NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 139

PEDESTRIANS AND TRAFFIC-CONTROL MEASURES

TRANSPORTATION RESEARCH BOARD
National Research Council

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C.

NOVEMBER 1988

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an assurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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NCHRP SYNTHESIS 139

Project 20-5 FY 1985 (Topic 17-11)
ISSN 0547-5570
ISBN 0-309-044-24-3
Library of Congress Catalog Card No. 88-50292

Price: $9.00

Subject Areas
Transportation Safety
Human Factors
Operations and Traffic Control

Mode
Highway Transportation

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Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This synthesis will be of interest to traffic engineers, safety engineers, and others concerned with pedestrian safety. Information is presented on the traffic-control measures being used by states and local agencies to enhance pedestrian safety.

Administrators, engineers, and researchers ae continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Approximately 15 to 20 percent of all highway fatalities are pedestrians, and although most pedestrian accidents occur in urban areas, all agencies should pay more attention to the needs of pedestrians. This report of the Transportation Research Board describes and discusses more than 20 traffic-control measures and their effects on pedestrian safety including the advantages and disadvantages of each and the conditions under which each is most and least likely to be of benefit.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Robert E. Skinner, Jr., Director for Special Projects. The Principal Investigators responsible for conduct of the synthesis were Thomas L. Copas and Herbert A. Pennock, Special Projects Engineers. This synthesis was edited by Judith Klein.

Special appreciation is expressed to Charles V. Zegeer, Staff Associate, Highway Safety Research Center, University of North Carolina, Chapel Hill, N.C., and Sharon F. Zegeer, Human Factors Consultant, Chapel Hill, N.C., who were responsible for the collection of the data and the preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Janet A. Coleman, Program Analyst, Federal Highway Administration; Kay Colpitts, Traffic Engineer, City of Charlotte DOT; Patricia Ehrlich, Highway Safety Specialist, Federal Highway Administration; John C. Fegan, Project Manager, Federal Highway Administration; David G. Fielder, Traffic Engineer, City of Akron; and John J. Fruin, Consultant, Massapequa, N.Y.

David K. Witheford, Engineer of Traffic and Operations, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

PEDESTRIANS AND TRAFFIC-CONTROL MEASURES

SUMMARY

Traffic-control measures are typically designed with the primary purpose of facilitating motor vehicle flow and safety. However, approximately 15 to 20 percent of all U.S. highway fatalities are pedestrians; thus, there is an urgent need to consider the effects of various types of measures on pedestrian safety. As discussed in this report, traffic-control measures are considered to include all traffic-control devices and highway engineering strategies that are implemented for both pedestrian and motor vehicle movements. Detailed information was obtained from the literature and from 48 state and local highway agencies on more than 20 specific traffic-control measures.

The problem of pedestrian accidents is primarily an urban one, with approximately 83 percent of all pedestrian accidents and 74 percent of all pedestrian fatalities in the United States in 1985 occurring in urban areas. The most frequently occurring pedestrian accident types in urban areas include dart-outs (mostly in midblock) and intersection dash accidents. On rural roadways, the most common type is related to pedestrians walking along the road, and the most frequent pedestrian accident type on freeways involves a pedestrian working near a disabled vehicle.

The effect of any traffic-control measure is highly dependent on specific locational characteristics, such as traffic conditions (e.g., volumes, speeds, turning movements), pedestrian volumes, and mix (e.g., young children, college students, older adults, handicapped), street width, existing traffic controls, area type, sight distance, accident patterns, presence of enforcement, and many other factors. Thus, agencies should avoid blanket installation of any measure, but should "tailor fit" the most appropriate measure(s) to suit the site conditions. For example, painted crosswalks may be quite helpful at signalized intersections with heavy pedestrian activity, but they may give pedestrians a false sense of security and increase the risk of an accident if applied at uncontrolled midblock crossings having high vehicle speeds and poor sight distance.

Many other traffic-control measures may also be beneficial if carefully chosen. Pedestrian signals are essential at signalized intersections with exclusive pedestrian intervals or where the traffic signals are confusing or cannot be seen by pedestrians. However, pedestrian signals should be used selectively. Overhead lighting and grade-separated crossings can be highly effective in reducing pedestrian accidents when installed at critical locations. If used where not justified, however, grade-separated crossings will go largely unused by pedestrians and overhead lighting will have a minimal benefit for a costly investment of funds.

Other measures that are sometimes helpful to pedestrians include:

- Sidewalks or separate paths in residential areas
- Crossing guards in school zones where pedestrians must cross at dangerous street locations
- Use of far-side bus stops and/or prohibition of on-street parking at intersections with a problem of intersection dash accidents
- Use of barriers at midblock locations experiencing midblock dash accidents, particularly involving adult pedestrians
- One-way street systems and pedestrian malls, which are highly desirable for pedestrian safety if they are also practical in terms of traffic circulation
- Use of exclusive pedestrian signal timing (which can be beneficial at locations where motorist and pedestrian delay would not be excessive and signal compliance is good)
- Neighborhood traffic-control measures (e.g., chokers, traffic diverters, cul-de-sacs)

It is apparent that the needs of pedestrians are largely ignored in many traffic situations. Too often, traffic-control measures are designed for the sole interests of motorists; pedestrians are left to fend for themselves in construction zones and on streets with inadequate crossing times, confusing traffic-control devices, excessive delays, and extreme traffic hazards. Nonstandard and ineffective warning signs are sometimes installed as a "quick fix" for a serious safety problem. On the other hand, some transportation agencies place a high priority on the needs of pedestrians. Agencies in Milwaukee, San Diego, Seattle, and Phoenix are only a few examples of those that have comprehensive pedestrian-safety programs based not only on engineering roadway treatments but also on effective educational and enforcement programs complemented with community involvement.

As various traffic-control measures are installed for motor vehicle considerations, agencies should routinely consider their possible effects on pedestrians. For example:

- Sufficient walking time should always be provided at a signalized intersection for pedestrians to safely cross the street. Pedestrian push buttons may be provided to extend the crossing interval in certain instances. High-speed arterial intersections in suburban areas often create hazards for pedestrians who often deserve special considerations.
- Adequate access and traffic control should be provided for pedestrians in construction zones.
- At the intersection of expressway off-ramps with local streets, proper traffic control should be used for traffic and pedestrians.
- At intersections with confusing traffic signal phasing and/or unusual intersection geometrics, potential dangers to pedestrians must be considered in terms of providing pedestrian signals and other measures, as appropriate.
- Roadways near pedestrian generators should have provisions for pedestrians, such as sidewalks, separated paths, or at least shoulders suitable for walking. Such pedestrian facilities should provide the shortest or most desired path for pedestrians to travel.
- Special types of traffic-control measures should be considered at locations with a substantial number of young children, older adults, and/or handicapped pedestrians.

Many state and local highway agencies need to place more emphasis on providing for the needs of pedestrians with improved traffic-control measures on public streets

and highways. The best way to accomplish this is through the use of a comprehensive pedestrian-safety program. In such a program, the agency should conduct studies of pedestrian accident types and the locations of these accidents along with information on sites with unsafe pedestrian and motorist behavior (e.g., jaywalking, pedestrian and motorist signal violations, speeding motorists, drunk driving and walking). The best project alternatives should then be selected and implemented, and the effectiveness of those measures on pedestrian accidents should be evaluated so the program can be maintained in the best possible manner. The 1987 version of the "Model Pedestrian Safety Program—Users' Guide" was written for the Federal Highway Administration and describes procedures for a highway agency to plan, implement, and evaluate a pedestrian-safety program.

CHAPTER ONE

INTRODUCTION

BACKGROUND OF THE PEDESTRIAN-SAFETY PROBLEM

Accidents between pedestrians and motor vehicles represent a serious safety problem in the United States. According to the National Safety Council, approximately 8,400 of 45,600 motor vehicle fatalities in 1985, or 18.4 percent, were pedestrians (*1*). Of all pedestrian fatalities, 2200 (26.2 percent) occurred in rural areas, and 6100 (73.8 percent) occurred in urban areas. Of the 60,000 nonfatal injuries to pedestrians in the United States in 1985, approximately 83.3 percent (50,000) were in urban areas and 16.7 percent (10,000) were in rural areas (*1*).

Between 1983 and 1985, 20.1 percent of all fatalities, 39.7 percent of urban fatalities, and 8.9 percent of rural fatalities involved pedestrians. (Note: These National Safety Council statistics for fatalities include deaths that occur from the accident within a one-year period.) It is not surprising that pedestrian accidents are predominantly an urban problem, because these are the major pedestrian activity areas. Large volumes of pedestrians must contend with high traffic speeds and volumes not only at intersections but also at midblocks, parking lots, and along roadways. In fact, in one study of urban pedestrian accidents in U.S. cities from 1976 through 1978, 60 percent occurred in places other than intersections (*1*).

Many factors contribute to the pedestrian accident problem. Studies have consistently found that young and elderly pedestrians are overrepresented in pedestrian accidents. Alcohol impairment of pedestrians and/or drivers is a causal factor in many pedestrian accidents. Nighttime also poses a special problem in drivers' ability to see pedestrians, and pedestrian accidents are clearly overrepresented at night (*2*). Many different accident causes and problems are associated with deficient or confusing roadway designs when pedestrians and vehicles are present.

In short, pedestrian accidents represent a highly diverse and complex problem that has no easy answers. Instead, improvements to pedestrian safety may involve consideration of a combination of numerous factors, including (*3*):

- Education programs for pedestrians (particularly those of elementary school age) and motorists, and for parents of preschool and elementary school children
- Enforcement of existing traffic laws and ordinances for motorists (e.g., obeying speed limits, yielding to pedestrians when turning, traffic signal compliance, obeying drunk-driving laws) and pedestrians (e.g., crossing the street at legal crossings, obeying pedestrian signals)
- Use of retro-reflective clothing and materials by pedestrians
- More forgiving vehicle designs that minimize pedestrian injury in an accident
- Traffic-control measures, which include all traffic-control devices and engineering strategies implemented on streets and highways for both pedestrian and vehicular movements.

The focus of this report is on those traffic-control measures that represent alternatives that traffic and transportation officials may use to make the roadway environment safer and more convenient for pedestrians. Traditionally, such pedestrian-related traffic-control measures are often considered to be only those measures that are installed with pedestrians specifically in mind (e.g., crosswalks, pedestrian signals, pedestrian overpasses). Although such measures will be addressed in this report, consideration is also given to other measures and devices that are usually installed to improve traffic flow with little or no consideration of their effect on pedestrians. Examples include stop signs, traffic signals, separate left-turn signal phasing, design of intersections of freeway off-ramps with local streets, and other measures that may affect pedestrian flow and safety.

TRAFFIC-CONTROL MEASURES

The installation of traffic-control measures for safe and efficient pedestrian movement is often in conflict with that of motor vehicles, particularly in urban areas. According to a 1984 American Association of State Highway and Transportation Officials (AASHTO) publication, *A Policy on Geometric Design of Highways and Streets* (*4*):

> Because of the demands of vehicular traffic in congested urban areas, it is often extremely difficult to make adequate provisions for pedestrians. Yet this must be done, because pedestrians are the lifeblood of our urban areas, especially in the downtown and other retail areas. (Pp. 110-111.)

One of the problems with installing traffic-control measures to consistently reduce pedestrian accidents is that pedestrian accidents are normally scattered over large areas and are seldom concentrated at any one location. Thus, a site with two pedestrian accidents in a given year is likely to have no pedestrian accidents over the next several years, regardless of whether any physical changes are made at the site. This highly random nature of pedestrian accidents presents a problem to pedestrian-safety experts who must determine what roadway accident countermeasures are effective in terms of reducing pedestrian accidents (*3*).

A second problem in selecting appropriate traffic-control measures involves the conflicting research results and differing opinions on which measures are beneficial to pedestrians and which

measures are harmful under various conditions. For example, some agencies install marked crosswalks, pedestrian signals, and various types of signs frequently in an attempt to improve pedestrian flow and safety. Other agencies cite the false sense of security that such measures give to pedestrians and use such measures sparingly or only at specific problem locations.

Traffic-control measures that may affect pedestrians include such things as:

- Traffic signals (e.g., vehicular signals, pedestrian signals, signal-timing schemes, left-turn signals, signal timing);
- Signs (e.g., pedestrian-crossing signs, stop signs, yield signs, school warning signs, 25 MPH WHEN FLASHING school signs, NO TURN ON RED, WALK ON LEFT FACING TRAFFIC, speed limit reductions, PUSH BUTTON FOR WALK SIGNAL, NO LEFT TURN signs, and various other regulatory, warning, and guide signs);
- Pavement markings (e.g., marked crosswalks, stop bars, including offset or angled);
- On-street traffic-flow measures (e.g., conversion to one-way street networks, parking restrictions, far-side bus stops, use of school crossing guards);
- Physical roadway or design measures (e.g., roadway lighting, physical barriers, sidewalks and separate paths, grade-separated crossings, pedestrian malls, refuge islands); and
- Special facilities for the handicapped (e.g., audible pedestrian signals, long WALK signal intervals, curb ramps, widened sidewalks, guidestrips).

When considering these and other traffic-control measures, one must consider the unique combination of site characteristics, because a given traffic-control measure may work well at one site but may be harmful (or of less benefit) to pedestrians at another site. Criteria of this type (i.e., conditions when a traffic-control measure is most beneficial and when it is least beneficial or possibly harmful) are contained in this report and are based on the experiences of 48 state and local transportation agencies. The results of previous research and safety studies of various traffic-control measures are also presented.

PURPOSE OF THE SYNTHESIS

Traffic-control measures are typically designed with the primary purpose of facilitating motor vehicle flow and safety. However, since approximately 15 to 20 percent of all U.S. highway fatalities are pedestrians (*1*), there is an urgent need to consider the effects of various types of measures on pedestrians. As discussed in this report, traffic-control measures are considered to include all traffic-control devices and highway engineering strategies that are implemented for both pedestrian and motor vehicle movements.

This report includes information regarding traffic-control measures and their effects on all types of areas (rural, urban, and suburban) and the manner in which pedestrians and motorists understand and react to them. Also, each of approximately 20 types of traffic-control measures is discussed in terms of its accident effects (from past research) and how state and local highway officials judge its effectiveness. The traffic-control needs of special pedestrian groups (children in school zones, children at play in or near a roadway, elderly and handicapped, college students, and pedestrians in construction sites) are addressed in addition to special activities of pedestrians. Finally, recommendations are made for selecting the most appropriate traffic-control measures for pedestrians and for future research.

This report can be used in several ways. First, a reader may review it in its entirety to gain a general overview of all issues covered. Agencies just starting a pedestrian-safety program may be most interested in studying information on pedestrian-accident causes and countermeasures (Chapter Two), details specifically of those traffic-control measures that they are considering on their own street network (Chapter Four), and selection of effective traffic-control measures (Chapter Eight). The examples of city practices (Appendix A) may also be useful for gaining additional insights from other successful agencies (*5*).

Agencies that already maintain successful pedestrian-safety programs may be most interested in a summary of past literature and new information on each of the 20 traffic-control measures, based on experiences of state and local agencies. In particular, details are given on roadway conditions when each of the traffic measures is most and least effective. Some of the specialized chapters (e.g., Chapters Three, Five, Six, and Seven) give added input from state and local agencies on traffic-control needs, uses, and experiences related to pedestrians. This could be particularly useful to agencies that are aware of specific problems for pedestrians (e.g., in work zones, school zones, shopping centers). Many references are cited to direct readers to other documents with more details on certain topics.

SOURCES OF INFORMATION

The information on which this synthesis is based was gathered from two basic sources. First, an in-depth review of available literature was conducted relative to the effects of various traffic-control measures on pedestrian safety and movement. Second, surveys (see Appendix A) were sent to representatives of more than 100 state and local (i.e., city and county) highway and transportation agencies throughout the United States asking specific detailed questions on the topic based on their experiences and opinions on relevant issues of interest. Completed questionnaire responses were received from 15 state and 33 local agencies, for a total of 48 responses. These were:

States	Cities/Counties	
Arizona	Akron, Ohio	Milwaukee, Wis.
California	Arlington, Tex.	Minneapolis, Minn.
Connecticut	Baltimore, Md.	Montgomery Co., Md.
Florida	Baton Rouge, La.	New Orleans, La.
Georgia	Birmingham, Ala.	Oakland, Calif.
Illinois	Cheyenne, Wyo.	Orlando, Fla.
Maryland	Cincinnati, Ohio	Omaha, Neb.
Michigan	Columbus, Ohio	Phoenix, Ariz.
Nevada	Dallas, Tex.	Portland, Ore.
Ohio	Detroit, Mich.	Seattle, Wash.
Oregon	Kansas City, Mo.	St. Louis, Mo.
Pennsylvania	Knoxville, Tenn.	St. Paul, Minn.
Virginia	Little Rock, Ark.	Tampa, Fla.
West Virginia	Louisville, Ky.	Troy, Mich.
Wisconsin	Los Angeles, Calif.	Virginia Beach, Va.
	Madison, Wis.	Washington, D.C.
	Miami, Fla.	

Examples of agency guidelines, policies, and evaluation results regarding traffic-control measures were also obtained and discussed in many cases.

DEFINITIONS OF TERMS

Traffic-Control Measures All types of engineering strategies and traffic-control devices that are implemented for pedestrians and vehicular movements.

Grade-Separated Crossing A facility that allows for free-moving noninteracting movement of pedestrians and motor vehicles. Examples of grade-separated crossings include pedestrian overpasses (e.g., bridges and skyways) and pedestrian underpasses (e.g., tunnels and subways) (*5*).

Adult Crossing Guards Parents, police, or other trained adults who are responsible for assisting children across the street, usually in school zones for children traveling between home and school.

Physical Barriers Chains, fences, guardrails, or other devices that physically separate pedestrians from motor vehicles.

Curb Parking Restrictions Time limitations or prohibition of motor vehicle parking next to the curb within a certain distance of an intersection, midblock, or other location.

Crosswalk That marked or unmarked portion of the roadway designated for pedestrians to cross the street.

Pedestrian Signals Electronic devices used for controlling the movement of pedestrians at signalized midblocks or intersections, which may include the WALK/DON'T WALK messages or the symbolic walking man/hand message.

Far-Side Bus Stop A transit stop or a school bus stop located on the far side of an intersection.

Sidewalks At-grade areas for pedestrians to travel, which include walkways between the edge of a roadway and the adjacent property lines.

Safety Islands Pedestrian-refuge areas between opposing traffic lanes within an intersection that may consist of pavement markings only or of a raised island installed to channelize motor vehicles and/or for pedestrian use.

CHAPTER TWO

PEDESTRIAN-ACCIDENT CAUSES AND POTENTIAL COUNTERMEASURES

PEDESTRIAN-ACCIDENT CHARACTERISTICS

Many studies have been conducted to better quantify the nature of pedestrian accidents in terms of pedestrian ages, use of alcohol, when such accidents most commonly occur, and other factors. In terms of age, pedestrian accidents are most overrepresented among the young and older adult pedestrians. Based on accident data from more than 1900 cities, the American Automobile Association (AAA) found that children between ages 2 and 14 (particularly ages 5 and 6) were overrepresented in pedestrian-accident involvement based on their population. Numerous studies have found that persons older than 55 years of age are overrepresented in pedestrian fatalities for the most part because of the greater accident severity to pedestrians in that older age group (*2*).

The overuse of alcohol has also been found to be a common factor in pedestrian accidents. One study revealed that 36 percent of fatally injured adult pedestrians had a blood alcohol level of 0.10 percent or more. Also, the pedestrians were found to be at fault in 70 percent of those accidents. Another study of pedestrian accidents in rural and suburban areas revealed that only about 12 percent of pedestrians had been drinking, were on drugs, or on medication (*2*).

Pedestrian accidents in urban areas have been found to peak between the hours of 3:00 to 6:00 p.m., when about 30 to 40 percent of them occur; smaller peaks in pedestrian accidents occur between 7:00 to 9:00 a.m. and 12:00 noon to 1:00 p.m. (*2*). Such periods of high pedestrian-accident occurrence generally correspond to periods of highest urban activity by pedestrians and motor vehicles. Friday and Saturday are the days of highest overrepresentation of pedestrian accidents, and Sunday was underrepresented. December is the month that has the greatest overrepresentation of pedestrian accidents in rural and urban U.S. data samples (*2*).

PEDESTRIAN-ACCIDENT TYPES AND DESCRIPTORS

Before discussing the many types of traffic-control measures available for improving pedestrian safety and movement, it is important to have an understanding of the predominant "types" of pedestrian accidents. Several studies were conducted for the U.S. Department of Transportation (DOT) in the 1970s that involved field observations, personal interviews, and information from accident reports to identify specific accident types for urban, rural, and freeway locations (*6, 7, 8, 9*). The purpose of these detailed accident studies was to develop countermeasures for identified accident causes.

As shown in Table 1, the most frequently occurring accident types in urban areas include dart-outs (first half) (23 percent), intersection dash (12 percent), dart-outs (second half) (9 percent), and midblock dash (7 percent). A description of the location and/or critical behavior of each accident type is discussed in Table 1 (*6, 7*).

A similar table for rural pedestrian accident types and related behaviors is given in Table 2. The most common accident types in rural areas include walking along roadway (12 percent), dart-out (first half) (11 percent), dart-out (second half) (10 percent), midblock dash (10 percent), intersection dash (10 percent), weird (unusual circumstances that are not corrective through countermeasures) (8 percent), and disabled-vehicle-related (6 percent). The most notable difference in occurrence of accident types between urban and rural areas is in the walking-along-roadway type (either with traffic or against traffic), which is the leading accident type in rural areas (*8*).

On freeways (Table 3), the most common accident type is disabled-vehicle-related (20 percent), in which a pedestrian is struck while working near a disabled vehicle. Other types with 1 percent or more include: result of vehicle-vehicle crash (10 percent), weird (10 percent), hitchhiking (9 percent), walking to/from disabled vehicle (8 percent), dart-out (5 percent), walking along roadway (5 percent), and working on roadway (3 percent). Because pedestrian travel is prohibited on many freeways, these pedestrian-accident types are largely related to disabled vehicles, previous accidents, and roadway construction and maintenance activities (*9*).

GENERAL PEDESTRIAN-ACCIDENT COUNTERMEASURES

In previous studies, alternative countermeasures were proposed for each of the predominant accident types at urban, rural, and freeway locations, as shown in Tables 4, 5, and 6 (*6, 7, 8, 9, 10*). These countermeasure tables are based on judgments of the researchers or professionals consulted for the studies. For each type of pedestrian accident, one or more relevant countermeasures from a list of engineering and physical treatments, child-related safety programs, educational programs, and police enforcement are indicated with dots.

To illustrate the use of the tables, consider dart-out (first half) accidents in urban areas in Table 4. Potential countermeasures listed include:

TABLE 1

URBAN PEDESTRIAN ACCIDENT TYPES AND CRITICAL BEHAVIORAL DESCRIPTORS (*10*)

DART-OUT (FIRST HALF) (23%)

Midblock (not at intersection).

Pedestrian sudden appearance and short time exposure (driver does not have time to react to avoid collision).

Pedestrian crossed less than halfway.

DART-OUT (SECOND HALF) (9%)

Same as above except pedestrian gets at least halfway across before being struck.

MIDBLOCK DASH (7%)

Midblock (not at intersection).

Pedestrian running but *not* sudden appearance or short time exposure as above.

INTERSECTION DASH (12%)

Intersection.

Short time exposure *or* running.

Same as *Dart-out* except it occurs at an intersection.

VEHICLE TURN-MERGE WITH ATTENTION CONFLICT (4%)

Intersection or vehicle merge location.

Vehicle turning or merging into traffic.

Driver is attending to auto traffic in one direction and collides with pedestrian located in a different direction than that of the driver's attention.

TURNING VEHICLE (5%)

Intersection or vehicle merge location.

Vehicle turning or merging into traffic.

Driver attention *not* documented.

Pedestrian not running.

MULTIPLE THREAT (3%)

One or more vehicles stop in traffic lane (e.g. Lane 1) for pedestrian.

Pedestrian is hit as he steps into next parallel *same direction* traffic lane (e.g. Lane 2) by a vehicle moving in the same direction as the vehicle that stopped.

Collision vehicle driver's vision of pedestrian obstructed by the stopped vehicle.

BUS STOP RELATED (2%)

At a bus stop.

Pedestrian steps out from in front of bus at a bus stop and is struck by vehicle moving in same direction as bus while passing bus.

Same as Multiple Threat except that stopped vehicle is a bus at a bus stop.

VENDOR-ICE CREAM TRUCK (2%)

Pedestrian struck while going to or from a vendor in a vehicle on the street.

DISABLED VEHICLE RELATED (1%)

Pedestrian struck while working on or next to a disabled vehicle.

RESULT OF VEHICLE-VEHICLE CRASH (3%)

Pedestrian hit by vehicle(s) as a result of a vehicle-vehicle collision.

TRAPPED (1%)

Signalized intersection.

Pedestrian hit when traffic light turned red (for pedestrian) and cross traffic vehicles started moving.

TABLE 2

RURAL PEDESTRIAN ACCIDENT TYPES AND CRITICAL BEHAVIORAL DESCRIPTORS (*10*)

DART-OUT (FIRST HALF) (11%)

Midblock (not at intersection).

Pedestrian sudden appearance and short time exposure (driver does not have time to react to avoid collision).

Pedestrian crossed less than halfway.

DART-OUT (SECOND HALF) (10%)

Same as above except pedestrian gets at least halfway across before being struck.

MIDBLOCK DASH (10%)

Midblock (not at intersection).

Pedestrian running but *not* sudden appearance or short time exposure as above.

INTERSECTION DASH (10%)

Intersection.

Short time exposure *or* running.

Same as *Dart-out* except it occurs at an intersection.

VEHICLE TURN-MERGE WITH ATTENTION CONFLICT (1%)

Intersection or vehicle merge location.

Vehicle is turning or merging into traffic.

Driver is attending to auto traffic in one direction and collides with pedestrian located in a different direction than that of the driver's attention.

TURNING VEHICLE (2%)

Intersection or vehicle merge location.

Vehicle turning or merging into traffic.

Driver attention *not* documented.

Pedestrian not running.

MULTIPLE THREAT (2%)

One or more vehicles stop in traffic lane (e.g. Lane 1) for pedestrian.

Pedestrian is hit as he steps into next parallel *same direction* traffic lane (e.g. Lane 2) by a vehicle going in the same direction as the vehicle that stopped.

Collision vehicle driver's vision of pedestrian obstructed by the stopped vehicle.

SCHOOL BUS RELATED (3%)

Pedestrian is hit while going to or from a school bus or school bus stop.

VENDOR-ICE CREAM TRUCK (1%)

Pedestrian struck while going to or from a vendor in a vehicle on the street.

DISABLED VEHICLE RELATED (6%)

Pedestrian struck while working on or next to a disabled vehicle.

RESULT OF VEHICLE-VEHICLE CRASH (1%)

Pedestrian hit by vehicle(s) as a result of a vehicle-vehicle collision.

BACKING-UP (2%)

Pedestrian hit by vehicle backing up.

WALKING ALONG ROADWAY (12%)

Pedestrian struck while walking along the edge of the highway or on the shoulder.

Can be walking facing or in the same direction as traffic.

HITCHHIKING (2%)

Pedestrian hit while atempting to thumb a ride.

WEIRD (8%)

Unusual circumstances.

Not countermeasure corrective.

TABLE 3

FREEWAY PEDESTRIAN ACCIDENT TYPES AND CRITICAL BEHAVIORAL DESCRIPTORS (*10*)

DISABLED VEHICLE RELATED (20%)

Pedestrian struck while working on or next to a disabled vehicle.

RESULT OF VEHICLE-VEHICLE CRASH (10%)

Pedestrian hit by vehicle(s) as a result of a vehicle-vehicle collision.

WEIRD (10%)

Unusual circumstances.

Not countermeasure corrective.

HITCHHIKING (9%)

Pedestrian hit while attempting to thumb a ride.

WALKING TO/FROM DISABLED VEHICLE (8%)

Pedestrian struck while walking along the edge or shoulder of highway.

Reason for walking is because of disabled vehicle.

Can be walking facing or in same direction as traffic.

DART-OUT (5%)

Not at interchange.

Pedestrian sudden appearance and short time exposure (driver does not have time to react to avoid collision).

WALKING ALONG ROADWAY (5%)

Pedestrian struck while walking along the edge of the highway or on the shoulder.

Can be walking facing or in the same direction as traffic.

WORKING ON ROADWAY (3%)

Pedestrian (flagman or other construction worker) struck while working on the roadway or shoulder.

MIDBLOCK DASH

Not at interchange.

Pedestrian running but *not* sudden appearance or short time exposure.

VEHICLE TURN-MERGE WITH ATTENTION CONFLICT

Vehicle merge location.

Vehicle merging into traffic.

Driver is attending to auto traffic in one direction and collides with pedestrian located in a different direction than that of the driver's attention.

TURNING VEHICLE

Vehicle merge location.

Vehicle merging into traffic.

Driver attention *not* documented.

Pedestrian not running.

- Median Barriers
- Roadside/Sidewalk Barriers
- Midblock Crosswalks
- Diagonal Parking for One-Way Streets
- Urban Pedestrian Environment (e.g., Pedestrian Malls)
- Play Streets
- Pedestrian Education
- Driver Education
- Police Enforcement

A similar list of countermeasures is indicated for dart-out (second half) accidents, except that safety islands are also included for this accident type. Note that 20 different accident types are listed in Table 4, with between 1 and 11 potential treatments for each countermeasure. Similarly, Tables 5 and 6 provide guidance on countermeasure selection for rural areas and freeways, respectively.

In using these countermeasure tables, one should be aware of several points. First of all, these tables represent only a general guide of potential countermeasures; that is, for a specific highway site, not all of the countermeasures will always be appropriate. Thus, for two different sites with similar pedestrian-accident types, the same countermeasure may not be appropriate for both because of differences in pedestrian volumes, street width, traffic speeds, sight distance, area type, and many other factors. Chapter Four discusses some of the locational factors for which various traffic-control measures will be likely to be most and least effective.

TABLE 4

RELATIONSHIP BETWEEN FREQUENTLY OCCURRING ACCIDENT TYPES AND POTENTIAL COUNTERMEASURES—URBAN SETTING (*10*)

Countermeasures / Behavioral and Locational Accident Type	Engineering and Physical																					Child			Educ.		
	Barrier: Median	Barrier: Roadside/Sidewalk	Barrier: Street Closure	Bus Stop Relocation	Crosswalk: Intersection	Crosswalk: Midblock	Diagonal Parking-1Way Street	Grade Separation	Facilities for Handicapped	Lighting: Crosswalk	Lighting: Street	One-Way Streets	Retroreflective Materials	Safety Islands	Sidewalk/Pathway	Signal: Ped. (Shared)	Signal: Ped. (Delayed)	Signal: Ped. (Separated)	Signal: Traffic	Signs and Markings	Urban Ped Environment	Crossing Guards	Play Streets	Safe Route to School	Education: Pedestrian	Education: Driver	Enforcement
Dart-out (First Half)	●	●				●	●														●		●		●	●	●
Dart-out (Second Half)	●	●				●	●							●							●		●		●	●	●
Midblock Dash	●	●				●								●							●		●		●	●	●
Intersection Dash					●			●						●											●	●	
Turn-Merge Conflict								●									●	●				●			●	●	
Turning Vehicle								●									●	●				●			●	●	
Multiple Threat								●		●	●					●	●	●	●		●		●		●	●	
Bus Stop Related				●																	●				●	●	
School Bus Stop Related				●																					●	●	
Ice Cream Vendor																				●					●	●	
Trapped								●						●		●	●	●							●	●	
Backup																									●	●	
Walking on Roadway		●									●		●		●					●					●	●	
Result Vehicle-Vehicle Crash																				●					●	●	
Hitchhiking											●		●												●	●	
Working in Roadway																				●						●	
Disabled Vehicle Related																				●							
Nighttime Situation										●	●		●												●	●	
Handicapped Pedestrians									●																	●	
In General																									●	●	●

*Dots designate countermeasures known to positively affect the indicated behavior/accident types.

TABLE 5

RELATIONSHIP BETWEEN FREQUENTLY OCCURRING ACCIDENT TYPES AND POTENTIAL COUNTERMEASURES—RURAL SETTING (*10*)

Countermeasures / Behavioral and Locational Accident Type	Engineering and Physical																						Child			Educ.		
	Barrier: Median	Barrier: Roadside/Sidewalk	Barrier: Street Closure	Bus Stop Relocation	Crosswalk: Intersection	Crosswalk: Midblock	Diagonal Parking-1 Way Street	Grade Separation	Facilities for Handicapped	Lighting: Crosswalk	Lighting: Street	One-Way Streets	Retroreflective Materials	Safety Islands	Sidewalk/Pathway	Signal: Ped. (Shared)	Signal: Ped. (Delayed)	Signal: Ped. (Separated)	Signal: Traffic	Signs and Markings	Urban Ped Environment	Crossing Guards	Play Streets	Safe Route to School	Education: Pedestrian	Education: Driver	Enforcement
Dart-out (First Half)	●	●				●																			●	●	●
Dart-out (Second Half)	●	●				●						●		●											●	●	●
Midblock Dash	●	●				●								●											●	●	●
Intersection Dash					●					●	●			●			●	●		●					●	●	●
Turn-Merge Conflict																	●	●							●	●	
Turning Vehicle																	●	●							●	●	
Multiple Threat										●	●					●	●	●	●						●	●	
Bus Stop Related				●																					●	●	
School Bus Stop Related				●																					●	◐	
Ice Cream Vendor																				●					●	●	
Trapped					●									●			●								●	●	
Backup																									●	●	
Walking on Roadway		●									●		●		●					●					●	●	
Resu'+ Vehicle-Vehicle Crash																				●					●	●	
Hitchhiking											●		●												●	◐	
Working in Roadway																				●						●	
Disabled Vehicle Related																				●							
Nighttime Situation										●	●		●												●	●	
Handicapped Pedestrians									●																	●	
In General																									●	◐	◐

*Dots designate countermeasures known to positively affect the indicated behavior/accident types.

TABLE 6

RELATIONSHIP BETWEEN FREQUENTLY OCCURRING ACCIDENT TYPES AND POTENTIAL COUNTERMEASURES—FREEWAY SETTING (*10*)

Countermeasures / Behavioral and Locational Accident Type	Engineering and Physical																							Child			Educ.		
	Barrier: Median	Barrier: Roadside/Sidewalk	Barrier: Street Closure	Bus Stop Relocation	Crosswalk: Intersection	Crosswalk: Midblock	Diagonal Parking-1Way Street	Grade Separation	Facilities for Handicapped	Lighting: Crosswalk	Lighting: Street	One-Way Streets	Retroreflective Materials	Safety Islands	Sidewalk/Pathway	Signal: Ped. (Shared)	Signal: Ped. (Delayed)	Signal: Ped. (Separated)	Signal: Traffic	Signs and Markings	Urban Ped Environment	Crossing Guards	Play Streets	Safe Route to School	Education: Pedestrian	Education: Driver	Enforcement
Dart-out (First Half)	●	●						●																	●	●	●
Dart-out (Second Half)	●	●						●																	●	●	●
Midblock Dash	●	●						●																	●	●	●
Interchange Dash	●	●													●										●	●	●
Turn-Merge Conflict		●						●																	●	●	
Turning Vehicle		●																							●	●	
Multiple Threat								●			●														●	●	
Bus Stop Related																											
School Bus Stop Related																											
Ice Cream Vendor																											
Trapped																											
Backup																									●	●	
Walking on Roadway		●									●		●							●					●	●	●
Result Vehicle-Vehicle Crash		●																		●					●	●	
Hitchhiking		●									●		●							●					●	●	●
Working in Roadway											●		●							●					●	●	
Disabled Vehicle Related																				●					●	●	
Nighttime Situation											●		●												●	●	
Handicapped Pedestrians																											
In General																									●	●	●

*Dots designate countermeasures known to positively affect the indicated behavior/accident types.

CHAPTER THREE

AGENCY OPINIONS OF TRAFFIC-CONTROL MEASURES

Based on questionnaire responses from 15 state and 33 local highway agencies, traffic-control measures and situations that are considered to affect pedestrians adversely include:

- Permitting right turn on red (RTOR)
- Using painted crosswalks (particularly when overused, with low pedestrian volumes, at midblock crossings, and/or at crossings with no signal control)
- Adding protected left-turn signal phasing (particularly when left-turn and pedestrian volumes are high or where pedestrians cannot view the signals for both directions simultaneously)
- The flashing aspect of the DON'T WALK as a clearance interval for pedestrians (it is often misunderstood by pedestrians)
- Lack of proper traffic control during street construction
- Eight-phase or other complex signal-phasing traffic signals without pedestrian signals
- Center two-way left-turn lane
- Large corner radii at intersections
- Traffic signals operated for short periods of time at school crossings without adult supervision (where vehicle violations may be high and pedestrians may rely solely on the signal for a safe gap)
- Stop signs and all-way stop sign control (they can give a false sense of security to pedestrians)
- Sidewalk closures
- Yield signs
- Free-flow right-turn channelization at intersections
- Four-lane divided highways with narrow safety islands
- Wide roadway designs that create substantially increased pedestrian-crossing times
- Installing traffic signals
- Removing traffic signals
- Near- and far-side bus stops
- CHILDREN AT PLAY signs
- Installing pedestrian signal indications
- Failing to enforce pedestrian ordinances
- Inadequate signal timing
- Fully activated signals without pedestrian push buttons
- Failing to provide signal heads that are visible to the pedestrian

Several observations deserve mention. First of all, permitting RTOR was mentioned most often as adversely affecting pedestrians. This could be, for the most part, because of the long-standing controversy and debate within the traffic-engineering profession on the potential adverse safety effects of RTOR and the widely inconsistent opinions and research study results on RTOR. The use of exclusive left-turn phasing was also cited as adversely affecting pedestrians, particularly when pedestrian signal control is not used. The eight responses of adverse effects of painted crosswalks generally cited certain conditions when crosswalks were detrimental to pedestrians (e.g., midblock crossings, uncontrolled crossings, etc.).

Most of the other items were mentioned by only one or two agencies as adversely affecting pedestrians, and some responses were contradictory. For example, one official listed "installing traffic signals" as a problem, but another official listed "removing traffic signals." One official listed installing pedestrian signal indications as adverse to pedestrians, noting that a false sense of security to the pedestrian is created from pedestrian signals, whereas several officials listed examples where pedestrian signals are needed (e.g., at complex intersections). Such responses emphasize the need to carefully consider conditions at each site, because a given traffic-control measure may create a problem to pedestrians at some sites but be beneficial at other sites.

Transportation officials were then asked to rank each of 23 preselected traffic-control measures based on their general effects as:

- Large benefit
- Some benefit
- Little or no effect
- Some adverse effect
- Large adverse effect
- Unknown

Traffic-control measures that were most often considered to have large or some benefit include:

Rank	Traffic-Control Measure	Percent of Respondents
1	School crossing guards in rural and urban areas	100%
2	Pedestrian signals	98%
3	Pedestrian malls	97%
4	Sidewalks in suburban areas	96%
5	Separate pedestrian paths in rural and urban areas	92%
6	Fences or physical barriers separating sidewalk from street	89%
7	Traffic signals at unsignalized intersections	87%

8	Safety islands for pedestrians	87%
9	Overhead street lighting	85%
10	Grade-separated pedestrian overpasses or underpasses	85%
11	Curb parking restrictions	83%
12	Painted crosswalks	80%

Of the 23 traffic-control measures listed in the questionnaire, 15 of them were considered by one or more respondents as having at least some adverse effect on pedestrians. The measures most often thought to produce some or large adverse effects for pedestrians include:

Rank	Traffic-Control Measure	Percent of Respondents
1	Expressway off-ramps that intersect with local streets	72%
2	Separate left-turn phasing at signalized intersections	48%
3	Curb ramps	10%
4	Traffic signals at intersections (without pedestrian signals)	8%
5	Adding painted crosswalks	8%
6	Fences or physical barriers separating sidewalk from street	8%
7	Conversion from near-side to far-side bus locations	8%

Those traffic-control measures considered most often to have little or no effect on pedestrians include:

Rank	Traffic-Control Measure	Percent of Respondents
1	Reducing the speed limit on urban or residential streets	61%
2	Adding warning or regulatory signs aimed at motorists relative to watching for or yielding to pedestrians	47%
3	Adding warning or regulatory signs aimed at pedestrians crossing streets	42%
4	Adding stop signs at intersections	33%
5	Converting from near-side to far-side bus stop locations	33%
6	Installing NO LEFT TURN signs at intersections	31%

In giving responses as noted above, many respondents qualified their response with conditions under which a traffic-control measure would produce some beneficial or adverse effect. It is interesting that some measures were consistently considered to be beneficial (e.g., school crossing guards) or to cause an adverse effect (e.g., expressway off-ramps) to pedestrians. However, opinion was mixed for such treatments as:

- Fences or physical barriers
- Curb ramps
- Adding traffic signals
- Adding painted crosswalks
- Converting near-side to far-side bus stops

These differing opinions could be because of different experience with these traffic-control measures in various cities or simply because of differences in opinions on perceived effectiveness of various traffic-control measures. Also, it must be remembered that the effectiveness of each type of traffic-control measure may depend largely on the conditions where it is used.

CHAPTER FOUR

DETAILS OF TRAFFIC-CONTROL MEASURES

A review was conducted of literature and other published information on the effects of various traffic-control measures on pedestrians. Twenty such measures are discussed individually below.

In many cases, research studies reported in the following sections give an indication of the general safety effects of various traffic-control measures. However, it is essential to recognize that a given measure may work well in some situations and not in others. To help determine the relative merits and problems associated with each traffic-control measure in a given setting, one must consider the vast array of other locational conditions, such as (but not limited to):

Geometric Design Features
- Street width
- Sight distance and alignment of roadway
- Presence of highway shoulders and sidewalks

Traffic Features
- Volume of pedestrians (day and night)
- Mix of pedestrians (young children, older adults, handicapped, or tourists)
- Traffic volume and vehicle mix (presence of many large trucks)
- Vehicle speeds
- Presence of bicyclists, joggers, and other road users
- Percent and volume of turning traffic
- Traffic circulation and arrangement of nearby streets and roadways
- Local levels of pedestrian and motorist compliance with traffic-control devices

Environmental and Locational Features
- Type and condition of existing traffic control
- Prevalent weather in an area or range of weather
- Type of area (rural, urban, suburban, downtown, urban fringe, etc.)
- Roadway operation (one-way or two-way)
- Level of crime in an area
- Whether a midblock or intersection crossing location
- Accident and conflict characteristics of the location
- Relative location of schools, parks, shopping centers, universities, etc.

In selecting traffic-control measures appropriate for a given situation, it also helps to be aware of the specific advantages and disadvantages associated with each measure. In the sections below, a listing of pros and cons for each measure is provided, as taken or modified from the Federal Highway Administration "Model Pedestrian Safety Program—Users' Guide," which was originally developed in 1977 by Vallette and McDivitt and updated in 1987 by Knoblauch and Crigler (*10*).

Also, each section includes a summary based on questionnaire responses from 48 state and local highway and transportation agencies regarding: (a) conditions when the measure is most beneficial and (b) conditions when least beneficial or possibly harmful. Such information, although somewhat subjective, represents actual agency experiences in using the various traffic-control measures. Because a given measure may not work well in every situation, these kinds of experimental data are crucial in selecting appropriate measures. Detailed information on maintenance and implementation considerations related to such measures are not contained in this report.

CHILD-PROTECTION MEASURES

According to accident studies, between 40 and 45 percent of pedestrian accidents in the United States involve children. Further, nearly 80 percent of pedestrian accidents involving children are the result of an unsafe or illegal act by the child. Residential areas other than intersections account for almost two-thirds of pedestrian accidents to children (*7, 8*).

Numerous types of traffic-control measures have been used to improve child pedestrian safety in school zones, including (*3*):

- School crossing guards, preferably adult crossing guards or police guards (*11*).
- Safe-route-to-school programs, such as those taught by the AAA (*12, 13*).
- Parking restrictions near intersections and/or midblock crossings in school zones.
- Pavement markings (e.g., "SLOW SCHOOL," "SCHOOL ZONE") in school zones, as specified in the *Manual on Uniform Traffic Control Devices* (MUTCD) (*14*).
- Signing, including school crossing signs and flashing regulatory speed limit signing.
- Speed enforcement by local police to reduce the number of speeding motorists.

Several studies have been conducted to evaluate traffic-control measures in school zones. One such study field-tested five school pedestrian-crossing designs in six U.S. cities as alternatives to full signalization at the intersection of a high-volume arterial

street with a low-volume residential street. These treatments included (*15*):

1. Warning sign and flashing beacon on the major street, and a stop sign on the local residential street.
2. Flashing yellow signal (major street) and flashing red beacon (local residential street).
3. Flashing green signal (major street) and stop sign (local residential street).
4. Green signal (major street) and stop sign (local residential street).
5. Crossing guard (major street) and stop signs (local residential street).

Each of the five pedestrian-crossing designs was evaluated in a time series analysis using matched control sites. The measures of effectiveness included compliance, volume, and behavior for both vehicles and pedestrians, and fully signalized intersections were used as control sites. The results showed that the warning signs, flashing yellow beacon, and stop sign design (option 1) were less desirable than full signalization. The flashing yellow signal and flashing red beacon (option 2) was equivalent to the fully signalized control site. The other three designs had operating characteristics more desirable than those of the fully signalized control site but similar operating characteristics to each other (*15*).

In 1979 Zegeer and Deen (*16*) evaluated the regulatory "25 MPH WHEN FLASHING" sign at 48 school zone sites in terms of its effect on vehicle speeds and operations. Comparing vehicle speeds during flashing periods versus non-flashing periods, they found that the flashers reduced speeds an average of only 3.6 mph. Also, speed reductions of 10 mph or more were observed at only two of the sites (Figure 1), and the flashing signs were not effective in reducing speeds to 25 mph (Figure 2). The presence of crossing guards and/or police enforcement was found to contribute to lower vehicle speeds during flashing periods compared with the use of only the flashers. The presence of children in the school zone was found to result in little or no improvement in speed compliance. For rural high-speed locations, the use of the 25 mph flashers during school periods was found to increase the vehicle speed variance and therefore increase the chance of rear-end collisions. The use of higher regulatory school speeds (e.g., 35 MPH WHEN FLASHING) was recommended at high-speed rural sites (*16*).

Other measures that have been used to promote the safety of children in school zones include (*10*):

- Use of retro-reflective clothing and/or patches on children's jackets
- Construction of sidewalks and separate paths for pedestrians
- Supervision of children in playgrounds near the street
- Prohibition of on-street parking at critical locations
- Enforcement of vehicle speeds
- Use of play streets in dense urban areas where residential streets are closed to traffic during certain times and days
- Education programs for children and the public

In summary, there are clearly some traffic-control measures that are helpful for child pedestrians. For example, there is strong evidence of safety benefits from the use of well-trained adult crossing guards (Figure 3) in school zones, and at least

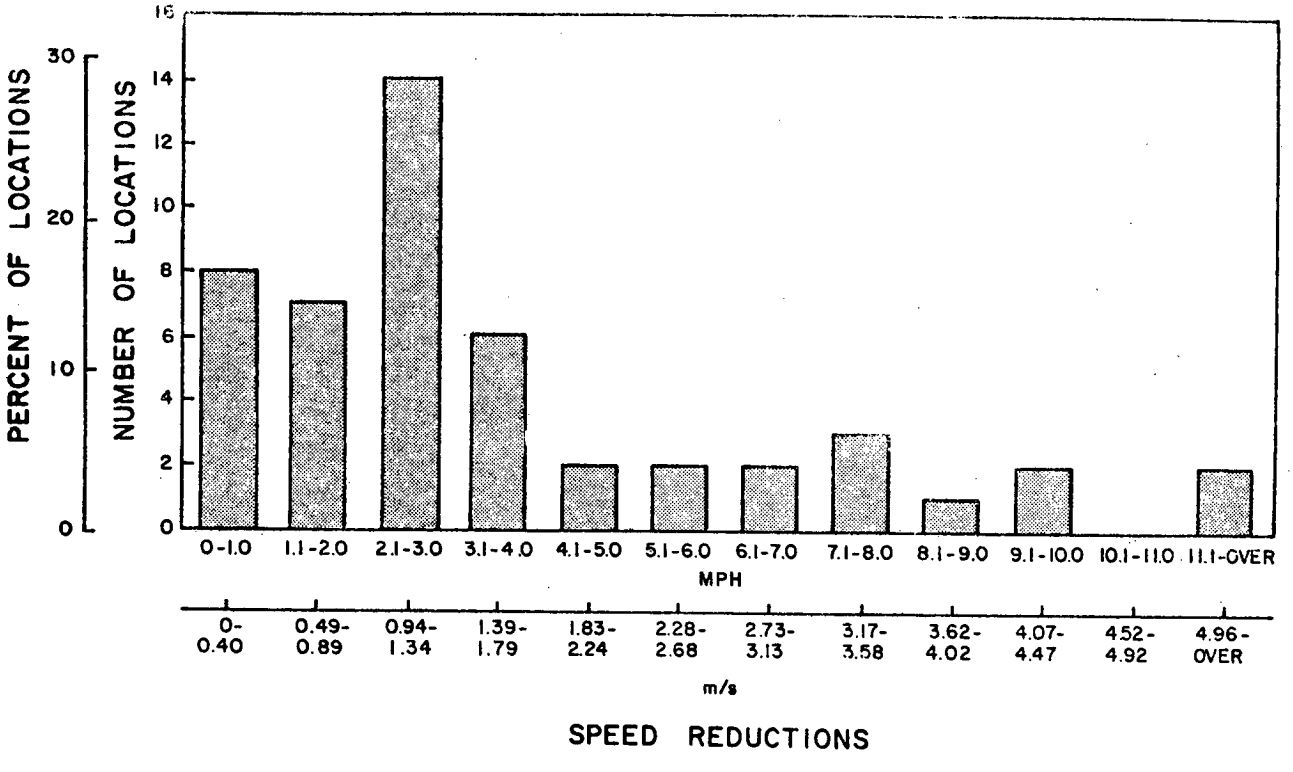

FIGURE 1 Speed reduction caused by flasher operation (*16*).

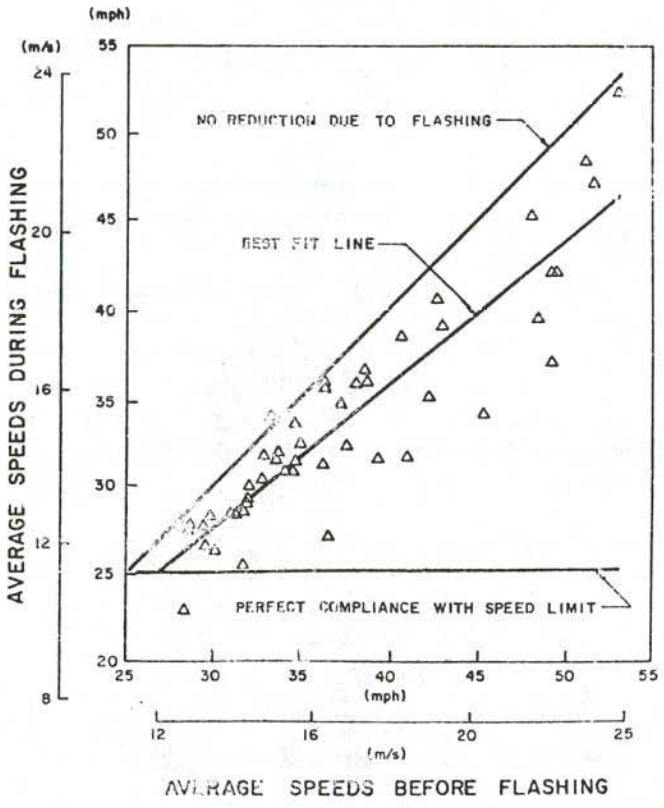

FIGURE 2 Average vehicle speeds before and during flashing (*16*).

temporary benefits can also be gained from on-site police enforcement. The effectiveness of signs, pavement markings, and other traffic-control measures in school zones or other roadway situations remains somewhat unclear. In certain types of hazardous roadway crossing situations, such measures may provide some degree of added protection to children.

Conditions Where Adult School Crossing Guards Are Most Beneficial

On roadways near schools, particularly:

- When there are not adequate gaps in the traffic stream for pedestrian crossings.
- Where there are dense pedestrian movements on high-speed and/or high-volume roads, particularly where no traffic signals exist.
- As part of a coordinated safety program involving the school board and local traffic officials.
- When warrants are met (see publication entitled "A Program for School Crossing Protection" by the Institute of Transportation Engineers) (*17*).
- When there are large numbers of young pedestrians (i.e., elementary school).
- On roadways with poor sight distance.

Conditions When Adult School Crossing Guards Are Least Beneficial or Possibly Harmful

- Poorly instructed crossing guards (who may stop traffic, needlessly causing motorist violations).
- Low volumes of pedestrians with low traffic speeds and volumes.
- Where older children (e.g., high school) cross.

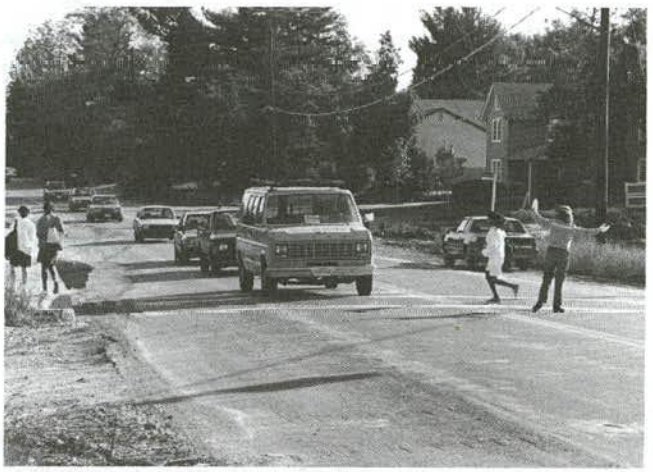

FIGURE 3 Adult school-crossing guards.

Advantages of Child-Protection Measures (*10*):

- Often necessary at locations where there are insufficient gaps in traffic, confusing traffic situations, and/or high vehicle speeds or volumes.
- Can help motorists to be more aware of children so they can take proper precautions.

Disadvantages of Child-Protection Measures (*10*):

- May give some children a false sense of security so they are not as cautious.
- Some children may place too much reliance on them and fail to look out for themselves (although, because some children are just too young to be able to look out for themselves, parental supervision is often critical).

CURB PARKING REGULATIONS

As discussed previously, 39 percent of urban pedestrian accidents involve pedestrians running into the street at midblock locations [i.e., 23 percent dart-outs (first half), 9 percent dart-outs (second half), and 7 percent midblock dash], and another 12 percent involve intersection dash (*6*). One of the contributing factors in these accidents is the visual obstruction between pedestrians and motorists, often caused by on-street parking. Prohibiting on-street parking at certain locations or using diagonal parking are considered potential countermeasures for pedestrian accidents.

According to the Uniform Vehicle Code and many state statutes, parking is prohibited within a crosswalk or within 20 feet of a marked pedestrian crossing at an intersection. Such provisions, however, may not include marked midblock pedestrian crossing locations (*18*). Parking prohibitions have been rec-

TABLE 7

RECOMMENDED GUIDELINES FOR SIDEWALK INSTALLATION (*22*)

Land-Use/Roadway Functional Classification/ Dwelling Unit	New Urban and Suburban Streets	Existing Urban and Suburban Streets
Commercial & Industrial/ All Streets	Both sides.	Both sides. Every effort should be made to add sidewalks where they do not exist and complete missing links.
Residential/Major Arterials	Both sides.	
Residential/Collectors	Both sides.	Multi-family - both sides. Single-family dwellings - prefer both sides required at least one side.
Residential/Local Streets More than 4 Units Per Acre	Both sides.	Prefer both sides, required at least one side.
1 to 4 Units Per Acre	Prefer both sides; required at least one side.	One side preferred, at least 4-ft. shoulder on both sides required.
Less than 1 Unit Per Acre	One side preferred, shoulder both sides required.	At least 4-ft. shoulder on both sides required.

NOTES:

(1) Any local street within two blocks of a school site that would be on a walking route to school - sidewalk on at least one side.

(2) Sidewalks may be omitted on one side of new streets where that side clearly cannot be developed and where there are no existing or anticipated uses that would generate pedestrian trips on that side.

(3) Where there are service roads, the sidewalk adjacent to the main road may be eliminated and replaced by a sidewalk adjacent to the service road on the side away from the main road.

(4) For rural roads not likely to serve development, provide a shoulder at least 4 feet in width, preferably 8 feet on primary highways. Surface material should provide a stable, mud-free walking surface.

ommended to be at least 100 feet in advance of a crosswalk or intersection, particularly for roads with higher vehicle speeds (e.g., 35 mph or greater) to increase vehicle stopping sight distance (*19*).

Angle parking at the curb is another alternative to reduce the incidence of pedestrians darting from between parked cars. Angle parking is more commonly used along one-way streets, although it is sometimes used on two-way streets, particularly on low-speed roadways (*3*). In a 1975 study by Berger, pedestrians were found to act more cautiously and vehicle speeds to decrease with angle parking (*20*). With angle parking, approaching motorists and entering pedestrians can generally see each other better. However, multivehicle accidents can sometimes increase when angle parking is used, because of vehicles backing up in traffic.

In summary, dart-out and intersection dash accidents are clearly major pedestrian-accident problems, and visual obstruction created by parked vehicles is one of the causes. The actual effects of previous projects involving parking restrictions and angle parking are relatively unknown. This is probably because of the practical problems of implementing such regulations. However, at locations with substantial dart-out pedestrian accident problems and poor sight distance caused by on-street parking, the use of such curb parking regulations is likely to be effective in improving pedestrian safety.

Conditions Where Curb Parking Restrictions Are Most Beneficial

- Where pedestrian dart-out accidents are common.
- Where no sidewalk exists or sight distance at the intersection is poor.
- Where vehicles park too close to the crosswalk.
- At midblock crossing locations.

Conditions Where Curb Parking Restrictions Are Least Beneficial or Possibly Harmful

- Strip business areas where convenient alternative parking is unavailable (i.e., when businesses are adversely affected).
- Wide streets with high vehicle speeds.

Advantages to Front-in Angle Parking (*10*):

- Can improve driver and pedestrian sight lines and also pedestrian scanning behavior.
- Can reduce vehicle speeds. Some drivers may use more caution when they observe vehicles backing out of angle parking spaces.

Disadvantages to Front-in Angle Parking (*10*):

- Reduces the space for travel lanes.
- Increases the risk of a parked vehicle being hit while pulling out of parking space.

Advantages to Restricting Curb Parking (*10*):

- Can improve the stopping sight distance between motorists and pedestrians.
- Roadway or intersection capacity may increase, particularly during peak periods on major arterials.

Disadvantages to Restricting Curb Parking (*10*):

- Eliminates parking spaces for motorists.
- Is usually opposed by nearby business owners.
- Vehicle speeds may increase after on-street parking is removed (which is undesirable for pedestrians).

SIDEWALKS AND OTHER PEDESTRIAN PATHS

Sidewalks and pedestrian paths are areas for pedestrian travel separate from vehicle travel, and usually parallel to the vehicular roadway. They may specifically include several varieties (*10*):

- Sidewalk—These are paved (typically concrete) walkways that are separated from the street by at least a curb and gutter.
- Pathway—This is a gravel or asphalt walkway near a roadway and may either be temporary or permanent.
- Widened sidewalk—This is a walkway that has been widened by reducing the street width and/or the parking lane or increasing the building setback.
- Shoulder improvements—Areas next to the travel lanes in rural and suburban areas may also be widened or paved to provide an area for pedestrians to walk.

Sidewalks are commonly used in residential and urbanized areas, but normally are not constructed in rural areas because of cost considerations.

The ITE *Transportation and Traffic Engineering Handbook* provides the following information on sidewalk design (*21*):

> As a minimum, sidewalks should be provided along streets, used for pedestrian access to schools, parks, shopping areas, and transit stops. Minimum sidewalk widths should be 4 ft (1.2 m); widths of 8 ft (2.4 m) or greater are required in commercial areas. Sidewalks may be located next to the curb, but, desirably, they should be at least 5 ft (1.5 m) and preferably from 12 (3.6 m) to 15 ft (4.6 m) from the edge of curb. Borders should be made as wide as practical. As indicated previously, the border should generally be from 4 to 8 ft (1.2 to 2.4 m) plus the sidewalk width. In rural areas wider border areas are usually applicable.

Sidewalks not only provide separation between pedestrians and motor vehicles, but have been shown to reduce pedestrian accidents in residential and business areas. Sidewalks in residential areas also provide paved areas for children to play, instead of playing in the street (*10*). Additional pedestrian traffic can be generated as a result of new sidewalk installations. The ease of pedestrian movements on sidewalks, however, is reduced when they are cluttered with numerous poles, newsstands, trash cans, and other obstacles (Figure 4). Also, sidewalks that are used extensively by bicyclists and pedestrians often have a high incidence of related conflicts and/or accidents.

In a 1986 study by Knoblauch, et al. (*22*), involving an analysis of pedestrian accidents and exposure under various roadway situations, locations with no sidewalks were more than two times more likely to have pedestrian accidents than sites with sidewalks were. The presence of sidewalks was found to have a particularly large safety benefit in residential and mixed residential areas. However, sidewalks had no effect on hazard in commercial areas. Recommended guidelines for sidewalk installation are given in Table 7, as given in the 1986 study (*22*).

In summary, the use of sidewalks and separated paths for pedestrians clearly provides the potential for increased pedes-

FIGURE 4 Cluttered sidewalk.

trian safety by separating pedestrian traffic from motor vehicle traffic. In suburban and rural areas where sidewalks are not used, their installation probably would be highly beneficial, particularly where there are pedestrian volumes and in areas where children walk.

Conditions Where Sidewalks Are Most Beneficial

- Suburban streets, particularly with moderate to high pedestrian travel and/or streets with high volumes or speeds and where a high percent of truck traffic exists.
- Streets where there is no other place for pedestrians to walk except in or near the travel lane.
- Narrow streets with pedestrian traffic.
- High-pedestrian-accident areas.
- On roads near schools, parks, or areas with young children at play.

Conditions When Sidewalks Are Least Beneficial or Possibly Harmful

- Where constructed too close to high-speed roadways.
- When used by bicyclists and/or too narrow.
- When sidewalks are cluttered with poles, trash cans, fire hydrants, benches, and other obstacles (Figure 4).

Conditions Where Separate Pedestrian Paths in Rural and Suburban Areas Are Most Beneficial

- An area near schools or other areas heavily traveled by pedestrians.
- Areas with high traffic speeds or volumes and heavy volumes of pedestrians.
- Areas with considerable pedestrian activity with well-defined origins and destinations (e.g., connecting residential area with shopping center).
- On narrow streets with narrow shoulder or areas where pedestrians would otherwise have to walk in the road, particularly where nighttime pedestrian activity exists.
- Recreational areas with joggers, etc.

Conditions Where Separate Pedestrian Paths in Rural and Suburban Areas Are Least Beneficial or Possibly Harmful

- In high-crime areas.
- When pedestrian activity is low.

Advantages of Pedestrian Paths and Sidewalks (*10*)

- Can reduce the number of pedestrian accidents in residential and business areas.
- Provides separation between pedestrians and motor vehicles.
- Can provide a more direct pathway than the road (such as on college campuses).
- Can provide safer and more easily traveled areas for all pedestrians (particularly the elderly and the handicapped).
- Provides paved places for children to play as an alternative to playing in the street.
- Sidewalks are often funded by property owners.
- Sidewalk widening increases space for pedestrians, reduces pedestrian congestion, may provide an additional buffer zone between pedestrians and vehicles, reduces visual obstruction caused by parked motor vehicles, and provides more space for necessary sidewalk furniture.

Disadvantages of Pedestrian Paths and Sidewalks (*10*)

- Can create snow-removal problems.
- Cracking of sidewalks caused by severe weather requires expenditures for maintenance.
- Sidewalk widening may reduce the width for vehicle travel lanes and/or parking space, is more expensive than temporary walkways, and in areas with substantial bicycle travel, could lead to conflicts or accidents between bicyclists and pedestrians on pedestrian paths and sidewalks.

BARRIERS

Barriers separating pedestrians from vehicular traffic include fences, chains, guardrails, or other devices (Figure 5). Such barriers may be used to either channel pedestrians to a safe crossing point or to prevent pedestrians from crossing at dangerous locations. In urban areas, approximately 40 percent of pedestrian accidents occur when pedestrians cross the street between intersections (*10*). According to the FHWA "Model Pedestrian Safety Program—Users' Guide," the types of barriers include (*10*):

- Median Barriers. Usually chain-link fences that are located along roadway medians or areas separating opposing traffic

FIGURE 5 Pedestrian barriers.

lanes. Barriers can also discourage pedestrians from crossing at nonintersection locations.

- Sidewalk Barriers. Barriers that are located near the edge of a sidewalk to help channel pedestrians to crosswalks or grade-separated facilities. Construction materials typically include chain-link fencing, pipes, hedges, planters, or sidewalk furniture.
- Roadside Barriers. These are generally high chain-link fences that are located alongside a high-speed or high-volume highway to prevent pedestrians from crossing the road.

In a 1975 study, Berger found that midblock crossings and running into the roadway can be significantly reduced by the use of median barriers (*20*). Also, the author found a reduction in pedestrians darting from behind parked cars into traffic through the use of median and parking meter post barriers (i.e., chain sections 3 ft high supported by parking meter posts).

The effect of pedestrian barrier fences was evaluated along 18 highway sections in Tokyo in a 1969 study (*2*). Pedestrian accidents dropped by nearly 20 percent after installation of the barriers, with similar reductions for pedestrian accidents in midblocks and intersections. Total accidents dropped by 4 percent after installation of the barriers (*2*).

In summary, barriers can be effective in reducing dart-outs and intersection dash accidents, particularly when unsafe pedestrian crossing behavior is common. They are particularly helpful in some downtown areas, near pedestrian overpasses, and where high-speed traffic exists and pedestrian flows cannot otherwise be controlled. However, they may be of minimal effectiveness in areas near high school or college campuses, especially where students may maneuver over or under them.

Conditions When Roadside Barriers Are Most Beneficial

- In conjunction with pedestrian overpasses.
- High vehicle speeds on uncontrolled access roads and young pedestrians.
- Where little or no separation exists between roadway and sidewalk on high-speed roadways, particularly where no curbs exist and curves exist.
- Near schools, arenas, or other high-pedestrian generators where pedestrians spread out in numerous directions.
- Downtown areas with high pedestrian flows on high-volume high-density roadways, where jaywalking is common.
- On bridges with both pedestrian and vehicle traffic.
- Where pedestrian flows cannot otherwise be controlled.

Conditions Where Least Beneficial or Possibly Harmful

- Where needed pedestrian crossing points are not provided.
- Where stranded motorists need access to sidewalk.
- On roads and streets with curb parking.
- Where city blocks are too long.
- In situations in which pedestrians are likely to climb over or under barriers and/or walk in the street inside of the barriers.
- In cases where barriers cause sight restrictions.

Advantages of Barriers (*10*)

- May be helpful in channelizing pedestrians to safe crossing facilities (e.g., overpasses, underpasses, signalized intersections).
- Can prevent some pedestrians from crossing at hazardous locations.
- Can reduce the frequency of pedestrians running into the roadway.
- Can protect pedestrians from hazards that are not always obvious (e.g., where sight distance is restricted).
- Can protect pedestrians from errant vehicles.

Disadvantages of Barriers (*10*)

- Can cause maintenance problems with snow, leaf, and trash removal.
- Some people try to climb barriers or cut holes in them.
- Physical barriers are more expensive than some other types of treatments (e.g., signs and markings).
- Can interfere with on-street parking, vehicle loading and unloading, and emergency vehicles (e.g., fire trucks, ambulances).
- May put stranded motorists in danger, by forcing them to walk along high-speed or hazardous roads (e.g., freeways).
- Rigid roadside barriers present a roadside obstacle to motorists.

GRADE-SEPARATED CROSSINGS

Grade-separated pedestrian crossings are facilities allowing for the free-flowing movement of vehicles and pedestrians, and such facilities are located one or more levels above or below the vehicle level (*10*).

The types of grade-separated facilities include (*10*):

- Overpass/Bridge: These are aboveground passageways over a roadway, in which both ends of the overpass are at grade level, and stairs or ramps lead up over the roadway (or else the road is depressed and the bridge is at ground level). A pedestrian overpass is illustrated in Figure 6.
- Underpass/Tunnel: These facilities provide stairs or ramps leading down to an underground passage (or else the road is elevated and the underpass is at ground level).
- Below-Grade Networks: These are extensive underground walkways that usually carry pedestrians perpendicular and par-

FIGURE 6 Pedestrian overpass.

FIGURE 7 Pedestrian skyway.

allel to motor vehicles (traveling above them). Such networks are sometimes used with rapid-transit rail (subway) systems.

- Elevated Walkways: These are essentially sidewalks located above ground level that run parallel to the direction of traffic flow. They can be freestanding or connected to an adjacent building.
- Skyways/Skywalks: These facilities (Figure 7) are usually enclosed walkways one or more levels above the ground level that often connect buildings at the elevated level in midblock (and perpendicular to traffic flow).

Pedestrians' use of grade-separated crossings, therefore, eliminates their conflicts with motor vehicles and can reduce or eliminate pedestrian-involved accidents at sites where such crossings exist and are used by pedestrians. The effectiveness of grade-separated crossings depends on how much they are used by pedestrians.

A 1965 study by Moore and Older (*23*) found that the amount of use of grade-separated crossings by pedestrians was highly dependent on walking distances and the convenience of the facility. The measure of convenience, R, was defined as the ratio of time on the subway or bridge route divided by the time on the alternative ground-level route. As shown in Figure 8, 95 percent of pedestrians would use an underpass if the travel time were equal to that of the at-grade street crossing (i.e., R=1). However, an R-value of 0.75 or less was required in order for 95 percent of pedestrians to use an overpass. If an overpass requires 30 percent longer than an at-grade crossing (R=1.3), then virtually no one will use the overpass (*23*).

A 1969 study was conducted in Japan (*2*) of reported pedestrian accidents for six-month periods before and after pedestrian overpasses were installed at 31 locations. As shown in Table 8, pedestrian-related accidents per structure decreased from 2.16 to 0.32 (an 85.1 percent reduction) on 200 m sections on either side of the overpasses. The reduction on the 100 m sections closest to the overpasses was 91.1 percent. During that same period, nonrelated (assumed to be nonpedestrian) accidents increased. The increase of accidents within the control group with

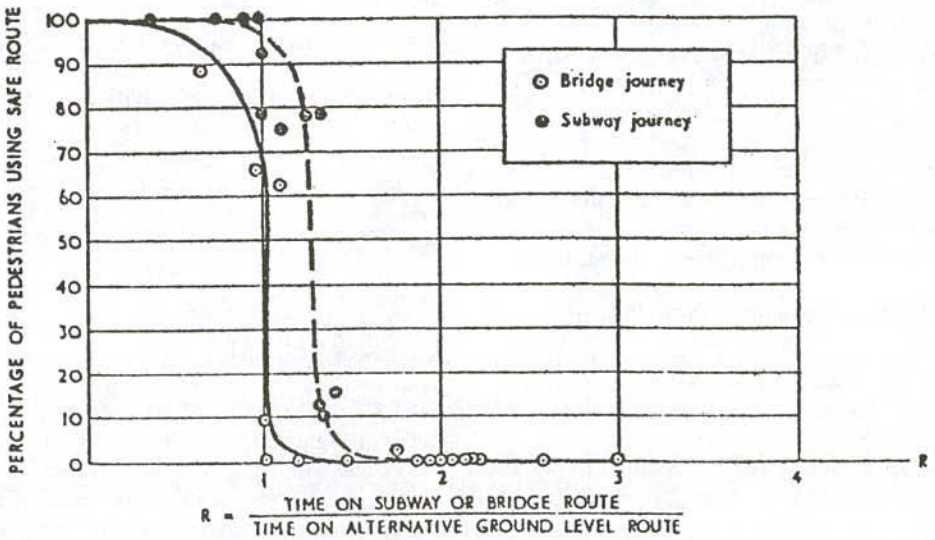

FIGURE 8 Expected usage rate of pedestrian bridges and underpasses (*23*).

TABLE 8

EFFECTS OF PEDESTRIAN OVERPASSES ON ACCIDENTS IN TOKYO, JAPAN (*2*)

Accident Type	Accidents per Structure (6 months before and after)					
	200-meter Sections			100-meter Sections		
	Before	After	Reduction(%)	Before	After	Reduction(%)
Pedestrian Related	2.16	0.32	85.1	1.81	0.16	91.1
Non-pedestrian Related	2.26	2.77	-22.9	1.65	1.87	-13.7
Total	4.42	3.09	29.9	3.46	2.03	41.1

the decrease in pedestrian accidents indicates that overpasses at those sites were indeed the cause of the reductions in pedestrian accidents.

In summary, a high potential exists for reducing pedestrian accidents by the physical separation of the travel paths of pedestrians from vehicles with the use of pedestrian overpasses or underpasses. However, the effectiveness of grade-separated crossings depends on their use by pedestrians, and many pedestrians may be unwilling to use those facilities. The use of such facilities depends on convenience and walking distances, compared with alternative crossing locations.

Conditions Where Grade-Separated Crossings Are Most Beneficial

- Where pedestrian demand is moderate to high to cross freeways or expressways.
- Large volume of young children (i.e., near schools) who regularly must cross a high-speed and/or high-volume road.
- Streets with high vehicle volumes and high pedestrian-crossing volumes and where extreme hazard exists for pedestrians (e.g., high-speed traffic, wide street, poor sight distance).
- One or more of the conditions stated above in conjunction with well-defined pedestrian origin and destination (e.g., residential neighborhood to school, parking structure to university, apartment complex to shopping mall).

Conditions Where Least Beneficial or Possibly Harmful

- In high-crime areas (where underpasses in particular are often underutilized).
- When the facility is poorly designed and inconvenient for use by handicapped or other pedestrians.
- When no physical barriers are built to control at-grade crossing activity.
- In areas where the majority of pedestrians are unlikely to use the facility (e.g., near high schools).

Advantages of Grade-Separated Crossings (*10*)

- Provide separated facilities for pedestrians and vehicles.
- Often improve vehicle circulation.
- Can reduce pedestrian and vehicle delay.
- Overpasses/bridges provide convenient and safe crossings for pedestrians and are usually easier to maintain and less expensive to construct than underpasses.
- Underpasses/tunnels do not create as much visual clutter as overpasses, protect pedestrians from bad weather conditions, and are usually shorter in length than overpasses (i.e., they only have to be deep enough for a pedestrian to go under the road, whereas overpasses must be high enough to allow trucks to pass under them). However, underpasses must be strong enough to support the weight of motor vehicles, whereas overpasses must only support the weight of pedestrians.
- Below-grade networks provide protection for pedestrians from sun and harsh weather, don't disturb the urban street system, and don't have to follow grid pattern of streets.
- Elevated walkways can provide direct, convenient paths free of motor vehicles, are often compact and efficient arrangements of retail space, provide cover for at-grade pedestrian level below, and can be enclosed to protect pedestrians from bad weather.

Disadvantages of Grade-Separated Crossings (*10*)

- Some pedestrians won't use grade-separated facilities.
- Can increase pedestrian travel time by forcing pedestrians to take a longer route.
- Poorly planned or designed grade-separated facilities often are not used by most pedestrians, and therefore may not be effective in reducing accidents at sites where they are installed.
- Overpasses/bridges are expensive, especially for adding provisions for handicapped pedestrians, require high clearances for trucks, can be visually displeasing, and may require additional right-of-way area to be purchased.

- Underpasses/tunnels typically have high construction costs; have potential maintenance problems from drainage, litter, vandalism, and lighting; and require adequate design and lighting to discourage crime and encourage use.
- Below-grade networks can create emergency service problems and some pedestrians consider them to be unsafe and monotonous, unless they are properly planned and lighted.
- Elevated walkways must be properly enclosed to avoid the potential danger of falling objects, may cause a decline in retail activity at-grade, may result in additional visual clutter, can have emergency service problems, and may be difficult to coordinate with at-grade and below-grade systems.

ROADWAY LIGHTING

Roadway lighting here refers to providing new or improved overhead lighting for street and/or crosswalk locations. Previous studies by Knoblauch (*7, 8*) indicate that 35 to 42 percent of pedestrian accidents occur during dark conditions, even though pedestrian travel is relatively low at night.

In a 1978 study at 99 sites in Israel, a signing and illumination program was implemented (*24*). Using 39 unilluminated control sites, the number of night accidents dropped from 28 to 16 at the project sites, a 43 percent reduction. Nighttime accidents increased at the control sites, and daytime accidents remained relatively unchanged. After checking the possible site changes (e.g., pedestrian and traffic volume, weather changes, national accident changes, etc.), the authors attributed the accident reduction primarily to the illumination (*24*).

A 1972 study by Pegrum investigated the use of floodlighting of pedestrian crosswalks at 63 sites in Perth, Australia (*2*). The illumination at each site involved two floodlights (one on each end of the crosswalk) mounted at a height of 17 ft approximately 12 ft from the crosswalk. Each floodlight was aimed at a point approximately 3 ft above the pavement. Each luminaire was a 100 W sodium lamp. The results are shown in Table 9 for a pilot study (6 crossing sites with five years of accident data, before and after treatment) and the full study (57 crossing sites with two years of before-and-after data). In summary, the nighttime pedestrian accidents decreased from 32 to 13 at the 57 sites, a 59 percent reduction. Daytime pedestrian accidents and also accidents involving vehicles alone (control groups) remained relatively unchanged. Thus, the author concluded that the sodium floodlighting resulted in a significant decrease in nighttime pedestrian accidents (*2*).

In summary, roadway lighting primarily is used as a motorist aid or as a crime deterrent, but nighttime pedestrian safety can be an additional benefit. Although installation of roadway lighting is relatively expensive compared with other pedestrian-safety treatments, it may be justified in areas of moderate to high nighttime pedestrian activity.

Conditions Where Roadway Lighting Is Most Beneficial

- Arterial streets and other roadways with high traffic volumes, particularly near intersections.
- Streets or areas with high nighttime pedestrian activity, particularly where other high-pedestrian areas in the city or area are also lighted.
- Streets or intersections with a high incidence of nighttime accidents.
- Dark residential streets with high volumes of child and/or older adult pedestrians.

Conditions Where Least Beneficial or Possibly Harmful

- Where placed improperly (overhead lighting can make traffic signals less visible).
- Where light intensity is insufficient.
- Where the poles interfere with pedestrians (e.g., lack of adequate right-of-way).

TABLE 9

ACCIDENTS AT PEDESTRIAN CROSSINGS PROVIDED WITH SODIUM FLOODLIGHTS (PERTH, AUSTRALIA) (*2*)

	Pedestrian Accidents[a]			Accidents Involving Vehicles Alone[a]		
Study	Day	Night	Total	Day	Night	Total
Pilot Test (6 crossings)						
5 years before	19 (1)	7 (1)	26 (2)	5	1	6
5 years after	21 (1)	2	23 (1)	9	0	9
Follow-on (57 crossings)						
2 years before	57 (2)	32 (1)	89 (3)	19	2	21
2 years after	58 (2)	13 (1)	71 (3)	18 (1)	1	19 (1)

[a]Fatalities shown in parentheses.

Advantages of Roadway Lighting (*10*)

- Helps pedestrians to use streets more safely at night.
- Increases clothing brightness from drivers' perspective.
- Causes some pedestrians to be more alert at street crossing locations.
- May provide adequate stopping sight distance for motorists at night if sufficient illumination is used.

Disadvantages of Roadway Lighting (*10*)

- Pedestrians may develop a false sense of security on well-lighted streets.
- Some overhead street lighting configurations primarily illuminate the crosswalk and the top of the pedestrian's head. This may not make the pedestrian more visible to the driver.
- Under certain situations, may reduce sight distance.

FAR-SIDE BUS STOPS

Bus-stop accidents represent 2 percent of pedestrian accidents in urban areas and 3 percent in rural areas (*7*). One possible treatment for this accident type is to move a transit or school bus stop location from the near side of an intersection to the far side. Far-side bus stops generally result in more pedestrians crossing the street in back of the bus instead of in front, making them more visible to motor vehicles approaching from behind the bus (*20*).

Berger (*20*) reported the effects on pedestrian behavior of relocating near-side bus stops to far-side stops at two intersections. One of the sites was an unsignalized intersection in Miami, Florida (a two-way, four-lane street intersecting with a two-way, two-lane street), and the other was a signalized intersection in San Diego, California (a two-way, four-lane street intersecting a one-way, three-lane street). In the initial condition, half of the crossings were considered to be completed in an undesired manner, but undesirable crossing behavior was virtually eliminated in the period afterward (*20*).

The moving of transit or school bus stop locations from the near side to the far side of an intersection is often a feasible and beneficial pedestrian-safety measure. In spite of certain types of problems that may result from far-side bus stops (e.g., the bus may have to block traffic on all approaches if cars are illegally parked in bus stops), the relocation of bus stops from near side to far side is relatively inexpensive and can improve pedestrian safety at certain locations.

Conditions Where Far-Side Bus Stops Are Most Beneficial

- In areas of high bus traffic and high bus ridership (and/or with exclusive bus lanes).
- Along streets with a moderate or heavy volume of right-turn traffic on the bus street.
- In central business district (CBD) areas and/or other areas with heavy pedestrian volumes and high traffic volumes.
- At either signalized or nonsignalized intersections with one or more of the conditions mentioned above.

Conditions When Least Beneficial or Possibly Harmful

- When large volumes of pedestrians must cross a busy street to reach the far-side bus stop.
- When there are a large number of transfers (pedestrian movements at an intersection may be substantially increased).
- When most of the pedestrian demand is near-side.

Advantages of Far-Side Bus Stops (*10*)

- Can reduce the number of bus stop-related accidents, where used appropriately.
- Buses at far-side bus stops are less likely to obscure traffic signals and signs or pedestrian movements at intersections than at near-side bus stops.
- Can reduce conflicts between stopped buses and right-turning vehicles.
- Can reduce the number of people who enter the street in front of a bus.

Disadvantages of Far-Side Bus Stops (*10*)

- May increase the time of bus stop operation, because delays at signals will no longer be used for passenger pickup/dropoff.
- Cars illegally parked in far-side bus stops may cause buses to overhang into the cross street.

PEDESTRIAN REFUGE ISLANDS

Pedestrian refuge islands (i.e., safety islands) are areas between lanes of traffic or within an intersection where pedestrians may pause until traffic clears (Figure 9). Safety islands may be delineated with roadway markings and/or raised above the street surface. They are commonly installed on wide, multi-lane streets where adequate pedestrian crossing time cannot be provided without having an adverse effect on traffic flow (*10*). Ramps or cut-through islands for wheelchair users should be provided on the islands.

Little evidence exists on the safety effects of pedestrian refuge islands. They are, of course, necessary on wide streets where sufficient crossing time is not provided to pedestrians during a single crossing period. There are traffic situations in which pedestrians may not be willing to stop in the median and wait until the next WALK interval.

Conditions Where Refuge Islands Are Most Beneficial

- Wide two-way streets with high vehicle volumes, high speeds of travel, and large pedestrian volume.
- Wide streets where elderly, handicapped, and/or child pedestrians cross regularly.
- Streets where signal timing is not sufficient for pedestrians to cross safely.
- Wide, two-way intersections with heavy traffic volumes and crossing pedestrians.

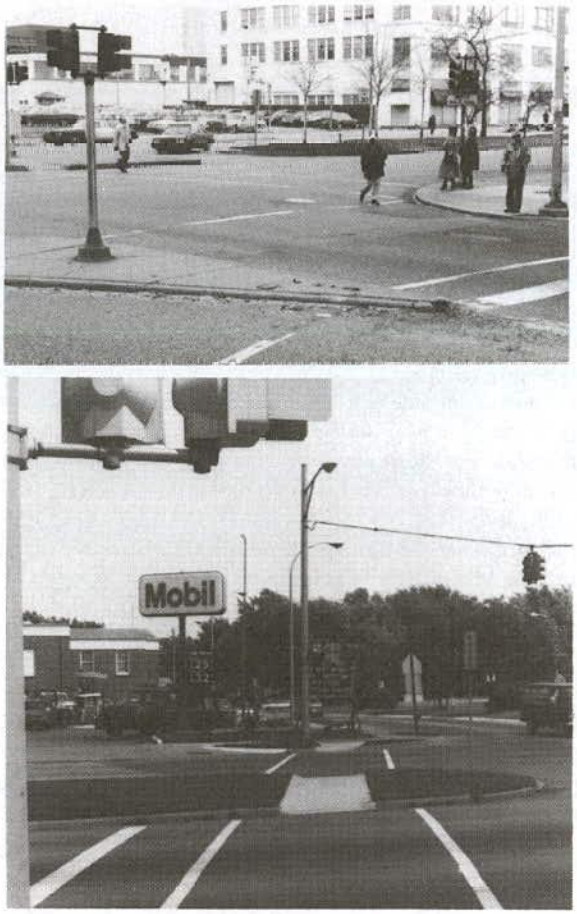

FIGURE 9 Pedestrian refuge islands.

Conditions Where Refuge Islands Are Least Beneficial or Possibly Harmful

- On narrow streets and/or when narrow safety islands are used.
- Where a high turning volume of large trucks exists.
- Where roadway alignment obscures the island so it is not easily seen and vehicles are likely to drive into them.
- In areas where the presence of a safety island hampers snowplowing.

Advantages of Pedestrian Refuge Islands (*10*)

- Can reduce pedestrian exposure to traffic, and allow pedestrians to cross in stages.
- Permit pedestrians to look for traffic in only one direction at a time.
- Give pedestrians a resting place when crossing wide roads or intersections.

Disadvantages of Pedestrian Refuge Islands (*10*)

- May present an illusion of safety.
- May cause street sweeping or plowing problems.
- May cause damage to vehicles if drivers hit them.

ONE-WAY STREETS

Conversion from two-way to one-way street systems can reduce the level of complexity for pedestrians crossing the street, because they must look only in one direction. Also, drivers can give more attention to pedestrians, because they do not have to worry about opposing traffic (*10*). The initial period after converting to one-way street systems may require public education. Also, one-way street systems should be planned in terms of the total traffic network in an area.

Numerous studies have attempted to determine effects of one-way street systems on pedestrian safety. In a 1982 research study by Zegeer (*25*) of signalized intersections in 15 U.S. cities, a comparative analysis was used to identify factors associated with pedestrian accidents. Intersections of two-way streets had significantly higher pedestrian accidents, compared with intersections having one-way streets, when controlling for other important traffic and roadway variables. The presence of one-way streets was the geometric feature found to be most related to low pedestrian accidents (although less related than pedestrian volume or traffic volume) (*25*).

Various studies in the United States and Canada have evaluated the accident effects of converting two-way street systems to one way. A study in Sacramento found a 62 percent reduction in pedestrian accidents after 19 central area streets were converted to one way (*11*). In Hamilton, Ontario, pedestrian accidents were also found to decrease, after 27 miles of streets were converted to one-way operation (*26*). In fact, pedestrian accidents dropped by 9 (10 percent) during the first six months after the one-way street conversion, and by 58 (66 percent) during the second six-month after period. During those same periods, pedestrian accidents increased on two-way streets in the city, which helps to confirm that the reductions in pedestrian accidents were the result of the one-way street conversion and not caused by random accident fluctuations. Conversion of a span of streets from two-way to one-way streets in Manhattan reduced pedestrian accidents from 117 to 77, as reported by Bruce in 1967 (*27*).

In summary, conversion from two-way to one-way street systems has consistently been found to reduce pedestrian accidents, because it can greatly reduce the complexity of crossings for pedestrians and allows motorists to pay more attention to crossing pedestrians. Where one-way street systems are feasible in terms of traffic-circulation patterns, improved pedestrian safety is a likely result.

Conditions Where One-Way Streets Are Most Beneficial

- Downtown grid street networks, particularly on narrow streets with high traffic volumes.
- Streets with inadequate gaps for vehicle turns.
- Streets with heavy pedestrian activity and a high frequency of conflicts between turning vehicles and pedestrians.
- Where there is a substantial number of left-turn accidents, right-turn accidents, and/or midblock pedestrian accidents.

Conditions Where Least Beneficial or Possibly Harmful

- When vehicle speeds would be substantially increased as a result (e.g., some very wide streets).

- Where numerous complex intersections exist along the route for which wrong-way driving is likely.
- Where traffic circulation and overall travel time in the area would be hampered.
- Streets with relatively low traffic volumes.

Advantages to One-Way Streets (*10*)

- Drivers do not have to be concerned with opposing traffic and can thus give more attention to pedestrians.
- Greater gaps in traffic often result.
- Street capacity often is higher.
- Can reduce pedestrian and vehicle delay.
- May permit simpler signalization.
- May reduce some types of turning accidents.

Disadvantages to One-Way Streets (*10*)

- At some signalized intersections, pedestrians may not be able to see the traffic signals because there is only one direction of traffic flow but there are two directions of pedestrian flow. Thus, pedestrian signals may be needed.
- One-way streets may result in increased vehicle speed and vehicle volume.
- Possible problems with neighborhood acceptance may occur.
- Possible negative effects for transit and emergency vehicles.
- Some vehicles will have to increase their travel distance.

FACILITIES FOR THE HANDICAPPED AND OLDER ADULTS

According to Herms, more than 25 percent of the population can be considered as handicapped (*28*). In a 1979 study by Templer, elderly and handicapped persons who experience greater than normal levels of risk include (*29*):

- Developmentally restricted people (based on size and maturity).
- Users of wheelchairs.
- People with impairments to their lower extremities (legs and feet) who walk with special aids.
- People with severe sight impairments.

Numerous types of traffic-control measures are in use for addressing the special needs of the handicapped, including (*10*):

- Signal-Related Measures. These include audible pedestrian signals, which use buzzers, bells, horns, birdcalls, or other sounds to indicate to pedestrians when the WALK interval is on (as have been used in San Diego, Washington, D.C., and other cities at one or more locations). In Japan, vibrating signal pedestal posts have been used to indicate to blind pedestrians when the WALK interval is on. Special pedestrian push buttons are used at some locations (with some slower pedestrians) that extend the WALK interval when the button is pushed.
- Sign-Related Measures. These include Braille maps and also warning signs aimed at motorists to indicate that handicapped people are in the area (e.g., CAUTION: DEAF AND BLIND CHILDREN).

FIGURE 10 Curb ramp.

- Sidewalk-Related Measures. Curb ramps (Figure 10) are used in many areas as an aid to those in wheelchairs, for baby carriages, for people on crutches, or for older adults. Guidestrips (tactile strips made of sand or glass beads set in thermoplastic paint placed on a walkway) are used to aid the blind. The placement of handrails (to assist those with visual problems, equilibrium problems, or mobility problems) and careful placement of street furniture (to minimize obstacles) are also helpful in many situations.
- Crosswalk-Related Measures. Guidestrips are raised markings made of epoxy and gravel that can be felt by blind people with a cane. When placed within a crosswalk, they can be helpful to blind people crossing the street.

Other traffic-control measures mentioned by Templer as potentially useful for handicapped pedestrians include widened sidewalks, pedestrian refuge islands, and prohibitions of RTOR (*29*). A summary of the advantages and disadvantages of various traffic-control measures for the handicapped is given in Table 10, as taken from the 1977 version of the "Model Pedestrian Safety Program—Users' Guide."

Procedures for providing networks of pedestrian facilities were developed in an FHWA study (*30, 31*). The procedures were applied in the cities of Baltimore, Seattle, and New Orleans and provisions were also made for a technical analysis and for setting priorities for pedestrian improvements. Using the procedures, a jurisdiction can develop a program to better accommodate the needs of elderly and handicapped pedestrians. An example of countermeasures using this process is given in Table 11, based on identified problems.

The use of special facilities for the handicapped and older adults not only is becoming more common, it is required on many projects constructed with federal funding. The effectiveness of such facilities in reducing pedestrian accidents is relatively unknown, although they can definitely improve the ability of many pedestrians to travel more freely from place to place. Also, many people believe that society has a moral obligation to make reasonable provisions for older adults and people who are handicapped.

Conditions Where Curb Ramps Are Most Beneficial to Handicapped Pedestrians

- Where persons in wheelchairs must cross the street unassisted.
- In areas near hospitals or retirement homes.
- In downtown areas and/or those with dense pedestrian movements.

TABLE 10

FACILITIES FOR THE HANDICAPPED COUNTERMEASURE MATRIX (*10*)

	ADVANTAGES	DISADVANTAGES
IN GENERAL.	Permit those with minor and serious handicaps to travel more freely. Can also benefit people who aren't handicapped (1).	Are generally expensive. Require research and careful planning.
SIGNALS.		
Audio	A majority of the blind, even those with hearing problems also, prefer them (4). Can also benefit the sighted who have allowed their attention to wander (4). Signals of varying frequencies may also help the deaf (4). Can give directional sound clues (4).	Disturb area residents at night. May mask other street noises upon which the blind depend. May cause the blind to become over-dependent on audio signals, reducing their skills to cross unsignalized intersections (4).
Tactile	Tell blind people when it is safe to cross the street. Allow the blind to hear traffic sounds on which they depend (4). Have an unambiguous association with the relevant crossings (4).	Difficult to find. The blind feel selfconscious using them (4). Lack of tracking function (4). Those designed are crude and have maintenance problems (4).
Combination Audio and Tactile	Inexpensive. Tactile boxes are easy to find because they give off a clicling noise.	Don't tell pedestrians in which direction it is safe to cross.
Lengthened phases.	Allow more crossing time for the elderly, the handicapped and slow walkers.	Increase vehicle delay. May disturb the overall signal system.

TABLE 10

FACILITIES FOR THE HANDICAPPED COUNTERMEASURE MATRIX (*10*) (*Continued*)

	ADVANTAGES	DISADVANTAGES
CURB RAMPS.	Allow the elderly and others with mobility problems to move more freely across intersections.	May cause orientation problems for the blind. Involve redesigning of curbs. Snow and litter removal problems. Possible increase in bicycle use of sidewalks, because ramps allow easy crossing of streets. Ramps built up to the curb may be run over by cars and may cause drainage problems.
SIDEWALK GUIDESTRIPS.	Help the blind travel more freely and safely down the sidewalk. Warn the blind about non-sidewalk areas (e.g., the street, edges of parking lots).	Require careful planning by experts.
LOCATION OF STREET FURNITURE AWAY FROM PEDESTRIAN STREAM.	Provides a clear path for all pedestrians. Removes possibly hazardous objects from the path of the blind.	Involves additional expense for moving existing street furniture. Street furniture may block drivers' view of potential dart-outs.
CROSSWALK GUIDESTRIPS (3).	Help the blind align themselves with intersections. Help the blind across complicated intersections. Are relatively permanent.	Require careful planning by experts. The blind need special training in their use.

TABLE 11

EXAMPLES OF COUNTERMEASURES BASED ON SPECIFIC DISABILITIES (*31*)

HANDICAPPING CONDITION		EXAMPLES OF COUNTERMEASURES REQUIRED
LIMITED STAMINA	● Cannot travel far without stopping and resting	● Stopping and resting places
	● Cannot travel unless there are places to sit.	● Seating
SLOW TRAVEL SPEED	● Moves much slower than the average pedestrian	● Additional pedestrian walk interval time at signalized intersections.
SLOW REACTION TIME	● Cannot physically react quickly	● Additional walk interval time
IMPAIRED VISION	● Cannot see at all	● Detectable warning cues
	● Cannot see low overhanging projection	● Elimination of low projection
	● Cannot react to visual information and signs	● Tactile and audible signage systems
	● Cannot react to small print	● Signage with large letters
IMPAIRED HEARING	● Cannot hear public address systems	● Visual information systems
	● Cannot hear sound warnings	● Visual and tactile warnings
LIMITED USE OF LOWER EXTREMITIES	● Uses a wheelchair	● Provide ramps; smooth hard surfaces; maneuvering space, etc.
	● Cannot detect heat or cold sensation with certain parts of the body	● Avoid the use of metal surfaces that may become very hot or cold
	● Cannot traverse steep ramps	● Provide steps as an alternative to ramps
IMPAIRED BALANCE	● Cannot tolerate being bumped	● Walkways must be wide enough for the anticipated number of pedestrans
	● Cannot traverse ramps and stairs without something to lean on	● Provide handrails
	● Increased likelihood of falls	● Ensure that surfaces are not slippery and will not cause trips

Conditions When Curb Ramps Are Least Beneficial to Handicapped Pedestrians

- When ice and snow are not removed.
- When sidewalks are not used by persons in wheelchairs.
- When design is poor and curb ramps point directly into moving traffic.
- When construction is poor and ramps can cause tripping and stumbling.
- On narrow sidewalks with short curb radii.

STREET CLOSURES AND PEDESTRIAN MALLS

The closing of streets to motor vehicles to provide for environments partially or totally for pedestrians is an ideal solution for improving pedestrian safety and movement (although not necessarily for motorists and/or business owners in the area). The development of pedestrian malls (Figure 11) and other auto-free areas is usually the result of an urban renewal or downtown revitalization effort and not primarily for pedestrian-safety considerations.

Various alternatives have been tested to partly restrict motor vehicles from the pedestrian environment, including (*2*):

- Residential Yards—Shared streets that are designed for driving, playing, cycling, walking, and parking, where motor vehicles are the "intruders" and must move with great care and may park only in designated areas. Pedestrians and children may use the entire street width but not unnecessarily obstruct the progress of motor vehicles. In two neighborhoods in Delft, the Netherlands, residential yards (called "Woonerfs") did not produce less serious conflicts than conventional streets, because parents supervised young children more on conventional streets than on residential yards.
- Play Streets—These are residential streets that are closed to vehicular traffic during certain hours to allow for a supervised program of activities. An evaluation was conducted of pedestrian accidents two years before and after play streets were initiated at seven sites in Philadelphia. A significant reduction in pedestrian accidents occurred for children ages 5 to 14 for the combined areas. Benefits were greatest within a radius of one-quarter mile of each facility, even though more children used the facilities and crossed streets going to and from the sites (*2, 32*)
- Transit/Pedestrian Malls—These are malls where pedestrians share the space with buses (and sometimes trucks and taxis) but other motor vehicles are not allowed. Transit stops are normally provided at each end of the mall. Studies were conducted before and after the implementation of transit malls in Philadelphia and Minneapolis (*2*). Overall, only marginal or small positive accident benefits resulted, although pedestrian delay was improved, compared with full traffic conditions. The lack of safety benefits to pedestrians was attributed to more jaywalking and midblock crossings (encouraged by low bus volumes) and inadequate designs of malls (e.g., narrow roadways, lack of barriers, and placement of phone booths too close to curb) (*2*).

In summary, the conversion of streets to full pedestrian malls is an ideal way to provide safe and free flow of pedestrians in an area, such as for retail shopping. Although the conversion of streets to pedestrian malls is usually the result of efforts to revitalize downtown areas, improved pedestrian safety can be a beneficial result of such malls. Also of value seems to be the total closing of residential streets to motor vehicles during certain hours of the day, such as with play streets. However, a lesser degree of success has resulted from closing streets only partially to motor vehicles, such as with residential yards and transit malls.

FIGURE 11 Pedestrian mall.

Conditions Where Pedestrian Malls Are Most Beneficial

- CBD and high-pedestrian-volume areas.
- Where sidewalks are overcrowded and vehicle volumes are low.
- High-density downtown shopping areas with heavy pedestrian activity.
- Where vehicular traffic circulation would not be adversely affected.

Conditions Where Least Beneficial or Possibly Harmful

- Where truck delivery shares mall space.
- In high-crime areas.
- In high-speed areas with relatively low pedestrian activity.

Advantages of Pedestrian Malls and Street Closures (*10*)

- May reduce pedestrian delays and/or relieve pedestrian congestion.
- May enhance the aesthetic and social environment of the downtown area.
- Can provide greater accessibility to retail merchants.
- Can increase the use of public transportation.
- May decrease noise and air pollution on affected street.
- Can increase revenues, sales, and land values.
- Can be implemented in stages.

Disadvantages of Pedestrian Malls and Street Closures (*10*)

- Malls generally have high cost of installation, maintenance, and operation.
- Vehicle traffic must be rerouted to other streets.
- On nearby streets, may reduce retail activity and increase noise and air pollution.
- May disrupt utility and emergency services.
- Can disrupt bus routes and delivery of goods.
- Placement problems may exist with street furniture for visually handicapped pedestrians.
- Parking problems must be corrected.
- Security and policing problems may be a concern.

CROSSWALKS AND STOP LINES

The primary types of pavement markings that relate to pedestrian safety and movement include:

- Stop lines (i.e., limit lines), which are painted strips across a traffic lane to indicate where vehicles should stop at a stop sign or traffic signal.
- Painted crosswalks, which provide a delineated path for pedestrians to cross the street.

Although stop lines are often placed approximately 4 ft in front of the nearest crosswalk, the state of North Carolina sometimes uses stop-line modification (*33*). On multilane roads, the stop line is sometimes placed farther from the crosswalk to reduce the chance of cars stopped at the stop line obscuring the view of the pedestrian from vehicles in the adjacent lane. As illustrated in Figure 12, the pedestrian in the crosswalk is more likely to be seen by vehicles other than the one directly in front of him or her. This treatment would be directed at the multiple-threat type of pedestrian accident.

Unmarked crosswalks are simply the extension of the sidewalks leading up to the street. Marked crosswalks may be painted either at intersections or at midblock crossing locations, and generally are one of the following types (Figure 13) (*10*):

- Solid parallel lines.
- Zebra, which has diagonal lines painted between the parallel lines.
- Ladder design, which consists of short stripes painted parallel to the direction of the traffic flow.
- Solid marking made by painting the entire area within the crosswalk lines.

Knoblauch et al. (*22*) conducted a laboratory evaluation of the visiblity to drivers of three different types of crosswalk marking configurations: edge lines, diagonal, and ladder designs. Using 35 mm slides of these crosswalk markings with various spacing, 59 test subjects rated the visibility of the markings. Based on the laboratory tests and cost considerations, a ladder configuration with a 12 in. stripe and 24 in. space was recommended for crosswalks when possible.

Considerable controversy exists regarding the effect of painted

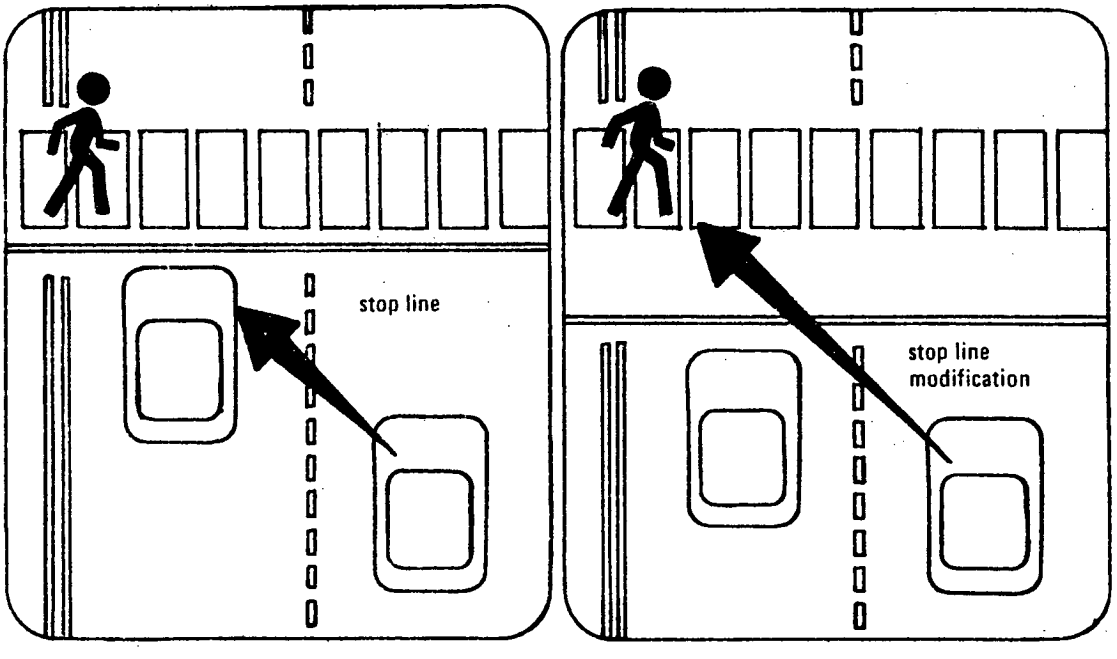

FIGURE 12 Illustration of improved sight distance from relocated stop bar (*33*).

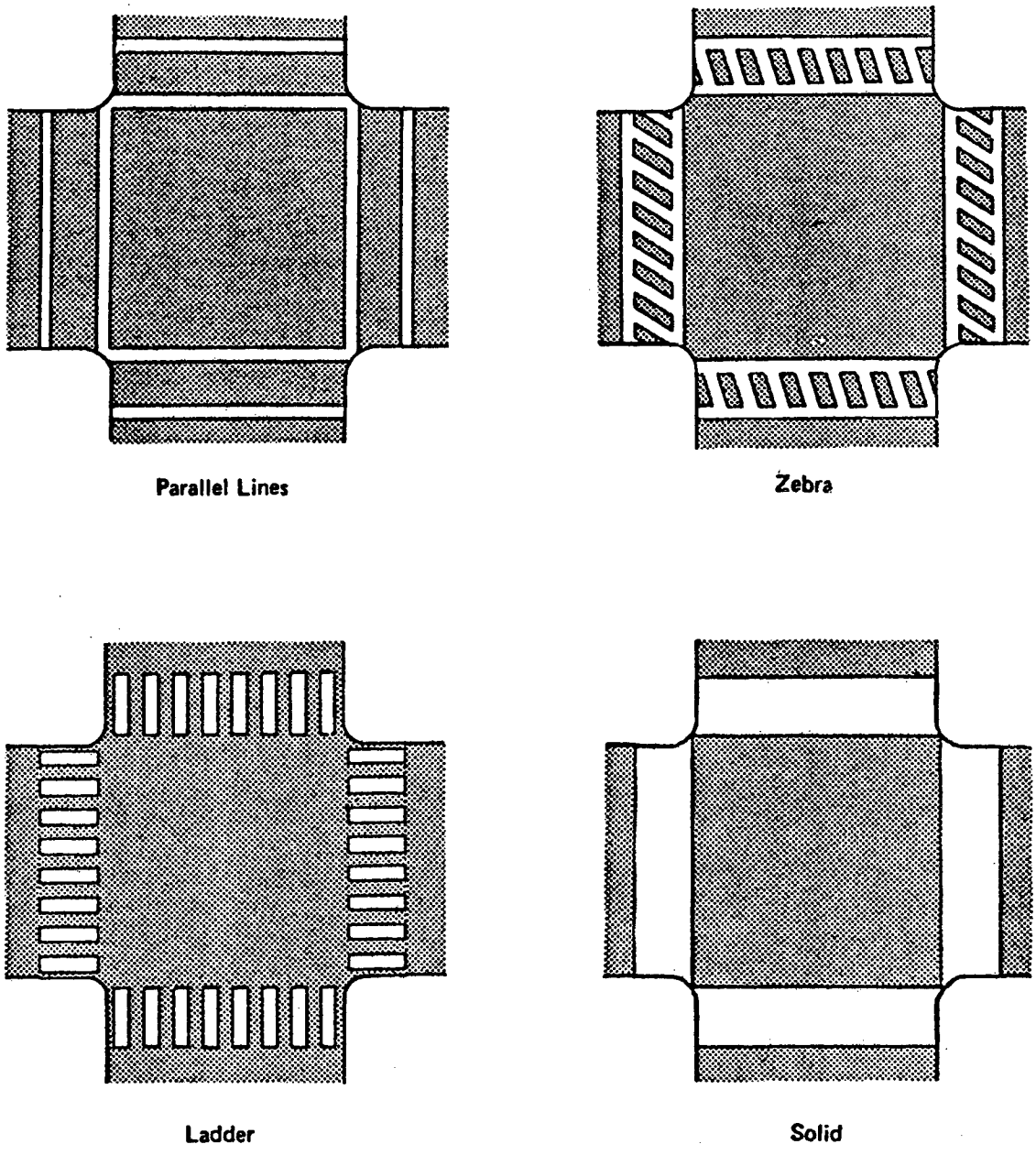

FIGURE 13 Illustration of crosswalk-marking patterns (*10*).

crosswalks on pedestrian accidents. The largest study to date on this subject was a 1972 study by Herms of 400 intersections in San Diego (*34*). At each intersection, one crosswalk was marked and the other not marked across the major street. In a five-year study of pedestrian accidents, the author reported a total of 177 pedestrian accidents in the painted crosswalks and only 31 pedestrian accidents in the unpainted crosswalks, a ratio of nearly 6 to 1. Pedestrian volume in the painted crosswalks was about three times as high as in the unpainted crosswalks, so painted crosswalks were determined to have twice as many accidents as unpainted crosswalks. The author concluded that marked crosswalks contributed to approximately twice as many pedestrian accidents, compared with unmarked crosswalks, probably in part because of an increased false sense of security from the marked crosswalks (*34*).

Knoblauch et al. (*22*) assessed the relative risk of many roadway situations using measures of pedestrian exposure and pedestrian accidents. The relative risk was found to be less for pedestrians in marked crosswalks than in unmarked crosswalks for nearly all types of roadway situations tested. The results of this study seem to contradict the study by Herms, which could be the result of different analysis approaches and/or locational conditions.

A study by the Illinois Department of Transportation (*35*) was intended to evaluate the effect of well-marked crosswalks (including stop lines) on pedestrian and traffic violations and also on pedestrian accidents. At 17 crosswalk locations in Peoria, a significant reduction in the percent of violations occurred after crosswalks were re-marked. However, the installation of thermoplastic crosswalks and stop lines at 229 previously unmarked

Peoria crosswalks had no measurable effect on pedestrian-accident experience based on two years of pedestrian accidents both before and after crosswalk installation. The total sample of pedestrian accidents was small, however, with only 13 to 15 per year at all sites combined.

The state of Arizona DOT Highway Division makes the following observation about marked crosswalks (*36*):

> When warranted and located properly, a marked pedestrian crosswalk may achieve the following results:
> 1) Act, in a limited manner, as a warning device and reminder to motorists that pedestrian conflicts can be expected.
> 2) Point out to the pedestrian the safest crossing path.
> 3) Limit pedestrian crossings to specific locations.
> 4) Aid in enforcing pedestrian crossing regulations.
>
> Unjustified or poorly located marked crosswalks may, and often do, have the following effects:
>
> 1) Increase accident frequency by lulling both pedestrians and drivers into a false sense of security.
> 2) Create general disrespect for *all* traffic control devices.
> 3) Result in unnecessary installation and maintenance costs.
> 4) Cause a greater number of rear-end and associated collisions due to pedestrians not waiting for adequate gaps in traffic.

The city of San Diego uses a pedestrian crosswalk warrant based on gap time, pedestrian volume, vehicle approach speed, and general conditions, as given in Appendix B.

In summary, there is considerable uncertainty and disagreement about whether marking crosswalks improves pedestrian safety, reduces pedestrian safety, or has little effect under various traffic and roadway conditions. There are clearly some locations where marked crosswalks are useful, such as where large pedestrian volumes cross at low-speed signalized intersections and at school crossing locations controlled by crossing guards. On the other hand, marking crosswalks may be harmful to pedestrian safety at some locations, such as uncontrolled midblock crossings with high vehicle speeds and limited sight distance. Common parallel painted crosswalks and less common textured crosswalks are shown in Figures 14 and 15.

FIGURE 14 Parallel crosswalk.

FIGURE 15 Textured crosswalk.

Conditions Where Marked Crosswalks Are Most Beneficial

- Signalized intersections with heavy pedestrian volumes, particularly with complex intersection geometrics (e.g., five or more legs, skewed intersecting roadways, wide streets).
- Midblock crossing locations that are controlled by traffic signals and pedestrian signals.
- School crossing locations that are controlled by adult (or police) crossing guards during school crossing periods.

Conditions When Least Beneficial or Possibly Harmful

- Unsignalized midblock crossings.
- Unsignalized intersections.
- Locations with low pedestrian-crossing volumes.
- When markings are overused in a city or area and/or when two or more crosswalks are closely spaced.
- When poorly located (e.g., not well seen by approaching motorists because of poor sight distance).
- When crosswalks are painted in an attempt to relocate pedestrian movements.

Advantages of Marked Crosswalks (*10*)

- Can channelize pedestrians across complex or dangerous intersections.
- Can help position pedestrians where they can best be seen by drivers.
- Midblock crosswalks tend to be used by pedestrians when they are available and may reduce crossings from behind parked vehicles and running in the road.

Disadvantages of Marked Crosswalks (*10*)

- Pedestrians may feel overly secure near marked crosswalks.
- Motorists don't notice marked crosswalks as well as pedestrians may think.
- Overuse of such markings may cause disrespect for other pedestrian and traffic-control devices.
- Pedestrians won't use them if they feel they are inconvenient.
- Midblock crosswalks may increase vehicular traffic delay.

HIGHWAY SIGNING

As described in the MUTCD, a variety of highway sign types are used to provide information to motorists and pedestrians. The three basic sign types include (*14*):

- Regulatory Signs—These signs provide information on legal requirements for motorists or pedestrians that are needed as a reminder.
- Warning Signs—Such signs are used when it is necessary to advise motorists of potentially hazardous conditions on or near a highway or street.
- Guide Signs—These are needed to provide navigational information to motorists along streets and inform them of intersecting routes, cities, and towns, and important destination points (e.g., rivers, forests, historical sites).

Regulatory signs directed at pedestrians include the following (*14*):

FIGURE 16 Pedestrian crossing prohibition.

FIGURE 17 Pedestrian/motorist interaction at stop sign.

- PEDESTRIANS PROHIBITED signs such as are often placed along entrance ramps to interstate highways.
- WALK ON LEFT FACING TRAFFIC, which are used to encourage safer walking behaviors in rural areas where no sidewalks are provided.
- NO HITCHHIKING, which is used to prohibit pedestrians from soliciting a ride.
- Pedestrian Crossing signs, which are used to limit pedestrian crossings to safe places (e.g., CROSS ONLY AT CROSSWALKS sign or USE CROSSWALKS) (Figure 16).
- Signs installed with traffic signals, with messages to pedestrians such as CROSS ON GREEN LIGHT ONLY, CROSS ON WALK SIGNAL ONLY, PUSH BUTTON FOR GREEN LIGHT, PUSH BUTTON FOR WALK SIGNAL.

In addition to signs directed at pedestrians, many types of regulatory signs that could affect pedestrian flow and safety are also directed at motorists. Examples include stop signs (Figure 17), yield signs, speed limit signs, turn prohibitions (e.g., NO LEFT TURN), one-way street signs, no parking signs, and others. NO TURN ON RED signs are also selectively installed at intersections (discussed in more detail later).

Warning signs used directly relative to pedestrians include (*14*):

- Advance Pedestrian Crossing Signs—to alert motorists to upcoming roadway crossings by pedestrians.
- Crossing Signs—to define the specific point along the road where pedestrians may cross (and a crosswalk may exist).
- Playground Sign—to warn motorists in advance of a designated play area for children or a potentially high concentration of children in the area.
- School Warning Signs, including:

  School Advance Warning Sign
  School Crossing Sign
  BUS STOP AHEAD Sign
  School Speed Limit Sign (e.g., SCHOOL, 25 MPH WHEN FLASHING)

Guide signs are sometimes used to direct pedestrians to sidewalks, walkways, bus stops, hiking trails, overpasses, and other types of facilities. Although they can be of obvious im-

portance in terms of pedestrian movement, they can also help keep pedestrians out of dangerous locations and areas.

Use of improper or nonstandard warning signs is not recommended because they may create confusion or a false sense of security. In fact, the *Traffic Control Devices Handbook* (section 2 D-4) states, "Obsolete or inappropriate signs such as the nonstandard DANGEROUS INTERSECTION or CAUTION—CHILDREN AT PLAY should be removed and proper signing installed as required for the specific condition" (*37*).

Further, in section 7 C-1, the *Traffic Control Devices Handbook* states (*37*):

> Uniformity of the physical characteristics of signs (size, shape, color) is especially critical near school areas and care should be exercised to assure conformance to the standards outlined in the MUTCD. Nonuniform signs such as "CAUTION—CHILDREN AT PLAY," "SLOW— CHILDREN," or similar legends should not be permitted on any roadway at any time. While these signs may serve to alert drivers, they could also be interpreted by others to infer that children are permitted to play in roadways. On the contrary, every means should be used to point out that children should not play on or near any road, street or alley, no matter how remote or "safe" the roadway appears. Consequently, the removal of any nonstandard signs should carry a high priority.

Conditions Where Highway Signing Is Most Beneficial

- Regulatory and/or warning signs aimed at motorists are most useful in areas such as:
  - Where motorists do not expect pedestrians
  - Where visibility obstructions exist (e.g., crosswalks on hill crest or sharp horizontal curves)
  - At school crossing locations
  - At rural and high-speed locations
  - At midblock crossing locations
  - At intersections with heavy turning movements
- Regulatory and/or warning signs aimed at pedestrians are most useful in areas such as:
  - At complex intersection geometrics (five or more legs, offset approach legs, etc.)
  - Where signal phasing is complex
  - At prohibited-pedestrian crossings
  - Where pedestrians must cross high-speed or other unsafe roadways
  - Where there are unexpected conflicts to pedestrians and/or heavy turning volumes exist

Conditions Where Highway Signing Is Least Beneficial or Possibly Harmful

- Regulatory and/or warning signs aimed at motorists are least beneficial in areas such as where:
  - Used excessively or needlessly (unwarranted)
  - Time restrictions are used
  - Vague, confusing, lengthy, or unreasonable messages are used
  - Pedestrians are given a false sense of security by the signs
  - Signs are hidden or difficult to read
  - Motorist laws are not enforced by police
- Regulatory and/or warning signs aimed at pedestrians are least beneficial:
  - In areas with low vehicle traffic volumes and speeds
  - When used as a "quick-fix" to attempt to correct a serious pedestrian safety problem
  - When the sign is vague, unreasonable, unnecessary, and/or confusing
  - When overused
  - When pedestrian laws are not enforced

Advantages of Signing (*10*)

- Signs are relatively inexpensive.
- Signs can tell people of regulations that are specific to locations or times.
- Signs give advance warning of schools or other locations where extra caution is needed.

Disadvantages of Signing (*10*)

- Some people have difficulty understanding signs.
- Installation of new or novel signs may require a publicity program.
- In urban areas, signs may be ineffective if they have to compete with other visual objects.
- Signs may be easily destroyed.
- Signed regulations considered unnecessary or unwarranted will often be violated.
- Excessive use of warning signs may cause most motorists to ignore them.
- Pedestrians often do not believe warning signs.

In summary, the use of highway signs at dangerous crossing locations can be effective in alerting pedestrians or motorists to a potential danger. Signs often provide a low-cost and easy treatment for an apparent pedestrian-safety problem. However, in many instances they only represent an ineffective treatment when a major-cost improvement is needed to solve the problem. Also, overuse or inappropriate use of signs is a common problem that breeds disrespect and noncompliance with the signs. Signs must also be easily understood to be effective.

EXPRESSWAY RAMPS INTERSECTING WITH LOCAL STREETS

Information was received from the highway agencies relative to severe adverse effects on pedestrians at intersections of expressway ramps with local streets. At such intersections, high-speed vehicles exiting from the expressways often are still traveling at a relatively high rate of speed when they pass through the intersection or merge with surface street traffic. Also, exiting motorists may be looking for oncoming traffic and not pedestrians.

Situations where high-speed expressway ramps intersect with local streets were identified as having lessened adverse effects when:

- Pedestrian volumes and local traffic volumes are relatively low and good roadway designs are used.
- Suitable traffic-control devices are used at the local street and/or grade separation (where appropriate).

The conditions listed as possibly harmful include:

- High traffic volumes and/or speeds on the off-ramp.
- Moderate to high pedestrian volumes crossing at the intersection.
- Insufficient traffic controls at the intersection (e.g., off-ramp traffic controlled by yield signs only).
- High-speed traffic on ramp having poor sight distance and/or an unexpected intersection.

In summary, pedestrian safety can be severely threatened at intersections where freeway off-ramps intersect with local streets, because of the high-speed traffic mixing with crossing pedestrians. However, the level of hazard can be reduced through the use of proper intersection design; grade separation, where appropriate; and/or adequate traffic-control devices (e.g., signals and signs) to reduce vehicle speeds and alert pedestrians and motorists.

SIGNALIZATION

Signalization, as it relates to pedestrians, includes many aspects, including:

- The presence of traffic signals, signal timing, and turn phasing.
- The use of pedestrian signals (i.e., WALK/DON'T WALK or symbolic signals), timing of signals (i.e., standard timing, early release, late release, exclusive pedestrian interval, etc.), and type of signal indications (symbolic or word message).

Traffic signals are usually installed at intersections if they satisfy 1 or more of the 11 signal warrants, as specified in the MUTCD. These warrants include (*14*):

- Warrant 1 - Minimum vehicular volume
- Warrant 2 - Interruption of continuous traffic
- Warrant 3 - Minimum pedestrian volume
- Warrant 4 - School crossings
- Warrant 5 - Progressive movement
- Warrant 6 - Accident experience
- Warrant 7 - Systems
- Warrant 8 - Combination of warrants
- Warrant 9 - Four-hour volumes
- Warrant 10 - Peak-hour delay
- Warrant 11 - Peak-hour volume

Although two of the warrants listed above relate to pedestrians (i.e., warrants 3 and 4), a 1976 study by Lieberman et al. found that only 1.3 percent (171 out of 12,780) of traffic signals are installed based on the pedestrian volume warrant (*38*). As of March 1988, amendments have been proposed to modify the minimum pedestrian volume warrant (Warrant 3). This would make it easier for agencies to justify the installation of traffic signals based on pedestrian volume. The amendment also accounts for the special needs of elderly and handicapped pedestrians (*39*).

Theoretically, the addition of traffic signals can be of value to pedestrians at sites where there are insufficient numbers of adequate gaps in traffic for pedestrians to cross safely and artificial gaps in traffic flow are created by traffic signals for pedestrians to cross. However, there are many factors that may actually affect pedestrian-accident experience at signalized intersections, including the pedestrian and motorist compliance with the signals. In a 1959 study by Young in Cincinnati (*40*), new traffic signals were installed at 152 intersections. The pedestrian accidents were affected as follows:

- No significant change occurred in pedestrian accidents at 90 sites (59 percent).
- Annual pedestrian accidents increased at 30 sites (20 percent).
- Annual pedestrian accidents decreased at 32 sites (21 percent).

It should be mentioned, however, that it was not known whether pedestrian signals were also installed at the sites or what the nature of the locational volumes, geometrics, or levels of motorist and pedestrian compliance was.

Pedestrian-signal indications (i.e., WALK/DON'T WALK or symbolic signals) are used extensively by some cities (i.e., at nearly every signalized intersection where any pedestrian traffic exists) and rarely if ever by other cities. Pedestrian signals at a location are usually timed according to one of the following patterns (*41, 42*):

- Concurrent (standard) timing provides for pedestrians to walk concurrently (parallel) with traffic flow on the WALK interval. Vehicles are generally permitted to turn right (or often left) on a green light while pedestrians are crossing on the WALK interval.
- Early release timing gives pedestrians a WALK indication earlier than parallel traffic is given a green light. Thus, pedestrians are permitted to have a head start into the crosswalk before motor vehicles are permitted to turn. Milwaukee uses early release timing at many signalized intersections (*5*).
- Late release timing holds pedestrians until a certain portion of the signal phase has been given to turning vehicles, and then pedestrians are released with a WALK interval. Omaha, Nebraska, and Sioux City, Iowa, are examples of cities that have used this timing pattern (*5*).
- Exclusive timing involves providing a separate exclusive signal interval when traffic is stopped in all directions during an interval and pedestrians are allowed to cross in any direction. Scramble or Barnes Dance timing refers to exclusive timing during which pedestrians are also allowed to cross diagonally. Exclusive pedestrian intervals have been used at some signalized intersections in Denver, Colorado; Tampa, Florida; Washington, D.C.; and New Haven, Connecticut (*41*).

At some wide street crossing locations, some agencies set signals so that pedestrians have time only to cross to the median (or pedestrian refuge island) during each cycle. This results from an attempt to minimize vehicle stopping delay on the wide street, and pedestrian signals should be placed in the median and also on each end of the crosswalk. An illustration of the various pedestrian signal timing patterns is illustrated in Figure 18 (*3*).

The sequence of most pedestrian signals during routine operation, according to the MUTCD, is as follows (*14*):

- The steady DON'T WALK indication indicates that pedestrians shall not enter the roadway.

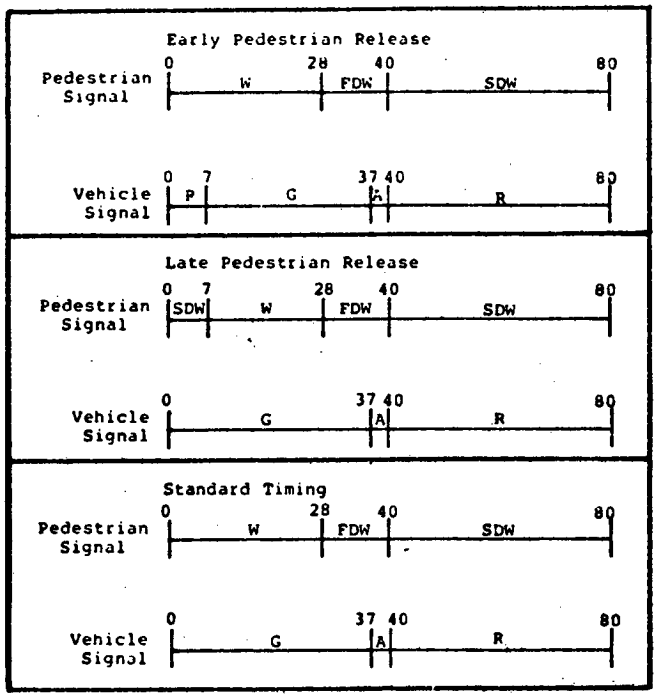

FIGURE 18 Illustration of various pedestrian signal-timing options (*3*).

- The flashing DON'T WALK indication means that pedestrians should not enter the roadway, but if pedestrians entered the road on the WALK indication, they should continue to cross to the other side of the street or safety island.
- The WALK indication implies that pedestrians may proceed in the direction of the indication.

The word and symbolic pedestrian signal heads are shown in Figure 19 (*14*).

Until recently, the MUTCD also allowed the use of a flashing WALK indication (which was in use in some cities and states). In areas where it is still used, the flashing WALK is a warning to pedestrians that there may be turning vehicles (and the steady WALK used at other locations indicates the absence of turning vehicles during the WALK interval).

Several studies have found problems associated with pedestrian-signal indications. For example, Robertson reported that only about 2 percent of pedestrians fully understand the meaning of the steady WALK and flashing WALK message and that only about half of pedestrians understand the flashing DON'T WALK (i.e., as a pedestrian-clearance interval) (*43*). Zegeer recommended elimination of the flashing WALK from the MUTCD, stating (*41*):

> Confusion commonly occurs since many pedestrians either do not know the meaning of the flashing WALK, or believe that any WALK indication (whether flashing or steady) means that they need not look around for cars or use caution. The danger occurs when a motor vehicle runs the red light or turns across a crosswalk without yielding to pedestrians. Although a pedestrian has the right-of-way, he should also exercise caution whenever crossing the street, since he is the most susceptible to injury or death in the event of a collision with a motor vehicle.

Use of the flashing WALK interval may soon be discontinued in the United States.

The safety effects of pedestrian signals and various signal-timing options were investigated in a 1982 study by Zegeer et al. for FHWA (*25, 41*). The study involved a detailed collection and analysis of accident, traffic, and design data for 1297 urban intersections (with 2081 pedestrian accidents) in 15 U.S. cities. The presence of concurrently timed pedestrian signals had no significant effect on pedestrian accidents, compared with the absence of any pedestrian signals. However, sites with exclusively timed pedestrian signals were associated with significantly lower pedestrian accidents than were sites with either standard signal timing or with no pedestrian signals. The authors cited several possible reasons for the lack of effectiveness of concurrently timed pedestrian signals:

- Poor compliance and respect by pedestrians for pedestrian-signal indications in some of the test cities
- False sense of security by some pedestrians from the signal indications
- Lack of understanding by many pedestrians of the flashing WALK and flashing DON'T WALK signals
- Infrequent use of pedestrian push buttons to actuate the WALK interval

The authors of that study further recommended that agencies (*25*): "take a closer look before indiscriminantly installing pedestrian signals at all traffic signalized locations," based on the high cost of pedestrian signals and their ineffectiveness at many locations.

Although pedestrian signals may not be highly effective when overused or inappropriately used, the MUTCD lists conditions under which pedestrian signals are necessary, including (*14*):

1. When traffic signals are installed based on meeting the minimum pedestrian volume or school crossing warrants.
2. When an exclusive pedestrian interval is provided, i.e., with all conflicting vehicular traffic being stopped.
3. When the vehicle signals are not visible to pedestrians (such as at one-way streets or "T" intersections).
4. At signalized intersections within established school crossing locations.

In terms of the types of pedestrian signal face designs, a 1977 study by Robertson found that the symbolic displays are preferable to the standard word messages (*43*). The symbolic messages include a walking man symbol (in white) and a palm of a raised hand (in portland orange) to replace the WALK and DON'T WALK messages (Figure 19).

Another consideration with pedestrian signals is the possible use of push buttons to extend the crossing period and/or provide a crossing interval for pedestrians. In a 1982 study for FHWA, field observations at 64 intersection approaches with push buttons in southeastern Michigan found that 66 percent of 1014 pedestrians began crossing illegally (on the steady or flashing DON'T WALK) (*41*). Only 51 percent of the crossing pedestrians pushed the button to actuate the pedestrian signal. Numerous problems were found with the design and operation of the push-button signals.

Several considerations were recommended as they relate to pedestrian push-button signals, including (*41*):

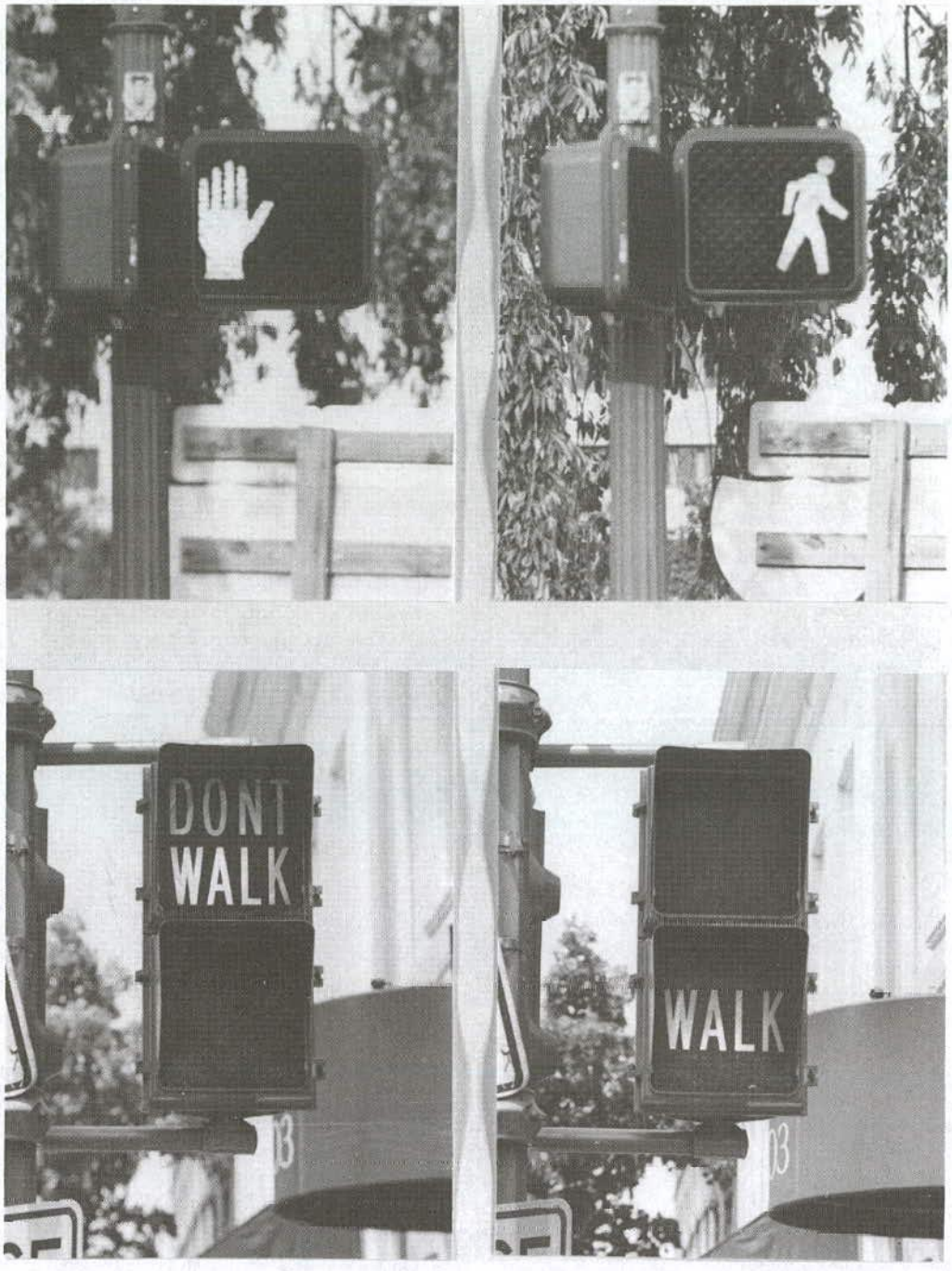

FIGURE 19 Symbolic and word pedestrian-signal displays.

- Actuation devices must be properly maintained and in good operation to be effective.
- Signals with pedestrian-actuation devices should be timed to provide a reasonable waiting time (e.g., 30 seconds or less) to the pedestrian after the button is actuated. Otherwise, pedestrians may assume the push button is not working.
- Supplemental signs designating the specific streets (e.g., PUSH BUTTON TO CROSS MAIN STREET) can increase pedestrian use of push buttons.
- Use of a special device (e.g., a light that comes on when the button is pushed) can increase pedestrian use and respect for push buttons. This may help pedestrians to see that by pushing the button, their request was accepted.
- If a pedestrian device is designed to operate only for specific times of the day (e.g., off-peak traffic periods), a sign should accompany the actuation device (e.g., PUSH BUTTON IS NOT IN OPERATION FROM 2:00 to 6:00 P.M. ON WEEKDAYS).
- Numerous types of signs and markings may also be installed to supplement or help explain the pedestrian signals.

Conditions Where Pedestrian Signals Are Most Beneficial

- When one or more of the following conditions exists (as specified in the MUTCD), pedestrian signals "shall be installed":
  - When a traffic signal meets the minimum pedestrian volume or school crossings warrant.
  - When an exclusive pedestrian phase is provided.
  - When vehicular signal indications are not visible to the pedestrian.
  - At established school crossings.
- At intersections with multiphase (e.g., left-turn phasing) signals.
- At intersections with complex designs (e.g., five or more intersection legs, wide streets, refuge islands for pedestrians to cross only part of the street during a single signal phase).
- In cities where pedestrian compliance is high.
- At intersections or midblock locations where pedestrian push buttons are used. (In some cities, the push-button actuation alters the cycle split to allow for more time for pedestrians to cross the street.)
- In areas with considerable volumes of young children and/or older adults.

Conditions Where Pedestrian Signals Are Least Beneficial or Possibly Harmful

- Where there are very low pedestrian volumes with high-speed traffic.
- Where there is a long delay in signal cycle between WALK intervals.
- Where pedestrians rely on the pedestrian signals to protect them.
- Where signals are not timed to provide adequate WALK and clearance time.

Advantages of Signals and Signal Timing (*10*):

- Traffic signals:
  - Can create artificial gaps in traffic flow, so pedestrians may cross the street while traffic is stopped.
  - Are understood and obeyed by pedestrians more frequently than pedestrian signals are.
  - Can improve the traffic capacity of intersections.
- Pedestrian signals:
  - Warn pedestrians (and motorists) of an impending signal change sooner than the vehicle amber signal does.
  - Can give pedestrians more time to cross the street.
- Exclusive phase signals will result in completely separate intervals for pedestrians and vehicles as long as pedestrians and motorists all obey their signals (e.g., pedestrians crossing during the DON'T WALK interval and motorists running the red light present the risk of a pedestrian accident).

Disadvantages of Signals and Signal Timing (*10*):

- Traffic signals:
  - Are more expensive than many other facilities (except grade-separation and horizontally separated pedestrian environments).
  - May increase pedestrian congestion on sidewalks and pedestrian delay at corners.
  - Suspended overhead often cannot be seen by pedestrians standing on the corner. In such cases, pedestrian signals (i.e., WALK/DON'T WALK) are needed.
  - Are often disobeyed by drivers and pedestrians.
- Pedestrian signals:
  - There is a failure by pedestrians to understand the meanings of the flashing DON'T WALK (i.e., only about half of pedestrians understand the difference between the flashing and steady DON'T WALK).
  - Younger pedestrians often disregard the pedestrian signal or depend too much on it.
  - Pedestrians may feel overly safe (from turning vehicles and other traffic) when they see a WALK indication.
  - Many pedestrians will not use the push button.
- Separated signal phasing (i.e., scramble timing) can cause serious vehicle and pedestrian delay.

REDUCING THE SPEED LIMIT ON URBAN OR RESIDENTIAL STREETS

The state of North Carolina sometimes lowers speed limits in consideration of pedestrian and bicyclist safety (*33*). In particular, areas around schools are often considered for reductions in speed limits in an attempt to reduce the frequency and also the severity of accidents to pedestrians and bicyclists in such areas. The North Carolina DOT gives special consideration to speed limit reduction at the following types of roads, where speeds are often dangerously high and motorists may not expect to see pedestrians and bicyclists (*33*):

- New residential developments on country roads
- One-way streets in residential areas
- Through streets that connect neighborhoods to shopping centers

From the questionnaire survey responses, however, state and local highway officials reported that reducing speed limits below the 85th percentile traffic speeds is only feasible when speeds are reduced to levels reasonable to motorists and that are also enforced. According to agency responses, reductions in speed may be most beneficial when one or more of the following conditions exist and enforcement will be routinely accomplished:

- In vicinity of school zones, playgrounds, and high-pedestrian-volume crossings.
- On wide streets with high vehicle speeds and no pedestrian refuge.
- Near blind curves before pedestrian crossings or on other roads with an unexpected encounter between motor vehicles and pedestrians.
- On roadways where speeding is a problem, visibility is poor, and where no sidewalks or curbs exist.
- On roads with substantial on-street and lot parking.

RIGHT TURN ON RED

Right turn on red, or RTOR, refers to the practice of legally allowing motorists to turn right on a red signal indication at intersections after stopping and yielding to pedestrians and other

TABLE 12

SUMMARY OF RTOR VIOLATIONS AT RTOR-PROHIBITED SITES (*44*)

City	Total Approaches	Right Turns	Total RTOR Violations	Percent RTOR Violations	Total RTOR Opportunities	Percent RTOR Violations/ Opportunity
Detroit	59	33,400	1,119	3.4	5,904	19.0
Washington, D.C.	27	22,742	888	3.9	4,122	21.5
Dallas/Austin	24	11,205	493	4.4	2,288	21.5
Totals	110	67,347	2,500	3.7	12,314	20.3

vehicles having the right of way unless there is a sign prohibiting such movement. RTOR is now allowed throughout the United States (unless otherwise signed), except in New York City, where a RTOR maneuver is prohibited unless specifically permitted by sign. Numerous research studies have been conducted during the past 20 years on the effects of RTOR on safety, fuel consumption, and operations of traffic and pedestrians (*44*).

In spite of widespread adoption of RTOR, controversy still exists, particularly relative to its safety effects. As noted in a 1985 study by Zegeer and Cynecki (*44*):

> While no studies have been completely successful in isolating and quantifying the safety impacts of RTOR, considered together the studies provide considerable evidence which suggests that RTOR is associated with an increase in the potential for pedestrian accidents.

In that same study, observational studies were made of RTOR motorist compliance and also of traffic, geometric, and other site characteristics at signalized intersections in Detroit, Washington, D.C., Dallas, and Austin. At 110 RTOR-prohibited intersection approaches, only 3.7 percent of all right-turning drivers were found to violate RTOR-prohibition signs, for a sample of more than 67,000 drivers (Table 12). However, about 20 percent of motorists commit a RTOR violation (i.e., run through a NO TURN ON RED sign), given an opportunity. Of those RTOR violators, about 23.4 percent (about 5 percent of all right turns) result in conflicts to pedestrians or side-street vehicles.

In-depth site studies were conducted of locational characteristics associated with high violation of NO TURN ON RED signs. These included (*44*):

- Confusing and inappropriate use of partial prohibition NO TURN ON RED signs.
- Far-side or hidden NTOR signs.
- Long signal cycle lengths.
- Multi-leg intersection approaches that are confusing to motorists.
- Unjustified prohibition of RTOR (e.g., combinations of a low traffic volume, high volume of cross-street traffic, and/or low pedestrian volumes).

The second type of RTOR violation involves vehicles failing to make a full stop at intersections where RTOR is allowed. At 29 RTOR-allowed intersection approaches in a 1985 study (*44*), the overall violation rate (percent not fully stopping) was 56.9 percent. This compares with 68.2 percent of vehicles found to not make a complete stop at 28 stop sign approaches (Table 13). However, the slightly lower number of stopping violations for RTOR compared with those at stop signs (56.9 compared

TABLE 13

SUMMARY OF DATA COLLECTED AT RTOR-PERMITTED AND STOP SIGN APPROACHES (*44*)

Approaches	Right Turns Per Hour	RTOR Per Hour	Percent RTOR	Stopping Violations Per Hour	Percent Stopping Violations			Percent Full Stops			Number of Approaches
					Total Violations	Rolling Stop	No Stop	Total Full Stop	Voluntary Full Stop	Forced Full Stop	
RTOR Allowed Approaches (Totals)	67.3	16.3	26.2	9.2	56.9	42.1	14.8	43.1	7.2	36.0	29
Stop Sign Approaches (Totals)	38.3		N/A	27.1	68.2	57.3	10.9	31.8	7.1	24.7	28

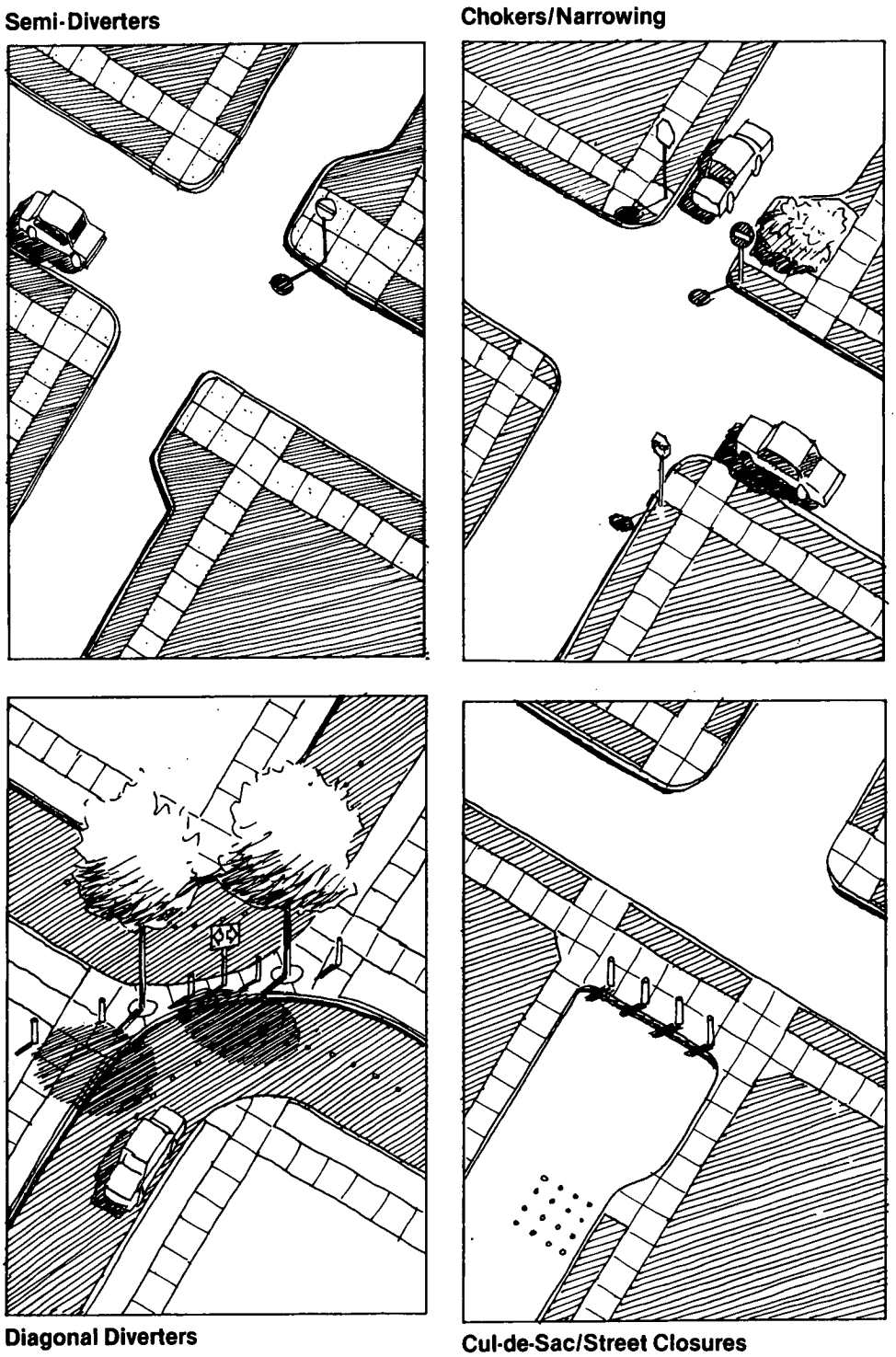

FIGURE 20 Illustration of various neighborhood traffic-control measures (*45*).

with 68.2 percent) was determined to be primarily caused by lower cross-street volumes at stop sign approaches (i.e., more opportunities for a rolling stop or no stop at stop sign approaches).

Locational characteristics that were found to be related to high noncompliance (i.e., fewer full stops) where RTOR is allowed include (*44*):

- Good sight distance to traffic to the left, combined with low pedestrian volume and low side-street volume.
- High volume of right-turn traffic.
- Signal timing where there is a minimum amount of conflicting traffic for part of the red interval (i.e., motorists do not see a need to make a full stop).
- Offset streets that lower or delay conflicting traffic and increase the opportunity for a RTOR vehicle to make a rolling stop or no-stop.
- Presence of a nearby signalized intersection on the cross street upstream, which creates artificial gaps in cross-street traffic and provides greater opportunities for RTOR rolling stops or no-stops.

NEIGHBORHOOD TRAFFIC-CONTROL MEASURES

In addition to the traffic-control measures discussed previously, numerous other special measures are commonly used in residential neighborhoods. As illustrated in Figure 20, some of these include (*45*):

- Cul-de-sacs—Closing streets either at midblock or at an intersection that blocks through traffic and reduces vehicle speeds and volumes on the street.
- Chokers or curb extensions (or neckdowns)— Narrowing the street by widening the sidewalk close to the intersection or providing an on-street parking area in the midblock area. Pedestrian crossings are often made easier as a result of the narrower street crossings at the intersections.
- Semi-diverters—Limiting access to a street to one direction only by blocking half of the street. Traffic volumes are often reduced on these streets, although they allow greater access to emergency vehicles than full diverters do.
- Diagonal diverters—Placing a diagonal barrier across an intersection that disconnects the intersection legs. Traffic volumes are reduced and traffic-circulation patterns are changed, although they provide more overall freedom of circulation than cul-de-sacs do.
- Traffic circles—Using raised circular islands in the middle of the intersection to create a one-way, circular flow of traffic in the intersection. Traffic circles are intended to separate conflict points and slow vehicular traffic (Figure 21).

Portland, Oregon, and Seattle, Washington, are examples of cities that have active programs in the use of various types of neighborhood traffic-control measures (*5, 47*). A summary of various traffic-management devices is listed in Table 14, as taken from a 1980 FHWA report (*45*). Additional details of improvements related to suburban and rural areas may be found in a recent NCHRP study (*46*).

FIGURE 21 Traffic circle.

LEFT-TURN PHASING AND RESTRICTIONS

One of the major causes of pedestrian accidents at intersections is from vehicles that turn right or left and strike pedestrians in crosswalks. In a sample of 2081 pedestrian accidents at traffic-signalized intersections in 15 U.S. cities, Zegeer et al. found the following vehicle maneuvers were involved (*41*):

Vehicle Maneuver	Number	Percent
Straight	1256	60.3
Right-turn	308	14.8
Left-turn	468	22.5
Other/Unknown	49	2.4
Total	2081	100.0

Left-turning vehicles were involved in 22.5 percent of pedestrian accidents, with right-turning vehicles involved in 14.8 percent. Although the total percentages of left- and right-turning vehicle volumes were not readily available for those intersections, the high percentage of pedestrian accidents resulting from left-turning vehicles is indicative of a serious pedestrian-safety problem.

A 1980 study by Habib (*48*) of streets in the Borough of Manhattan Island reported roughly a 2:1 ratio of left-turn to right-turn pedestrian accidents (24.8 percent to 13.1 percent). The author found that the poor driver visibility from within the vehicle and bad driving habits are the major contributing causes of left-turn pedestrian accidents. The blockage of the driver's visibility is illustrated in Figure 22 for left-turning vehicles, whereas only minor visibility impairments exist for drivers of right-turning vehicles (*48*). The blockage of vision for left-turn motorists is supported by the higher percentage of drivers cited as being at fault in pedestrian left-turn accidents compared with pedestrian right-turn accidents (62 percent compared with 49 percent).

Traffic signal location was also identified as a contributing factor to left-turn pedestrian accidents. The solutions proposed by Habib include changing vehicle designs (e.g., increasing size of windshield), adding an additional signal on the left far side of the crosswalk, and increasing driver awareness of this problem through driver-education programs (*48*).

Some of the methods that have been tested for reducing the

TABLE 14

INFORMATION ON NEIGHBORHOOD TRAFFIC-CONTROL MEASURES (EXTRACTED IN PART FROM TABLE 1, P. 22 OF REFERENCE *45*)

DEVICES	DIRECT TRAFFIC EFFECTS						
	Volume Reductions	Speed Reductions	Directional Control	Change In Composition	Noise	Safety	Emergency & Service Access
Physical Controls							
Speed Bumps	Possible	Inconsistent	Unlikely	Unlikely	Increase	Adverse effects	Some problems
Undulations	Possible	Yes	Unlikely	Unlikely	No change	No problems documented	No problems documented
Rumble Strips	Unlikely	Yes	Unlikely	Unlikely	Increase	Improved	No problems
Diagonal Diverters	Yes	Likely	Possible	Possible	Decrease	Shifts accidents	Some constraints
Intersection Cul-De-Sac	Yes	Likely	Yes	Possible	Decrease	Shifts accidents	Some constraints
Midblock Cul-De-Sac	Yes	Likely	Yes	Possible	Decrease	Shifts accidents	Some constraints
Semi-Diverter	Yes	Likely	Yes	Possible	Decrease	Shifts accidents	Minor constraints
Forced Turn Channelization	Yes	Likely	Yes	Possible	Decrease	Improved	Minor constraints
Median Barrier	Yes	On curves	Possible	Possible	Decrease	Improved	Minor constraints
Traffic Circle	Unclear	Minor	Unlikely	Possible	Little change	Questionable	Some constraints
Chokers and Road Narrowing	Rare	Minor	Unlikely	Unlikely	Little change	Improved ped. crossings	No problems
Passive Controls							
Stop Signs	Occasional	Site red.	Unlikely	Unlikely	Increase	Mixed results	No problems
Speed Limit Signs	Unlikely	Unlikely	Unlikely	Unlikely	No change	No change	No effect
Turn Prohibition Signs	Yes	Likely	Yes	Possible	Decrease	Improved	No effect
One-Way Streets	Yes	Inconsistent	Yes	Possible	Decrease	Possible imp.	No effect
Psycho-Perception Controls							
Transverse Markings	No change	Yes	No effect	No effect	Possible red.	Possible imp.	No effect
Crosswalks	No effect	Unlikely	No effect	No effect	No effect	Ineffective	No effect
Odd Speed Limit Signs	No effect	No effect	No effect	No effect	No effect	No effect	No effect
Novelty Signs	No effect	Undocumented	No effect	No effect	Unlikely	No effect	No effect

Specific details of individual applications may result in performance substantially variant from characterizations in this matrix. See text sections on individual devices for more complete performance data, assessments and qualifications.

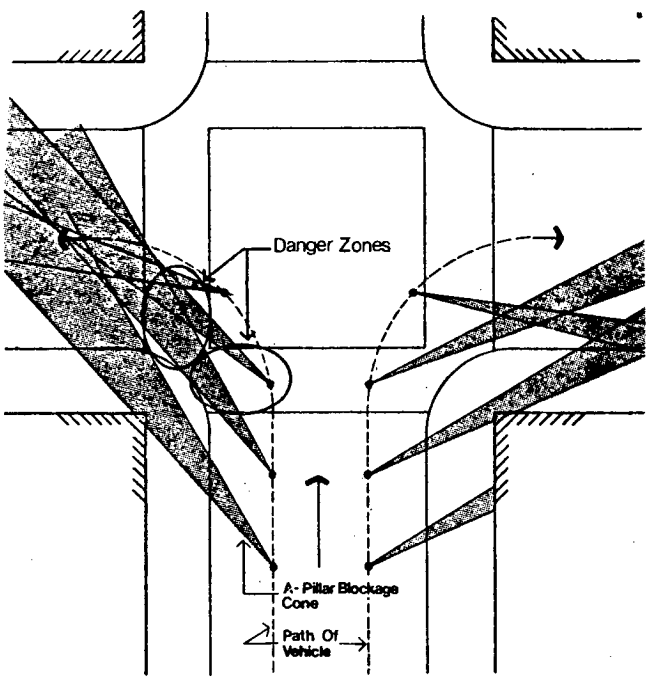

FIGURE 22 Illustration of motorist sight-distance obstructions during left turn (*48*).

number of left-turn pedestrian accidents at an intersection include:

- Prohibiting left turns.
- Providing exclusive left-turn phasing.

Prohibiting left turns at an intersection is only effective at intersections with heavy pedestrian activity and a low to moderate left-turn volume with adjacent intersections at which the left-turn maneuvers can be made much more safely. Otherwise, this action merely moves the problem to another location.

Providing separate left-turn phasing only reduces the conflicts between pedestrians and motor vehicles when pedestrians are provided with a DON'T WALK signal during the interval when the green arrow is given to left-turning motorists and pedestrians are in compliance with the pedestrian signal. Left-turn signals are often installed at intersections with heavy left-turn and through volumes, where left-turn motorists would otherwise have insufficient gaps to turn. However, adding an exclusive left-turn signal may mean longer waiting periods between WALK intervals (because cycle lengths are usually increased), and pedestrian compliance with the DON'T WALK signal is important. Also, the increased cycle length can create delay for other motorists.

RAILROAD GRADE CROSSINGS

In 1986, 80 accidents involving pedestrians occurred at railroad-highway grade crossings. Although this number represents only a small percentage (1.36) of the total accidents at such locations, 44 fatalities and 36 injuries resulted. Also, these numbers only reflect mishaps occurring at crossings, not at other locations along the tracks (*49*).

Controlling pedestrian safety around railroads is especially difficult, because those on foot can easily maneuver around lowered gates. Also, pedestrians may ignore a designated crossing in favor of a shorter path across the tracks (*50*).

Trespassers are involved in many railroad accidents, and several methods can be used to promote safety. Tall fencing may be used to enclose the right of way and thus restrict the pedestrian's access to the tracks. However, this is very costly and does not prevent entrance at crossing points.

Another safety device is to provide grade-separated crossings at intervals along the track. Pedestrians should be clearly routed to these crossings by barriers, fences, or signs (*50*).

Improved signing is another alternative for increasing pedestrian safety near railroad grade crossings. For example, electrified rail lines should be clearly marked with signs bearing both words and symbols. Other safety alternatives include the use of either an audible warning bell or temporary crossing guard to supplement existing or passive warning signs. Separate pedestrian crossing sections may be needed. Of course, special attention should be paid to safety in railroad construction and maintenance sites. Routine inspection of all traffic-control elements is also warranted (*50*).

Surveillance and enforcement of trespassing regulations are also necessary to reduce railroad accidents involving pedestrians. One of the most important approaches to railroad safety is education. Information should be directed not only at adults, but also, through the schools, at children, who are of major concern when they play near railroad tracks (*50*).

FIGURE 23 Word signal explanation sign (*41*).

INNOVATIVE AND SPECIAL-USE MEASURES

Many different types of traffic-control measures have been tested during the past 20 years for a variety of pedestrian-safety problems. Two of the most common problems for pedestrians include:

- The ineffectiveness and confusion associated with pedestrian-signal messages.
- Potential problems to pedestrians related to RTOR.

Innovative treatments for these two problems were developed and field tested in FHWA research studies, as discussed below.

In a 1983 study (*41*), alternatives were developed to warn pedestrians and/or motorists of potential problems between pedestrians and turning vehicles. These included (*41*):

Alternative	
1	A red and white 36 in. × 36 in. × 36 in. YIELD TO PEDESTRIANS triangular regulatory sign with a pedestrian symbol at the bottom.
2	A warning sign (black letters on yellow background) with the message PEDESTRIANS WATCH FOR TURNING VEHICLES.
3	An informational/educational sign explaining the signal display messages (Figure 23).
4	A three-section signal with the message WALK WITH CARE displayed during the crossing interval. The WITH CARE message is yellow, and the WALK WITH CARE is used in conjunction with the flashing DON'T WALK and steady DON'T WALK messages.
5	The flashing WALK is used during the WALK interval to indicate the potential for turning vehicles.

Alternatives were also developed as potential replacements for the clearance (i.e., flashing DON'T WALK interval). These included (*41*):

Alternative	
1	A sign that explains the meaning of the pedestrian-signal displays (Figure 24).
2	A steady DON'T WALK message to be used for the clearance interval as well as the prohibited-crossing period.
3	A three-head signal display, with a DON'T START for the clearance interval, to be used with the standard WALK and DON'T WALK.

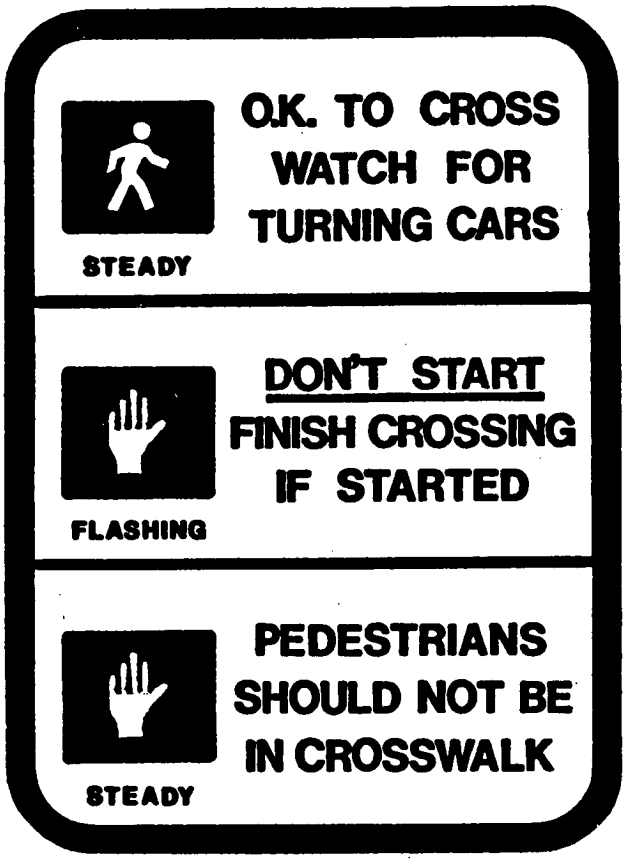

FIGURE 24 Pedestrian-signal explanation sign (symbolic) (*41*).

Each of the eight alternatives was tested at four sites (except the steady DON'T WALK, which was tested at only two sites). Cities used for field testing were Washington, Milwaukee, and three Michigan cities—Detroit, Ann Arbor, and Saginaw. Data were collected on pedestrian violations, several types of pedestrian/vehicle conflicts, and pedestrian and vehicle volumes before and after installation of the alternatives, in addition to physical site information. The Z-test for proportions was used to evaluate the effect of each device on pedestrian violations and conflicts. The following is a summary of results (*41*):

1. The pedestrian signal explanation signs had no effect at two sites but reduced pedestrian violations and turning conflicts at two other sites. They should be added to the MUTCD as an acceptable alternative at selected sites to help educate pedestrians on the meaning of pedestrian signals.
2. The steady DON'T START clearance display was a significant improvement over the flashing DON'T WALK display in terms of reducing pedestrian violations and conflicts at three of four test sites. Further testing of the three-phase DON'T START pedestrian signal is needed to determine whether it should be adopted for nationwide use, because (1) it was not effective at all sites and (2) the nationwide adoption of such three-head signal hardware would require considerable expense.
3. The use of the steady DON'T WALK indication for the clearance interval provides no improvement over the flashing DON'T WALK indication and should not be used as a clearance interval.
4. The regulatory YIELD TO PEDESTRIANS WHEN TURNING sign was found to be effective in reducing turning conflicts between pedestrians and motorists. This sign should be added to the MUTCD as an option for use at locations with a high number of pedestrian accidents involving turning vehicles.
5. The warning sign PEDESTRIANS WATCH FOR TURNING VEHICLES was also found to be effective in reducing right-turn conflicts. It also should be added as an optional sign in the MUTCD, but should only be used where high numbers of pedestrian accidents occur.
6. The WALK WITH CARE signal display was tested for the pedestrian crossing interval to warn pedestrians of possible turning vehicles. The results of the field tests at four sites in three cities showed that it is effective in reducing turning-related conflicts as well as reducing pedestrian violations. It was recommended to be added to the MUTCD as a special device that should be used only at sites with a high number of pedestrian accidents.
7. The flashing WALK message was not effective for warning pedestrians of turning vehicles. It should be removed from the MUTCD, because it generally confuses pedestrians.

In a study for FHWA by Zegeer and Cynecki (*44*), 30 different countermeasures were developed for accidents related to RTOR pedestrian hazards. Seven of them were selected for field testing, including (*44*):

1. A NO TURN ON RED sign with a red ball in the center. This sign was expected to be seen more easily by an approaching potential RTOR motorist (Figure 25).
2. Larger 30 in. × 36 in. NO TURN ON RED sign. At some intersections (such as on the far side of a wide intersection), the standard-sized (24 in. × 30 in.) sign cannot easily be seen. Thus, the larger sign was expected to be more conspicuous.
3. NO TURN ON RED WHEN PEDESTRIANS ARE PRESENT sign. The WHEN PEDESTRIANS ARE PRESENT supplementary message was believed to be more desirable than time-designated restrictions (e.g., NO TURN ON RED 7:30-9:00 A.M. AND 2:00-3:00 P.M. ON SCHOOL DAYS). This sign would allow motorists to turn right on red when conditions were appropriate, would be less confusing, and would also remind motorists to yield to pedestrians.
4. A red ball NO TURN ON RED sign with a WHEN PEDESTRIANS ARE PRESENT legend. This combined countermeasure numbers 1 and 3 above (Figure 26).

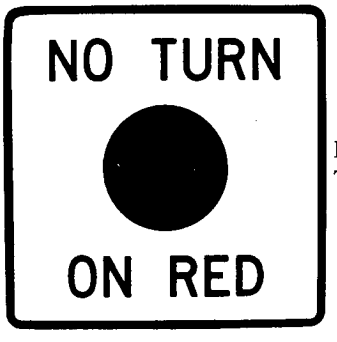

FIGURE 25 Red ball NO TURN ON RED sign (*44*).

FIGURE 26 NO TURN ON RED WHEN PEDESTRIANS ARE PRESENT sign (*44*).

5. Offset stop bar. This was selected with the intent of improving sight distance to RTOR vehicles in the right lane by moving back the stop bar for vehicles stopped in the adjacent lanes (in the left or middle lanes) by approximately 6 to 10 feet. Assuming that other motorists stopped at the stop bar as intended, RTOR motorists could get a better view of cross-street traffic and pedestrians coming from the left (Figure 27).

6. LOOK FOR TURNING VEHICLES pavement marking in the crosswalk. This low-cost measure was intended to remind pedestrians to be alert for turning vehicles, including RTOR and other turning vehicles.

7. Variable message NO TURN ON RED/blankout sign. This was another option to time-designated RTOR prohibitions. It would illuminate the NO TURN ON RED message only during times or intervals when there was a need to prohibit RTOR (Figure 28).

The seven selected devices were field tested at 32 total intersection approaches in Washington, D.C., Dallas, Austin, Detroit, Lansing, and Grand Rapids. Before-and-after data were collected of numerous types of conflicts (including those between pedestrians and RTOR vehicles), motorist violations, and other events, including those on right turn on red and right turn on green. Using the Z-test for proportions, the effect of each treatment was evaluated. The following results were found (*44*):

FIGURE 27 Offset stop bar.

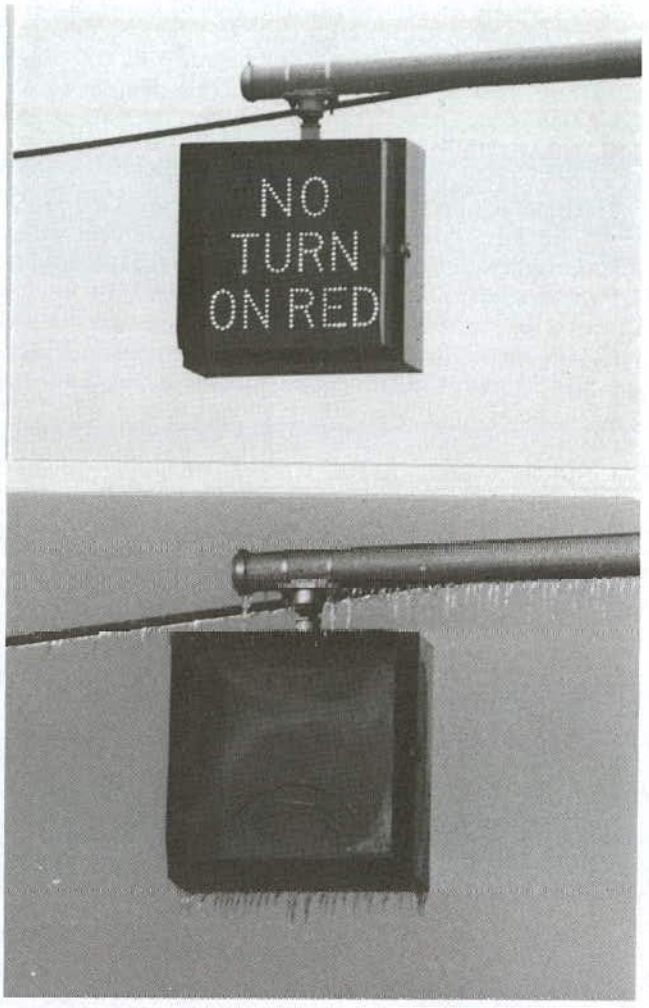

FIGURE 28 NO TURN ON RED blankout sign.

1. The red ball NO TURN ON RED (NTOR) sign was found to be more effective than the standard black and white NTOR sign in terms of RTOR violations and pedestrian conflicts. Subject to laboratory testing and/or additional field testing, the black and white NTOR sign should be replaced with the red ball NTOR sign in the MUTCD.

2. The larger 30 in. × 36 in. NO TURN ON RED sign reduced the proportion of motorist violations at most of the test sites in one city and reduced total conflicts in some situations. The larger sign should be considered by agencies at sites where the existing sign is hard to read, such as at far-side post mounting when overhead mounting is not feasible.

3. The NO TURN ON RED sign with the supplementary WHEN PEDESTRIANS ARE PRESENT message was effective at several sites at which right-turn vehicle volumes were low or moderate. However, it was less effective when RTOR volumes were high. It was recommended that the supplemental message WHEN PEDESTRIANS ARE PRESENT be added to the MUTCD as an accepted message that may be used with a NTOR sign when right-turn volume is light to moderate and pedestrian volumes are light or occur primarily during intermittent periods (e.g., in school zones).

4. The red ball NTOR sign in conjunction with the WHEN PEDESTRIANS ARE PRESENT message reduced total pedestrian conflicts in one instance and increased RTOR usage, as desired (from 5.7 percent to 17.4 percent), compared with full-RTOR prohibitions. The supplemental WHEN PEDESTRIANS ARE PRESENT sign should be added to the MUTCD as an optional sign, as described in item 3 above.

5. The offset stop bar was intended to improve sight distance to the left for RTOR motorists. It was effective in reducing RTOR conflicts with cross-street traffic. It also resulted in more RTOR vehicles making a full stop behind the stop bar, as desired. The offset stop bar was a recommended countermeasure at RTOR-allowed sites that have two or more lanes in each direction, especially at sites where conflicts or accidents are resulting between RTOR vehicles and cross-street traffic.

6. The LOOK FOR TURNING VEHICLES pavement marking was generally not effective, and the markings quickly wore away. Thus, they were not recommended for general use.

7. The electronic NO TURN ON RED/blank-out sign was found to be a slight improvement at the test sites, compared with the standard NO TURN ON RED sign in terms of fewer violations. It was also effective in increasing RTOR maneuvers when RTOR was appropriate (i.e., blank-out mode) and thus reduced unnecessary vehicle delay. Although this electronic device is more expensive than signs and markings, it may be justified in certain situations: (1) when pedestrian protection is critical during certain periods (such as school zones) or (2) during a portion of the signal cycle when a split-phase opposing left turn may conflict with an unsuspecting RTOR motorist.

CHAPTER FIVE

SPECIAL PEDESTRIAN SITUATIONS

Certain unique activities may require the application of traffic-control measures specifically aimed at improving pedestrian safety and movement. State and local agencies were asked to list the measures they use in handling pedestrians involved in three special situations: entertainment and sporting events, work trip travel, and pedestrian movements in and around shopping centers. In the following sections, the number in parentheses beside each traffic-control measure indicates how many times it appeared in the lists and reflects a combined total of state and local responses. Some of the agencies did not provide any information on this issue, but multiple responses were given by many of those who did.

Several respondents, primarily states, indicated that they do not have jurisdiction over special planning geared toward pedestrians (total of 10 responses for all three activity types combined). This generally is handled at the local level or, in the case of shopping centers, may involve private property and therefore not fall under public agency jurisdiction at all (although pedestrian impacts may be a part of an environmental impact statement).

A number of other responses (14 total) suggested that these activities do not always require special treatment. Rather, they are automatically taken care of in the course of normal traffic planning and control. This is especially true of work trip travel. One agency indicated that it "seldom does anything other than accommodate pedestrians in vehicular control strategies." Reliance on regular or existing traffic-control devices was mentioned frequently. Other agencies implied that "special" pedestrian activities are taken care of through general compliance with the MUTCD or with city-wide pedestrian policies and programs. However, most responses regarding this issue did name specific treatments used to enhance the movement and safety of pedestrians engaged in special activities.

ENTERTAINMENT AND SPORTING EVENTS

The measure most frequently mentioned for handling the large crowds attending entertainment and sporting events was the use of traffic-control personnel (33 responses) to direct pedestrian and vehicular traffic. Most of the agencies rely on police officers, including off-duty and reserve officers. Crossing guards were mentioned once.

Another frequently used method involves temporarily changing the traffic flow patterns (13). This is accomplished through the use of street closures, detours, and temporary one-way street operations. Pedestrian signals (7) were also considered important in facilitating the movement and safety of large groups of people on foot. Traffic signals (6), including temporary ones, were mentioned frequently. Other responses indicated adjustments of traffic signal timing (6), with or without manual signal control by traffic personnel.

Some agencies said they use informational signs (6), indicating the use of "Do Not Cross Here" signs. Parking control (5), crosswalks and oversize crosswalks (4), and pedestrian fences or barriers (3) are other methods listed by the various agencies. Traffic-control measures receiving only one response included speed reduction, adding stop signs, rerouting buses and/or encouraging bus loading at less congested locations, shuttle service, and pedestrian malls.

WORK TRIP TRAVEL

To promote safety and facilitate movement of pedestrian commuters, the most frequently mentioned approach was the use of pedestrian signals (25), with or without push buttons. Push buttons were also mentioned as being used at traffic signals without pedestrian signals to extend the crossing time.

Crosswalks (13) were mentioned almost as often as pedestrian signals. One response indicated that they are necessary where parking is isolated. Emphasis was placed on clearly identifying the crosswalks by having them painted, striped, signed, or by using special wide markings (e.g., the zebra).

The states and local agencies also rely on existing or specially added traffic signals (7) to control the pedestrian flow. Traffic signals are considered useful with or without pedestrian signals. Several agencies also referred to the value of pedestrian walkways along the roadside (6). Sidewalks in general, wide sidewalks, sidewalks in suburban areas, and separate pedestrian paths in rural and suburban areas were all specifically mentioned.

Another approach involves the use of signs (4), including crossing warning signs and stop signs. Adjusting signal timing (4) or using traffic signal progression to create pedestrian gaps were also mentioned as helpful in regulating work trip travel.

Several traffic-control measures were listed twice each:

-parking restrictions
-police officers used to direct traffic in unusual situations
-lighting (e.g., adding overhead street lighting)
-turn restrictions, such as NO TURN ON RED
-grade-separated pedestrian underpasses and overpasses, including skyways from parking ramps

Seven other items were mentioned only once each:

-removal of visibility obstructions
-bus shelters
-conversion to one-way streets
-fences or physical barriers separating sidewalks from streets
-pedestrian malls
-safety islands for pedestrian refuge
-carpool signs and lots

PEDESTRIAN MOVEMENTS IN AND AROUND SHOPPING CENTERS

Pedestrian signals (13) and traffic signals (11) appeared with almost equal frequency on the list of measures used to handle pedestrians at shopping centers. Two respondents specified the use of push buttons on either the pedestrian or regular signals, but most did not mention this feature. With regard to regular traffic signals, it was often pointed out that they are employed only "where warranted"—such as at large shopping centers or at heavily used entrances. Sidewalks (6) and well-identified (i.e., painted, striped, or signed) crosswalks (10) were also mentioned frequently in relation to shopping center activities.

Parking (3) and bus (3) traffic near a shopping center are other factors that affect the safety and movement of pedestrians. Implementing parking restrictions, making lots adjacent to the stores, and removing conflicts between pedestrian and car traffic through proper design of parking areas are some approaches taken by the various agencies. Proper location of bus stops and the use of bus bays also help pedestrians maneuver safely through a shopping area. One agency said its object is to "check the routes to bus areas and safeguard the street crossing points."

Other measures listed include: adding stop signs or multi-way stops (4), minimizing driveways or controlling their location (2), adjusting signal timing or using a traffic signal progression system to create pedestrian gaps (2), and having police officers assist when necessary (2).

Traffic-control measures mentioned only once were: refuge islands, left-turn signals, lighting, speed limits, one-way streets, skywalks, and removal of visibility obstructions. Unfortunately, nonstandard signs and markings are still used in some shopping centers, and many shopping centers fail to properly provide for pedestrian needs.

CHAPTER SIX

TRAFFIC-CONTROL NEEDS AND USES FOR PEDESTRIANS

Most of the state and local agencies reportedly use a variety of traffic-control measures routinely. Those mentioned, in order of frequency, include:

- Pedestrian signals
- Painted crosswalks
- Sidewalks and walkways
- Traffic signals (with or without pedestrian signals)
- Warning and/or regulatory signs
- Exclusive and special pedestrian phasing
- School flashers
- Curb ramps for the handicapped
- General signs and markings
- Pedestrian push buttons
- Refuge islands
- Midblock signals
- Stop signs
- School crossing signs and markings
- Pedestrian overpasses
- Adjustment of signal timing
- Far-side bus stops
- Median and channelizing devices
- School crossing guards
- Reduction of the speed limit
- Removal of on-street parking
- Special crosswalk treatment

City agencies more often than state agencies cited detailed lists of traffic-control measures. Although many of the state agencies were reported to take an active role in roadway treatments for pedestrians, some states have limited responsibility or priority for pedestrian traffic-control measures, as illustrated by the following quotes:

State A

> In summary, the subject [pedestrians and traffic-control measures] is of great interest to us. However, like many other jurisdictions, we undoubtedly are way behind in providing positive response to the problems at hand.

State B

> Neither bureau has much direct involvement with pedestrian safety problems (our jurisdiction is over state highways outside municipal corporate limits), although the Bureau of Design Services does get involved with urban contract improvements, which may require pedestrian safety considerations.

State C

> [The area of responsibility in our state] is largely suburban/rural in nature, and thus from our perspective, we are not generally faced with issues involving heavy pedestrian traffic.

State D

> We hardly ever do any work where there [are] pedestrians.

When assessing the uses of various traffic-control measures, it is also important for traffic and transportation agencies to consider the needs of the various pedestrian groups. For example, a different traffic-control measure may be appropriate where there is a prevalence of elderly and handicapped pedestrians, compared with sites where college students or child pedestrians are frequent. Thus, the questionnaire survey was used to obtain information on how much emphasis (i.e., high, medium, or low) transportation agencies place on traffic-control measures for the following special groups or situations:

- Child safety in school zones
- Children at play in or near the roadway
- Elderly and handicapped
- College students
- Construction sites

The reason for their response was also asked in each case, and the responses are summarized in Table 15. The following is a summary of responses for each of the five groups.

TABLE 15

SUMMARY OF STATE AND LOCAL AGENCY RESPONSES ON EMPHASIS PLACED ON VARIOUS PEDESTRIAN GROUPS

Special Group or Situation	Number of Agencies Responding (percent given in parentheses)					
	State Agencies			Local Agencies		
	High	Medium	Low	High	Medium	Low
Child Safety in School Zones	12 (80)	2 (13)	1 (7)	29 (91)	3 (9)	0 (0)
Children At Play In Or Near Roadway	1 (7)	7 (47)	7 (47)	3 (9)	11 (34)	18 (56)
Elderly and Handicapped	5 (33)	9 (60)	1 (7)	11 (34)	18 (56)	3 (9)
College Students	1 (7)	4 (27)	10 (67)	4 (13)	11 (35)	16 (52)
Construction Sites	7 (47)	5 (33)	3 (20)	21 (66)	9 (28)	2 (6)

CHILD SAFETY IN SCHOOL ZONES

Twelve of the 15 states responding to this question indicated that their agencies give high priority to ensuring the safety of children in school zones. Of the 32 city/county agencies that responded on this item, 29 (91 percent) marked the "high emphasis" column. In both groups, the basic reason given was the obvious importance of protecting vulnerable young children from dangerous traffic situations. Also, a dominant factor is the large amount of public concern and support focused on this issue. Two states who marked "high" mentioned the need for compliance with specific relevant state regulations. However, the two states that indicated only medium emphasis explained that this is considered primarily a local issue.

CHILDREN AT PLAY IN OR NEAR ROADWAY

Only 1 out of 15 states (7 percent) indicated a high emphasis on the problem of children playing in or near roadways. Seven state agencies (47 percent) said they give a medium amount of attention to the problem. The other seven placed low priority on this issue.

Two basic reasons emerged from their explanations. First of all is the feeling that children should not be playing in roads to begin with, and to address this issue would only encourage children to play where they should not be. Second, such play is more likely to occur on neighborhood roads than on state highways, so it is primarily a matter of local or parental responsibility.

Only 3 of 32 city/county agencies (9 percent) indicated a high degree of emphasis on this item. Eleven agencies (34 percent) marked "medium," and 18 (56 percent) marked "low." As with the states, a common reason given for medium or low emphasis was the fact that roadways are not playgrounds; i.e., children should not play in the street. According to one respondent, even when controls (e.g., signs) are used in an effort to regulate playing near the roadway, they are often ineffective because children are unpredictable. Thus, to approach the problem of children playing in or near the road through agency controls only creates a false sense of security. Obviously, children must be protected while they play. The two important keys to safety suggested by the city/county respondents are: (1) parental supervision and (2) education of children regarding where to play and the dangers of traffic.

OLDER ADULTS AND HANDICAPPED

Of 15 states, 5 (33 percent) responded that they give "high" priority to the problems of older adults and handicapped and 9 states indicated "medium" emphasis. Eleven of the city/county responses were "high" and 18 indicated "medium." For both state and city/county agencies, the explanation of these ratings suggests a general consensus that the special needs of older adults and handicapped deserve special consideration. Among the states, five agencies referred to these needs. Four city/county agencies did likewise.

Despite the acknowledgment that these needs are real, providing for this population subgroup does not seem to be an automatic consideration at either the state or local level, although one state mentioned that it provides curb cut ramps on all new construction with curb and gutters. The general approach appears to be addressing the problem when it arises on a case-by-case basis. Several agencies indicated that they deal with problems of older adults and handicapped only when demand is high enough or when specific problems become known.

Four states listed specific methods of accommodating older adults and handicapped. Eight city/county agencies did the same. Some of the measures used include: special crosswalk signing, curb cut ramps, preferential parking, and adjusted pedestrian-signal timing.

COLLEGE STUDENTS

Ten of the 15 states surveyed responded that their agencies place low emphasis on pedestrian problems specifically related to college students. Four states indicated medium emphasis, and only one marked "high."

Thirty-one of 33 city/county agencies answered this item on the questionnaire. The majority (16) said they place low emphasis on special planning for the needs of college-age pedestrians. Eleven indicated medium emphasis, and four marked "high."

Obviously, as one state and three local agencies pointed out, the degree to which college students as a group may become a problem is influenced by the high or low concentration of educational institutions within a given locale. However, the real problem is not that college students have special needs. One-third (5) of the states, as well as seven local agencies, suggested that college students are adults who are highly capable of dealing with traffic situations. The problem is that they ignore or violate the adequate traffic controls that are already in place. Four states and six local agencies expressed frustration with the "general disregard for traffic controls" displayed by college students.

WORK SITES

A general schematic drawing for accommodating pedestrians in work zones is illustrated in Figure 29, as taken from the *Traffic Control Devices Handbook* (*37*). The use of barricades, handrails, fencing, and bridges along with warning and guide devices was suggested for pedestrians and motorists in work zones, according to the report "Traffic Controls for Construction and Maintenance Work Zones" (*51*). However, these guides often are not followed, particularly by contractors working on private construction (Figure 30).

A 1983 study by Chadda and Brisbin (*52*) investigated agency practices for accommodating pedestrians in highway work zones based on the state of the art, current practice, field investigations, and discussions with professionals. A variety of informational signs were found in use at various construction sites (as listed in Table 16), and some examples were found in construction plans where walkways and other facilities for pedestrians were specified. The authors, however, conclude that only general

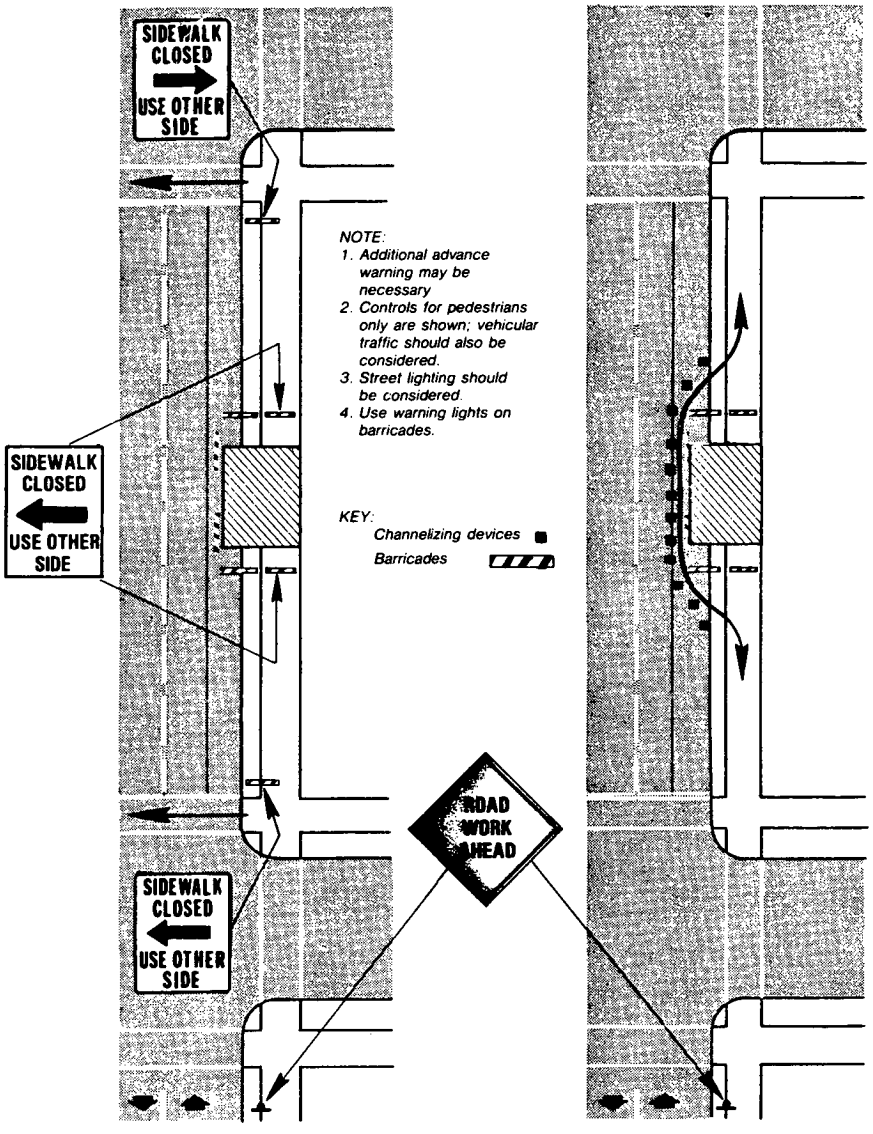

FIGURE 29 Typical application of two methods for accommodating pedestrians in work zones (*37*).

references to pedestrians are discussed in the MUTCD, and city and county construction manuals.

Based on the results of their study, Chadda and Brisbin concluded (*52*):

> It seems as though there is no real concerted effort being made by any organization, group, or agency to afford the pedestrian the same rights and privileges that a vehicle has as it passes through a construction zone. The vehicle is provided with an open, nearly unrestricted, relatively smooth, fairly well-marked way to proceed either around and through or detoured completely away from construction areas and problems. The pedestrian, however, is simply allowed to fight through construction areas full of debris, mud, and other obstructions.

The authors also recommend that further guidelines for accommodating pedestrians in work zones should be prepared at the federal level and preferably made a part of the MUTCD. Such guidelines should include techniques and devices to be used for site-specific needs (*52*).

In terms of the questionnaire responses, 7 of the 15 states (47 percent) indicated that they give high priority to pedestrian problems involving construction sites. Five (33 percent) indicated a medium degree of emphasis, but only three (20 percent) marked "low." Most (5) of the "medium" and "low" rankings were explained by the presence of little pedestrian traffic near rural construction projects and the preference for evaluating

FIGURE 30 Private construction forcing pedestrians to use the street.

needs on a site-by-site basis. Four states in the "high" and "medium" categories based their rankings on and necessity of compliance with federal and state regulations.

Of the 32 local agencies responding on this item, 21 (66 percent) said they give high priority to pedestrian problems related to construction sites. Nine (28 percent) indicated medium emphasis. One of those agencies explained that it "should be high—but lack of manpower prevents more emphasis."

Five states and three local agencies suggested that the degree of emphasis on construction-related problems depends on the amount and location of current construction activity. The relative presence or lack of affected pedestrians (e.g., rural highway versus busy downtown area) is also a factor. Even so, a majority of both state and local agencies gave this item the highest ranking. Such treatment is warranted by the obvious special safety hazards inherent in construction activities. According to one response, construction work creates unexpected, "abnormal conditions that require special protective measures." Four states and eight local officials referred to the unusual hazards found at construction sites and the resulting increased potential for accidents and liability suits.

Five local agencies listed specific measures they use to accommodate pedestrians in construction zones: frequent inspections for correct traffic-control devices; requirement of advance traffic-control plans; construction signs; provision of a walk area by the contractor if the sidewalk is blocked; and temporary, sheltered sidewalks.

TABLE 16

EXAMPLES OF CONSTRUCTION ZONE SIGNS FOR PEDESTRIANS IN USE (*52*)

SIGN MESSAGE	COLOR BACKGROUND	COLOR LETTERING	MATERIAL
CROSSWALK CLOSED USE OTHER SIDE	WHITE	BLACK	WOOD
SIDEWALK CLOSED PEDESTRIANS USE OTHER SIDE	WHITE	BLACK	WOOD
PEDESTRIANS USE OTHER BRIDGE	WHITE	BLACK	METAL
DANGER NO PEDESTRIANS	RED	BLACK	METAL
SIDEWALK CLOSED PEDESTRIANS CROSS OVER	WHITE	BLACK/ RED	WOOD
PEDESTRIANS USE WALKWAY	WHITE	BLACK	METAL
PEDESTRIANS KEEP RIGHT	CONSTRUCTION ORANGE	BLACK	METAL
PEDESTRIANS	CONSTRUCTION ORANGE	BLACK	METAL
PEDESTRIANS SIDEWALK	CONSTRUCTION ORANGE	BLACK	METAL
SIDEWALK CLOSED USE EAST SIDEWALK	WHITE	BLACK	METAL
PEDESTRIAN WALKWAY	WHITE	BLACK	CARD-BOARD
SIDEWALK CLOSED	WHITE	BLACK	WOOD/ METAL
SIDEWALK CLOSED PEDESTRIANS	WHITE CONSTRUCTION ORANGE	BLACK	METAL
PEDESTRIAN CROSSING	WHITE	BLACK	METAL
PEDESTRIANS PROHIBITED ON THIS SIDE	WHITE	BLACK	METAL
DANGER DO NOT WALK ALONG FENCE	YELLOW	BLACK	METAL

NOTE: SIZES OF SIGNS VARY AND ARE IRREGULAR.

CHAPTER SEVEN

SOURCES OF INFORMATION

In an effort to determine which sources of information are most valuable in planning traffic-control measures, the agencies were asked to rank various reference documents and guides in terms of their usefulness. Each source was evaluated twice. First, it was ranked according to its helpfulness in planning for general traffic-control measures. Then it was considered in terms of pedestrian-related procedures. Each reference was ranked on a descending scale from 5 to 1, in which 5 equals "very helpful," 3 means "moderate value," and 1 suggests "little or no value."

The Manual on Uniform Traffic Control Devices (MUTCD) (*14*) received high ratings from both state and local agencies. Fourteen out of 15 states (93 percent) and 23 of 30 local officials (77 percent) said the MUTCD is "very helpful" in planning general traffic measures. However, both groups considered it slightly less useful in accommodating pedestrians, giving it a moderate to high (3 to 5 range) rating.

On general traffic measures, the states' ratings of FHWA's *Traffic Control Devices Handbook* (*37*) were spread pretty evenly over the 5 to 2 range on the scale, with the 50 percentile falling in the "moderate value" column. Sixteen of the 29 local responses (55 percent) also indicated "moderate value." Like the MUTCD, this handbook was found to be slightly less useful for pedestrian-related planning. Seven of the 15 states (47 percent) gave the handbook a 2 ranking, which implies a moderately low degree of helpfulness. Nine of the 29 local responses (31 percent) were in the "moderate value" column, and 10 agencies (34 percent) indicated a "moderately low" level of usefulness.

Several states and approximately one-third of the cities and counties responding to the questionnaire either did not respond regarding FHWA's "Model Pedestrian Safety Program—Users' Guide" (*10*) or said that they do not use it. Of the state and local agencies who did respond, most considered this guide to have "moderately low" to "little or no" value with regard to both general and pedestrian-related traffic-control measures.

The ITE *Transportation and Traffic Engineering Handbook* (*21*) appears to be slightly more helpful to local agencies than to the states, as well as somewhat more useful in dealing with general traffic control than with pedestrians. State rankings in terms of general traffic were evenly spread across the moderate range of the scale. Ten local agencies considered this handbook to be of "moderate value," but 17 gave it higher marks. Concerning pedestrians, nine states gave the handbook a "moderate" rating, but four more checked the "moderately low" (2) column. The local agencies' evaluations were pretty evenly spread over the 5 to 2 range. Almost one-third (9) of the agencies considered the handbook to be of "moderate value," but 13 gave it higher ratings, which suggests a greater level of usefulness than indicated by the states. However, it also received eight low rankings on the pedestrian issue, compared with only three low marks for general traffic planning.

"Engineering judgment" was a resource that ranked consistently high with regard to both general and pedestrian-related planning for both state and local agencies. Fourteen out of 15 states (93 percent) gave this resource either a 4 or 5 rating for general planning. Twenty-one local agencies out of 31 (68 percent) gave it a 5 ("very helpful") rating. This is one highly ranked general resource that received equivalent scores regarding pedestrian concerns. Thirteen states (86 percent) gave "engineering judgment" a 4 or 5 rating for pedestrian matters. Twenty local offices (65 percent) gave it the highest mark (5).

Next to be evaluated were the American Association of State Highway and Transportation Officials (AASHTO) Standards [i.e., *A Policy on Geometric Design of Highways and Streets* (*4*)]. State rankings of these resources' value for general traffic planning were spread across the moderate (4 to 2) range, with the highest number (6 out of 15, or 40 percent) in the "moderately high" column. Local marks were spread fairly evenly over the entire scale, but "moderate value" received the highest number of marks (11 out of 31, or 35 percent). Both state and local agencies considered the standards to be less useful for pedestrian problems. The states' rankings of this resource fell mostly in the "moderate" (nine states, or 60 percent) to "moderately low" (four states, or 27 percent) end of the scale. Twenty-five out of 29 local offices' ratings (86 percent) also appeared on the lower half of the scale, with 14 agencies (48 percent) assigning the standards "little or no value."

The respondents were also asked to list additional sources of information that they refer to for guidance in traffic planning. One state and five city/counties mentioned their reliance on established agency policies, practices, and experiences. The guidelines unique to each agency were considered "very helpful" to the engineers and planners.

Other documents mentioned by state or local agencies as being helpful to some degree included: the ITE publication "A Program for School Crossing Protection" (*17*) (very helpful with pedestrians); other ITE articles and reports (more useful with general planning than pedestrians); the Transportation Research Board's Highway Capacity Manual (very helpful with general traffic, little or no value with pedestrians); Matson, Smith, and Hurd's *Traffic Engineering* (*53*) (very helpful, in general; almost as good for pedestrians); and various FHWA publications (moderately helpful overall).

In summary, three general statements can be made about the resource guides evaluated here by state and city/county agencies. First, there is a striking overall consistency between state and local evaluations of the individual references. Second, most of

the guides are less helpful in addressing the pedestrian issue than they are where general traffic is concerned. Finally, there are three resources that seem to be most helpful overall, especially with regard to pedestrians. They are the MUTCD, engineering judgment, and individual agency practices and experience.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

This report involved compiling information from the literature and from state and local highway agency officials on traffic-control measures and their effects on pedestrian safety and movement. Information was provided not only on measures traditionally installed with pedestrians in mind (e.g., crosswalks, pedestrian signals, pedestrian overpasses), but also on measures usually installed for motor vehicle considerations (e.g., traffic signals, separate left-turn signal phasing, design of intersections of freeway off-ramps with local streets).

Information was provided for more than 20 different traffic-control measures in terms of previous studies of their effect on pedestrian accidents and the advantages and disadvantages of each. It was found that traffic-control measures may work well in some situations and poorly in others, depending on such locational characteristics as traffic and pedestrian volumes, pedestrian mix (young children, older adults, handicapped), vehicle speeds, street width, existing traffic-control devices, area type, sight distance, accident patterns, and many other factors. In fact, questionnaire responses based on experiences from state and local agencies provided useful information on conditions under which each measure is most beneficial and also least effective (or possibly harmful).

Information was summarized on special activities of pedestrians, including entertainment and sporting events, work trip travel, and shopping center activities. Traffic-control needs of special pedestrian groups were also discussed in terms of such groups as children in school zones, children at play in or near roadways, older adults and handicapped pedestrians, and college students, and in relation to construction zones. The following are recommendations based on the findings of this report.

SELECTION OF EFFECTIVE TRAFFIC-CONTROL MEASURES

Because the effect of any traffic-control measure is so highly dependent on specific locational characteristics, agencies should avoid blanket installation of any measure. Examples of such measures include pedestrian signals and marked crosswalks, both of which may be helpful treatments for pedestrians under certain conditions but whose overuse may give pedestrians a false sense of security. Other measures, such as nighttime lighting and grade-separated crossings, are costly but can be highly effective in reducing pedestrian accidents when installed at critical locations. However, if used where not justified, grade-separated crossings will go largely unused by pedestrians and overhead lighting may have minimal benefit and be a costly investment of taxpayer dollars. Thus, great care must be exercised by agencies in determining the specific traffic-control needs for pedestrians under certain situations. The specific information provided in this report represents the experiences of many state and local traffic officials on control measures for pedestrians and should provide helpful guidelines for their effective use.

It is apparent that the needs of pedestrians are largely ignored in many traffic situations. Too often, traffic-control measures are designed with the sole interest of motorists in mind, and pedestrians are left to fend for themselves on streets with inadequate crossing times, confusing traffic-control devices, and excessive delays, and in construction zones with extreme traffic hazards. Nonstandard and ineffective warning signs are sometimes installed as a quick-fix treatment for a serious safety problem.

On the other hand, some transportation agencies place a high priority on the needs of pedestrians. Milwaukee, San Diego, Seattle, and Phoenix are only a few examples of such agencies that not only have comprehensive pedestrian-safety programs based on engineering treatments, but also have solid educational and enforcement programs, as well as community involvement to help enhance pedestrian and motorist safety. (See Appendix A for further details on selected city pedestrian programs.) Several state highway agencies appear to take a strong interest in pedestrian safety but are largely responsible for rural roadways and have little involvement with pedestrian-safety operations. It is still necessary for many state and local agencies to place more emphasis and priority on the needs of pedestrians by improving public streets and highways with traffic-control measures.

Implementing and maintaining a comprehensive program to enhance pedestrian safety should include several steps, as given in the FHWA "Model Pedestrian Safety Program." As a part of the overall pedestrian-safety program, agencies should follow the guidelines contained in:

- The *Manual on Uniform Traffic Control Devices for Streets and Highways* (*14*).
- *Traffic Control Devices Handbook* (*37*).
- 1984 American Association of State Highway and Transportation Officials Standards (i.e., *A Policy on Geometric Design of Highways and Streets*) (*4*).
- ITE "A Program for School Crossing Protection" (*17*).

Other sources [e.g., research reports, ITE *Transportation and Traffic Engineering Handbook* (*21*), AAA publications] may also be helpful. Care should be exercised, however, before accepting any one research study as correct, because considerable disagreements and controversy exist in the literature on certain

issues. Each agency should use its own experiences with certain measures based on its proper evaluations of previous projects conducted on its highway system.

As various traffic-control measures are installed for motor vehicle considerations, agencies should routinely consider their possible effects to pedestrians. For example:

- Sufficient walking time should always be provided at a signalized intersection for pedestrians to safely cross the street. Pedestrian push buttons may be provided to extend the crossing interval in certain instances. High-speed arterial intersections in suburban areas create special hazards for pedestrians and often deserve modification for pedestrian-safety purposes.
- Adequate traffic control for pedestrians should be provided at construction sites. Staged construction may be necessary in some cases to better accommodate pedestrians.
- Proper traffic control for pedestrians must be used at the intersection of expressway off-ramps with local streets.
- At intersections with confusing traffic signal phasing and/or intersection geometrics, potential dangers to pedestrians must be considered in terms of providing pedestrian signals and other measures, as appropriate.
- Roadways near pedestrian generators should have some types of provisions for pedestrians, such as sidewalks, separated paths, or at least a shoulder suitable for walking.
- Special types of traffic-control measures should be considered at locations with a substantial number of young children, older adults, and/or handicapped pedestrians.
- In suburban areas, pedestrian-crossing provisions are important. The use of far-side bus stops, properly timed traffic signals, and other measures should be considered, as appropriate.

Each agency should conduct a study of pedestrian accident types and the locations of those accidents along with supplemental information on where unsafe pedestrian behavior (e.g., jaywalking, pedestrian and motorist signal violations, speeding motorists, drunk driving and walking) is occurring, to identify problem pedestrian locations and areas. Then, appropriate pedestrian-safety treatments should be tailored to specific problem sites or sections. Examples of a few of the treatments that are sometimes effective include:

- Overhead and crosswalk lighting where there is a nighttime pedestrian-accident problem.
- Sidewalks or separate paths in residential areas.
- Adult crossing guards in school zones where pedestrians must cross at dangerous locations.
- Use of far-side bus stops and/or on-street parking prohibition at intersections having a problem with intersection dash accidents.
- Use of barriers at midblock locations with midblock dash accidents, particularly involving adult pedestrians.
- Grade-separated crossings only at locations experiencing extreme hazards to crossing pedestrians, such as over high-speed multi-lane roadways.
- One-way street systems and pedestrian malls (if practical in terms of traffic circulation).
- Use of exclusive pedestrian signal timing at locations where motorist and pedestrian delay would not be excessive and signal compliance is good.
- Neighborhood traffic-control measures (e.g., chokers, traffic diverters, cul-de-sacs), where practical.

FUTURE RESEARCH NEEDS

Although considerable amounts of useful information are known about various traffic-control measures, there are many gaps in current knowledge of traffic-control measures and their effects on pedestrians. The following are only a few suggestions for future research:

1. Examine the safety of pedestrians, both workers and passersby, in work zones on the roadway to suggest promising guidelines and solutions.
2. Investigate more recent accident data bases and identify specific pedestrian-safety problems by type of locational characteristics.
3. Develop practical guidelines for use by state and local agencies to design and apply pedestrian-safety measures more effectively.
4. Better quantify the effect of marked crosswalks on pedestrian accidents and the conditions under which marked crosswalks should and should not be used.
5. Determine the safety effects of refuge islands for pedestrians under various traffic and roadway conditions and develop guidelines for their effective use.
6. Further test the improved alternatives for the flashing DON'T WALK (i.e., clearance) interval, particularly the use of the steady DON'T START message in conjunction with the WALK and DON'T WALK messages, to determine the improved level of understanding, compliance, and potential cost of implementation nationwide.
7. Develop and evaluate different strategies to increase pedestrian and motorist compliance with traffic laws and devices (e.g., traffic signals, stop signs, legal street crossings, motorists yielding to pedestrians when turning).
8. Develop guidelines for installation of sidewalks in residential areas.
9. Develop specific guidelines for the optimal use of barriers, diagonal parking, and parking regulations as countermeasures to midblock dart-out accidents.
10. Investigate innovative types of signs and markings that may be useful in improving the behavior of pedestrians and/or motorists.

In addition to these types of future research efforts, there is a great need for better methods for distributing current information to state and local agencies relative to traffic-control measures related to pedestrians.

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APPENDIX A

EXAMPLES OF TRAFFIC-CONTROL MEASURES USED IN THREE CITIES FOR PEDESTRIANS

Adapted and updated from the original source: "Pedestrian Safety Programs—A Review of the Literature and Operational Experience," by Gerald R. Vallette and Judith A. McDivitt, Report No. FHWA/RD-80/190 (January 1981).

SEATTLE, WASHINGTON

Safety Program Coordination

The Seattle City Council and Mayor have the ultimate authority in determining what efforts will be made in regard to safety. However, they have given the Traffic Engineering Department a lot of freedom to do as it sees fit.

Complaints and requests for changes are generally sent directly to the Traffic Engineering Department. In the case of a school-related traffic complaint, the School Safety Committee (composed of members from the police, fire, traffic engineering departments, the Safety Council, AAA, and the schools) will first review the request. If a study is required, the T.E. Department will do it and make the final decision on whether or not a change is made.

Traffic Engineering

The T.E. Department has the authority to be innovative where it is deemed necessary in order to make the streets safe for users—especially pedestrians.

Signalization

Pedestrian WALK/DON'T WALK signals are put in with every new traffic signal, whether warranted by pedestrian volumes or not. However, at several older traffic signals, where there are currently no pedestrian signals, their installation in the future will depend on the availability of funds for adding signal heads.

There are several intersections where the signals have been installed for pedestrian use only. Most of these have an overhead steady green signal presented to through traffic with stop signs on the side streets. When activated by the pedestrian, the signal goes to red, allowing the pedestrian to cross the through street.

A pedestrian-actuated yellow beacon with an internally illuminated sign has been used for about 10 years. The sign (2′ × 8′) has the legend "CROSSWALK" and the yellow beacons are attached to each end. The beacons begin to flash when a pedestrian pushes a button at the end of the crosswalk and continue to flash for about one minute. The intent of this device was to condition drivers to expect pedestrians when the lights were flashing. Observations of driver behavior have not revealed any noticeable difference when compared to other non-controlled crossings and the operation is being terminated. The beacons are being placed into 24-hour operation.

Signing

The level of experimentation taking place in Seattle is most evident with some of the signing being installed. In residential areas where there are generally moderate to low volumes of pedestrians, crosswalks have been identified using large overhead signs above the marked crosswalks. It is felt that these signs designate the crosswalks' presence better than standard ground-mounted signs.

Near areas where there are blind pedestrians, the figures on the symbolic "Pedestrian Crossing" signs have had reflective white canes added, thus indicating a crosswalk used by the blind.

Crosswalks

Unsuccessful attempts were made to establish statistical warrants for marking crosswalks. Currently, crosswalks are marked only if one or more of three criteria are met:

- At signalized locations where vehicular traffic might block pedestrian travel when stopping for the red signal indication;
- At designated school crossings; and
- At nonsignalized locations where the level of usage and the geometry of the location would make the use of specially aligned crosswalks desirable.

Most of the crosswalks put in are standard two-line markings. However, ladder-style markings are being used in midblock and high-density pedestrian crossings to draw more attention to the potential presence of pedestrians.

Grade Separation

One pedestrian overcrossing has been constructed in the last seven to eight years. With a cost of about $600,000, very few are likely to be built in the future. This installation goes over a major double arterial road between a residential area and a large school. There are also bus stops beneath it which generate a high volume of pedestrians.

Sidewalks

Sidewalks have been built by the local improvement districts over the years. No city ordinance requires sidewalks in new developments. Local neighborhoods, if they desire a sidewalk, must first petition the City Council. If it is approved, a cost estimate is obtained from the Engineering Department. If the neighborhood still wants the sidewalk, the Engineering Department designs the project and hires a contractor to the job. Costs are assessed to the property owners.

Barriers

Some use has been made of pipe fences to channel pedestrians to marked crosswalks. These fences are only used where a legal crosswalk is being permanently closed. "DO NOT CROSS HERE" signs are used in conjunction with the fences.

In residential areas, a raised median or traffic diverter has been constructed connecting two of the diagonal corners at designated intersections. Traffic is thus required to turn at these intersections. Two benefits are seen from these installations: reduced overall vehicle speed through these neighborhoods and reduced volumes of through traffic through the residential neighborhood. These diverters are not commonly used because local residents object to their obstruction of local access.

School and Child Safety Programs

School Crossing and Safe Route Program

Every school crosswalk across a major arterial is marked with crosswalk lines and with two signs. These markings are also used to define the recommended path for children to follow.

The Traffic Engineering Department has made up maps for every public elementary school identifying the recommended routes for children to take to their school. The schools hand out the maps in a packet of safety literature at the beginning of the school year. There are attempts to have a kindergarten "Walk Day" where parents will show new students the route for them to take to school.

Crossing Guards

Of the some 750 marked school crosswalks, about 250 also have adult or student safety patrols. The Police Department School Safety Education Unit organizes and instructs the student patrols and the adult crossing guards. Adult crossing guards are paid by the City. There are also several "Officer Friendly" patrolmen who go to the elementary schools and teach safety practices.

Provisions for the Elderly and the Handicapped

Wheelchair ramps are being put in all over the City. The City has adopted a standard construction plan and locational criteria for their placement at intersection corners.

Public Information

Television spots are used quite extensively to transmit traffic-related information. These are usually done by the Washington State Traffic Safety Program or the AAA.

Enforcement

Strict enforcement of pedestrian-related regulations is upheld. In court, the violating pedestrian can pay up to a $15 fine.

MILWAUKEE, WISCONSIN

Safety Program Coordination

Final approval or rejection of all traffic-related ordinances is done by the Milwaukee Common (City) Council. When a complaint is received or a problem identified, the Council requires the Traffic Engineering Department to do a study evaluating the situation. If a modification is warranted, it must be approved by the Council prior to the change being made.

Because citizens of Milwaukee pay higher than average city taxes, they demand a high level of service. Therefore, every request and complaint is investigated. Favorable responses are made (that is, something is done) on nearly half of all requests.

Under the Mayor and Common Council is the Milwaukee Safety Commission (MSC) whose primary purpose is to be a vehicle for public information on all aspects of safety (fire, home, traffic, etc.). The Commission has 18 members who oversee activities and 10 advisory members. These people are appointed by the Mayor and approved by the Common Council. All disciplines (police, fire, engineering, school, medical, etc.) are represented on the Commission.

The MSC has several committees which deal with specific safety problems. The Traffic/Schools Committee works closely with the Police, Traffic Engineering Department, and the school systems on traffic-related problems. This Committee also monitors the school crossing guard, Safety Cadet, and safety-education programs.

Traffic Engineering

Signalization

Milwaukee's overriding philosophy has been to accommodate the pedestrian in the total traffic system. Toward this end they have automatically installed pedestrian signals with traffic signals. Nearly 100 percent of the intersections with traffic lights also have pedestrian signals.

Along the major arterial streets in the City, all traffic signals are synchronized. However, as part of the effort to facilitate pedestrians, special cycles have been programmed into the signal system. For example, on one six-lane arterial, there is an elderly population living on one side that uses a shopping center on the opposite side. The normal synchronized traffic cycle is 60 seconds. When the pedestrian signal button is pushed, the signal goes through two 90-second cycles, thereby giving the slower-moving elderly pedestrians more time to cross the major street. The phasing reverts back to the 60-second cycle at the end of

an even number of 90-second cycles, thus falling back into synchronization with the rest of the road. (Return to the 60-second cycle after an odd number of longer cycles would result in that signal being 30 seconds out of synchronization with the rest on that arterial.) The signal remains on the longer cycle as long as the pedestrian signal button is activated. A sign is posted on the signal pedestal stating "Elderly/Disabled Push Button for Extra Walk Time."

Another example of facilitating the pedestrian is as follows. On other arterial streets, the traffic signals are on a 90-second cycle during the day, but, due to lower volumes relative to the side streets, at night they are on a 45-second cycle. Signs are posted at these intersections telling pedestrians to cross only half-way (to or from the median) during each 45-second cycle between 10 p.m. and 6 a.m.

At signalized intersections where there is a shared cycle for vehicles and pedestrians, the "WALK lead" has been used. The pedestrian WALK light will activate before the green traffic light. This allows pedestrians to get out into the street before any turning vehicles, and gives drivers a better line of sight for pedestrians in the crosswalk. This technique is more effective in a *non*congested traffic situation. It does delay some vehicles, giving about 5 to 10 seconds less green signal time. The use of this operation is very limited.

Several marked crosswalks have pedestrian-activated traffic signals. With no pedestrians present, the traffic signal normally shows a flashing amber light. Upon activation by the pedestrian, the light turns green for 10 to 15 seconds, then turns red. After four more seconds, the WALK phase shows on the pedestrian signal. This delay was incorporated because pedestrian traffic is very light and the signal is used infrequently. As a result, drivers don't expect to see the red light and sometimes run it when it is activated. The delay gives an additional margin of safety to the crossing pedestrian.

Crosswalks

Marked crosswalks are being limited to major arterials and signal-controlled intersections. Pedestrians are seemingly more attentive to traffic when crossing at unsignalized intersections. Marking a crosswalk at these locations may give pedestrians a false sense of security because the state law gives pedestrians the right of way in marked crosswalks.

Grade Separation

There are a few pedestrian overpasses in the City situated at unique geometric or high-traffic-volume locations. It is felt that if the signalization system is utilized properly by both drivers and pedestrians, there should be no need for grade separation in most situations. Public awareness and compliance are cheaper and should be more cost-effective.

School and Child Safety Programs

The Milwaukee Safety Commission, in cooperation with the public and parochial school systems, is responsible for developing and teaching all school safety education programs.

Crossing Guard Program

Milwaukee has some 5,000 trained Safety Cadets, taken from the fifth through eighth grades. The responsibility of the Safety Cadets at school crossings is to keep the children on the curb until there is a sufficient gap in the traffic for them to cross. The Cadets *don't* go into the streets themselves, except to look around parked vehicles. Local community organizations and the Safety Commission are involved in awards and incentive programs for students serving as Safety Cadets. Recognition luncheons for representative students of award-winning schools are held by four community organizations. Other incentives to keep Cadets on the job are a mid-year Safety Cadet Day at the movies (sponsored by a local theater chain), a year-end trip to Wisconsin Dells, Milwaukee Brewers game, and awards certificates and ballpoint pens distributed to students at the schools.

Three employees of the MSC go to the 200 elementary schools and hold training programs for new Cadets during the spring and fall. By the time they start working in September, the new members have had some experience.

The 230 adult crossing guards are uniformed, paid paraprofessional police personnel posted only at major arterial highway crossings. They *do* enter the road to stop traffic when necessary. Adult guards and Safety Cadets are used only at elementary school crossings.

School Crossings/Safe Route Program

All signed school crosswalks on arterial highways also have pavement markings. This serves to keep the children within fairly well-defined limits, and also brings drivers' attention to the possibility of children in the vicinity.

The Safe Route to School Program designed by the Institute of Traffic Engineers is used. School district maps, marked with arrows indicating preferred streets for children to follow to and from school, are handed out in the classrooms.

Education

The MSC gives over 900 "Officer Friendly" type presentations each year in public and private schools and preschool centers. The Public Health Department endorses pedestrian safety literature in the package sent to new parents with their baby's birth certificate.

Because of the large number of school-age children to be reached, the Safety Commission uses School Cadets as supplemental instructors. The School Cadets are taught by the MSC. Cadets then go into individual classrooms and explain the pedestrian signal system, using an instructional aid, "Minisignal."

Provisions for the Elderly and the Handicapped

Curb-cut ramps are being put in at newly constructed or replaced intersections. However, there are very few people in wheelchairs using the ramps in the City. There have been problems with these ramps: The Sanitation Department is unable to properly clear out ice and debris in the ramps, and skateboarders and bicyclists ride down them into the street with little regard for vehicular traffic in the road.

Safety lectures have been given to organizations for the elderly. Attempts have been made to get elderly persons involved in this lecture process (as with Safety Cadets in the schools). However, their reduced capability for travel and other limitations precluded this from being very successful.

A study done on the elderly in Milwaukee indicated that most elderly pedestrians have never driven a car. They are therefore often unaware of driving practices and have a limited capability to judge vehicle speeds and stopping distances. Part of the education process is oriented to teaching elderly persons about this potential handicap.

Enforcement

One of Milwaukee's public-relations statements is that it is a "Safe Place to Live." While this slogan is oriented around anticrime programs, it also relates to the relatively low accident rate in the City.

Enforcement of traffic laws is considered a prime factor in inducing people to use the safety facilities provided. Police Department philosophy states that traffic and pedestrian law violators will be arrested. A selective enforcement program is in effect, concentrating on specific locations, times of day, days of week, seasons, etc.

Accident Analysis

Milwaukee has had a dramatic decrease in pedestrian accidents for several years in a row. There is an ongoing study trying to determine why this has been the case.

Safety Program Philosophy

The overall emphasis in the safety program in Milwaukee is on the pedestrian—both from an educational and facilities-installation standpoint. They are trying to make the City safer for pedestrians "from the cradle to the grave." Only through an informed general public can the safety countermeasures be workable. Their public-information programs hopefully will augment the physical installations and enforcement.

Milwaukee safety personnel know they are doing a good job because this is reflected in the accident statistics. However, it does not take much for the accident rate to start climbing again. Therefore, the "pressure" must be kept on in all areas of traffic and pedestrian safety.

While state law does give pedestrians the right of way in a crosswalk, in *reality* cars take the right of way. Only through constant vigilance in all areas can the City be kept safer for pedestrians.

SAN DIEGO, CALIFORNIA

Safety Program Coordination

The City Department of Transportation has budgeted six full-time positions aimed at traffic safety functions. Close coordination is maintained between traffic engineers, the Police Department, and the Department of Education. Further safety coordination with the community is provided through the San Diego Public Safety Committee (founded in 1921), the local chapter of the National Safety Council, and the local Parent-Teachers Association.

For the most part, San Diego has avoided highly publicized short-range safety programs in favor of long-range behind-the-scenes safety efforts, involving enforcement personnel, educators, engineers, and other key safety elements in the community. Consequently, there is less thrust on producing "immediate results" and less chance of disillusionment and possible abandonment of safety efforts.

Traffic Engineering

Signalization

All signalized intersections have pedestal-mounted signals with most arm signals provided where needed. No span wire signals are used because they are difficult for pedestrians to see and account for much pedestrian frustration and possible pedestrian accidents where they are used. All "pedestal signals" are easily seen by pedestrians. Supplementary WALK/DON'T WALK signals are provided at the following locations:

- Fixed Time Signals requiring a pedestrian-clearance interval because of heavy pedestrian traffic, heavy vehicular traffic, and/or excessive street width.
- Traffic-Actuated Signals requiring special detection and timing for pedestrians. Pushing the pedestrian button not only activates the WALK signal, but also gives the pedestrian additional time to cross the street.

Pedestrian activator buttons are used at all traffic-actuated signals. Local surveys have indicated that pedestrians, particularly from the eastern cities, seem to have a poor understanding of the purpose and use of pedestrian buttons. Special efforts are made to educate school children in their proper use. The City has a few signals that are installed exclusively to accommodate school crossings at *midblock* locations. These are also equipped with pedestrian activator buttons.

San Diego cooperated with the 3M Company by installing and helping to evaluate the innovative and promising "Dynamic Pedestrian Signal." Basic signal design allows persons walking in the crosswalk to always see a WALK message, while pedestrians arriving at the curb late in the cycle would see DON'T WALK. That is, pedestrians already walking would know to continue, rather than have a DON'T WALK message presented when they are halfway across the street.

Unfortunately, field tests indicated that the signal did not function properly for short persons (children and the elderly). This problem was accentuated at hilly sites. Other problems centered around its electro-mechanical operation, which occasionally stuck on WALK when the cross traffic had a green light. As a result, further field evaluations were terminated.

Crosswalks

A five-year study of accidents in marked versus unmarked crosswalks found that twice as many pedestrians were hit and

killed in marked crosswalks. As a result, San Diego took the following steps:

- Revised its crosswalk warrants and greatly restricted the installation of new marked crosswalks.
- Reevaluated all existing crosswalks under its street-resurfacing program. If an old crosswalk failed to meet the new warrants, it was not re-marked.
- Started an education program in cooperation with the Police Department, City schools, senior citizens center, and the media to alert pedestrians to being just as careful while using marked crosswalks as they are when crossing in unmarked crosswalks.

Less than 7 percent of the City's 13,000+ intersections have marked crosswalks. (This includes marked crosswalks at signals and school crossings.) On all new marked crosswalks "ladder-striping" is being used because it is easier for motorists to recognize than other striping patterns.

Grade Separation

Separate pedestrian bridges are used extensively over the freeway system. These are equipped with special screen guards to prevent vandals from dropping objects on the road below. In addition, approximately 20 pedestrian bridges cross arterial (surface) streets to facilitate pedestrian safety and mobility. The newest bridges are wheelchair accessible and quite aesthetically pleasing. Pedestrian bridges are particularly useful in the vicinity of local university campuses. At one time San Diego had about 10 pedestrian tunnels serving various high schools and junior high schools in the area. The last of these tunnels was closed about a year ago because of vandalism and other social problems.

Sidewalks

San Diego inherited a sizeable sidewalk deficiency problem about 20 years ago when it began expanding and annexing previously semi-improved unincorporated areas. To overcome this, the City has published special brochures encouraging property owners to install sidewalks and curbs and to upgrade their property by means of the California 1911 Act Improvement and Assessment Procedures. Where it is not possible for property owners to install sidewalks, and where there is a demonstrated need for a walkway, the City has provisions for installing temporary asphalt walkways on at least one side of the street. To date, over 10 miles of such walkways have been installed. Particular attention is given to the needs of school children and the disabled.

Barriers

Extensive use is made of pedestrian barriers and diversion signs to direct pedestrians from high-hazard crossings to legs of the intersections having reduced exposure to traffic or improved sight characteristics. Chain-link fence has also been used effectively as a pedestrian barrier on medians where there is a midblock crossing problem. These are frequently associated with a grade-separated crossing facility.

School and Child Safety Programs

In San Diego, the School Traffic Safety Program is composed of four elements: safety planning, safety education, safety operation, and special arbitration.

Safety Planning

This is a joint function of the School District and Planning, Transportation, and Police Departments. The purpose is to forestall future pedestrian problems by determining the best locations for new schools, school boundaries, and school routes such that there will be a minimal conflict between school children and traffic.

Safety Education

The main thrust of pedestrian safety education occurs at the elementary school level and is handled primarily by the Police Department. A special School Safety Unit consisting of 14 policemen has been established on a *full-time* basis by the Police Department. This unit works directly with each school principal in both the public and private schools. The officers conduct safety classes for the students, give talks, and show films. Of particular interest are some of their special programs and live demonstrations, including: "Kids and Skids," "Officer Friendly," "Bicycle Rodeos," and "Safe Route to School Programs."

Having the Police Department handle this program has given the children an opportunity to become personally acquainted with police officers under friendly and favorable circumstances, thereby forming positive attitudes on safety and law enforcement.

Safety Operations

The core of the safety operations is the School Safety Patrols, which guard selected crossing locations and control the movement of school children and vehicular traffic at these locations. This function is also under the responsibility of the Police Department School Safety Unit. Fifth and sixth grade boys and girls are selected on the basis of leadership, scholarship, and citizenship to participate in this program. They wear special easily seen uniforms consisting of white trousers, red blazers, and yellow caps. They receive individual training under police supervision and meet weekly with their assigned police officer supervisor to discuss problems and procedures. Special incentive awards and activities are provided, including scholarships, summer camp, Christmas barbecue picnics, and special outings to pro-baseball/pro-football games, the zoo, etc. The effectiveness of this program can be measured by the fact that in 42 years since its inception, there have been no fatalities and only two child injuries in a school crossing.

Special Arbitration

Special school safety problems that cannot be resolved in the usual manner at the working level (between the parent, the

school authorities, the Police Department, and the City Traffic Engineer) are referred to the "School Safety Advisory Committee" for review and arbitration.

Provisions for the Elderly and the Handicapped

"Save-Our-Seniors"

In 1970 San Diego initiated a "defensive walking" program aimed at senior citizens. This program recognizes that the senior pedestrians undergo a loss of visual acuity, ambulatory ability, and head and neck mobility as they grow older. Also they tend not only to be more vulnerable to traffic accidents but less apt to recuperate after being hit than younger pedestrians. As a result, it is extremely important for senior citizens to avoid involvement in *any* pedestrian accidents. This program was developed in cooperation with the Senior Citizens Coordinator, the Police Department, the Traffic Engineers' Office, the Auto Club of Southern California, and the National Safety Council.

Guidestrips for the Blind

Two-inch-wide epoxy-gravel tactile guidestrips for blind pedestrians were developed as a joint effort by the City Traffic Engineers and the Service Center for the Blind as a means of helping blind pedestrians find their way across complex and confusing intersections. Blind pedestrians use it by straddling the strip with their feet and touching the strip with the tip of their canes in a sweeping motion on every other step. The guidestrips help orient the blind user and help prevent their drifting into the path of traffic, particularly while crossing skew intersections.

Removal of Mobility Barriers

In 1975 San Diego created an ad hoc Advisory Committee for the Removal of Architectural Barriers. This committee consisted of representatives of the blind community, the wheelchair community, the elderly, and others with disabilities. The purpose of this committee was to advise City staff on the most effective ways to eliminate mobility barriers on the public right of way. The major accomplishments were to develop an improved design for wheelchair ramps that were satisfactory to both the blind and wheelchair communities and develop a cost-effective program of "preferred wheelchair routes." Routes are identified that will provide optimum service for the elderly and disabled in terms of access to medical facilities, recreational facilities, senior citizens' high-rise apartments, and educational and employment opportunities. Consideration is given to topography, availability of sidewalks, and other safety and mobility features. In certain cases, ramps may be routed on only one side of the street to provide maximum continuous route mobility and more favorable safety characteristics.

Public Information and Education

San Diego has good cooperation with the television and newspaper media in getting exposure on safety matters. The San Diego Union/Tribune has published a public-service booklet entitled "You and Traffic" that covers various types of vehicle and pedestrian traffic problems. The City, in cooperation with the Auto Club of Southern California, has published a booklet entitled "Engineering for Your Safety—Understanding San Diego's Traffic Engineering Problems" that is distributed to citizens requesting information on traffic-control devices. Many public-safety talks are provided by police and traffic engineering staff.

Enforcement

In 1976 the San Diego Police Department issued 11,046 citations against pedestrians for miscellaneous violations and 1,634 citations against motorists for violating the pedestrian's right of way. During 1976 the Juvenile Traffic Court handled 2,836 citations against juvenile pedestrians and 3,365 citations against juvenile bicyclists.

Accident Analysis

A key element in the City's safety program is the comprehensive and sophisticated accident-surveillance system maintained by the Traffic Operations Section. The Police Department cooperates by providing reports on virtually every traffic accident occurring on the public right of way, regardless of severity. The *circumstances* of the accident, rather than *severity,* are considered to be most relevant to effective accident analysis. Over 20,000 accidents per year are pinned on a wall map and coded into the City's computer for a wide variety of computer listings used by the Traffic Engineers and Police Department. Past accident records are maintained for a period of 10 years to provide an in-depth look at accidents on a city-wide basis or at individual locations. Priority lists of intersections and street sections are provided in terms of frequency and accident rates.

Accident data are used by the Police Department in its selective-enforcement program and by the Traffic Engineers in their signal-priority program and in the evaluation of other traffic-control devices. Computer accident lists are supplemented by detailed collision diagrams and strip maps, which are very useful in identifying accident patterns and other recurring accidents subject to correction. San Diego places special emphasis on its surveillance of pedestrian accidents. This is where the extensive accident history becomes particularly useful in identifying accident patterns of a low-frequency nature that might not otherwise be recognized.

Emergency Medical Services

The San Diego Police Department operates the City's primary ambulance service. Because these units are deployed in the field with other patrol units, the average response to an accident or emergency is five minutes. This rapid response time is helpful in reducing the mortality and severity of accident injuries, especially those involving senior citizens.

Safety Program Philosophy

The Traffic Engineers' job is to maximize *people* flow, whether they are in vehicles, on bicycles, or are pedestrians. California traditionally tends to favor the pedestrian. However, the vehicle code does *not* give the pedestrian the absolute right of way. The pedestrian has certain responsibilities that he or she shares with the motorist in using the street in a safe and reasonable manner. Education programs are aimed at emphasizing the need for pedestrians to watch out for vehicles. Whether he or she has the right of way or not, the pedestrian usually is the loser if an accident occurs.

APPENDIX B

EXAMPLES OF WARRANTS FOR CROSSWALKS, TRAFFIC SIGNALS, AND PEDESTRIAN SIGNALS

CITY OF SAN DIEGO

Warrants

PEDESTRIAN CROSSWALKS

In order to qualify for a marked crosswalk, a location must (A) meet the following basic warrants and (B) rate 16 points or more under the following point system:

A) Basic Warrants

Pedestrian Volume Warrant

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

Approach Speed Warrant

Crosswalks will not be installed on roadways where the 85th percentile approach speeds are in excess of 45 mph. The approach speeds shall be determined by approved engineering speed study techniques.

Visibility Warrant

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

Illumination Warrant

Proposed crosswalk site must have adequate crosswalk lighting in existence or scheduled for installation prior to the installation of the crosswalk (see Section 12.16).

B) Warrant Point System

Pedestrian Volume Warrant

Criterion	Point Assignment Pedestrian Total	Points
The total number of pedestrians crossing the street under study during the peak pedestrian hour. This includes pedestrians in both crosswalks at an intersection. Crosswalks will not be installed where the ped volume (peak ped hr.) is 10 or less.	0-10	0
	11-30	2
	31-60	4
	61-90	6
	91-100	8
	Over 100	10
	Maximum	10

General Conditions Warrant

		Points
(a)	Will clarify & define pedestrian routes across complex intersections.	2
(b)	Will channelize pedestrians into a significantly shorter path.	2
(c)	Will position pedestrians to be seen better by motorists.	2
(d)	Will position pedestrian to expose him to fewer vehicles.	2
	Maximum	8

Gap Time Warrant

Criterion

The number of unimpeded vehicle time gaps equal to or exceeding the required pedestrian crossing time in an average five-minute period during the peak vehicle hour.

Point Assignment

Average number of gaps per 5-minute period	Points
0 - 0.99	10
1 - 1.99	8
2 - 2.99	6
3 - 3.99	4
4 - 4.99	2
5 or over	0
Maximum	10

Computations

(1) Pedestrian Crossing Time = $\frac{\text{Street width curb to curb}}{\text{4.0 feet per second}}$

(2) Average Number of Gaps per Five-minute Period

$$= \frac{\text{Total usable gap time in seconds}}{\text{Pedestrian Crossing Time} \times 12}$$

Provisions

(A) The above criterion is based on a one-hour field survey consisting of 12 five-minute samples.

(B) All roadways having a raised median or a painted median (4-foot minimum width) will be considered as two separate roadways, if the pedestrian has a protected place to stand out of the path of traffic.

(C) See Appendix One for survey methods and warrant field form.

Phone 266-4761

DEPARTMENT OF TRANSPORTATION Room 502, *city-county building, madison, wisconsin 53709*

CITY OF MADISON

TRAFFIC SIGNAL HEAD INSTALLATION POLICY

12" SIGNAL HEADS SHALL BE USED:

(1) First signal when entering City
(2) All overhead signals
(3) If three or more approach lanes
(4) If traffic volume is high and accident experience shows a need for the signal indications to be larger
(5) If the physical distractions in the area are so great that they cause the signal indications to become difficult to notice as you approach the intersection.
(6) If a high percentage of large trucks and/or buses obstruct the drivers view of two indications and accident experience shows that the third indication is not being seen by drivers
(7) All arrow indications

3M SIGNAL HEADS SHALL BE USED:

(1) If separate left turn sequence (left turn on arrow only)
(2) Special vision problems
(3) Skew intersection where louvered signal heads are not satisfactory
(4) Separate lane control is desired
(5) Where sequence is such that pedestrians may be confused by seeing signal

WALK LIGHTS SHALL BE USED:

(1) At all CBD signals
(2) When traffic signals are warranted under the pedestrian warrant
(3) When the traffic signal is at a heavily used school crossing or if a school crossing guard is stationed at the intersection
(4) When the crossing of pedestrians is to be restricted to certain legs of the intersection
(5) When the pedestrian volume is high and accident experience has shown that the WK-FDWK sequence should be displayed
(6) If the pedestrian is unable to see a green light to walk with
(7) 3M walk lights should be used for "split walk" crossings if viewing the wrong indication causes confusion to pedestrians

MAST ARM SIGNAL INSTALLATIONS SHALL BE USED:

(Far right indication only)
(1) If three or more approach lanes
(2) If traffic volume is high and accident experience shows a lack of recognition of signal indications
(3) If a high percentage of large trucks and/or buses obstruct the driver's view of signal indications and accident experience shows that a far right overhead signal indication is needed
(4) If special lane control signals are used

January, 1981

MONTGOMERY COUNTY, MARYLAND
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRAFFIC ENGINEERING

GUIDELINES FOR PEDESTRIAN SIGNALS

The following are guidelines for the application of pedestrian signals or other provisions for pedestrian crossing time at signalized intersections. These guidelines have been used in County signal designs for a number of years. However, they are not a substitute for sound engineering judgment.

I. General - All Intersections

A. If there is a demonstrated absence of any existing or potential pedestrian crossing activity (due to very rural area, land use not generating pedestrian crossings, no bus stops or schools in area, etc.), provisions for pedestrians may be deleted from the signal control.

B. In all other cases, some provision for adequate time for pedestrians to cross the main street should be provided. In certain circumstances (see below), such provisions should also be made for pedestrians to cross the minor street.

C. In most cases where pedestrian crossing time provisions are to be made for crossing the major street, this will be done for crossing both legs of that main street.

1. If one of the two pedestrian crossings across the major street would be subjected to considerably more conflict from the right and/or left turns out of the side streets than the other crossing, then consideration should be given to restricting pedestrians to the crossing that has the least conflict.

2. There may be other factors, such as right turn overlaps, pedestrian volumes, sight distance, unusual geometry, etc., that may justify limiting pedestrian crossing provisions to only one leg of the major street.

II. Two-Phase Intersections

A. The provision of adequate time for pedestrians to cross the major street should usually be via "Walk-Don't Walk" pedestrian signals, especially in urban high pedestrian volume areas or where school children cross.

1. In some cases, especially where the controller would have to be replaced in order to allow operation of pedestrian signal indications, an acceptable alternate treatment is to provide either a) adequate side street green time at fixed-time intersections, or b) pedestrian push buttons and a relay-timer that will guarantee an adequate duration of side street green time for pedestrians to cross the major street at actuated intersections.

B. Ordinarily, two-phase intersections will not have pedestrian signals for crossing the side street legs. At pretimed or semi-actuated intersections, there is usually more than enough guaranteed main street green time to allow safe pedestrian crossings across the side streets without any special treatment.

1. At fully-actuated intersections where pedestrian movements across the side streets exist, the main street "minimum green" time should be set high enough to accommodate them and the main street phase should be put on minimum recall.

2. If the main street and side street are fairly equal in width and/or volume, or if there are other unusual factors, consideration may be given to providing pedestrian signals for crossing both the major street and the minor street at two-phase intersections.

III. Intersections with Main Street Left Turn Phases:

A. The provision of adequate time for pedestrians to cross the major street should be via "Walk-Don't Walk" pedestrian signals. The alternate treatment of "adequate side street green time" that is allowable for two-phase intersections is generally not appropriate for multi-phase intersections due to the more complex phasing.

B. If there are left turn phases for both directions of the major street, then "Walk-Don't Walk" pedestrian signals should be provided for crossing both minor street legs due to the potential conflict with the "protected" left turns.

C. If there is a left turn phase for only one direction of the major street, then "Walk-Don't Walk" pedestrian signals should be provided for crossing the one minor street leg into which the "protected" left turn is made.

1. No pedestrian signals would ordinarily be provided for crossing the other minor street leg, into which no "protected" left turns are made. However, if that minor street leg is unusually wide or has a large pedestrian crossing volume, pedestrian signals for that leg may be provided.

IV. Intersections with "Split-Phase", Double Left Turns, or Other Special Phasing:

A. Intersections with these special phasings require more detailed attention to pedestrian crossing provisions.

1. Pedestrian crossings shall not be allowed to operate simultaneously with a vehicular movement involving a double left turn across that crosswalk.

2. Where the minor street is "split-phased", consideration should be given to restricting the crossings of the major street to one of the two legs.

WSW/mjo

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