HIGHWAY RESEARCH RECORD

Number 406

Pedestrian Protection

5 reports
prepared for the
51st Annual Meeting

Subject Areas

51 Highway Safety
52 Road User Characteristics

HIGHWAY RESEARCH BOARD
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FOREWORD

Pedestrian research may be on its way to coming of age. A session devoted exclusively to the subject was presented for the first time at the 51st Annual Meeting of the Highway Research Board.

In this RECORD we have papers on the pedestrian and crosswalk effectiveness, walking trip length, accident causes and possible cures, rights to urban space, and vehicle-free zones.

Marked crosswalks have been assumed to prevent accidents to their users. Herms, using data covering a 5-year period for the simple situation of accidents at marked and unmarked crosswalks, found the unmarked superior. He believes that this may be due to the pedestrian's attitude and lack of caution when using the marked crosswalks.

How far do people walk? Maring satisfied his curiosity on the subject by conducting a survey of walkers in a largely high socioeconomic level apartment dwelling section of Washington, D. C. A tendency was found for people to take walking trips of about one-third of a mile.

It is a truism that anything that can cause an accident will. In practice, however, we need to concentrate on those factors that most frequently cause accidents. Snyder, after studying many pedestrian accidents, found that half of them could be classified into five frequent types. Based on a logical analysis, he has suggested possible solutions.

Fruin has highlighted the tendency for machine transportation to isolate the pedestrian on an "ever-narrowing sidewalk enclave." He believes there is a need to give the pedestrian a greater right to urban space.

The merits of physical separation of motor vehicles and pedestrians are discussed by Orski. Besides safety there can be benefits from the standpoint of a purer environment.

All in all, these papers take up the cause of the "second-class citizen"—the pedestrian—and rather objectively provide data and/or schemes for giving him a better deal in the walker-motor vehicle system.

—Robert B. Sleight

PEDESTRIAN CROSSWALK STUDY: ACCIDENTS IN PAINTED AND UNPAINTED CROSSWALKS

Bruce F. Herms, Traffic Engineering Section, City of San Diego

This is a report of a study of pedestrian accident experience at unsignalized intersections and whether it is less in marked or unmarked crosswalks. Accident experience covering a 5-year period was studied at 400 intersections, each having one marked and one unmarked crosswalk crossing the main thoroughfare. In addition, pedestrian and vehicle traffic characteristics were studied to determine the pedestrian's relative use of marked and unmarked crosswalks and his exposure to vehicular traffic. The results show that during the 5-year period 177 pedestrians were hit in the 400 marked crosswalks compared with 31 pedestrians hit in the 400 corresponding unmarked crosswalks. This included 18 fatalities in the marked crosswalks versus 3 fatalities in the unmarked crosswalks. In general, the study showed that, in terms of the number of pedestrians using the crosswalks, approximately twice as many pedestrian accidents occur in marked crosswalks as in unmarked crosswalks. Evidence indicates that the poor accident record of marked crosswalks is not due to the crosswalk being marked as much as it is a reflection on the pedestrian's attitude and lack of caution when using the marked crosswalk. Recommendations include a pedestrian education program and limiting crosswalks to only those locations where warranted.

•PAINTED or marked pedestrian crosswalks (the terms "painted" and "marked" are used interchangeably in this report when referring to crosswalks) are one of the most commonly used pedestrian traffic control devices. Yet, little research has been conducted to evaluate their effectiveness as a "safety" device. An obvious approach toward checking this effectiveness would be to compare the accident experience of a marked crosswalk with that of an unmarked crosswalk.

One of the difficulties encountered when conducting a comparison study is the problem of maintaining equivalent conditions. If one intersection is compared with another, it is likely that a multitude of unrelated variables will enter the picture: differences in volume, turning movements, orientation, and environment, to name a few. If the same intersection is compared with itself on a before-and-after basis, it is possible that other undetectable variables may occur with respect to time: shifting traffic patterns, unrelated weather conditions, and seasonal differences.

PHASE I

Phase I of this study attempted to keep the variables to a minimum by adopting the following criteria:

1. Use of a single time period;
2. Use of only those intersections that have one painted crosswalk and one unpainted crosswalk, both crossing the same main thoroughfare (Figs. 1-4)—this means that, for all practical purposes, the vehicular traffic crossing each painted crosswalk would be nearly the same as the traffic crossing the corresponding unpainted crosswalk;
3. Use of only those crosswalks crossing the major flow of traffic—crosswalks on minor legs were not considered;
4. Use of only unsignalized intersections;

Figure 1. Aerial view of First Avenue at Juniper Street, a typical 4-leg perpendicular intersection having one marked and one unmarked crosswalk across the main thoroughfare. Minor streets are controlled by stop signs and stop bars. ADT on the main street is approximately 5,800 vehicles per day; total pedestrian volume crossing the main street is about 1,100 persons per day.

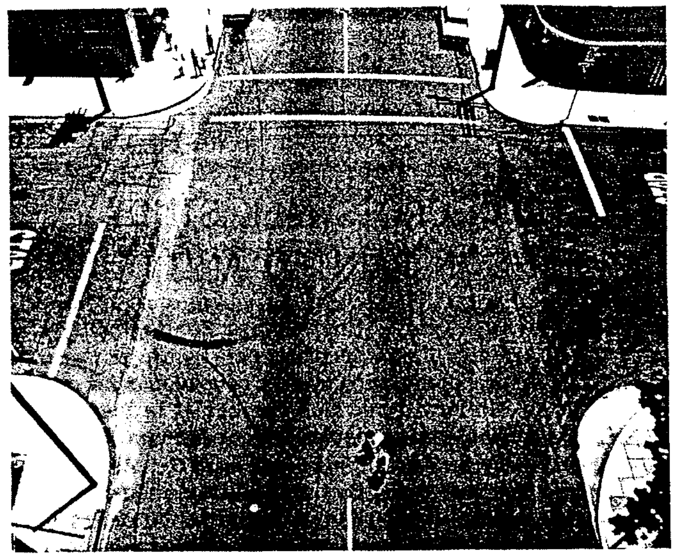


Figure 2. Motorist's view of marked crosswalk at First Avenue and Juniper Street from about 100 ft away.

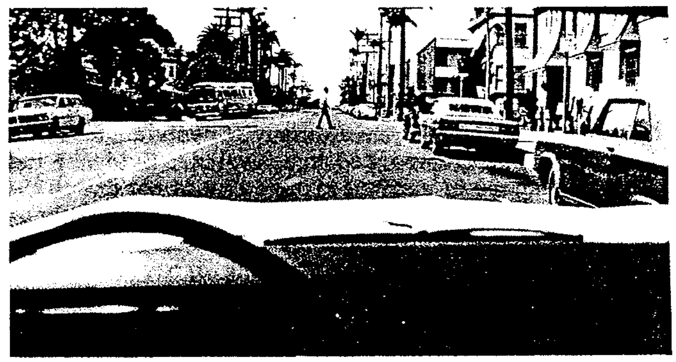
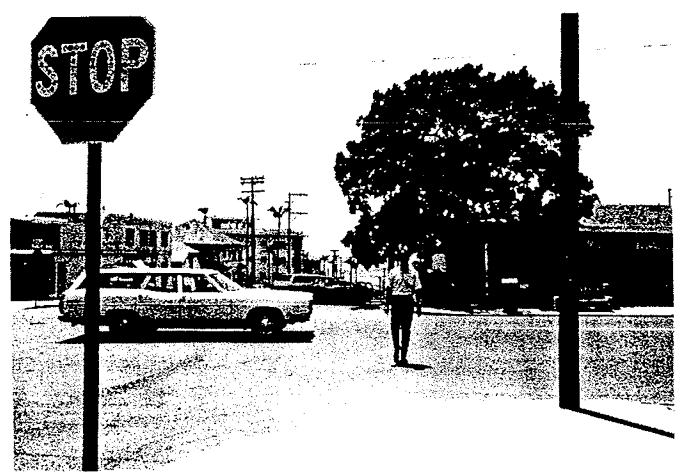


Figure 3. Pedestrian's view of marked crosswalk at First Avenue and Juniper Street; approximately 780 pedestrians use this crosswalk each day. Crosswalk is delineated by means of plastic material.

Figure 4. Pedestrian's view of unmarked crosswalk at First Avenue and Juniper Street; approximately 320 pedestrians use this crosswalk each day.



5. Exclusion of school crosswalks because the nighttime visibility characteristics of the yellow paint might affect the study results;
6. Exclusion of midblock crosswalks; and
7. Exclusion of any intersection having unusual flow patterns, sight distance problems, or unusual geometrics that could affect the results (Tee intersections and offset intersections were included).

To further minimize the effect of chance variables, it was decided to obtain as large a sample as possible and extend the observations over as long a period as practical. Therefore, a 5-year observation period was established, and a total of 400 intersections were found that met the necessary criteria (Fig. 5).

In tallying the pedestrian accidents during the study period, several other guidelines were adopted to ensure consistency.

1. In the painted crosswalk, only those pedestrian accidents occurring within the confines of the crosswalk were counted.
2. In the unpainted crosswalk, where it might be difficult for the reporting officer to determine the crosswalk limits, it was decided to count all pedestrian accidents within an arbitrary 20-ft zone to make certain that no borderline pedestrian accident was overlooked. (This in effect amounted to overcounting the pedestrian accidents at the unpainted crosswalk.)
3. No bicycle accidents were counted as pedestrian accidents.
4. Only valid pedestrian accidents were counted. If, for example, a person were struck while directing traffic, it would not be counted as a typical pedestrian accident.
5. In those accidents involving more than one pedestrian, the age of the eldest pedestrian was used for age tally purposes.

PHASE II

It is recognized that an accident study of painted and unpainted crosswalks at the same intersection would be of questionable value unless it could be related to the amount of pedestrian use. In other words, if no pedestrians use a certain route, one would hardly expect any pedestrian accidents to occur there.

To clarify this matter, it obviously would be desirable to have pedestrian counts at each crosswalk to correspond with the accident history. Comprehensive pedestrian volume counts are difficult and expensive to obtain. In the initial study (Phase I), a compromise procedure was adopted whereby 4-hour manual counts were obtained at 40 of the 400 intersections. These counts covered the period from 2 to 6 p.m. (7).

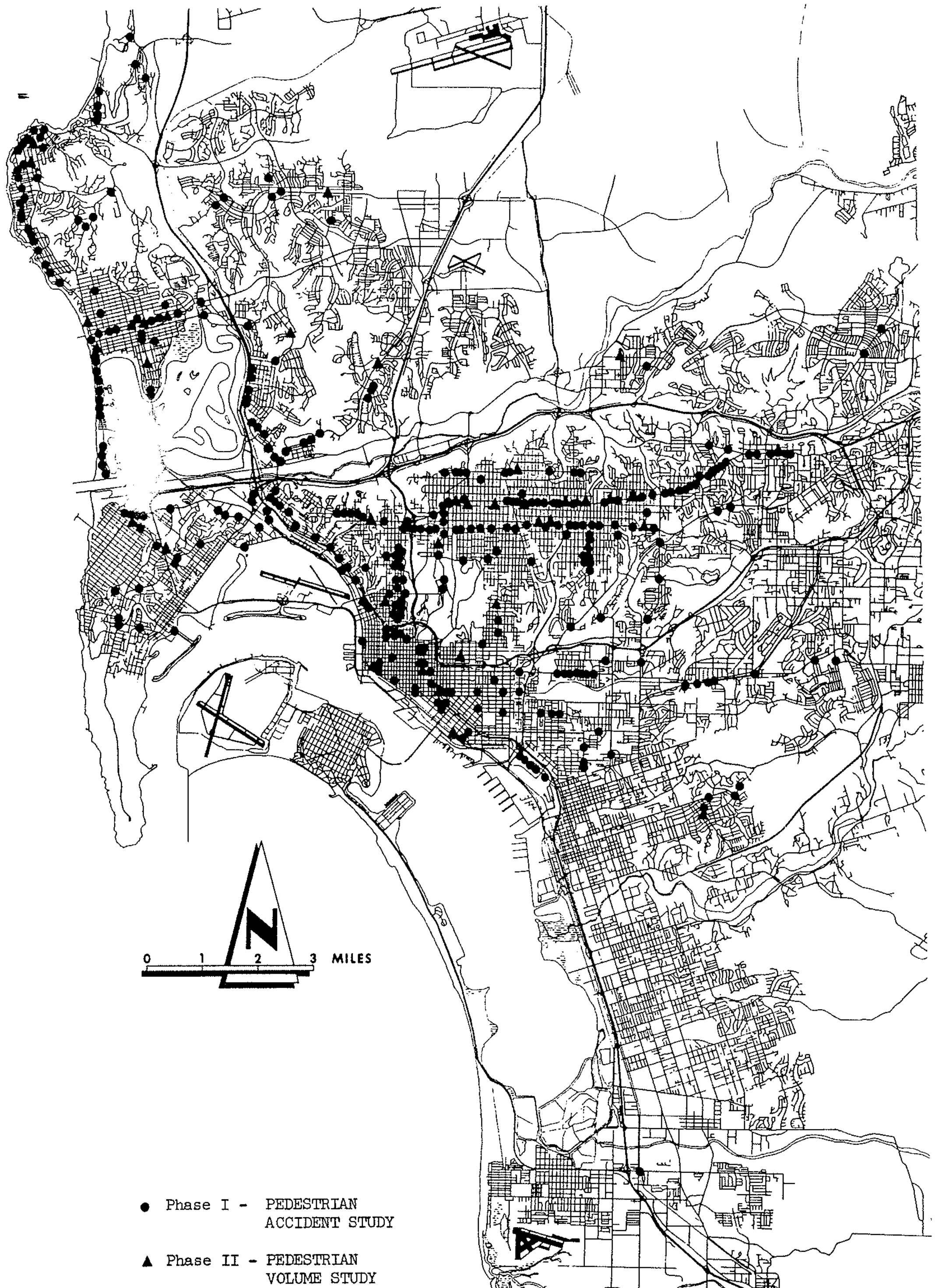
Because these counts covered such a short period of the day, it was felt that the data were not necessarily indicative of the overall daily pedestrian traffic. Fortunately, under provisions of the Federal Highway Safety Act of 1966 and with the assistance of the California State Office of Traffic Safety, the City received a grant to make it possible to gather additional pedestrian volume data based on 24-hour counts (Phase II).

Several possibilities for conducting this study were explored, including the possible use of time-lapse 16-mm cameras. But in view of the amount of data to be tabulated and analyzed, it was decided that conventional manual counting techniques performed by part-time student engineers would be the most efficient and economical method.

Excluding periods when schools are not in regular session, there are approximately 175 weekdays per year that qualify for making counts, assuming satisfactory weather and counting conditions. In terms of available time and personnel, it would take over 2 years to count all 400 intersections. Therefore, it was decided to provide a 10 percent sample by counting 40 intersections, each for 24 hours. This involved about 2 months of counting time. These counts were made during the fall of 1969 (Oct. 10 through Dec. 18, excluding weekends and holidays).

Briefly, the counts were obtained by using a team of men counting from midnight to midnight in eight 3-hour shifts. Supplementary help was provided whenever it appeared advisable. The count personnel were screened and indoctrinated in the office. Training was accomplished in the field by having the new count personnel make duplicate field

Figure 5. Location map of crosswalks under study.



counts along with experienced crewmen until they learned the procedure and could maintain consistently accurate counts. Close liaison was maintained with the field crew at all times during the counting operations to ensure continuity and quality of data.

In order to obtain compatible data, manual counts were limited to nonholiday weekdays. In the event of inclement weather, accidents, construction, or other conflicting conditions, supplementary counts were made to ensure representative data. To ensure further compatibility of data, counts were made only at 4-leg perpendicular intersections at which the main thoroughfare carries two-way traffic.

Standard intersection manual counting procedures were employed using an intersection tally board that counted (a) the vehicular traffic entering the intersection on each leg by individual traffic movements—right turns, straight-through, and left turns—and (b) the nondirectional pedestrian traffic crossing each leg of the intersection (Fig. 6).

In view of the mass of field data to be tabulated and analyzed during and after the field study, it was decided to utilize the City of San Diego's IBM 360 computer. To facilitate this, the field sheets were designed as source documents (Fig. 7). This permitted direct keypunching and subsequent computation and summarization by electronic data processing.

A special computer program was prepared that summarized and printed the count data, exposure ratios, and crosswalk use ratios for rach intersection and then combined each data element to provide a composite intersection count representing all of the intersections counted (Table 3).

To aid in the evaluation of the volume data at the 40 intersections, a supplementary 5-year accident analysis was made for the 40 intersections only. In past years, the City of San Diego maintained only 3 years plus the current year of accumulated traffic accident records in its files. This policy was changed in 1968 to permit the accumulation of 5 years of accident records. Unfortunately, the 1963 accident records were no longer available for the purpose of making a 40-intersection composite collision diagram analysis (Fig. 12). Consequently, the latest 5-year period was used, covering January 1, 1965, through December 31, 1969.

FINDINGS

Table 1 gives the number of pedestrian accidents occurring in marked and unmarked crosswalks by month and year. The total number of fatal pedestrian accidents occurring in the 400 intersections during the 5-year period was 18 in the marked crosswalks and 3 in the unmarked crosswalks. This represents an accident ratio of 6:1. During this same period, the total pedestrian accidents (fatal and nonfatal) occurring was 177 in marked and 31 in unmarked crosswalks, representing a ratio of 5.7:1.0. The month showing the highest 5-year accumulation of accidents is December, with 24 accidents occurring in marked crosswalks and 7 accidents in unmarked crosswalks. July was the month during which the least number (7) of pedestrian accidents occurred in marked crosswalks. September showed a surprising record of no pedestrian accidents occurring in the unmarked crosswalks for the 5-year period.

In Table 2 the number of pedestrian accidents in marked and unmarked crosswalks is arranged by day of week and time of day. In the marked crosswalks the highest incidence of accidents occurred on Saturday, with 38 accidents; the lowest incidence was on Tuesday, with 13. In the unmarked crosswalks, the highest incidence of accidents was on both Tuesday and Friday with 7 accidents each; the lowest incidence was on Wednesday, with 1 accident.

Figure 8 shows pedestrian accidents in marked and unmarked crosswalks compared by pedestrian age groups. As might be expected, the highest incidence of pedestrian accidents involves the very young and the very old in both the marked and unmarked crosswalks. For example, the highest incidence of accidents for both the marked and unmarked crosswalks involved those persons 70 years or older, with 35 accidents in marked and 7 accidents in unmarked crosswalks. This was followed closely by the 5- to 9-year age group, with 29 accidents in marked and 6 accidents in unmarked crosswalks. There were, however, some surprising paradoxes found in the remaining age group data. For example, the 65- to 69-year age group was involved in 13 accidents

Figure 6. Student engineer making manual count at intersection. Pocket watch is used for timing the count; supplementary timer on dashboard is used to warn personnel in advance of the count-recording interval each half hour.

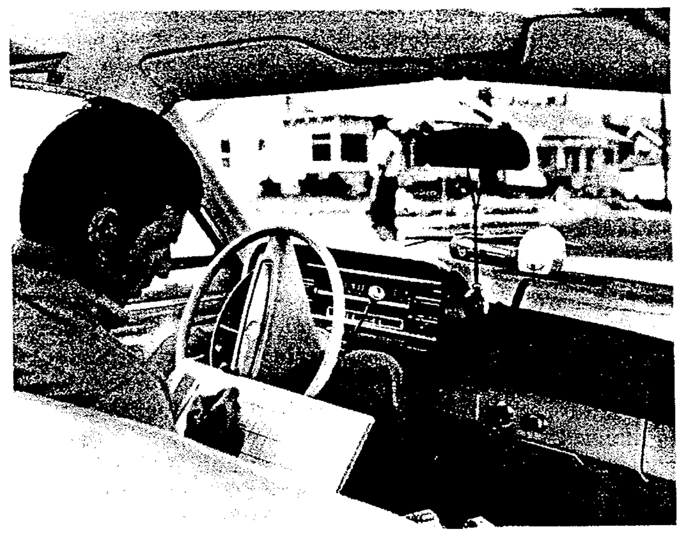


Figure 7. Student engineer recording count data on special field form adapted for subsequent keypunching and electronic data processing.

Table 1. Pedestrian accidents in marked and unmarked crosswalks by month and year.

	Fatal Accidents		Fatal and Injury Accidents by Year											
			1963		1964		1965		1966		1967		Total	
Month	M	U	M	U	M	U	M	U	M	U	M	U	M	U
January	2		5	2	4	1	4	0	4	0	1	0	18	3
February	1		1	0	6	1	4	0	2	0	3	0	16	1
March	2		4	0	2	0	5	1	3	0	3	0	17	1
April			1	0	2	0	4	1	3	0	2	1	12	2
May		1	3	0	2	0	2	1	4	1	4	1	15	3
June	1	1	1	1	4	0	3	0	2	2	1	0	11	3
July	1		0	2	2	1	2	0	2	0	1	0	7	3
August	1		3	0	0	0	2	1	3	0	3	1	11	2
September	3		3	0	1	0	1	0	4	0	2	0	11	0
October	1	1	6	1	1	0	4	1	3	0	3	0	17	2
November	3		2	0	5	1	5	0	2	1	4	2	18	4
December	3	–	3	1	6	4	6	0	2	1	7	1	24	7
Total marked	18		32		35		42		34		34		177	
Total unmarked		3		7		8		5		5		6		31

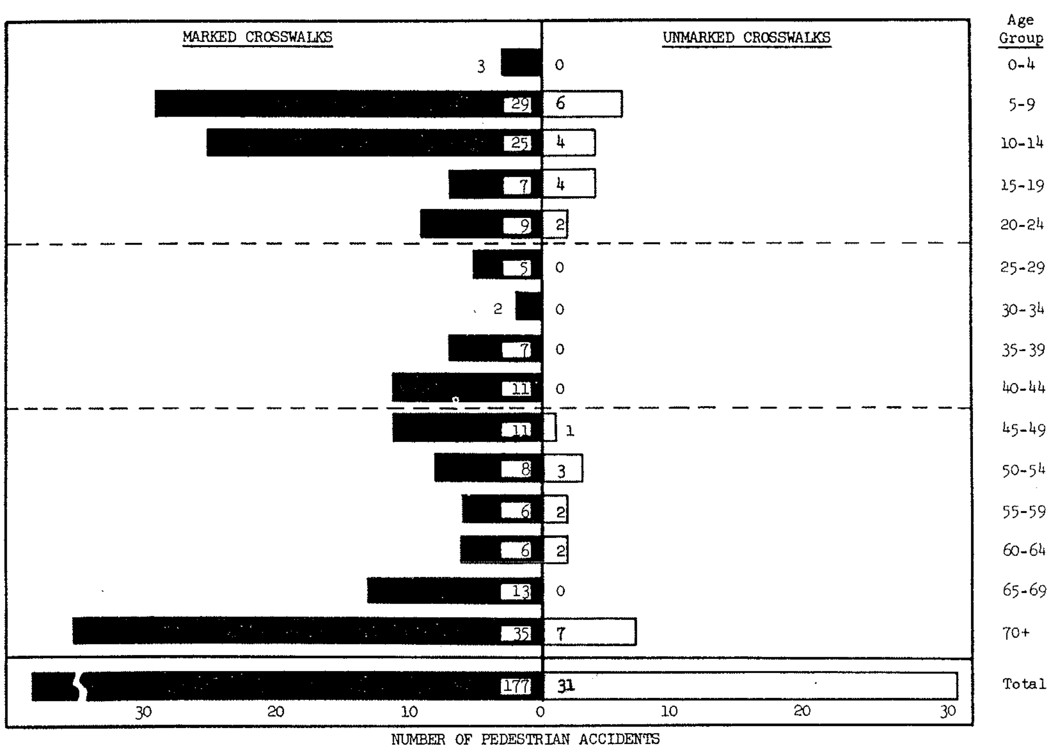
Based on 5 years of data at 400 intersections.
M = marked crosswalks, U = unmarked crosswalks.

Table 2. Pedestrian accidents in marked and unmarked crosswalks by time and day of week.

Time	Day Mon. M	Mon. U	Tue. M	Tue. U	Wed. M	Wed. U	Thur. M	Thur. U	Fri. M	Fri. U	Sat. M	Sat. U	Sun. M	Sun. U	Total M	Total U
12-1 a.m.							2				1			1	3	1
1-2											2				2	0
2-3									1				1		2	0
3-4														1	0	1
4-5															0	0
5-6															0	0
6-7					1										1	0
7-8	1	2	2		2		1	2		1	1				7	5
8-9			1	1			1		1						3	1
9-10	1		1		1							2			3	2
10-11		1			1				1			1			2	2
11-12							1		2		4				7	0
12-1 p.m.	2		1		1	1			1	1	1		1		7	2
1-2	1				2					1	3		1		7	1
2-3	2									1	2		1		5	1
3-4	3		3	1	3		1		1		2				13	1
4-5			1	2	3		1		3		3		1		12	2
5-6	1		5		11		2		4		2		1		26	0
6-7	1		6		2		1		5		5		3		23	0
7-8	3		1	2					4		3	1	4		15	3
8-9	1		1		4		2	1	3		4	1	3		18	2
9-10	1		1	1	2		1	1		2	1	1	2		8	5
10-11					2			1	1		2		1		6	1
11-12			2						2	1	2		1		7	1
Total marked	17		25		35		13		29		38		20		177	
Total unmarked		3		7		1		5		7		6		2		31

Based on 5 years of data at 400 intersections.
M = marked crosswalks, U = unmarked crosswalks.

Figure 8. Pedestrian accidents in marked and unmarked crosswalks by age group (based on 5 years of data at 400 intersections).



in marked crosswalks but showed no involvement during the same period in unmarked crosswalks. Similarly, the 25- to 44-year age group showed an involvement of 25 accidents in marked crosswalks, but during this same period they showed no accident involvement in unmarked crosswalks.

Figure 9 is a graph of pedestrian accidents occurring in marked and unmarked crosswalks plotted as a function of the time of day. The time intervals showing the highest incidence of accidents during the 5-year period are 5 to 6 p. m., with 26 accidents, and 6 to 7 p. m., with 23 accidents. These accidents occurred in marked crosswalks. Interestingly, the unmarked crosswalks showed no accidents during the same time intervals. This represents an accident ratio of 49:0. The unmarked crosswalks show peak accidents occurring at 6 to 7 a. m., with 5 accidents, and 8 to 9 p. m., also with 5 accidents. The accident ratio is 5.7:1.0 in marked versus unmarked crosswalks.

Table 3 is the manual count summary for the composite 40 intersections (Phase II). This is based on the 24-hour pedestrian and vehicle volume counts made at 40 of the 400 unsignalized intersections having marked and unmarked crosswalks. The exposure ratio indicates the ratio of vehicles to pedestrians crossing the major street at the marked (leg 1) and unmarked (leg 3) crosswalks. The crosswalk use ratio indicates the ratio of pedestrians using the marked crosswalk versus the number of pedestrians using the unmarked crosswalk. This is shown as 2.86 pedestrians using the marked crosswalk to 1.00 pedestrian using the unmarked crosswalk.

Figure 10 is a graph of pedestrian volumes in marked and unmarked crosswalks plotted as a function of the time of day. The volume ratio (crosswalk use ratio) is 2.9 persons crossing in the marked crosswalks to 1.0 person crossing in the unmarked crosswalks.

Figure 11 is an intersection traffic flow diagram showing the composite volumes for the 40 sample intersections.

Figure 12 is a collision diagram showing the pedestrian accidents in the marked and unmarked crosswalks at the composite 40 sample intersections. Pedestrian accidents are based on the most recent 5-year period (1965-1969). From this diagram it can be seen that 56 pedestrian accidents occurred in the marked crosswalk versus 12 in the unmarked crosswalk. This includes 7 fatal pedestrian accidents in the marked crosswalk versus 3 in the unmarked crosswalk.

A further analysis can be made that relates the accidents to the relative position of the pedestrian and vehicle. Of importance here is (a) whether the vehicle is approaching the crosswalk from the nearside or far side of the intersection and (b) whether the pedestrian is just starting to cross the street or just finishing crossing the street. Note that "finishing" in this analysis means that the pedestrian is over halfway across the street. Of special interest in this group of accidents is the fact that the greatest number of pedestrian accidents (24, including 5 fatal) occurred at the "far-side finish" position. In other words, the vehicle struck the pedestrian on the far side of the intersection while the pedestrian was finishing crossing the street. This is contrary to the popular expectation that the majority of pedestrian accidents tend to occur at the "nearside starting" position. In fact, the nearside starting position showed up somewhat favorably in this analysis, with only 6 pedestrian accidents, none fatal. These 6 accidents represent only 8.8 percent of the total 68 pedestrian accidents occurring in the 40 sample intersections. Also of interest is the fact that only 2 of the 68 pedestrian accidents (on the major street) involved vehicles making turning movements from the minor street. Both of the turning accidents involved left turns. There were no pedestrian accidents involving right-turning vehicles in this sample of 40 unsignalized intersections.

Of special concern is the high proportion of nighttime accidents involving pedestrians being hit after they were over halfway across the street. One explanation is that the approaching vehicle's head lamps are not illuminating the pedestrian sufficiently and in time to permit the motorist to stop. [Another study (10) shows that under certain conditions the pedestrian may be some distance from the point of impact at the moment the motorist must perceive the danger and come to a safe stop.] Pedestrians should be made aware of this potential danger so that they avoid walking into the path of an oncoming vehicle at night, thinking that the vehicle will stop in time.

Figure 9. Pedestrian accidents in marked and unmarked crosswalks as a function of time of day (based on 5 years of data at 400 intersections).

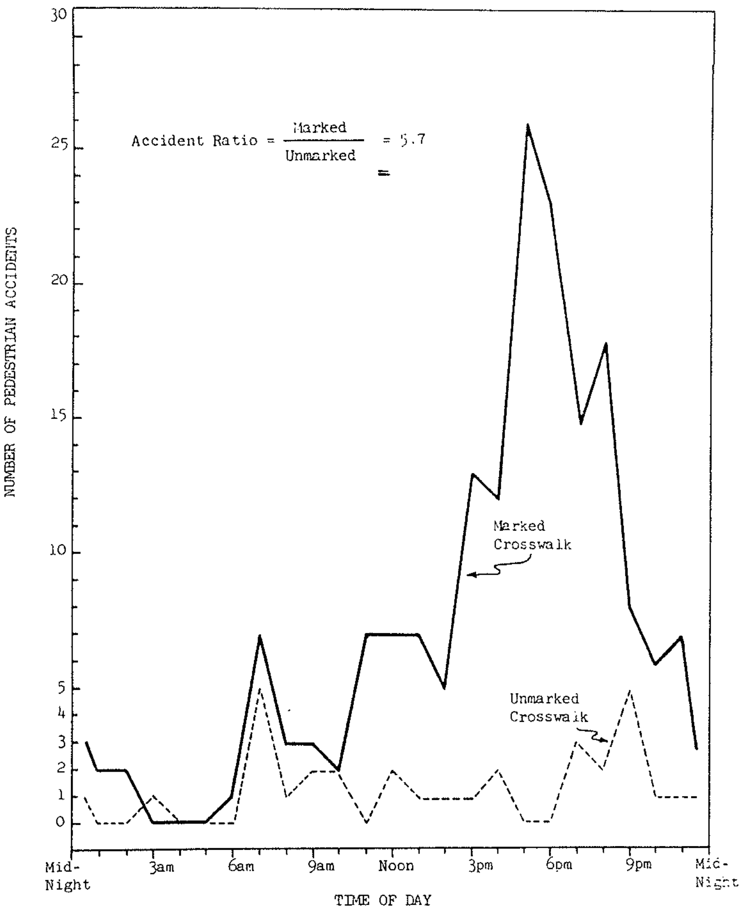


Table 3. Manual count summary, composite of 40 intersections.

	Marked Crosswalk								Unmarked Crosswalk							
	Leg 1				Leg 2				Leg 3				Leg 4			
Time	RT	ST	LT	PED	RT	ST	LT	PED	RT	ST	LT	PED	RT	ST	LT	PED
12-1 a. m.	104	3,224	106	14	98	81	71	27	104	3,309	115	10	83	35	66	61
1-2	64	1,840	60	11	55	36	23	17	71	1,877	83	8	58	41	49	50
2-3	48	1,278	32	8	23	29	26	13	29	1,199	49	4	30	15	25	30
3-4	12	756	22	4	19	15	23	4	25	734	26	0	25	6	19	6
4-5	23	700	18	9	38	22	20	5	12	632	30	3	17	12	26	9
5-6	90	2,022	44	33	87	54	68	28	55	1,983	76	12	65	28	83	26
6-7	300	8,580	251	123	329	251	254	129	226	8,405	214	41	292	308	309	122
7-8	639	21,645	535	500	836	545	454	573	508	19,677	539	161	756	527	418	452
8-9	686	17,483	582	688	697	524	455	686	542	16,911	536	253	689	376	360	526
9-10	509	15,808	549	489	623	427	457	649	571	14,964	520	165	603	290	371	487
10-11	585	18,001	544	619	686	453	505	926	688	17,638	656	237	656	317	423	789
11-12	717	20,489	715	796	773	580	582	974	754	19,580	777	239	776	383	487	914
12-1 p. m.	764	21,437	756	844	806	590	545	986	761	21,116	819	301	894	400	507	1,038
1-2	714	21,071	712	702	819	536	594	946	731	20,575	763	267	833	368	484	990
2-3	854	22,659	772	852	828	574	601	1,230	776	22,754	994	309	915	453	465	1,234
3-4	984	25,178	932	1,287	1,039	756	648	1,646	990	25,128	1,085	473	889	538	469	1,500
4-5	1,116	27,626	1,200	1,030	1,237	894	668	1,177	1,072	28,706	1,328	310	1,057	597	557	1,138
5-6	1,057	26,870	1,191	766	1,105	758	634	878	1,029	28,337	1,234	250	1,057	596	497	810
6-7	673	19,612	754	416	777	444	533	619	668	19,572	715	119	730	364	451	571
7-8	528	16,765	584	301	605	369	442	442	556	16,315	617	98	582	271	390	465
8-9	408	12,467	461	250	407	275	357	333	469	12,675	440	98	447	224	302	392
9-10	418	11,873	371	169	333	201	256	262	384	12,226	425	79	329	210	246	296
10-11	237	8,308	265	93	228	146	192	135	255	8,711	268	47	214	130	198	210
11-12	241	6,140	183	53	162	116	127	100	152	6,033	207	30	136	92	159	121
Total	11,771	331,833	11,639	10,057	12,610	8,676	8,535	12,785	11,428	329,057	12,516	3,514	12,133	6,581	7,361	12,237
Approaching			355,243				29,821				353,001				26,075	
Departing			349,028				29,648				352,501				32,963	
Total			704,271				59,459				705,502				59,038	

Exposure ratio (vehicles per pedestrian crossing major street): Leg 1 (marked crosswalk) 70.03
Leg 3 (unmarked crosswalk) 200.77

Crosswalk use ratio (pedestrians in marked versus unmarked crosswalks): 2.86

RT = right turns, ST = straight, LT = left turns, PED = pedestrian.

Figure 10. Pedestrian volume in marked and unmarked crosswalks as a function of time of day (based on 24-hour manual counts at 40 intersections).

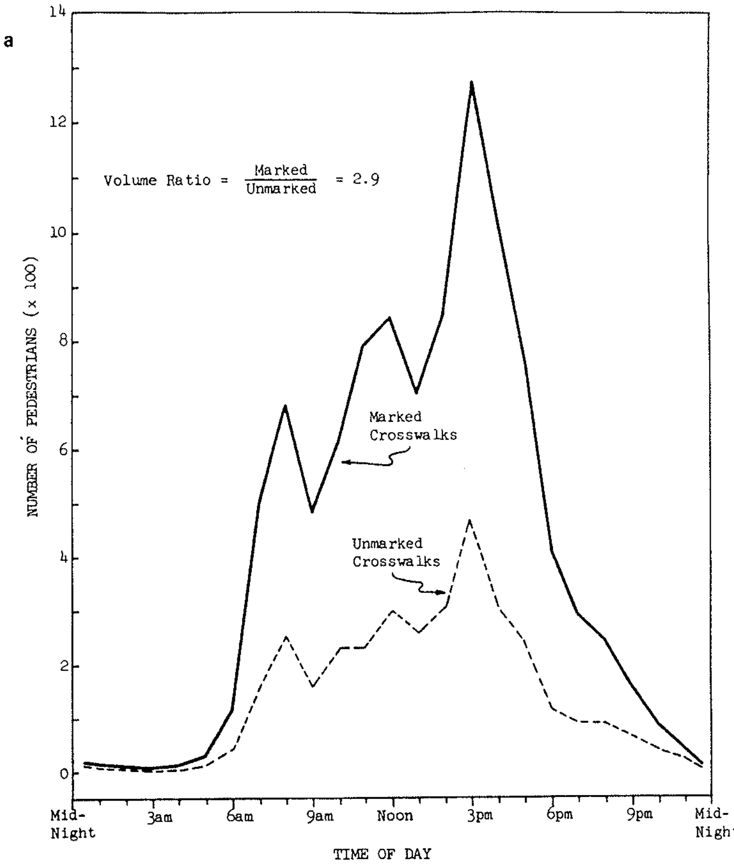


Figure 11. Intersection traffic flow diagram showing composite volumes of 40 intersections (based on 24-hour manual count data at 40 intersections).

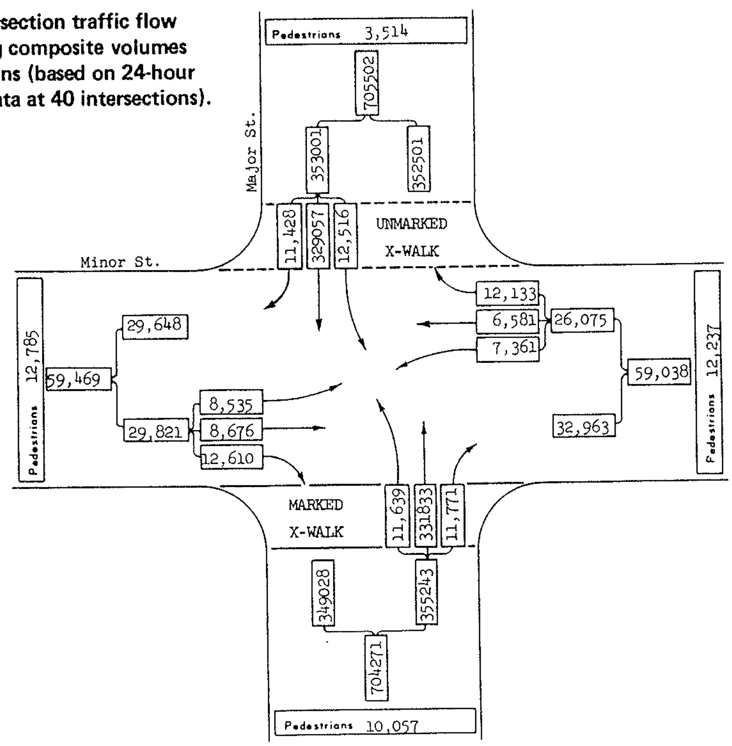


Figure 12. Intersection collision diagram showing composite collisions involving pedestrians in marked versus unmarked crosswalks at 40 intersections (based on 5 years of data).

COLLISION DIAGRAM

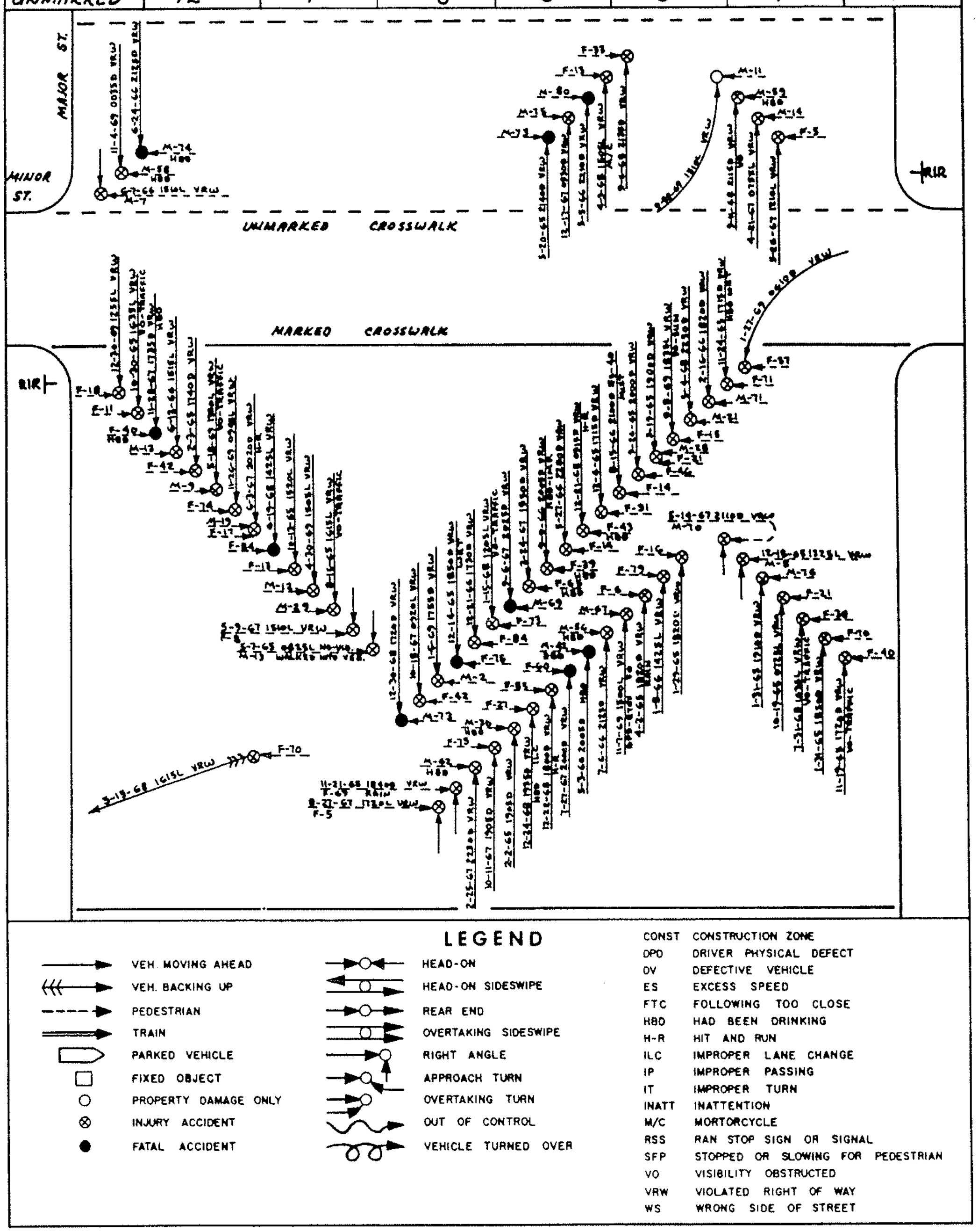
CITY OF SAN DIEGO, CALIFORNIA
PUBLIC WORKS DEPARTMENT
TRAFFIC ENGINEERING SECTION

LOCATION: Composite of 40 Intersections

DRAWN BY: RHILL
DATE: 12-2-71
PERIOD: 1-1-65 TO 12-31-69

NO. ACCIDENTS BY TYPE

YEAR	TOTAL	PROP. DAMAGE	INJURY	FATAL	LIGHT	DARK	WET
MARKED	56	0	49	7	21	35	4
UNMARKED	12	1	8	3	5	7	0



It should be noted that 27 of these "finishing" accidents, including 5 fatal accidents, involved pedestrians crossing in marked crosswalks. Therefore it would appear desirable, whenever marked crosswalks are installed, that special consideration be given to nighttime visibility and illumination.

CONCLUSIONS

The results of this study show that pedestrian accident ratios and crosswalk use ratios tend to cover a range of values depending on the type of intersection where the crosswalk is located. But, in general, more pedestrian accidents occur in marked crosswalks than in unmarked crosswalks by a ratio of approximately 6 to 1. Further comparison of the volume of pedestrians using the marked and unmarked crosswalks shows that the crosswalk use ratio is approximately 3 to 1. This would indicate, in terms of use, that approximately twice as many pedestrian accidents occur in marked crosswalks as in unmarked crosswalks.

Evidence suggests that this poor accident record is not due to the crosswalk being marked as much as it is a reflection on the pedestrians' attitude and behavior when using the marked crosswalk.

In general, marked crosswalks have the following advantages.

1. They may help pedestrians orient themselves and find their way across complex intersections.
2. They may help show pedestrians the shortest route across traffic.
3. They may help show pedestrians the route with the least exposure to vehicular traffic and traffic conflicts.
4. They may help position pedestrians where they can be seen best by oncoming traffic.
5. They may help utilize the presence of luminaires to improve pedestrian nighttime safety.
6. They may help channelize and limit pedestrian traffic to specific locations.
7. They may aid in enforcing pedestrian crossing regulations.
8. They may act, in a limited manner, as a warning device and reminder to motorists that this is a location where pedestrian conflicts can be expected.

Marked crosswalks also exhibit some disadvantages.

1. They may cause pedestrians to have a false sense of security and to place themselves in a hazardous position with respect to vehicular traffic.
2. They may cause the pedestrian to think that the motorist can and will stop in all cases, even when it is impossible to do so.
3. They may cause a greater number of rear-end and associated collisions due to pedestrians not waiting for gaps in traffic.
4. They may cause an increase in fatal and serious-injury accidents.
5. They may cause an increase in community-wide accident insurance rates.
6. They may cause a disrespect for all pedestrian regulations and traffic controls.

Unjustified and poorly located marked crosswalks may cause an increased expense to the taxpayers for installation and maintenance costs that may not be justified in terms of improved public safety. Indeed, such crosswalks may tend to increase the hazard to pedestrians and motorists alike. Therefore, the following recommendations are presented for further consideration and implementation.

RECOMMENDATIONS

1. Existing crosswalk warrants should be reviewed and updated. Special consideration should be given to pedestrian channelization needs, nighttime illumination, vehicle approach speed, and motorist inability to see pedestrians or the crosswalk at the critical safe stopping distance.
2. No new crosswalks should be installed unless they meet the conditions established by the warrants.
3. Existing crosswalks should be reevaluated to see whether they meet the revised warrants.

4. Efforts should be made to reeducate pedestrians regarding the limitations of the marked crosswalks and to alert them to some of the special hazards that they may encounter while crossing streets.

5. Attention should be given to the long-range needs of the pedestrian when planning new communities and developing existing communities in order to reduce the conflict between pedestrian and vehicle.

6. Research should be continued on a national scale to gain a better understanding of the pedestrian safety problem and to seek workable solutions and alternatives to the problem.

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.

ACKNOWLEDGMENTS

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PEDESTRIAN TRAVEL CHARACTERISTICS

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A survey of pedestrian trips was conducted in Washington, D.C., and supplemented by data from the Nationwide Personal Transportation Study conducted by the Bureau of the Census for the Federal Highway Administration. The major purpose of the Washington survey was to analyze data on walking trip lengths as a function of age, sex, trip purpose, and day of week for use in transportation and community planning. The Nationwide Personal Transportation Study provided supplemental data on walking to work. Results of the Washington survey show that 90 percent of the walking trips were less than 1 mile. This should be considered a maximum distance for any significant walking to community services. The median walking trip length was 1,600 ft. This seems to be a desirable distance in which to provide frequently visited services such as convenience shopping or recreation facilities. Men generally made longer walking trips than women. There were differences in trip length distributions by age group, but the trend was not clear. Trip lengths were the longest for the trip to work. The Nationwide Personal Transportation Study showed shorter trip lengths than the Washington survey for the work trip, with almost 71 percent less than ½ mile. Nationwide, 5 percent of the working population reported walking as the usual method of getting from home to work. There was a higher proportion of persons with incomes under $4,000 walking to work than in those income groups over $10,000. The youngest and oldest working age groups reported higher-than-average walking to work.

• IT IS recognized that more effort in transportation planning should be directed toward reducing vehicular trip demands. Much of our recent residential land use development has forced the necessity for vehicular trips. Segregation of land uses has kept most commercial activity away from residential areas, and thus a car is usually required for convenience shopping. Even for walking enthusiasts, the lack of sidewalks is certainly a discouraging factor.

Consideration of satisfying certain trip demands by walking would seem to be a reasonable goal in transportation studies. As Mumford (1) emphatically puts it, "Every urban transportation plan should put the pedestrian at the center of all proposals. The pedestrian must be treated with respect as we now treat the auto."

The United Nations symposium on planning of metropolitan areas and new towns (2) stated that residential districts should include "those institutions, services, and amenities that are visited by the public frequently ... such as cinemas, clubs, health clinics, shopping centers, etc. The facilities should be sited within easy walking distance of all dwellings they serve." This is an especially important consideration in apartment and townhouse developments.

A great deal of effort has been devoted to the transportation planning process. A significant portion of resources has been used for origin-destination data collection. These studies have identified the travel patterns of motorists. However, very little effort has been devoted to studies of pedestrians.

To gather some base data for community pedestrian consideration, a survey of residentially based walking trips was conducted. The survey was made in the southwest section of Washington, D. C. The residential areas surveyed consist of large apartment buildings and clusters of townhouses. With this dense residential development and the location of shopping, recreation, and employment facilities in the area, the possibility for a significant number of walking trips exists. Analyses of the pedestrian data are included in this report.

The survey in Southwest Washington is supplemented by data from the Nationwide Personal Transportation Study conducted by the Bureau of the Census for the Federal Highway Administration. Data on those walking to work cross-classified by household characteristics were available.

SOUTHWEST WASHINGTON PEDESTRIAN TRAVEL SURVEY

The major objective of the pedestrian survey was to determine distributions of walking trip distances by day, purpose, age, and sex. Attitudes toward walking and bicycling were also investigated. These data should be important for planning community services for various age groups.

Procedures

The survey was conducted in two residential developments in the southwest area of Washington, D. C. One development was River Park Mutual Homes, a cooperative consisting of two high-rise apartment buildings with 384 units and a group of 134 townhouses. The residents are primarily professionals. The other development, Channel Square, is adjacent to River Park and is a subsidized moderate-income rental complex consisting of a high-rise apartment of 128 units and 75 townhouses.

A sample of one in three households was selected for interviewing in the River Park development. Because of lower response rates in lower income households, it was decided to increase the sample rate in Channel Square to one in two households.

Data were collected for four days, Saturday through Tuesday, to show weekend and weekday characteristics. A pre-sample showed that this was feasible.

Several factors affecting trip length were included in the questionnaire. Trip distances for males and females would be expected to be different because of physical capacity and because of safety considerations. Age was also considered to be an important factor. In order not to force a person to give his specific age, he was asked to indicate his age group. The trip purpose was asked to determine differences in trip length by purpose. The estimated number of blocks for each trip was asked and also the location so the distance could be checked if it was not given. Household data such as number of adults, number of children, and number of automobiles were asked for comparison with trip-making. Factors were indicated that might affect the decision to walk. Attitudes toward bicycling were also asked.

A cover letter and questionnaire were left at each sampled household on Tuesday evening, November 3, 1970, asking for walking trips for the previous four days, Saturday through Tuesday.

With one follow-up letter, the response rate was 35 percent overall. As expected, the response rate from Channel Square was lower than in River Park—25 percent compared to 43 percent.

Results

In all, 294 walking trips were reported from the survey. Figure 1 shows the cumulative trip length distribution of all trips; 89 percent of the trips are less than 1 mile, and 50 percent are less than 1,600 ft.

Walking trip lengths by age group are given in Table 1. A chi-square test of significance was used to check for differences in trip length by age group. The hypothesis tested is that the distributions of trip length are the same for all age groups. Table 2 shows the contingency table for the chi-square analysis. The value of chi square as calculated by the formula $\chi^2 = (O - E)^2/E$ is 20.39. The chi-square value at the 0.05 level of significance with 10 degrees of freedom is 18.3. Therefore, the hypothesis can be rejected. By rejecting the hypothesis, there are only 5 chances in 100 of being wrong. Although the trip length distributions by age are significantly different, the three curves cross over in Figure 2, which indicates no clear relationship between trip length and age.

Table 3 gives the relationship between sex and trip length. As anticipated, male trip lengths were longer than female trip lengths (Fig. 3). A chi-square analysis was used to test the hypothesis that the two distributions were the same. The value of chi square was calculated to be 28.12. Entering the chi-square table with 8 degrees of freedom, it was determined that the hypothesis could be rejected at the 0.005 level of significance. The difference between distributions of trip length made by males and females is somewhat influenced by the relatively long work trips made by men.

Table 4 gives the trip length by purpose. Although there is quite a bit of scatter in the figures, relative trip lengths by purpose can be determined. It must be emphasized that trip lengths by purpose are affected by the location of services in the Southwest area. The shortest trip lengths were to board a mode of transportation outside the development (bus, car, taxi). The longest trips were to work.

Figure 4 shows the trip purpose distribution for all days combined. Shopping represents about half of all trips. The second most frequent trip purpose was outdoor recreation.

Trip purpose by day of week as given in Table 5 shows some interesting results. Three-fourths of all trips on Saturday were for shopping, primarily grocery shopping. Shopping trips on Sunday, Monday, and Tuesday were just over a third of all trips on those days. On both Saturday and Sunday outdoor recreation trips were the second most frequent trips. From the completed questionnaires it was noted that several of these were trips to walk dogs. Work trips were the second most frequent purpose for walking on Monday and Tuesday.

Tables 6 and 7 show trip purpose distributions by age and by sex. The significant difference by age group, as expected, is that those 60 years of age or over had a smaller proportion of work trips. The older age group had a higher proportion of shopping trips than the other age groups. The 18 to 39 age group had the highest proportion of outdoor recreation trips. The trip purpose distribution by sex shows that females made more shopping and personal business trips and that men made more work trips.

Trip production varied little by housing type. For all adults making trips, the average number of trips for the four survey days was 3.1 trips per adult. For households with walking trips, the average number of trips for the four survey days was 4.1 trips per household, but 21 percent of the households had no walking trips. For all households, the average number of trips per household was 3.3 trips.

Vehicle trip productions are often related to family size. To test if there was a difference in walking trip production by family size a chi-square analysis was done. The hypothesis was that number of trips per household was independent of family size. The value of chi square was 3.32. The hypothesis could not be rejected at the 0.10 confidence level. Therefore, it is probable that the number of walking trips is independent of family size.

Respondents, whether or not they walked, were asked to rank those factors that discourage them from walking. The following were listed on the questionnaire: unfavorable weather, crime, lack of adequate sidewalks, heavy automobile traffic, smog or pollution, and other (please specify). According to Table 8, the greatest number of respondents ranked crime as the most significant factor discouraging walking. Written comments indicated that crime was an especially significant factor at night. Many people indicated that they did not walk at all at night because of crime. Unfavorable weather was listed as the most important factor by 24 people as compared to 37 indicating crime; 16 indicated other factors as most significant. These included factors such as distance or time, laziness, lighting, health, and heavy shopping bundles. Three indicated heavy automobile traffic as the most significant.

Bicycling

With the increasing popularity of bicycling among adults, it was decided to assess bicycle use and attitudes toward bicycling for short trips. Only five persons indicated use of a bicycle in the previous week. Interestingly, these persons all lived in River Park. This may indicate that income and occupation have some influence on bicycling.

Figure 1. Pedestrian trip length-frequency distribution.

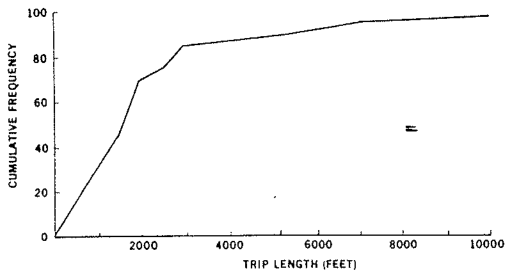


Table 1. Pedestrian trip length by age group.

Pedestrian Trip Length (ft)	Age Group, Percentage 18-39	40-59	60 or Older
1-500	18.0	15.9	6.4
501-1,000	18.1	15.3	10.6
1,001-1,500	10.1	13.0	21.3
1,501-2,000	18.0	28.4	27.7
2,001-2,500	5.6	6.5	6.4
2,501-3,000	19.2	3.6	19.1
3,001-4,000	1.1	0.7	0.0
4,001-5,280	2.2	5.8	0.0
5,281-7,000	5.5	2.9	0.0
7,001-8,500	0.0	2.9	2.1
8,501-10,000	0.0	1.4	0.0
10,001-12,500	2.2	3.6	6.4
Total	100.0	100.0	100.0

Table 2. Contingency table for chi-square analysis of trip length by age group.

Pedestrian Trip Length (ft)	Number in Age Group 18-39 O	E	40-49 O	E	60 or Older O	E	Total O
1-50	16	13.3	22	20.7	3	7.0	41
501-1,000	16	13.6	21	21.2	5	7.2	42
1,001-1,500	9	12.0	18	18.6	10	6.4	37
1,501-2,000	16	22.1	39	34.2	13	11.7	68
2,001-3,000	22	15.6	14	24.2	12	8.2	48
Over 3,000	10	12.3	24	19.3	4	6.4	38
Total	89		138		47		274

O = observed, E = expected.

Figure 2. Pedestrian trip length by age group.

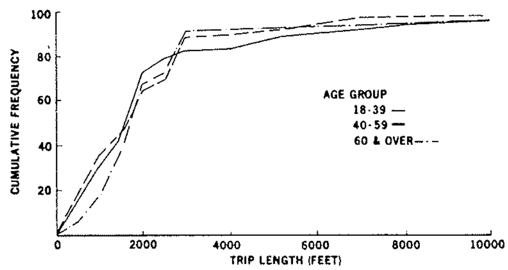


Table 3. Pedestrian trip length by sex.

Pedestrian Trip Length (ft)	Sex, Percentage Male	Female	Pedestrian Trip Length (ft)	Sex, Percentage Male	Female
1-500	10.7	18.4	4,001-5,280	4.6	2.5
501-1,000	14.5	15.3	5,281-7,000	8.4	3.1
1,001-1,500	14.5	12.9	7,001-8,500	2.3	1.2
1,501-2,000	22.1	26.4	8,501-10,000	1.5	0.0
2,001-2,500	6.9	4.9	10,001-12,500	7.6	0.0
2,501-3,000	6.1	14.7	Total	100.0	100.0
3,001-4,000	0.8	0.6			

Figure 3. Pedestrian trip length by sex.

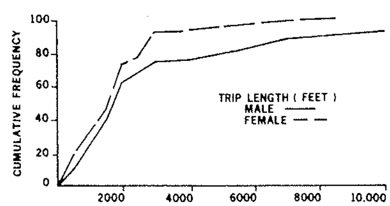
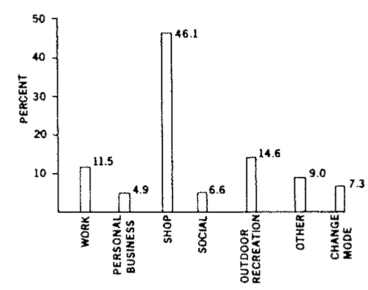


Table 4. Pedestrian trip length by trip purpose.

Pedestrian Trip Length (ft)	Trip Purpose, Percentage Work	Personal Business	Shop	Social	Outdoor Recreation	Other	Change Mode
1-1,000	12.1	20.0	32.1	47.4	24.4	7.7	73.9
1,001-2,000	0.0	40.0	54.0	36.8	41.4	11.5	26.1
2,001-3,000	6.1	26.7	13.9	5.3	12.2	61.6	0.0
3,001-5,280	18.2	0.0	0.0	0.0	7.3	11.5	0.0
5,281-8,500	48.4	0.0	0.0	10.5	7.3	0.0	0.0
8,501-12,500	15.2	13.3	0.0	0.0	7.3	7.7	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Figure 4. Trip purpose distribution.



The distribution of attitudes toward bicycling for short trips is as follows: 35 people were very favorable; 22, favorable; 12, unfavorable; and 9, very unfavorable. This indicates a generally favorable attitude toward bicycling. However, several people indicated that they were reluctant to ride in the traffic stream. They indicated a need for separate bikeways.

Written Comments on Questionnaires

There were many interesting comments provided by respondents that cannot be summarized neatly in a table but deserve some consideration. Several of the responses follow:

"Potential criminal acts discourage free and open walking."

"Favor bicycling, but there must be safe and convenient bicycle racks at all stores. There must be bicycle paths to stores separated from automobile traffic. You can't cope with packages, a bicycle, traffic, going up and down curbs all at once."

"I can't remember when I've walked last. I have walked to the park but not recently."

"Would like to see walkway developed to the Hill, using the pedestrian underpass—diagonaling up through the Southwest development, with a sidewalk cafe or two. I feel city and construction firms have been very amiss not to prepare walkways through or along construction that blocks 4th Street (shopping center construction). A year or so of walking in the parking lot and across the mud, dust, and dirt of the Methodist Church lawn is most disheartening, hard on shoes, dangerous in parking lot, etc. Many people must feel this."

"I believe strongly with Jane Jacobs that residential areas should not be solely residential. I would like little bookstores, art galleries, fruiterers, bakers, florists, etc., interspersed among townhouse areas, possible marginal operations in people's houses—much more fun that way, more interesting walking, pleasant small expeditions getting people out of their boxes often and easily, leading to sociability."

"Enjoy walking to park but no other place to walk."

"My husband used to walk to work on Capitol Hill, but the lack of adequate sidewalks, deserted fields, dismal atmosphere, and pollution . . . have stopped it."

"Walking and bicycling are good for health and for relieving tension, but you need an inspiring view and a place to move freely."

"I am unfavorable to bicycling with present traffic hazards, but I would be favorable to bicycling if bikeways were provided."

"My bicycle was stolen the last time I used it for transportation, and the problem of potential theft prevents my using my new one for anything except riding around."

"We do not walk any distance except to the car—then drive to work or shop."

"At present my health precludes any extensive walking."

WALKING CHARACTERISTICS FROM NATIONWIDE PERSONAL TRANSPORTATION STUDY

Data from the Nationwide Personal Transportation Study conducted by the Bureau of the Census under contract to the Federal Highway Administration were used to supplement the Southwest Washington survey. The sample consisted of two panels of approximately 3,000 addresses, each distributed throughout the United States. Data from the two panels were combined to provide a broader base for statistical analysis. On the travel-to-work portion of the questionnaire, information was obtained on mode, including walking. Information gathered at the household allows comparison of mode, in this case walking only, with household characteristics such as income and occupation. In addition, the trip length data can provide some comparisons with the data from the Southwest Washington survey. The income and occupation distribution from the Nationwide Personal Transportation Study includes persons working at home or no fixed place. Trip length data exclude these persons.

In the nationwide survey, 5.0 percent of the employed persons 16 years of age and older reported walking as the usual mode of transportation to work. The reported trip length is given in Table 9. Almost 71 percent reported walking less than ½ mile to

Table 5. Pedestrian trip purpose by day of week.

Purpose	Day of Week, Percentage: Saturday	Sunday	Monday	Tuesday	All Four Days
Work	2.3	0.0	18.1	23.5	11.5
Personal business	3.5	0.0	7.2	7.4	4.9
Shop	73.2	35.2	36.3	32.4	46.1
Social	7.0	11.8	4.8	4.4	6.6
Outdoor recreation	11.6	29.4	12.0	10.3	14.6
Other	1.2	21.6	9.6	8.8	9.0
Change mode	1.2	2.0	12.0	13.2	7.3
Total	100.0	100.0	100.0	100.0	100.0

Table 6. Pedestrian trip purpose by age group.

Trip Purpose	Age Group, Percentage: 18-39	40-59	60 or Over
Work	12.4	9.2	4.3
Personal business	5.6	4.9	4.3
Shop	46.1	43.6	63.2
Social	7.9	4.2	8.7
Outdoor recreation	20.2	12.0	13.0
Other	6.7	10.6	6.5
Change mode	1.1	15.5	0.0
Total	100.0	100.0	100.0

Table 7. Pedestrian trip purpose by sex.

Trip Purpose	Sex, Percentage: Male	Female	Trip Purpose	Sex, Percentage: Male	Female
Work	17.4	6.8	Outdoor recreation	15.2	16.5
Personal business	2.2	7.5	Other	9.8	10.5
Shop	38.0	42.2	Change mode	12.0	7.5
Social	5.4	9.0	Total	100.0	100.0

Table 8. Rank of factors that discourage walking.

Rank	Unfavorable Weather	Crime	Lack of Adequate Sidewalks	Heavy Auto Traffic	Smog or Pollution	Other
1	26	37	0	3	0	16
2	24	17	1	6	4	6
3	5	2	6	11	7	2
4	3	3	4	4	6	2
5	1	2	7	2	6	0
6	0	2	3	2	1	0

Table 9. Percentage of persons who walk to work by distance.

Reported Miles to Work	Percent	Cumulative Percent
½ or less	70.8	70.8
1	24.0	94.8
2	4.5	99.3
3 or more	0.7	100.0
Total	100.0	

Source: Nationwide Personal Transportation Study.

Table 10. Percentage of persons in each income group who walk to work.

Household Income ($)	Percent Who Walk to Work	Household Income ($)	Percent Who Walk to Work
Under 3,000	11.9	7,500-9,999	4.5
3,000-3,999	12.7	10,000-14,999	2.9
4,000-4,999	7.0	15,000 and over	3.3
5,000-5,999	5.5	All income groups	5.0
6,000-7,499	5.3		

Source: Nationwide Personal Transportation Study.

Table 11. Percentage of persons classified by occupation who walk to work.

Occupation Group	Percent Who Walk to Work
Professional and semiprofessional	2.8
Managers (farm)	0.0
Other proprietors	3.3
Store and office clerks	5.8
Craftsmen of skilled labor	3.5
Semiskilled	5.5
Protective services	6.4
Personal services	9.1
All occupations	5.0

Source: Nationwide Personal Transportation Study.

Table 12. Percentage of persons who walk to work by age group.

Age	Distribution of Those Walking Only	Distribution of Working Population
16-19	12.4	6.5
20-24	10.5	12.0
25-29	7.0	11.4
30-34	6.9	9.4
35-39	8.1	9.7
40-49	20.6	22.7
50-59	18.9	18.2
60 and over	15.6	10.1
Total	100.0	100.0

Source: Nationwide Personal Transportation Study.

work. This percentage is higher than that reported for the Southwest Washington survey for work trips. This may be related to the distinct separation of residences and employment in Southwest and to possible instability of data from the Southwest survey when analyzing trip length for a single purpose.

Tables 10 and 11 give walking trip distributions by income and occupation respectively. There was a significantly higher proportion of persons with incomes under $4,000 walking than in those income groups over $10,000. By occupation group, professionals or semiprofessionals reported walking to work the least, with those in personal services reporting the highest rate of walking to work.

The distribution of persons walking to work by age group in Table 12 shows higher-than-average walking for the youngest and oldest age groups. Those in the 20-49 age groups reported less than average walking. (Note: If all age groups had the same walking trips per person, the distribution of walking trips would be the same as the distribution of the working population.)

SUMMARY AND CONCLUSIONS

Although based on a small sample, the survey of walking trips in Southwest Washington can be used as an indicator in providing transportation and other community facilities.

Ninety percent of walking trips were less than one mile. This should probably be considered a maximum distance for the provision of facilities to which any walking is anticipated. The median walking trip length was 1,600 ft. This would seem to be a desirable distance within which to provide those services that are visited frequently.

Men made longer walking trip lengths than women; however, this was influenced by the long walking trips to work by some male respondents. If these work trips are excluded, trip lengths would be similar for men and women.

Trip length distributions by age group were different by a chi-square analysis, but the relationship was not clear. The trip length distributions for each age group (Fig. 2) crossed each other several times. This seems to indicate no special consideration for different trip distances by age group.

For all survey days combined, shopping represented the most frequent trip purpose—about 50 percent. The second most frequent trip purpose was for outdoor recreation. Shopping was most frequently for groceries. Outdoor recreation trips were most frequently to the waterfront area along the Potomac River. Because trips are frequent for convenience shopping and recreation, these facilities should be provided within walking distance of residences when possible.

Number of trips per household varied little by development or by housing type. The number of trips per household did not appear to be related to family size.

Unfavorable weather and crime were the most significant factors discouraging walking trips. The attitude toward bicycling for short trips was generally favorable, but many people indicated the desire for separate bikeways.

The Nationwide Personal Transportation Study showed that 5.0 percent of employed persons walk to work. Almost 71 percent walk less than ½ mile to work. There was a higher proportion of walking trips among those in the under $4,000 income groups than in those income groups earning over $10,000 per year. The youngest and oldest working age groups reported higher-than-average walking to work. In developments with high numbers of low-income residents or high numbers of the youngest and oldest working age groups, special consideration should be made for walking.

ACKNOWLEDGMENT

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TRAFFIC ENGINEERING FOR PEDESTRIAN SAFETY: SOME NEW DATA AND SOLUTIONS

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This paper describes involvement patterns for a number of specific types of pedestrian accidents. It also describes traffic engineering actions designed to change the behavior of pedestrians and drivers to make them more likely to avoid these specific types of accidents. The patterns and solutions are drawn from a study of over 2,100 individual pedestrian accident cases.

•A GROWING awareness of the nature and extent of the pedestrian safety problem is likely to lead to greater requirements for action by traffic engineers and others to reduce pedestrian casualties. A few facts illustrate the magnitude and trend of the pedestrian problem: Each year there are about 400,000 pedestrian victims, and more than 10,000 of them die. Although the number of fatalities had been slowly decreasing until the late 1950's, the trend has reversed itself and has increased 36 percent since 1958. It has been estimated that there will be about 13,000 pedestrian fatalities in 1980. With improvements in vehicle occupant protection taking place, pedestrians could account for one-third to one-half of highway fatalities by 1980.

TRAFFIC ENGINEERING AND SOLUTION APPROACHES

There are three main approaches to reducing pedestrian casualties. First, we can physically separate the participants and reduce the opportunity for collisions. However, all conflicts cannot be avoided. The second approach is to develop safer behavior so that drivers and pedestrians can avoid accidents. Because this is not likely to be 100 percent effective in the near future, the third approach calls for modifying the impact dynamics, primarily through vehicle design, to reduce the severity of the injury.

This paper is concerned with the second approach. The underlying contention is that traffic engineering can contribute to the development of safe behavior by (a) restricting participants' action possibilities; (b) enhancing their capability to act safely; and (c) enhancing their predisposition or tendency to act safely.

A second underlying contention is that traffic engineering can be most effective when it is part of a comprehensive local pedestrian safety program. The particular focus of this paper is on some specific solutions supported by new data on pedestrian accidents.

METHODOLOGY AND DATA BASE

The methodology and data on which this work is based are reported in detail elsewhere (1). They are only summarized briefly as background for the conclusions.

Data were collected on over 2,100 cases of pedestrian accidents as they occurred during a 10-month period in 13 major cities in the United States. Data were secured by means of interviews with participants and witnesses, on-scene observations, and police records. The focus was on the sequence of events and behavior leading to the accident as well as on selected situational factors that might influence those events. Causal conclusions were drawn for each case individually, and cases were grouped into types primarily on the basis of similarity of causation. Other data were then tabulated for the cases in each type.

GENERAL CONCLUSIONS

Three general conclusions from the overall study are especially relevant. First, there are a number of distinct types of pedestrian accidents that need individual attention. These types may be differentiated on the basis of (a) the sequence of events and behavior leading to the collision; (b) the important factors that predispose that sequence to occur; and (c) the characteristics of the people, vehicles, and locations typically involved. Second, different accident types occur more frequently in different areas of the city. Third, pedestrian search and detection failures are frequent causal factors.

These three points will be clarified as selected specific accident types and solutions are summarized. The percentage given for each type indicates the percent of urban accidents studied that were definitely assigned to this category. One can multiply that percentage by 360,000 to get a rough idea of the estimated number of accidents in that category each year.

DART-OUT, FIRST HALF (24 PERCENT)

A pedestrian, not in an intersection crosswalk, appears suddenly from the roadside. His quick appearance and short exposure to the driver are the critical factors. The pedestrian often may be running, and parked cars often obstruct vision, but neither need be present if the basic condition of sudden appearance to the driver's view is met. The prime example of the dart-out is a school-aged child running out from between parked cars on his own block in a residential area in the center city in the afternoon after school. He heads straight across the relatively narrow street, looking where he is going, and is struck less than halfway across. The driver, traveling at a normal rate of speed, does not have enough time to stop after detecting the child.

Almost 90 percent of these dart-out pedestrians were under 14. About half of the incidents happened between 3:00 p.m. and 6:00 p.m., 78 percent were between 2:00 p.m. and 9:00 p.m., and 80 percent were in the daytime. The crashes took place in residential areas (72 percent) and did not involve high speeds (85 percent were below 30 mph). Most of the time the pedestrian was struck within 2 blocks of his home (65 percent) while crossing a street less than 40 ft wide (74 percent). Figure 1 shows the typical type 1 dart-out. The analysis of the problem has shown that the main items to be attacked and overcome are (a) a risky pedestrian course—exposing him to view briefly; (b) failure of the pedestrian to search and detect; and (c) parked cars that interfere with driver and pedestrian vision. An innovative potential countermeasure that is directed at this problem is parking redeployment. Two steps would be taken in selected residential locations. First, parking would be removed from one side of the street, probably the left. Second, head-in diagonal parking would replace parallel parking on the right (Fig. 2). In appropriate locations this would accomplish the following: Visual obstructions would be removed from the left side of the road giving the driver an increased view and more time to detect and react. The diagonal parking would provide a physical control that would tend to slow down the pedestrian as he ran across the street but, even more important, would angle him into traffic and direct his field of vision more in the direction of the threatening vehicles. Also, he would be able to execute evasive action more readily than when crossing directly across the street. Approaching on an angle would let him change course to avoid being struck, rather than having to stop. Finally, it appears that the average driver maintains a greater clearance from cars parked at an angle (2), and this improves his view of pedestrians entering from the parking side.

Because this is an innovative countermeasure, it offers greater potential as a solution to a stubborn problem but at the same time will evoke some resistance because it disturbs commonly accepted ways of handling on-street parking. Some legitimate questions can be raised that should be answered relative to traffic flow, parking accidents, and public acceptance. Previous reports about accidents and diagonal parking have dealt with its use in business areas rather than the kind of application suggested here. The data were gathered 20 to 35 years ago. (Changes in vehicle design and driving habits could change present-day results.) Although they showed a reduction in parking accidents when parallel parking replaced diagonal, most studies had no controls or insufficient baseline data for drawing firm conclusions about the cause. The effect of parking redeployment on parking accidents can and should be determined. However, even if this countermeasure were to increase auto-with-auto accidents, it still might be worth it. (A trade of personal-injury accidents for property-damage accidents appears to be generally acceptable.)

With respect to traffic flow, Johnston (2) has reported that for angle parking it takes the average driver 12 seconds to back out of a stall and proceed forward in the traffic lane; for parallel parking the average driver takes 32 seconds to back into a stall and clear the traffic lane. For the 85th percentile, maneuver time was 17.4 seconds for angle and 53.5 for parallel parking.

Another innovative potential countermeasure also deals with the problem of the child dart-out who runs into the street looking straight ahead and fails to detect the threatening vehicle. The measure requires the cooperative efforts of educators and engineers. It consists of special training and curb marking in high-incidence areas to condition children to look toward traffic as they approach the curb. This is different from education in the traditional sense, since the special training is aimed at conditioning an automatic physical response or habit—turning the head—rather than trying to get the child to think of what to do as he is running out into the street.

The special curbside markings would provide the trigger to set off this automatic response and help to maintain the habit. Alternating colored diagonal stripes facing at a 45-degree angle toward the traffic is a possible marking. The heavy incidence of child dart-outs in high-density center-city residential areas helps to localize this application. It is hoped that future research will permit an accurate pinpointing of the high-risk streets.

Other countermeasures that would be helpful for this type of accident are (a) prohibition of street parking, (b) off-street parking and play areas, and (c) sidewalk parks with fences.

DART-OUT, SECOND HALF (9 PERCENT)

The second-half dart-out is the same as the dart-out described for the first half except that the pedestrian covers half of a normal crossing before being struck. A third of these cases occurred in commercial areas. The basic characteristics of the situation were very similar to the first-half dart-out but not quite as extreme. For example, 77 percent of the pedestrians were under 14 (versus 87 percent); 69 percent of the cases had speeds below 25 mph (versus 85 percent); 52 percent were in residential areas (versus 72 percent); 74 percent were mid-block (versus 87 percent); and 72 percent were in the daytime (versus 80 percent). Differences were greater with respect to specific location: 34 percent of the streets were under 40 ft across (versus 74 percent for first-half dart-outs), and 17 percent of the pedestrians were 10 or more blocks from home (versus 5 percent for the first-half dart-outs). Thus the second-half dart-out is generally similar to the first-half dart-out, but his running and driver-detection failures as a result of traffic come into play more often, and the accidents happen on wider nonresidential streets as well as on the narrower residential streets. The pedestrian may be watching traffic, although he still does not detect danger in time. In commercial areas with on-street parking meters, small fences or railing extending out a few feet from either side of the meter post could combine with parked cars to form a barrier to prevent dart-outs.

INTERSECTION DASH (9 PERCENT)

The intersection dash category covers cases similar to dart-outs with regard to pedestrian exposure to view, but the incident occurs in or near a marked or unmarked crosswalk at an intersection. One of the predisposing factors identified for the intersection dash was the inducement to pedestrian risk-taking coming from the traffic signal. The pedestrian is wrong to cross against the light. He should wait until he has the proper signal, but it is apparent that some will become impatient when they must wait. In some locations, longer-than-usual waiting periods are involved in order to move heavy traffic volumes. However, it must now be recognized that this may induce pedestrians to take

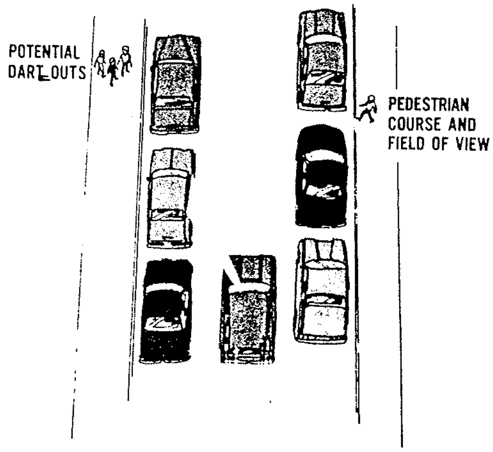


Figure 1. Typical first-half dart-out type of accident.

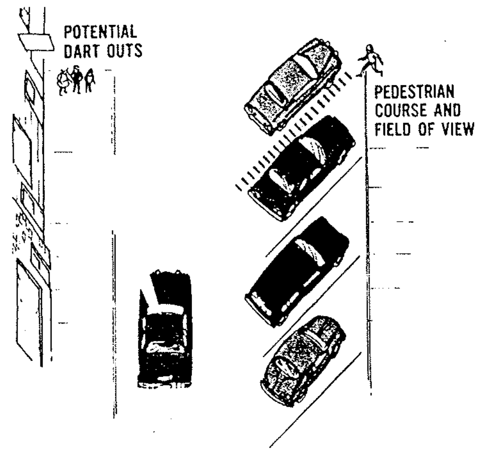
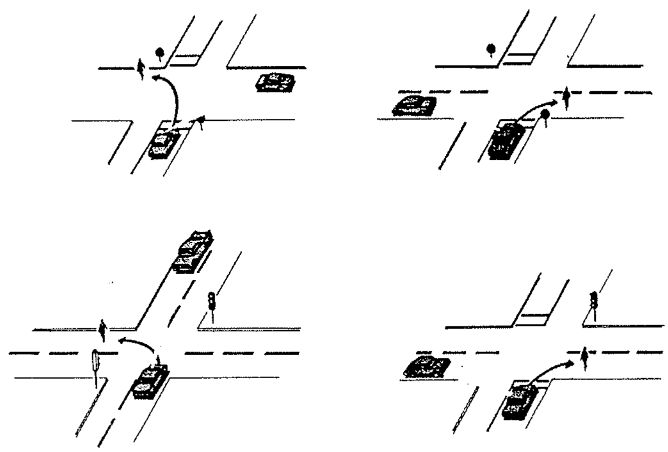


Figure 2. Redeployment of parking to counter dart-out accidents.

Figure 3. Examples of vehicle turn with attention conflict.



risks because they are impatient. Standard time periods cannot be recommended on the basis of this study. The best specific treatment will depend on the individual nature of the intersection and its vehicle and pedestrian volumes. It is recommended that local traffic engineers review intersections with the longer pedestrian waiting periods, especially in commercial and multifamily dwelling areas surrounding the central business district, and consider the following possibilities.

1. Reset cycles to bring pedestrian waiting time in line with the norm, or lower if other considerations permit.
2. If rush hour volumes do not permit complete retiming, reduce pedestrian waiting periods during nonpeak hours (two-thirds of intersection dashes occurred before or after the 4:00 p.m. to 6:00 p.m. rush period).
3. Provide a signal indicating the waiting time remaining to green. This could be a numeric countdown signal giving the seconds remaining, but need not be; color codes or 10-second intervals could be used. Such a signal could be integrated with the wait-walk type pedestrian signals.

MULTIPLE THREAT (3 PERCENT)

The pedestrian is struck by car x after other cars blocking the vision of car x stopped in other lanes going the same direction and avoided hitting the pedestrian. For example, cars in lanes one and two stop and permit the pedestrian to cross, but car x in lane three going in the same direction hits the pedestrian as he steps out in front of the car in lane two. This multiple-threat type also occurs with cars starting from a signal. Most pedestrians were watching traffic but not the collision vehicle; 42 percent were running, and 42 percent were walking normally. More than 60 percent of the pedestrians were in a crosswalk. More than half did not recognize the need for evasive action; 38 percent did just prior to impact. Most drivers were looking ahead (74 percent) and proceeding at sustained speed (58 percent) prior to the accident. However, 19 percent were slowing down, 14 percent were stopped or proceeding from a stop, and 11 percent were accelerating. Some 21 percent did not recognize the need for evasive action, and 63 percent did just prior to impact. Pedestrian age was spread out: 39 percent were under 15, 32 percent were between 15 and 35, and 20 percent were over 60. Most incidents occurred in daytime (84 percent), in commercial areas (65 percent), and at intersections (80 percent). As to the locations, 53 percent had no traffic control, 7 percent had a stop sign, and 38 percent had a traffic signal. Speeds were not high (88 percent under 30 mph).

Stop line modification is a countermeasure directed primarily at multiple-threat accidents occurring at signalized intersections in commercial areas. To reduce the incidents where cars stopped at the stop line obscure the view from the striking car, a wide stop or limit line should be placed a number of feet ahead of the crosswalk. Although specific design would depend on a number of factors at the particular location, the objective is to stop the cars far enough back so that a pedestrian in the walk is likely to be noticed by cars other than the ones facing him. The recommendation given by the Manual on Uniform Traffic Control Devices for a stop line about 4 ft in front of the nearest crosswalk may not go far enough. This countermeasure might also be used at nonsignalized intersections, but the specific location of the stop line would have to take into account the need for the driver to see cross traffic if it is not controlled.

VEHICLE TURN OR MERGE WITH ATTENTION CONFLICT (7 PERCENT)

The driver is turning into or merging with traffic; the situation is such that he attends to the traffic in one direction and hits the pedestrian who is in a different direction from his attention. A critical feature is that the attention conflict is built into the situation. Usually the driver directs his attention in a given direction to determine an acceptable gap into which he will enter. Figure 3 shows some of these situations. Pedestrian age was strikingly different from the typical pedestrian pattern, as were some other characteristics. Only 5 percent of the pedestrians were under 15 years, whereas more than half were 55 or over. Although 60 percent of the cases occurred between 1:00 p.m. and 8:00 p.m., they were spread much more evenly than usual over the normal waking hours; 71 percent were during daylight hours, 73 percent were in commercial areas, and practically all were at intersections. Of special interest is the finding that 55 percent of the cases occurred at locations with red, green, and amber signals, and an additional 23 percent occurred at signalized locations where right turn on red was permited. Pre-involvement speeds were quite low—83 percent were 15 mph or less.

Right-turn attention conflict reduction is one countermeasure aimed at reducing the numbers of this type of accident. It involves the review of intersections in commercial areas with the objective of removing the basic attention conflict situation for the driver by selecting one of several possible actions. Some of these actions are

1. Removal of right turn on red;
2. Signalization of intersection;
3. Controlling cross traffic by stop sign;
4. Effecting one-way traffic on street to right, coming from the right;
5. Erecting pedestrian barrier if right turn on red is needed; and
6. Introducing pedestrian-only signal phase.

The first two possibilities could remove the need for the driver to look to his left to identify an acceptable gap while turning right. The barrier in effect removes the crossing conflict, andpedestrian-only phase gives the pedestrian an opportunity to cross between the cars turning on the green and on the red. Once again the specific action requires location study.

The problems and actions for left-turn attention conflict reduction are the same as for the right turn with one difference. The left-turn problem also includes the situation in which a driver is proceeding on the green and must select a gap in oncoming traffic in order to make his left turn. Additional actions to be considered are

1. Prohibition of left turns;
2. Use of left-turn-only arrow (protected from oncoming traffic); and
3. Use of leading or lagging green with notice to driver.

There are two other general pedestrian accident countermeasures that apply to this type as well as to other types that occur at signalized intersections; they are (a) pedestrian threat information and (b) crossing simplification.

Pedestrian Threat Information Content

The use of pedestrian signals is growing, andthe information provided by the common "walk-don't walk" signal is minimal. The fact that "don't walk" does not mean that at all is probably not serious because people can be expected to learn that it means "don't leave the curb." However, the signals give advice rather than information, and many people do not accept advice.

The red signal to a driver gives him advice and information. It not only tells him that he is legally advised not to go; it also tells him that someone else is being told to proceed across his path. For the pedestrian, however, "walk" is only advice. Vehicles may or may not be told to cross his path at the same time. Of the 13 cities in our data base, only in Denver was it noted that the removal of "don't walk" (followed by no pedestrian signal) meant it was permissible to cross, but one was subject to some legal vehicle threat. In Denver, "walk" means that no vehicles are permitted to cross the pedestrian path.

The pedestrian should be given better information about the threat he faces at a signal. He could be informed of the three basic conditions, (a) heavy, fast-moving, or direct traffic flow across the pedestrian path, (b) turning and/or lighter traffic across the pedestrian path, or (c) no legally permitted traffic across the pedestrian path.

These conditions are somewhat comparable to red, green, and amber (RGA). Perhaps the pedestrian should have a distinct RGA, obviously different enough not to be confused with the vehicle signal (e.g., a sign that flashes "pedestrian" in the appropriate color).

Crossing Simplification

Many of the countermeasures discussed have the effect of simplifying the crossing situation. It would be expected that the fewer directions from which threatening traffic can arrive, the more likely it is the pedestrian will be able to handle the situation. The positive effect of one-way streets in simplifying pedestrian crossings, reducing pedestrian accidents, and improving traffic flow is documented elsewhere (3) and is apparently not disputed. The existence of many two-way streets, however, makes it desirable to call attention to this measure once again.

Another approach to crossing simplification is the use of non-intersection pedestrian crossings. This would reduce the threat from turning vehicles. Mid-block signals and corner pedestrian barriers might be required. Difficulties with traffic flow might make mid-block signalization difficult, but it may be feasible in some locations. A crossing some feet in from the intersection would mean that a pedestrian only has traffic coming from his side rather than from behind on his side and in front on his side. Again, this approach is suggested for further analysis and testing rather than immediate implementation.

BUS-STOP RELATED (3 PERCENT)

Bus-stop-related accidents include cases in which the location or design of the stop appears to be a major factor in the causation; e.g., the pedestrian crosses in front of the bus standing at a stop on the corner, and the bus blocks the view of cars. It does not include those cases that may be considered as exiting from a vehicle, nor does it include cases in which the stop is only an attraction or distraction. Our data support those who have recommended "far side" bus stops. It is suggested that bus stops be located at the far side of the intersection to minimize visual interference. One city in the study had no bus-stop-related accidents. Upon investigation it was determined that over 90 percent of its bus stops had already been relocated to the far side.

CONCLUSION

Pedestrian accidents are a serious and growing problem. A study of the specific circumstances and events of pedestrian accidents has indicated some promising solutions. Those involved in traffic engineering in our cities can reduce pedestrian deaths and injuries by testing the application of these proposed solutions. Their efforts will be easier, and most effective, if they work with police, educators, and other members of a local team.

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PEDWAYS VERSUS HIGHWAYS: THE PEDESTRIAN'S RIGHTS TO URBAN SPACE

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•TRANSPORTATION has always been a determinant of urban structure. Many of the cities of the past were characterized by their more human qualities because their design was based on walking as the primary means of internal transport. For example, the buildings and monuments of the Acropolis, the upper city of ancient Athens, were said to be placed in such a way that when approaching it on foot it could be viewed as a unified whole but with each building and monument still individually discernible and not interfering with the other.

The ancient Romans and Hebrews recognized the disruption to scale caused by vehicular intrusion. Julius Caesar decreed that heavy wagons be forbidden within the central city after dusk. The Forum of Pompeii (Fig. 1) was an extensive pedestrian precinct protected by large slab-like stone barriers placed at all entrance points to prevent intrusion by vehicles. The Talmud, the Hebraic book of laws, decreed that special areas be set aside along main thoroughfares for pedestrians to unload their burdens and rest. These areas were to be clearly marked and separated from vehicular intrusion by a perimeter of metal spikes or stone bollards.

Medieval city planners recognized the need for human communication and interaction by providing a central pedestrian plaza. It was designed as an open space to serve and visually complement the cathedral and other important buildings located around its perimeter. The plaza was the marketplace, a place for public pronouncements, religious and festive occasions, and recreation. The size of the plaza was a function of the number of people who might come together for these purposes.

The human comfort and convenience of pedestrians also were not overlooked by medieval planners. Pedestrians were protected from the elements by gallerias, canopies, colonnades, and porticos. The old city of Bologna (Fig. 2) has a 20-mile network of sidewalks covered by porticos that provide a cool, dry, pedestrian way in the summer and are free from snow in winter. This latter aspect is significant in a mountain town that has its quota of snowstorms. Bologna's system of covered sidewalks has been admired by many famous writers and philosophers for its pleasurable strolling and the native sociability that it encourages. The covered, elevated sidewalk, a feature of some recent pedestrian proposals, also makes an occasional appearence in medieval architecture.

The great Leonardo da Vinci, master of all arts and sciences, recognized the value of a grade-separated system for pedestrian and vehicular traffic. He planned a city with a double network of streets, one elevated for pedestrians, the other at ground level to serve vehicles. Da Vinci the engineer recognized that the most efficient traffic system for both pedestrians and vehicles required separate, continuous networks for each. Da Vinci the artist recognized that the requirements of visual aesthetics could best be satisfied by a distinctive human perspective set above the city's milieu.

There also appears to have been at least some recognition by medieval planners that building floor area should be a function of street width. Medieval cities limited building heights to two times the width of the street. Da Vinci was of the opinion that a ratio of one to one was more desirable. This contrasts with some modern cities where pavement and sidewalk widths have remained constant for a century or more, while building heights have been extended by hundreds of feet. In many of these instances sidewalk space has actually been reduced during this time to facilitate the movement of vehicles.

THE PEDESTRIAN AND THE CITY OF TODAY

The advent of machine transportation has changed the perspectives of city planning, forcing man into an unbalanced competition for urban space (Fig. 3). The railroad made the first great incursions into the city, lacing them with ribbons of steel. But the railroad is confined to its tracks, which can be hidden underground if necessary. The ubiquity of the auto has introduced much greater demands for space, pervading every part of the urban structure, literally confronting man at every turn, causing a vast dichotomy in the goals of city planning and design.

Despite its advantages of personal mobility, the auto is responsible for a great many negative changes in our society. It is a force that has imposed itself on every aspect of urban life, destroying many of the elements that made cities cohesive units dedicated to the social and cultural advancement of their inhabitants. The auto's fumes contaminate the air, and its noises and vibration disturb sleep, conversation, or contemplation. It kills and maims pedestrian man, forcing him to remain constantly alert and vigilant lest their paths cross. It imposes its scale on urban design, requiring the allocation of vast amounts of space for its movement and storage. It isolates pedestrian man in a limited, ever-narrowing sidewalk environment, reducing opportunities for human social interaction and visual enjoyment. It has produced a visual clutter of traffic signals and signs. It is a source of frustration and humiliation to the pedestrian, who is not only forced to wait in the rain and snow while the autoist in his climatized capsule environment enjoys traffic priority, but who may even be honked at or splashed if he does not react quickly enough.

The street and building spaces of the urban core of the typical central business district magnify these problems because of their intensive concentration of pedestrians. The central business district (CBD) is usually made up of variable land uses: office buildings, government centers, shopping and entertainment centers, restaurants, historical sites, and, in some cases, high-rise residential developments. The CBD is the focal point of the regional transportation network and the center of confluence of transit and highways. Walking, because of its infinite diversity, is the only means of transportation that can satisfy the many short, dispersed trip linkages required within the CBD. Downtown origin and destination surveys show that, in most cities, about 90 percent of all internal trips within the CBD are walking trips.

The traditional urban core is usually superimposed on an archaic street system surviving from the land use and functional scale of the past. The street system of the downtown financial district of Manhattan, for example, is a survivor from colonial times, when the tallest structure was of 2 or 3 stories. Now these same streets serve buildings that rise 50 to 100 stories in the air, representing millions of square feet of office space. Thousands of workers and visitors enter and leave these buildings each day, exceeding the capacity of the sidewalk and spilling over into the roadway. In a situation like this, maximum use of sidewalk area and flow capacity is a necessity.

In many high-density central business districts, the sidewalk width has actually been reduced to facilitate vehicular traffic movement. This results in a reduction of pedestrian traffic capacity but does not always produce a commensurate increase in vehicular capacity. The wider streets increase the probabilities of pedestrian-vehicle crosswalk conflicts, which limit the vehicular capacity of the intersection. The potential pedestrian capacity of the CBD sidewalks is reduced further by the intrusion of various sidewalk impedimenta. Refuse cans, fire hydrants, fire alarm boxes, parking meters, traffic signals and poles, news stands, telephone booths, kiosks, mail boxes, planters, sewer and ventilation gratings, and similar devices detract from sidewalk capacity. In addition, building-service operations, such as the unloading or loadings of trucks, inconvenience and sometimes endanger the pedestrian. In many instances, no control has been exercised over the location of fixed sidewalk paraphernalia, and they often appear in clusters at corner intersections, the most critical points in the pedestrian circulation network (Figs. 4 and 5). Space is needed at intersection corners for accumulations of pedestrians waiting for traffic signals and for the weaving of intersecting sidewalk flows. Because of its concentrations of traffic, the corner is the ideal location for news stands, telephone booths, and mail boxes. It is also the most common for bus stops and rapid transit entrances. The pedestrian is further harassed at the corner by vehicles stopped in the crosswalk or turning into crossing pedestrians. When a rapid transit entrance is situated within a narrow sidewalk near an intersection, it is an outstanding example of compounded insensitivity to the pedestrian. Because the sidewalk itself is narrow, excessively narrow subway stairs are provided, causing pedestrian queues both in the transit station below and on the surface above at the point where pedestrian space is already critically deficient. All these factors add up to inconvenience and delay for the pedestrian. But despite the fact that the total amount of pedestrian delay time may far exceed driver delay time within the CBD, traffic signalization is invariably designed to facilitate vehicular flow (Fig. 6).

The rectangular grid pattern of the typical CBD is not conducive to the characteristically short pedestrian trips that occur there. In some instances, the grid pattern of Manhattan's streets requires a time- and energy-consuming 1,000-ft walk for a straight-line trip distance of only 200 ft. Larger mid-block buildings with frontages on adjacent streets are often used as through-routes so that the pedestrian can shorten trip distances. This practice is more common in inclement weather. Depending on city location, one day in four may be too windy, cold, or wet for the pedestrian's comfort. Protection of the pedestrian from the elements is an almost forgotten amenity in most cities.

PEDESTRIAN SAFETY

Each year about 50,000 people are killed by motor vehicles in the United States, and about one-sixth of this total is pedestrians. An additional 150,000 pedestrians are injured annually by motor vehicles. This loss of human life and the suffering caused by these accidents are a serious national problem. The economic cost in salary loss and medical expenses probably exceeds a half-billion dollars annually.

The majority of adult pedestrian fatality victims are persons who have not been licensed to drive. The pedestrian who has never driven faces special hazards because he is unfamiliar with the limitations of the vehicle or driver. He is not aware of the driver's limited vision, particularly at night, nor is he capable of estimating a car's minimum stopping distance at various speeds. The child pedestrian is an especially vulnerable accident victim because of gaps in language, perception, and visual and auditory comprehension.

Many aspects of human perception, such as peripheral vision, depth perception, judgment of speed and direction, and sound recognition, are attained through experience, which the child pedestrian has not yet acquired. This lack of experience causes not only perceptual difficulties but also uncertain reactions under the stress of frightening or unusual confrontations with moving traffic. In addition, children do not comprehend road signs, or, if they do, they do not fully understand their responsibilities to obey these signs.

Reduction of the pedestrian accident toll is a national problem that is being treated at the local level with varying degrees of concern. Although some standardization of pedestrian signs and signals has been recommended in the Manual on Uniform Traffic Control Devices, the manual itself has two standards for pedestrian signals, one for neon tube signs with a green "walk" and the red "don't walk" indication, and the other for incandescent signals with white "walk" and orange "don't walk" indication.

Similar confusion exists in pedestrian signing and traffic laws (Fig. 7). Some states have strong pedestrian right-of-way laws, whereas others do not. Motorists and pedestrians accustomed to signs, signals, and rules in one part of the country may be confronted by significant differences in another. The lack of a uniform national approach to pedestrian safety causes confusion for both motorist and pedestrian and undoubtedly results in unnecessary pedestrian casualties. Pedestrian safety is a problem that crosses all state lines. This requires the establishment of a national system of traffic laws, traffic signalization, and signs implemented uniformly throughout the country, with federal assistance if necessary.

THE HANDICAPPED PEDESTRIAN

An estimated 12 million persons in the United States have serious physical disabilities that limit their mobility and the activities and work that they may do. The seriously

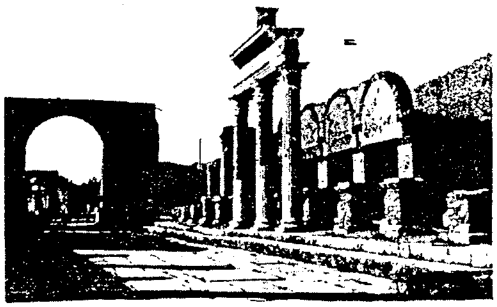

Figure 1. The Forum of Pompeii was an exclusive pedestrian precinct protected from vehicular intrusion by barriers at all entrances.

Figure 2. Covered sidewalks were common pedestrian amenities in medieval cities; this scene is from Bologna, Italy.

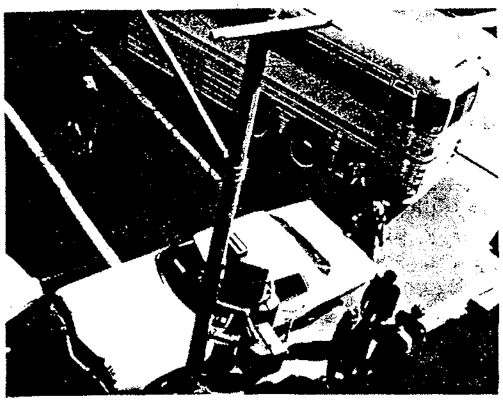

Figure 3. The automobile has forced man into an unbalanced competition for urban space.

Figure 4. The placement of pedestrian traffic flow impedimenta on the sidewalk is virtually uncontrolled in most cities.

Figure 5. This collection of sidewalk paraphernalia literally blocks a pedestrian crosswalk.

Figure 6. Traffic signals are timed for vehicles although total pedestrian delay time in the CBD may exceed vehicular delay.

handicapped include 250,000 in wheelchairs, 2 million orthopedically impaired children, and 5 million cardiac cases. Each year, 100,000 children are born with birth defects that will force them to use crutches, braces, or wheelchairs for the rest of their lives. In addition to these serious disabilities, many millions have minor sight deficiencies or other physical impairments that limit their locomotive capabilities. Added to the ranks of permanently handicapped pedestrians are the aged whose motor capabilities have slowed down, persons temporarily disabled due to accidents, and persons encumbered with baby carriages, heavy baggage, or packages. The ranks of the physically handicapped have been expanding much faster than the general population growth for a variety of reasons:

1. Medical advances have decreased the number of accidental deaths, thus increasing the number of disabled;
2. Longer average life spans have increased the number of aged and infirm; and
3. More leisure time, greater personal mobility, and expanded opportunities for recreation have increased accident exposure for all persons.

Because of thoughtless barriers, many of these persons have been denied opportunities for education, employment, and recreation. Although they comprise a large segment of the public, they have been denied access to many "public" buildings and transit systems. This has relegated many of the aged and handicapped to the status of disenfranchised citizens who are denied access to courts, polling places, or public educational and cultural institutions. There are instances where handicapped citizens have been unable to attend court to defend their own interests.

The common barriers to the aged and handicapped include (Figs. 8 and 9) steps or curbs that are too high; long flights of stairs; inaccessible elevators; steep and narrow walks; gratings in walkways; doors that are too narrow, that revolve, or that are hard to open; too-narrow aisles in theaters, stadiums, and other public gathering places; and lack of accommodations for wheelchairs. In addition, little if any consideration has been given to improving the mobility and safety of the blind and partially sighted by supplemantary auditory or tactile means. Needless to say, every effort should be made to improve the personal mobility and quality of life for these persons subjected to the daily hardships connected with their disabilities. Furthermore, improvements made for the aged and the handicapped are improvements that enhance the mobility of all.

NEW DEVELOPMENTS IN PLANNED PEDESTRIAN ENVIRONMENTS

A number of cities have recognized a need for a return to the human scale of the cities of the past, an increased awareness of the need for human interaction and communication, and realization of the importance of the human sense of belonging to, and relating with, the design environment. All this stems from the recognition that a space should serve its users free of the incoherence and confusion of conflicting purposes.

The London Barbican is an example of one such development. During World War II, bombs devasted a large area adjacent to the downtown section of the city of London. Because of its proximity to the downtown financial district, the area could have been easily reconstructed with high-density office building developments. However, the area is rich in historical importance, dating back to the days of the early Roman occupation. The magnificent dome of St. Paul's Cathedral, designed and built by Christopher Wren after the great London fire of the late seventeenth century, is the dominating landmark in the area.

Instead of more office buildings, the Corporation of London built the Barbican, a combined cultural and residential complex designed to serve the needs of the business district and to preserve the historical significance of the area. The Barbican contains 2,113 flats, maisonettes, and terrace houses for up to 6,500 residents; a 200-room hotel for students and young city workers; the new Guildhall School of Music and Drama; a theater; an art gallery; a concert hall; a cinema; a library; shops; restaurants; and pubs. The development is served by a segregated system of elevated pedestrian walkways (Fig. 10) with roads, truck service bays, and parking below, out of sight of the pedestrian level.

The network of elevated pedestrian ways connects directly with the financial district so that it is possible to live, work, and enjoy all the area's cultural advantages without vehicular conflicts. The elevated plazas have been attractively landscaped, and particular care has been taken to maintain and enhance the vistas of historic St. Paul's. An ancient Roman wall, perhaps 1,500 years old, presents an unusual interest feature at one location. The Barbican is an excellent example of human-scale design and the preservation and enhancement of the sense of place or space image.

Both Montreal and Toronto, Canada, have embarked on programs to establish pedestrian networks beneath their central business districts. The Montreal system began in 1962 with the development of the Place Ville-Marie shopping mall and its associated 42-story office tower. Underground linkages were built between the Place Ville-Marie complex and the nearby Canadian Railway Station and Queen Elizabeth Hotel. The initial small-scale network proved so popular that subsequent linkages were made to other large developments in the area. In 1971, the system totaled approximately 2 miles of connecting pedestrian passageways serving 40 acres of prime office, hotel, and retail space, including 300 underground shops, 50 restaurants, and 2,500 hotel rooms.

The underground network is completely enclosed and climate-controlled in both summer and winter (Fig. 11). This is most appreciated during the rigorous Canadian winter because it allows the pedestrian to avoid the cold and slush above. A reduction in downtown-district pedestrian accidents has also been noted since its inception, which has been attributed to the reduction of pedestrian-vehicle conflicts. Montreal's system is largely unplanned, and there is no overall master plan. Each developer initiates his own plans, and the total network is somewhat deficient because of it. There is also lack of visual relationship with surface elements, which affects the imageability of the system. The city planning department has initiated studies and developed concepts for a more coherent system for the future.

Toronto's underground pedestrian circulation system is less developed than Montreal's, but a completed downtown network is envisioned by 1980. The Toronto concept is similar to that of Montreal, linking major generators such as shopping centers and hotels with transportation nodes. The Toronto system is also dependent on individual developers, but there has been active participation by city planners and partial funding by the city. The Toronto Transit Commission, which owns and operates the Metro system, has also taken an active part in the development, promoting direct linkages to subway stations and major traffic generators in the system. Toronto planners are convinced that the total image of the city and its ability to attract new investment is dependent in a large measure on the ease, freedom, and pleasure with which pedestrians can move about. Profiting from Montreal's experience, they have attempted to increase the imageability of the underground network, opening it to the street environment above. This has limited opportunities for climate control but has contributed to an increased variety of visual experience. Plans for the proposed Metro center, an air-rights development above the Union Station that would have 20,000 residents and 40,000 daytime workers, include provision for visual relationship with the underground pedestrian network. The visual orientation of the pedestrian has been considered in the design of the Center's approaches from the underground network. Outdoor courtyards, entrances, and building shopping ways may all be encompassed in a single gaze.

The cities of Cincinnati and Minneapolis have embarked on programs for aerial walkway networks in their downtown central business districts. Unlike Montreal and Toronto, the two cities have no underground subway system to integrate with, allowing the freedom to choose the less expensive skyway alternative. The overhead systems have the advantage that they can be built quickly, without conflict with underground utilities or surface traffic. Also, the overhead systems allow a clearer visual relationship with the elements of the cityscape. However, the design of aesthetically attractive bridge connections between buildings is a challenge to the architect and structural engineer. Elevated street bridges in Minneapolis have been constructed of prestressed concrete, with finished steel railings and tinted glass paneling enclosures. Maximum

Figure 7. The lack of a uniform national system of traffic laws, signs, and signals undoubtedly causes unnecessary pedestrian casualties.

Figure 8. High curbs and sewer gratings cause difficulties for all pedestrians, particularly the handicapped.

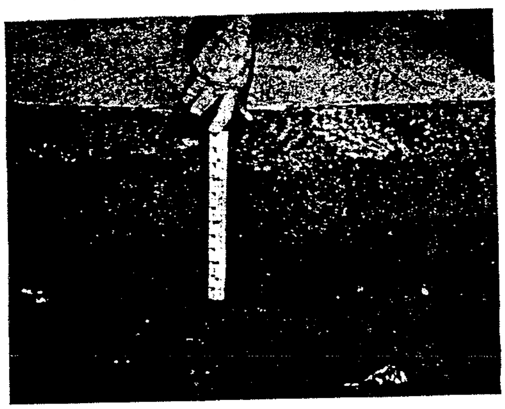

Figure 9. Long flights of stairs make some buildings inaccessible to the handicapped.

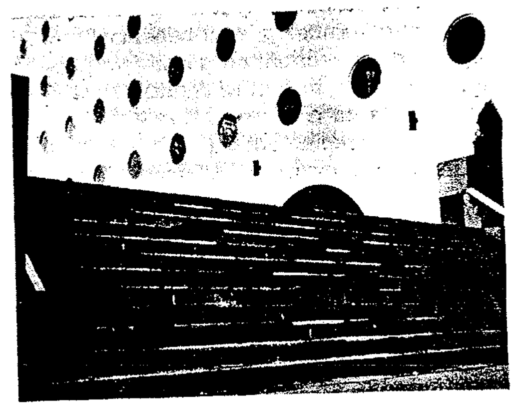

Figure 10. The London Barbican elevated pedestrian system enhances the human sense of place image.

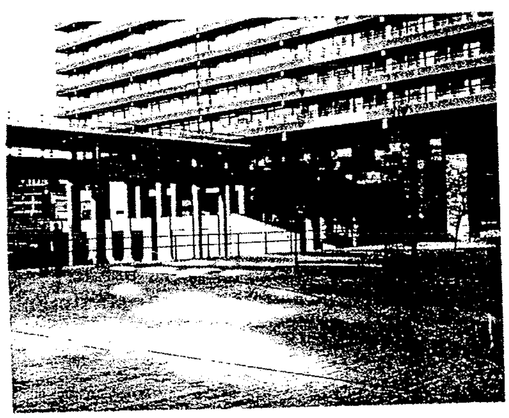

Figure 11. Montreal's underground pedway network provides a functional and attractive pedestrian system protected from the elements.

use has been made of glass and high levels of lighting for security purposes. Although all skyways have not been climate-controlled, provision has been made for this eventuality.

The Cincinnati system interconnects 10 square blocks in the heart of the downtown district. An additional spur serves Cincinnati's 56,000-seat riverfront sports stadium. The Cincinnati skywalk system is being developed with a combination of private, municipal, and federal financing. Plans for pedestrian circulation within the core recognize the need to walk quickly and unencumbered by vehicular conflict between major pedestrian traffic generators. The second-level walkway system connects the city's retail section and a showcase concentration consisting of the convention hall and hotels on the west, the office building concentration on the east, and the riverfront stadium on the south. An added moving walk linkage to the stadium has been considered because of long walking distances from the CBD. The city's plans include provisions for additional grade-level improvements for pedestrians, with arcading of building fronts, widening of sidewalks, and the improvement of street furniture design. A pedestrian mall containing Cincinnati's historic Tyler Davidson Fountain is designed as the central focal point of the development.

The elevated connection to the riverfront stadium has proved to be one of the most valuable links of the system. Originally intended to make downtown parking available to stadium spectators because of a parking capacity deficiency at the stadium itself, it brings large numbers of these persons into the downtown area during sporting events. This has significantly increased downtown restaurant and shopping business volumes on these days.

Minneapolis has the distinction of being one of the most people-oriented cities in the United States. Its famed 8-block-long Nicollet mall is an outstanding example of the development of a prime retail street into a visually exciting pedestrian precinct where private vehicles are banned. Although the Nicollet mall development is significant by itself, the ambitious skyway plan of Minneapolis has received much more attention. It is expected that, by 1985, 64 pedestrian bridges will connect 54 blocks of the downtown CBD. An additional 13 blocks will be joined by underground concourses.

Minneapolis city officials began studying elevated walkway systems as early as 1958 but literally could not get the development "off the ground" because of merchants' concern for potential loss of business from street-level stores. Finally, a few private developers thought that such a system would be economically feasible and proved their point when the first skyway was built in 1962 as part of the Northstar Center development. Property values immediately soared in the vicinity of the Center, persuading a number of businesses to remain downtown instead of moving to the suburbs. Five more skyways were privately financed and built, linking a total of 16 downtown buildings.

Instead of decreasing rental values, the skyway and arcade system increased the rental receipts of the second level of the connecting building so significantly that the second-level rates now approximate the rates on the street floor, without lowering street-floor values. Costs of skyways have been surprisingly low, averaging about $100,000, split between owners on each side of the street. Remodeling of second-story arcades has proved to be more expensive than the skyways themselves, but these costs are substantially less when the arcade is included in original construction.

The guidelines for the skyway system development adapted by the Minneapolis Planning and Development Department include provisions for adequate walkway dimensions, pedestrian comfort, security, and imageability. Minimum clear walkway widths are set at 12 ft, and preferably 20 ft, for connections to major traffic generators. Minimum headroom is set at 8 ft. Unobtrusive design is recommended for all skyways with a use of glass and high lighting levels for "openness" and security. Pedestrian access and use of the system are to be facilitated by good signing, and arcades will make use of multilevel courts and open spaces to visually link the street with the second-level system. Every effort to introduce interest and variety along the route of the system is advocated. Standardized structural design and details are recommended to simplify skyway construction and reduce costs.

These examples indicate what can be done with a dedication to improvement and enhancement of the rights of the pedestrian to urban space, with the concomitant benefits of improvement of the human qualities of the urban environment.

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CAR-FREE ZONES AND TRAFFIC RESTRAINTS: TOOLS OF ENVIRONMENTAL MANAGEMENT

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With the current emphasis on pure environment, there is likely to be a growing public pressure for curbing traffic in central urban areas. Available experience shows that traffic bans are operationally feasible and commercially successful. The paper also relates the effect of vehicle-free zones on air pollution levels.

•ALTHOUGH pedestrian streets have existed in cities for a number of years, it was only in the late 1960's that the idea of creating traffic-free environments in central urban areas really gained momentum. Within the last several years the number of cities that have introduced motor vehicle bans (experimentally or on a permanent basis) has grown impressively. In Germany alone 28 cities have created auto-free zones since 1967 (1). Large numbers of pedestrian areas have also sprung up in Dutch, British, and other European towns (2-5). Perhaps the most widely publicized efforts have been those of Tokyo, Rome, and New York City. Each of these cities has excluded traffic on a part-time experimental basis from portions of busy central areas: Tokyo from the Ginza, Shinjuku, Ikebukuro, and Asakusa districts; Rome from a number of its most famous piazzas; and New York City from midtown sections of Fifth and Madison Avenues (6-10). A complete listing of cities with vehicle-free zones is given in the Appendix of this paper.

Rising public concern about the declining quality of the urban environment has played a major role in paving the way for these initiatives. To be sure, architects and urban planners have long argued in favor of reducing the conflict between the pedestrian and the motor vehicle. As far back as 1962 Victor Gruen, for example, advanced a far-reaching proposal to turn the central core of the city of Fort Worth, Texas, into a vehicle-free area. But such plans found little response at a time when the public was freshly discovering the wide range of opportunities that come from owning an automobile. Today, mounting congestion and an increased perception of the auto's undesirable effects on the environment have somewhat qualified people's enthusiasm for the car and made the public more receptive to automobile controls.

In the United States, in particular, concern about urban air pollution has given rise lately to widespread public sentiment in favor of curbing the use of the motorcar in the city. This sentiment has been echoed even at official levels: Both the Secretary of Transportation and the head of the Environmental Protection Agency have recently spoken in favor of auto restraints (11-13).

EFFECT ON AIR POLLUTION LEVELS

Such evidence as is available indicates that traffic bans are indeed an effective means of lowering the levels of air pollution—at least locally, at street level. In New York City the closure of Madison Avenue to traffic in the spring of 1971 resulted in the reduction of CO concentration levels from 22 ppm to 8 ppm (14, 15). The recently introduced ban on cars in the inner city of Vienna has lowered carbon monoxide levels by 54 percent and lead levels by 67 percent (1, 16, 17). In Tokyo auto exclusion produced equally impressive results (Table 1).

Further evidence of the effectiveness of traffic restraints in reducing vehicular pollution concentrations has recently become available from the city of Marseilles.

During the period October 7-27, 1971, Marseilles conducted a series of large-scale experiments in traffic restrictions of unprecedented scope. A total ban on parking was imposed in the central area of the city, covering some 24 hectares (about 0.25 km^2), and 9 km of exclusive bus lanes were added to the existing bus lanes to improve public transport service. All public transport was made available free of charge during one day to test ridership response to free service. During the first phase of the experiment (October 7-16) all automobile traffic with the exception of taxis was excluded from the central area. During the second phase (October 17-27) car traffic was allowed, but strict enforcement of the no-parking ban was maintained (18).

Air quality in the experimental area was monitored throughout the experiment. The results are given in Tables 2 and 3. These results show convincingly the beneficial effects of traffic reduction on air quality.

However, car-free zones are not by themselves a complete answer to the vehicular air-pollution problem. Air quality in the city is influenced by two separate phenomena: the street-level pollution, high in concentration but localized in nature, and the less concentrated but more widespread pollution consisting of a mixture of vehicular exhausts and pollutants from stationary sources that in certain circumstances build up as a blanket over the city and, in the presence of sunlight, produce secondary photochemical products known as oxidants (smog).

Exclusion of vehicles effectively reduces street-level concentrations of pollutants, particularly carbon monoxide, in the immediate area; it will contribute little to improving the overall urban air quality, which is a function of emissions from thousands of vehicles spread throughout the metropolitan area (19).

In most cities, however, airborne pollutants are subject to relatively rapid dispersion and mixing and do not tend to build up as an envelope over the urban area; the main problem is how to reduce local pollutant concentrations in the street environment. In such cities, strategies involving auto-free zones and other measures tending to reduce vehicle activity in pollution-prone areas deserve careful attention as an alternative to source control.

PRESERVING THE CITY CENTER

Reinforcing the environmental concern has been the desire to preserve the historic character of the city center and to maintain its economic preeminence within the metropolitan area.

In Europe, in particular, the historic quality of the city is regarded increasingly as being threatened by the invasion of the automobile. In Paris, for example, a partial ban on traffic in the historic Ile Saint-Louis was introduced primarily to preserve the ancient character and historic ambiance of that area. The move was endorsed by the residents of the island but met with strong opposition from local restaurant owners. Today the ban is only weakly enforced (20).

Steps to exclude cars from historic squares and streets in a number of European cities—Place de Furstemberg and Rue Mouffetard in Paris; Piazza Navona, Piazza Fontana dei Trevi, and Piazza Maria di Trastevere in Rome; Getreidegasse in Salzburg; Rue du Gros-Horloge in Rouen; and the centers of Florence, Perugia, and Verona, for example—were also motivated primarily by the desire to preserve the heritage and beauty of the historic city center.

The predominant motivation for traffic bans, however, has been the wish to enhance the commercial and aesthetic appeal of the inner city and to create a more livable environment for those who live or work there. It is widely believed that a traffic-free environment makes walking more pleasant. An area from which the auto has been excluded, therefore, is likely to attract more shoppers and strollers, be able to resist more effectively the competition of outlying shopping centers, and contribute toward a healthier, more viable city core.

This has been the avowed rationale behind the creation of car-free zones in the centers of a number of cities and towns: Norwich, Coventry, Leeds, and Bolton in the United Kingdom; Bremen, Stuttgart, Cologne, Hanover, and Munich in Germany; The Hague and Eindhoven in the Netherlands; Columbus, Ohio, and Minneapolis in the

Table 1. Impact of auto exclusion on air pollution in Tokyo.

Sampling Station	ppm of CO Before	After	Remarks
Ginza			
Okura Building	14.2	2.9	Average of 5 hourly readings (1 p. m.-6 p. m.)
Victor Building*	5.5	2.4	
Gas Hall	5.4	2.3	
Shinjuku			
Kome Theatre	2.2	1.2	Average of 8 hourly readings (11 a. m.-7 p. m.)
Yamaichi Sec. Bldg.*	9.8	2.3	
Electro-board	11.3	2.3	
Ikebukuro			
Parco	9.5	3.5	Average of 7 hourly readings (12 noon-7 p. m.)
Seibu Dept. Store	6.7	3.0	
Sumitomo Bank	5.7	4.2	
Asakusa			
Rokku	1.7	1.9	Average of 9 hourly readings (10 a. m.-7 p. m.)
Ward Office Branch	3.2	2.2	

Source: Traffic Division, Metropolitan Police Department, Tokyo (courtesy of Shinji Nishida, Chief, Traffic Regulations Section).
Before: July 26, 1970 (wind velocity: 3.9 m/sec).
After: August 2, 1970 (wind velocity: 3.3 m/sec).
*Survey by automatic recorder; in all other locations, hourly sampling and analysis by infrared method.

Table 2. Effects of traffic restraints on air pollution in Marseilles, by location.

Sampling Station	ppm of CO Before	After (1)	After (2)	Remarks
Banque Italienne	19.3	3.9	12.9	Average of 7 readings per day at each location (8 a. m.-6 p. m.)
Dames de France	19.4	2.8	10.9	
Magasin Général	17.5	3.8	10.4	
Belle Jardinière	18.9	4.0	12.1	
Mean value	18.8	3.6	11.6	

Source: Association pour la prévention de la pollution atmosphérique, Comité Marseille-Provence.
Before: Sept. 13-Oct. 6, 1971; total of 1,138 samples taken at 2-hour intervals.
After (1): Oct. 7-16 (total ban on parking, partial ban on vehicular traffic with buses and taxis allowed); total of 496 samples taken at 2-hour intervals.
After (2): Oct. 17-27 (total ban on parking, no ban on traffic); total of 502 samples taken at 2-hour intervals.

Table 3. Effects of traffic restraints on air pollution in Marseilles, by time of day.

Time	ppm of CO Before	After (1)	After (2)	Remarks
8 a. m.	20.2	5.5	18.9	Average of readings at 4 locations
10 a. m.	19.8	3.3	15.7	
12 noon	14.7	3.6	9.7	
2 p. m.	14.2	2.7	9.4	
4 p. m.	19.8	3.3	12.8	
5 p. m.	20.3	2.9	7.4	
6 p. m.	22.3	4.1	7.0	

Source: Association pour la prévention de la pollution atmosphérique, Comité Marseille-Provence.
Before: Sept. 13-Oct. 6, 1971; total of 1,138 samples taken at 2-hour intervals.
After (1): Oct. 7-16 (total ban on parking, partial ban on vehicular traffic with buses and taxis allowed); total of 496 samples taken at 2-hour intervals.
After (2): Oct. 17-27 (total ban on parking; no ban on traffic); total of 502 samples taken at 2-hour in-intervals.

United States; Klagenfurt, Zurich, and many others. This also appears to be the rationale behind the recently disclosed plans to close off Bond Street in London to traffic and to convert Madison Avenue in New York City into a "pedestrian transitway" (21-26).

Available evidence indicates that traffic bans do indeed have a positive effect on retail sales. In Vienna shopowners reported a 25 percent to 50 percent increase in business in the first week after the traffic ban went into effect. In Norwich all but two shops in the exclusion area did more business, some experiencing an increase in sales of 10 percent or more. In Essen the increase in trade has been reported to be between 15 percent and 35 percent depending on the type of shop; in Rouen, between 10 percent and 15 percent. In Tokyo, of 574 shops surveyed, 21 percent showed an increase in sales, 60 percent no change, and 19 percent a decrease; 74 percent of the merchants interviewed pronounced themselves in favor of the scheme. The popularity of vehicle exclusion among shopkeepers has been graphically demonstrated in the city of Florence: "Some shopkeepers on the first traffic street on the south of the zone went on strike to press demands that the car ban be expanded to include their street" (27).

THE PITFALLS OF SMALL-SCALE PROJECTS

The scale of past efforts to create auto-free environments has been admittedly modest. In most cases vehicle bans have not gone beyond the closure of one street, usually the main shopping street, in the downtown area. Such has been the case in Copenhagen (Strøget), Amsterdam (Kalverstraat, and more recently Leidesestraat), and Helsinki (Aleksanterinkatu). Sometimes traffic bans go as far as to include several shopping streets (e.g., The Hague, Cologne, Essen, Düsseldorf). In some cities efforts have been made to turn such streets into landscaped malls—e.g., in Minneapolis (Nicollet Avenue); Fresno, Burbank, Pomona, and Riverside in California; Ottawa (Sparks Street)—or to have them "face-lifted", as in the case of Rouen's Rue du Gros-Horloge or Northumberland Street in Newcastle upon Tyne (28, 29).

Numerous small pedestrian areas can also be found in new communities and large-scale redevelopments, where they often form an integral part of the master plan.

Small-scale attempts at pedestrianization are not without their critics (30, 31). It has been argued that an isolated pedestrian street or mall will fail to achieve a significant improvement in the environment of an entire city core and that, in any case, in order to be truly effective, traffic bans must be combined with a practical program to solve problems of transportation, parking, traffic access, and circulation:

> Introducing one pedestrian mall into a city core area without taking the necessary steps to improve circulation and to provide automobile storage space only serves to multiply the troubles instead of eliminating them. If a point of attraction is created for the sake of the crowds who for a few days will flock there, and improved accessibility to this new attraction area is not offered simultaneously, those who have been attracted by the mere novelty will be thoroughly disenchanted and will probably never return. Thus, in the wake of an abandoned mall experiment comes an avoidance of the downtown area as a whole, usually greater than before the experiment started (30).

Closing streets to traffic on a large scale, however, soon begins to pose a host of transportation-related problems: fringe parking, improved access, goods delivery, traffic rerouting, and internal circulation. It is probably no accident that existing pedestrian precincts seldom exceed 400 to 500 m in length: This may be the distance it is felt an average shopper is willing to negotiate on foot. Beyond that some mechanized circulation system may be necessary.

AREA-WIDE TRAFFIC BANS

Nevertheless, large-scale projects involving total or partial traffic exclusion have been attempted. The city of Essen, for example, has recently extended its network of pedestrian streets and malls to create a car-free zone nearly 1 km in length and 300 m in width. The Hague and Düsseldorf both possess traffic-free zones that span a total of 2.4 km and 3.4 km of streets, respectively. Copenhagen's Strøget, a highly successful venture in traffic exclusion, is 1,080 m long; a further extension in 1968 has added 300 m of adjoining streets to the pedestrian area. Munich has recently created a large traffic-free zone as part of its vast redevelopment of the city center. Florence has probably gone further than any other city by banning automobiles from a 40-block area in the historic center. By far the most ambitious schemes are those planned by the cities of Vienna and New York. The former is contemplating the creation of a large traffic-free "environmental oasis" with a diameter of about 1.2 km comprising all of the old historic center of the city. Inasmuch as the area would be too large to be served exclusively by movements on foot, non-polluting taxis and minibuses running on liquid gas would be allowed to circulate within the exclusion area. An experimental traffic ban involving a small portion of the inner city (parts of Graben, Kärtnerstrasse, and Stephan Platz) went into effect in late November 1971 (32).

New York is seriously contemplating the conversion of a 15-block stretch of Madison Avenue between 42nd and 57th Streets into a permanent pedestrian mall as an initial step in its ambitious long-range program to improve the quality of the midtown environment. The proposed Madison Mall would be closed to all traffic except regular buses, smaller public transit vehicles, emergency vehicles, and delivery vehicles during limited hours. Extending for a distance of 3 km and including extensive tree plantings, Madison Mall would become the longest pedestrian street and the boldest project of its kind in the world (14, 33-35).

Banning private cars completely from even more extended central areas, however, would require vastly improved public transport service and perhaps also the willingness to accept a reduced standard of accessibility. Certainly, no combination of bus and subway service as we know them today is capable of satisfying all of the transport needs of a large inner city area at the level of accessibility we have been accoustomed to. Perhaps some of the new systems of the "people mover" or "personal transit" variety may someday offer this promise. However, real-world implementation of such systems is at best some time away.

It has also been argued that large-scale bans on cars might be undesirable because of their possible long-term adverse effects on the city:

> The solution to the auto-transit problem involves the delicate balance between technology and humanity that creates a living city. If New York goes too far in preventing use of automobiles and banning them from the city, it is feared that the city will die as those who live there will move out—except for the rich and the poor (a trend already well established). In effect . . . the city would be re-establishing medieval walls, erasing the mobility of modern urban civilisation . . . . One thinks of the empty caverns of Wall Street on Sunday afternoon to illustrate the potential future of a city without people (16).

While it is probably true that some long-run readjustment in land use patterns is bound to occur as a result of large-scale vehicle exclusion, it does not necessarily follow that such shifts would be undesirable. Most affected by the traffic ban would be large-scale business and commercial activities, whose relocation to more outlying places in the metropolitan area could be beneficial in any event. The inner city would gradually resume its original role of fulfilling the needs of people in search of amusement, entertainment, and relaxation and of providing a place where visitors and residents alike can shop, visit museums, or simply sit at a sidewalk café watching the world go by. Viewed in this light, automobile bans cease to have the negative connotation that some would ascribe to them and become a positive instrument for desirable urban change.

At least one city has embraced this point of view. The master plan of Rome envisages shifting major business, administrative, and commercial activity from its present location in the old city to a new center, leaving the classical center to services, hotels, boutiques, tourism, etc. Future traffic restraints in the old city are viewed as a means of discouraging the location of further business activity in the historic center of the city (37).

PARTIAL TRAFFIC RESTRAINTS

Nevertheless, banning vehicles completely from a large central area may simply prove to be politically infeasible. For this reason less drastic schemes—whose objective is not to exclude vehicles but to limit their use—are receiving increasing attention. The cities of Göteborg and Bremen have pioneered in the use of this approach. By dividing the city center into quadrants and by erecting physical barriers between the quadrants, through traffic within the center has been made impossible. Each quadrant has in effect become a self-contained precinct with only local circulation allowed. All other traffic must use a circumferential road, leaving and entering each quadrant at designated locations. Göteborg's experience has shown that this traffic management approach can reduce internal circulation by as much as 50 percent. Although the scheme has been in operation only since August 1970, it has already had a number of beneficial environmental effects: There has been a reduction of 10 percent in accidents; mean concentrations of CO in the central business district have been lowered from 30 ppm to less than 5 ppm; noise levels have gone down from 75 dBA to 72 dBA (38).

LONG-RANGE EFFECTS OF TRAFFIC RESTRAINTS

The city of Bremen is of particular interest because a similar traffic restraint scheme has been in existence there for over 10 years. In 1960 the historic central area, approximately 1 km in length and 600 m wide, was divided into four "cells", and traffic between them was banned. Part of each precinct was turned into a pedestrian area and the remaining streets were made one-way.

In adopting the scheme Bremen's planning officials gave early recognition to Colin Buchanan's concept of environmental management:

> The concept, in effect, is to convert the old city into four "rooms" each with its "doors" from a new external corridor system, instead of each room being in direct communication with the next through a multitude of doors. If this seems a startling concept we can only observe that a policy somewhat on these lines, with the discipline it will involve for motor traffic, seems to be the only way of saving the old city from a descent into such chaos that eventually an irresistible demand will arise for it to be swept away (39).

Buchanan's precept seems to have successfully passed the test of time. A full decade after the introduction of the scheme, the central district remains the city's principal center of activity. Business and commerce not only have not declined, they have grown and prospered. Two major department stores that originally intended to move out of the city center to suburban locations decided to remain in their original location because of improved conditions in the center (40). Whether this has happened because of or in spite of the traffic measures is hard to assess. The fact remains, however, that severe vehicle restrictions have failed over a long run to affect adversely the center city's development or to promote its decentralization. Whether this is due to the peculiar character of the city or whether the experience of Bremen has a degree of universal validity remains to be seen as other cities introduce similar measures.

CONCLUSIONS

With the current emphasis on a purer environment and the "quality of urban life", we are likely to see growing public pressure for curbing traffic in central urban areas.

Available experience shows that traffic bans are operationally feasible and commercially successful. The degree to which they can be implemented will vary widely in different cities depending on such critical factors as the geography and climate of the city; the size, character, and function of the central area; the availability of public transport; the shape of the urban road network; the urgency of the local air pollution problem; and—not the least—people's propensity to walk. It will also depend on the local attitudes and the goals the given city hopes to achieve: A city that actively seeks to preserve a healthy, economically viable center is likely to adopt a different strategy from one that tolerates or wishes to encourage the dispersal of activities to the suburbs.

Total vehicle exclusion is likely to find the widest scope for application in the central districts of small and medium-sized towns, especially ones of historic character, with streets largely devoted to retail commerce. However, even in larger and newer, more automobile-oriented cities whose central districts contain a mix of business, commercial, and service activities, there may be considerable room for trade-offs between accessibility and environmental quality.

Perhaps the most striking merit of the traffic ban is its effectiveness in improving air quality and lowering noise at street level. In countries where the number of cities with serious atmospheric inversion conditions and area-wide pollution problems is too small to justify a stringent national automotive emission control program, vehicle exclusion and partial traffic restraints may offer an inexpensive and effective way for coping with high pollutant concentrations in the micro-environment of the inner city.

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APPENDIX

CITIES WITH VEHICLE-FREE ZONES OR PEDESTRIAN PRECINCTS
(Permanent exclusion of all vehicular traffic except where noted)

Austria

Klagenfurt
Salzburg
St. Pölten
Vienna

Belgium

Brussels[1]
Liège

Denmark

Aalborg
Ballerup
Copenhagen
Federicia
Helsingør
Holstebro
Horsens[1]
Hørsholm
Kolding
Naestved
Nyvøbing
Odense
Randers
Svendborg
Viborg

Finland

Helsinki

France

Amiens[1, 2]
Aix-en-Provence[1, 2]
Avignon[1]
Bordeaux[1, 2]
Cherbourg[1]
Dieppe[1]
Grenoble
Lille[1]
Marseilles[1, 2]
Metz[1, 2]
Mulhouse[1, 2]
Paris[1]
Poitiers[1]
Rouen
St. Etienne[1]
Thionville[1]

Germany

Augsburg
Baden
Berlin
Bielefeld
Bochold
Bochum
Bonn
Braunschweig
Bremen
Castrop Ranxel
Dortmund
Duisburg
Düsseldorf
Essen
Esslinger
Frankfurt
Gelsenkirchen
Hamburg
Hameln
Hanover
Heilbronn
Hildesheim
Itzehoc
Karlsruhe
Kassel
Kiel
Krefeld
Cologne
Lübeck
Lüneburg
Mainz
Munich
Münster
Neuss
Nuremberg
Oldenburg
Osnabrück
Regensburg
Salzgitter
Solingen
Stuttgart
Ulm

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[1]Selective traffic ban (during certain hours of the day or exempting certain categories of vehicles).
[2]Temporary ban.

Wiesbaden
Wolfsburg
Wuppertal
Würzburg
Wilhelmshaven

Italy

Florence
Perugia
Rome
Venice
Verona

Ireland

Cork

Japan

Tokyo[1]

Netherlands

Arnhem
Amsterdam
Apeldoorn
Breda
Deventer
Dokkum
Eindhoven
Enschede
Grovingen
Haarlem
The Hague
Heusden
's-Hertogenbosch
Hilvervn
Maastricht
Meppel
Roosendaal
Rotterdam
Utrecht
Zwolle

Norway

Oslo[1]
Trondheim

Portugal

Lisbon[1, 2]

Sweden

Göteborg[1]
Stockholm

Switzerland

Bern[1]
Geneva
Lausanne[1]
Lucerne[1]
St. Gall[1]
Winterthur
Zurich

United Kingdom

Antrim (N. Ireland)
Bolton
Chichester
Leeds
Liverpool
London
Norwich
Portsmouth
Reading
Southend
Southampton
Watford[1]

United States

Atchinson, Kan.
Cincinnati, Ohio
Williamsburg, Pa.
Columbus, Ohio
Dennison, Texas
Denver, Colo.[1]
Fresno, Calif.
Grand Junction, Colo.
Kalamazoo, Mich.
Knoxville, Tenn.
Miami, Fla.
Miami, Okla.
Minneapolis, Minn.
Montevideo, Minn.
New York, N. Y.[1, 2]
Paterson, N. J.[1, 2]
Pomona, Calif.
Providence, R. I.
Riverside, Calif.
Sacramento, Calif.
Stamford, Conn.
Tulsa, Okla.
Urbana, Ill.
Washington, D. C.[1, 2]

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[2]Temporary ban.

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