENTS AT SIGNALIZED INTERSECTIONS: DATA FROM UNITED STATES AND ISRAEL

Study	Percentage of Accidents by Vehicle Direction: Left Turn	Right Turn	Straight and Other	No. of Accidents	No. of Intersections	Source of Study Data
United States						
Fruin *(6)*	31	14	55	172	32	One-way grid intersections, Manhattan
Habib *(7)*	25	13	62	455	45	One-way grid intersections, Manhattan
Zeeger et al *(4)*	22	15	63	2,081	1,297	Fifteen cities
Robertson and Carter *(1)*	17	12	71	202	62[a]	Washington, D.C., area
Israel	13	17	70	850	520	All signalized intersections

[a] Of which 54 were signalized.

countermeasure for preventing pedestrian–vehicle conflicts at RTOR-type turns. Pedestrian signalization practices in Israel provide an opportunity to evaluate the effectiveness of three basic crossing arrangements that are also used in the United States.

PEDESTRIAN SIGNALIZATION PROVISIONS IN ISRAEL

All traffic signals are equipped with pedestrian indications at the zebra-marked crosswalks. Two symbolic indications are used—a red standing man and a green walking man.

Most urban intersections have a separate pedestrian phase at one or more of the intersection legs. A second common provision is a partially concurrent phase with right-turning vehicles. Left turns are usually controlled by a separate indication. Pedestrians have the legal right-of-way, and this fact is emphasized by the provision of a flashing amber beacon with a symbol of a pedestrian facing the right-turning vehicles or a standard sign, Yield to Pedestrian, or both. There is no RTOR provision in the Israeli traffic code.

The third arrangement provides for a separate uncontrolled right-turn lane channeled to merge into the intersecting road. Usually a marked crosswalk diagonally connects the curb to the traffic island, but sometimes a crosswalk is in the usual corner position. In the former case, pedestrians cross to the island without a signal; in the latter, they are still controlled by a pedestrian indication. In either case, drivers are alerted to the crosswalk by a flashing amber beacon and a Yield sign.

Because of delays and capacity considerations, there is a tendency in Israel to convert, wherever possible, an exclusive phase to a separate right-turn lane or to a concurrent-phase arrangement. Yet there are concerns about possible safety trade-offs associated with the more economical crossing provisions. In this study the safety performance of the three pedestrian crossing arrangements at urban signalized intersections is examined.

METHOD

The study is based on analysis of accident data from most of the signalized intersections (317) in the three major cities in Israel—Jerusalem, Tel Aviv, and Haifa—during the period 1977–1982. Detailed characteristics of the geometry and traffic and signal devices at the intersections were collected. These included traffic volumes, level of pedestrian activity, typical approach speed, number of legs and lanes, turning directions on each leg, and type of crossing provision. For each intersection, detailed data on all accidents that occurred during the 6-year period were extracted from the national data file of injury accidents.

The analyses were performed separately for two 3-year periods (1977–1979 and 1980–1982) in order to increase uniformity within each period and to examine the stability of the findings.

The data in the computerized accident file do not include information on the specific location of the accident, so direction of vehicle movement could not be linked to a specific leg of an intersection. Therefore, the unit of analysis was an intersection rather than a leg, and all pedestrian or vehicle accidents were included and not only those related to turning movements.

The basic logic of the analysis is that, given a large enough data base, it is possible to group the intersections so that each group is characterized by a different combination of crossing arrangements. It should thus be possible to detect significant differences in accident frequencies among the groups, if such differences do exist. However, it must be admitted that an analysis at the intersection level may not be sensitive to small differences or to complex associations between specific crossing combinations and accidents.

The intersections were classified into six groups by type of crossing provision, as follows:

1. Complete separation at all legs,
2. Uncontrollable crossing at an exclusive right-turn lane or a concurrent phase at one of the junction's legs,
3. Uncontrolled crossing at two intersection legs (and exclusive phases at all others),
4. Concurrent phases at two legs (and exclusive phases at all others),
5. Concurrent phases at three legs (and exclusive phases at all others), and
6. Mixed arrangements—at least one leg with an uncontrolled crossing and one leg with a concurrent phase.

The classification was constrained by the need to have a sufficient number of intersections in each category for analysis. The following intersection characteristics were used in the analyses: number of entering vehicles [annual average daily traffic (AADT)], level of pedestrian activity, approach speed, number of legs, number of conflict points, and type of crossing provision. Pedestrian activity and approach speeds were rated by traffic engineers who were familiar with the intersections. Pedestrian activity was graded on a three-level scale: low (less than 200 pedestrians crossing at peak hour); medium (200 to

TABLE 2 ACCIDENT STATISTICS FOR 317 URBAN SIGNALIZED INTERSECTIONS STUDIED

	Pedestrian Accidents		Vehicle Accidents		Total	
Statistic	1977–1979	1980–1982	1977–1979	1980–1982	1977–1979	1980–1982
No. of accidents	787	523	2,930	2,202	3,717	2,725
Intersections with no accidents (%)	20	36	6	11		
Avg no. of accidents per intersection	2.48	1.65	9.24	6.95	11.73	8.6
Correlation coefficient between accidents at same intersection during two time periods	$r = 0.49$		$r = 0.79$			

600 pedestrians at peak hour); and heavy (more than 600 pedestrians at peak hour). Approach speed had two levels, low and high. The number of conflict points was determined by the number of legs and the number of turning and through lanes, which reflect the complexity of traffic at the junction.

RESULTS

Table 2 summarizes the accident data for the 317 intersections. Pedestrian accidents accounted for 20 percent of the total in 1977–1979.

During 1980–1982, there was a general decline in urban accidents in Israel, a fact also reflected in Table 2. Pearson correlation coefficients were calculated between the number of accidents at each intersection during the two time periods. The coefficients, for both vehicle and pedestrian accidents, are statistically significant. The lower correlation coefficient between pedestrian accidents during two periods compared with the corresponding coefficient for vehicle accidents reflects the higher variance of pedestrian accidents.

Pedestrian Accidents

The univariate associations between intersection characteristics and the number of pedestrian accidents are shown in Table 3. Univariate associations between number of accidents and the

TABLE 3 PEDESTRIAN ACCIDENTS PER INTERSECTION IN THREE YEARS BY INTERSECTION CHARACTERISTICS

	Accident Data			
	1977–1979		1980–1982	
Category	Avg No. of Accidents	No. of Intersections	Avg No. of Accidents	No. of Intersections
No. of conflicts				
1–6	2.08	109	1.58	108
7–20	2.44	133	1.69	132
21+	3.13	75	1.65	78
No. of legs				
3	1.74	81	1.24	87
4	2.68	216	1.76	212
5+	3.40	20	2.21	19
Approach speed				
Low	2.52	192	1.88	185
High	2.48	105	1.25	113
AADT				
–14,999	1.88	52	1.28	47
15,000–17,999	1.88	40	1.18	38
18,000–21,999	2.74	46	1.96	47
22,000–24,999	2.97	29	2.43	80
25,000–29,999	2.97	40	1.60	40
30,000+	3.67	43	2.09	45
Pedestrian activity level				
Low (< 200 crossings/hr)	1.71	117	1.04	117
Medium (200–600 crossings/hr)	3.12	81	2.40	79
High (> 600 crossings/hr)	3.40	67	2.82	71
Type of crossing provision				
Separate phase	2.33	42	1.78	46
Concurrent or uncontrolled at one leg	2.43	68	1.40	72
Uncontrolled turn at two legs	2.15	33	1.23	39
Concurrent phase at two legs	2.14	83	1.64	75
Concurrent phase at three-plus legs	3.07	60	1.96	55
Mixed arrangements	2.94	31	2.03	30
All intersections	2.48	317	1.65	317

characteristics of the intersections were tested by using a one-way analysis of variance. The average number of accidents per intersection increases with the number of intersection legs, traffic volumes, the level of pedestrian activity, and the number of conflict points. No clear relationship was found with approach speed.

The joint effect of traffic volume and pedestrian activity on accidents is shown in Figure 1. Traffic volumes were dichotomized to those less than and more than 18,000 vehicles (AADT) according to the findings in Table 3. A second possible cutoff point at 30,000 vehicles was not used because of the small number of intersections with such high volumes. Similar cutoff points for the effect of traffic volumes on pedestrian accidents (18,000 and 27,000) were found by Zegeer et al. *(4)*.

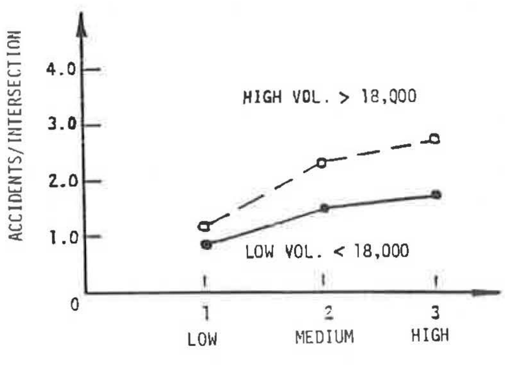

FIGURE 1 Accidents as a function of traffic volume and pedestrian activity.

Both vehicle volume and pedestrian activity are positively correlated with the average number of accidents. The effect of vehicle volume is larger in conjunction with medium or high levels of pedestrian activity. Pedestrian accidents for the period 1980–1982 were also analyzed by pedestrian action, age of casualty, and severity of the accident. Most accidents (83 percent) occurred during crossing; 25 percent were severe or fatal. Of the pedestrian casualties, 15 percent were children under the age of 14, and 21 percent were elderly, aged 65 and over. No differences were found among the different types of crossing arrangements except for a slightly higher percentage of elderly casualties at intersections with a concurrent pedestrian phase at two or more legs. This finding may be related to the higher level of alertness needed when crossing such intersections.

Comparison of Crossing Provisions

The average number of accidents per intersection for the six categories of crossing provision is presented in Table 3. The number of accidents at intersections with mixed provisions and at intersections with a concurrent phase at three of the legs was higher than that for intersections with the other provisions. However, one-way analysis of variance revealed no significant differences among categories.

The net effect of the type of crossing provision, after the effects of other traffic characteristics were controlled for, was evaluated by means of a multivariate analysis of variance. Traffic volume and pedestrian activity had a significant main effect on accidents ($P = .001$), with no interaction effect. The effect of crossing provision after adjustment for vehicle and pedestrian volumes was not significant ($P = .70$). Similar results were obtained for the two time periods. Further analyses containing additional characteristics of the intersections as control variables all revealed the same basic findings: effects of traffic volume and level of pedestrian activity were significant and effects of the type of crossing provisions were not significant.

It was possible that the classification of intersections grouped together intersections that were not homogeneous enough and, consequently, that differences between types of crossing provisions were masked in the analysis. Therefore the analysis was repeated on a subset of 205 intersections that had similar types of crossing provision on most of the intersection legs. The intersections were classified into three groups:

1. Intersections with a separate pedestrian phase on all legs,
2. Intersections with uncontrolled crossings on at least two legs, and
3. Intersections with a concurrent phase on at least two legs.

The mean number of accidents for 2 × 2 combinations of traffic and pedestrian volumes and for each crossing type is given in Table 4. The number of accidents is not shown for cells containing less than six intersections. It seems that the three types of crossing arrangements do not differ when traffic volumes are low. However, when vehicle volumes are high and pedestrian volumes are low, the mean number of accidents for

TABLE 4 PEDESTRIAN ACCIDENTS PER INTERSECTION BY CROSSING TYPE, TRAFFIC VOLUME, AND LEVEL OF PEDESTRIAN ACTIVITY

		1977–1979 Data by Crossing Type						1980–1982 Data by Crossing Type					
		Exclusive Pedestrian Phase		Uncontrolled Crossing (2+ legs)		Concurrent Phase (2+ legs)		Exclusive Pedestrian Phase		Uncontrolled Crossing (2+ legs)		Concurrent Phase (2+ legs)	
Traffic Volume	Pedestrian Activity	Avg. No. of Accidents	No. of Intersections	Avg. No. of Accidents	No. of Intersections	Avg. No. of Accidents	No. of Intersections	Avg. No. of Accidents	No. of Intersections	Avg. No. of Accidents	No. of Intersections	Avg. No. of Accidents	No. of Intersections
Low	Low	–	–	1.9	8	1.6	27	–	–	0.4	10	1.2	21
Low	High[a]	2.6	12	–	–	2.4	28	1.8	14	–	–	1.6	27
High	Low	1.4	7	1.1[b]	14	2.4[b]	25	1.0	8	0.7[b]	18	1.5[b]	25
High	High	3.4	13	4.3	8	4.0	43	3.0	14	3.3	8	2.5	37

[a]Previously medium and high combined.
[b]Differences between means are statistically significant ($P < .05$).

TABLE 5 VEHICLE ACCIDENTS PER INTERSETION IN THREE YEARS BY INTERSECTION CHARACTERISTICS

	Accident Data			
	1977–1979		1980–1982	
Category	Avg. No. of Accidents	No. of Intersections	Avg. No. of Accidents	No. of Intersections
No. of legs				
3	7.67	81	5.44	87
4	8.04	78	5.93	72
5+	10.60	159	8.22	159
AADT				
–14,999	4.92	52	3.96	47
15,000–17,999	5.22	40	3.82	38
18,000–21,999	9.00	46	6.72	47
22,000–24,999	8.34	29	6.20	30
25,000–29,999	10.97	40	6.82	40
30,000+	22.44	43	17.60	45
No. of conflicts				
1–6	5.47	109	4.44	108
7–20	9.47	133	6.49	132
21+	14.32	75	11.17	78
Approach speed				
Low	7.50	193	5.20	186
High	12.34	106	9.61	113
Pedestrian activity level				
Low	8.40	113	6.99	113
Medium	10.32	78	7.56	75
High	7.89	61	5.58	65
Type of crossing provision				
Separate phase	8.05	42	5.54	46
Concurrent or uncontrolled at one leg	9.99	68	7.60	72
Uncontrolled turn at two legs	9.24	33	7.36	39
Concurrent phast at two legs	8.45	83	6.11	75
Concurrent phase at three-plus legs	10.57	60	8.29	55
Mixed arrangements	8.81	31	6.63	30

intersections with a concurrent phase is higher than for intersections with the other two provisions—exclusive phase or uncontrolled crossing with a separate turn lane. This result was found for both time periods. However, not all pairwise comparisons were statistically significant. When both vehicle volume and pedestrian activity level are high, a separate phase appears safer than uncontrolled crossing, but the differences were not statistically significant.

Vehicle Accidents

Table 5 shows the mean number of vehicle accidents for various intersection characteristics. The number of accidents increases with traffic volume, number of conflict points, typical approach speed, and complexity of the intersection. As expected, no systematic relationship can be noted with level of pedestrian activity or with type of crossing provisions. The results are similar for the two time periods. These results also were essentially upheld in a multivariate analysis.

DISCUSSION

The main purpose of the study was to compare the level of safety of three basic pedestrian crossing provisions in urban signalized intersections: complete separation in time between vehicles and pedestrians (separate phase); a concurrent phase for pedestrians and turning vehicles (mostly right turns), and a free right-turn lane combined with uncontrolled crossing. The analysis was based on 6-year injury accident data and the characteristics of 317 urban intersections.

Several intersection characteristics are clearly related to increased likelihood of accidents. The most obvious ones are traffic volume and amount of pedestrian activity. The complexity of an intersection as measured by either number of legs or number of conflict points is also related to number of pedestrian and vehicle accidents.

The type of pedestrian crossing provision appears to have only a slight effect on pedestrian accidents and no effect on vehicle injury accidents. Pedestrian and vehicle volumes are the most important factors determining the apparent differences between crossing provisions. At low vehicle volumes (less than 18,000 AADT), it makes little difference which crossing arrangement is provided for pedestrians (within the types used in Israel), irrespective of the level of pedestrian activity. Only at high vehicle and pedestrian volumes might an exclusive pedestrian phase possibly be advantageous. Zegeer et al. *(4)* report a similar conclusion. The concurrent-phase provision appears to be more dangerous to pedestrians compared with the other provisions when vehicle traffic is heavy but pedestrian traffic is light.

In order to understand the relative efficacy of pedestrian crossing provisions, one must consider their operational aspects. For example, the arrangements differ in the delays they cause motorists and pedestrians, which in turn influence the behavior of motorists and pedestrians. Khasnabis et al. *(10)* arrived at a similar conclusion after reviewing the literature.

The actual performance of either a separate or a concurrent pedestrian phase depends on the willingness of drivers to yield to pedestrians and on the compliance of pedestrians with the signal indication. Pedestrians do not necessarily wait for green or their exclusive green. In practice, many utilize gaps in traffic even against a red light. At low traffic volumes, noncompliance does not entail a serious risk, and therefore potential differences between crossing arrangements would be reduced. Paradoxically, it is very likely that noncompliance will be relatively high at separate-phase crosswalks when traffic volume is low, because of larger delays and the perceived lack of justification for waiting.

In a study of RTOR violations by motorists, Zegeer and Cynecki *(3)* observed both RTOR and RTOG violations and conflicts with pedestrians. High rates of violations were associated with low (cross-street) traffic and low pedestrian volume. Intersection geometry that allows an easy right-turn movement also encourages violations. This situation is similar to the exclusive right-turn lane combined with uncontrolled crossing. At high pedestrian and vehicle volumes, pedestrians will have a hard time finding safe gaps for crossing, and under these conditions, the separate-phase provision would have an advantage over other provisions.

With high pedestrian volumes, concurrent provisions might also function reasonably well, because pedestrians can force their right of way and drivers cannot easily ignore them. It would seem that measures to increase the conspicuity of the crosswalk and the driver's obligation to yield to the pedestrian *(8)* could be effective under these conditions. In Israel all concurrent-phase crossing provisions are emphasized with flashing beacons and Yield signs. Nevertheless, at low pedestrian activity and high vehicle volume, these provisions are not as safe as others. The inescapable conclusion might be that at low traffic volumes, pedestrians could fend for themselves fairly well no matter what the provisions were, but at heavy traffic volumes only an unambiguous separate pedestrian phase (or complete spatial separation) can provide an acceptable level of safety for pedestrians while crossing a signalized intersection.

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Issues Related to Planning for Pedestrian Needs in Central Business Districts

PRIANKA SENEVIRATNE AND PHILIP FRASER

The complexity of pedestrian travel patterns has resulted in the lack of in-depth research and standard procedures for planning and designing pedestrian facilities compared with those for other modes. A pedestrian circulation study was conducted in downtown Halifax, Nova Scotia, to analyze factors affecting the choice of routes. These factors were examined in relation to the physical characteristics of the location, personal characteristics of the trip makers, and the type of trip being made. The investigation of circulation patterns and needs suggests that the primary objective of central business district pedestrians is movement between points by the shortest path and that protection from weather, congestion-free sidewalks, and safety are only secondary concerns. Planning policies and guidelines are suggested that will enable user needs to be better incorporated into the planning process. An attempt is also made to compare these findings with those from other Canadian and European cities. These findings seem to suggest that pedestrians' needs and the difficulty of implementing new planning policies are similar in many ways.

The focus on pedestrians in general has been changing slowly since the early 1970s. However, this vital mode still receives low priority relative to the highly visible and attractive automobile and other transportation systems.

Walking constitutes a very small part of a journey. The average length of a typical central business district (CBD) walk trip ranges from approximately 350 m in a small CBD such as Halifax, Nova Scotia *(1)*, to just over 600 m in central Detroit *(2)*. Those arriving in CBDs by other modes walk approximately 250 m on average between terminals and final destinations *(1, 3)*. However, walking is the prime mode of travel to a vast number of visitors to the CBD. For example, approximately 10 percent walk to and from work in Halifax, whereas the corresponding proportion in Calgary, Alberta *(3)*, and in several larger cities in the United Kingdom *(4)* is approximately 2 and 4 percent, respectively. Walking is also the main mode of travel for intra-CBD trips. For instance, more than 75 percent of intra-CBD trips are reportedly made on foot in large cities such as Atlanta, Detroit, and Norfolk *(2)*.

Recently, Mitchell and Stokes *(5)*, Hitchcock and Mitchell *(4)*, and Seneviratne and Morrall *(6)* investigated pedestrian needs in detail. These studies showed that basic pedestrian needs are not sufficiently addressed by current planning and design guidelines. It is apparent that existing design standards focus on capacity rather than accessibility *(7)*.

The existing planning procedures for the Halifax CBD are reported in this paper and factors are identified that have impeded the complete realization of the objectives of its municipal development plans, such as failure to recognize primary pedestrian needs and the lack of coordination between developers and the municipality. The discussions and suggestions are based largely on data from a questionnaire survey conducted in the Halifax CBD in the fall of 1985.

The population of the city of Halifax and the surrounding urban centers is approximately 290,000. Almost 23,000 have their primary workplace in the CBD (Figure 1). The walking portion of travel to and within the Halifax CBD is included with other modes in Figure 2.

The city of Halifax formulated a Municipal Development Plan (MDP) in 1978, outlining the new policies for dealing with current and future land use and transportation facilities. The ultimate goal of the MDP with regard to pedestrians is to "discourage the use of the private automobile to, within, and through the CBD, and give priority to the pedestrian and public transit" *(8)*.

The city government has, however, been hesitant in implementing its policies related to pedestrians. The recently completed sidewalk rehabilitation program near the waterfront, as shown in Figure 1, which was designed to emphasize pedestrian right-of-way or priority space, was initiated by the Halifax Waterfront Development Corporation. A few other projects, such as the four elevated walkways and the conversion of one block at the end of Granville Street into a pedestrian mall, were done independently by the developers at the time that adjacent buildings were constructed. The city's involvement in these projects has been minimal in terms of implementing its policies related to pedestrians, except at the time that development applications were approved.

DATA COLLECTION

A series of personal interviews was conducted during two consecutive weeks. Pedestrians were intercepted at entrances to buildings, at transit stops, midblock, and on the elevated (enclosed) walkways. A total of 410 interviews were obtained. Survey times were morning, lunch, and midafternoon intervals. These time periods allowed a wide mix of pedestrians with different trip purposes to be included in the sample.

The questionnaire shown in Figure 3, developed after a pilot survey in 1982, proved effective for the purpose. Respondents

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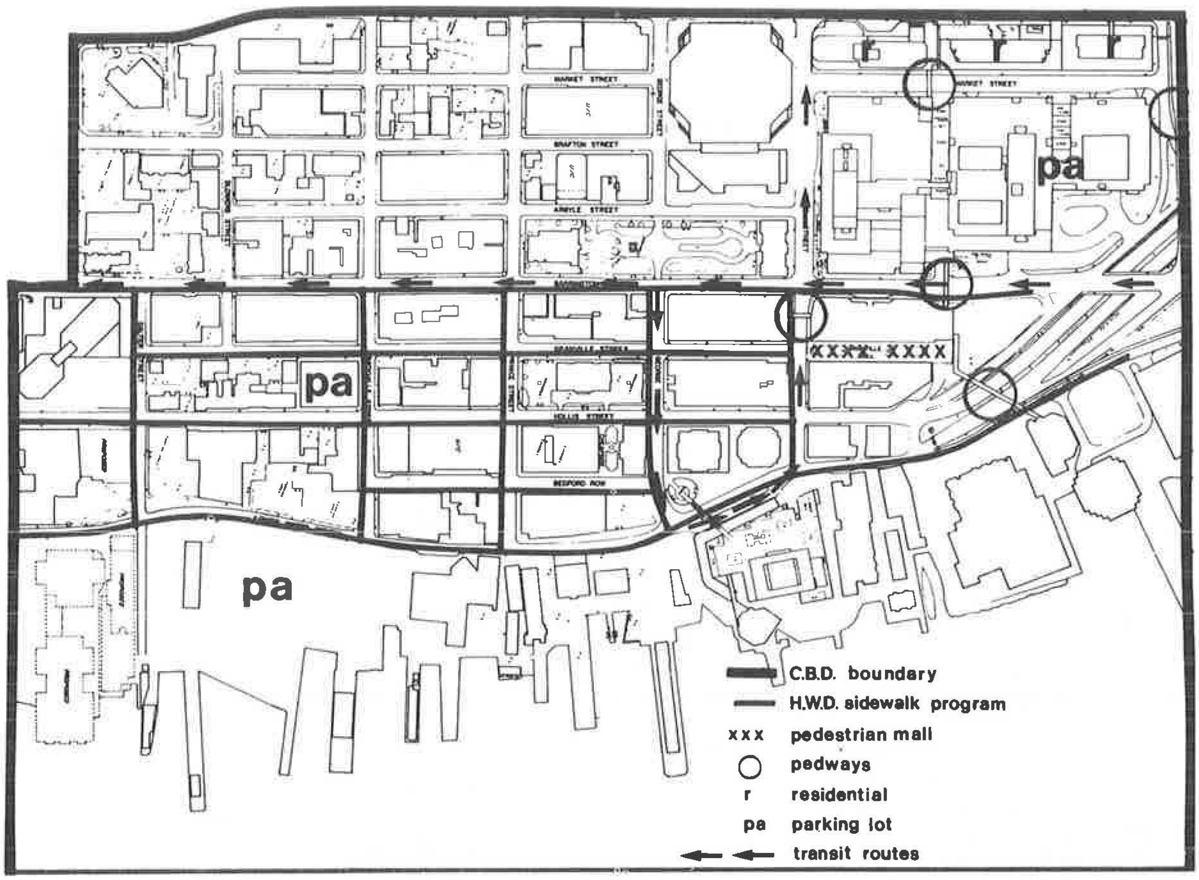

FIGURE 1 Central business district of Halifax, Nova Scotia.

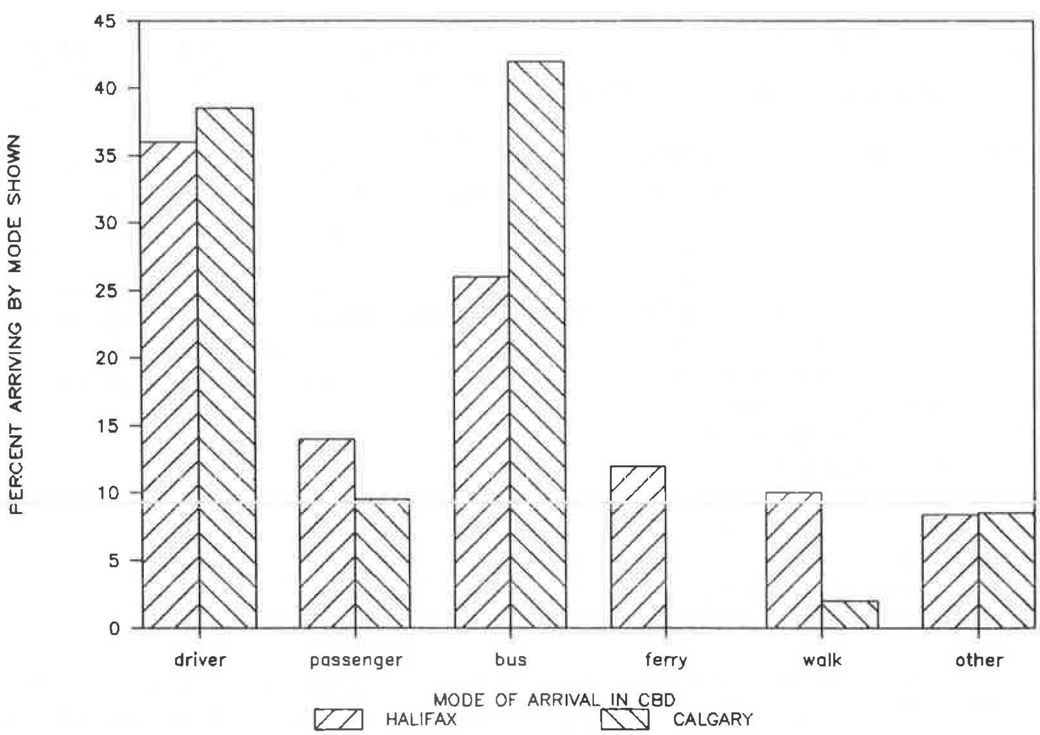

FIGURE 2 Percentage of arrivals in CBD by different modes.

Downtown Halifax
Pedestrian Circulation Study

(1) How did you arrive in the downtown today:

Car driver	______	Ferry	______
Car passenger	______	Bicycle	______
Drop off	______	Walk	______
Bus	______	Other	______

(2) Where in downtown Halifax are you coming from?

Parking lot ______
Bus stop ______
Ferry terminal ______
Place of work (office) ______
Business meeting ______
Shop ______
Restaurant ______
Other (please specify) ______

(3) What is the main purpose of your visit to this location today?

Place of work	______	Shopping	______
Business	______	Other	______

(4) Could you please indicate the route walked, from where you are coming on this map. (Indicate direction of travel by arrow).

(5) How would you best describe your decision to choose this walking path? (Select only one)

(i) I always go that way ______
(ii) It is the only route available ______
(iii) It is the quickest route ______
(iv) It has the least number of streets to cross ______
(v) It is the least crowded ______
(vi) It has more shops, stores, restaurants, etc. ______
(vii) It offers most protection from the weather ______
(viii) It has the least number of hills ______
(ix) It offers most personal security ______
(x) Other (please specify) ______

(6) Sex: Male ☐ Female ☐

(7) Age: ______
15-30 ______
30-50 ______
50-60 ______
60+ ______

(8) Time: ______ (9) Day of week: ______

(10) Location of survey: ______ (11) Weather: ______

FIGURE 3 Questionnaire for pedestrian circulation study.

were willing and able to provide accurate descriptions, and this is reflected in the high number of usable forms finally obtained (87 percent). The most time-consuming aspect was obtaining walking distances. These had to be retrieved from maps and coded with great care in order to minimize the errors. The network was developed based on distances between centers of intersections in the grid network in both CBDs.

The findings of a similar survey in Calgary, Alberta *(6)*, summarized in Table 1, enable one to examine the validity of several assumptions about pedestrian behavior that have been the basis of pedestrian planning procedures for more than a decade. For example, walking trips consist of two distinct types, total walking trips and access or egress trips. The former include lunch-time shopping trips by employees in a CBD or business trips between locations in the CBD (intra-CBD trips). The second type are the trips from the parking facilities and transit stops to places of work, or vice versa. These two types of trips have very different needs. Hence, sections with shopping facilities, restaurants, and similar opportunities, which are the primary destinations of total walking trips, are provided with aesthetic sidewalk surfaces, attractive lighting, and sometimes wider sidewalks. Conversely, access from transportation terminals to workplaces is often left circuitous or congested. The needs of access-egress trips have remained unfulfilled, even though they constitute more than 75 percent of the number of total daily walking trips. For instance, in Halifax there are at least 50,000 daily access-egress trips, whereas total

TABLE 1 RANKING OF FACTORS AFFECTING ROUTE CHOICE

Variable / Route Selection Criterion	Characteristics of trip maker											Characteristics of trip													Physical features				
		Sex		Age				Purpose of visit				Trip type								Time of day					Location				
	Overall sample population	Males	Females	15–30 yrs	30–50 yrs	50–60 yrs	60+ yrs	Downtown employee	Business person	Shopper	Other	Bus to work	LRT to work	Parking to work	Work to restaurant	Parking to business	Shop to shop	Work to shop	Bus to shop	AM peak	Morning	Noon hour	Afternoon	PM peak	Retail core	Retail +15	Office +15	Pedestrian mall	Office core
F_1—Always use	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	3	3	2	3	2	2	2	2	2	2	3	2	3	2
F_2—Only available	3	4	4	4	4	4	–	3	4	5	4	3	3	3	4	2	–	4	4	3	5	4	4	3	3	5	3	4	3
F_3—Quickest	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
F_4—Least # of st. crossings	5	5	5	5	5	5	4	5	6	4	–	4	6	4	5	–	4	4	–	6	4	6	5	5	5	4	5	4	5
F_5—Least crowded	6	5	7	6	6	5	–	6	5	–	5	6	5	4	3	3	–	5	–	4	6	5	–	6	6	6	–	5	5
F_6—Most attractions	4	3	3	3	3	3	3	4	3	2	2	5	4	4	3	4	1	3	2	5	3	3	3	4	4	2	4	2	4
F_7—Most weather protection	7	7	6	7	7	6	–	7	–	6	–	6	–	–	–	–	4	–	–	–	7	8	6	7	8	5	–	–	7
F_8—Least noise/air pollution	8	6	8	8	8	6	–	8	7	–	–	6	6	–	–	–	–	–	–	7	8	7	7	6	7	6	5	–	6
F_9—Most security	9	–	9	8	9	–	–	9	–	–	–	7	–	–	–	–	–	–	–	–	–	–	–	8	9	–	–	–	–
% Using other criterion	14.2	15.5	13.0	9.9	16.1	23.5	14.0	13.1	22.5	11.2	19.3	10.4	12.6	11.5	12.5	12.1	12.3	17.2	7.3	12.2	16.2	15.8	16.3	10.9	13.6	8.4	6.4	34.4	14.2
Total # of respondents	2 685	1,319	1,366	1,050	1,370	221	43	2,077	293	206	104	625	261	131	160	58	81	204	55	566	650	493	447	524	1,049	227	91	131	1,186
% of total sample population	100	49.1	50.9	39.1	51.0	8.2	1.6	77.4	10.9	7.7	4.1	23.3	9.7	4.9	6.0	2.2	3.0	7.6	2.0	21.1	21.1	18.5	18.5	16.6	39.1	8.5	3.4	4.9	44.2

(–)—no respondents in that category based their decision on that criterion. Ranks: 1- most important , 10- least important

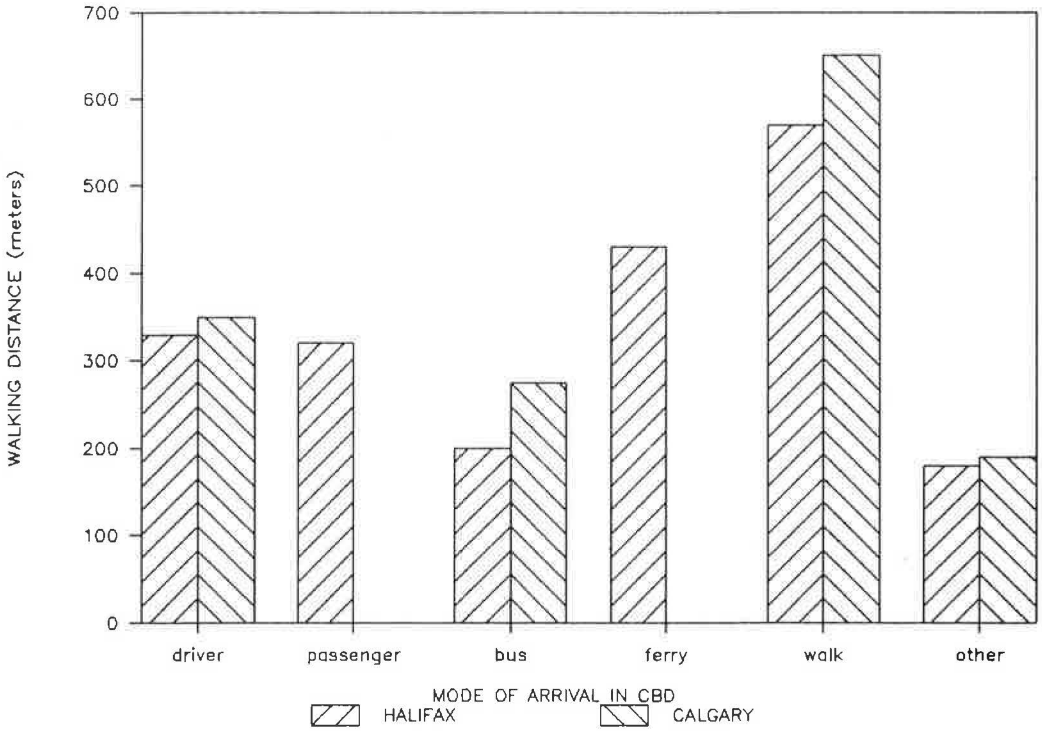

FIGURE 4 Average walking distance by mode of arrival in CBD.

TABLE 2 ARRIVAL MODE IN CBD AND PERCENTAGE USING A PARTICULAR ROUTE-SELECTION CRITERION IN HALIFAX

	Percentage by Route-Selection Criterion									
Mode	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Driver	23.3	4.6	60.5	0	0	2.5	4.6	0	0	4.6
Passenger	17.6	17.6	53	0	0	5.8	0	0	0	5.8
Bus	29	3.3	58	0	0	3.2	0	0	0	6.4
Ferry	28	0	57	57	0	7	0	0	0	7.1
Walk	33	0	25	0	8.3	8.3	0	16.6	0	8.3

NOTE: The following criteria were used: F1 = I always go that way; F2 = it is the only route available; F3 = it is the quickest route; F4 = it has the least number of streets to cross; F5 = it is the least crowded; F6 = it has more shops, stores, restaurants, etc.; F7 = it offers most protection from the weather; F8 = it has the least number of hills; F9 = it offers most personal security; F10 = other (please specify).

walking trips account for less than 20,000 trips a day. Accordingly, the primary need of the access-egress trip, that is, direct access by the shortest path, should also receive the same treatment as or higher priority than the substantially smaller number of total walking trips, for which aesthetics are more important.

Other fundamental characteristics of pedestrian movement and differing needs that became evident from the Halifax study are discussed in the following sections.

CIRCULATION CHARACTERISTICS

Mode of Arrival and Walking Distances

The primary arrival modes of visitors to the CBD and their respective mean walking distances are shown in Figures 2 and 4. It is evident from Tables 1 and 2 that whatever the mode of arrival or the city, the visitor's primary aim is to gain access to his destination by the shortest path.

Criteria for Selection of Route

One of the main purposes of the survey was to determine the primary pedestrian needs, that is, the type, quality, and, of course, the ideal location of facilities desired by pedestrians. Thus, the questionnaire was designed to obtain this information in terms of the factors that pedestrians consider in selecting the route for a particular journey. These factors were expected to indirectly reflect pedestrians' basic requirements. It is difficult or physically impossible to provide for every factor, and hence the subjects were asked to indicate only the most significant factor from the list of 10 (Table 2). This approach also eliminated the need for the respondents to rank the factors in order of importance, although one may argue that the subsidiary factors are equally useful for planning purposes.

Fifty-six percent of the subjects in Halifax selected a particular route because it was perceived to be the shortest path between their origin and destination (Figure 5). The second-largest group of subjects, 25 percent, selected the route because

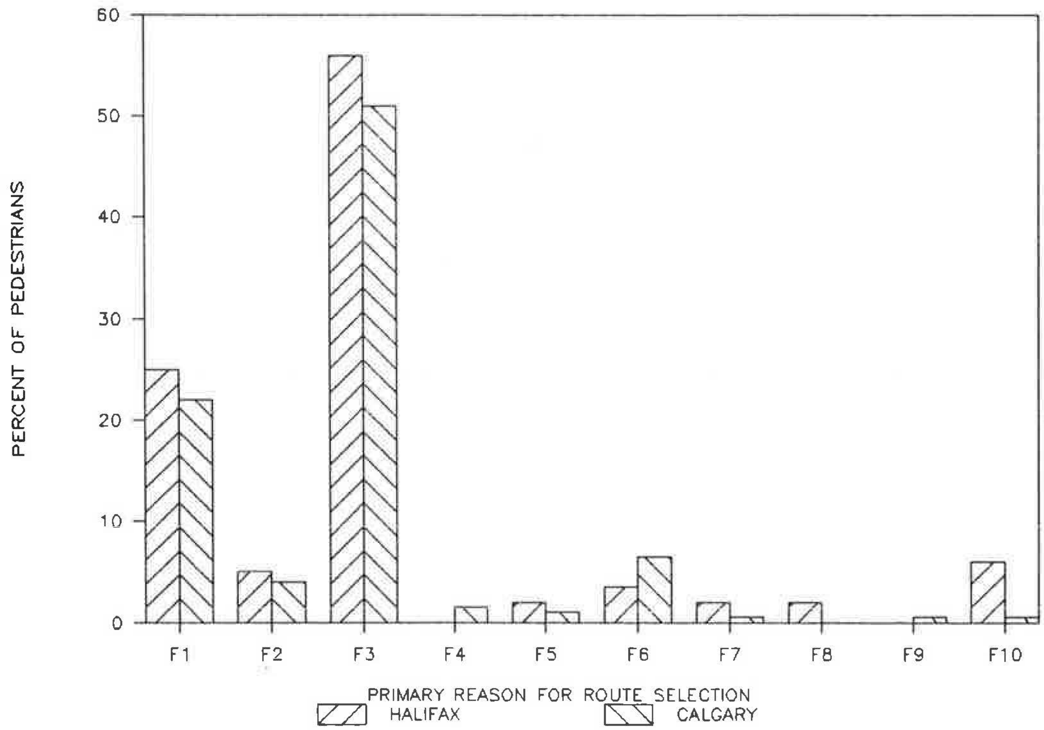

FIGURE 5 Percentage of pedestrians and the primary route-selection criteria.

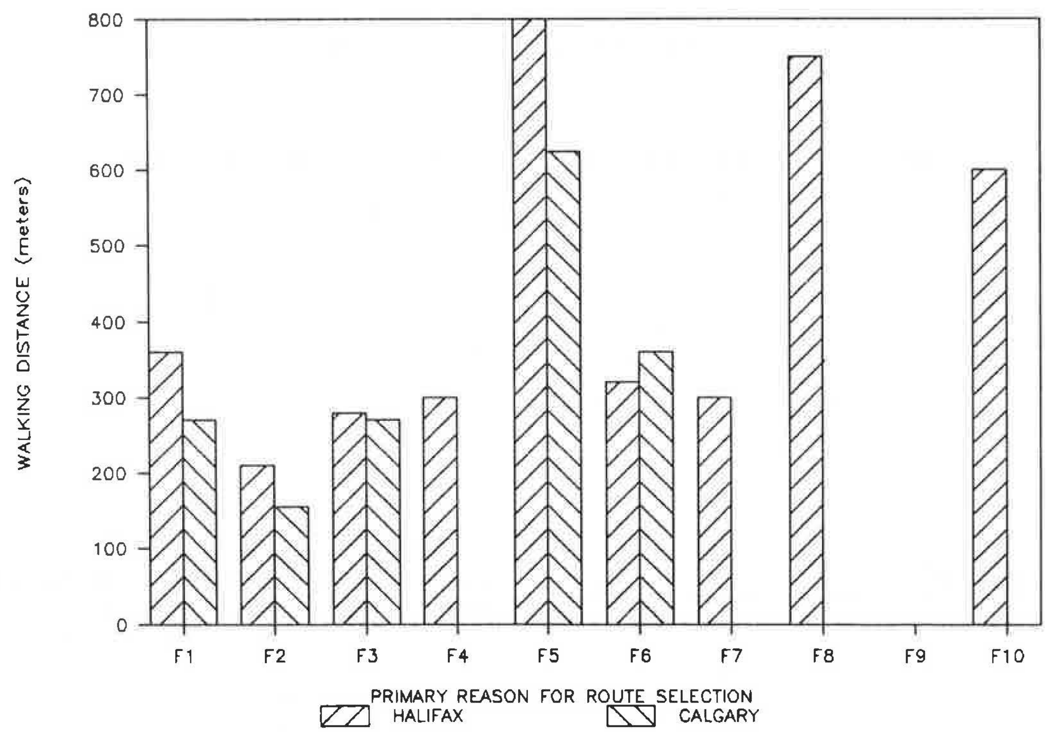

FIGURE 6 Average walking distance and route-selection criteria.

it was their regular one, and 5 percent selected their route because they believed it to be the only one available. The average walking distance of the last group (Figure 6) is less than that of the group that selected the route based on the perception that it was the shortest. This suggests that those who perceive a particular route to be the only available one have settled for a route that in fact is the shortest. This does not reflect an interviewing failure. Figure 6 also shows that in Calgary the pedestrians who selected the shortest path and those who have regular routes appear to walk similar distances, whereas those who chose the only available route walk the shortest mean distance.

In general, therefore, it appears reasonable to assume that at least 80 percent of pedestrians consider distance to be the most significant factor, and protection from weather, safety, congestion on sidewalks, and so on, to be only secondary factors.

This finding is consistent with those in Calgary *(6)* and also in the United Kingdom *(4)*, with the exception of the disabled, the elderly, and those with young children. In Calgary, 51 percent selected routes based on distance, 22 percent chose routes that they always use, and 4 percent chose those thought to be the only available ones. Mitchell and Stokes *(5)* found that in the few instances in which subsidiary factors were mentioned, they related to nonelderly women with children, who indicated that traffic and road crossings were an impedance.

Trip-Maker and Trip-Type Characteristics

Pedestrians, regardless of their age and sex (Table 3), prefer to travel between activities by the shortest path. It should, however, be noted that the subjects in this study were all under the age of 65. The primary needs of the handicapped and elderly are quite different, as indicated by Mitchell and Stokes *(5)*. These groups were eliminated from this study because of their small numbers in CBD areas.

TABLE 3 ROUTE SELECTION CRITERIA BY SEX AND AGE

	Percentage by Route-Selection Criteria			
Characteristic	Path/Quickest	Always Go That Way	Only Route Available	Other
Sex				
Male	60.0	24.0	4.0	12.0
Female	50.0	26.0	6.0	18.0
Age				
15–30	51.0	29.0	6.0	14.0
30–50	62.0	21.0	2.0	15.0
50–60	67	0.0	16.0	17.0

The factors that determined the route and the overall needs, however, were found to vary slightly according to trip type. Trip type is defined according to the origin and destination. For instance, a person's access trip from the place of work to the car is defined as a work-to-parking trip.

The variation from the most common factor (shortest path) was evident for work-to-shopping trips and shop-to-shop trips, or total walking trips. The factors that determined the route for these two trip categories were availability of opportunities and aesthetics (see Table 1).

SOME DEFICIENCIES IN THE TRADITIONAL PLANNING APPROACH

It is fairly apparent that with the exception of a small proportion, pedestrians simply prefer shorter walking distances to any other quality of a pedestrian network. This should be one of the basic premises underlying all pedestrian plans.

Providing the facilities exactly where the pedestrians desire is not always feasible if traffic engineers, transit operators, developers, and merchants have conflicting objectives. For instance, traffic engineers prefer all pedestrian crossings to occur at intersections in order to avoid interruptions to traffic flow and possible conflict between people and vehicles. Transit operators also prefer the location of bus stops and terminals at intersections in order to minimize the number of stop-and-go operations, which affect reliability and travel time. Retailers often speak against pedestrianization schemes, which are thought to affect business through the loss of occupants of the diverted vehicles, who may have come to the shops if they were allowed adjacent parking *(9)*. Developers, especially of office buildings, claim that occupants often demand close-in parking, but recognize that the additional vehicular traffic that will be generated by these developments will affect pedestrian movement in the surrounding areas.

Until a compromise is reached among these conflicting interests, development plans are unlikely to be able to provide for the basic pedestrian need—direct walking links.

For example, one of the MDP objectives is to give "priority to the provision of weather-protected pedestrian routes in the east-west direction." The findings of the questionnaire survey in Halifax summarized in Figure 5 reveal that even on rainy and windy days, only 1.7 percent of pedestrians were most concerned about weather protection. Conversely, the primary need is to go from one place to another by the shortest possible path (*F3* in Figure 5). Therefore, before the need for redefining plan objectives to reflect user needs and the associated difficulties are examined, it is appropriate to consider the pedestrian behavior in general and some fundamental user needs.

Several municipalities have tried some radical approaches to enhance pedestrian comfort; for instance, totally segregated pedestrian networks such as those in Cumbernauld and Stevenage in the United Kingdom, where continuous at-grade pedestrian networks between residential areas and the town centers, and between activity centers in the town have been built. The elevated and enclosed walkways are a common sight in Calgary, Alberta; Des Moines, Iowa; and Minneapolis, Minnesota. Use of both elevated and at-grade segregated systems is relatively low and the claimed improved performance has been measured mostly in terms of observed pedestrian volumes *(11)* rather than the changes and the general level of satisfaction of the users *(12)*. The circuitous nature of these routes is evidently the major deterrent to increased use, although investigations on this aspect are not widely reported. Heglund *(11)* has compared elevated walkway crossings with at-grade crossings and concluded that the walkways attract more pedestrians. Nevertheless, he does not refer to the changes in trip type or trip length for at-grade crossings after the construction of the walkway. In the absence of such information it is unreasonable to estimate the time and cost advantages of alternative routes.

It is evident from most of these examples that pedestrians will benefit the most if the facilities or priority links are continuous and connect the major generators by direct corridors. Also, schemes have been evaluated using diverse subjective measures. For example, most U.K. pedestrian schemes have been evaluated primarily in relation to improvement in safety or reduction in accidents. This measure can be valid only if reference is made to the volume of vehicles and pedestrians. If pedestrianization led to a reduction in both pedestrians and vehicles, the reduction in accidents would not be that significant, because there is a likelihood that accidents would migrate to other locations or that the site would experience a random change in trend—regression to the mean. Furthermore, as Hitchcock and Mitchell *(4)* suggest, pedestrians value their convenience more than their safety.

Comprehensive measures of effectiveness could be changes in pedestrian volumes, walking distances, or travel times; route choice; delays to vehicles; and, of course, the long-term effects on safety. These indicators may be supplemented by data on changes in trade, rental incomes, and other environmental factors, which are undoubtedly harder to obtain. However, at least an effort to obtain the foregoing information could be the starting point for the development of an effective planning policy for pedestrians in CBDs.

Lovemark *(10)* in the early 1970s commented on many aspects of pedestrian planning. One aspect that has been neglected, even today, is the lack of pedestrian route information. His studies showed that people choose up to 30 percent longer distances along vehicular networks simply because of the convenience of finding their destinations with the least amount of detours, level changes, and waiting as opposed to those using the pedestrian network. In other words, pedestrians receive relatively little assistance in terms of signing, priority in crossing streets, and adequate lighting in enclosed areas within the designated pedestrian networks. Benz and Lutin *(9)* recognized the Manhattan system to be severely deficient with regard to these items. A better balance in these characteristics is critical for the success of special pedestrian systems such as segregated systems and pedestrian-only malls.

CONCLUSIONS

In planning for pedestrian needs, the city of Halifax's present pedestrian-related policies have the potential to adequately provide for pedestrians. However, attention should be focused on pedestrian needs instead of on automobiles.

It is evident that whatever the mode of arrival, pedestrians' primary aim is to gain access to their destination by the shortest path. Therefore, pedestrians will benefit the most if the facilities or priority links are continuous and connect the major generators by direct corridors.

The primary needs of the handicapped and elderly are quite different as indicated by Mitchell and Stokes *(5)*. These groups were eliminated from this study because of the small representation in CBDs. Nevertheless, understanding the needs of the handicapped and elderly along with comprehensive measures of effectiveness would result in a more effective planning policy for pedestrians in CBDs. Also, there is much to be learned about circulation characteristics and effectiveness of pedestrian projects. The findings reported here are based on summer and fall pedestrian movement patterns. It will be interesting to determine the changes in these patterns during different seasons. Lovemark *(10)* and Seneviratne *(3)* have reported on the effect of temperature on pedestrian volumes, but reasons for such changes can only be determined from further observations and pedestrian interviews.

Finally, it is apparent that quality of the environment is only a secondary concern. If the primary objective of the majority of trips is not met, improvements in visual quality are unlikely to provide higher levels of service. Once this objective has been satisfied, the plan can concentrate on the subsidiary elements such as furniture and fixtures or color of walking surfaces.

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Guidelines for the Installation of Crosswalk Markings

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There has been a great deal of confusion and misunderstanding regarding the use of crosswalk markings in the United States. Uniform guidelines for installing crosswalks are needed to increase the uniformity of crosswalk applications and to prevent the unnecessary proliferation of crosswalk marking. A literature review, a survey of current practice, and an analysis of pedestrian and vehicle volumes at marked and unmarked locations were used to generate a draft set of guidelines, which were reviewed by 30 practicing traffic engineers and highway safety researchers. A final set of guidelines was generated on the basis of that review. The recommended guidelines call for marked crosswalks at all signalized intersections with pedestrian signal heads and unsignalized locations that satisfy specified minimum vehicular and pedestrian volume criteria.

The *Manual on Uniform Traffic Control Devices* (MUTCD) *(1)* states the primary purposes of crosswalk markings (Section 3B-15):

> Crosswalk markings at signalized intersections and across intersectional approaches on which traffic stops, serve primarily to guide pedestrians in the proper paths. Crosswalk markings across roadways on which traffic is not controlled by traffic signals or STOP signs, must also serve to warn the motorist of a pedestrian crossing point. At non-intersectional locations, these markings legally establish the crosswalk.

It should be noted that a crosswalk legally exists across each leg of an intersection, even though it may not be marked.

The MUTCD provides only general guidelines regarding the application of crosswalk markings (*1*, Section 3B-15):

> Crosswalks should be marked at all intersections where there is substantial conflict between vehicle and pedestrian movements. Marked crosswalks should also be provided at other appropriate points of pedestrian concentration, such as at loading islands, midblock pedestrian crossings, or where pedestrians could not otherwise recognize the proper place to cross.

The manual continues with a discussion of precautions against indiscriminately using crosswalk markings: "Crosswalk markings should not be used indiscriminately. An engineering study should be required before they are installed at locations away from traffic signals or STOP signs." Indiscriminate use of crosswalk markings may also result in a reduction in motorist compliance with the law regarding both marked and unmarked crosswalks.

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The Uniform Vehicle Code indicates that pedestrians are to have the right-of-way in crosswalks. It states (*2*, Section 11-502):

> When traffic-control signals are not in place or not in operation the driver of a vehicle shall yield the right of way, slowing down or stopping if need be to so yield, to a pedestrian crossing the roadway within a crosswalk. . . .

Most state laws generally follow these guidelines. However, observation indicates that the foregoing priorities are seldom recognized or enforced. Although some areas of the country are reportedly better than others in this regard, there is general recognition that motorist compliance is declining, including yielding to pedestrians.

BACKGROUND

Although there has never been any recognition of more specific guidelines for crosswalk installation at a national level, some states and cities have developed their own. In many localities crosswalk marking is done in response to citizen or political requests or pressure, or both. Often great confidence is placed by the public in crosswalk markings as a safety device. However, there is substantial controversy over the actual effectiveness of crosswalk markings and increasing concern that crosswalk markings are more of a detriment than a benefit to pedestrian safety.

In a 1970 study in San Diego *(3)* accident rates at marked and unmarked crosswalks were compared. The accident rates of crosswalks at 400 unsignalized intersections that had one painted crosswalk and one unpainted crosswalk, both crossing the same main thoroughfare, were studied. It was found that the painted crosswalks had 5.7 times more accidents than the unpainted ones. Vehicle and pedestrian volume counts were made for 24 hr at a 10 percent sample of these intersections. It was found that marked crosswalks were used 2.9 times more than unmarked crosswalks. Thus, in terms of use, approximately twice as many pedestrian accidents occur in marked crosswalks than in unmarked crosswalks. However, before condemning marked crosswalks as being hazardous, one must question whether marked and unmarked crosswalks at the same intersections are appropriate comparison groups. At a given intersection one crosswalk may be marked for a variety of reasons, perhaps because of higher anticipated pedestrian volumes or because of the characteristics of the pedestrians that are using that crosswalk.

For example, one leg of an intersection may have a crosswalk marking because more high-risk pedestrians (very young or elderly) are using that crosswalk. Similarly, these same pedestrians may go out of their way to use a marked crosswalk, whereas the less cautious adult pedestrian may not do so. The study did, in fact, report that the very young and the very old had the highest accident incidence in both marked and unmarked crosswalks. One leg of an intersection may also be marked because of its location relative to specific pedestrian origins or destinations, or both (e.g., residences, bus stops, stores, bars). The study also reported differences in time of day and day of the week between marked and unmarked crosswalks. For example, 28 percent of the accidents in marked crosswalks occurred from 5:00 to 7:00 p.m., whereas the unmarked crosswalks had no accidents during that time period. These considerations suggest that there may be more differences between the San Diego marked and unmarked crosswalk locations than the presence or absence of crosswalk markings. If so, the use of the marked and unmarked crosswalk pairs may not be appropriate.

Although the San Diego study is frequently misquoted as having proved that crosswalks are dangerous and should not be used, this is not the case. The report ended with the following statement (*3*, p. 13):

> In conclusion, it is appropriate to restate that marked crosswalks will continue to be a useful traffic control device. But it is important that the general public recognize what marked crosswalks can and cannot do. It is also important that public officials not install them unless the anticipated benefits clearly outweigh the risks discussed in this report.

PURPOSE

Because of the misunderstanding and confusion regarding the use of crosswalk markings in the United States, it is apparent that a set of guidelines for their use is sorely needed. These guidelines should be based on research and on the experience of practicing engineers. The guidelines are needed for the following specific reasons:

1. To increase the uniformity of crosswalk application across the country.
2. To provide guidance to those who have not yet formulated a policy on where to apply crosswalk markings and to those who are unsure about their current practices.
3. To prevent the misapplication of markings in places where they could constitute a safety hazard or where the cost of installation and maintenance is not generally justified.
4. To prevent the unnecessary proliferation of crosswalk markings and the resultant increase in disregard for crosswalks in general.

It must be emphasized that crosswalk markings are not a substitute for other types of pedestrian accident countermeasures. One cannot simply stripe a crosswalk and expect an accident problem to clear up. Pedestrian refuge islands, improved signalization, and other strategies are often needed to directly address the safety problem.

PROCEDURE

The goal of this project was to develop a set of guidelines based on current research information that would be accepted and used by the practicing traffic engineer. In order to achieve this goal, a reiteration process was used. First, a set of draft guidelines was developed. The draft guidelines were based on current practices as identified during a literature review, a survey of local practitioners, and an examination of relevant pedestrian research. The guidelines were not based on either pedestrian accident occurrence or pedestrian-vehicle conflicts. The draft guidelines were then reviewed by about 30 practitioners and, on the basis of their comments, a final set of guidelines was prepared.

Current Practices

Practicing traffic engineers in nine geographically diverse state and municipal agencies were contacted to determine current operational practices pertaining to the installation of crosswalk markings. Each practitioner was asked specific questions involving

- Warrants, guidelines, and criteria used for installing marked crosswalks.
- Any problems involved in applying those warrants.
- What factors or criteria should be considered in developing noncrosswalk warrants.

It was found that very few of the respondents used specific quantitative procedures for the application of crosswalk markings. All of the respondents marked crosswalks on school routes and most marked crosswalks at signalized intersections. Several of the respondents used "point" warrant systems to rank locations by priority for crosswalk installations. Although three respondents indicated that they considered pedestrian volumes when installing crosswalks, only one quantified the minimum pedestrian volume warrant at 100 pedestrians/day. Most of the respondents believed that factors such as vehicle volumes, pedestrian volumes, vehicle speed, school children, and sight distance should be included in a new crosswalk warrant. At the same time, the practitioners cautioned that the new crosswalk warrants should not require extensive additional data collection.

A literature review was also conducted to identify any existing warrants. Many quantified warrants were found for pedestrian-oriented treatments, such as overpasses, signals, and crosswalk illumination. Only two quantitative threshold warrants for crosswalks were identified. Several localities used a point or priority-ranking system to identify potential crosswalk locations. Some of the existing warrants for various pedestrian-oriented treatments are summarized in Table 1.

Relevant Research

Several other sources of information were used for establishing the initial set of guidelines. The first consisted of data from the study of pedestrian exposure by Tobey et al. (*8*). In that study, data were collected on pedestrian and vehicular volumes, pedestrian accidents, and other site characteristics at numerous intersections in the United States. One part of the analysis involved a comparison of scatter diagrams of pedestrian and vehicular volumes at marked and unmarked crosswalks. It was hypothesized that one would find that crosswalks were marked

TABLE 1 EXISTING WARRANTS FOR VARIOUS PEDESTRIAN-ORIENTED TREATMENTS

	Warrant				
	Crosswalk	Crosswalk	Pedestrian Signals	Crosswalk Illumination	Adult Crossing Guard
Source	Illinois DOT *(4)*	Toronto *(4)*	Zegeer et al. *(5)*	Freedman et al. *(6)*	Caltrans *(7)*
Vehicle volume	More than 300 vph for each of any 8 hr of day	Not where turning movements excessive	Fewer than 600 gaps in traffic per hour	Exceeds in three nights: 1,000 vehicles/night (arterial); 500 vehicles/night (collector); 200 vehicles/night (local street)	Exceeds 350 vph in any 2 hr (300 vph if rural)
Pedestrian volume	Exceeds 75 pph for same 8 hr	Exceeds 100 pph in each of 8 hr in which 10 or more wait	Exceeds 60 pph for any 4 hr; 90 pph for any 2 hr; 110 pph for peak hr	50 pedestrians/night (local street or residential); 100 pedestrians/night (all other locations)	40 pph for same hr above (30 pph if rural)
Other	Urban signalized intersection	More than 700 ft to nearest crosswalk; speed less than 40 mph; no sight distance restrictions; four lanes or fewer	None	Three preventable accidents; sight distance considerations; minimum illumination level	More than 600 ft to "safe crossing"

NOTE: vph = vehicles per hour, pph = pedestrians per hour.

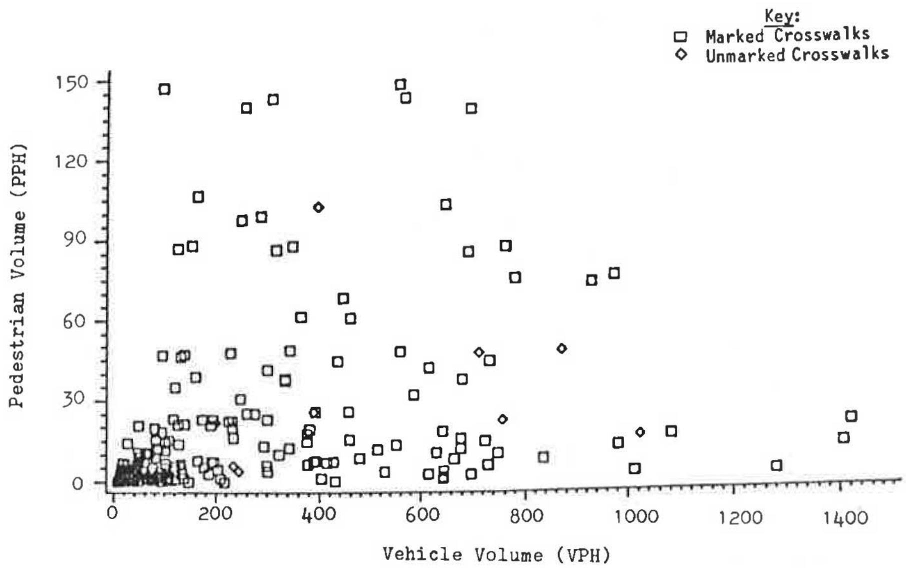


FIGURE 1 Pedestrian and vehicle volumes of marked and unmarked crosswalks at unsignalized local street intersections *(8)*.

at locations with higher pedestrian and vehicular volumes and not marked at locations with lower volumes. Although this was true in general, there was considerable overlap in the volume levels for marked and unmarked crosswalks. Marked crosswalks were sometimes found at very low volume levels, and unmarked crosswalks were found at high volume levels. Figure 1 shows the volume distributions for the local street sample.

The data in Figure 1 provide an indication of how practitioners and decision makers have, in the past, determined where crosswalks should be marked. If one makes the assumption that their judgment is reasonably good, an analysis of the data could be performed to derive an optimum volume threshold curve to use as part of the crosswalk guidelines. This analysis was conducted by fitting several trial curves through the data and identifying which curve minimized alpha and beta error. Alpha error would exist when a marked crosswalk fell below the volume threshold curve. Beta error would exist when an unmarked crosswalk fell above the volume threshold curve.

Logic dictated that the volume threshold curves would have a minimum vehicular and pedestrian volume and would be convex with respect to the origin. Using this general shape and minimizing alpha and beta error, a basic threshold curve was established that is approximately equivalent to the curve in the recommended set of guidelines. Additional curves were established with lower thresholds to cover wider streets and locations with higher proportions of young, elderly, and handicapped pedestrians.

A second source of information used in establishing the volume threshold curves consisted of existing warrants from outside the United States. Figure 2, prepared for a South African study *(9)*, indicates warrant threshold curves proposed or already in use in Australia, Israel, and South Africa for vehicles and pedestrians at midblock pedestrian crossings. The thresholds are generally higher than those in the suggested guidelines for the United States, which reflects the lower U.S. pedestrian volumes than those abroad. However, the overall philosophy of

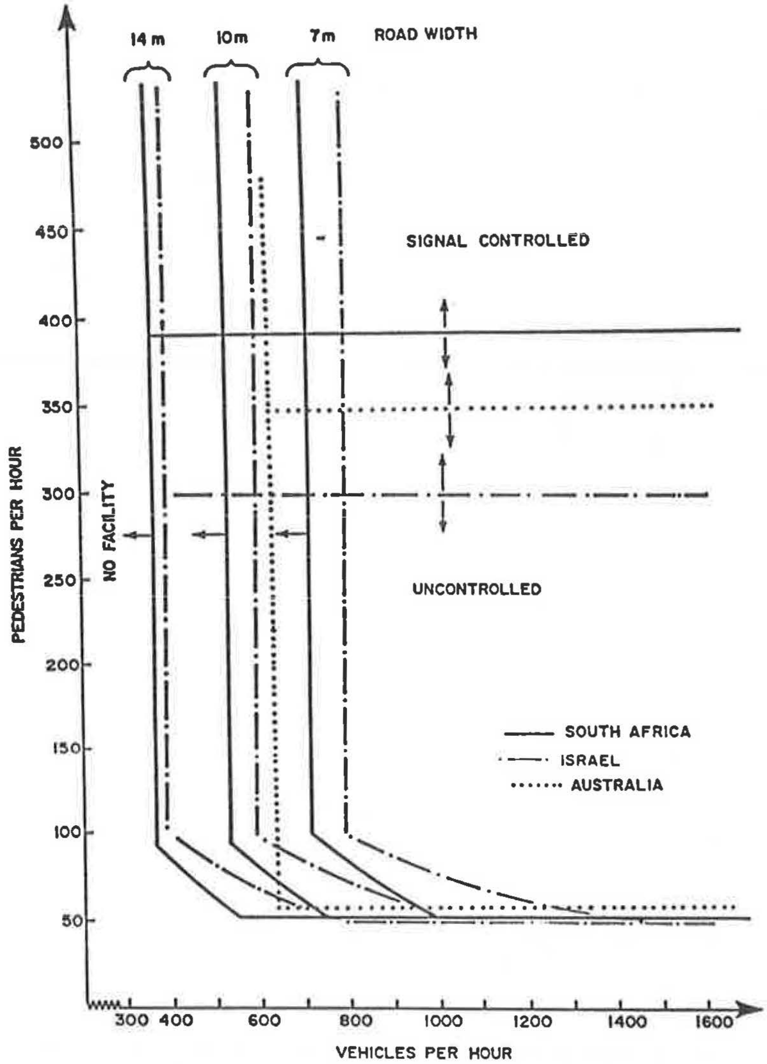


FIGURE 2 Warrants for midblock pedestrian crossings: South Africa, Israel, and Australia *(9)*.

volume-based thresholds is the same, and the thresholds are of the same order of magnitude.

Practitioner Review

The information gathered during the practitioner survey and the analysis of relevant research were used to generate a preliminary series of warrants for crosswalk markings. Through an iterative process, a draft set of guidelines that was intended to be both responsive to the needs of local practitioners and sensitive to the available research was developed. This draft was sent to 30 practitioners from the engineering and research community for their review. The individuals were selected from the Markings Technical Subcommittee of the National Committee on Traffic Control Devices and the Committee on Pedestrians of the Transportation Research Board.

The review process was believed to be particularly important because the guidelines must pass the test of reasonableness when eventually applied in the field. If their application is overly burdensome or results in the overapplication or underapplication of markings, the guidelines will not become a useful engineering tool. In addition, there are certain nonquantifiable aspects of crosswalk markings that can only be appreciated by those involved in the application of the guidelines.

The review by practitioners involved sending out the draft guidelines along with a set of questions used to evaluate various aspects. The questions asked were "Are such guidelines needed?" "Will the guidelines benefit state and local agencies?" "Is the format usable?" "Is the concept of a volume-based warrant valid?" "Are the thresholds reasonable?"

Responses by the reviewers were generally positive. There was a consensus that the guidelines were needed, and there appeared to be no major concern with overall approach. Reviewers believed that both the basic criteria and the volume-based thresholds were appropriate. There was some concern over the data collection needs, and this resulted in the inclusion of a peak-hour threshold in addition to the 4-hr threshold in the final set of guidelines. It was also noted that some cities do not mark at any crosswalks at signalized intersections as long as the stop bar is available to provide discipline in vehicle stopping location. This is believed to be an acceptable practice, but markings are still recommended for at least those signalized intersections with pedestrian signal heads. Some reviewers believed that the guidelines would result in the marking of more crosswalks, whereas others believed that fewer would be marked. The majority, however, thought that the guidelines would result in the marking of about the same number. The comments and suggestions made by the reviewers were considered when the final set of guidelines was prepared.

THE GUIDELINES

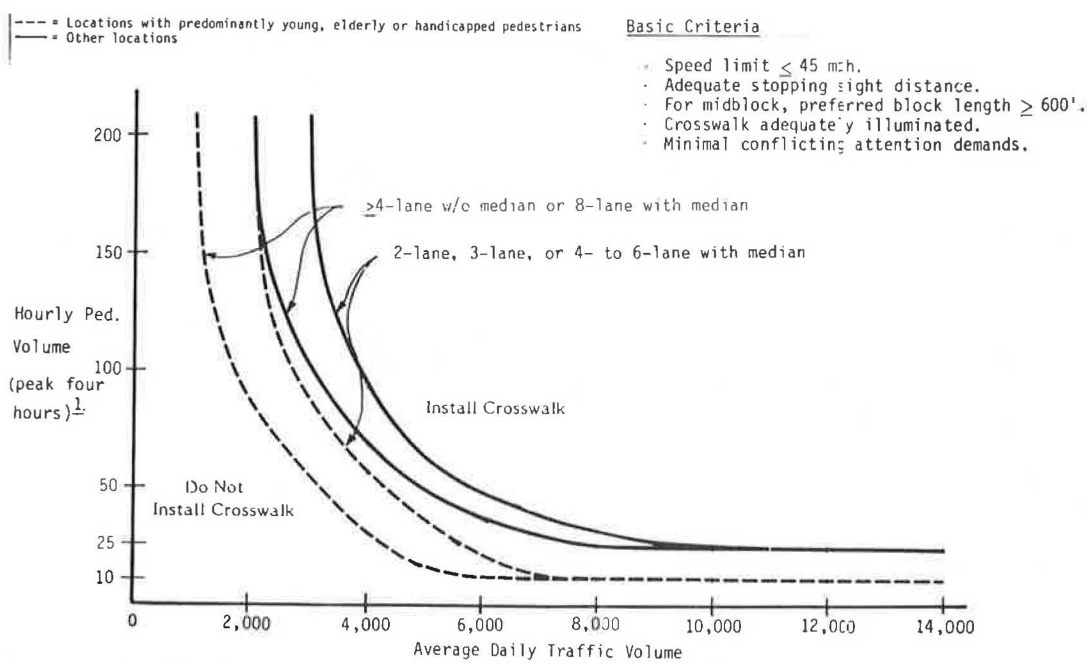
The development of a reasonable and succinct set of guidelines required that a set of basic rules or principles be postulated. These basic principles on locating crosswalk markings serve as the foundation for the guidelines:

1. Crosswalks should not be marked where it may be unusually dangerous to cross the street (e.g., locations with high traffic speeds, poor sight distance, or poor illumination).
2. In light of the installation and maintenance costs of pavement markings, crosswalk markings should be located at places expected to receive sufficient benefit. This suggests that crosswalks with low vehicular volume or low pedestrian volume, or both, do not warrant marking. The determination of minimum pedestrian and vehicle volume thresholds is an important part of establishing reasonable guidelines for installation of crosswalk markings.
3. Guidelines for installing crosswalk markings should include the type of pedestrians expected to be crossing the street. Lower volume thresholds should be considered for areas where there is a greater proportion of less experienced and less agile pedestrians (e.g., near schools or housing areas for the elderly, or both).
4. Crosswalk markings in higher-risk crossing areas (higher traffic volumes and speeds) should be supplemented by advance-warning signs and, in some cases, advance-warning pavement markings.
5. Crosswalks should be marked selectively. Allowing a proliferation of crosswalks reduces the overall effectiveness of each crosswalk.
6. Specific variables that should be considered when locating crosswalks include activities located nearby (e.g., schools, shopping), pedestrian volume, vehicular volume, sight distance, vehicular speeds, street width and presence of a median, one-way versus two-way operation, and geometrics of the highway or intersection being crossed.

The guidelines were developed on the basis of these principles. The final guidelines for installing crosswalk markings are as follows:

Crosswalk markings should be installed at

- All signalized intersections with pedestrian signal heads. Although it is not necessary to mark crosswalks at all signalized intersections (as long as the stop bar is adequately set back from the intersection), marking crosswalks where pedestrian signal heads are in place reinforces the idea that pedestrians can be expected.
- All locations where a school crossing guard is normally stationed to assist children in crossing the street.
- All intersections and midblock crossings satisfying the minimum vehicular and pedestrian volume criteria in Figure 3 and the following basic criteria:



1. If using only the peak hour, threshold must be increased by 1.5.
2. For streets with a median, use one-way (directional) ADT volume.

Other notes: Minimum striping is 6" parallel lines. Consider bolder markings and / or supplementary advance markings or signing at uncontrolled locations where speed limits exceed 35 mph.

FIGURE 3 Recommended guidelines for installation of crosswalk markings.

- Speed limit ≤45 mph
- Adequate stopping sight distance
- For midblock crosswalks, block length of at least 600 ft
- Adequate crosswalk illumination
- Minimal conflicting attention demands

(The last criterion is a judgmental factor suggesting that crosswalks not be marked where complex highway geometrics, signing, or other circumstances distract the driver's attention away from them. Legitimizing such locations as pedestrian crossing points could lead pedestrians into unsafe conditions. Special care should be exercised where drivers tend to look only left to make a right turn or only right to make a left turn, such as at the intersection of one-way streets or at ramp merging areas. Pedestrians should not be encouraged to cross in areas where the driver does not already scan for vehicular traffic.) As long as the basic criteria governing sight distance, speed limit, and so on, are met, a crosswalk marking is deemed appropriate if the pedestrian and vehicular volumes place it above the appropriate curve in Figure 3. Each crosswalk is analyzed by approach leg, indicating that a crosswalk marking might be warranted on one side of an intersection and not on the other. Thus the guidelines might suggest that only one crosswalk need be marked at a given intersection. If each approach warranted a crosswalk marking, then all would be marked. However, one should consider marking both crosswalks on a given roadway if the presence of only one would suggest to pedestrians that they make an unnecessary, hazardous crossing to get to it.

• All other locations at which there is a need to clarify the preferred crossing location because the proper location for crossing would otherwise be confusing.

These guidelines represent a melding of the philosophies found in foreign and domestic practice. The most important elements of the guidelines are the basic criteria, which place some restrictions on crosswalk-marking applications to prevent their being placed in locations that would be extremely hazardous to the pedestrian. Placing crosswalk markings in locations with high speeds or poor sight distance is never advisable. A crosswalk marking is not a solution to such situations, and other preventive measures should be considered.

It will generally be difficult to reach the pedestrian volume thresholds in suburban areas. This is viewed as an advantage to the pedestrian, because it will result in more selective use of crosswalk markings, which, it is hoped, will result in improved compliance with the markings in general. Crosswalk markings should not be so commonplace that drivers lose appreciation for their purpose.

The volume thresholds are reduced for locations where the young, elderly, or handicapped make up a significant proportion of the pedestrian population. A value of 50 percent or more is suggested, but this is best left to the judgment of the engineer.

At uncontrolled intersection legs and midblock crossings with speed limits of 40 to 45 mph, the guidelines suggest the placement of markings bolder than the standard 6-in. parallel lines, such as longitudinal (zebra) stripes. Supplemental crosswalk signs should be considered for crossings at uncontrolled intersection legs and midblock where the crossing is in a high-speed or potentially hazardous location.

DISCUSSION OF RESULTS

Another element of the evaluation involved a comparison of the pedestrian volume thresholds with other related warrants and criteria. A new pedestrian warrant for the installation of traffic signals was recently approved by the National Committee on Uniform Traffic Control Devices. The new warrant is based on an FHWA study and suggests a minimum pedestrian volume of 100 pedestrians per hour (pph) for 4 hr.

The current minimum volume requirements in the MUTCD for warranting a traffic signal are 150 pph in the same hours for which the peak 8 hr of vehicular volume occur. The new lower pedestrian volume threshold will make it easier to justify a signal on the basis of pedestrian volume. Justifying a signal on the basis of pedestrian volume would still be rare, however.

The recommended crosswalk marking guidelines appear to be reasonable when compared with the volume thresholds for other warrants. One would expect the volume threshold for crosswalk markings to be considerably lower than that for warranting traffic signals or pedestrian signals. Although the warrants are written to be applied in all land use settings, there could be a rationale for increasing the minimum volume thresholds in more densely developed settings to prevent too great a proliferation of markings. Local adjustments to the minimum thresholds may need to be considered as experience is gained.

The recommended guidelines for crosswalk markings fill a significant void in the treatment of crosswalks nationwide. If widely applied, they will greatly improve the consistency with which markings are applied, and ultimately produce a more cost-effective allocation of resources. However, they should not be viewed as significantly addressing the pedestrian safety problem. Many other techniques exist in education, engineering, and enforcement to more directly address safety concerns. Crosswalk markings are primarily a discipline tool, providing a degree of recognition for pedestrians and informing them of proper crossing locations.

One of the major concerns in pedestrian safety is the general lack of respect by drivers for pedestrian rights. Most state laws provide pedestrians with substantial rights, especially at marked crosswalks, but there is little observance of those rights in practice. Better enforcement is one of the few mechanisms available to produce better driver observance of pedestrian rights at crosswalks. In reality, however, it is not expected that observance will improve or that increased enforcement will be provided. Therefore, better discipline and consistency are needed in the marking of crosswalks. The proposed guidelines should help to accomplish this objective.

ACKNOWLEDGMENT

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DISCUSSION

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In August 1970 the city of San Diego published the results of a research project entitled Pedestrian Crosswalk Study—Accidents in Painted and Unpainted Crosswalks *(1)*. In brief, the 5-year study encompassed 400 intersections, each having one marked and one unmarked crosswalk across a main thoroughfare and uncontrolled by signals or school crossing guards. The study showed "in terms of usage" that about twice as many pedestrians were hit in the marked crosswalks as in the unmarked crosswalks. The elderly and young showed their usual high involvement pattern in both marked and unmarked crosswalks. More striking was the accident experience of those pedestrians in the 25 to 44 age group, who had no accidents in the unmarked crosswalks but were involved in 25 accidents in the marked crosswalks. As a result of this study, San Diego revised its crosswalk warrants in 1970 *(2)*. Since that time, many jurisdictions have indicated interest in the San Diego study and its revised warrants and guidelines. More recently, Smith and Knoblauch undertook to develop guidelines that might be adopted nationally to facilitate installation of marked crosswalks on a uniform basis. I would like to support them in their efforts. Many of their criteria are an outgrowth of the San Diego findings and warrants. Based on these similarities and the 16 years of experience with these warrants, this discussion is being conducted to point out the rationale for some of the basic criteria shared in common and, it is hoped, to provide constructive comments on improving the proposed guidelines.

SHARED CRITERIA

When San Diego modified its crosswalk warrants in 1970 *(2)*, several basic criteria for installing marked crosswalks were recognized.

Pedestrian Volume

Crosswalks will not be installed where the pedestrian volume is less than 10 pph during the peak pedestrian hour.

Rationale: There should be sufficient minimal pedestrian usage to warrant the installation of the markings and to provide credibility to the motorist that pedestrians indeed use the crosswalk *(3)*.

Approach Speed

Crosswalks will not be installed on roadways where the 85th-percentile approach speeds are in excess of 45 mph.

Rationale: Analysis and field studies show that at speeds above 45 mph, crosswalk markings are indiscernible by approaching motorists. Therefore, motorists at these speeds might not be able to see, react, and come to a safe stop in time to avoid a collision with a pedestrian *(4)*.

Visibility

Crosswalks will not be installed unless the motorist has an unrestricted view of all pedestrians at the proposed crosswalk site for a distance not less than 200 ft approaching from each direction. Sites with grades, curves, and other sight-restrictive features will require special attention.

Rationale: Again, analysis and field studies show that unless given sufficient time and space to see and react to the presence of a pedestrian, the motorist may not be able to stop in time to avoid a collision *(4)*. A conservative stopping distance of 200 ft was employed to provide for errant motorists traveling at speeds in the range of 45 to 50 mph.

Illumination

The proposed crosswalk site must have adequate lighting in existence or scheduled for installation before the installation of the crosswalk.

Rationale: A special analysis of pedestrian-vehicle collision courses during nighttime accidents suggested that the low beams of automobiles, which are often used in urban areas, may not be sufficient to illuminate the pedestrian in time to avoid a collision *(4)*. Therefore, if a marked crosswalk is installed, it is important that the jurisdiction provide adequate crosswalk lighting.

DIFFERENCES

It is interesting to see that Smith and Knoblauch have also incorporated the foregoing requirements into their guidelines, with two minor exceptions:

1. The minimum peak pedestrian volume has been increased from 10 to 25 pph, except where young, elderly, or handicapped pedestrians need to cross (in which case they provide for 10 pph). This higher figure may make certain crossings more difficult to qualify for marked crosswalks.
2. A basic criterion (Figure 3), "minimal conflicting attention demands," has been added, which may be a valid consideration. But in this set of guidelines, it is not adequately

explained what it means or how this criterion is to be applied. Presumably, if there are other features or characteristics in the vicinity of the crosswalk that might divert the motorist's attention away from the pedestrian, this would be sufficient reason for not installing a marked crosswalk. Unfortunately, in the urban setting, there are many things competing for the motorist's attention. Furthermore, what guarantee is there, after a marked crosswalk has been installed, that someone might not install an attention-getting animated sign?

There are several other similarities and differences between the San Diego 1970 warrants and Smith and Knoblauch's 1987 guidelines that merit examination.

Point System

In addition to the basic warrants, San Diego employs a point system requiring 16 out of 28 possible points to qualify for the installation of a marked crosswalk. These points are obtainable under three categories.

Pedestrian Volume

Pedestrian volume ranges from 2 points for 11 pedestrians crossing per peak hour to 10 points for over 100 pedestrians crossing per peak hour.

General Conditions

Up to 8 points are provided for improved channelization considerations. It should be emphasized that San Diego tends to place considerable stress on the role of the crosswalk as a channelization device rather than as a safety device per se.

Gap Time

The warrant for gap time provides for up to 10 points based on the average number of safe gaps per 5-min period available to permit the pedestrian to cross the street without being in conflict with a vehicle. Ideally, a pedestrian should not have to wait more than 1 min for there to be a safe gap in traffic to cross from one side of the street to the other or to cross to the center median. The rationale behind this warrant is that if a pedestrian has one or more safe gaps each minute to cross a street, it may not be as necessary to have a marked crosswalk. On the other hand, as traffic increases or the width of the street increases, there become fewer and fewer safe gaps available. In that case, the marked crosswalks may (provided other conditions are favorable) help the pedestrian communicate his need and right to cross the street. To some, this rationale may seem paradoxical, that is, some may ask, "If the vehicular volume is higher or if the street is wider, then isn't the exposure greater?" So it would seem, but as the various San Diego studies indicated in the original report, exposure is not the sole factor determining whether a pedestrian is at risk. What appears to be more important is the pedestrian's ability to assess the risk and his willingness to accept the risk. The San Diego data seemed to indicate that on narrower streets or streets where vehicular volumes were low, although the exposure was lower, the "risk-taking behavior" in marked crosswalks tended to be greater *(1)*. This would tend to indicate that jurisdictions might be better off not to install marked crosswalks if such markings might tend to reinforce aggressive pedestrian behavior or inflate a pedestrian's false sense of security. In such cases, not installing a marked crosswalk might tend to make the pedestrian more apprehensive and more alert to approaching vehicles and thereby avoid collisions. By contrast, as street widths and vehicular volumes increase, the exposure increases. But, more importantly, the risk-taking behavior in marked crosswalks tends to be lower. This may be due to the fact that the exposure and potential risks are more evident to the pedestrian. Thus, despite the presence of the markings, pedestrians tend to be more careful in crossing the street. Similarly, the gap-time concept takes both exposure (in terms of width and vehicle volume) and relative pedestrian risk-taking behavior into account. In other words, the greater the apparent exposure, the greater the likelihood that the pedestrian will exercise appropriate caution in crossing the street and will tend less to misuse a marked crosswalk. This rationale is not only one of the features of the 1970 San Diego warrants, but also of Smith and Knoblauch in their proposed guidelines.

Nomograph

The guidelines of Smith and Knoblauch differ primarily from the San Diego warrants in that, although they utilize the same basic warrants as San Diego (approach speed, visibility, illumination) instead of using a supplementary point system, they use a supplementary nomograph. The general concept of a nomograph is good. Some of their basic values appear to be reasonable. However, one must be careful with both a point system and a nomograph system in recognizing that the cut-off points or, in the case of the nomograph, the demarcation or decision line is not always as clearly defined as it may seem. Rather than a sharp line there is a blurred zone where conditions could go either way. Thus, when warrants or guidelines are applied, good engineering judgment based on experience and knowledge of the site are important aspects of the decision-making process. I recognize that Smith and Knoblauch have tried to simplify the decision-making process by utilizing "number of lanes" as a basis for their family of decision lines. But I must admit that ignoring the actual street width and pedestrian crossing time bothers me somewhat; that is, a narrow two-lane street is handled the same as a wide two-lane street and a six-lane street is handled the same as a four-lane street. Also, how does one handle a three-lane one-way street? The purpose of these comments is not to nitpick, but rather to point out some important deficiencies that need to be addressed.

Traffic Signals and School Crossings

Smith and Knoblauch have attempted to create a universal set of guidelines for installing marked crosswalks at traffic signals and school crossings. In some respects this effort appears commendable, but from a practical viewpoint it may be counterproductive. Crosswalks at traffic signals and school crossings function differently than crosswalks on uncontrolled thoroughfares. At signalized locations or school crosswalks, pedestrian movements are controlled by the traffic signal or the crossing guard rather than the crosswalk markings. Similarly, motorists' behavior is influenced to a much greater degree by the presence of a traffic signal or crossing guard than it is by the presence of crosswalk markings (although marked school crossings are an important and integral part of the school crossing program). My comment on these two items is not intended to ignore markings at signals or school crossings but rather to point out that they deserve more thought and space than three brief lines. If we say that all signals with pedestrian signal heads should be marked, does that mean that signalized intersections without pedestrian heads should not be marked? And is really necessary to mark all crosswalks where there are pedestrian signal heads? As a matter of fact, most of San Diego's traffic signals in its downtown area, and elsewhere, have had only a marked limit line without marked crosswalks for over 30 years and have functioned very well. Even so, the city recognizes that there are places where the geometrics are such (wide intersections, skew orientation, etc.) that marked crosswalks are both desirable and necessary. Conversely, there are other places, such as on one-way street systems, where the stop bars provide a useful supplemental warning to keep motorists from entering a one-way street in the wrong direction. In these cases, marked crosswalks on all legs with pedestrian heads may confuse the motorist without appreciably improving either the mobility or safety of a pedestrian.

Regarding the criteria for midblock crosswalks, in all fairness, I would say that both the San Diego warrants and the Smith-Knoblauch guidelines need better definition in terms of evaluating pedestrian use, and why, where, when, and how midblock crosswalks should be installed. Many jurisdictions would rather not use midblock crosswalks at all. But there are valid conditions for installing and utilizing marked midblock crosswalks in a safe and efficient manner *(5)*.

CONCLUSIONS AND RECOMMENDATIONS

Although San Diego's crosswalk warrants have served the city well for 16 years, San Diego does not claim to have the ultimate set of warrants. There are features in the San Diego warrants that need to be clarified and revised, particularly those involving midblock crosswalks. Similarly, Smith and Knoblauch's guidelines need further review and improvement. Several tests for good traffic warrants are the following:

1. Will the proposed installation produce the desired results in terms of safety and mobility for both the pedestrians and the drivers?
2. Will the proposed installation have credibility to and acceptance and compliance by the users (pedestrians and drivers)?
3. Are the warrants easy to understand and easy to apply by the agency's staff under all conditions?

With regard to the first two items, it is recommended that the guidelines be applied in a real-world situation in several cities and monitored in some appropriate controlled test to determine how they affect safety, mobility, and compliance.

With regard to the third item, it appears that the total evaluation time for the Smith-Knoblauch guidelines would be 4 hr for the pedestrian vehicle counts plus 30 min supplementary field and preparation time, 1 hr driving time to and from the site, and 1 hr office time, for a total of 6.5 hr for each evaluation. By comparison the city of San Diego's present warrants require 1 hr for the pedestrian gap study and pedestrian volume count plus 30 min supplementary field and preparation time, 1 hr driving time to and from the site and 1 hr office time, for a total of 3.5 hr for each evaluation. This is a saving of 3 hr per location over the Smith-Knoblauch evaluation procedure. This suggests that Smith and Knoblauch might wish to reassess their evaluation procedures to see whether they can be made more cost-effective. Other recommendations from the earlier commentary include the following:

- The basic criteria listed on the nomograph (Figure 3) including speed, stopping sight distance, illumination, and midblock length, appear to be valid, but perhaps unduly brief. It is suggested that an accompanying supplementary description be provided, especially concerning midblock crosswalk installations.
- The basic criterion "minimal conflicting attention demands" is too ambiguous and subject to potential litigation problems. It is recommended that it be either clarified or dropped.
- The nomograph evaluation is a good one. However, decision curves on the nomograph should reflect street width rather than number of lanes. This would eliminate the ambiguity of what to do with one-way streets or three-lane streets or six-lane streets, and so on. Streets with a median would be handled on the basis of the widest portion from curb to median.
- If my recommendation for utilizing a family of decision curves based on width rather than number of lanes is adopted, then I realize that the nomograph could become quite "busy." In this case, it may be desirable to develop a second nomograph with a new family of curves to handle the needs of the young, elderly, and disabled. Similarly, appropriate criteria must be developed to define when a jurisdiction should utilize the second set of curves (e.g., any combination of 10 children, seniors, or handicapped crossing per hour?).
- Consideration might be given to installing marked crosswalks on an "exception" basis for those special cases in which they are needed by partially sighted persons for guidance across certain intersections. Such crosswalks must not be installed indiscriminately, but in close consultation with appropriate experts such as specialists in orientation and mobility for the blind.
- If I understand their report correctly, Smith and Knoblauch, unlike the city of San Diego, do exempt "crosswalks used to clarify the preferred crossing location" from their other evaluation procedures, including the basic criteria and the nomograph evaluation. I can see certain advantages in exempting such channelization devices from either a point or nomograph evaluation, but they should definitely pass the basic criteria warrants on approach speed, visibility, and illumination. If not, they could become potential safety hazards.
- Although neither the San Diego warrants nor the Smith and Knoblauch guidelines provide for it, there appears to be

some advantage in providing a certain latitude to cover "unusual conditions" or what is sometimes referred to as "engineering judgment." The conditions cited in the two previous recommendations are cases in point. This is where a point system as opposed to a nomograph evaluation may have certain advantages.

- The criteria for marked crosswalks at either signalized intersections or school crossings should be handled separately. It is recommended, in order to do them justice, that they be deleted from this set of guidelines and appropriate guidelines be developed for each in accordance with its own unique problems and needs. Those who take on the job of preparing these supplementary warrants will, it is hoped, avoid jumping prematurely into quantitative assignments or threshold levels and ask themselves the basic question: Do marked crosswalks benefit the pedestrian at a standard signalized intersection, and if so, how? They may find that, with the exception of complex or wide intersections, pedestrians rely little or not at all on the marked crosswalks at signals.
- Finally, it is recommended that in addition to engineering and enforcement considerations, attention continue to be directed to educating pedestrians of all ages regarding what the marked crosswalk can and cannot do and to caution them to be just as careful in using a marked crosswalk as they are when using an unmarked crosswalk.

Smith and Knoblauch are to be commended in their efforts to develop a uniform set of guidelines for marked crosswalks. It is hoped that the comments and recommendations offered in this discussion and by others will help them to successfully achieve their goal in developing an improved, rational, and effective set of crosswalk guidelines that will enhance safety and mobility for the pedestrian and other road users.

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AUTHORS' CLOSURE

We appreciate the comments of Herms, particularly his practical perspective on an issue to which there are no absolute answers. Unfortunately, research provides less guidance than most people think on the question of whether crosswalk markings add to or detract from the safety of pedestrian crossings. Thus, we are left with the dilemma of wanting to provide information to both pedestrians and drivers that might help their decision-making process, but not having the firm research data to say with authority exactly how markings ought to be applied. Overlaid on this is the need to wisely allocate financial, staff, and material resources of local, state, and federal governments. Placing crosswalks everywhere is neither financially nor functionally sound. It is true with virtually any traffic control device that the more of them there are, the less they are respected. This would certainly be true of crosswalk markings. Thus, there must be some criteria for controlling where these traffic control devices are placed.

In retrospect, the attempt to device a useful set of criteria for crosswalk markings was as much an effort to describe where they should not be placed as where they should be placed. In effect, the criteria are a checklist for what should be looked for in deciding whether to accept or reject a candidate crosswalk marking location, with thresholds placed on some of the criteria to provide consistency from one jurisdiction to the next or within a single jurisdiction.

Unless history proves otherwise, we strongly suspect that our suggested guidelines are not perfect. They heavily incorporate engineering judgment, both our own and that of engineers from around the country who, for one reason or another, marked crosswalks that ended up as data points on our graphs. Even if a massive before-and-after safety study (with control group) of crosswalks were to be conducted, we would still need to rely to a great degree on engineering judgment for factors that one should consider in marking a crosswalk; and because engineering judgment is involved, there will undoubtedly be philosophical differences in the way these guidelines are approached.

One of the philosophical differences between our suggested guidelines and those developed in San Diego is the point system versus a nomograph-threshold approach, as suggested here. Although point systems have been widely used in the transportation industry, we believe that they introduce a temptation for the engineer to be more lax in thinking through all the factors that should be considered. They can more easily become a cookbook approach than will a nomograph-threshold approach. True, a point system can bring all those important factors into consideration, but it becomes too easy for the engineer to be removed from personally thinking through the pros and cons of each situation and there is no assurance that the weights assigned in the point system reflect what are the most important factors. We should also caution that just because a location passes the minimum volume thresholds in our nomograph system, it does not mean that a crosswalk is automatically warranted. There are, as Herms states, transitional areas that could be decided either way, depending on other factors.

The determination of whether to use street width itself or number of lanes could be reasoned either way, as long as the guidelines cover every possible combination. We selected number of lanes because it is simply stated and reflects the basic idea that wider streets are more difficult to cross, implying that crosswalk markings would therefore be more necessary. We think that people will instinctively translate feet into lanes and that it is better to provide them with lanes in the first place. In addition, using feet would also require subtracting out the width of parking lanes. The suggested guidelines consider lanes of moving traffic. If a parking lane is used for travel at any time during the day, it should be considered a travel lane.

Herms brings up a good point concerning the marking of signalized intersections. It should be a separate issue from crossings of uncontrolled intersection legs. Our rationale for suggesting markings at locations with pedestrian signal heads is based on the thought that if an investment has been made in the signal heads, the marking of a crosswalk involves a relatively small additional investment. In addition, the fact that a pedestrian signal is there usually means that there is at least some pedestrian volume warranting it. However, we do not take a strong stand that there must be crosswalk markings at all such locations. As long as the stop bar is adequately set back from the intersection, it should be clear enough, it is hoped, that this is the pedestrian's legitimate crossing area. Local policy should govern, but we believe that economics still dictates that the high-pedestrian-volume locations should be considered, even at signalized intersections. The addition of crosswalk markings can make the intersection as a whole more conspicuous and prominent, which may have some influence on driver sensitivity toward pedestrians as a side benefit.

There are several factors in the original paper that need clarification. The inclusion of the "minimal conflicting attention demands" criterion was an effort to recognize that the pedestrian can sometimes become lost to the driver's view on roads with cluttered visual backgrounds and complex maneuvering requirements. Although it is difficult to quantify these situations, it is a factor that should be included on the engineer's checklist when a particular situation is being evaluated. We have seen areas that could satisfy the other criteria at which we would not install a crosswalk because the driver was already being asked to do too much without having to watch out for pedestrians. One location to be particularly aware of is merging areas, where drivers must be looking backward to check for traffic merging from the right or left. Adequate illumination is also a critical and often-neglected element of consideration, but it is difficult to quantity. Ideally, crosswalk marking locations should be checked at night to determine how well the criterion is met, but the decision ultimately rests with the judgment of the engineer.

Separate nomographs for locations with young and elderly pedestrians would undoubtedly make the guidelines easier to apply for those groups. Likewise, volume thresholds could certainly be varied among or within urban areas. What may be appropriate in a dense urban area may not be appropriate in a small town. These are refinements that users of the overall framework should feel free to test.

Perhaps the word "framework" is the best way to describe our suggested crosswalk-marking guidelines. It is a way of logically addressing an often controversial and even political issue. We would not want the guidelines viewed as a black box, but at the same time we believe that they, or some future variation of them, will provide some assistance in making choices that must be made by someone. We also hope that the guidelines will be tried, modified, and improved, and we agree that the understanding of crosswalk markings by the general public is sadly lacking and would encourage additional efforts in that area as well.

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Bicycles on Transit: A Review of International Experience

MICHAEL REPLOGLE

A growing number of transit agencies across North America and Europe permit bicycles to be carried on board buses, subways, and railway vehicles. This marriage of bicycles and transit, which is part of the growing use of bicycles to get to and from suburban express transit services, combines many of the best features of both bicycles and public transportation. Recent research concerning bikes-on-transit from American cities and from foreign sources not readily accessible to North American transportation professionals is reviewed. Recommendations for the further development of bicycle-transit integration are offered as a potentially important strategy for reducing suburban traffic congestion and boosting the performance and productivity of suburban transit services.

Bike-on-rail service can provide high-quality metropolitan and intercity mobility largely independent of petroleum-fueled transportation. Bike-on-bus service can dramatically extend the service areas of rural and express suburban and urban bus routes and help overcome key barriers to bicycle transportation networks, for example, where bridge and tunnel access is a problem. Although express transit offers fast, efficient transportation between limited origins and destinations, the bicycle provides extensive access and egress opportunities that are not subject to the vagaries of local transit service.

As part of a comprehensive dual-mode system involving bicycles and public transportation, bike-on-rail and bike-on bus programs can play an important part. Secure bicycle parking at transit boarding points enables more convenient access to local transit routes at the home end. In typical European and Japanese suburbs, the bicycle is the predominant mode of access to express transit services, accounting for as many as 40 to 60 percent of passenger trips to rail stations and up to 20 percent of bus access.

When users are able to park bikes overnight in secure parking at stations near their workplace, bicycle egress from the station to work sites otherwise poorly served by transit becomes possible. Indeed, bicycle egress can open up entirely new markets for public transportation, making transit competitive with the automobile in terms of total travel time for intrasuburban commute trips ignored by most U.S. transit agencies. In many European suburbs, 10 to 20 percent of those leaving rail stations on the journey to work in the morning peak hours complete their journey by bicycle.

However, unless bicycles can be carried aboard rail cars or buses or rented at stations, only regularly made egress trips can be accommodated by bicycle. As was noted in an Australian report on bicycle–rail linkage (*1*, pp. 56–57):

> Dual mode travel is a field where the impact of 'the whole' is likely to be significantly greater than 'the sum of the parts.' Facilities for bike-bus and bike-tram travel . . . would complement bike-rail dual-mode to provide a comprehensive bike-public transport dual-mode option. . . . It could become the norm to regard the bike as a significant component of the household's stable, both for local *and metropolitan* trips [emphasis in the original].

HISTORIC PRECEDENT FOR BIKES ON TRANSIT

The original impetus for carrying bicycles on railways came from rail companies in the late 19th century. Hoping to attract additional passengers, railway or streetcar operators welcomed bicyclists and allowed them to transport their bicycles on board at no cost.

As the *Street Railway Journal* noted in 1897 *(2)*,

> One of the strongest competitors the street railways of the country have had to contend with in the last few years has been the bicycle. For this reason, street railway managers have for a long time been studying the problem of recovering a part of this lost traffic, by furnishing accommodations so that the bicyclist will find it more convenient to use the street cars, when looking for good roads, when caught in a storm, or when his wheel has become damaged by an accident. To provide this accommodation the "Doublehook" bicycle holder . . . has been introduced on a number of (rail) lines and is giving entire satisfaction.

As the bicycle became more popular, transit operators began to charge cyclists an extra fare for their vehicle. These fare surcharges provoked substantial political opposition from bicyclists (*3*, p. 222). In February 1896, a bill was introduced into the New York State Legislature requiring railroads to carry all bicycles free as personal baggage. Heavy political pressure, backed by 30,000 signatures on a supporting petition, led to nearly unanimous approval of this bill. In several other states, similar initiatives were introduced.

By early 1897, the Passenger Committee of the Trunk Line Association, a railroad management group, announced that its member railroads would henceforth carry bicycles at no charge. This action led to free bike-on-rail policies in New York, Pennsylvania, New Jersey, Ohio, Michigan, Indiana, and parts of Illinois, California, and Colorado *(3)*.

Throughout the rest of the nation, railroads and many streetcar lines offered bike-on-rail service, but imposed a surcharge. In 1897 the Market Street Railway Company of San Francisco carried an average of 1,800 bicycles a month on one route alone, with up to 6 bicycles suspended from hooks at the front and rear of the trams, generating added revenues of $180 a month, "unattended by any increase in the operating expenses

Maryland National Capital Parks and Planning Commission, 8407 Cedar Street, Silver Spring, Md. 20910.

whatever" *(4)*. The cyclist paid twice the standard nickel fare when transporting his or her bicycle.

Streetcars in a number of American cities, including Brooklyn, New York, offered similar services. In Pittsburgh, Pennsylvania, seats were removed from one side of a number of trolleys to accommodate bicycles *(5)*. Bicycle hangers were installed in the baggage cars of many commuter rail services in the 1890s. As motorbuses were introduced, bicycles were not uncommon elements of baggage, particularly for rural or longer-distance travel. In Europe in the early part of this century, a similar experience prevailed, with bicycles commonly carried on rail and bus services as baggage, sometimes for an additional fare, sometimes without surcharge.

BIKES-ON-RAIL IN CONTEMPORARY EUROPE AND AMERICA

Intercity Railroads

The national railways and most private railroads of Europe have long carried bicycles, usually relying on baggage areas for vehicle storage. As in America, demand for bike-on-rail service declined in Europe along with bicycle use during the post-World War II economic recovery. In recent years, however, there has been a sharp resurgence in bike-on-rail travel, as Table 1 shows. For example, the number of bicycles carried by the West German national railway doubled between 1977 and 1981, to more than half a million per year, despite increases in the surcharge for transporting bicycles.

TABLE 1 BICYCLES CARRIED ABOARD INTERCITY RAILWAYS

Country and Date	No. of Passengers with Bicycles
United States: Amtrak, 1982	10,000–15,000
Denmark: Danske Statsbaner	
Mid-1950s	1,000,000
Mid-1960s	40,000
1981	700,000
West Germany: Deutsche Bundesbahn	
1977	240,870
1979	310,577
1981	570,000
Holland: Nederlandse Spoorwegen, 1978	107,975

SOURCE: Compiled from published statistics of the respective railways and from discussions with railway officials.

In both Europe and America, the purchase of rail coaches lacking baggage areas suitable for bicycle storage over the past 30 years has made it more difficult for some railways to accommodate the recently increased demand for bicycle carriage. Some railroads, such as Nederlandse Spoorwegen (NS)—the Dutch National Railway—and Danske Statsbaner (DSB)—the Danish National Railway—are now purchasing new cars designed to accommodate bicycle storage.

In the meantime, on routes where coaches lack proper bicycle storage areas, some railways provide baggage cars to haul bicycles as freight. Deutsche Bundesbahn (DB)—German Federal Railways—as well as several Swiss light-rail systems operating in and near Zurich have installed rubber-coated bicycle hooks inside rail coaches to permit secure and space-efficient bicycle storage. The Austrian State Railway system has recently introduced some of the best-designed passenger coaches suitable for the carriage of bicycles, according to recent visitors.

Distance-based fares for bike-as-baggage use are common throughout Europe. For short journeys of up to 50 km (30 mi), typical bicycle charges are U.S.$2.50; on longer trips exceeding 150 km (90 mi), the maximum fee for transporting a bicycle is usually U.S.$5.00 to $7.00 *(6)*.

Cyclists do not fare as well in America. The principal intercity rail carrier, National Rail Passenger Corporation (Amtrak), appears to be the only major national rail system that requires bicycles to be partially dismantled and boxed before shipping, charging $10 for a shipping box. Demand for dual-mode intercity travel on Amtrak remains relatively low, at least in part because of the inconvenience and mechanical skills required to dismantle a bicycle for travel.

U.S. Commuter Railroads

The first American commuter rail system permitting bicycles in passenger coaches in recent years was the Southern Pacific (SP), serving San Francisco and San Jose, California. In a 4-month demonstration project sponsored by the California Department of Transportation (Caltrans) in 1982, cyclists were allowed to secure their bicycles in the aisles of the rail cars at no charge during nonpeak hours. No permit was required.

SP management, however, showed little enthusiasm for the project and accepted it only on payment of $73,000 by Caltrans to indemnify SP for potential accidents. In the 4 months of operation, there were no schedule delays, injuries, or inconveniences to other passengers attributed to the program. With a lack of publicity and a short duration, the service attracted only about 100 users a week *(7)*. Although no safety or operational problems were evident and the local railway workers' union voiced support for the program, SP management refused to continue the demonstration unless Caltrans paid $10,000 a month for insurance of clearly questionable necessity, given extensive incident-free experience with bike-on-rail carriage. For obvious reasons, the program was halted *(8)*.

To help overcome this resistance on the part of SP management, one-third of the 48 new SP passenger rail coaches recently ordered by Caltrans were to have provisions for bicycles and wheelchairs. Jump seats, which can be folded up to accommodate bicycles in nonpeak hours, were to be installed at one end of these cars. One bicycle-accessible rail coach was to be added to each SP commuter train *(9)*. Surveys on SP commuter trains have revealed a strong interest in permitting a bike-on-rail program during peak hours and little opposition to the idea from current passengers *(9)*.

Since late 1983, the Long Island Railroad has adopted a liberal bike-on-rail policy, barring bicycles only during peak hours. A permit is required that costs $5. Metro North, which runs trains into Grand Central Station in New York City, has also recently adopted a bike-on-rail program.

Subway and Metrorail Coaches

Until 1980 only a few subway systems in the world allowed bicycles inside rail cars. The Port Authority Trans-Hudson

(PATH), serving New York City and Newark, New Jersey, opened its doors to bicyclists during nonpeak hours in 1962. Since it opened in 1966, Oslo Sporveier, in Norway, has accommodated cyclists at all hours without problems. In San Francisco the Bay Area Rapid Transit (BART) System in 1975 began to accept bicycles on a permit basis during nonpeak hours.

BART has had the most popular American bike-on-rail program. By 1980 more than 9,000 bike-on-rail permits had been issued. Strong community support and the excellent safety record of the program prompted BART to relax restrictions on dual-mode travel in 1980. Permits were made available through the mail at $3 each and bike-on-rail service was extended to peak-period travel in the nonpeak direction between most stations. By 1985 more than 30,000 permits had been issued and only one minor accident claim had been recorded, according to BART staff.

With the success of the BART program, cyclists in other American cities began to press for bike-on-rail service. In 1981 the Washington Metropolitan Area Transit Authority (WMATA) began a bike-on-rail demonstration program after 5 years of intense and patient lobbying by local bicycle activists. "The demonstration program received almost universal acclaim from cyclists and non-cyclists alike," reported *Mass Transit* in 1982 *(10)*. A local magazine, *Washingtonian*, gave the program its "Best New Idea of 1981" award.

Favorable public and media reaction led WMATA to extend the initial weekend-only program to weekday evenings after 7:00 p.m. To obtain a bike-on-rail permit, WMATA requires cyclists to pass an hour-long safety training program offered only during scheduled times at the transit agency headquarters and charges a $15 fee. Despite these restrictions, more than 3,500 permits had been issued as of 1986.

The Metropolitan Atlanta Regional Transit Authority (MARTA) in Atlanta, Georgia, initiated Sunday-only bike-on-rail service in 1981, soon after subway operations had commenced. Signs inside stations inform cyclists of the safety rules and no permit is required. No significant problems have arisen from this policy, according to MARTA staff.

The success of early bike-on-rail programs combined with pressure from bicycle activists similarly led several European subway systems to initiate their own programs in the early 1980s. By 1982 at least 12 European and 6 North American metrorail operations allowed bicycles inside passenger railcars. Each year since then, several other systems have adopted similar policies. Several others have followed informal policies neither promoting nor discouraging dual-mode travel. The policies observed in a number of cities are summarized in Table 2, which does not include all known bike-on-rail systems.

North American bike-on-rail programs have tended to be somewhat more restrictive than their foreign counterparts. Several European systems permit bicycles in peak periods, sometimes but not always relying on small baggage areas inside passenger coaches for bicycle storage. Only three European systems restrict dual-mode travel to weekends. All others offer either unlimited or evening nonpeak period use.

Permits for bike-on-rail travel are not required by any transit system outside North America. Except for Montreal and Atlanta, all North American commuter or subway systems have imposed permit requirements on cyclists who would bring their bikes along as baggage. The open access provided by European systems makes bike-on-rail travel accessible to tourists, occasional users, and those trying dual-mode travel for the first time. The restrictive practices of North American systems, in requiring permits, make dual-mode travel far less useful to potential users and intentionally restricts demand to dedicated bicyclists, even though this reduces non-peak-period, low-marginal-cost, revenue-generating transit ridership.

The number of bicycles allowed per train or per car varies widely, from two bicycles per car in Berlin and New York to eight in the luggage compartment of Paris rail coaches and an indefinite number constrained only by the space available in Rotterdam, Amsterdam, and London.

Few counts of bicycles on trains have been conducted. However, average use has varied widely where estimated, from a few bicycles a day up to some 800 a day during the week in Hamburg and Berlin *(11)* and 3,000 a day on weekends in Berlin *(12)*. An average of several dozen commuters per station use the BART non-peak-direction, peak-period bike-on-rail service in San Francisco. Compared with the average daily ridership, the number of bicycles has varied from 10 per million passengers in Munich to 2,000 per million riders in Amsterdam (*12*, p. 4).

RESEARCH ON BIKE-ON-RAIL POLICIES

Because of political pressure on many transit managers to permit bike-on-rail programs, the Union International des Transports Publiques (UITP), an international association of transit agencies, was asked to survey its members and report on the status and issues surrounding this matter. Of 31 transit organizations responding to the 1981 UITP survey, only 8 permitted bicycles on trains. The reasons cited by railways for refusing to carry bicycles included potential safety hazards to passengers, potential nuisance to passengers due to dirt on bicycles, insufficient space in cars, potential hazards of moving bicycles on escalators, overcrowded station conditions, and a lack of local pressure for such programs from cyclists.

The UITP survey found that in no case has a bike-on-rail program required additional personnel or entailed new costs. Except for two minor incidents attributed to passenger behavior in Berlin, none of the eight operators reported any accidents or operating incidents related to the bike-on-rail program.

The UITP report concludes that, contrary to the fears of most transit agencies, "the excellent experience of undertakings which have granted temporary or definitive permission to carry bicycles should be noted. The apprehensions expressed before introduction of the facility (bikes-on-rail) have not so far been justified in practice" *(12)*.

Support for bike-on-rail programs among European transit officials appears to be growing. The Verband Öffentlicher Verkehrsbetriebe (VÖV), the West German Association of Public Transport, in 1982 researched and issued recommendations on dual-mode travel for its members. VOV encouraged member agencies to permit bicycles on all rail lines, excluding bicycles from peak-period, peak-direction travel. VOV advised agencies to set restrictions on the number of bicycles per car and to ban bicycles from escalators, confining them to stairs for station access and egress. Agencies were encouraged to charge extra for carrying bicycles, with the fee adjusted to the demand for dual-mode travel *(13)*.

TABLE 2 BIKE-ON-RAIL PROGRAMS

Country	Bike-on-Rail Subway System	Date Policy Began	Fare for Bicycle	Maximum No. of Bicycles Allowed	Bicycles Permitted: Peak Hours	Bicycles Permitted: Weekday Non-Peak	Bicycles Permitted: Weekend	Actual Hours and Comments
United States	Port Authority Trans-Hudson (PATH), New York–New Jersey	1962	0	2/car		X	X	M–F 930–1500, 1830–600, except Saturday 1300–1900 from NYC
	Bay Area Rapid Transit (BART), San Francisco, Calif.	1975	0	7/train	X	X	X	Not allowed peak period in peak direction; $3 mail-in permit
	Washington Metropolitan Area Transit Authority (WMATA), Washington, D.C.	1981	0	4/train		X	X	$15 permit and training class required; M–F after 1900; weekends all hours
	Metropolitan Atlanta Regional Transit Authority (MARTA), Atlanta, Ga.	1981	0	4/train			X	Sunday only
Canada	Toronto Transit Commission (TTC)	n.a.	0	n.a.	X[a]	X[a]	X[a]	Permit issued by station personnel
	Montreal Metro	1982	0	4/train			X	Permit required
England	London Transport	n.a.	35% full fare	n.a.		X	X	M–F 100–1600, 1900–2400; weekend all hours; district and metropolitan lines only
France	Régie Autonome des Transports Parisiens (RATP), Paris	n.a.	n.a.	8/car	X	X	X	Suburban regional metro lines only
Netherlands	Amsterdam Metro	1980	50% full fare	No limit	X	X	X	All stations, all times
	Rotterdamse Elektrische Tram (RET), Rotterdam	1980	0	No limit		X	X	M–F 900–2400; weekends all hours
West Germany	Berliner Verkehrs-Betriebe (BVG), West Berlin	1980	50% full fare	2/car		X	X	M–F 900–1400, 1800–0100; weekends all hours; bike hooks provided in cars
	Hamburg Verkehrs Verbund (HVV)	1981	Full fare	4/car		X	X	M–F 900–1600, 1800–2400; weekends all hours
	Munich Verkehrs Verbund (MVV)	1982	Low fare	8–16/train			X	Saturday 1400–Sunday 2400; S-bahn and U-bahn
	VAG, Nuremberg	1982	1.40 DM	n.a.			X	–
	Verkehrs Verbund Stuttgart	1982	0	n.a.		X	X	S-bahn except commuter trains; M–F 830–1600, 1830–2400; Saturday 1400–2400, all Sunday
	Frankfurt Verkehrs Verbund	1982	2 DM	n.a.			X	–
	Verkehrs Verbund Rhein-Ruhr	1982	2.40 DM	n.a.		X	X	M–F 900–1530, 1800–2400; weekends all hours
Norway	Oslo Sporveir	1966	Full fare	No limit	X	X	X	–

SOURCE: *The Carriage of Bicycles in Metropolitan Railway Cars (12)* and other sources.
[a]At discretion of TCC station personnel.

It should be noted that it has been a common and approved practice for cyclists to carry bicycles on escalators in many areas of the Netherlands, most notably at tunnel crossings of some waterways. The Dutch experience with this practice appears to have been favorable.

A few public transportation organizations have evaluated possibilities for retrofitting rail cars to accommodate bicycles. The Danske Statsbaner (DSB), in Denmark, estimated that removal of eight seats from a heavy rail coach and installation of four bicycle racks would cost 60,000 kroner (about U.S.$7,500) per coach. They also evaluated the feasibility of modifying S-bahn (commuter rail) cars to provide interior bicycle racks. Conversion costs were estimated to range from 6,650 to 10,000 kroner (U.S.$830 to $1,250) per unit of bicycle capacity for 6 to 12 bicycle racks per car. A simpler and far less expensive bicycle hook storage system like those now being used in many DB and Swiss rail coaches was not considered. DSB officials decided against any retrofitting because of anticipated costs *(14)*.

Although nearly all rail coaches can accommodate a limited number of bicycles on an ad hoc basis, it makes far more sense to design new rail cars with luggage areas capable of holding several bicycles, as several railways (e.g., BART, WMATA, SP, DB, several Swiss streetcar companies, and NS) are now doing.

With careful design, this can be achieved with no loss of capacity or increase in capital cost.

European systems have generated significant positive revenue by carrying bikes on trains and charging fares for bicycle carriage rather than requiring permits. This makes it easier for occasional users and tourists to take their bikes on a train and minimizes administrative costs, unlike the American required-permit systems. A recent article noted that "from the point of view of operational economics, allowing the conveyance of accompanied bicycles on HVV [Hamburg's Metro system] has had a positive result. The additional fare revenue from accompanied bicycles far exceeds the expenditure on information for passengers on the facility" *(11)*.

FOLDING BICYCLES

A little-used strategy for dual-mode transportation involves the use of folding bicycles, which the majority of rail and bus operators allow aboard their transit vehicles. Although folding bicycles offer great compactness, ideal for bike-on-rail and bike-on-bus transportation, they have thus far played a relatively minor role in dual-mode travel. Several factors limit their usefulness. Folding bicycles are relatively expensive, often costing $300 or more. Compactness can be achieved only by sacrificing some elements of comfort, handling, and riding performance.

Advances in folding-bicycle design are being made, however, and such vehicles may attain greater acceptance in the future, particularly for peak-period, peak-direction dual-mode travel. One action that transit agencies could take to foster greater use of folding bicycles would be to offer such vehicles for rent to cyclists on a trial basis. This would give transit passengers the opportunity to make an informed decision about whether they should invest in their own folding bicycle. BART undertook such a demonstration in 1983–1984. Although a strong level of interest was evident on the part of transit passengers, the particular folding bike used had recurrent maintenance problems.

BIKE-ON-BUS PROGRAMS

In the past decade, another form of dual-mode transportation has reemerged, gaining its strongest hold in the small cities and suburbs of America. This new concept, the bike-on-bus program, has taken several forms as transit agencies have experimented with different technologies.

Bike-on-bus service appears to be rare in Europe and nonexistent in Japan, although bicycles were formerly carried on a widespread basis by rural and intercity bus services in Europe several decades ago. Several Danish and Swedish bus companies providing suburban and regional services have relied for many years on rear-mounted bicycle racks or baggage compartment storage for dual-mode transportation. Since 1983 bike-on-bus service using bicycle trailers has been initiated in Hanover, Detmold, Holzminden, and Bonn, in West Germany, and in Amsterdam. The latter experiment was unsuccessful because of poor route choice and system design *(11)*. European ventures in this area have been looking to the more extensive recent American experience for guidance.

More than a dozen American public transportation organizations have adopted some type of bike-on-bus service since the early 1970s. Although most offer only limited service on one or two routes, a few transit agencies have developed more extensive bike-on-bus programs. The Santa Barbara Metropolitan Transit District (SBMTD) in California carried more than 42,000 bicycles on six routes in 1981. On one route, one-fourth of all riders brought bicycles with them *(15)*. In San Diego, California, 40 bicycle-rack-equipped buses on three routes handled more than 20,000 passengers with bicycles in the same year *(16)*.

Bike-on-bus service is functionally similar to bike-on-rail programs, but often operates in much lower-density corridors than rail transportation. By expanding a bus line's access and egress service areas, bike-on-bus programs can attract many passengers who would not otherwise be able to use transit for their trip, particularly in suburban areas where transit coverage is sparse.

There are several methods for accommodating bicycles on buses. The most common technology relies on a bicycle rack on the rear of the bus. Commercially available rear-mounted racks holding four to six bicycles have been used by at least eight American bus operations. Front-mounted racks, accommodating two or three bicycles, have won favor from several other transit agencies. Only one bus service has used a bicycle trailer towed behind a 20-passenger minibus. This system, found in Santa Barbara, California, can move up to 12 bicycles at a time. The simplest technology for bike-on-bus service permits bicycles to be stored inside the passenger compartment. This can be done without any modification on buses designed to accommodate wheelchairs. For vehicles not equipped for handicapped access, secure on-board bicycle storage usually requires the removal of several seats or the installation of jump seats. The locations of each of these approaches are given in Table 3.

Development of Bike-on-Bus Service

San Francisco

The initial impetus for bike-on-bus transportation arose from the lack of bicycle access to many major highway bridges in the United States. In the early 1970s, bicycle activists in the San Francisco Bay Area pressed local transportation authorities for bicycle shuttle service across the Oakland Bay Bridge, which was closed to cyclists. AC Transit, a local bus agency, removed half of the seats from a bus to make room for up to 24 cyclists and their bicycles, initiating the Pedal-Hopper, which offered limited weekend service across the bridge *(17–19)*.

California cyclists pressed ahead and won the attention of the state legislature, which in 1974 required Caltrans to develop solutions to the problems of bicycle and pedestrian access to state-owned toll bridges *(20)*. Shuttle van service using bicycle trailers was introduced by Caltrans at several locations, including the Oakland Bay Bridge and the San Diego–Coronado Bay Bridge. Although these services were popular and well used, the costs were considered excessive.

San Diego

Seeking a cheaper way to provide bicycle access across the Coronado Bay Bridge, Caltrans initiated a bike-on-bus demonstration project. Three San Diego Transit buses operating

TABLE 3 BIKE-ON-BUS PROGRAMS

Technology Used and Location	Date Program Began	Bicycle Capacity Per Bus	Bicycle Capacity System Total	No. of Bicycles Carried per Year
Rear-mounted racks				
San Diego Transit (San Diego, Calif.)	1976	5	80	22,000 (1981)
Santa Cruz Mass Transit District (Santa Cruz, Calif.)	1980	5	30	6,000 (1981–1982)
Southern California Rapid Transit District (Los Angeles, Calif.)[a]	1980	5	90	1,500–2,000 (1981)
Lane County Mass Transit District (Eugene, Oreg.)	n.a.	5	n.a.	n.a.
Lincoln Transportation System (Lincoln, Nebr.)	1981	5	5	n.a.
Tennessee Valley Authority (Knoxville, Tenn.)	1982	5	5	n.a.
Willamette, Connecticut, Transit Agency	1982	5	10	n.a.
Bettendorf Transit System (Bettendorf, Iowa)	1982	5	10	n.a.
Thinggaards Rutebiler (Copenhagen-Aalborg and Copenhagen-Fjerritslev, Denmark)	n.a.	8	n.a.	n.a.
Front- and rear-mounted racks: Lawrence Livermore Laboratory Shuttle Bus (San Francisco area, Calif.)	n.a	9	60+	8,000+ (1982)
Front-mounted racks				
Seattle Metro (Seattle, Wash.)	1978	2	40	4,000 (1980)
North County Transit (Oceanside, Calif.)	n.a.	5	50	n.a.
Evergreen State College (Olympia, Wash.)	1981	2	4	n.a.
Bicycle trailer towed by minibus: Santa Barbara Metropolitan Transit District (Santa Barbara, Calif.)[b]	1976	12	60	42,000 (1981)
Bicycle accommodated in wheelchair tie-downs: Westchester County Transit (northern New York City suburbs)	1979	2	210	n.a.
Seats removed from bus for bicycle storage rack: AC Transit (San Francisco, Calif.)	1973	24	24	n.a.
Bus baggage compartment for bicycle storage: HT Landevejsbus (Copenhagen, Denmark)	n.a.	2	n.a.	n.a.

[a]Bicycle rack service discontinued in 1982.
[b]Service with bicycle trailers sharply curtailed in January 1982 because of budget cutbacks.

across this bridge were equipped with rear-mounted bicycle racks in 1976 to replace shuttle van service.

The number of bicycles carried across the bridge fell substantially when the bike-on-bus service was first introduced. The van-trailer system had carried an average of about 1,500 bicycles a month during its 9 months of operations at an average cost of \$1.53 to \$1.72 per bicycle. The bike-on-bus program drew an average of about 500 cyclists a month during the first 9 months of service, at an estimated net cost of \$1.28 per bicycle.

Several factors accounted for this performance. The price of crossing the bridge with a bicycle increased from \$0.25 to \$0.45 when the bike-on-bus program was initiated. Boarding locations changed and the frequency of service dropped from every 30 min to every 40 to 50 min. Whereas the trailer accommodated eight bicycles at a time, the racks held only five bicycles. Moreover, many people could not figure out how to use the rack properly (*16; 21*, p. 2).

Persevering, San Diego Transit continued the service after the Caltrans demonstration program ended. The coin-operated bicycle rack locks were replaced with locking pins to eliminate excessive coin-box maintenance costs; the \$0.10 surcharge for rack use was eliminated. In 1977 additional racks were purchased. The former frequency of service on the bridge was restored and two other bike-on-bus routes were initiated in other parts of San Diego. Those measures paid off in increased rack use and ridership.

By 1981 San Diego Transit operated 40 rack-equipped buses and carried more than 20,000 passengers with bicycles. According to a San Diego Transit official, "A large number of the passengers currently using the bike rack system would not be riding the bus if the rack service were not available and therefore the revenue generated would be lost" (Ron Weisman, unpublished data).

Seattle

In Seattle, Washington, limited-access highway bridges across Lake Washington posed major barriers to cyclists. Responding to pressure from local bicycle activists, in 1978 Seattle Metro installed rear-mounted bicycle racks on their buses that cross the lake. A year later, front-mounted racks were substituted because of unconfirmed reports that children were hitching rides on the rear racks. The front rack accommodates only two bicycles, but folds flat against the bus when not in use. More than 4,000 bicycles a year are now being carried on the eight bike-on-bus routes. Twenty-three buses were rack equipped in 1981.

Bus company management support for extending bike-on-bus service appears to be weak, however. When a recent bid went out for temporary bicycle transport service across a Seattle area ship canal to provide continuous bicycle access during an 18-month bridge reconstruction project, Metro would not allow additional buses to be outfitted with front bicycle racks. Instead, a shuttle van service is planned to transport cyclists with their vehicles around the canal barrier.

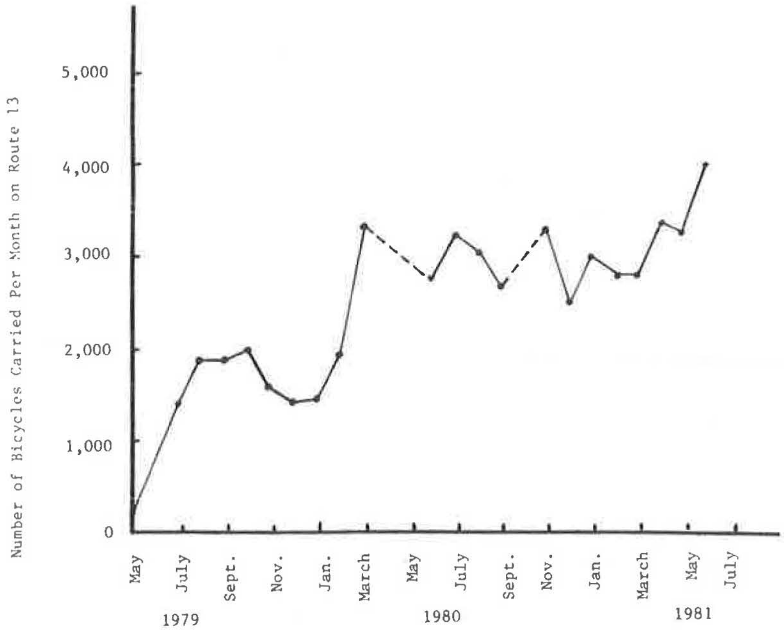

FIGURE 1 Growth in bike-on-bus use in Santa Barbara, California *(22)*.

Santa Barbara

SBMTD was the first American transit agency to institute bike-on-bus service unrelated to bridge-access problems. As an SBMTD official noted, "The project had as its primary goal, the development of new transit ridership by facilitating bicyclists' access to public transportation. A secondary goal was reduction of point-to-point travel times by transit, particularly for non-downtown trips, since bicycles are a faster access mode than walking. In this way, it was hoped to make transit more closely competitive with the private automobile in regard to door-to-door travel time" (22, p. 1).

An experimental bike-on-bus operation was initiated in 1975 using a 6.1-m (20-ft) Mercedes bus towing a custom-designed trailer that held 12 bicycles. The service operated over a single 16-km (10-mi) express route between the downtown Santa Barbara Transit Center and the University of California at Santa Barbara (UCSB). The prototype bicycle trailer was mechanically unreliable and awkward to use; numerous breakdowns led to service unreliability and customer dissatisfaction. Nonetheless, the experiment demonstrated substantial community interest in this form of dual-mode transportation.

After several years of intermittent bike-on-bus operations with two different designs of bicycle trailers, the SBMTD substantially upgraded the service under a Service and Methods Demonstration project grant from UMTA. A 2-year demonstration project began in mid-1979 using an improved trailer design, longer and different routes, and scheduling more suited to community needs.

Beginning with one 28-km (17-mi) bus route centered on the downtown Santa Barbara Transit Center, bike-on-bus service was gradually extended to six bus routes through the course of the demonstration. Demand was strongest on longer-distance express bus routes where dual-mode travel offered travel time and convenience competitive with other modes. One short route from the Pacific Coast to Westmont College in the coastal mountains also proved attractive to cyclists, who could avoid the steep uphill climb. Two other short and relatively slow bus routes failed to attract bicyclists because the dual-mode service could not compete effectively with the bicycle or automobile in terms of travel time. Bike-on-bus service was dropped from these two routes after several months of trial operation.

Good service reliability helped to bolster and maintain bike-on-bus ridership. The fleet of six new trailers experienced no major maintenance problems. One of the older trailers and one new trailer were held in reserve to ensure continual service delivery.

Ridership rose dramatically throughout the demonstration period. From December 1979 to the final quarter of 1980, the number of passengers with bicycles increased by 70 percent on bike-on-bus routes. On the principal bike-on-bus routes during this same period, ridership rose by 46 percent, and the level of bus service increased 19 percent. Systemwide SBMTD ridership grew only 15 percent in the corresponding time period. By 1980–1981, more than 42,000 passengers a year were bringing their bicycles with them by using the trailers *(15)*.

The most successful bike-on-bus operation was on Route 13 between the downtown Santa Barbara Transit Center and UCSB campus. Figure 1 shows the growth of bicycle carriage on this route. Between November 1979 and November 1980, the number of passengers with bicycles on Route 13 increased 118 percent. A further 20 percent increase in the number of bicycles carried on the Route 13 bus brought the monthly volume of bicycles transported in June 1981 to nearly 4,000, accounting for one-fourth of the total ridership *(15)*.

On other bike-on-bus routes, between 10 and 20 percent of the ridership used the bicycle trailer service. Figure 2 shows the level of trailer use for the SBMTD dual-mode system *(15*, pp. 6–8).

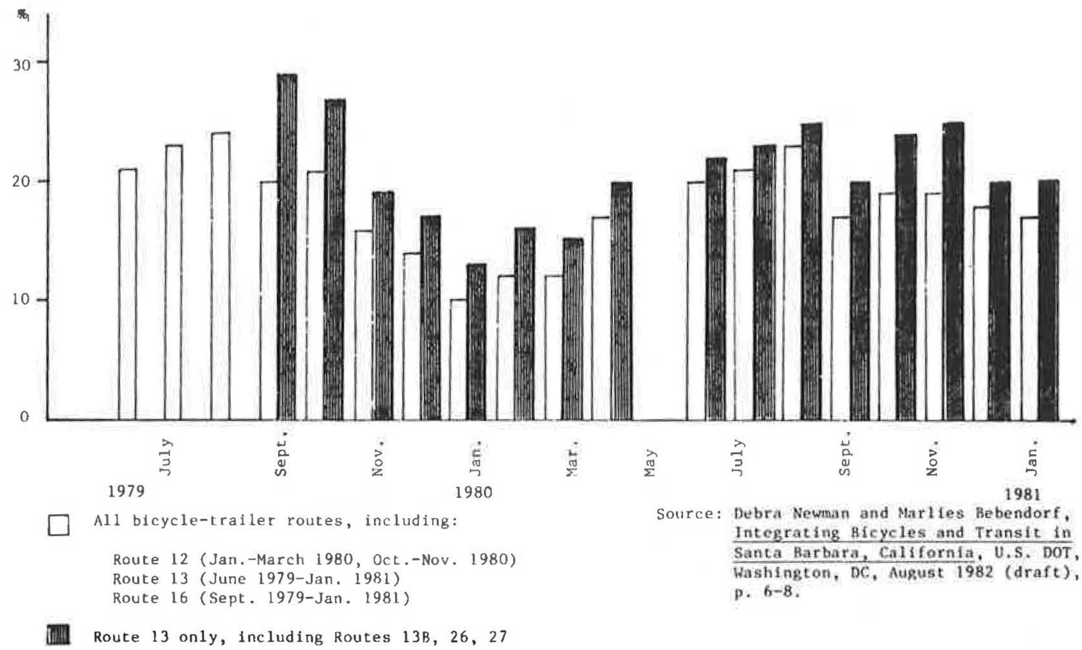

FIGURE 2 Bicycle trailer routes: passengers with bicycles as percentage of total weekday riders (*15*, pp. 6–8).

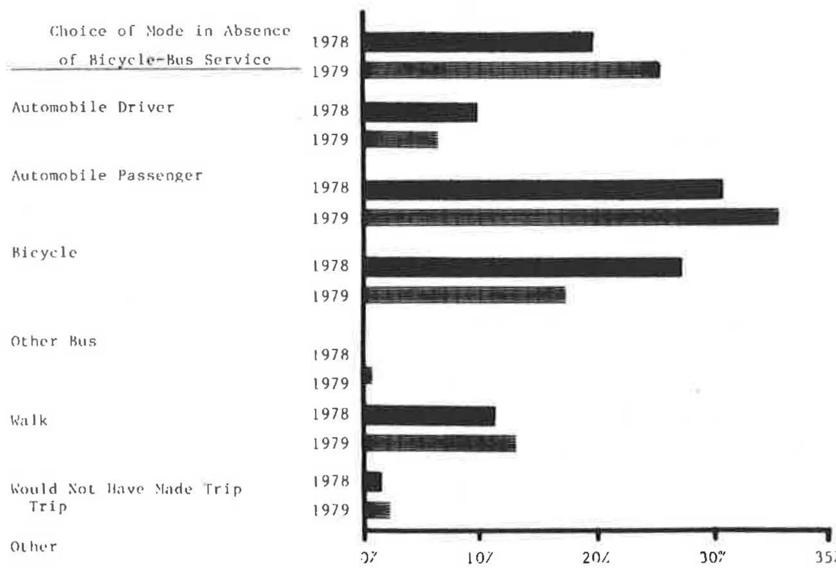

FIGURE 3 Diversion from other modes induced by bicycle-trailer service (*15*, pp. 6–19).

Surveys conducted as part of the demonstration program showed that the bike-on-bus service attained its goals of building transit ridership and reducing automobile use. More than 80 percent of the bicycle trailer users would not have used transit in the absence of bike-on-bus service; 31 percent would have used automobiles to make the trip instead. About one-third of the passengers with bicycles would have cycled the full distance if there had been no bicycle trailer. Figure 3 shows the diversion of travel induced by the bike-on-bus service (*15*, pp. 6–19).

The provision of bicycle parking at bus stops combined with the bicycle trailer service had a significant effect on access-mode choice. Although only 1.5 percent of access trips to the bike- on-bus routes were by bicycle in 1978, this share rose to 23 percent in 1980. Feeder-bus and automobile access-mode shares remained steady at about 18 and 4 percent, respectively. The proportion of passengers who walked to bus stops fell in this same period from 80 to 54 percent, although the number of pedestrian access trips rose as ridership increased. In 1980 more than 21 percent of egress trips from the bike-on-buses were by bicycle (*15*).

The success of the bicycle trailer services led the SBMTD to continue bike-on-bus operations after the end of demonstration project funding in December 1980. However, cutbacks in federal transit operating assistance under the Reagan administration forced the SBMTD to scale back services in 1982. All but one of the bike-on-bus routes were eliminated. The one remaining route, which climbs from the coast to Westmont College in the mountains, continued to carry about 300 passengers a month with bicycles in mid-1982, representing one-fifth of this route's ridership.

In an example of successful technology transfer, the Santa Barbara bike-on-bus trailers were sold to the Port Authority of New York and New Jersey in 1984 and put into operation carrying bicyclists across the George Washington Bridge between New Jersey and Manhattan. The bike trailers were well received and attracted substantial use until service was discontinued with the opening of bridge walkways *(23)*.

Westchester County

Although most transit agencies offering bike-on-bus service have relied on various devices to secure bicycles outside the bus, two agencies have decided that added hardware is unnecessary and allow bicycles inside their buses. The first, AC Transit in San Francisco, removed half the seats from a standard bus to provide space for bicycles. The second, the Westchester County Department of Transportation (WCDOT), located in the wealthy suburbs of New York City, simply adopted a permissive policy toward bicycles. A third agency, the Regional Transportation District in Denver, Colorado, is reported to allow bikes informally inside at least some buses equipped with baggage bins.

Like many American bus operators, WCDOT bought many lift-equipped buses in the late 1970s to comply with U.S. government regulations regarding handicapped access to public transportation. To maximize the use of these wheelchair-accessible buses, WCDOT adopted the policy that "everyone's welcome aboard." The space provided for wheelchair-bound passengers can be used by those traveling with baby carriages, shopping carts, bulky packages, or bicycles.

WCDOT has made this "welcome aboard" policy a significant element in their marketing efforts. As one of their promotional brochures states, "whether you are very young or old, whether you use a wheelchair or ride a bicycle, whether you are traveling to work or going shopping, our new buses were bought with you very much in mind and we hope you will ride them frequently" *(24)*.

In Westchester County, bicycles are permitted aboard only handicapped-accessible Advanced Design Buses and only in nonpeak periods. Wheelchair users are given priority over bicycles at all times. Two bicycles can be secured in the wheelchair tie-downs on each of the 105 lift-equipped buses.

Bike-on-bus service is operated on 27 of the 70 bus routes operated by WCDOT. Although there are no counts of how many bicycles are carried, WCDOT officials report light to moderate use of the dual-mode system and say that in several years of operation there have been no accidents or safety or insurance problems related to bicycles inside buses.

Costs of Bike-on-Bus Service

The capital and operating costs of providing bike-on-bus service vary widely depending on the technology used. Programs that permit bicycles inside lift-equipped buses entail no additional capital or operating costs related to bike-on-bus service and are therefore the cheapest way to provide dual-mode transportation. Bicycle racks and trailers may provide more bicycle capacity but they impose added costs on the transit agency.

Front-mounted racks holding two or three bicycles are commercially available for less than $200 each. The racks used in Seattle were fabricated in house for about $200 each and are specially designed to fold flat against the bus when not in use. Rear-mounted racks holding five or six bicycles can be purchased for about $1,250. The final working version of the Santa Barbara bicycle trailer cost $3,740 to fabricate. The design is unpatented and available for public use from the SBMTD.

Operating costs are subject to equally great variation and are generally not accounted for separately by transit agencies offering bike-on-bus service. Seattle reports that their front-mounted racks are virtually maintenance free. However, they must be removed frequently for bus cleaning. Removal and remounting takes about 6 min per rack. If one accounts for this added labor cost, it amounts to about $72 per rack each year, or $36 per unit of rack capacity *(16)*.

Maintenance is not insignificant for rear-mounted racks. Because they block the engine access panels, rear racks must be removed more frequently than front racks. The placement of rear racks also necessitates a built-in light, which may malfunction. San Diego Transit has identified four major costs related to rear-mounted racks: cleaning, repairs, road calls, and rack removal for bus servicing. Although it takes only 2 min to remove a rack from a bus, this action must be repeated at least once a day for engine servicing. Because it takes two people to remove a rack, a second person is required to handle bike-on-bus road calls.

In 1980 San Diego Transit estimated that the maintenance cost for their 16 racks then in active service was about $80 per rack per month, or about $192 per year per unit of capacity. Operating delay related to bike-on-bus use was negligible, because loading or unloading a bicycle takes only 10 to 15 sec *(21)*.

The Santa Barbara bicycle trailers, in contrast, cost $87 per year per unit of capacity for maintenance and cleaning. Four trailers in active service were each cleaned weekly by hand at an annual labor cost of $1,444. Maintenance costs were about equally distributed between parts and labor and averaged $0.0082 per vehicle mile of trailer service, amounting to $3,041 over a 12-month period in 1980–1981 *(16)*.

To date, there have been no major claims for accidents or damage related to any bike-on-bus service. In Santa Barbara liability claims over a 29-month period between May 1978 and September 1980 totaled $179. These and all subsequent claims have related mainly to minor damage to bicycles and ranged between $1.70 and $80. Although the SBMTD retained insurance on their trailers at a cost equal to insurance on their buses, this appears to be unwarranted *(15)*.

The costs of bike-on-bus service in several cities are summarized in Table 4. From a cost standpoint, allowing bicycles inside buses is preferred except for peak-period travel. Front-mounted racks are certainly less expensive than rear racks but offer less capacity, which may restrain demand in some locations. Trailer service offers lower marginal operating costs than rear racks where dual-mode demand is high, but trailers have thus far only been operated with small buses.

TABLE 4 COMPARISON OF BIKE-ON-BUS SERVICE COSTS IN SEVERAL CITIES *(16)*

Item	Santa Barbara, Calif.	San Diego, Calif.	Seattle, Wash.	Westchester County, N.Y.
Type of service	Trailer towed by minibus	Rear-mounted bicycle rack	Front-mounted bicycle rack	Bicycle inside bus (wheelchair tie-down)
Bicycle capacity per bus	12	5	2	2
No. of units in service	4 trailers	16 racks	20 racks	105 buses
Capital cost per bus ($)	3,740	1,350	200	0
Capital cost per unit capacity ($)	87	192	72	0
No. of users per year (1980–1981)	42,090	13,000	4,380	n.a.
Maintenance cost per user (1980–1981) ($)	0.10	1.20	0.65	0

The 19-passenger minibuses in Santa Barbara cost 32 percent less to operate per vehicle mile than SBMTD conventional-size buses. However, because larger buses can carry more passengers, overall efficiencies favor increased size. In Santa Barbara, the average cost per passenger for minibuses was 58 to 69 percent higher than that for conventional buses. The average number of passengers per mile ranged from 64 to 80 percent lower for minibus routes *(15)*.

It may be possible to develop bicycle trailer service with full-size buses, but several barriers would need to be overcome. The SBMTD found that conventional American transit buses lack sufficient structural strength to pull a 900-kg (2,000-lb) bicycle trailer *(15)*. Reinforcement would add substantial cost. European or Japanese buses may or may not be suitable for trailer towing without modification. Permits might be required for added length in any case. Special permits were required for rear-mounted racks on full-size buses in California, although these extended the bus length by only 1.1 m (44 in.). The successful operation of articulated buses (very long, high-capacity buses with articulated chassis) in many cities, however, suggests that the length added by a bicycle trailer would not pose an insurmountable problem.

Articulated buses themselves would be well suited to bike-on-bus service; jump seats could be used that would fold up to reveal bicycle racks or wheel wells in the floor for securing bicycles. This approach to bike-on-bus operation has not yet been attempted.

Growth in Bike-on-Bus Service

Nearly half the American bus operators now offering bike-on-bus service have initiated their programs since 1980. Only one transit agency, the SCRTD in Los Angeles, ceased bike-on-bus operations after initial experimentation because of a combination of low use, insufficient marketing, and resistance from the maintenance staff. Several transit agencies are planning to implement bike-on-bus service in the near future. The Humboldt Transit Authority, which serves a 50-mi rural corridor along the northern California coast, recently installed rear-mounted racks on its entire 11-bus fleet.

The popularity and feasibility of bike-on-bus programs has been amply demonstrated in a number of cities. Despite continued resistance to the concept by many transit agencies, the prospects for further growth in bike-on-bus service in both Europe and America appear good.

CONCLUSIONS

Integration of bicycles with public transportation can offer substantial help to transportation agencies seeking to increase the usefulness and competitiveness of public transport services in lower-density suburban areas. Indeed, the greater use of bicycles for express transit access and egress helps to account for the relatively healthier condition of European suburban transit services relative to their American counterparts *(22)*. U.S. transit agencies have become overreliant on automobiles for express transit access.

The lack of diversity in the U.S. transit access and egress system relative to that in Europe and Japan has reduced the size of the markets for suburban transit ridership from what they would be with a wider range of choices and options for getting to and from express transit stops. Although providing secure bicycle parking and improved access routes near transit stops are the most important areas for access system diversification, liberalized bike-on-transit policies have an important role to play in improving consumer transportation choices and adapting transit to the modern suburban environment *(25)*.

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Demographic and Energy Effects on the U.S. Demand for Bicycles

PETER M. KERR

The role played by demographics as well as the energy crisis in the resurgence of the demand for bicycles in the United States over the last 20 years is investigated. Although there have been several studies in this area, none presents an econometric estimation of demand. This study fills that void. The results are surprising. Demographics, and in particular the Baby Boom, have had no significant effect, whereas the energy crisis has. Less surprising is the conclusion that the resurgence of bicycle use in the early 1970s resulted from faddish preferences on the part of consumers. Some key elasticities are own price, –2.70; income, 2.77; price of gasoline, .51. For example, a 1 percent increase in the price of bicycles results in a 2.7 percent decline in their sales.

For the bicycle industry, the last 20 years have marked a resurgence of the Gay Nineties because sales per capita have exceeded the previous 1897 high in every year since 1965. According to a recent survey, the Bicycle Federation has estimated that in 1984 more than 75 million Americans rode bicycles and 1.6 million commuted by bicycle *(1)*. Periodic surveys by the National Park Service since 1960 indicate substantial increases in recreational cycling by those 12 years and over. Although there have been several studies in this area, none present an econometric estimation of demand. The current study attempts to fill this void.

Written in the midst, or at the close, of the bicycle boom of the early 1970s, the previous studies had insufficient data for econometric tests. Issues that were raised then, and since, can now be more fully evaluated. Bicycle sales seem to have taken off just when the baby boomers were coming of age; is there a significant relationship here? Did the energy crisis have any effect on bicycle sales? To what extent has the resurgence simply been a fad?

DETERMINANTS OF DEMAND

Bicycle sales for the sample period are plotted in Figure 1. The most distinguishing feature is the peak during 1972, 1973, and 1974. Earlier studies by Floyd *(2)*, Everett *(3)*, and Hirst *(4)* identified four factors that may explain the growth in bicycle sales: *(a)* the energy crisis, *(b)* greater interest in physical fitness and outdoor life, *(c)* refinement of the lightweight bicycle, and *(d)* environmental concerns. As suggested earlier, demographics may play an important role. The variables considered in this research are as follows:

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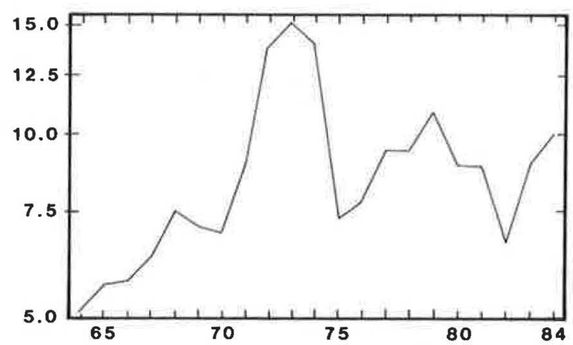


FIGURE 1 Annual bicycle sales (millions of units), 1964–1984.

SALES = total bicycle sales in the U.S. market. This figure is calculated by subtracting exports from the sum of domestic industry shipments and imports. The industry defines its product as bicycles with a wheel diameter of no less than 20 in. (Schwinn Sales, Inc., unpublished data).

STOCK = household stock of bicycles. Based on the Bicycle Manufacturers Association estimated average life span of 7 years for a bicycle, this figure is the sum of total bicycle sales for the previous 7 years.

LGWT = ratio of total lightweight sales (bicycles with wheels more than 20 in. in diameter) to total bicycle sales (Bicycle Manufacturers Association, unpublished data).

AYT = American Youth Hostels membership (American Youth Hostels, Inc., unpublished data).

BBP = total population of those aged 7 through 19. This group includes the ages of baby boomers during the boom years of bicycles sales (1972–1974). The baby boomers in this case represent both men and women who were born in those years when the number of births exceeded 4 million annually (1954 through 1964). This definition is suggested by the Population Reference Bureau for measuring the societal impact of the Baby Boom. The actual population figures are from the Bureau of Census.

MAGP = total population of those aged 7 through 44. The lower limit of this group is determined by the youngest age for which a 20-in. bicycle is recommended; the upper limit is determined by the oldest age to represent at least 10 percent of the subscribers to *Bicycling* magazine.

MAXP = total population of those aged 25 through 34. This group represents the largest 10-year cohort subscribing to *Bicycling*, which consistently makes up more than 30 percent of all subscribers.

CPIW = consumer price index (CPI) for urban wage earners and clerical workers, all items, annual average (1967 = 100). This variable is typically denoted *CPI-W* in data sources (Bureau of Labor Statistics, unpublished data).

CPIB = bicycle component of *CPI-W* (1967 = 100). Available only since 1964, this is the variable that limits the sample size.

CPIG = gasoline component of *CPI-W* (1967 = 100). This index includes both regular and premium grades.

CPIPRT = private transportation component of *CPI-W* (1967 = 100). This index includes new automobiles, used automobiles, regular and premium gasoline, premium motor oil, new tubeless tires, automobile repairs and maintenance, automobile insurance rates, automobile registration, and private and municipal parking fees.

CPIPUT = public transportation component of *CPI-W* (1967 = 100). This index includes local transit fares, taxicab fares, coach railroad fares, airplane fares (chiefly coach), and intercity bus fares.

CPIT = transportation component of *CPI-W* (1967 = 100). This index is the weighted average of the public and the private transportation components.

D1 = dummy variable that equals 1 for 1972 and 1973, zero otherwise. This variable attempts to measure a fad factor by singling out those years when sales were historically high and growing.

D2 = dummy variable that equals 1 for 1972 through 1974, zero otherwise. This variable more broadly defines the fad factor of *D1* by adding 1974. In this year, sales nearly matched the previous year and then dropped by almost half in the following year.

DG1 = dummy variable that equals 1 for 1973, 1974, 1979, and 1980; zero otherwise. This variable represents a substitute for the price of gasoline and attempts to capture the asymmetrical shock effect of the dramatic increases in the price of gasoline that occurred in those years.

DG2 = dummy variable that equals 1 for 1974 and 1979, zero otherwise. This variable more narrowly defines the shock effect for the increases in the price of gasoline.

NOMY = disposable personal income (Bureau of Economic Analysis, unpublished data).

HRS = average weekly hours per worker on private nonagricultural payrolls (Bureau of Labor Statistics, unpublished data).

Would the bulge in the population snake, that is, the Baby Boom, be a factor in the increased bicycle sales? Depending on the objective, the Baby Boom may be identified in a number of ways. With respect to measuring the societal impact, the Population Reference Bureau suggests consideration of the number of births. Bouvier (*5*, p. 7) concludes: "In looking at the number of births, then, one could say that the baby boom period was concentrated from 1954 through 1964 when over 4 million births occurred each year." Did the baby boomers come of age at the same time that the bicycle industry experienced its greatest sales, in the period from 1972 to 1974? During this time the baby boomers ranged in age from 7 to 19. Interestingly enough, the bicycle industry confines its product to those bicycles having wheels with a diameter of at least 20 in. Normally, this would exclude youngsters less than 7 years old from the market. In the preceding list, the variable *BBP* measures the size of the population in the Baby Boom age group that coincides with the bicycle boom.

Substitute demographic variables for *BBP* are also included in the preceding list. These variables are based on survey data obtained from *Bicycling* for 1978, 1980, and 1982. This magazine has long been recognized as the dominant popular publication. The variable *MAGP* broadens *BBP* to include older age groups that have a demonstrated interest in bicycling. In this instance, the ages range from 7 to 44. The upper limit is determined by the oldest age group to represent at least 10 percent of the subscribers to *Bicycling*. On the other hand, the variable *MAXP* narrows the age range to 25 through 34, the largest 10-year cohort subscribing to *Bicycling*.

Although the energy crisis may be measured in several ways, the most appropriate measure with respect to bicycles may be the price of gasoline. Everett (*3*, p. 598) points out that "car owners tend to compare only the variable (operating) cost of driving the car to the cost of riding a bicycle." In Figure 2 both the actual and the adjusted gasoline components of the CPI for urban wage earners and clerical workers (*CPI-W* or *CPIW*) are plotted. These are *CPIG* and *PGAS* (*CPIG* as a percentage of *CPI-W*), respectively. Comparison with Figure 1 shows that the peak years in bicycle sales frequently coincide with large jumps in the price of gasoline. The preceding list gives other substitute energy variables, which include the transportation, private transportation, and public transportation components of *CPI-W*.

Studies by Floyd (*2*), Hirst (*4*), Everett (*3*), and Parker (*6*) suggest a weak relationship between the energy crisis and bicycle sales. Consequently, a direct relationship between an energy-related price and bicycle demand may be difficult to discern. Nevertheless, the coincidental increases in bicycle sales and the price of gasoline are hard to ignore.

A noncontinuous relationship may exist in the sense that changes in the price of gasoline must pierce a relatively high (or low) threshold to have an effect on the demand for bicycles. Ordinarily bicycle sales may be insensitive to changes in the price of gasoline. Nevertheless, a huge and sudden increase in the price of gasoline might spur increased use of and demand for bicycles as consumers overreact to the price hike. Such an overreaction was illustrated by the enormous premiums that many consumers were willing to pay on the few fuel-efficient cars that were available during the early energy crisis. Whether consumers would act in the opposite way with a sudden downturn in the price of gasoline is less certain; the relationship may be asymmetric.

Evidence from the Annual Housing Survey conducted by the Bureau of the Census suggests that there was an increase in bicycle commute activity in the proximity of gasoline price increases. The available survey results are as follows (*7*, p. 4):

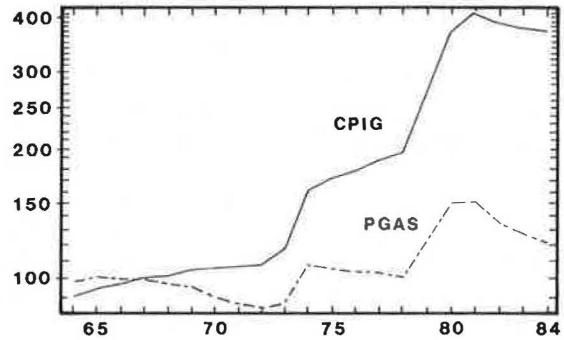
Year	*Percentage of Households Using Bicycle or Motorcycle for Journey to Work*
1974	1.1
1975	0.8
1976	0.8
1977	0.5
1978	0.6
1979	1.3

Although it may be tempting to argue that these figures are dominated by motorcycle use, such is not the case. The 1979 figure of 1.3 percent may be broken down into the 0.6 percent of all households that commuted by bicycle and the 0.7 percent that used motorcycles (*7*, p. 2). Though not directly comparable, in 1975 0.6 percent of all workers commuted by bicycle whereas 0.4 percent used motorcycles (*8*, p. 4).

Consideration of these figures hints at the shock effect of sudden and large surges in the price of gasoline. In 1974 and 1979 when the use ratio was greater than 1 percent, there had been dramatic increases in the price of gasoline. During the first 3 months of 1974, the price of gasoline increased at a compounded annual rate of 109.6 percent. An increase of 109.7 percent was registered from the end of March to the end of June in 1979. Occurring just before and during the buying season for bicycles, these jumps are likely to have significantly affected the demand for bicycles. In an attempt to account for this shock effect the dummy variable *DG2* is created, which is equal to 1 for 1974 and 1979 and zero for all other years. Reconsideration of Figures 1 and 2 suggests that this shock effect could be broadened to include 1973 and 1980; this is done with dummy variable *DG1*.

Although the preceding discussion focuses on the bicycle's use for commuting, it should not be forgotten that the bicycle is primarily a vehicle for recreational exercise. Floyd suggested two major factors for the bicycle boom in the early 1970s (*2*, pp. 140–141):

> What factors accounted for this tremendous increase in bicycle sales? Primarily the growing interest in physical fitness and outdoor life coincided with the refinement of the lightweight bicycle to result in a rediscovery of the bicycle by the adult and young adult population. The bicycle became not only socially acceptable but even fashionable (some would say faddish).



NOTE: ADJUSTED PRICE INDEX IS THE ACTUAL PRICE INDEX EXPRESSED AS A PERCENTAGE OF CPI-W.

FIGURE 2 Gasoline components of *CPI-W*: actual (*CPIG*) and adjusted (*PGAS*), annual averages, 1964–1984.

Although growing bicycle sales themselves could be used as a measure of greater interest in physical fitness and outdoor life, the best available independent measure of this heightened interest may be the membership of the American Youth Hostels, Inc. (AYH). Founded 50 years ago to provide inexpensive overnight accommodations for young hikers, AYH has progressed into organized activities for virtually every outdoor activity that does not involve athletic competition, including, but not limited to, hiking, backpacking, camping, bicycling, canoeing, and ice skating. The variable *AYT* listed earlier represents the total membership of AYH. Although it purports to measure an increased interest in fitness and outdoor life, as a membership figure it may also reflect the age distribution of the population. This raises the specter of multicollinearity should *AYT* be considered together with any of the demographic variables discussed earlier.

In his study Floyd considered the composition of bicycle sales as an indicator of growing adult interest. By industry definition, lightweight bicycles are essentially those with wheel diameters of 26 or 27 ins. Consequently, lightweight bicycles are the adult-size bicycles and the ratio of lightweight sales to total sales should directly reflect adult interest in bicycling. This ratio is designated *LGWT*.

Floyd's allusion to the refinement of the lightweight bicycle is the substitution of 10-speed bicycles for the less sophisticated 1-, 3-, and 5-speed bicycles. The boom of the 1970s may have reflected more a refinement in consumer tastes than in the bicycle itself. Popularly priced 10-speeds had been available long before the boom; for instance, Schwinn, a Chicago-based manufacturer, had offered a range of 10-speed models at least as early as 1965. Although a complete time series on 10-speeds is not available, they have made up the lion's share of lightweight sales. Therefore, the sales figures for lightweight bicycles may capture the effects of both a growing adult interest and the refinement of the bicycle.

Floyd also mentions the possibility that the bicycle boom was the result of a fad. The extraordinarily high sales in the period from 1972 to 1974 may simply reflect a dramatic overshift in consumer preferences for bicycles. Two dummy variables are established to take into account or negate the effect of the fad on the other, presumably more permanent relationships. In 1972 and 1973, bicycle sales were both historically high and growing. The dummy variable *D1* is equal to 1 for both of these years and zero for all other years. Although sales had declined from the previous year, they were still at a historically high level in 1974. The dummy variable *D2* broadens *D1* by including 1974 as a fad year. Coincidently, these variables, especially *D2*, may also negate any effect that the wage-price controls of the early 1970s may have had.

To continue with the notion that the bicycle serves in recreation, a boom in sales may reflect an increase in leisure time. To determine this effect, the average weekly hours per worker on private nonagricultural payrolls is considered as an inverse proxy for leisure. This variable is denoted as *HRS*.

A final determinant mentioned in earlier work is an increase in environmental concerns. If the advances over the control of noise and air pollution by environmental groups and agencies reflect the will of the public, it seems quite plausible that nonpolluting alternatives to recreation and transportation would experience increased interest and sales. Unfortunately, selection of a workable variable to quantify this factor has not been possible.

A final determinant is the household stock of bicycles (*STOCK*). Based on the industry estimated life span of 7 years, the stock variable is the sum of the total bicycle sales from the previous 7 years. This linear combination of the previous values of the dependent variable would lend a dynamic aspect to an otherwise static model. With such a lengthy life span, the bicycle should be considered a durable good and the stock variable should be inversely related to current sales.

ECONOMETRIC ESTIMATION TECHNIQUES

Econometric estimation can take two basic forms: single-equation estimation or simultaneous-equation estimation. The latter is theoretically preferred and among the various approaches, conditional demand analysis is particularly attractive.

Simultaneous-Equation Estimation

Although preferred, there are a number of factors that mitigate against the use of conditional demand analysis in the current study. This procedure relies solely on own price, income, and the prices of related goods for its explanatory variables and is better suited for groups of goods for which the relationships are nonchanging, such as basic commodities. In the case of bicycles as well as many other goods, sufficient information on the prices and sales of related goods is simply not available.

An additional shortcoming of the conditional demand analysis is its failure to recognize demographic factors. Ketkar and Cho concluded that (*9*, p. 16) "demographic characteristics of households are as important determinants of their expenditures as are price and income variables." Considering the previous section, age is a demographic factor that is likely to play a critical role in the demand for bicycles.

For the aforementioned reasons, conditional demand analysis is not used in this study. Reliance must be placed on the more conventional demand estimation techniques.

Single-Equation Estimation

Economic theory imposes several restrictions on any system of demand equations. Two that must be dealt with in single-equation estimation are homogeneity of degree zero and Slutsky negativity. A demand equation is homogeneous of degree zero if, when all prices and income are multiplied by the same factor, the quantity demanded does not change. Slutsky negativity merely refers to the fact that a good's own price effect is negative.

The most straightforward way to accomplish homogeneity of degree zero is to adjust all prices and income by dividing them by the index of consumer prices. More generally, real prices and income are considered instead of nominal prices and income. However, this adjustment can make it difficult to monitor Slutsky negativity. The double-logarithmic specification is the easiest way to accomplish both objectives.

The double-logarithmic form that would ensure homogeneity of degree zero is

$$\ln SALES = \alpha_0 + \alpha_1 \ln(CPIB/CPIW) + \alpha_2 \ln(NOMY/CPIW) \quad (1)$$

where

$SALES$ = bicycle sales,
$CPIW$ = CPI for urban wage earners and clerical workers (*CPI-W*),
$CPIB$ = bicycle component of *CPI-W*, and
$NOMY$ = disposable personal income.

In this instance, Slutsky negativity cannot be checked. To circumvent this problem, Equation 1 may be written in the following way:

$$\ln SALES = \alpha_0 + \alpha_1 \ln CPIB + \alpha_2 \ln NOMY + (-\alpha_1 - \alpha_2) \ln CPIW \quad (2)$$

Slutsky negativity can now be identified. A potential new problem has arisen in that under estimation Equation 2 has restricted coefficients. Fortunately, the restricted parameters are exactly identified and can be estimated by the following unrestricted model:

$$\ln SALES = \beta_0 + \beta_1 \ln CPIB + \beta_2 \ln NOMY + \beta_3 \ln CPIW \quad (3)$$

This specification would remain exactly identified with the inclusion of additional prices.

An initial estimation of Equation 3 yielded disappointing results. To improve the picture, each of the remaining explanatory variables was substituted in alternate regressions. The fad-factor dummies yielded much better results than any of the other variables, and *D2* did better than *D1*. The results of this second step are given in Table 1.

Given the tremendous jump in bicycle sales during the early 1970s, the significance of *D2* is not surprising. A characteristic of the double-logarithmic specification is that the coefficient of an independent variable is the coefficient of elasticity or, roughly, the percentage change that would occur in the dependent variable given a 1 percent change in the independent

TABLE 1 SINGLE-EQUATION ESTIMATION RESULTS: SECOND-STEP ESTIMATION

Explanatory Variable	Coefficient	*t*-Statistic	Significance of *t*-Test (two-tail)
Constant	17.5533	10.042	.0001
ln*CPIB*	−2.0809	−2.004	.0623
ln*NOMY*	2.1471	5.696	.0001
ln*CPIW*	−1.2625	−1.418	.1753
D2	0.5336	8.009	.0001

NOTE: Dependent variable, ln*SALES*; R^2 = .9382; adjusted R^2 = .9227; F = 60.72; significance of F-test = .0001; Durbin-Watson = 2.396 (reject autoregression at .01).

TABLE 2 SINGLE-EQUATION ESTIMATION RESULTS: THIRD-STEP ESTIMATION

Explanatory Variable	Coefficient	*t*-Statistic	Significance of *t*-Test (two-tail)
Constant	19.3278	10.169	.0001
ln*CPIB*	−2.6966	−2.625	.0191
ln*NOMY*	2.7698	5.648	.0001
ln*CPIW*	−2.3837	−2.305	.0359
D2	0.5383	8.640	.0001
ln*CPIG*	0.5058	1.825	.0880

NOTE: Dependent variable, ln*SALES*; R^2 = .9494; adjusted R^2 = .9326; F = 56.31; significance of F-test = .0001; Durbin-Watson = 2.439 (inconclusive). The t-test on the coefficient of the lagged residual where the concurrent residual is the dependent variable was significant at .2187.

variable. Hence, the constant coefficients of the regression force constant coefficients of elasticity. If elasticities were ever to change, the boom of 1972 through 1974 is the most likely spot. The dummy variable for the fad factor sets this period apart, allowing the more stable long-term relationships to surface. Indeed, an operational definition of a fad might be a situation in which heretofore constant relationships are disrupted. At this point it would seem that more than anything else, the bicycle boom of the 1970s was a fad.

Reinforcing the point of the previous paragraph, Kouris *(10)* has questioned the value of assuming constant elasticities with respect to energy demand. "There are so many factors that exert an influence on energy demand that cannot be quantified; they would inevitably reflect on the elasticities of the remaining variables in the equation" (*10*, p. 68). In a footnote, he explains the first half of this statement (*10*, p. 68):

> The statistical assumptions of the least-squares technique assume that any factors not accounted for explicitly in the explanatory side of the equation will be captured by the error term. This is only partially true because the regressors are to some degree collinear with such excluded factors and therefore capture some of their effect. Hence the size of the computed elasticities does not depend exclusively on the fluctuations of the explanatory variables but also on the degree of correlation between regressors and omitted factors.

Like the second step, a third step once again considered the remaining variables in alternate regressions. Both *DG1* and *CPIG* led the others in improving the results. With respect to the coefficient of determination and the significance of the t-test, *DG1* outperformed *CPIG* by only the narrowest of margins and it was not enough to choose the dummy over a genuine measure. The results of this third step are reported in Table 2. This estimation represents the final estimation, because a fourth step failed to produce any additional variables with a significance level less than 40 percent.

The equation indicates that the demand for bicycles is relatively sensitive to changes in either the price of bicycles or consumer incomes or, in other words, the demand for bicycles is both price and income elastic. For instance, the price coefficient indicates that if the price of bicycles increases by 1 percent, the demand for bicycles will decline by approximately 2.7 percent. Should income rise by 1 percent, sales would increase by nearly 2.8 percent. This relatively high coefficient for income elasticity places bicycles in the category of a luxury good. These results from the United States provide an interesting comparison with the findings from a less industrialized country, India. In the only other econometric study on bicycles to be found, Siddharthan's *(11)* model suggests that the Indian demand for bicycles is price inelastic and that the bicycle is a necessity. These results confirm what ordinarily might be expected. In India the bicycle may be the only form of personal transportation that many households can afford, whereas in the United States the bicycle appears to be largely a recreational item.

The remaining coefficients are also as expected. The cross-price elasticity of the price of gasoline is positive and small, which indicates that bicycles are a weak substitute for motorized transportation. Furthermore, the fad dummy is directly related to bicycle sales.

Recalling that this equation represents the exactly identified and unrestricted form of the original specification clouds the interpretation of the coefficient of *CPI-W*. Nevertheless, if the bicycle is a luxury good, the sign of the coefficient would be expected. A general increase in prices would stimulate households to target initial spending cuts at luxury goods.

CONCLUSIONS

Although a system approach was not possible in this study, the tenets of the conditional demand analysis are supported inasmuch as income and prices provide much of the explanation for the resurgence in bicycle sales over the last two decades. The only variable other than prices and income to be included in the final regression was a dummy variable that presumably accounted for the disruption of normal relationships as the result of a fad or, perhaps, wage-price controls.

These results may stem, in part, from explanatory variables that were poor proxies for the characteristics that they purported to measure. Indeed, an appropriate measure for one determinant, the growing concern for the environment, was not found. However, using this excuse in the case of the demographic variables is difficult. The Baby Boom seems not to have had an effect on bicycle sales.

Although the energy crisis does have a measurable effect on the demand for bicycles, the results of this study indicate that the bicycle continues to serve primarily as a recreational good in the United States. This supports the conclusions of earlier studies, which were based, necessarily, on less data.

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Abridgment

A Community Campaign That Increased Helmet Use Among Bicyclists

STEVEN P. BERCHEM

A community campaign was conducted to increase the use of helmets among bicyclists in Madison, Wisconsin. Helmets were promoted through the mass media by means of news releases, public service announcements, and advertising. Brochures and posters were distributed through schools, bicycle dealers, health and fitness centers, and other outlets to supplement interpersonal communication channels. Helmet prices were reduced, and rebates and prizes were provided as incentives to purchase and wear helmets. About one-half of the bicyclists interviewed in a random-sample survey after the campaign recalled exposure to helmet-related messages. The sales of helmets increased nearly 100 percent. Field counts showed that helmet use increased significantly from 15.0 percent before the campaign to 19.2 percent after.

The increased popularity of bicycling has been accompanied by an increase in bicycle accidents, injuries, and fatalities *(1)*. Head injuries are perhaps the most serious consequence of bicycle accidents. Head injuries are responsible for 75 percent of all bicycle-related fatalities not involving motor vehicles *(2)*. In bicycle-related fatalities involving motor vehicles, 86 percent of the fatally injured bicyclists received their most serious injury in the head or neck region *(3)*.

A coalition of Madison health care providers, bicycle organizations, and city and state government agencies conducted a bicycle helmet promotion campaign in May 1986. The two campaign objectives were to reach a significant proportion of Madison bicyclists and to achieve a significant increase in the use of helmets among them.

METHODS

Preparation

There is little basis for an estimate of the number of Madison bicyclists. However, because there are about 150,000 bicycles *(4)* in a city of 170,000 *(5)*, it was assumed that all but the very young, the very old, and the disabled bicycle. Local bicycle accident data suggest that those who bicycle most are young adults *(6)*.

To better define the campaign audience, local bicycle dealers and leaders of local bicycle organizations were consulted. They suggested that most Madison bicyclists probably thought about purchasing a helmet, but decided, in most cases, that one was not necessary. Among those bicyclists who thought that they might need a helmet but decided not to buy one, the local experts suggested that there were economic, fashion, or comfort constraints that precluded purchase. It was believed that there were relatively few bicyclists who had not thought about getting a helmet, and fewer still who had some idiosyncratic reason for not owning one.

The audience analysis suggested that the campaign try to convince bicyclists who think that they do not need a helmet that they do need such protection. It also suggested addressing the perceived economic constraint by either reducing the cost of helmets or persuading bicyclists that helmets are worth the monetary outlay, or both. The analysis further indicated that the campaign should present a positive fashion image for helmets and minimize the perception that helmets are uncomfortable.

A survey was conducted before the campaign to learn more about Madison bicyclists, to find out why some wear helmets and most do not, and to discern whether there were any demographic or other differences between those who wear helmets and those who do not. A local market research firm conducted telephone interviews with approximately 300 adult bicyclists. The sample was randomly selected from residential telephone numbers listed in the Madison-area telephone directory. Respondents were alternately screened for men and women bicyclists. The interviews were conducted with the adult in the household who bicycled the most, but at least once in 1985. The survey was conducted April 4–14, 1986. Selected results are analyzed in the Results section.

Implementation

The campaign incorporated mass and interpersonal communications and incentives with the major thrust channeled through mass media. The design emphasized maximizing audience exposure to campaign messages intended to persuade bicyclists to buy and wear helmets.

A bicycle helmet theme was established for Madison Bike Month (May). The theme served as the primary campaign message—a front-runner that allowed arguments for wearing helmets to follow.

It was decided that the theme need not specifically express the need for helmets or address the arguments against them. It was thought more important to have a positive, creative theme to gain audience attention, and then, once that attention was gained, to follow with arguments for wearing a helmet and counterarguments to the reasons for not wearing one.

The theme selected was Be a Well-Dressed Cyclist—Wear a Helmet. It was accompanied by materials showing bicyclists in

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formal attire and, of course, helmets. The seeming incongruity of formal wear, bicycles, and helmets was deemed likely to attract media and public attention. In addition, the tuxedo-helmet combination suggested that no matter how one is dressed or how one bicycles, a helmet is standard bicycling equipment.

The theme was followed with information on why helmets should be considered standard equipment and why cost, minor discomfort, and appearance should be of little concern. Whenever possible, the need for helmets was illustrated by accident data. The argument that helmets were too costly was countered with a reminder that they are low-cost insurance against pain, inconvenience, medical expenses, and loss of one's life. It was also mentioned that the cost of helmets represented little expense to ensure the security of loved ones. In addition, it was noted that there are many new kinds of helmets available and that the latest technology has made them cooler, more comfortable, and, for the fashion-conscious, more stylish.

These messages were emphasized in media contacts, particularly in interviews. They were also provided to interpersonal interaction leaders for their use in discussing helmets with bicyclists.

Madison's mayor launched the campaign at a May 1 news conference. The Wisconsin Department of Transportation Office for Highway Safety released two television public service announcements, one targeted at young adults, the other targeted at parents. The helmet campaign theme was included in a Madison Bike Month news release, in a bicycle column in the local cultural weekly, and in feature articles published in organizational newsletters. Some bicycle dealers advertised helmets during May. Helmet use was discussed during radio and television talk shows. Bicycle clubs made presentations on helmets before their rides.

The state Office for Highway Safety also published a brochure on bicycle helmets, using the campaign theme. The front cover illustration, a cartoon sketch of a helmeted couple in formal wear riding a tandem, and the theme were used for a poster distributed with the brochure. The posters and brochures were distributed by bicycle dealers, health care providers, police departments, and school officials.

A local bicycle touring club conducted a rebate program providing a $5 reimbursement to the first 100 persons who submitted proof of helmet purchase during the campaign. Another bicycle organization gave merchant-donated gift certificates to bicyclists who sent in pledges that they always wear a helmet when riding. Bicycle dealers offered special discounts on helmets.

RESULTS

Precampaign Survey

The precampaign survey sampled 305 bicyclists, 153 of whom were men and 152 women. Their ages ranged from 18 to 78 years, with the median at 28 years.

Although 19 percent of the respondents reported owning a helmet, only 12 percent said that they usually wore it. Of those who did not own helmets, 32 percent said that they never thought about it and 35 percent said that they did not need one. Only 10 percent said that helmets were too expensive, whereas 13 percent said that they were too hot. About 5 percent said that helmets were unattractive and less than 5 percent offered other reasons.

Although the local bicycle experts correctly identified the reasons that bicyclists cite for not wearing helmets, they underestimated the lack of awareness and greatly overestimated the significance of cost, comfort, and fashion. More than two-thirds of the respondents needed to be made aware of the need for helmets.

Bicyclists with higher education were significantly more likely to report that they wore helmets, but there was no significant association between helmet use and income or employment classification. The results also indicated that men and those who bike year-round are significantly more likely to wear helmets.

The respondents were also asked where they were most likely to obtain bicycling safety information. Newspapers were cited by 35 percent of the bicyclists; 18 percent said that television was their most likely source. Magazines were cited by 13 percent and bike shops by 12 percent. Radio and friends were each considered most likely sources by 7 percent; the remaining 7 percent noted other sources.

Postcampaign Survey

To estimate the level of exposure and awareness generated by the campaign, a telephone survey of bicyclists was conducted June 10–12. The precampaign sampling method was used again. The respondents were asked whether they recalled having read, seen, or heard anything about bicycle helmets in the previous 6 weeks. Those who had were asked to describe what they recalled.

Of the 68 respondents, 32 (47 percent) recalled reading, seeing, or hearing something about bicycle helmets in the previous 6 weeks. Of the 32, more than one-third remembered seeing something in a newspaper. About one-fifth cited an unspecified advertisement and one-fifth recalled seeing one of the television public service announcements produced for the campaign. Bike shops, word of mouth, and a brochure brought home from school by respondents' children were each mentioned more than once.

These results are very similar to the responses to the precampaign survey question about where bicyclists were most likely to obtain bicycling safety information: newspapers and television figure strongly in both surveys.

Bicycle Dealers

The 10 bicycle dealers who agreed to participate in the campaign were interviewed July 1–7. One dealer reported no change in helmet sales, whereas six estimated that sales increased 15 percent to 200 percent over their sales in May 1985. Three would not provide an estimate. The mean increase in sales among the six dealers who provided estimates was 92 percent.

Field Observations

To determine whether the campaign had an effect on behavior, pre- and postcampaign field observations were conducted. The observations involved counting the number of bicyclists who passed through four intersections and the number of those who were wearing helmets.

The precampaign field observations were conducted April 22–29. Of the 1,297 bicyclists observed, 194 (15.0 percent) were wearing helmets. The postcampaign field observations were conducted June 2–16. Of the 1,341 bicyclists observed, 247 (19.2 percent) were wearing helmets. The increase of 4.2 percent from the precampaign to the postcampaign observations is statistically significant.

DISCUSSION

The variety of quantitative and qualitative measures taken to evaluate this campaign indicates that the campaign was a success, and the sum of them makes that conclusion more certain. Without a doubt, the campaign objectives were attained: a significant proportion of Madison bicyclists was reached and there was a significant increase in the use of helmets among Madison bicyclists. The 4-week campaign reached perhaps 50,000 bicyclists and prompted roughly 5,000 to start wearing helmets.

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Note: Unabridged copies of this report are available from the Madison Department of Transportation, 215 Monona Avenue, Madison, Wis. 53710.

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