to crosswalks at intersections. Tolerable pedestrian delay is the prime criterion on which the proposed warrant is based, and such delay is essentially independent of the crosswalk location. It is recognized that at an intersection a pedestrian must contend not only with cross traffic but also with turning vehicles. Those vehicles turning from the cross streets will be few in number; however, since these intersections require a signal, they will have failed to satisfy the warrants for vehicle volume.

The numerical warrants for both midblock and intersection locations are presented in Figures 7 and 8. Before signals are installed, these warrants should be met or exceeded for 4 h on an average weekday. Alternatively, the warrant could be met or exceeded for 10 h on any weekend if at least 3 h are on the day with lighter volumes. These periods have been selected to correspond to those used for other warrants developed (3) and reflect the typical peaking characteristics of urban traffic.

All signals installed under this warrant should be provided with pedestrian signal heads and pedestrian push-button detectors. Normally these signals should not be flashed. If installed at an intersection location, the installation should be at least semiactuated for side-street traffic. A pedestrian signal installed at an intersection and meeting only the weekend requirements should be fully actuated.

ACKNOWLEDGMENT

This work was sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration of the U.S. Department of Transportation and was conducted in the National Cooperative Highway Research Program that is administered by the Transportation Research Board of the National Research Council.

The opinions and conclusions expressed or implied in the report are ours and not necessarily those of the Transportation Research Board, the National Academy of Sciences, the Federal Highway Administration, the U.S. Department of Transportation, the American Association of State Highway and Transportation Officials, or the individual states participating in the National Cooperative Highway Research Program.

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Publication of this paper sponsored by Committee on Pedestrians.

Knowledge and Perceptions of Young Pedestrians

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The progress of a research study on school-age pedestrians has been previously reported in a paper that dealt with the behavior of drivers in relation to the existing signing at four school sites in three states. That research study has now been completed, and this paper deals primarily with the findings regarding youngsters in the 5 to 14-year-old age group. Data are provided on the accident experience of the young pedestrians and on their behavior, attitudes, and knowledge. Students in sections of the eastern United States were observed walking to school and were then surveyed on their pedestrian behavior and knowledge. Significant differences by age groupings were noted for both the accident data and knowledge responses.

This paper describes a school walking-trip study that was undertaken during the summer of 1973 and completed in the spring of 1975 with the publication of a walking-trip guidebook. The study objective was to develop guidelines for the protection of young pedestrians (ages 5 to 14 years) walking to and from school. These guidelines were based on field surveys of the young pedestrian and the driver regarding designated school zones and specific school-crossing protective devices. The guidelines are described in detail in a companion report (1).

Two sources of information were used to define problems and develop guidelines for safety programs: a review of literature that included accident data and surveys of the knowledge and stated behavior of young pedestrians and of the knowledge and observed behavior of drivers. The accident data were primarily gathered from an urban area and used to determine the magnitude of school-trip accidents and the specific ages of the young pedestrians involved. The student survey was conducted in several states at urban, suburban, and rural schools. The survey techniques used were developed through a series of pilot tests. Materials for kindergarten students were pictorial and involved a story-line approach. Third, sixth, and eighth graders were queried by a self-administered survey that incorporated pictorials and other graphics.

Separate driver surveys were conducted at four school sites in three states. The techniques used for the collection of driver data were developed through a series of pilot tests. The driver was interviewed in his or her vehicle after having driven through the school zone. Driver perception of existing signing was tested, and driver speed through the school area was recorded. The survey format used recall items (free response) rather than recognition items (multiple choice). The driver surveys are not addressed in this paper, and the interested researcher is directed to another report (2).

ACCIDENT PROBLEM

National Accident Data

A report by the National Safety Council (3) provides some general data on the motor vehicle accidents that occurred in 1973, including those accidents that involved school-age pedestrians. Of the 16.6 million U.S. motor vehicle accidents in 1973, there were an estimated 300 000 accidents that involved pedestrians (250 000 urban and 50 000 rural). The age distribution of pedestrians in accidents is provided in terms of a subpopulation of an estimated 120 000 injury accidents. Within this group, there were 58 000 or 48 percent injury accidents to young pedestrians under 15 years of age. Analysis of the pedestrian accident distribution by increments of 10 years of age indicates that the 5 to 14-year-old population represents 38 percent of all pedestrian accidents, and this population has almost four times the number of accidents that any other age group has (3).

Through use of National Safety Council statistics (3), several calculations may be made to provide a rough indication of the accident frequency for school-age pedestrians. Of the estimated 300 000 pedestrian accidents occurring in 1973, there were an estimated 114 000 (38 percent) school-age pedestrian accidents.

Urban Accident Data

Knoblauch (4) provides detailed accident data on 2044 pedestrian accidents from six study cities (Akron and Toledo, Ohio; Miami, Florida; New York City, New York; San Diego, California; and Washington, D.C.). This study indicated that pedestrians between 5 and 14 years of age represented 34 percent of the pedestrian accident data base. The period between 2:00 and 4:00 p.m. represented the highest accident time period for this population. This age group was most likely to become involved in an accident (a) on a weekday, (b) in the first lane of a two-lane road, (c) in a residential area, (d) in an area without traffic controls, and (e) with a car going straight. This age group was also involved in accidents when (a) they did not cross at an intersection or crosswalk (midblock), (b) the driver's vision was blocked by a parked vehicle, (c) the pedestrian was running, and (d) the pedestrian was crossing from behind a parked vehicle.

School Walking-Trip Accidents

For the accident population in Knoblauch's study only the information recorded in Toledo, Ohio, noted whether school was the trip origin or destination for each young-pedestrian accident occurring in 1973. Young pedestrians (5 to 14 years) accounted for 135 of the 285 pedestrians struck by vehicles for cases in which supplementary accident forms were completed by the researchers. It was noted that 43 percent of the young pedestrians were struck between the hours of 8 and 9 a.m., 12 and 1 p.m., and 2 and 4 p.m. These time periods are the basis for most of the calculations of the school-trip pedestrian accidents. The Toledo forms indicated that an actual 17 percent of the young-pedestrian accidents occurred when the students were en route to and from school.

These data are in agreement with previous studies that indicate that 10 to 20 percent of young-pedestrian accidents (5, 6, 7) occur during the school walking trip. When applied to national data, these limits show that the magnitude of the school walking-trip accidents is approximately 10 000 to 20 000 annually for young pedestrians. Most young-pedestrian accidents (80 to 90 percent) occur after school hours near the child's home and within a block of it (5, 6, 7).

In England, Grayson (8) found that, for a group of 420 pedestrians, the journey purpose for 24 percent of the 5 to 9-year-olds in pedestrian accidents and 27 percent of the 10 to 14-year-olds in pedestrian accidents was to or from school (8).

A study (5) was performed by the American Automobile Association (AAA) that provided an age distribution of the students in 1910 school-trip pedestrian accidents. Through these figures and the public school enrollment figures for each age provided by the U.S. Department of Commerce (9), it is possible to calculate a school-trip, accident involvement rate for each age between 5 and 14 years. The analysis reveals that there is a near-monotonic relation between the age and the accident involvement rate for the 5 to 14-year-old population. The youngest students are considerably overrepresented in the school-trip accident data, and the oldest students are underrepresented (Figure 1). The accident rate can be calculated by dividing the percentage of the pedestrian accident population represented in a specific age group by the percentage of the school-age population in that group. For example, the 5-year-olds represent 12.8 percent of the AAA 5 to 14-year-old school-trip accident population. Of the 5 to 14-year-old population enrolled in public schools, the 5-year-olds represent 7 percent. Thus, the school-trip accident involvement rate for 5-year-olds is 1.83 (12.8 ÷ 7).

Young-Pedestrian Exposure and Actions

One hypothesis for the overinvolvement of the youngest pedestrians is their degree of exposure to vehicles as pedestrians; however, this does not prove to be the case. Two studies comparing pedestrian exposure and accident data are those by Routledge and others (10, 11). The analysis of young pedestrians who were observed during a 20-min period after school showed a highly significant increase in exposure (road crossings and traffic density encountered) with age. The risk per road crossing and risk per encounter with a car decrease with age as does the accident involvement rate.

Several studies have characterized the activities of young pedestrians involved in accidents. Marks (12) describes the most frequent actions (comprising over 68 percent of the young-pedestrian accidents) in decreasing order: darting into the street, crossing midblock, and playing in the street. Knoblauch (4) indicates that the most prevalent young-pedestrian actions are as follows:

	Action by Age (%)	
Action	5 to 9	10 to 14
Darting out	42	31
Dashing from intersection	17	18
Dashing from midblock	16	7

Other recurring characteristics involved in accidents in this study are children running, pedestrians not crossing at intersection or crosswalk, and drivers' or pedestrians' vision blocked.

Accident Causation

Although there are many characteristic conditions under which accidents occur, there is little knowledge regarding why these accidents happen. Several previously mentioned studies have suggested various hypotheses for young students' accident proclivities.

Sandels (13, 14), in describing studies performed in Sweden, suggests that the average child does not attain the requisite degree of maturity as a pedestrian until the child is between the ages of 9 and 12. Sandels points out that (a) the diminutive stature of children makes it difficult for them to judge a traffic stiuation; (b) children are incapable of distributing their attention because they concentrate on one thing at a time—often play—or take a vague overall impression; (c) they cannot distinguish between right and left; (d) they have difficulty discriminating the direction of sound; and (e) many children believe the safest way to cross a street is to run. In England, Backett (15) compared 100 children who were pedestrian accident victims with 100 children who were not involved in accidents. The control group was chosen so that both groups were similar in age, sex, school, neighborhood, social class, and distance walked to school. The accident victims differed significantly from their controls by having less parental supervision and by coming from homes and neighborhoods that had fewer play areas. Similar findings were made by Read and Backett and others (15, 16). The following results of the student survey may assist future researchers in analyzing the factors that make almost every accident unique.

STUDENT SURVEY

Development of Survey

A survey of students from primary and secondary schools was devised to provide some basic facts with respect to the students' stated school walking-trip behavior and knowledge that relates to school-trip safety. The objectives of these surveys were to (a) identify the students' knowledge that needs modification; (b) identify the students' behaviors that need modification; and (c) identify the procedures for modification of knowledge and behaviors. The questions addressed by the student survey were as follows.

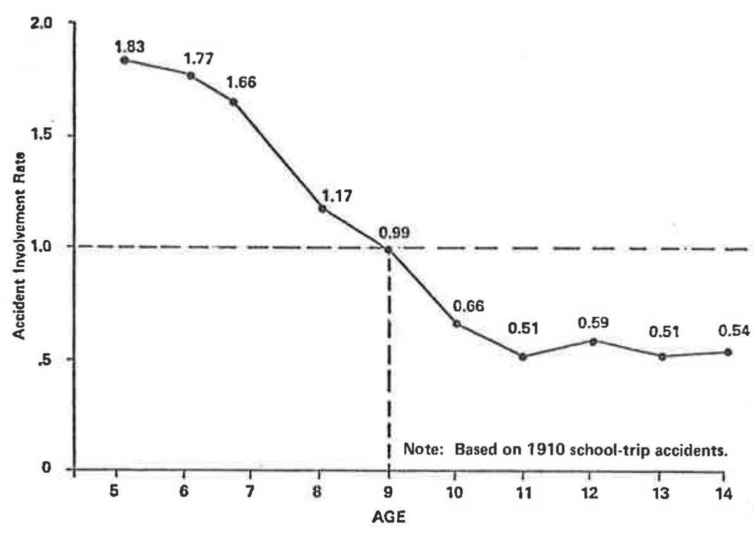
1. What do students know about traffic control devices?
2. What fears do students have in reference to traffic?
3. How do students select their route to school?
4. How do students cross the street?

Based on previous research and on the pattern of young-pedestrian accidents, items addressing each of the above topic areas were generated. Through a series of six pilot tests, the subject matter was shaped into an efficient instrument for soliciting the information required. After each pretest session, a complete review was made. Techniques were devised and items reworded to make the survey clear to children of various ages. Response alternatives were adjusted to include those responses actually used by the children.

The iterative process used in the pilot testing phase resulted in the following modifications being incorporated in the final survey form.

1. The survey was divided into two formats: one for younger children (individual administration) and one for older children (group administration);
2. The questions were portrayed by pictures, a card sorting technique was used for cases in which several choices among response alternatives were desired, and pictorial stickers were used as a mode of response;
3. The wording was changed to use the vocabulary of the children in items and response alternatives; and
4. Stories and familiar situations were used to avoid the possibility of threatening the children.

Figure 1. School-trip pedestrian accident involvement rate of students by age.



Data Collection Methodology

Data were collected on 933 students at schools in Montgomery and Howard counties in Maryland, Fairfax and Prince William counties in Virginia, and New York City. This sample represents students from urban, suburban, and rural schools. The population of interest to this study is school children between the ages of 5 and 14. The student survey was aimed at those students in this age group who walk to school. This group was represented by students in kindergarten (age 5 to 6), third grade (age 8 to 9), sixth grade (age 11 to 12), and eighth grade (age 13 to 14). A minimum requirement of 50 students from each grade was set for urban and suburban schools. In most instances, more than 50 students were surveyed because the questionnaire was administered in the classroom and the class size was generally in the range of 28 to 30 students, which necessitated two administrations per grade per school.

The rural subsample was taken at a school that only included grades one through five. A group of 52 students from third grade was surveyed, and a smaller group of students from fifth grade was tested to provide some basis of comparison by age. Since very few rural students walk to school, transportation mode was not used as a selective criterion for this subsample (Table 1).

To collect data from urban, suburban, and rural segments of the population, officials of several school systems were contacted. The schools chosen met the following criteria:

1. There was a high percentage of walking students;
2. There were an adequate number of students enrolled in the school; and
3. There was voluntary cooperation between the principal and school staff and the researchers in the planning and conducting of the surveys.

In all, 11 schools were selected for the survey sites. A follow-up meeting with the principal of each school was held to ascertain information about the background characteristics of the student body and the surrounding area. Questions such as how far the students had to walk to get to school, whether the students were exposed to major intersections, and what type of areas the students came through with respect to traffic and traffic control devices were asked. This meeting was also used to determine the best date and time for survey administration.

Group interviews were administered in the classroom to about 20 to 30 children in each group. An administrator read the questions aloud while one or two proctors (depending on the size and age of the group) circulated throughout the room to answer questions and check the children's understanding of the procedures (answering each question and checking only one answer per question). The teacher was asked to stay in the classroom during the survey administration. The same administrators interviewed the children in kindergarden individually. In most cases, this interviewing was done outside the classroom so that other children did not hear the questions and so that the child being interviewed was not distracted.

Table 1. Percentage of students in each grade.

Type of Area	Grade K	Grade 3	Grade 5	Grade 6	Grade 8	Total
Urban	4	9	0	9	6	28
Suburban	15	16	0	16	17	64
Rural	0	5	3	0	0	8
Total	19	30	3	25	23	100

Note: N = 933.

RESULTS

Comparisons by Location, Grade, and Sex

In Appendix A of the study final report (2), the knowledge and behavioral survey items of 115 students are compared on the basis of where the student lives, the grade of the student, and the sex of the student. This section represents some of the highlights from that analysis. All the comparisons between groups described in this section were found to be statistically significant at the 0.05 level (two tail). A Z-test of uncorrelated portions was used to test differences. The information (2) should prove useful in the design of future accident-reduction programs, particularly for those programs that orient specific treatments (educational and public information) for different audiences (location, age, and sex).

The results indicate that male students are more likely to travel to school alone and are willing to take more risks than female students. Also, male students are more likely to

1. Go to school alone,
2. Choose a school route because it is the shortest,
3. Run across the street when there is a break in traffic,
4. Cross when the traffic signal facing them is red,
5. Indicate that nothing happens to a child when struck, and
6. Think it is safer to run rather than walk across the street.

However, female students are more likely to

1. Choose a school route because their parents took them that way,
2. Go a different way if told to do so by parents or if the route was safer, and
3. Consider the unprotected corner as the safest crossing location.

In general, the pattern of responses indicates a progression of understanding and capability from the kindergarten to the eighth grade students. The youngest students have less walking exposure, particularly alone, and usually cross at protected locations where there are crossing guards. These students generally do not relate to or indicate an understanding of traffic control devices and safety techniques other than crossing guards.

In relation to younger students, older students (sixth and eighth grade) are more likely to

1. Walk to school;
2. Walk alone;
3. Take the shortest route;
4. Cross streets without guards;
5. Be fearful when it is dark;
6. Take greater risks such as crossing in the middle of the block or running across the street when there is a break in traffic.
7. Cross at crosswalks;
8. Pick the traffic signal as the safest place to cross; and
9. Take a different route only if friends do.

On the other hand, younger students (kindergarten and third grade) are more likely to

1. Take the school bus or be driven by car;
2. Be taken by parents;
3. Take the route that avoids traffic;
4. Cross three or more streets with guards;
5. Be fearful when there are no safety patrols or guards;
6. Cross when the traffic signal facing them is red;
7. Cross at unprotected corners;
8. Pick a crossing with guards as the safest location; and
9. Take a different route to school if told to do so by parents or school officials.

Some comparisons by location have been made in the discussion of general results. In relation to suburban and urban students, rural students are more likely to

1. Cross the street when the traffic signal facing them is red, and
2. Cross the street at an unprotected midblock location.

In relation to suburban and rural students, urban students are more likely to

1. Wait for a traffic light before crossing a street,
2. Run out into the street if no cars are coming or if cars are moving slowly, and
3. Cross the street at an unprotected corner.

In relation to urban and rural students, suburban students are more likely to

1. Run out into the street if they dropped something (ball or paper) in the street,
2. Choose a location where there is a guard because it is the safest place to cross, and
3. Cross at three or more streets where there are crossing guards.

The pattern of responses indicates a progression in pedestrian capability from the kindergarten to the eighth grade students. Several pictorial questions illustrated this capability dramatically. The percentages of kindergarten, third grade, sixth grade, and eighth grade students who indicated that an unmarked corner or a midblock location was safer for crossing than a corner with a marked crosswalk were 43, 21.5, 10, and 9 respectively.

Another indication of the progression of understanding with age was the fact that, throughout the grades covered in the survey, a group of children whose number decreased with age said they would cross the street when the traffic signal facing them was red. The percentages of kindergarten, third grade, sixth grade, and eighth grade students who indicated they would cross when the traffic signal facing them was red were 47.5, 42.3, 26.9, and 23.3 respectively.

A special field study was conducted to verify the findings that concerned traffic signals. The study consisted of two parts. First, a class of 20 students was administered the traffic signal items in a classroom setting. Second, the students were taken by a researcher to a signal-controlled intersection adjacent to the school. At this intersection, the students were asked to face the researcher with their backs to the intersection. They remained standing in this position until the researcher said, "Turn around, look at the traffic light, and tell me when you would cross this street." One-half of the students were asked to turn so that they could view the signal on the red interval, and the other half viewed the signal on the green interval. The students indicated the point in the cycle when they would cross and did not give a color response.

The McNemar test of significance (17), for cases in which subjects are observed twice, was used to test the null hypothesis: The proportion of subjects choosing either green or red as the appropriate traffic signal interval during which to cross the street is not different for the written test and field situations. Through use of the 0.05 probability level, no significant difference was detected between responses in the classroom and field situations. Based on the results from the comparison between the classroom and field traffic signal responses, it appears plausible that the pictorial questionnaire item reflects the school childrens' responses to traffic signals in the real world. It is suggested that other researchers replicate this field study and vary the location (urban, suburban, rural) as well as the age groups tested.

Figure 2 shows the responses of all those students (882) who provided information on their age, how they got to school, and the color of the traffic signal facing them when they would cross the street. It can be seen that, as age increases, a greater proportion of the students will cross on the green signal. This relation between the students' increased knowledge of traffic control devices and age closely matches the decreasing rate of student involvement in accidents: There is a near-monotonic relation between age and accident involvement. Although the students' proclivity toward risk-taking (taking the shortest route, crossing in the middle of the block, running across when there is a break in traffic, running into the road) increases with age, the accident data indicate that this situation may be offset by knowledge of when and how to take risks. This is particularly true in light of the finding of Routledge and others (10, 11) that children's exposure to traffic as pedestrians (going to and from school in England) increases with age between the ages of 5 and 10 years.

The percentage distribution by age of those walking students who would cross when the traffic signal facing them is red has been plotted against the school walking-trip accident involvement rate by age and is shown in Figure 3. This figure is similar to the plots made by Routledge and others (10, 11) that compared risk per road crossing and risk per encounter with a car by young-pedestrian age.

For the youngest students, the accident risk and lack of knowledge concerning traffic control devices should be considered in relation to how those children choose their school routes and who can influence their choices. The survey responses to questions on route choice and route change indicate an increasing independence from parents and an increasing influence of peer group pressure. The percentage of kindergarteners who said their parents had recommended or taken them on their route to school was 61.5. In comparison, the percentages of third, sixth, and eighth grades were 49.3, 26.1, and 7.7 respectively. The most frequent response of the sixth and eighth graders was that they chose their route because it was the shortest.

Similarly, the percentages of kindergarten and eighth grade students who would change their route if their parents told them to do so were 83.8 and 65.2 respectively. The percentages of kindergarten and eighth grade students who said they would change their route if told to by the school were 72 and 41 respectively. The percentages of kindergarten, third, sixth, and eighth grade students who would change their route if friends went another way were 50, 79, 39, and 66 respectively. In the pilot test, when all the students' responses were tape recorded, the percentage of third graders who said nothing would make them change their route was 50. In contrast, the

Figure 2. Respondents' means of transport to school and indication of traffic signal color when crossing, by age.

Means of Transport	Walk			School Bus			City Bus	Train		Car		Bike		Total
Color of Traffic Signal When Student "Would" Cross	R	Y	G	R	Y	G	R	G	R	R	G	R	G	
Age (Yrs.)														
5	34	1	39	2	1	7				13	8			105
6	23	3	24	7		3	1			5	5			71
8	36		61	11	1	4				15	12			140
9	31	1	55	11	1	10	1		1	7	8	3	2	131
11	24		66	10		2				4	14	1	3	124
12	26	1	68	1				1		5	4	1	6	113
13	18	2	76							1	5	1	1	104
14	20		69			1				1	2	1		94
														882

Key: Red, Yellow, Green

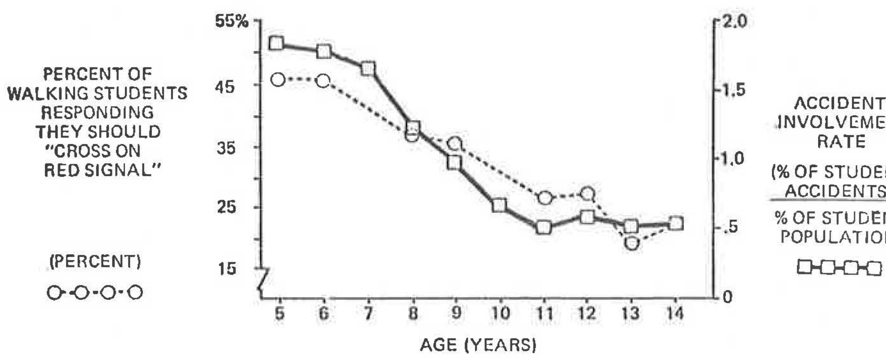


Figure 3. Comparison of student national accident involvement rate and surveyed traffic signal knowledge.

sixth graders in the pilot test most often said they would take a different route if their friends did.

CONCLUSIONS

Significantly more younger students (who need the most help) than older students indicated they would change their route if told to do so by their parents. These results appear to indicate differing influences on the routes of the students at various age levels and may have implications for channels of information to promote change. For example, the parents may be the most useful channel of information for the younger children, while the peer group may have more influence on the older children. A broad safety program (1) that involves traffic engineers, parents, educators, police, Parent-Teachers Association, and the public communications media as well as the students may be effective in reducing shcool walking-trip accidents if applied through a long-range, broad-based program. For the interested reader, the two student surveys and accompanying art work can be found in Appendix A of the final report (2).

ACKNOWLEDGMENT

This paper is based on a study for the Federal Highway Administration of the U.S. Department of Transportation. The opinions, findings, and conclusions are mine and are not necessarily those of the sponsoring agency.

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Publication of this paper sponsored by Committee on Pedestrians.

Abridgment

Pedestrian Signal Displays: An Evaluation of Word Message and Operation

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In 1974, a study was initiated by the Federal Highway Administration to define the problems associated with pedestrians crossing at urban intersections and to evaluate remedial measures aimed at reducing or eliminating these problems. The results of the problem identification phase of the study (1, 2) indicated that pedestrian signal displays were the source of several problems and that certain improvements in the displays could result in a higher level of compliance, safer pedestrian behavior, and better user understanding.

Two problem areas are addressed in the research described here. One problem involved the display of the pedestrian clearance interval. Pedestrians complained that there was not enough WALK (W) time to complete their crossing. They did not understand that a clearance interval was provided for them to complete their crossing before traffic was released. Additionally, some 15 percent of pedestrians hit by vehicles at signalized intersections were crossing against the signal. At 71 percent of 38 site pairs (intersections) that were matched by high and low occurrence of pedestrian accidents in Washington, D.C., the percentage of pedestrians who started crossing during the clearance display was greater than that at the high-accident location. Finally, 40 percent of the pedestrians observed crossing against the pedestrian signal started on the clearance indication, which is the flashing DONT WALK (FDW).

The second problem area centered on the effectiveness of flashing the W indication to warn pedestrians that vehicles might be turning through their crosswalk. A study by D'Angelo in 1973 (3) showed that pedestrians did not understand the intended meaning of flashing WALK (FW) and that an educational campaign produced no change in pedestrian crossing behavior. Observations in the earlier phase of this project confirmed that there was no significant difference in compliance between locations with FW and locations with steady W. The accident data indicated that turning vehicles represented a serious safety hazard to pedestrians. Approximately 25 percent of pedestrian accidents at intersections involved turning vehicles.

STUDY METHODOLOGY

Three experimental conditions were devised to address these two problem areas. In all cases, the experimental condition was compared to the current recommended Manual on Uniform Traffic Control Devices (MUTCD) standard. Experiment 1 compared a steady DONT WALK (DW) clearance indication to the standard FDW clearance indication. The hypothesis was that, if pedestrians were not shown a distinct clearance-interval indication, compliance would increase, undesirable behaviors would decrease, and the need to understand the clearance interval would be eliminated, i.e., W means it is safe to cross, and DW means it is not safe to cross. However, this hypothesis contained a possible flaw. Would the pedestrian understand what to do if he started on the W and the signal changed to DW while he was still in the street?

Experiment 2 was designed to address this question and consisted of a DONT START (DS) message in place of the DW message. The operation was the same as the experimental condition in experiment 1, i.e., a steady DS indication during the clearance and prohibited intervals. The hypothesis was that, when the DS message was displayed, pedestrians already in the street would continue their crossing while those still on the curb would not start their crossing.

Experiment 3 dealt with the second problem area and compared steady W to FW. The objective was to determine whether pedestrians understood the intended meaning of FW and steady W and whether pedestrians behaved differently with the two displays. Figure 1 shows the experimental design.

All three experiments were conducted simultaneously in Buffalo, New York, and Phoenix, Arizona. A before and after study design was employed. Each experiment was conducted at two different test intersections (one central urban and one suburban) in each of the two cities, i.e., 4 intersections/experiment. A 2-month acclimation period was allowed after installation of the experimental condition. One exception was that experiment 3