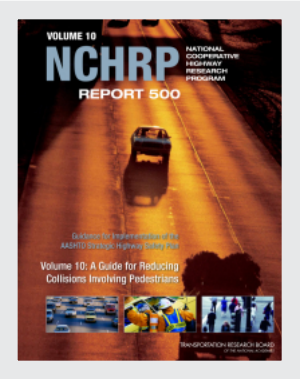

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 500

Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

Volume 10: A Guide for Reducing Collisions Involving Pedestrians

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SUBJECT AREAS
Safety and Human Performance

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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FOREWORD

By Charles W. Niessner
Staff Officer
Transportation Research Board

The goal of the AASHTO Strategic Highway Safety Plan is to reduce annual highway fatalities by 5,000 to 7,000. This goal can be achieved through the widespread application of low-cost, proven countermeasures that reduce the number of crashes on the nation's highways. This tenth volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* provides strategies that can be employed to reduce the number of collisions involving pedestrians. The report will be of particular interest to safety practitioners with responsibility for implementing programs to reduce injuries and fatalities on the highway system.

In 1998, AASHTO approved its Strategic Highway Safety Plan, which was developed by the AASHTO Standing Committee for Highway Traffic Safety with the assistance of the Federal Highway Administration, the National Highway Traffic Safety Administration, and the Transportation Research Board Committee on Transportation Safety Management. The plan includes strategies in 22 key emphasis areas that affect highway safety. The plan's goal is to reduce the annual number of highway deaths by 5,000 to 7,000. Each of the 22 emphasis areas includes strategies and an outline of what is needed to implement each strategy.

NCHRP Project 17-18(3) is developing a series of guides to assist state and local agencies in reducing injuries and fatalities in targeted areas. The guides correspond to the emphasis areas outlined in the AASHTO Strategic Highway Safety Plan. Each guide includes a brief introduction, a general description of the problem, the strategies/countermeasures to address the problem, and a model implementation process.

This is the tenth volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*, a series in which relevant information is assembled into single concise volumes, each pertaining to specific types of highway crashes (e.g., run-off-road, head-on) or contributing factors (e.g., aggressive driving). An expanded version of each volume, with additional reference material and links to other information sources, is available on the AASHTO Web site at http://transportation1.org/safetyplan. Future volumes of the report will be published and linked to the Web site as they are completed.

While each volume includes countermeasures for dealing with particular crash emphasis areas, *NCHRP Report 501: Integrated Management Process to Reduce Highway Injuries and Fatalities Statewide* provides an overall framework for coordinating a safety program. The integrated management process comprises the necessary steps for advancing from crash data to integrated action plans. The process includes methodologies to aid the practitioner in problem identification, resource optimization, and performance measurements. Together, the management process and the guides provide a comprehensive set of tools for managing a coordinated highway safety program.

Contents

Acknowledgments

This volume of *NCHRP Report 500* was developed under NCHRP Project 17-18(3), the product of which is a series of implementation guides addressing the emphasis areas of AASHTO's Strategic Highway Safety Plan. The project was managed by CH2M Hill, and the co-principal investigators were Ron Pfefer of Maron Engineering and Kevin Slack of CH2M Hill. Timothy Neuman of CH2M Hill served as the overall project director for the team. Kelly Hardy, also of CH2M Hill, served as a technical specialist on the development of the guides.

The project team was organized around the specialized technical content contained in each guide, and the team included nationally recognized experts from many organizations. The following team of experts, selected based on their knowledge and expertise in this particular emphasis area, served as lead authors for the Pedestrian guide:

- Charles V. Zegeer
  University of North Carolina Highway Safety Research Center
- Jane Stutts
  University of North Carolina Highway Safety Research Center

Development of the volumes of *NCHRP Report 500* utilized the resources and expertise of many professionals from around the country and overseas. Through research, workshops, and actual demonstration of the guides by agencies, the resulting documents represent best practices in each emphasis area. The project team is grateful to the following list of people and their agencies for supporting the project through their participation in workshops and meetings and additional reviews of the Pedestrian guide:

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SECTION I

Summary

Walking is a basic human activity, and almost everyone is a pedestrian at one time or another. The 2001 edition of the AASHTO Green Book states that "pedestrians are a part of every roadway environment, and attention should be paid to their presence in rural as well as urban areas" (American Association of State Highway and Transportation Officials, 2001). It goes on to state, ". . . pedestrians are the lifeblood of our urban areas, especially in the downtown and other retail areas" (p. 96).

Even though pedestrians are legitimate roadway users, they are frequently overlooked in the quest to build more sophisticated transportation systems. Whether building new infrastructure or renovating existing facilities, it should be assumed that people will walk, and plans should be made to accommodate pedestrians. Where people aren't walking, it is often because they are prevented or discouraged from doing so. Either the infrastructure is insufficient, has serious gaps, or there are safety hazards. Aesthetics (e.g., pleasant walking environments that include trees, landscaping, displays of public art, etc.) and destinations within walking distances also play important roles in determining levels of walking.

Safety concerns can significantly influence a person's decision to walk or use other modes of transportation. However, understanding pedestrian safety issues has proven difficult for engineers and planners. Traditionally, safety problems have been identified by analyzing police crash reports, and improvements have been made only after crashes have occurred. Such methods are not sufficient to fully understand and effectively address pedestrian safety concerns. Waiting for crashes to warrant actions carries a high price, as pedestrian crashes tend to be severe. Crash reports do not provide a complete picture of perceived safe or unsafe pedestrian environments and hence do not offer guidance on effective, proactive measures to promote a safe pedestrian environment.

Recent experience and research has shown that a comprehensive approach is most effective in creating safer walking environments. Many pedestrian safety problems cannot be solved simply by addressing one of the "three Es" (engineering, education, enforcement) in isolation. Engineers, law enforcement, designers, planners, educators, and citizens should all play a role in identifying and implementing effective countermeasures for improving pedestrian safety.

There is also a need to take proactive measures to address pedestrian safety issues. For example, planners can host interactive public workshops, surveying pedestrians and drivers, and talking with police and traffic engineers to identify safety problems in an area *before* crashes occur. Pedestrian safety, both actual and perceived, and the provision of appropriate pedestrian infrastructure will influence how many people will walk and the number and type of pedestrian crashes that will occur.

Finally, in making any decisions about program or countermeasure implementation, consideration should be given to the special characteristics and needs of the population being targeted. This is especially true with respect to education or enforcement interventions, but even road signs and pavement markings can be affected. People of

different cultures and ethnic backgrounds, non-English speaking populations, those with physical impairments, and even children and the elderly may necessitate modifications to the countermeasure to ensure that it reaches its intended target audience and has the desired safety benefits.

In recent years, walking has received increased attention as a mode of transportation that should be encouraged for a variety of reasons. On April 22, 1994, the U.S. Department of Transportation presented its National Bicycling and Walking Study (NBWS) to the U.S. Congress, which, in addition to documenting the state of bicycling and walking in the United States, contained two overall goals:

> Double the percentage of total trips made by bicycling and walking in the United States from 7.9 percent to 15.8 percent of all travel trips[1] and simultaneously reduce by 10 percent the number of bicyclists and pedestrians killed or injured in traffic crashes. (Zegeer, 1994)

Congress adopted the Study's goals, effectively creating a directive to Federal transportation agencies to implement the Study's nine-point Federal Action Plan with 60 specific action items for the Office of the Secretary, Federal Highway Administration, National Highway Traffic Safety Administration, and Federal Transit Administration; and a five-point State and Local Action Plan with a range of suggested activities for state and local agencies. In addition, Congress, prior to adoption of the NBWS, had vastly increased the amount of Federal funding available for pedestrian projects with the adoption of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, and, later, the Transportation Equity Act for the 21st Century (TEA-21) (1998). Spending of federal transportation funds on these two modes rose from $6 million in 1990 to more than $238 million in 1997.

While the number of annual pedestrian fatalities due to traffic accidents had generally decreased across the United States over the latter part of the 1990s (about 13 percent overall from 1992 to 2002, per NHTSA Web site), that trend seems to have changed somewhat over the early years of the new millennium (see Exhibit I-1). There were 71,000 pedestrians injured in traffic crashes in 2002 (per NHTSA Web site).

The number of conflicts and fatalities remains high in many urban areas and for specific segments of the population. In addition, results of travel surveys suggest that the observed drop in pedestrian fatalities in recent years may simply reflect reduced exposure rather than any gains in pedestrian safety.

The need to reduce pedestrian deaths and injuries (see Exhibit I-2), even in the face of ongoing efforts to increase levels of walking, continues to be an important goal for the engineering profession. Specific groups that do not or cannot drive primarily depend on walking for transportation, including children, the elderly, and low-income populations. These groups are particularly in need of a safe walking environment to help lower their risk of injury and death.

---

[1] The National Bicycling and Walking Study (NBWS) target of doubling the percentage of trips made by bicycling and walking from 7.9 percent to 15.8 percent was based on numbers collected in the 1990 Nationwide Personal Transportation Survey (NPTS). In 1990, a total of 18 billion walking trips and 1.7 billion bicycling trips were made representing 7.2 percent and 0.7 percent respectively of all trips counted by the study.

EXHIBIT I-1
Pedestrians Killed in Crashes with Vehicles, 1994–2002 (Source: NHTSA Web site)

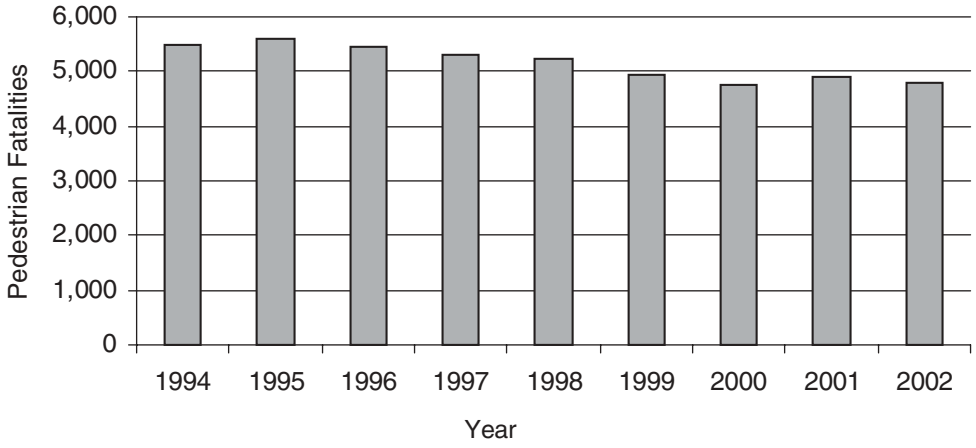
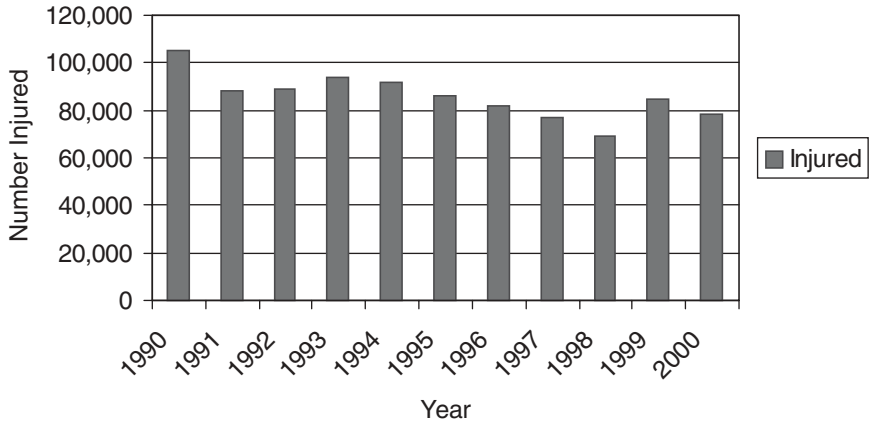


EXHIBIT I-2
Pedestrians Injured or Killed in Crashes with Vehicles, 1990–2000 (Source: NHTSA Web site)
Note: A significant number of pedestrian injury crashes requiring emergency room treatment but not reported to police agencies are not included in these reported fatalities and injuries.



The U.S. Census is the most complete information on the percent of journey-to-work trips made by walking. For the 2000 U.S. Census, the percentage of journeys to work by foot was 2.9 percent, or 3.8 million workers 16 years and over (Reschovsky, 2004). This is lower than the 1990 Census data, which showed 3.9 percent of workers 16 years and over, or 4.5 million people, walking to work.

The Nationwide Personal Transportation Survey (NPTS), which measures travel of all kinds at the national level, also indicates there has been a decrease in the percent of trips made by walking. In 1995, approximately 20 billion trips, or 5.4 percent of all trips, were made by

walking (U.S. Department of Transportation, 1995). These numbers compare to 18 billion walking trips, or 7.2 percent of all trips, in 1990 (Hu and Young, 1992, 1993).[2] While the absolute number of walking trips increased by about 11 percent between the 1990 and 1995 NPTS surveys, it was far less than the increase in trips by private auto, creating a reduction in the percentage of total trips by walking. If walking trips had increased at the same rate as private auto trips, the observed reduction in pedestrian fatalities would likely have been much smaller. During the 5-year time period covered by the two NPTS surveys, pedestrian fatalities decreased by 13.9 percent (from 6,482 to 5,584). Engineering improvements coupled with enhanced safe behavior by pedestrians and motorists are needed to further reduce pedestrian fatalities.

The following is a list of requests (objectives) that transportation professionals are likely to face when working to provide pedestrian safety and mobility:

- Reduce the speed of motor vehicles
- Improve sight distance and visibility for motor vehicles and pedestrians
- Reduce pedestrian exposure to vehicular traffic
- Improve pedestrian access and mobility
- Improve pedestrian and motorist safety awareness and behavior

Each of these objectives can be accomplished through a variety of the 16 individual strategies (treatments) presented in Exhibit I-3. Most strategies will work best when used at multiple locations and in combination with other treatments.

In addition, many of the strategies (treatments) will accomplish two or more objectives. The key is to make sure that the right treatments are chosen to accomplish the desired effect.

EXHIBIT I-3
Emphasis Area Objectives and Strategies

Objectives	Strategies
9.1 A Reduce Pedestrian Exposure to Vehicular Traffic	9.1 A1 Provide Sidewalks/Walkways and Curb Ramps
	9.1 A2 Install or Upgrade Traffic and Pedestrian Signals
	9.1 A3 Construct Pedestrian Refuge Islands and Raised Medians
	9.1 A4 Provide Vehicle Restriction/Diversion Measures
	9.1 A5 Install Overpasses/Underpasses
9.1 B Improve Sight Distance and/or Visibility Between Motor Vehicles and Pedestrians	9.1 B1 Provide Crosswalk Enhancements
	9.1 B2 Implement Lighting/Crosswalk Illumination Measures
	9.1 B3 Eliminate Screening by Physical Objects
	9.1 B4 Signals to Alert Motorists That Pedestrians Are Crossing
	9.1 B5 Improve Reflectorization/Conspicuity of Pedestrians

[2] The NPTS survey methodology changed between 1990 and 1995 from a telephone survey to a travel-diary survey. This resulted in an increase in the reported number of trips overall in 1995, a change which does affect the accuracy of comparisons between different year NPTSs.

EXHIBIT I-3 (Continued)
Emphasis Area Objectives and Strategies

Objectives	Strategies
9.1 C Reduce Vehicle Speed	9.1 C1 Implement Road Narrowing Measures
	9.1 C2 Install Traffic Calming—Road Sections
	9.1 C3 Install Traffic Calming—Intersections
	9.1 C4 Provide School Route Improvements
9.1 D Improve Pedestrian and Motorist Safety Awareness and Behavior	9.1 D1 Provide Education, Outreach, and Training
	9.1 D2 Implement Enforcement Campaigns

SECTION II

Introduction

Walking is a basic human activity, and almost everyone is a pedestrian at one time or another. The 2001 edition of the AASHTO Green Book states that "pedestrians are a part of every roadway environment, and attention should be paid to their presence in rural as well as urban areas" (American Association of State Highway and Transportation Officials, 2001). It goes on to state, ". . . pedestrians are the lifeblood of our urban areas, especially in the downtown and other retail areas" (p. 96).

Even though pedestrians are legitimate roadway users, they are frequently overlooked in the quest to build more-sophisticated transportation systems. Whether building new infrastructure or renovating existing facilities, it should be assumed that people will walk, and plans should be made to accommodate pedestrians (Exhibit II-1). Where people aren't walking, it is often because they are prevented or discouraged from doing so. Either the infrastructure is insufficient, has serious gaps, or there are safety hazards. Aesthetics (e.g., pleasant walking environments that include trees, landscaping, displays of public art, etc.) and destinations within walking distances also play important roles in determining levels of walking.

Safety concerns can significantly influence a person's decision to walk or use other modes of transportation. However, understanding pedestrian safety issues has proven difficult for engineers and planners. Traditionally, safety problems have been identified by analyzing police crash reports, and improvements have been made only after crashes have occurred. Such methods are not sufficient to fully understand and effectively address pedestrian safety concerns. Waiting for crashes to warrant actions carries a high price, as pedestrian crashes tend to be severe. While analysis of crash reports is an important and valuable activity, it does not provide a complete picture of perceived safe or unsafe pedestrian environments and may not offer the best guidance on effective, proactive, measures to promote a safe pedestrian environment.

EXHIBIT II-1
Whether building new infrastructure or renovating existing facilities, it should be assumed that people will walk, and plans should be made to accommodate pedestrians. (Photo by Dan Burden)

Recent experience and research has shown that a comprehensive approach is most effective in creating safer walking environments. Many pedestrian safety problems cannot be solved simply by addressing one of the "three Es" (engineering,

education, enforcement) in isolation. Engineers, law enforcement, designers, planners, educators, and citizens should all play a role in identifying and implementing effective countermeasures for improving pedestrian safety.

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Finally, in making any decisions about program or countermeasure implementation, consideration should be given to the special characteristics and needs of the population being targeted. This is especially true with respect to education or enforcement interventions, but even road signs and pavement markings can be affected. People of different cultures and ethnic backgrounds, non-English speaking populations, those with physical impairments, and even children and the elderly may necessitate modifications to the countermeasure to ensure that it reaches its intended target audience and has the desired safety benefits.

In recent years, walking has received increased attention as a mode of transportation that should be encouraged for a variety of reasons. On April 22, 1994, the U.S. Department of Transportation presented its National Bicycling and Walking Study to the U.S. Congress, which, in addition to documenting the state of bicycling and walking in the United States, contained two overall goals:

- Double the percentage of total trips made by bicycling and walking in the United States from 7.9 percent to 15.8 percent of all travel trips[1]
- Simultaneously reduce by 10 percent the number of bicyclists and pedestrians killed or injured in traffic crashes

Congress adopted the Study's goals, effectively creating a directive to Federal transportation agencies to implement the Study's Nine-Point Federal Action Plan with 60 specific action items for the Office of the Secretary, Federal Highway Administration, National Highway Traffic Safety Administration, and Federal Transit Administration; and a Five-Point State and Local Action Plan with a range of suggested activities for state and local agencies. In addition, Congress, prior to adoption of NBWS, had vastly increased the amount of Federal funding available for pedestrian projects with the adoption of the ISTEA of 1991, and, in 1998, the TEA-21. Spending of federal transportation funds on these two modes rose from $6 million in 1990 to more than $238 million in 1997. Clearly, any agency charged with construction, operation, and maintenance of highway infrastructure must devote attention to accommodating safe pedestrian activity.

What progress has been made towards achieving NBWS's goal of reducing injuries to pedestrians and bicyclists by 10 percent? In 1993, the last year prior to the release of the

[1] The NBWS target of doubling the percentage of trips made by bicycling and walking from 7.9 percent to 15.8 percent was based on numbers collected in the 1990 NPTS. In 1990, a total of 18 billion walking trips and 1.7 billion bicycling trips were made representing 7.2 percent and 0.7 percent respectively of all trips counted by the study.

study, 5,649 pedestrians were killed in collisions with motor vehicles. In 2000, the last year for which data are available, the number of pedestrian fatalities had fallen to 4,739. These numbers reflect a 16.6 percent decline in fatalities, which far exceeds the safety goals set by NBWS.

Unfortunately, this drop in pedestrian fatalities may reflect decreased walking activity as much as it does improved safety. According to both the U.S. Census and the Nationwide Personal Transportation Survey, the percentage of trips made by walking has declined over the past decade. The U.S. Census indicates a decrease in the percent of walk-to-work trips from 3.9 to 2.7 (1980 and 1990 U.S. Census), while NPTS indicates a decrease in percent of all trips by walking from 7.2 to 5.4 (Hu and Young, 1992, 1993; U.S. Department of Transportation, 1995). Clearly NBWS's goal of increasing the percentage of trips made by walking has not been achieved. When available, data from the 2000 Census and NPTS surveys will help clarify any downward trends in walking activity. In the meantime, it is important to recognize that increased emphasis, as well as increased funding, is being devoted to promoting walking, making it especially critical that pedestrian safety issues remain a high priority for State and local transportation officials.

ADA Design Guidelines

One of the goals of the Americans with Disabilities Act (ADA) is to ensure that all people, including those with disabilities, have equal access to transportation. People with disabilities may have physical limitations, impaired vision, impaired cognitive ability, or a combination of disabilities, which is more common as a person grows older. Over 90 percent of the population will experience a disability on a permanent or temporary basis at some point in their lives.

This document is intended to be a guide for addressing traffic safety issues associated with pedestrians. It is not intended to be a design guide or to deal with accessibility. However, as those who are doing design and working to create access for pedestrians of all types perform their tasks, they should understand potential highway-safety issues involved.

Further details are contained within this guide relative to providing facilities for people with disabilities. Specifically, such discussion is provided within the strategy of sidewalks and walkways. Details on accessible pedestrian signals are given within the discussion of traffic and pedestrian signals.

More information can be found on ADA regulations from the following web sites:
www.access-board.gov
www.walkinginfo.org/de/index.htm fhwa.dot.gov/environment/bikeped/publications.htm

Other Guidelines

In addition to this pedestrian guide, many state and local agencies develop their own design or planning guidelines that address pedestrian safety. Some of these exemplary guides can be found at http://www.walkinginfo.org/rd/for_ped.htm#guide.

SECTION III

Type of Problem Being Addressed

General Description of the Problem

While the number of annual pedestrian fatalities due to traffic accidents had generally decreased across the United States over the latter part of the 1990s (about 13 percent overall from 1992 to 2002, per NHTSA Web site), that trend seems to have changed somewhat over the early years of the new millennium (see Exhibit III-1). There were 71,000 pedestrians injured in traffic crashes in 2002 (per NHTSA Web site).

The number of conflicts and fatalities remains high in many urban areas and for specific segments of the population. In addition, results of travel surveys suggest that the observed drop in pedestrian fatalities in recent years may simply reflect reduced exposure rather than any gains in pedestrian safety.

The need to reduce pedestrian deaths and injuries (see Exhibit III-2), even in the face of ongoing efforts to increase levels of walking, continues to be an important goal for the engineering profession. Specific groups that do not or cannot drive primarily depend on walking for transportation, including children, the elderly, and low-income populations. These individuals comprise up to 30 percent of the population in many communities and are particularly in need of a safe walking environment to help lower their risk of injury and death.

The U.S. Census is the most complete information on the percent of journey-to-work trips made by walking. For the 2000 U.S. Census, the percentage of journeys to work by foot was 2.9 percent, or 3.8 million workers 16 years and over (Reschovsky, 2004). This estimate is

EXHIBIT III-1
Pedestrians Killed in Crashes with Vehicles, 1994–2002 (Source: NHTSA Web site)

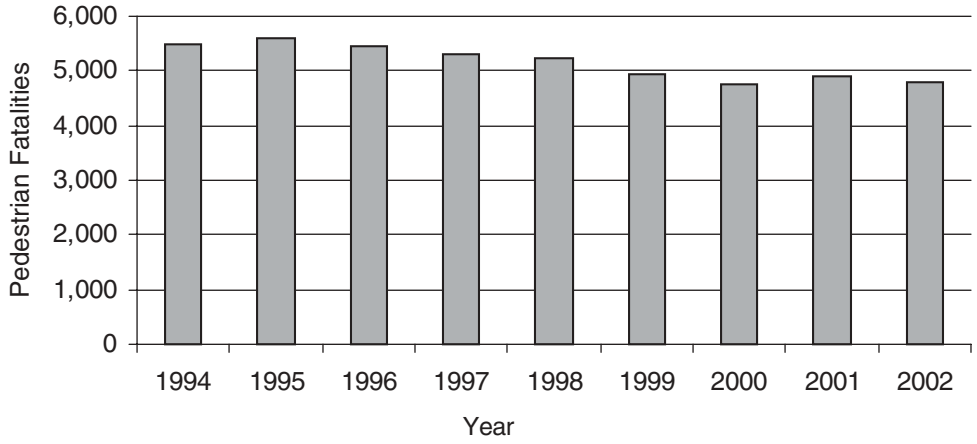
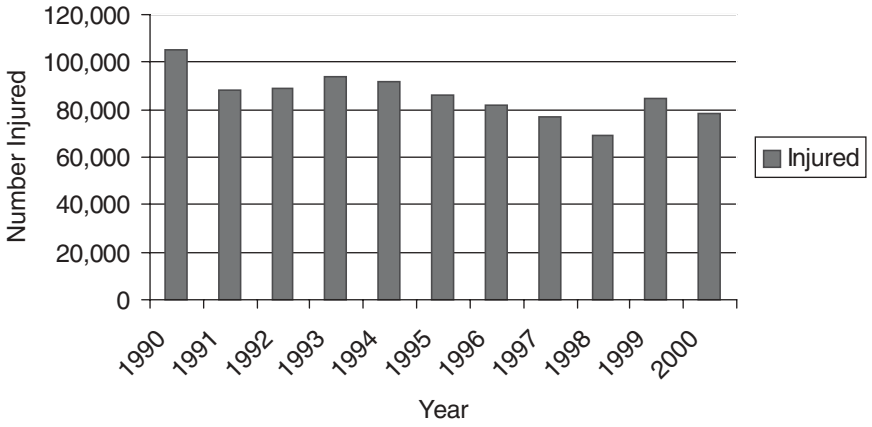


EXHIBIT III-2
Pedestrians Injured or Killed in Crashes with Vehicles, 1990–2000 (Source: NHTSA Web site)
Note: A significant number of pedestrian injury crashes requiring emergency room treatment but not reported to police agencies are not included in these reported fatalities and injuries.



lower than the 1990 Census data, which showed 3.90 percent of workers 16 years and over, or 4.5 million people, walking to work. About 1 in 5 trips involve travel to or from work.

The Nationwide Personal Transportation Survey, which measures travel of all kinds at the national level, also indicates there has been a decrease in the percent of trips made by walking. In 1995, approximately 20 billion trips, or 5.4 percent of all trips, were made by walking. These numbers compare to 18 billion walking trips, or 7.2 percent of all trips, in 1990.[1] While the absolute number of walking trips increased by about 11 percent between the 1990 and 1995 NPTS surveys (Hu and Young, 1992,1993; U.S. Department of Transportation, 1995), it was far less than the increase in trips by private auto, creating a reduction in the percentage of total trips by walking. If walking trips had increased at the same rate as private auto trips, the observed reduction in pedestrian fatalities would likely have been much smaller. During the 5-year time period covered by the two NPTS surveys, pedestrian fatalities decreased by 13.9 percent (from 6,482 to 5,584). Engineering improvements coupled with enhanced safe behavior by pedestrians and motorists are needed to further reduce pedestrian fatalities.

States and Local Areas with the Highest Numbers of Crashes

Crash statistics differ significantly by State and local jurisdictions. States with the highest number of pedestrian crashes per 100,000 population in 2000 included Florida, Arizona, Delaware, and New Mexico; the District of Columbia also has a high rate. State pedestrian traffic fatality counts and fatality rates are presented in Exhibit III-3.

[1] The NPTS survey methodology changed between 1990 and 1995 from a telephone survey to a travel-diary survey. This resulted in an increase in the reported number of trips overall in 1995, a change which does affect the accuracy of comparisons between different year NPTSs.

EXHIBIT III-3
Pedestrian Traffic Fatalities and Fatality Rates by State, 2000

State	Total Traffic Fatalities	Resident Population (thousands)	Pedestrian Fatalities	Percent of Total	Pedestrian Fatalities per 100,000 Population
Alabama	995	4,451	61	6.1	1.4
Alaska	103	653	8	7.8	1.2
Arizona	1,036	4,798	130	12.5	2.7
Arkansas	652	2,631	38	5.8	1.4
California	3,753	32,521	670	17.9	2.1
Colorado	681	4,168	80	11.7	1.9
Connecticut	342	3,284	49	14.3	1.5
Delaware	123	768	22	17.9	2.9
District of Columbia	49	523	18	36.7	3.4
Florida	2,999	15,233	492	16.4	3.2
Georgia	1,541	7,875	137	8.9	1.7
Hawaii	131	1,257	29	22.1	2.3
Idaho	276	1,347	6	2.2	0.4
Illinois	1,418	12,051	187	13.2	1.6
Indiana	875	6,045	51	5.8	0.8
Iowa	445	2,900	25	5.6	0.9
Kansas	461	2,668	19	4.1	0.7
Kentucky	820	3,995	53	6.5	1.3
Louisiana	937	4,425	100	10.7	2.3
Maine	169	1,259	15	8.9	1.2
Maryland	588	5,275	91	15.5	1.7
Massachusetts	433	6,199	82	18.9	1.3
Michigan	1,382	9,679	170	12.3	1.8
Minnesota	625	4,830	38	6.1	0.8
Mississippi	949	2,816	64	6.7	2.3
Missouri	1,157	5,540	88	7.6	1.6
Montana	237	950	11	4.6	1.2
Nebraska	276	1,705	20	7.2	1.2
Nevada	323	1,871	43	13.3	2.3
New Hampshire	126	1,224	7	5.6	0.6
New Jersey	731	8,178	145	19.8	1.8
New Mexico	430	1,860	47	10.9	2.5
New York	1,458	18,146	335	23.0	1.8
North Carolina	1,472	7,777	144	9.8	1.9
North Dakota	86	662	5	5.8	0.8
Ohio	1,351	11,319	96	7.1	0.8
Oklahoma	652	3,373	43	6.6	1.3
Oregon	451	3,397	50	11.1	1.5
Pennsylvania	1,520	12,202	170	11.2	1.4
Rhode Island	80	998	6	7.5	0.6
South Carolina	1,065	3,858	84	7.9	2.2
South Dakota	173	777	13	7.5	1.7
Tennessee	1,306	5,657	99	7.6	1.7
Texas	3,769	20,119	412	10.9	2.0
Utah	373	2,207	33	8.8	1.5
Vermont	79	617	7	8.9	1.1
Virginia	930	6,997	92	9.9	1.3
Washington	632	5,858	66	10.4	1.1
West Virginia	410	1,841	25	6.1	1.4
Wisconsin	799	5,326	51	6.4	1.0
Wyoming	152	525	12	7.9	2.3
U.S. Total	**41,821**	**274,634**	**4,739**	**11.3**	**1.7**
Puerto Rico	566	3,809	181	32.0	4.8

Note: Totals may not equal sum of components due to independent rounding.
Sources: Fatalities — Fatality Analysis Reporting System, NHTSA. Population — Bureau of the Census.

Factors Affecting the Number and Severity of Crashes

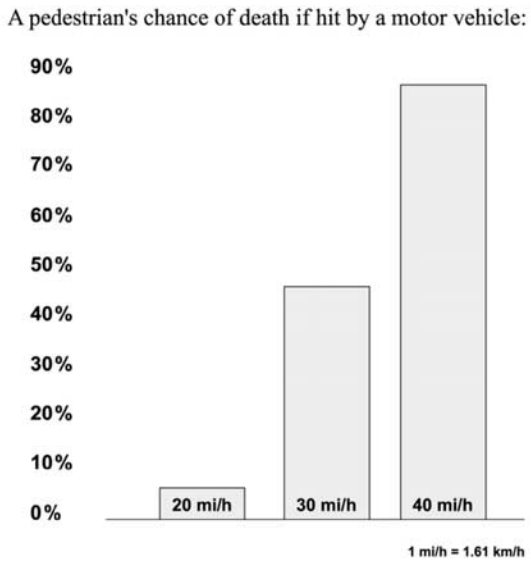
Alcohol Impairment

Alcohol impairment may be as serious a problem for pedestrians as it is for motor-vehicle drivers, although there is evidence the problem may be lessening, based upon fatal crash data for the year 2000. From 1980 through 1987, 37 percent to 44 percent of fatally injured pedestrians had a reported blood-alcohol concentration (BAC) of 0.10 or greater (Federal Highway Administration, 2002). In 1997, that figure was 29.5 percent, and in 2002 it decreased to 21 percent (NHTSA Web site). Alcohol involvement in pedestrian crashes continues to be a concern, however, due to the continued high percentage of either drivers or pedestrians who have some level of BAC. Alcohol involvement—either for the driver or the pedestrian or both—was reported in nearly one-half of all pedestrian fatalities (NHTSA Web site). However, care should be taken in using these results, as NHTSA cautions that BAC results reported to the Fatality Analysis Reporting System (FARS) are from state measurements and many are untested. Also, it is not clear whether the drop in pedestrian fatalities involving alcohol-impaired pedestrians may be partly the result of less reporting of alcohol involvement due to changes in police practices in 2000.

Speed

Speed is a major contributing factor in crashes of all types (see Exhibit III-4). In 2000, high vehicle speed was a contributing factor in 29 percent of all fatal crashes, a number slightly lower than in previous years—30 percent in 1994, 1996, 1997, 1998, and 1999 and 31 percent in 1995 (NHTSA Web site). Speed has serious consequences when a pedestrian is involved (see Exhibit III-4). A pedestrian hit at 64.4 km/h (40 mph) has an 85-percent chance of being killed; at 48.3 km/h (30 mph), the likelihood goes down to 45 percent, while at 32.2 km/h (20 mph), the fatality rate is only 5 percent (U.K. Department of Transport). Faster speeds

EXHIBIT III-4
Fatalities Based on Speed of Vehicle (Source: U.K. Department of Transport)



also increase the likelihood of a pedestrian being hit. At higher speeds, motorists are less likely to see and react to a pedestrian, and are even less likely to be able to stop in time to avoid hitting one (Federal Highway Administration, 2000). Speed, however, is always a factor in crashes, regardless of whether it is illegal (i.e., above the posted speed limit) or not. S*peed limits that are set inappropriately high* can also contribute to pedestrian crashes and injuries.

Types of Pedestrian Crashes

In order for engineers and planners to address specific pedestrian hazards and high-crash locations, information is needed on *where* the pedestrian crashes occur (city, street, intersection, two-lane road, etc.), *when* they occur (time of day, day of week, etc.), *characteristics* of the victims involved (age, gender, injury severity, etc.), and the *events* that precipitated the crash (child chasing ball onto road, motorist swerving around a parked car, etc.).

Where Crashes Occur

Area Type

Pedestrian crashes occur most frequently in urban areas where both pedestrian activity and traffic volumes are greater than in rural areas. The National Safety Council estimates that 85.7 percent of all nonfatal pedestrian crashes in the United States occur in urban areas and 14.3 percent occur in rural areas. However, 25 percent of pedestrian fatalities occur in rural areas, where vehicle speeds are higher than on city streets (Zegeer et al., 1992, 1993). In addition, many rural areas have no sidewalks, paths, or shoulders to serve as separated pedestrian facilities, and no lighting to increase the visibility of pedestrians at nighttime.

Location Type

According to the NHTSA, "most pedestrian fatalities in 2000 occurred in urban areas (71 percent), at nonintersection locations (78 percent), in good weather conditions (91 percent), and at night (64 percent)." Additionally, "more than two-thirds (68 percent) of the 2000 pedestrian fatalities were males." While all age groups are more likely to be killed at nonintersection locations, the numbers are higher for children primarily because of dart-outs into the street. Likewise, the oldest age groups are more likely to be struck at intersections since older pedestrians tend to cross at intersections more often than younger ones. Moreover, some older pedestrians have physical, visual, and/or hearing impairments that place greater demand on intersection design (Zegeer et al., 1992). Studies have shown that older pedestrians are particularly over-represented in crashes at intersections involving vehicles turning left and right (National Highway Traffic Safety Administration, 1990b) (see Exhibit III-5 and Exhibit III-6).

When Crashes Occur

Exhibit III-7 and Exhibit III-8 show the time of day for when crashes occur.

- Pedestrian crashes are most prevalent during morning and afternoon peak periods, when traffic as well as pedestrian volumes are highest (National Highway Traffic Safety Administration, 1990).

- Fatal pedestrian crashes occur most often late in the day, between 5 and 11 p.m., when peak periods, darkness, and alcohol use are factors (National Highway Traffic Safety Administration, 1990a).
- Child pedestrian fatalities are greatest in May, June, and July, perhaps due to an increase in outside activity (Zegeer et al., 1992).
- Older pedestrians are more likely to be struck during daylight hours, when they are also most likely to be exposed to traffic (Zegeer et al., 1993).

EXHIBIT III-5
Percent of Pedestrian Crash Fatalities at Intersections (Approximately 22 Percent of All Fatalities) by Age, 2000 (Source: Zegeer *et al*., 1993)

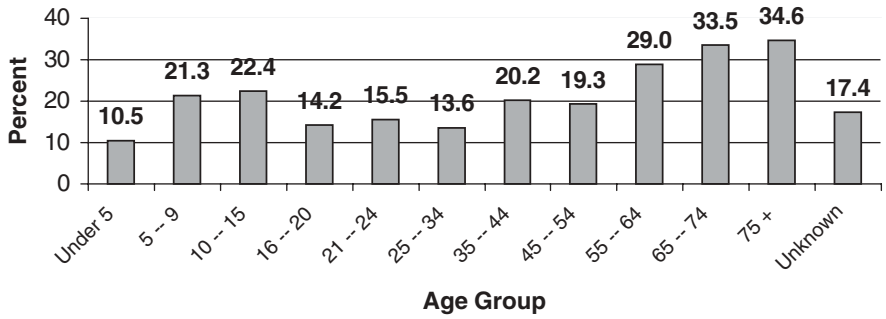
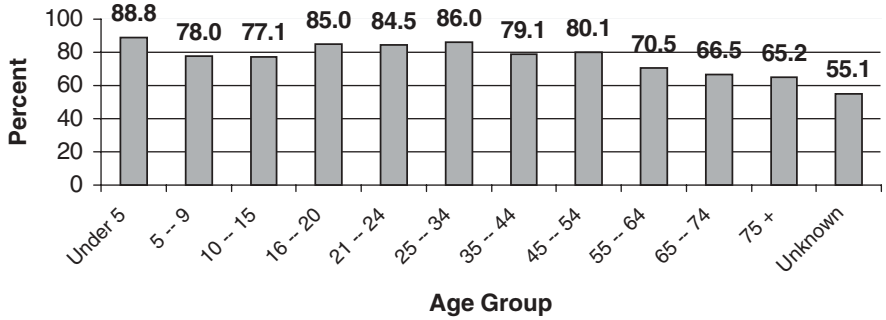


EXHIBIT III-6
Percent of Pedestrian Crash Fatalities at Nonintersection Locations (Approximately 77 Percent of All Fatalities) by Age, 2000 (Source: Zegeer *et al*., 1993)



Characteristics of the Victims

Specific populations that are heavily represented in crash injury and fatality statistics are children under the age of 16 and older pedestrians. Both of these groups deserve special attention because for many of them driving is not an option and, in the case of older pedestrians that no longer drive, their numbers will increase dramatically as a result of the "graying of the population." "Older pedestrians (ages 70+) accounted for 17 percent of all pedestrian fatalities and 6 percent of all pedestrians injured. The death rate for this group, both males and females, was 3.18 per 100,000 population—higher than any other age group" (NHTSA Web site). The pedestrian age group that is most likely to be involved in a

EXHIBIT III-7
Percent of Fatal Pedestrian Crashes by Time of Day, Weekday (Source: National Highway Traffic Safety Administration, 1990)

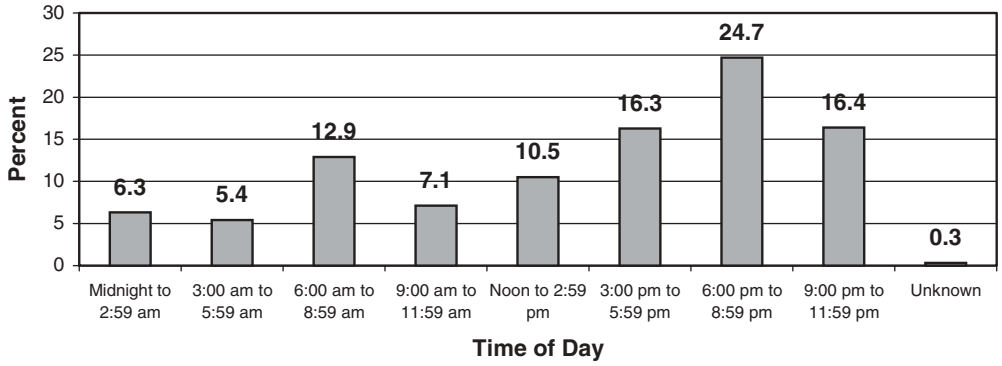
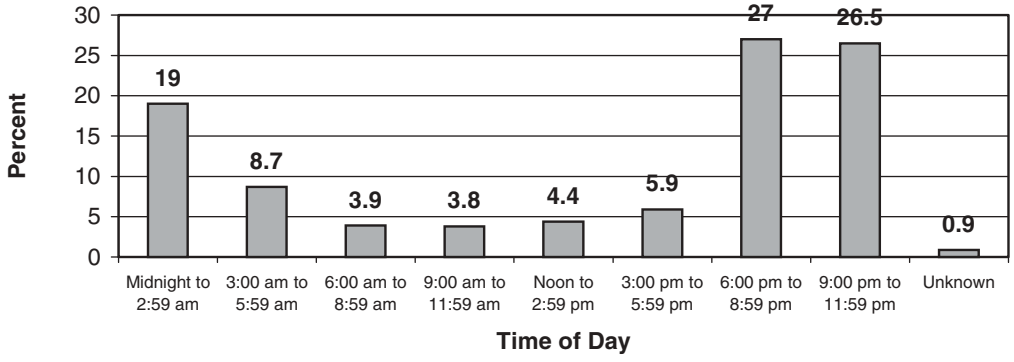


EXHIBIT III-8
Percent of Fatal Pedestrian Crashes by Time of Day, Weekend (Source: National Highway Traffic Safety Administration, 1990)



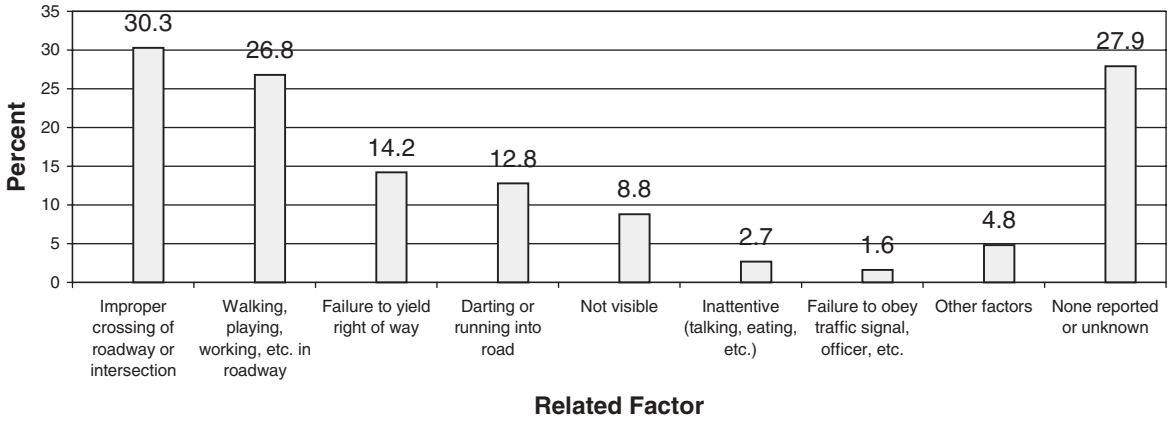
crash is 5- to 9-year-old males, who tend to dart out into the street, a problem that can be aggravated by higher vehicle speeds in areas where children are walking and playing (U.S. Department of Transportation, 2001).

Precipitating Events

To address pedestrian motor-vehicle safety problems, agencies must have information on factors precipitating a crash. Exhibit III-9 below contains information on factors related to fatal collisions involving a pedestrian and a single motor vehicle. The percentages in the graph total more than 100 percent because in some instances more than one related factor was identified. Most frequently cited were improper crossing of a roadway or intersection and walking, playing, or working in the roadway.

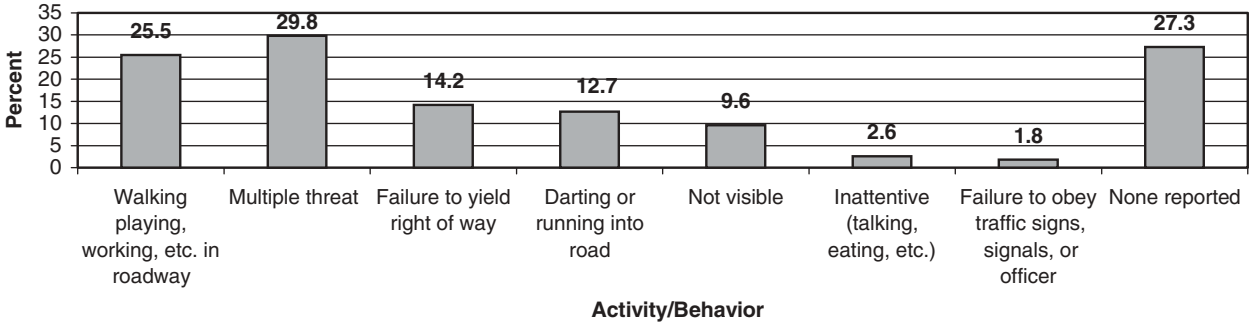
The National Highway Traffic Safety Administration developed a methodology for typing pedestrian crashes in the 1970s (National Highway Traffic Safety Administration, 1971). The

EXHIBIT III-9
Related Factors in Single Vehicle Fatal Pedestrian Crashes, 1998–2000 (Shankar, 2003)



method was refined in the early 1990s and used to determine the crash types for more than 5,000 pedestrian crashes in the States of California, Florida, Maryland, Minnesota, North Carolina, and Utah (Hunter et al., 1995; National Highway Traffic Safety Administration, 1971) (see Exhibit III-10).

EXHIBIT III-10
Pedestrian Activity/Behavior That Preceded Fatal Crashes, 2000



Key findings of this study, which pertained to both fatal and nonfatal crashes, included the following:

- 41 percent of pedestrian crashes occurred at roadway intersections and an additional 8 percent at driveway or alley intersections
- Most frequent intersection crash types included vehicle turning at intersection (10 percent), intersection dash (7 percent), and driver violation at intersection (5 percent)

- Half of all midblock crashes involved a pedestrian either darting into the intersection with the motorist view blocked or running into the intersection when the motorist's view was not blocked
- 8 percent involved a pedestrian walking along the roadway, and in two-thirds of these crashes the pedestrian was walking with traffic when struck from behind
- Two-thirds (66 percent) of pedestrians were coded for at least one contributing factor to their crash. Most frequently noted were running into the roadway (15 percent), failure to yield (12 percent), alcohol impairment (10 percent), stepping from between parked vehicles (7 percent), and walking or running in the wrong direction, with traffic (5 percent)
- 55 percent of motorists were coded for at least one contributing factor to the crash; most frequently cited were hit-and-run (16 percent), failure to yield to pedestrian (15 percent), and improper backing (6 percent)

Crash types that were the most severe as measured by the percentage of pedestrians seriously injured or killed were

- Midblock, other (46.8 percent serious and fatal injury)
- Disabled vehicle related (41.7 percent serious and fatal injury)
- Walking along roadway (40.4 percent serious and fatal injury)
- Driverless vehicle (37.8 percent serious and fatal injury)

Least severe crashes included

- Vehicle turning at intersection (18.4 percent serious and fatal injury)
- Backing vehicle (22.5 percent serious and fatal injury)
- Bus-related (22.7 percent serious and fatal injury)
- Driver violation at intersection (27.8 percent serious and fatal injury)

Based upon these findings and additional research, 13 crash type groupings (12 specific types and 1 miscellaneous type) have been identified for use with crash data to identify safety problems and corresponding countermeasures (see Exhibit III-11 for the 12 specific types). They can also be used to help educate safety professionals, as well as the general public, about the types of situations that pose dangers to pedestrians. These crash types form the basis for the Pedestrian and Bicycle Crash Analysis Tool software known as PBCAT (Harkey et al., 2000).

Appendix 1 presents a matrix of these 12 major crash types showing which strategies might be considered to help mitigate each crash type.

EXHIBIT III-11
Twelve Crash-Type Groupings

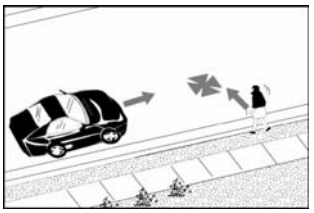
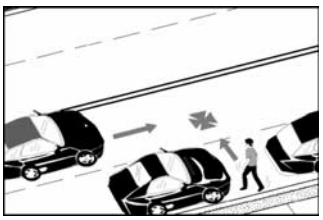
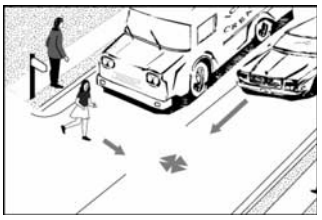
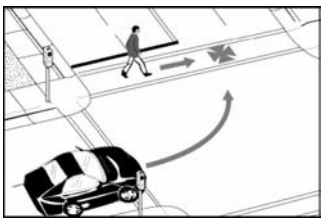
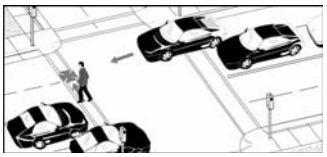
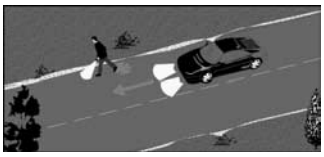
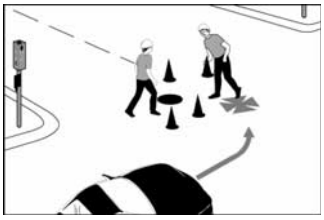
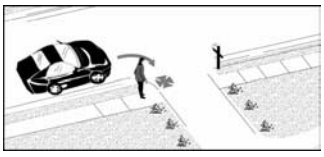
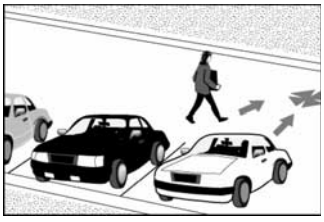
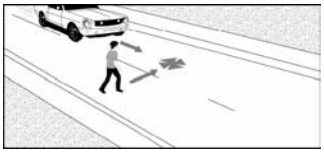
Definitions of Pedestrian Crash Types	Example
1. Midblock: Dart/Dash Definition: The pedestrian walked or ran into the roadway and was struck by a vehicle. The motorist's view of the pedestrian may have been blocked until an instant before the impact, and/or the motorist may have been speeding.	
2. Multiple Threat Definition: The pedestrian entered the traffic lane in front of stopped traffic and was struck by a vehicle traveling in the same direction as the stopped vehicle. The stopped vehicle may have blocked the sight distance between the pedestrian and the striking vehicle, and/or the motorist may have been speeding.	
3. Mailbox or Other Midblock Definition: The pedestrian was struck while getting into or out of a stopped vehicle or while crossing the road to/from a mailbox, newspaper box, ice-cream truck, etc.	
4. Failure to Yield at Unsignalized Location Definition: At an unsignalized intersection or midblock location, a pedestrian stepped into the roadway and was struck by a vehicle. The motorist failed to yield to the pedestrian and/or the pedestrian stepped directly into the path of the oncoming vehicle.	
5. Bus-Related Definition: The pedestrian was struck by a vehicle either (1) by crossing in front of a commercial bus stopped at a bus stop, (2) going to or from a school bus stop, or (3) going to or from or waiting near a commercial bus stop.	
6. Turning Vehicle at Intersection Definition: The pedestrian was attempting to cross at an intersection and was struck by a vehicle that was turning right or left.	

EXHIBIT III-11 (Continued)
Twelve Crash-Type Groupings

Definitions of Pedestrian Crash Types	Example
7. Through Vehicle at Intersection Definition: The pedestrian was struck at a signalized or unsignalized intersection by a vehicle that was traveling straight ahead.	
8. Walking Along Roadway Definition: The pedestrian was walking or running along the roadway and was struck from the front or from behind by a vehicle.	
9. Working/Playing in Road Definition: A vehicle struck a pedestrian who was (1) standing or walking near a disabled vehicle, (2) riding a play vehicle that was not a bicycle (e.g. wagon, sled, tricycle, skates), (3) playing in the road, or (4) working in the road.	
10. Not in Road (Driveway, Parking Lot, Sidewalk or Other) Definition: The pedestrian was standing or walking near the roadway edge, on the sidewalk, in a driveway or alley, or in a parking lot, when struck by a vehicle.	
11. Backing Vehicle Definition: The pedestrian was struck by a backing vehicle on a street, in a driveway, on a sidewalk, in a parking lot, or at another location.	
12. Crossing an Expressway Definition: The pedestrian was struck while crossing a limited-access expressway or expressway ramp.	

SECTION IV

Index of Strategies by Implementation Timeframe and Relative Cost

Exhibit IV-1 classifies strategies according to the expected timeframe and relative cost for this emphasis area. The implementation time will be dependent upon such factors as the agency's procedures, the extent of the educational or enforcement program, roadway-section length, street width, and other factors. The range of costs may also vary for some of these strategies, due to many of these same factors. Cost ranges are given in the detailed description of each strategy. The table is meant to reflect the most common application of each strategy. A strategy may include several treatments, with different costs and timeframes.

EXHIBIT IV-1
Classification of Strategies

Timeframe for Implementation	Relative Cost to Implement and Operate			
	Low	**Moderate**	**Moderate to High**	**High**
Short (less than a year)	9.1 B1 Provide crosswalk enhancements 9.1 B5 Improve reflectorization/ conspicuity of pedestrians 9.1 C4 Provide school route improvements	9.1 D2 Implement Enforcement Campaigns	—	—
Medium (1–2 years)	—	9.1 C1 Implement road narrowing measures 9.1 C2 Install traffic-calming measures—road sections 9.1 C3 Install traffic-calming measures—intersections 9.1 D1 Provide education, outreach, and training 9.1 B3 Eliminate screening by physical objects 9.1 B4 Signals to alert motorists that pedestrians are crossing	9.1 A2 Install or upgrade traffic and pedestrian signals 9.1 A3 Provide pedestrian refuge islands and raised medians 9.1 A4 Provide vehicle restriction/diversion measures 9.1 B2 Implement lighting/crosswalk illumination measures	—
Long (more than 2 years)	—	—	9.1 A1 Provide sidewalks/walkways with curb ramps	9.1 A5 Install overpasses/ underpasses

SECTION V

Strategies for Addressing the Problem

Objectives of the Emphasis Area

Deciding on the set of treatments that will provide the greatest safety benefits for pedestrians requires transportation and land-use planners, engineers, and community leaders to engage in problem-solving. The problem-solving effort will often require application of engineering judgment, as well as judgments based upon understanding of the character and needs of the particular community.

Pedestrians face a variety of challenges when they walk along and across streets with motor vehicles. Communities are asking for help to "slow traffic down," "make it safer to cross the street," and "make the street more inviting to pedestrians." An example of one city's pedestrian program may be found at http://www.seattle.gov/transportation/pedestrian.htm.

Tools are available to help those planning to improve pedestrian safety. The FHWA is completing the development of a software package called "PedSafe," which will provide guidance on measures to improve, including a catalog of case studies. PedSafe may be found at www.walkinginfo.org/de/pedsafe.

For citizens and citizen groups, there are resources such as the "Neighborhood Walking Guide," developed by the Pedestrian and Bicycle Information Center (PBIC). This Guide provides detailed information on how to address common problems and includes further Web links to technical information. The specific Web address of the Neighborhood Walking Guide is: www.walkinginfo.org/cps/guide.htm.

The following is a list of requests (objectives) that transportation professionals are likely to face when working to reduce pedestrian/vehicle conflicts and improve pedestrian safety and mobility:

1. Reduce pedestrian exposure to vehicular traffic
2. Improve sight distance and visibility for motor vehicles and pedestrians
3. Reduce the speed of motor vehicles
4. Improve pedestrian and motorist safety awareness and behavior

Each of these objectives can be accomplished through a variety of the strategies (treatments) listed in Exhibit V-1. Most strategies will work best when used at multiple locations and in combination with other treatments. In addition, many of the strategies (treatments) will accomplish two or more objectives. The key is to make sure that the right treatments are chosen to accomplish the desired effect.

A chart has been prepared (see Appendix 1) which links the strategies listed in Exhibit V-1 to the specific crash types they are intended to address. In using the chart, it is important to remember that it is simply a guide. In all cases, good engineering judgment should be applied when making decisions about what treatment will be best for a specific location.

EXHIBIT V-1
Emphasis Area Objectives and Strategies

Objectives	Strategies
9.1 A Reduce Pedestrian Exposure to Vehicular Traffic	9.1 A1 Provide Sidewalks/Walkways and Curb Ramps (P)
	9.1 A2 Install or Upgrade Traffic and Pedestrian Signals (P, T, & E)
	9.1 A3 Construct Pedestrian Refuge Islands and Raised Medians (P)
	9.1 A4 Provide Vehicle Restriction/Diversion Measures (P & T)
	9.1 A5 Install Overpasses/Underpasses (P)
9.1 B Improve Sight Distance and/or Visibility Between Motor Vehicles and Pedestrians	9.1 B1 Provide Crosswalk Enhancements (P & T)
	9.1 B2 Implement Lighting/Crosswalk Illumination Measures (P)
	9.1 B3 Eliminate Screening by Physical Objects (T)
	9.1 B4 Signals to Alert Motorists That Pedestrians Are Crossing (T & E)
	9.1 B5 Improve Reflectorization/Conspicuity of Pedestrians (T)
9.1 C Reduce Vehicle Speed	9.1 C1 Implement Road Narrowing Measures (T)
	9.1 C2 Install Traffic Calming—Road Sections (P & T)
	9.1 C3 Install Traffic Calming—Intersections (P & T)
	9.1 C4 Provide School Route Improvements (T)
9.1 D Improve Pedestrian and Motorist Safety Awareness and Behavior	9.1 D1 Provide Education, Outreach, and Training (P)
	9.1 D2 Implement Enforcement Campaigns (T)

P = proven; T = tried; E = experimental

In some cases, there may be a tradeoff between pedestrian and vehicular crashes, i.e., a particular strategy, implemented in a particular location, may succeed in reducing pedestrian crashes but contribute to an increase in vehicular crashes. In general, all types of road users must be considered when selecting a strategy to implement. Factors such as vehicular speeds and volumes, pedestrian volumes, roadway function, and availability of alternate routes should all be considered when making decisions about measures for reducing pedestrian crashes. In the best situations, pedestrian improvements increase safety for motorists as well as pedestrians. Especially in urban environments, slowing vehicle speeds and/or separating the movements of vehicles and pedestrians can be beneficial to both categories of road users.

Much of the technical information in this guide on specific strategies is based upon information found in the *Pedestrian Facilities Users Guide—Providing Safety and Mobility* (Federal Highway Administration, 2002), which is available at http://www.walkinginfo.org/pdf/peduserguide/peduserguide.pdf.

Or see the material at

- http://safety.fhwa.dot.gov/saferjourney/index2.htm
- http://www.cwdnet.com/qlc/tc_pedestrians.htm
- http://www.nhtsa.dot.gov/people/injury/pedbimot/ped/index.html

A program titled "PED SAFE" provides additional resources. See Appendix 2 for further details.

Details are provided on a wide variety of pedestrian safety, planning, and research topics at the following Web address: http://www.walkinginfo.org. This Web site covers pedestrian-related crash analysis, in addition to strategies related to engineering, education, and enforcement.

Many jurisdictions will implement a combination of these in the context of a general pedestrian safety plan. Some involve the implementation of committees that represent engineering, enforcement, and educational disciplines and the agencies they serve. Some details regarding this, and the plans that they produce, are in Appendix 3.

Classification of Strategies

The strategies in this guide were identified from a number of sources, including the literature, contact with state and local agencies throughout the United States, and federal programs. Some of the strategies are widely used, while others are used at a state or even a local level. Some have been subjected to well-designed evaluations to prove their effectiveness. On the other hand, it was found that many strategies, including some that are widely used, have not been adequately evaluated.

The implication of the widely varying experience with these strategies, as well as the range of knowledge about their effectiveness, is that the reader should be prepared to exercise caution in many cases, before adopting a particular strategy for implementation. To help the reader, the strategies have been classified into three types, each identified by letter symbol throughout the guide:

Proven (P): *Those strategies which have been used in one or more locations and for which properly designed evaluations have been conducted that show them to be effective*. These strategies may be employed with a good degree of confidence, but understanding that any application can lead to results that vary significantly from those found in previous evaluations. The attributes of the strategies that are provided will help the user judge which are the most appropriate for their particular situation(s).

Tried (T): *Those strategies that have been implemented in a number of locations and may even be accepted as standards or standard approaches, but for which there have not been found valid evaluations*. These strategies, while in frequent, or even general, use, should be applied with caution, carefully considering the attributes cited in the Guide, and relating them to the specific conditions for which they are being considered. Implementation can proceed with some degree of assurance that there is not likely to be a negative impact on safety, and there very likely will be a positive one. It is intended that as the experiences of implementation of these strategies continues under the AASHTO Strategic Highway Safety Plan initiative, appropriate evaluations will be conducted, so that effectiveness information can be accumulated to provide better estimating power for the user and so that the strategy can be upgraded to a "proven" one.

Experimental (E): *Those strategies that are ideas that have been suggested and that at least one agency has considered sufficiently promising to try on a small scale in at least one location.* These strategies should be considered only after the others have proven not to be appropriate or feasible. Even where they are considered, their implementation should initially occur using a very controlled and limited pilot study that includes a properly designed evaluation component. Only after careful testing and evaluations show the strategy to be effective should broader implementation be considered. It is intended that as the experiences of such pilot tests are accumulated from various state and local agencies, the aggregate experience can be used to further detail the attributes of this type of strategy so that it can be upgraded to a "proven" one.

It is particularly difficult to evaluate the impacts of countermeasures on pedestrian crashes. Reasons include the following:

- Pedestrian crashes are even rarer events than vehicle crashes not involving pedestrians, making it difficult to assess impacts at a given location and over reasonable lengths of time
- Pedestrian-oriented street improvements are often done in conjunction with other improvements, making it difficult to separate the specific effects of the pedestrian-oriented strategies

As a result of these types of difficulties, evaluation work has often focused upon surrogate measures, primarily related to pedestrian and vehicle behaviors and conflicts. Although these surrogates have not been solidly demonstrated to be linked to crash experience, they may serve as interim indications of safety impacts, until more valid evaluations become available.

The needs of pedestrians should be considered in all work zone areas, in addition to motor-vehicle safety. The strategies described below do not address specifically the issues of providing for pedestrian safety in work zones. The reader should refer to the Work Zone Guide for information.

The problem of pedestrians under the influence of alcohol will be addressed in the planned guide on alcohol countermeasures. Since that guide is under development, Appendix 4 has been provided in the interim.

Signs and pavement markings are not usually sufficient, unaided, to solve a serious pedestrian safety problem. These devices have their place in providing helpful information to pedestrians and/or motorists in certain situations, and they often are best used to supplement other more substantial treatments. Details on signs, signals, and markings are contained in the Manual on Uniform Traffic Control Devices.

When designing facilities for pedestrians, it is important to account for the interaction of pedestrians with other road users. For example, large trucks may create special problems for pedestrians, such as trailer off-tracking while turning right (and possibly striking a pedestrian standing on the sidewalk). Also, compared to other motor vehicles, some trucks have longer stopping distances, limited visibility (e.g., blind spots), and problems with nighttime visibility. Bicyclists also travel on roadways and sometimes conflict with pedestrians. In short, engineers and planners need to provide a roadway environment that balances the needs of all road users.

Related Strategies for Creating a Truly Comprehensive Approach

The strategies listed above, and described in detail below, are those considered unique to this emphasis area. However, to create a truly comprehensive approach to the highway safety problems associated with this emphasis area, there are related strategies recommended as candidates in any program planning process. These are of five types:

Public Information and Education Programs (PI&E)

Many highway safety programs can be effectively enhanced with a properly designed PI&E campaign. The primary experience with PI&E campaigns in highway safety is to reach an audience across an entire jurisdiction, or a significant part of it. However, it may be desired to focus a PI&E campaign on a location-specific problem. While this is a relatively untried approach, as compared to area-wide campaigns, use of roadside signs and other experimental methods may be tried on a pilot basis. Within this guide, where the application of PI&E campaigns is deemed appropriate, it is usually in support of some other strategy. In such a case, the description for that strategy will suggest this possibility (see the attribute area for each strategy entitled "Associated Needs for, or Relation to, Support Services"). In this guide, since independent PI&E campaigns are deemed appropriate for the emphasis area, the strategy is explained in detail (see Strategy 9.1 D1).

Enforcement of Traffic Laws

Well-designed and -managed law-enforcement programs can have a significant positive effect on highway safety. It is well established, for instance, that an effective way to reduce crashes and their severity is to have jurisdiction-wide programs that enforce an effective law against driving under the influence (DUI), or driving without seatbelts. When that law is vigorously enforced, with well-trained officers, the frequency and severity of highway crashes can be significantly reduced. This should be an important element in any comprehensive highway safety program. Enforcement programs are conducted at specific locations by the nature of how they must be performed. The effect (e.g., lower speeds, greater use of seatbelts, giving right-of-way to pedestrians, reduced red-light running, safer vehicles, and reduced impaired driving) may occur at or near the specific location where the enforcement is applied. Coordinating the effort with an appropriate PI&E program can often enhance this effect. However, in many cases (e.g., speeding, pedestrian right-of-way, and seatbelt usage) the impact is area-wide or jurisdiction-wide. The effect can be either positive (i.e., the desired reductions occur over a greater part of the system) or negative (i.e., the problem moves to another location as road users move to new routes where enforcement is not applied).

A pilot program is recommended when it is unclear how the enforcement effort may impact behavior or where it is desired to try an innovative and untried method. Within this guide, the application of enforcement programs is often deemed appropriate in support of some other strategy. Many of those strategies can be targeted at either the whole system or a specific location. In such cases, the description for that strategy will suggest this possibility (see the attribute area for each strategy entitled "Associated Needs for, or Relation to, Support Services"). For the pedestrian emphasis area, an independent enforcement program is deemed appropriate and the strategy is explained in detail. As additional guides are

completed for the AASHTO Plan, they may address the details regarding the design and implementation of enforcement strategies. When that occurs, the appropriate links will be added from this emphasis area guide.

Strategies to Improve Emergency Medical and Trauma System Services

When pedestrians are struck by vehicles, the risk of serious or fatal injury is high. Rapid and proper treatment of injured parties at highway crashes can have a significant impact on recovery, as well as survival. Thus, a comprehensive emergency care program is a basic part of a highway safety infrastructure. While the types of strategies that are included here are often thought of as simply support services, they can be critical to the success of a comprehensive highway safety program. Therefore, for this emphasis area, an effort should be made to determine if improvements could be made, especially for programs that are focused upon location-specific (e.g. corridors) or area-specific (e.g., rural areas) issues. An additional guide for the AASHTO Plan may address the design and implementation of emergency medical systems strategies. If this occurs, the appropriate links will be added to this emphasis area guide.

Strategies Directed at Improving the Safety Management System

The management of the highway safety system is essential to success. There should be in place a sound organizational structure, as well as infrastructure of laws, policies, etc., to monitor, control, direct, and administer a comprehensive approach to highway safety. It is important that a comprehensive program not be limited to one jurisdiction, such as a state DOT. Local agencies are often responsible for the majority of the road system and its related safety problems. They also have a better understanding of the problems. However, local jurisdictions need to work together and coordinate their safety programs in a region or metropolitan area. As additional guides are completed for the AASHTO Plan, they may address the details regarding the design and implementation of strategies for improving safety management systems. When that occurs, the appropriate links will be added from this emphasis area guide.

Strategies That Are Detailed in Other Emphasis Area Guides

Pedestrians move along and across all types of road facilities. The strategies in this guide attempt to reflect that, by addressing a wide range of facility elements. However, there are other emphasis areas that address road features, which also relate to pedestrian safety. Further details on other applicable strategies may be found in the companion guides for unsignalized intersections (17.1) and signalized intersections (17.2).

Objective 9.1 A—Reduce Pedestrian Exposure to Vehicular Traffic

Strategy 9.1 A1: Provide Sidewalks/Walkways and Curb Ramps

Sidewalks and Walkways

Sidewalks and walkways provide people with space to travel within the public right-of-way that is separated from roadway vehicles. They also provide places for children to walk, run, skate, ride bikes, and play away from the street. Such facilities also improve mobility for

pedestrians and provide access for all types of pedestrian travel to and from home, work, parks, schools, shopping areas, transit stops, etc. Walkways should be part of every new and renovated roadway, and every effort should be made to retrofit streets that currently do not have sidewalks or walkways (Exhibit V-2).

EXHIBIT V-2
Walkways should be part of every new and renovated roadway. (Photo by Dan Burden)

Examples of successful implementation of sidewalks and walkways can be found at the following Web sites:

- New York State Department of Transportation, http://www.dot.state.ny.us/pubtrans/bpfacilities.html#pa
- Texas Statewide Transportation Enhancement Program, http://www.dot.state.tx.us/des/enhance/projcat1.htm
- National Capital Planning Commission, http://www.ncpc.gov/actions/pdf/2002/MallWalkway_050202.pdf

Additional information on sidewalks and walkways can be found at PBIC, Walking Design and Engineering: Pedestrian Facility Design Treatments—Sidewalks and Walkways, http://www.walkinginfo.org/de/curb1.cfm?codename=1a&CM_maingroup=PedestrianFacilityDesign.

Curb Ramps

Requirements for curb ramps are provided by the U.S. Access Board, as detailed in www.access-board.gov.

Curb ramps (also called wheelchair ramps) provide transition in elevation between the sidewalk and roadway for people using wheelchairs, strollers, walkers, crutches, handcarts, and bicycles, as well as for pedestrians with mobility impairments who have trouble stepping up and down high curbs. While curb ramps are needed on all types of streets, highest priority locations should be in downtown areas and on streets near transit stops, schools, parks, medical facilities, government agencies, shopping areas, and near residences with wheelchair users (Exhibit V-3). More details on design of sidewalks and walkways, including curb ramps may be found in the FHWA report, *Designing Sidewalks and Trails for Access,* parts 1 and 2 (Federal Highway Administration, 1999, 2001).

EXHIBIT V-3
Curb ramps provide transition in elevation between the sidewalk and the roadway for people using wheelchairs, strollers, walkers, crutches, handcarts, and bicycles, as well as people who have trouble stepping up and down high curbs. (Photo by Michael Ronkin)

Further discussion of design considerations for these may be found in Appendix 5.

Additional information on curb ramps can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Pedestrian Facility Design—Curb Ramps, http://www.walkinginfo.org/de/curb1_print.cfm?codename=2a&CM_maingroup=PedestrianFacilityDesign
- United Nations, Accessibility Design Manual, Urban Design, http://www.un.org/esa/socdev/enable/designm/AD1-05.htm

Bollards and Protective Barriers

EXHIBIT V-4
Bollards or other protective barriers should be considered to help protect pedestrians where motorists are likely to encroach into areas where pedestrians are present. (Photo by Michael Ronkin)

Other features that may also be needed to help protect pedestrians on sidewalks or walkways are various types of posts, bollards, or protective barriers (Exhibit V-4). Such barriers should be considered at locations where motorists are likely to encroach into areas where pedestrians are present. Further details on guidelines related to bollards and other protective barriers are given in the publication, *Design and Safety of Pedestrian Facilities*, by the Institute of Transportation Engineers (March 1998).

EXHIBIT V-5
Strategy Attributes for Providing Sidewalks/Walkways and Curb Ramps

Attribute	Description
Technical Attributes	
Target of the Strategy	This strategy targets pedestrians who wish to walk adjacent to streets and highways. In particular, curb ramps address the needs of people in wheelchairs and pedestrians with mobility impairments.
Expected Effectiveness	The presence of sidewalks on both sides of the street has been found to be related to significant reductions in the "walking along roadway" pedestrian crash risk (i.e., probability of a pedestrian being struck) compared to locations where no sidewalks or walkways exist. Reductions of 50 to 90 percent of these types of pedestrian crashes have been found in previous research. Knoblauch et al. (1987) found that locations with no sidewalks were more than two times more likely to have pedestrian crashes than locations with sidewalks. Sidewalks were found to have a large safety benefit in residential and mixed residential areas, but not in commercial areas. McMahon et al. (2002) investigated the effects of sidewalks, other roadway design attributes, and neighborhood demographics on the likelihood of pedestrian crashes. They analyzed a total of 47 crash sites involving pedestrian "walking along roadway" crashes and 94 comparison sites. Physical design factors that were associated with a significantly higher likelihood of being a crash site were higher speed limit, the lack of wide grassy walkable areas, and the absence of sidewalks. Taking into account speed limit and traffic volume, the likelihood of a site with a sidewalk being a crash site was 88 percent lower

EXHIBIT V-5 (Continued)
Strategy Attributes for Providing Sidewalks/Walkways and Curb Ramps

Attribute	Description
	than a site without a sidewalk. Hence, the presence of a sidewalk clearly had a strong beneficial effect of reducing the risk of "walking along roadway" pedestrian crashes. When the design factors were controlled for, nongeometric factors that were associated with a significantly higher likelihood of being a crash site were high levels of unemployment, older housing stock, lower proportions of families within households, and more single parents. The authors concluded that some neighborhoods might be especially appropriate locations for installing sidewalks and other pedestrian treatments. (See Appendix 6 for guidelines for sidewalk installation that resulted from the study.)
Keys to Success	A key to successful sidewalks and walkways is careful planning in the subject neighborhood or area. For example, a flat sidewalk with a cross slope of no more than 2 percent should be provided across driveways that slope to the roadway to accommodate wheelchair users. The network of sidewalks and walkways should be well connected to meet the needs of the community. More details on design of sidewalks and walkways, including curb ramps may be found in the FHWA report, *Designing Sidewalks and Trails for Access,* parts 1 and 2 (Federal Highway Administration, 1999, 2001). All newly constructed and altered roadway projects should include curb ramps. It is recommended that separate curb ramps be provided for each crosswalk at an intersection, wherever feasible, rather than having a single ramp at a corner for both crosswalks. This provides improved orientation for pedestrians, particularly for visually impaired pedestrians. Similarly, tactile warnings are also important to alert pedestrians to the sidewalk/street edge. The ADA Standards for Accessible Design requires that a strip of truncated dome-type tactile warning be placed at the base of the crosswalk. Agencies should upgrade existing sidewalks by first conducting audits of their pedestrian facilities to make sure transit services, schools, public buildings, parks, etc. are accessible to pedestrians who use wheelchairs.
Potential Difficulties	Agencies must overcome decades of street and road construction projects that may have routinely ignored the need for sidewalks and walkways. Pro-pedestrian policies and construction programs need to be approved and implemented to correct this problem.
Appropriate Measures and Data	A key performance measure is the frequency and percent of "walking along roadway" or midblock-crossing pedestrian crashes. The proportion of pedestrian traffic that is walking in the roadway and crossing midblock may be a useful surrogate measure. The perceived convenience and safety that result from the provision of sidewalks and curb ramps suggest using a count of the change in the pedestrian volume along a route as an additional measure of success. Process measures include the number of feet/miles of sidewalk/walkway and/or the number of new curb ramps which have been added (or upgraded).
Associated Needs	A buffer zone is desirable and should be provided to separate pedestrian walkways and sidewalks from the street. The buffer zone width can vary according to the street type and available right-of-way. In downtown or commercial districts, a street furniture zone is usually appropriate as a buffer zone. Parked cars and/or bicycle lanes can also provide an acceptable buffer zone. In more suburban or rural areas, a landscape strip is generally more suitable.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	The ADA must be followed when constructing sidewalks, walkways, and curb ramps. For example, tactile patterns must be detectable to vision-impaired pedestrians.

(*continued on next page*)

EXHIBIT V-5 (Continued)
Strategy Attributes for Providing Sidewalks/Walkways and Curb Ramps

Attribute	Description
Issues Affecting Implementation Time	State and local design, planning, and zoning ordinances may need upgrading to require sufficient right-of-way for sidewalks and other pedestrian facilities. Further information on designing sidewalks for better accessibility is found in *Designing Sidewalks and Trails for Access* (Federal Highway Administration, 1999, 2001).
Costs Involved	Funding needs to be earmarked for sidewalk improvements. Proper planning of pedestrian needs is also essential to set priorities for needed sidewalk installations and enhancements. For more on funding, see http://www.ite.org/library/accessibleped.asp. Costs for sidewalks will vary, depending upon factors such as width and materials used. Typical costs for sidewalks and curb ramps are given in Appendix 7.
Training and Other Personnel Needs	Training is needed in problem identification and in proper design and installation methods. In addition to DOT personnel, anyone involved in the design, construction, or maintenance of streets and sidewalks (including planners, developers, designers, contractors, inspectors, and engineers) needs training on ADA requirements and the need to provide access for pedestrians during street construction projects.
Legislative Needs	Some agencies have local ordinances requiring developers to install sidewalks along all streets and highways that are adjacent to the developed property. Such ordinances are important to help create a network of sidewalks and walkways for safe walking within a community. Legislation may be needed to prevent contractors and developers from blocking pedestrian access when working in urban areas.
Other Key Attributes	
	Street furniture should be positioned on sidewalks to avoid restricting pedestrian flow and screening pedestrians from a driver's view at crossing points.

Strategy 9.1 A2: Install or Upgrade Traffic and Pedestrian Signals

This strategy includes six countermeasures: traffic signals, pedestrian signals, pedestrian signal timing, accessible pedestrian signals, signal enhancements, and right-turn-on-red restrictions. Further detailed information is available in the *Manual on Uniform Traffic Control Devices for Streets and Highways* (2000 MUTCD) (Federal Highway Administration, 2000a) and the ITE *Traffic Control Devices Handbook, 2001*, (2001b) Chapter 13, Pedestrians.

Traffic Signals

Traffic signals can create gaps in the traffic flow of sufficient size to allow pedestrians to cross the street. Warrants for traffic signals are based upon the number of vehicles and pedestrians crossing the intersection, along with other factors (Federal Highway Administration, 2000a). Judgment must also be used on a case-by-case basis. For example, if a new park or recreational path is built, there will be additional pedestrian activity, and the *projected* crossing demand should be taken into account when deciding if a traffic signal is warranted. However, even when warrants are met, the installation of a new traffic signal often results in an increase in total crashes. Specifically, rear-end crashes may increase considerably, although there may be a

decrease in angle collisions and also a decrease in overall crash severity. Traffic signals can also create overall lower level of service for vehicles and pedestrians. Consideration must also be given to the possibility that traffic will divert to adjacent neighborhood streets to bypass delays associated with the signal.

Additional information on the use of traffic signals can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Signals and Sign Treatments—Traffic Signals, http://www.walkinginfo.org/de/curb1.cfm?codename=37f&CM_maingroup=Signals%20and%20Signs
- City of Fort Collins, Colo., Department of Transportation, http://www.ci.fort-collins.co.us/traffic/signals.php
- City of Arlington, Va., Department of Public Works, http://www.co.arlington.va.us/dpw/traffic/signals/hb16.htm

Pedestrian Signals

Pedestrian signals should ideally be installed at all traffic signals in urban or suburban areas. They are especially important at intersections with (1) multiphase traffic signals, such as left-turn arrows and split phases, (2) school crossings, and (3) double-right or double-left turns. They are also important at high-use midblock crossings and multilane roads (Exhibit V-6).

EXHIBIT V-6
Pedestrian signals should ideally be installed at all traffic signals in urban and suburban areas. (Photo by Dan Burden)

Many pedestrians do not understand the meaning of the pedestrian signal indications, particularly the flashing DON'T WALK. An informational sign can be installed to tell pedestrians what they should do during the WALK, flashing DON'T WALK, and steady DON'T WALK indications (Exhibit V-7).

Marked crosswalks should be used at all signalized intersections and signalized midblock crossings to guide pedestrians to the preferred crossing location. Crosswalks may also discourage motorists from encroaching into the pedestrian crossing area. Pedestrian signals need to also indicate the crossing interval by audible and/or tactile means if pedestrians with visual impairments are to take advantage of them. While median refuge islands reduce the crossing distance and are very helpful on wide streets, it is highly desirable to give pedestrians enough time to cross the entire street.

EXHIBIT V-7
An informational sign can tell pedestrians what they should do during each of the pedestrian signal phases.

Additional information on pedestrian signals can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Signals and Sign Treatments—Pedestrian Signals http://www.walkinginfo.org/de/curb1.cfm?codename=38f&CM_maingroup=Signals%20and%20Signs
- City of Fremont, Calif., http://www.ci.fremont.ca.us/Community/Traffic/PedestrianSignals.htm
- Washington State Department of Transportation, Pedestrian Signals, http://www.wsdot.wa.gov/biz/trafficoperations/traffic/pedsignals.htm
- FHWA, Office of Safety, Pedestrian Signals Q & A, http://safety.fhwa.dot.gov/fourthlevel/pdf/planning2.pdf

Pedestrian Signal Timing

At wide intersections, pedestrian crossing times often dictate vehicle green splits and cycle lengths. As a result, minimum WALK (start) and flashing DON'T WALK (clearance) times are commonly used. The 2000 MUTCD recommends a minimum WALK interval of 7 seconds. With such a short interval, pedestrians may only traverse one or two lanes before the flashing DON'T WALK appears. This may confuse or even panic pedestrians who do not understand the meaning of the flashing DON'T WALK. It is desirable to provide a longer WALK interval whenever practical. Timing clearance (i.e., flashing DON'T WALK) intervals to assume slower walking speeds than the standard 1.2 m/sec may also be appropriate, particularly at locations where older pedestrians or children cross the street regularly. However, longer clearance intervals may result in the designer providing shorter walk times and/or longer cycle lengths. The latter could lead to longer waits for pedestrians between crossing opportunities.

There are several pedestrian signal–timing schemes. The most common is standard (or concurrent) timing, in which the WALK signal is displayed at the same time as the green indication for parallel vehicular traffic. Under this timing scheme, right- and left-turning motor vehicles may conflict with pedestrians crossing on the WALK signal (and many turning motorists will not yield to pedestrians). Alternatives to standard timing are early release, late release, exclusive, and scramble timing.

An informational sign can tell pedestrians what they should do during each of the pedestrian signal phases (Exhibit V-7).

An early-release timing scheme displays the WALK signal for pedestrians while parallel traffic still has a red signal. That is, pedestrians are "released" early and have a chance to begin crossing and occupy the crosswalk before vehicles start turning right (or left) into their paths. With late release, parallel traffic gets the green signal first, while pedestrians still have the steady DON'T WALK signal. This scheme holds pedestrians back before

"releasing" them, so that turning vehicles will presumably be gone by the time that the WALK signal appears; late release is only effective if there is not a constant stream of turning vehicles. At intersections where there is a very high volume of turning traffic, early-release signals are generally more appropriate.

With exclusive timing (sometimes referred to as the "scramble system"), all vehicular traffic is stopped, and pedestrians are allowed to cross in any crosswalk. The WALK signal is displayed for all crosswalks at the same time. With scramble timing, all vehicular traffic is stopped and pedestrians are allowed to cross in any crosswalk or diagonally across the intersection (Exhibit V-8). Exclusive-timing schemes are most appropriate at signalized intersections with large pedestrian volumes (1,200 or more per day) and relatively low motor-vehicle speeds and volumes (e.g., central business districts and commercial centers). Because pedestrians often have to wait a long time for an exclusive signal, many will choose to ignore the signal and cross when there is a gap in traffic. Another problem at signalized intersections involves left-turn vehicles that turn on a green-ball indication and conflict with pedestrians who are crossing with the signal. In many cases, a solution is to provide a separate protected left-turn phase for motorists. Pedestrians are given a DON'T WALK signal when the left-turn arrow is displayed. When pedestrians have a WALK display, left-turning motorists have a red (no turn) indication.

The use of a short all-red interval (Exhibit V-8) can provide a better separation between motorists and pedestrians.

Additional information on pedestrian signal timing can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Signals and Sign Treatments—Update/Modify Pedestrian Signal Timing, http://www.walkinginfo.org/de/curb1.cfm?codename=39f&CM_maingroup=Signals%20and%20Signs
- University of Idaho, Basic Signal Timing Elements, http://www.webs1.uidaho.edu/niatt_labmanual/Chapters/signaltimingdesign/theoryandconcepts/BasicSignalTimingElements.htm
- City of Edgewood, Washington, http://www.ci.edgewood.wa.us/Cops/Safe%20Journey/Library/countermeasures/41.htm

EXHIBIT V-8
With scramble timing, all vehicular traffic is stopped while pedestrians are allowed to cross in any crosswalk or diagonally across the intersection. (Photo by Dan Burden)

Accessible Pedestrian Signals (APS)

At signalized intersections, pedestrians who are blind or visually impaired typically start to cross the street when they hear a surge of traffic parallel to their direction of travel. Some intersection geometries and traffic conditions make it very difficult for visually impaired persons to know when to cross. These include skewed or very wide intersections, intersections with split-phase signal timing, intersections with intermittent traffic, and intersections with pedestrian push buttons. (Visually impaired pedestrians may not realize that they have to push a button, or they may have trouble finding the button).

Accessible pedestrian signals (APS) provide audible and/or vibrotactile information coinciding with visual pedestrian signals, to inform visually impaired pedestrians precisely when the WALK interval begins and when it is no longer safe to cross (Exhibit V-9). Pedestrians who know when the crossing interval begins will be able to complete their crossing before the signal changes. Audible signals can also provide directional guidance, which is particularly useful at skewed or angled intersections and at wide multilane crossings.

The characteristics of different APS technologies are described in *Accessible Pedestrian Signals* (Bentzen and Tabor, 1998), which is available at http://www.access-board.gov/research&training/pedsignals/pedestrian.htm.

The Institute of Transportation Engineers provides a toolbox for accessible intersections at http://www.ite.org/library/accessibleint.asp.

An interactive synthesis and guide to best practices on APS is given at http://www.walkinginfo.org/aps. The printed report and guide on APS are found at http://gulliver.trb.org/publications/nchrp/nchrp_rrd_278.pdf.

EXHIBIT V-9
Accessible pedestrian signals (APS) provide audible and/or vibrotactile information to assist visually impaired pedestrians on when to cross the street. (Photo by David Harkey)

Audible signals actuated by push buttons are the most commonly used. These often emit a chirp or "cuckoo" tone during the WALK interval. The tones may alternate from one side of the crossing to the other. A second type of APS consists of infrared or LED transmitters that emit a verbal message that can be heard with a hand-held receiver. The message may identify the pedestrian's location and direction of travel, give the name of the street to be crossed, and provide real time information about the WALK and DON'T WALK intervals. A third type of APS uses vibrotactile push buttons. By feeling the button, the pedestrian knows that the button has been pushed and when the WALK interval appears. Audible tones may be used in conjunction with the vibrotactile buttons to let the pedestrian know that a button must be pushed, where the button is located, and when the WALK interval appears.

Push button locator tones are also recommended to inform the visually impaired that a pedestrian push button exists and to locate the position of the push button. If the tone for the walk interval is similar to the push button locator tone, the walk interval tone should have a faster repetition rate than the push button locator tone (Federal Highway Administration, 2000a).

Signal Enhancements

A variety of traffic and pedestrian signal enhancements can benefit pedestrians. These include automated pedestrian detectors, larger traffic signals to insure visibility, and countdown signals, as well as signal placement, so that motorists waiting at a red light cannot see the signals on the cross street and anticipate the green indication.

Because many pedestrians will not activate push buttons, automated pedestrian detectors have been installed in some U.S. cities. These use microwave or infrared technology to detect pedestrians and then "call" the WALK signal. Automated detectors can also be used to monitor pedestrians as they cross and extend the clearance interval if needed, up to a preset maximum.

Automated pedestrian detectors (Exhibit V-10) are discussed thoroughly in an FHWA report produced in 2001 titled *Evaluation of Automated Pedestrian Detection at Signalized Intersections* (Hughes *et al.,* 2000). This document is available at http://www.tfhrc.gov/safety/pedbike/pubs/00-097.pdf.

The use of animated "eyes" along with the WALK sign has been shown to increase the percentage of pedestrians that look for turning vehicles. The use of the moving eyes reinforces the message taught to children in school and could be particularly useful at crosswalks used by children and youth. It could also be of value at intersections where left-turning vehicles pose a threat to pedestrians.

A pedestrian countdown signal contains a timer display and counts down the number of seconds left to finish crossing the street. Countdown signals begin counting down either when the WALK or when the flashing DON'T WALK interval appears and stop at the beginning of the steady DON'T WALK interval (Exhibit V-11). Countdown signals can reassure pedestrians who are in the crosswalk when the flashing DON'T WALK interval appears that they still have time to finish crossing. This information is contained in Part 4 of the *Manual on Uniform Traffic Control Devices* (Federal Highway Administration, 2003).

Additional information on signal enhancements can be found at the following Web sites:

EXHIBIT V-10
Automated pedestrian detectors use microwave or infrared technology to detect pedestrians as they cross and extend the clearance interval if needed, up to a preset maximum. (Photo by Herman Huang)

EXHIBIT V-11
A pedestrian countdown signal shows the number of seconds left for pedestrians to finish crossing the street. (Photo by Dan Burden)

- PBIC, Walking Design and Engineering: Signals and Sign Treatments—Signal Enhancements, http://www.walkinginfo.org/de/curb1.cfm?codename=40f&CM_maingroup=Signals+and+Signs&go.x=14&go.y=11
- City of Edgewood, Wash., http://www.ci.edgewood.wa.us/Cops/Safe%20Journey/Library/countermeasures/42.htm

Right-Turn-on-Red (RTOR) Restrictions

In all 50 states and the District of Columbia, motorists may turn right on red at any intersection, after coming to a full stop, unless a NO TURN ON RED sign (Exhibit V-12) prohibits the turn. RTOR restrictions can be limited to certain hours of the day or can extend to all hours. The only exception is New York City, where turning right on red is allowed only if a sign permits the turn. The Institute of Transportation Engineers (1984) noted that relative to motor vehicles, allowing RTOR results in "substantial benefits in reduced energy consumption, positive environmental impacts, and reduced operational delays."

RTOR can, however, increase crash risk for pedestrians. Motorists who stop at the intersection and look left to see if the road is clear sometimes do not look right before turning right. Therefore, they may not see pedestrians coming from the right. Preusser *et al.* (1981) found that right-turn crashes involving pedestrians increased slightly after RTOR went into effect. Other studies concluded that RTOR does not create a pedestrian safety problem (AASHTO, 1979; McGee, 1976). Also, many motorists do not come to a complete stop as legally required.

EXHIBIT V-12
Full-time restrictions of right-turn-on-red may be needed at certain types of intersections. (Photo by Dan Burden)

The 2000 MUTCD identifies five conditions when the NO TURN ON RED sign may be used. Two of these conditions pertain to pedestrians: (1) where an exclusive pedestrian phase exists; (2) where an unacceptable number of pedestrian conflicts result from RTOR, especially conflicts involving children, older pedestrians, or persons with disabilities.

RTOR restrictions during the busiest times of the day may be sufficient at some locations. However, full-time restrictions of RTOR may be needed near schools or in downtown areas

with constant pedestrian activity; where sight distance is limited; where the intersection has more than four approach legs, or has a complex signal timing pattern; as well as where there are high concentrations of seniors and persons with disabilities.

Prohibiting RTOR is a simple, low-cost countermeasure to implement. Together with a leading pedestrian interval, the signal changes can benefit pedestrians with minimal impact on traffic.

Additional information on RTOR restrictions can be found at the following Web site:

- PBIC, Walking Design and Engineering: Signals and Sign Treatments—RTOR Restrictions, http://www.walkinginfo.org/de/curb1.cfm?codename=41f&CM_maingroup=Signals%20and%20Signs

EXHIBIT V-13
Strategy Attributes for Installing or Upgrading Traffic and Pedestrian Signals

Attribute	Description
Technical Attributes	
Target(s)	Pedestrians and vehicles at signalized intersections, or at midblock locations, where a significant volume of through or turning vehicular traffic is present.
Expected Effectiveness	*Pedestrian Signal Timing* Early release was found to reduce the vehicle-pedestrian conflict rate by up to 95 percent in St. Petersburg, Florida (Insurance Institute for Highway Safety, 1997). Exclusive phasing for left turns and pedestrians has been associated with approximately a 50-percent reduction in motor vehicle–pedestrian crashes as compared to standard timing (Zegeer et al., 1982). Exclusive and scramble phases eliminate conflicts with turning vehicles if pedestrians and motorists obey their signals. Wider intersections require longer cycle lengths. Leading pedestrian intervals have been used successfully in New York City and elsewhere, and studies have demonstrated reduced conflicts for pedestrians (Insurance Institute for Highway Safety, 1997). Zegeer *et al.* (1983) conducted a comprehensive study of the effects of pedestrian signal timing on pedestrian crashes. They analyzed 2,081 pedestrian crashes at 1,297 signalized intersections in 15 U.S. cities. About 61 percent of the intersections had concurrent, exclusive, or other pedestrian signal timing schemes. They found that the use of concurrent timing had no significant effect on pedestrian crashes, compared to locations with no pedestrian signals. Exclusive (protected) phasing was associated with significantly fewer pedestrian crashes, compared to either concurrent timing or to no pedestrian signals. They suggested possible reasons as to why concurrent timing was not effective: (1) Low levels of pedestrian compliance to signals, (2) False sense of security on the part of some pedestrians, (3) Lack of understanding of the WALK and flashing DON'T WALK signals, and (4) Infrequent use of pedestrian push buttons to actuate the WALK signal. *Accessible Pedestrian Signals (APS)* The information conveyed by audible signals increases the attention of all pedestrians to traffic and may contribute to a reduction in pedestrian-vehicular conflicts and

(*continued on next page*)

EXHIBIT V-13 (Continued)
Strategy Attributes for Installing or Upgrading Traffic and Pedestrian Signals

Attribute	Description
	crashes at signalized intersections (Van Houten et al., 1997). It is widely believed in many European countries, where audible signals are more widely used than in the United States, that the audible signals increase the speed at which most pedestrians initiate their crossings, thereby decreasing the necessary length of the pedestrian interval. Audible signals may also increase the safety of persons with cognitive disabilities. However, two recent surveys of visually impaired pedestrians, as well as orientation and mobility specialists, found a number of problems. For example, visually impaired pedestrians may be unable to tell if a push button is present. They may have difficulty finding the push button. The audible signal may not clearly indicate which crosswalk has the WALK signal, or they may not be able to use the audible signal for guidance as they cross the street (Bentzen et al., 2000; Carroll and Bentzen, 1999). *Signal Enhancements* Automated pedestrian detectors have been found to improve pedestrian compliance with signals. They also reduce conflicts between pedestrians and motor vehicles (Hughes et al., 2000). Countdown signals have been shown to result in fewer pedestrians still in the crosswalk when the steady DON'T WALK signal appears (compared to sites without countdown signals). However, countdown signals have had the undesired effect of reducing pedestrian compliance (Huang and Zegeer, 2000) *Right-Turn-on-Red Restrictions* Zegeer and Cynecki (1986) found that about 21 percent of motorists violated NO TURN ON RED signs if given the opportunity. Twenty-three percent of RTOR violations resulted in a motor vehicle–pedestrian conflict. Illuminated NO TURN ON RED signs, NO TURN ON RED signs with a red ball underneath, and offset stop bars at intersections where right-turn-on-red is allowed were all effective in reducing risk to pedestrians. The NO TURN ON RED sign with the red ball was more effective than the standard black and white NO TURN ON RED signs. For motorists making a right-turn-on-red, an offset stop-bar was found to increase compliance (i.e., making a full stop before turning right on red) and also reduced conflicts with cross-street traffic. An electronic NO TURN ON RED sign that was actuated only during school crossing times or other critical times was slightly more effective, but considerably more costly, than traditional signs. In general, driver compliance was improved when the right-turn-on-red restriction was limited to peak pedestrian times, instead of all times.
Keys to Success	*Traffic and Pedestrian Signals* Signal cycles should be kept short (ideally 90 seconds maximum), to reduce pedestrian delay. Pedestrians are very sensitive to delays, so that if they perceive a long delay, they are likely to disobey the signal. *Pedestrian Signals and APS* Where pedestrian traffic is regular and frequent, pedestrian phases should come up automatically. Pedestrian actuation should be used only when pedestrian crossings are intermittent. Ensure that signals are always visible to pedestrians, including those in the crosswalk and those waiting on the far side of the street. If push buttons are used, they must be well signed and visible and within reach and operable from a flat surface for all pedestrians, including those in wheelchairs.

EXHIBIT V-13 (Continued)
Strategy Attributes for Installing or Upgrading Traffic and Pedestrian Signals

Attribute	Description
	Furthermore, it is desirable for the user to receive an audible feedback that the "call" has been registered. Push buttons should be mounted approximately 1.1 m (3.5 ft) above the sidewalk, within 1.5 m (5 ft) of the extended crosswalk and within 3 m (10 ft) of the edge of the curb, shoulder, or pavement. If buttons are needed to cross both streets, they must be separated by at least 3 m (10 ft), and each button should be parallel to the crosswalk to be used (Federal Highway Administration, 2003). Locator tones on APS push buttons can provide guidance on the existence of a pedestrian push button and help visually impaired pedestrians locate the button. *Pedestrian Signal Timing* Pedestrian signal timing changes should not have significant adverse effects on vehicle traffic operations. *Right-Turn-on-Red Restrictions* NO TURN ON RED signs should be installed adjacent to the signal indication on the right side of the street, so as to be clearly visible to right-turning motorists stopped in the curb lane at the crosswalk. A PI&E effort, coordinated with an enforcement of the installations, will help establish conformity to the law.
Potential Difficulties	*Pedestrian Signal Timing* Longer WALK or pedestrian clearance intervals may require longer cycle lengths, which in turn can add to vehicular delay. Exclusive and scramble timing usually create longer cycle lengths and longer waits for the WALK signal. Thus, vehicle and pedestrian delay are increased. With exclusive and scramble timing, it may not be possible to synchronize signals at adjacent intersections. The benefits of alternative signal timing schemes may not extend to pedestrians with vision impairments. Optimal signal timing, to accommodate phasing for left-turn movements or split-timing schemes, as well as an exclusive pedestrian phase, will usually require cycle lengths of 120 seconds or more. Added delay to vehicles may cause motorists to use neighborhood streets to bypass queues or to change routes, which may create safety problems at other locations. Since countdown pedestrian signals are not included in the 2000 MUTCD, permission for using them must be granted by the FHWA for those agencies that have adopted the Millennium Edition of the MUTCD. *Right-Turn-on-Red Restrictions* RTOR restrictions may result in more right-turn-on-green conflicts. The use of leading pedestrian intervals can usually address this situation. RTOR restrictions will increase delay at the intersection for motor vehicles.
Appropriate Measures and Data	The principal measures of effectiveness are vehicle-vehicle and vehicle-pedestrian crashes. Surrogate safety measures include conflicts between pedestrians and motor vehicles, pedestrian compliance with signals, the ability of pedestrians to finish crossing by the end of the clearance interval, and motorist compliance with right-turn-on-red restrictions. Motorist delay and traffic volumes are measures of operational

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EXHIBIT V-13 (Continued)
Strategy Attributes for Installing or Upgrading Traffic and Pedestrian Signals

Attribute	Description
	impact. Care should be taken to measure conditions at all locations potentially affected by the changes in control.
Associated Needs	Major changes in signal timing should be preceded with a public information campaign to avoid violating expectations of most drivers and to facilitate compliance. A coordinated enforcement program will also help maximize the benefits of some of these changes.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	The needs of pedestrians, bicyclists, and motorists need to be balanced when designing and operating intersections. For example, a design walking speed of 3 ft/sec (instead of 4 ft/sec) means that the pedestrian clearance intervals will be longer and pedestrians will have more time to cross. However, vehicle delay and cycle lengths may increase, which could in turn result in more pedestrian delay. At intersections where RTOR prohibitions are installed, there may be a need to provide police enforcement to help insure motorist compliance.
Issues Affecting Implementation Time	It may take more than a year to implement these countermeasures. Traffic engineers often conduct engineering studies to determine whether one or more of these countermeasures are warranted at a specific location. The availability of funds to cover the costs of hardware, signs, installation, and maintenance depends on local and state funding cycles. Innovative countermeasures such as automated detectors may require some additional time for adjustments to improve operations. Depending on local climatic conditions, installation may be feasible year-round or only during the warmer months.
Costs Involved	Costs associated with this strategy will vary widely, depending upon the countermeasure to be implemented and the conditions at the site. See Appendix 8 for specific estimates of cost.
Training and Other Personnel Needs	There do not appear to be any special personnel needs. Some training may be needed for less commonly used countermeasures, such as automated pedestrian detectors.
Legislative Needs	The use of any device that is not contained in the MUTCD requires the approval of the FHWA.
Other Key Attributes	
	None.

Strategy 9.1 A3: Construct Pedestrian Refuge Islands and Raised Medians

Raised pedestrian refuge islands, or medians at crossing locations along roadways, provide another strategy to reduce exposure between pedestrians and motor vehicles. Refuge islands and medians that are raised (i.e., not just painted) provide pedestrians more secure places of refuge during the street crossing. This simplifies the crossing maneuver for pedestrians by creating the equivalent of two narrower one-way streets instead of one wide two-way street. State and local DOTs may choose to install raised medians and refuge islands not only for improved pedestrian safety, but also to provide improved motor-vehicle safety. Adding a raised median converts an undivided road to a divided road, which helps channel motor vehicles.

Raised Medians

"A median is defined as the portion of a divided highway separating the traveled way for traffic in opposing directions" (AASHTO, 1994). Medians are either painted on the pavement or raised above it. Raised medians can serve as a place of refuge for pedestrians who cross a street midblock or at an intersection location (Exhibit V-14). They may also provide space for landscaping that can help to change the character of a street and reduce vehicle speeds. However, landscaping should not block sight distance between motorists and pedestrians. Raised medians allow pedestrians to concentrate on only one direction of traffic at a time. When considering raised medians, turning movements need to be carefully evaluated, so that motorists are not encouraged to travel on inappropriate routes, such as residential streets, or make unsafe U-turns. Medians and islands that are only painted (i.e., not raised) do not provide the same benefits as raised ones. Median crossings must be fully accessible by means of curb ramps or cut-throughs. With medians, it is also important to ensure that there is enough room for wider sidewalks, bike lanes, and planting strips before proceeding with construction. While raised medians are not appropriate for all roadways (for example, they are generally not recommended on higher-speed rural highways), on certain roadways they have been shown to reduce motor–vehicle, as well as pedestrian, crash rates. In Florida, for example, raised medians are frequently installed on suburban arterial streets to reduce crash rates.

See Florida Department of Transportation *Median Handbook* (Planning Division, 1997) for more explicit policy on raised medians: http://www.dot.state.fl.us/planning/systems/sm/accman/pdfs/mhb_2.pdf.

Additional information on the use of raised medians can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Roadway Design—Raised Medians, http://www.walkinginfo.org/de/curb1.cfm?codename=12b&CM_maingroup=Roadway Design
- Iowa State Center for Transportation Research and Education, *Access Management Toolkit*, http://www.ctre.iastate.edu/Research/access/toolkit/17.pdf

EXHIBIT V-14
Raised medians can serve as a place of refuge for pedestrians who cross a street midblock or at an intersection. (Photo by Dan Burden)

Crossing Islands

Crossing islands, which are also known as center islands, refuge islands, pedestrian islands, or median slow points, are raised islands placed in the street at intersection or midblock locations to help protect crossing pedestrians from motor vehicles (Exhibit V-15). Raised center crossing islands will allow pedestrians to concentrate on (or cross) only one direction of traffic at a time; they can stop partway across the street and wait for an adequate gap in traffic before completing their crossing. Where crosswalks are installed at uncontrolled locations (i.e., where no traffic signals or stop signs exist), raised crossing islands should be considered as a possible supplement to the crosswalk. Crossing islands are also appropriate at many signalized crossings. If there is adequate width and on-street parking, center crossing islands can be used with curb extensions to create an improved pedestrian crossing.

Additional information on the use of crossing islands can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Calming—Crossing Islands, http://www.walkinginfo.org/de/curb1.cfm?codename=21d&CM_maingroup=Traffic%20Calming
- City of Edgewood, Wash., http://www.ci.edgewood.wa.us/Cops/Safe%20Journey/Library/countermeasures/25.htm

EXHIBIT V-15
Crossing islands are raised islands placed in the street to help protect pedestrians from motor vehicles. (Photo by Michael Ronkin)

EXHIBIT V-16
Strategy Attributes for Constructing Pedestrian Refuge Islands and Raised Medians

Attribute	Description
Technical Attributes	
Target(s)	This strategy targets pedestrians who attempt to cross multilane arterial or collector streets.
Expected Effectiveness	The FHWA (Federal Highway Administration, 2002) found that the presence of a raised median (or raised crossing island) was associated with a significantly lower pedestrian crash rate at multilane crossing locations, with both marked and unmarked crosswalks. (See Strategy 9.1 B2 for a graph of findings.) In contrast, painted (not raised) medians and center two-way left-turn lanes did not offer significant safety benefits to pedestrians on multilane roads, compared to no median at all. This article is available at www.walkinginfo.org/rd/devices.htm#cros1. Bowman and Vecellio (1994) compared undivided multilane roadways, two-way left-turn lanes, and raised-curb medians. In both central business district and suburban locations, the pedestrian crash rate was significantly higher on undivided arterials than on arterials with raised medians. After analyzing intersections in Stockholm and Malmö, Sweden, Gårder (1989) concluded that installing a refuge island decreased the pedestrian crash risk to two-thirds of what it was originally. However, the incidence of red-walking (i.e., the percentage of pedestrians who arrive on a red signal but decide to cross the street before the signal allows them to) was higher when a refuge island was present (15 percent) than when there was no refuge island (10 percent).
Keys to Success	Raised medians are most useful on arterial streets, where there are typically high traffic volumes and multilane operation. They should be designed to provide tactile cues for pedestrians with visual impairments to indicate the border between the pedestrian refuge area and the motorized vehicle roadway. Also, islands should be designed to accommodate pedestrians in wheelchairs. Refer to Section 8-18 of the FHWA report *Designing Sidewalks and Trails for Access: Part II of II* (Federal Highway Administration, 2001) Landscaped medians should not obstruct the visibility between pedestrians and approaching motorists and should not include objects that represent a collision hazard to vehicles that may run onto the median. Crossing islands should be illuminated, as well as highlighted with streetlights, signs, and/or reflectors, to ensure that motorists see them. Larger islands that are more visible to motorists are less likely to be hit by a vehicle. An island can be made to appear larger through the use of pavement markings.
Potential Difficulties	Continuous raised medians may not be appropriate in all situations. Sometimes, separating opposing traffic flow and eliminating left-turn friction can increase traffic speeds. Medians may also take up space that can be better used for wider sidewalks, bicycle lanes, landscaping buffer-strips, or on-street parking. Medians may also cause problems for emergency vehicles. At some locations, medians can be constructed in sections, creating an intermittent rather than continuous median. Raised crossing islands at intersections or near driveways may affect left-turn access. Raised, continuous median channelization may be opposed by businesses along a corridor as a perceived inhibitor to their business, with expected loss of revenue. This can sometimes be mitigated through driveway consolidation (access management), allowing the median breaks to be minimized. Another strategy is to construct midblock

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EXHIBIT V-16 (Continued)
Strategy Attributes for Constructing Pedestrian Refuge Islands and Raised Medians

Attribute	Description
	U-turns (i.e., the Michigan left turn; go to http://www.michiganhighways.org/indepth/michigan_left.html), so that businesses are easily accessible.
	Pedestrian refuge islands may conflict with the need to provide open pavement for right-turning traffic with large turning paths. A right-turn slip lane can accommodate trucks and other vehicles with large turning paths, but it needs to be well designed to discourage high-speed vehicle turns and to improve the right-turning motorist's view of pedestrians.
	Raised medians require landscape maintenance. They can also make utility placement and maintenance more difficult and complicate construction zone detours.
Appropriate Measures and Data	Performance measures include the number of crashes involving pedestrians crossing a street. The installation of a median barrier may have safety benefits for vehicular traffic as well. Therefore, vehicular crashes should also be documented, especially those related to left-turn and angle crashes at driveways. Operational impacts may also occur that should be measured. Surrogate pedestrian safety measures include pedestrian-vehicular conflicts, pedestrians trapped in the middle of the road, and aborted crossings.
Associated Needs	A public information campaign will help businesses and motorists prepare for changed traffic conditions.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	The DOT, or other public agencies that implement these changes, should involve all potentially affected parties early in the planning process. Agencies may need to develop new or revised policies regarding the use of these devices. Public hearings may be needed if driveway access will be restricted.
Issues Affecting Implementation Time	Implementation time may be affected by the amount of public involvement and controversy surrounding the proposed program This can occur during the planning, design, and funding acquisition processes.
Costs Involved	The cost for pedestrian refuge islands and raised medians will vary widely, depending upon the design, site conditions, and use of landscaping and whether the median can be added as part of another street construction project. See Appendix 9 for estimates of typical cost.
Training and Other Personnel Needs	None identified.
Legislative Needs	None identified.
Other Key Attributes	
	None Identified.

Strategy 9.1 A4 Provide Vehicle Restriction/Diversion Measures

This strategy involves the installation of physical features in the roadway to force or prohibit specific motorist actions such as turns or through movements. These physical features create a visual impression that the street is not intended for through traffic. Signs such as "No Through Traffic" and "Dead End" are needed to advise drivers that they are approaching a vehicle-restricted area. Restriction and diversion measures should be used sparingly and

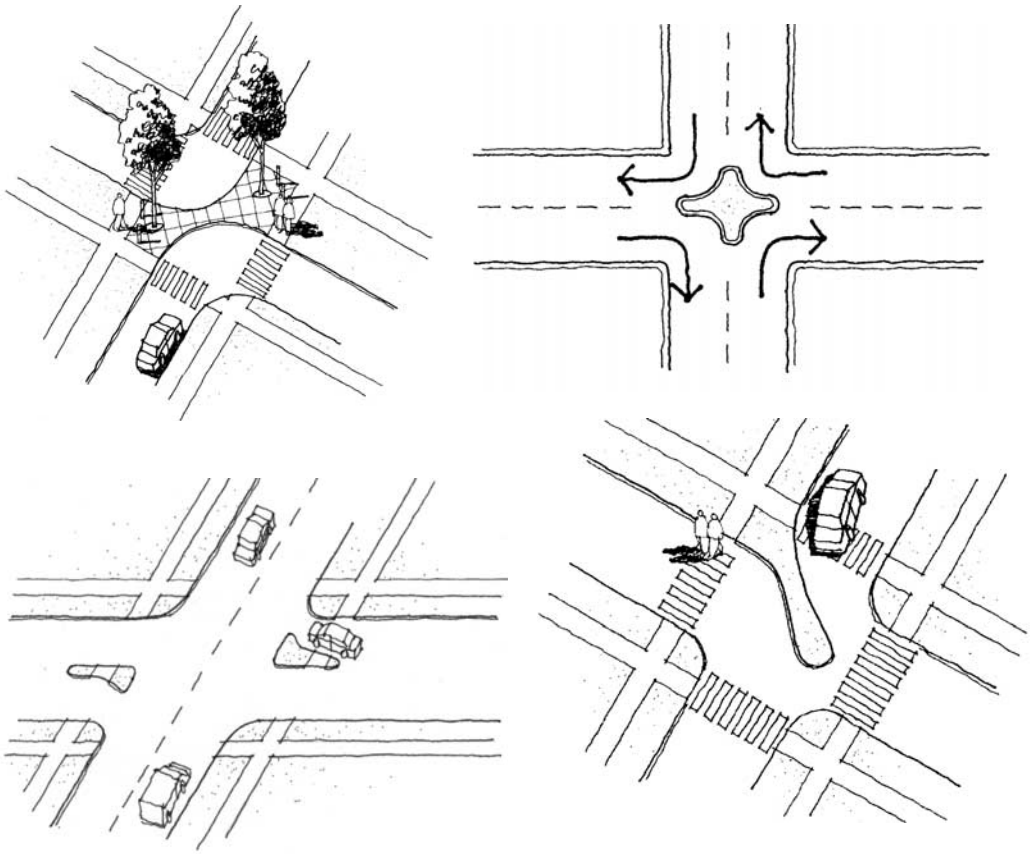
thoughtfully, since they can cause the vehicular problem to simply shift to another street. For most problem situations, traffic calming is the appropriate solution.

This strategy includes four countermeasures (see also FHWA's *Pedestrian Facilities Users Guide* (U.S. Department of Transportation, 2002), available at http://www.walkinginfo.org/pdf/peduserguide/peduserguide.pdf).

Diverters

Diverters prevent certain through and/or turning movements at residential street intersections. Exhibit V-17 illustrates four types of diverters. A diagonal diverter prevents through movements by forcing right or left turns. A star diverter consists of a star-shaped island placed in the intersection to force right turns from each approach. A truncated diagonal diverter has one end open, to allow additional turning movements. Other types of island diverters, such as a forced turn diverter, can be placed on one or more approach legs to prevent through movements and left turns, so that vehicles are forced to turn right. Pedestrian, bicycle, and emergency vehicle access, as well as stormwater drainage, should be accommodated when designing diverters. If a street is a major bicycle corridor, consideration should be given to constructing a diverter that still allows bicyclists to pass through, and in general less-restrictive measures should be considered before installing diverters.

EXHIBIT V-17
Four of several types of diverters.



Additional information on the use of diverters can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Management—Diverters, http://www.walkinginfo.org/de/curb1_print.cfm?codename=33e&CM_maingroup=TrafficManagement
- Fehr and Peers Transportation Consultants, Traffic Calming.Org, http://www.trafficcalming.org/toolbox/diag-divert.html
- Portland Department of Transportation, Traffic Calming, http://www.trans.ci.portland.or.us/trafficcalming/devices/Volume/DIVERTERS.HTM
- EcoCity Cleveland, Transportation Choices, http://www.ecocitycleveland.org/transportation/traffic/tools/diverter.html

Partial Street Closure

A partial street closure involves physically closing or blocking one direction of motor-vehicle travel into or out of an intersection (Exhibit V-18). It could also block one entry point to a two-way street (although after this point the street may remain two way). A partial street closure should always allow for easy access by pedestrians (including those in wheelchairs) and bicyclists, as well as emergency vehicles. The impact of a closure on traffic flow patterns on the surrounding streets should be considered before implementing a partial street closure at the entrance to a neighborhood or area (Exhibit V-18).

Additional information on the use of partial street closure can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Management—Partial Street Closure, http://www.walkinginfo.org/de/curb1_print.cfm?codename=35e&CM_maingroup=Traffic+Management&1.x=16&1.y=14
- City of Edgewood, Wash., http://www.ci.edgewood.wa.us/Cops/Safe%20Journey/Library/countermeasures/38.htm
- ITE—Traffic Calming Measures: Raised Intersection, http://www.ite.org/traffic/closure.htm

EXHIBIT V-18
A partial street closure involves physically closing or blocking one direction of motor-vehicle travel into or out of an intersection. (Photo by Dan Burden)

Full Street Closure

With a full street closure, a physical barrier is installed to block a street to motor-vehicle traffic and provide some means for vehicles to turn around (Exhibit V-19). If a full street closure is done, it should always allow for easy access by pedestrians (including those in wheelchairs) and bicyclists. Emergency vehicles should also be able to access the street. This can be done using an electronically operated barrier that permits large vehicles, but not passenger cars, to traverse it. Alternatively, one can use ground-cover plantings that emergency vehicles can easily traverse. Finally, surface drainage must be accommodated.

Additional information on the use of full street closure can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Management—Full street closure, http://www.walkinginfo.org/de/curb1_print.cfm?codename=34e&CM_maingroup=Traffic+Management&1.x=10&1.y=14
- City of Palo Alto, Calif., http://www.cityofpaloalto.org/transportation/ntcp/appendix/item18.pdf

Pedestrian Street

There are two types of pedestrian streets: (1) those that eliminate motor-vehicle traffic (deliveries may be permitted during off-peak hours) and (2) those that allow some motor-vehicle traffic (often limited to buses or taxis) at very low speeds. A pedestrian street can be part time, as in New Orleans, where removable barriers are used to close French-Quarter streets to motorists at night. Pedestrian streets have been successful in places that are thriving and have high volumes of pedestrians.

There are several examples of successful pedestrian street implementation:

- http://web.dailycamera.com/pearl/19xwor.html
- http://www.getboulder.com/25th/pearlstreet.html
- http://www.streetswithoutcars.com/

EXHIBIT V-19
A full street closure should always allow for easy access by pedestrians and bicyclists. (Photo by Dan Burden)

Additional information on the use of pedestrian streets can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Management—Full street closure, http://www.walkinginfo.org/de/curb1_print.cfm?codename=36e&CM_maingroup=Traffic+Management&1.x=15&1.y=2
- Project for Public Spaces (PPS), *Traffic Calming 101*, http://www.pps.org/imagedb/category?gallery_id=829

EXHIBIT V-20
Strategy Attributes for Providing Vehicle Restriction/Diversion Measures

Attribute	Description
Technical Attributes	
Target(s)	Motor vehicles: These countermeasures are designed to reduce or eliminate motor-vehicle traffic on low-volume streets, especially cut-through traffic in neighborhoods.
Expected Effectiveness	*General* Pedestrians benefit because they are exposed to fewer motor vehicles, which means less risk of a crash, fewer conflicts, and a higher perception that it is safe to walk without being hit by a vehicle. *Street Closure* In Upsala, Sweden, streets were closed to vehicular traffic, one-way flow was instituted on bypass routes, and bus-only streets were implemented. Lovemark (1974) examined the impact of this area-wide traffic-restriction plan on pedestrian risk, defined as the probability of a collision that resulted in personal injury. The risk for pedestrians fell by 29 percent within the restricted area, but rose by 30 percent outside the restricted area. A study of street closures and other devices at 19 sites in London, England, found that pedestrian crashes declined by 24 percent (Brownfield, 1980).
Keys to Success	**A.** Any full or partial street-closures must be coordinated with local school officials (for bus service), sanitation, fire and police departments, and any other agency that needs to use the street to ensure services are maintained. **B.** Those countermeasures that are permanent must be appropriate at all hours of the day and night. **C.** These countermeasures should be part of an overall traffic management strategy. **D.** When considering these measures, it is highly desirable to include the entire neighborhood in the decision-making process. This will allow input from the entire affected area and will help prevent the level of road safety in one part of the neighborhood from being sacrificed to benefit another part. It is important to keep residents and businesses informed on what is being proposed, how it can benefit them, and what the likely tradeoffs are. A public-information and education program is thus important to the success of such projects. The affected residents and businesses should be able to provide input so that their concerns can be addressed. **E.** A test period should be used to identify, and make adjustments to, potential problems for residents and others in the adjacent areas, as well as emergency and school access.

EXHIBIT V-20 (Continued)
Strategy Attributes for Providing Vehicle Restriction/Diversion Measures

Attribute	Description
Potential Difficulties	*General* The disadvantages of these countermeasures are their potential high cost, negative impact on emergency-vehicle response times, loss of convenient motor-vehicle access to some parts of a neighborhood, and diversion of traffic onto nearby streets. *Diverters* Diverters affect residents more than through traffic. *Street Closure* Full street closures will create extensive out-of-the-way travel for some residents and can have negative economic effects on adjacent businesses. Partial street closures will create out-of-the-way travel for some residents, but are less disruptive to neighborhood access, drainage, and emergency/large vehicle access. Vehicle speeds may increase on streets that become one-way. *Pedestrian Street* Pedestrian streets, which are created with the intent of attracting people in declining areas, have usually been unsuccessful.
Appropriate Measures and Data	The primary measure of effectiveness is frequency of crashes, both vehicle-vehicle and vehicle-pedestrian. The number of motor vehicles, number of conflicts between motor vehicles and pedestrians, and vehicle speeds may also be used as safety surrogates. Measures of safety should be assessed for nearby neighborhood-street segments affected by the diverted traffic and not just the targeted road segment. Operational impact measures include motorist delay and vehicle-miles of travel. If businesses are affected, any evaluation of program effectiveness must also take into account economic losses or gains for these businesses.
Associated Needs	The closure of one or more road segments has area-wide impact. A public information campaign is needed to make affected populations aware of the reasons for, and benefits of, the program. In addition, an enforcement program will greatly enhance the effort, especially during the introductory period for the changes.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	Mechanisms are needed for including the entire neighborhood in the decision-making process. Residents, area businesses, and schools, as well as local sanitation, fire, and police departments should be included in the process.
Issues Affecting Implementation Time	It may take 1 or more years to implement these countermeasures. Studies should be conducted to determine whether one or more of these countermeasures would be helpful at a specific location and to identify potential negative consequences. The process includes working with affected residents, businesses, schools, the local police and fire departments, and others to address their concerns. This public involvement process may take awhile, especially if the proposed countermeasures prove to be controversial. The types of vehicle diversion, and the locations within a neighborhood, may need to be modified. The availability of funds to cover the costs of installation depends upon local and state funding cycles.

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EXHIBIT V-20 (Continued)
Strategy Attributes for Providing Vehicle Restriction/Diversion Measures

Attribute	Description
Costs Involved	Costs will vary widely, depending upon the type of countermeasure chosen and the environment in which it is to be installed, including modifications needed to accommodate drainage. Some typical costs are given in Appendix 10.
Training and Other Personnel Needs	*General* Training is needed on how to work with neighborhood groups and build a consensus for a traffic mitigation plan. *Partial Street Closure* Police enforcement may be needed to prevent motorists from violating a partial street closure.
Legislative Needs	Police may be encouraged to enhance enforcement of a restriction if an ordinance were passed that allowed for a reduced fine and no points for violating cut-through traffic restrictions that are not safety related. This might also help gain public support for the measures.
Other Key Attributes	
	None.

Strategy 9.1 A5: Install Overpasses/Underpasses

Pedestrian Overpasses and Underpasses

Pedestrian overpasses and underpasses (i.e., bridges and tunnels) allow for the uninterrupted flow of pedestrians separate from vehicular traffic (Exhibit V-21). Because these are high cost, require extensive time to implement, and are usually visually intrusive, they are primarily used as measures of last resort.

EXHIBIT V-21
Pedestrian overpasses and underpasses allow for the uninterrupted flow of pedestrians separate from vehicular traffic. (Photo by Yan Jai)

EXHIBIT V-22
Strategy Attributes for Installing Overpasses and Underpasses

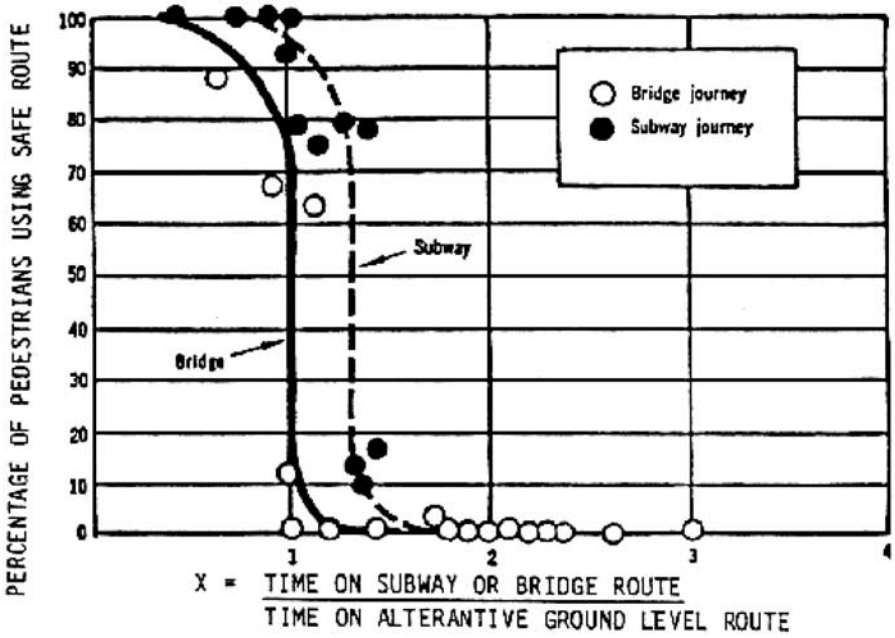
Attribute	Description
Technical Attributes	
Targets	This strategy principally targets pedestrians who are faced with crossing a freeway or other high-speed, high-volume arterial street and is especially relevant at locations with high pedestrian volumes. Railroad tracks are also sometimes targeted for overpasses or underpasses.
Expected Effectiveness	The effectiveness of these treatments depends largely upon the likelihood they will be used by most or all pedestrians who will cross the street. Reductions in pedestrian crashes of up to 90 percent have been found in Tokyo, Japan, after installing overpasses along with fencing to prevent at-grade crossings. *Accident Prevention Effects* (Japan Road Association, 1969) reported the effects of 31 pedestrian overpasses in Tokyo, Japan, on pedestrian crashes. When the numbers of crashes within 100 meters of the overpasses during the 6-month periods before and after installation were compared, it was found that pedestrian-related crashes decreased by 91 percent. The number of crashes within 200 meters fell by 85 percent. The effectiveness of pedestrian grade separation depends largely upon the proportion of pedestrians crossing at or near it that uses it. In turn, the level of use depends on convenience and walking distances compared with alternative crossing locations. Moore and Older (1965) found that most pedestrians will use an overpass if the walking time to use the overpass is the same (or less) as crossing at street level. However, if the walking time to use an overpass is 50 percent longer than crossing at street level, almost no one will use the overpass. This is illustrated in the figure below. 

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EXHIBIT V-22 (Continued)
Strategy Attributes for Installing Overpasses and Underpasses

Attribute	Description
Keys to Success	As depicted above, studies have shown that many pedestrians will not use an overpass or underpass if they can cross at street level in about the same amount of time. Overpasses work best when the topography allows for a structure without ramps (e.g., overpass over a below-grade freeway). Underpasses work best when designed to feel open and accessible. Pedestrians will generally not use these facilities if a more direct route is available. Tall fences and other pedestrian barriers are often used to channel pedestrians to use the overpass or underpass. However, these are not always effective, since pedestrians may cut the fence or simply go around the barriers and cross at driveways or intersections. Ramps must be designed to accommodate pedestrians in wheelchairs and meet ADA standards. Stairs or elevators used to supplement the ramp will increase use while reducing the crossing time. Some pedestrian bridges have included public art projects to improve their appearance and make them more appealing to the public.
Potential Difficulties	Difficulties include obtaining funds for retrofitting or installing an overpass or underpass. Also, it is often difficult to ensure that pedestrians will use the facility without providing high fencing, and such fencing can be visually unappealing and not always effective (e.g. when pedestrians cut holes in the fence). Nearby residents and other property owners may find a pedestrian bridge "ugly," and some residents may complain of a loss of privacy. The extensive ramps required by ADA often use sizable amounts of right-of-way on each side of the overpass. Underpasses can have chronic drainage and associated debris problems if not properly designed and maintained. Crime, vandalism, and graffiti can also cause problems. Adequate lighting is essential.
Appropriate Measures and Data	Performance measures include the number or percent of crashes involving pedestrians crossing the street and the change in probability of being involved in a crash. A surrogate safety measure is the percentage of pedestrians who use the facility compared to those crossing at street level.
Associated Needs	Overpasses and underpasses must accommodate all persons, as required by the ADA. These measures include ramps or elevators. Extensive ramping will accommodate wheelchairs and bicyclists but results in long crossing distances that discourage use. High fences or other barriers may be needed to block pedestrians from crossing at street level.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	State and many local DOTs have the organizational structure to implement this strategy. Overpasses and underpasses can either be retrofitted to existing roadways or included in the planning and design of new roads.
Issues Affecting Implementation Time	The time required to implement overpasses or underpasses is certainly affected by the ability and desire of the agency to obtain needed funding. Further, there is a need to satisfy ADA requirements, which can affect the schedule for implementation. Finally, significant time is required to design the structure and acquire any additional right-of-way for it.

EXHIBIT V-22 (Continued)
Strategy Attributes for Installing Overpasses and Underpasses

Attribute	Description
Cost Involved	The cost for an overpass or underpass can range from $500,000 to $4 million, depending on site characteristics and right-of-way acquisition required.
Training and Other Personnel Needs	Designers must be trained regarding ADA requirements.
Legislative Needs	None.
Other Key Attributes	
	Underpasses can also work very well for bicyclists, since cyclists gain speed going down, which then propels them up the other side.

Objective 9.1 B—Improve Sight Distance and/or Visibility Between Motor Vehicles and Pedestrians

Strategy 9.1 B1: Provide Crosswalk Enhancements

The intent of marked crosswalks is to indicate the optimal or preferred locations for pedestrians to cross. They also help designate right-of-way and may encourage motorists to yield to pedestrians. Marked crosswalks are commonly installed at signalized intersections, as well as other high-volume pedestrian-crossing locations, such as school zones. Acceptable crosswalk marking patterns are given in the MUTCD. Marked crosswalks are desirable at some locations having regular pedestrian crossing activity (often in conjunction with other measures). In some cases, crosswalks can be raised and should often be installed in conjunction with other physical roadway enhancements that reinforce the crosswalk and/or reduce vehicle speeds. It is sometimes useful to supplement crosswalk markings with motorist warning signs (Exhibit V-23). The report recommends that on multilane roads with traffic volumes above about 12,000, more substantial pedestrian crossing treatments are needed to help pedestrians to cross them safely.

EXHIBIT V-23
It is sometimes useful to supplement crosswalk markings with motorist warning signs. (Photo by Michael Ronkin)

Another crosswalk enhancement sanctioned in the 2003 MUTCD is in-pavement flashing lights. Amber lights are embedded in the pavement on both sides of the crosswalk, oriented to face oncoming traffic. When the pedestrian activates the system, either by

using a push button or through detection from an automated device, the lights begin to flash at a constant rate, warning the motorist that a pedestrian is in the vicinity of the crosswalk ahead. There have been several municipalities that have implemented in-pavement lights, including the city of Kirkland, Washington, which successfully installed lights in 17 locations in 1997. For more information see http://www.walkinginfo.org/pedsmart/plkirk.htm.

Marked crosswalks should only be used at locations with adequate visibility. Reasonable accommodation should be made to make crossings convenient as well as safe.

Crosswalk markings should be visible to motorists, particularly at night, and should not be slippery or create tripping hazards (Exhibit V-24). Although granite and cobblestones are aesthetically appealing materials, they are generally not appropriate for crosswalks because they can cause tripping hazards and difficulties for wheelchairs. Stamped or colored concrete should be accompanied with paint lines and have a nonstamped area in the center, between the two strips of stamped concrete. Inlay tape is one of the best materials for marking crosswalks because it is highly reflective, long lasting, slip resistant, and low maintenance. Both inlay tape and thermoplastic are more cost-effective in the long run than paint. Inlay tape is recommended for new and resurfaced pavement, while thermoplastic may be a preferred option on rough pavement surfaces. Crosswalk markings should be placed to include the curb ramps, so that a wheelchair does not have to leave the crosswalk to access the ramp.

Recommended guidelines and priorities and/or enhancements for crosswalk installation at uncontrolled locations are available in the 2000 MUTCD and the *Traffic Control Devices Handbook* (Institute of Transportation Engineers, 2001b) Chapter 13, Pedestrians. These guidelines are based upon a major nationwide study for FHWA (see Appendix C of Federal Highway Administration [2002]). Recommendations are also given for providing other pedestrian crossing enhancements at uncontrolled locations with and without a marked crosswalk.

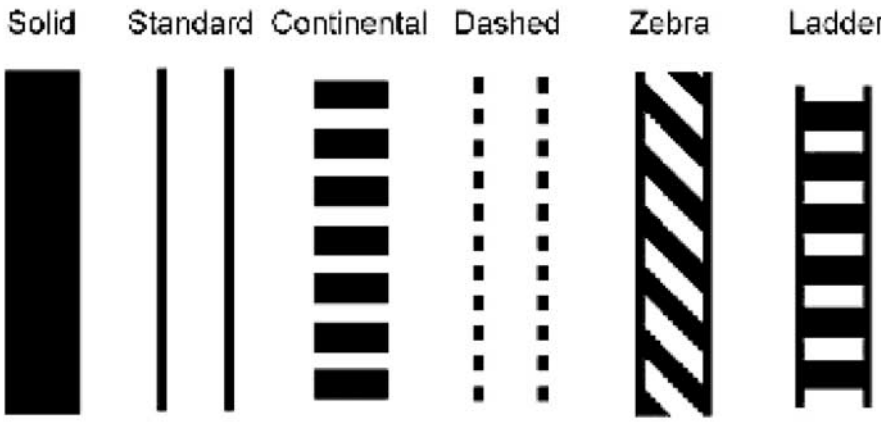
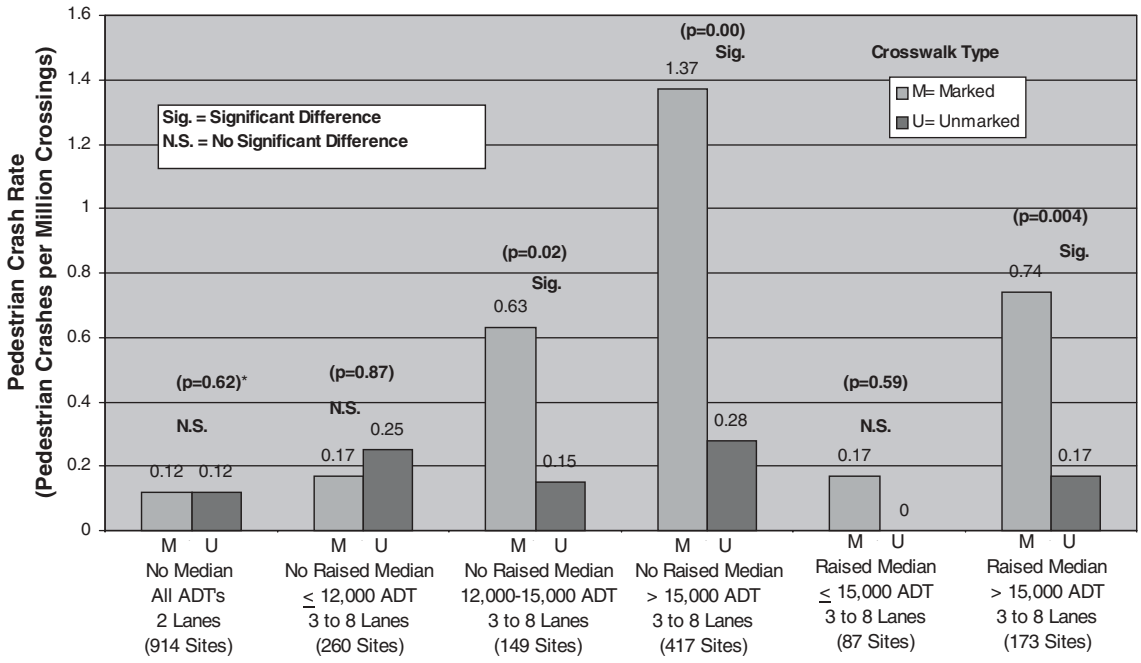


EXHIBIT V-24
Example of Crosswalk Marking Patterns (Note: Neither the solid crosswalk nor the dashed lines (which are common in Europe) are included in the 2000 MUTCD.)

EXHIBIT V-25
Strategy Attributes for Providing Crosswalk Enhancements

Attribute	Description
Technical Attributes	
Target(s)	This strategy is directed at pedestrians, to guide them to the best location to cross a high-volume, or wide, street when a signal is not present. Marked crosswalks may also serve to alert drivers of pedestrian crossing activity. (For signalized crossings, see Strategy 9.1 C3.)
Expected Effectiveness	Zegeer et al. (2002) performed a study of 1,000 marked crosswalk sites and 1,000 matching unmarked sites in 30 U.S. cities. The study found that on two-lane roads there was no statistical difference in pedestrian crash rate between a marked crosswalk with no supplementary treatments at an uncontrolled location and an unmarked crosswalk. On multilane roads with traffic volumes above about 12,000 vehicles per day, a marked crosswalk (without other substantial improvements) was associated with a significantly higher pedestrian crash rate (after controlling for other site factors) compared to an unmarked crosswalk (see exhibit below). One reason for the higher crash rate was an increase in "multiple-threat" crashes. This situation arises when a motorist stops to let a pedestrian cross and the pedestrian is struck by a motorist traveling in the same direction whose view of the pedestrian is blocked by the stopped vehicle (see Exhibit III-10). Another reason for the higher crash rates at marked crosswalk-locations was that pedestrians over 65 years old were much more likely to cross at these locations, and, compared to other age groups, these older pedestrians have a higher risk of being struck by cars.



Pedestrian Crash Rates vs. Types of Crossing, Uncontrolled Approaches

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EXHIBIT V-25 (Continued)
Strategy Attributes for Providing Crosswalk Enhancements

Attribute	Description
	The same study revealed that raised medians were associated with significantly lower pedestrian crash rates on multilane roads compared to roads with no raised median. Again, older pedestrians had crash rates that were high relative to their crossing exposure. The figure above summarizes the study findings. The report's recommendations for adding crosswalks and other pedestrian crossing enhancements are contained in Appendix 11. Although there was no significant difference in the pedestrian crash rates for three-lane roads vs. those with four or more lanes, the report recommendations address each of these situations separately. For more details on this study, see Appendix 11 and the referenced report. The reader is also referred to the ITE Web site (http://www.ite.org/) for updated guidelines currently under development by the ITE Pedestrian and Bicycle Council, Subcommittee on Pedestrian Treatments at Uncontrolled Crossings.
Keys to Success	Crosswalk locations should be convenient for pedestrians and should be accessible for pedestrians in wheelchairs. Crosswalk markings, without related enhancements, are unlikely to increase pedestrian safety. Ideally, crosswalks should be used in conjunction with other measures, such as curb extensions, to improve the safety of the crossing, particularly on multilane roads with average daily traffic (ADT) above about 10,000. Marked crosswalks are important for pedestrians with vision loss. Detectable warnings are needed to advise pedestrians with visual impairments where the curb ramp ends and the street begins. See also “Accessible Pedestrian Signals,” Strategy 9.1 A2. For more details, see section 4.4.2 of the report *Designing Sidewalks and Trails for Access, Part II of II* (Federal Highway Administration, 2001). Marked crosswalks should guide pedestrians to cross at locations where there is street lighting at night.
Potential Difficulties	Inconsistent or excessive use of marked crosswalks can result in confusion to both pedestrians and drivers, violate driver expectancies, and lead to disrespect for the control devices being used. It may also pose liability risks for the public agency.
Appropriate Measures and Data	Measures of effectiveness include the number of pedestrians struck while crossing the street. Measures of driver and pedestrian behavior (e.g., near misses, conflicts, and violations of the crosswalk) may be used as safety surrogates. The proportion of pedestrians using the marked crosswalk may also be a measure of effectiveness.
Associated Needs	A program to improve pedestrian crossings should be coordinated with an enforcement and public-information and education campaign (see Objective 9.1 D)
Organizational and Institutional	
Organizational, Institutional, and Policy Issues	It is important to establish a sound policy for installing pedestrian crossing enhancements. The city of Seattle has implemented an excellent policy in this regard (check: http://www.seattle.gov/transportation/pedpolicy.htm). Also see material available at the following pedestrian web-site: http://www.walkinginfo.org/pdf/r&d/crosswalk_021302.pdf
Issues Affecting Implementation Time	Significant time will be required to prepare a truly comprehensive approach. Weather and season of the year may also affect the scheduling of adding or re-striping marked crosswalks. In general, it is possible that a program can be completed within a year.
Costs Involved	$100 for standard striped crosswalk, $300 for a ladder crosswalk, and $3,000 for a patterned concrete crosswalk.

EXHIBIT V-25 (Continued)
Strategy Attributes for Providing Crosswalk Enhancements

Attribute	Description
Training and Other Personnel Needs	Training most importantly relates to which type of crossing enhancement to select under different traffic and roadway conditions.
Legislative Needs	A set of laws are needed at the state and local level to support the proper relationship between pedestrians and vehicles on the roadway. The Model Uniform Vehicle Code (http://www.ncutlo.org) can serve as a resource. An example of a set of laws in Seattle, Washington may be found at http://www.seattle.gov/transportation/pedpolicy.htm. This location also links to a pictorial representation of the State of Washington law on crosswalks.
Other Key Attributes	
	None.

Strategy 9.1 B2: Implement Lighting/Crosswalk Illumination Measures

Good placement of lighting and adequate lighting levels can enhance an environment for walking, as well as increase pedestrian safety and security. Pedestrians often assume that motorists can see them at night, since the pedestrian can see the oncoming headlights. Therefore, emphasis is needed on providing the driver the help needed to see the pedestrian in time to stop.

In commercial areas with nighttime pedestrian activity, streetlights and building lights can enhance the visibility of pedestrians to motorists. It is best to place continuous streetlights along both sides of arterial streets to provide for consistent levels of lighting along a roadway. Nighttime pedestrian crossing areas should be properly illuminated. This includes lighting pedestrian crosswalks and approaches to the crosswalks (Exhibit V-26).

In commercial or downtown areas, pedestrian-level lighting may be placed over the sidewalks to improve pedestrian safety, security, and comfort. Mercury vapor, incandescent, or less-expensive high-pressure sodium lighting may be used for pedestrian-level lighting. Low-pressure sodium lights are more energy-efficient and create less light pollution, but their yellow color can "mask" the amber lights at traffic signals, and they are generally less popular with both pedestrians and drivers.

EXHIBIT V-26
Nighttime pedestrian crossing areas should be properly illuminated. (Photo by Dan Burden)

EXHIBIT V-27
Strategy Attributes for Implementing Lighting/Crosswalk Illumination Measures

Attribute	Description
Technical Attributes	
Target	This strategy is directed at motorists who are driving at night in areas with pedestrian activity.
Expected Effectiveness	In Perth, Australia, there were 62 percent fewer pedestrian crashes at night after crosswalks were floodlighted than before (Pegrum, 1972). The installation of a combined illumination and signing system for crosswalks in Israel reduced nighttime pedestrian crashes by 43 percent, while daylight crashes were relatively unchanged (Polus and Katz, 1978). Freedman et al. (1975) observed the impacts of improved lighting on driver and pedestrian behavior in Philadelphia. It was found that pedestrian search behavior improved significantly, and drivers appeared to be more aware of crosswalks.
Keys to Success	Install lighting on both sides of wide streets and streets in commercial districts. Provide uniform lighting levels to avoid “dark spots.”
Potential Difficulties	Difficulties include acquiring adequate funding to install new lighting in developing areas. Also, it should be noted that existing street lighting may be ineffective for pedestrians if it is too high or if trees block the light from reaching the sidewalk.
Appropriate Measures and Data	Measures of effectiveness for evaluating lighting improvements include the number of nighttime pedestrian crashes and the percentage of all crashes that occur at night. Increased pedestrian activities and lower crime rates can also be used as measures of improved conditions.
Associated Needs	In addition to installing good-quality lighting, there is a need to provide regular maintenance and monitoring of lighting levels.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	It is important for state and local agencies to establish policies for lighting in pedestrian areas, as well as a procedure for identifying and implementing needed lighting improvements. Many state DOTs have policies that limit or prohibit payment for lighting as part of road construction projects, leaving its funding as a local contribution.
Issues Affecting Implementation Time	Availability of funding for lighting improvements is a key issue affecting implementation time. Also, local governments often prefer more expensive, decorative lighting versus the standard lighting provided by many state standards. Resolving these issues, including who pays for what, can delay lighting project completion.
Costs Involved	Cost varies widely, depending upon the type of lighting fixtures, the location of the power source, overhead versus underground power services, and service agreement with local utility company.
Training and Other Personnel Needs	Lighting improvements can be made by agency personnel or by private contract. In either case, experienced personnel are needed to design and install lighting improvements. Monitoring and maintenance programs are needed, including night inspections.
Legislative Needs	None.
Other Key Attributes	
Legislative Needs	The type of lighting (mercury vapor, incandescent, or high-pressure sodium) should be selected based on the needs for a given roadway situation.

9.1 B3: Eliminate Screening by Physical Objects

Sight Distance. Crosswalks should not be placed close to horizontal or crest vertical curves to avoid inadequate sight distance to crossing pedestrians.

Parking. Pedestrian crashes become more likely when the motorist and pedestrian cannot see they are on intersecting paths. Screening can occur in several ways. First, a parked vehicle can screen the view of a pedestrian beginning to cross the street (Exhibit V-28). Restricting parking in advance of the crosswalk is one way to eliminate this problem. The MUTCD indicates that there should be no parking 20 feet in advance of crosswalks. Another way to solve this problem is to install curb extensions at intersection and midblock crosswalk locations (see Section 9.1 A3). This treatment increases the visibility of pedestrians starting to cross, but the pedestrian is still already in the lane of travel once he or she enters the roadway. Therefore curb extensions do not eliminate the requirement to restrict parking in advance of the crosswalk.

Utility Poles, Signs, and Street Furniture. A properly designed street corner will improve sight distance. Crashes can occur when a pedestrian steps out from behind a utility pole or other obstructions which block the pedestrian's and motorist's view of each other. Eliminating trash cans, newspaper boxes, and other clutter from the intersection can improve intersection sight distance.

EXHIBIT V-28
Restricting parking in advance of a crosswalk is one way to improve the sight distance between motorists and pedestrians. (Photo by Charlie Zegeer)

Vehicles Yielding Too Close to Crosswalk. This is documented to be the most dangerous type of screening situation involving crosswalks. In this instance, a motorist stops so close to the crosswalk that the stopped vehicle will block the view of other oncoming motorists in the adjacent lane. If the pedestrian steps out from behind the yielding vehicle just as the other oncoming vehicle arrives at the crosswalk, a crash is likely to occur. There is a secondary danger that may occur in this situation. A vehicle following behind the yielding vehicle could attempt to pass the stopped vehicle and will not see the pedestrian until it is too late. Both types of crashes are very dangerous because the driver only sees the pedestrian at the last moment and therefore has little or no time to brake. The best way to address this problem is to install yield markings along with a sign instructing motorists to yield at the marking (Exhibit V-29). If the motorist stops sufficiently far back, it increases sight distance and markedly reduces the chance of a multiple-threat crash.

The use of advance markings also reduces the chance of a rear-end crash, which could result when an inattentive driver crashes into the back of a vehicle that is yielding to a pedestrian. This type of crash can produce serious injuries not only to the vehicle occupants but also to the pedestrian, if the front vehicle is pushed into the pedestrian as a result of the crash. If there is sufficient separation between the yielding vehicle and the pedestrian, it may be possible to avoid the pedestrian being involved in such a crash.

EXHIBIT V-29
Installing advance yield markings along with a sign instructing motorists to yield can reduce the chance of a pedestrian crash and also reduce the likelihood of a rear-end collision. (Photo by Michael Ronkin)

EXHIBIT V-30
Strategy Attributes for Reducing Screening by Physical Objects at Crosswalks

Attribute	*Description*
Technical Attributes	
Target	This strategy is directed at physical conditions which result in a pedestrian, who is crossing the street, being screened from view.
Expected Effectiveness	Studies have shown that reducing visual screening by installing advance yielding markings can produce large reductions in motor-vehicle/pedestrian conflicts at

EXHIBIT V-30 (Continued)
Strategy Attributes for Reducing Screening by Physical Objects at Crosswalks

Attribute	*Description*
	crosswalks (Van Houten et al., 2003, 2001c). Compliance with the markings has been shown to be high (Nee and Hallenbeck, 2003; Van Houten et al., 2003, 2001c) and conflict reductions of between 76 percent and 77 percent have been reported (Van Houten et. al, 2003, 2001c).
Keys to Success	A basic key to success is having a mechanism for identifying problem locations and programming improvements. This can be a combination of active agency field review along with provision for input from law enforcement and the community.
	Design guidelines and criteria are needed to help identify inadequate situations as well as to arrive at effective improvements.
	Where a new control, such as the advance yield marking, is to be employed, it will be important to educate the public on its meaning and appropriate behaviors toward it.
Potential Difficulties	Physical constraints will sometimes make it infeasible to meet the desired standards. For example, markings for advance yield points on approaches to crosswalks may be placed between 20 and 50 feet in advance of the crosswalk. Sometimes the locations of intersections or driveways make optimal placement difficult. Another example is where the street and sidewalk network, along with traffic volumes, creates a natural pedestrian crossing point at an undesirable curve location. In such cases, it will often be expensive, or just infeasible, to change the alignment. Furthermore, the inconvenience to pedestrians that may result from a relocation of the crossing point could make it unacceptable. In such cases, other strategies may have to be employed, including advance warning signs and flashers. As a final example, any time there is elimination of parking, there may be strong resistance, depending upon the surrounding land use and availability of alternative parking locations.
Appropriate Measures	The primary measure of effectiveness would be the change in number of crashes, by type, including crossing pedestrians and rear-end. Pedestrian-vehicle and vehicle-vehicle conflicts might be used as surrogates for early evaluation of a program. Process measures include the number of improvements made and the number of pedestrians affected by the improvements made.
Associated Needs	Advance crosswalk warning signs, electronic devices to alert motorists when pedestrians are crossing, and raised pedestrian refuge islands work together with advance yield markings to increase safety at crosswalks at multilane locations.
	A public-information and education campaign may be needed to inform the public of the institution of new controls with which they may not be familiar.
Organizational and Institutional Attributes	
Organizational Issues	It is often difficult to gain acceptance for a reduction in parking supply in urban areas. It is important to work closely with those merchants, or other users of adjacent development, who may be affected by a reduction in parking. Increased pedestrian flows may result from safer crossing conditions, potentially offsetting the loss of market exposure that a merchant may experience from a small reduction in parking.
	New design criteria and guides may be needed to provide a foundation for implementing some of these strategies.
Cost Involved	Cost components will primarily involve new signs and markings. Conditions may occur where some reconstruction of the roadway or relocation of street furniture may be

(*continued on next page*)

EXHIBIT V-30 (Continued)
Strategy Attributes for Reducing Screening by Physical Objects at Crosswalks

Attribute	*Description*
	involved. In addition, there may be a cost associated with mounting an associated PI&E campaign.
Training and Other Personnel Needs	It will be important for agency staff and others who do this work for the agency to be trained in both identifying the conditions in the field under which the problems being addressed exist and how to redesign the site to eliminate the problem.
Legislative Needs	None

Strategy 9.1 B4: Signals to Alert Motorists That Pedestrians Are Crossing

Pedestrian-Activated Yellow Beacons. Research has demonstrated that the use of overhead pedestrian signs, with flashing beacons, increases driver yielding to pedestrians (Federal Highway Administration, 2000b, 2001; Van Houten et al., 1999b). However, the effects are modest at best. There are two reasons why flashing beacons are not more effective in obtaining driver compliance at crosswalks. First, the use of yellow flashing warning beacons is not specific to pedestrians. Hence, drivers might not expect a pedestrian when they see a flashing beacon. Second, if the beacon is timed for slower pedestrians, the pedestrian has often finished crossing when a driver approaches. Hence, the driver may quickly conclude the pedestrian has finished crossing if a yielding vehicle or a parked vehicle screens the view of the pedestrian. The first problem can be fixed by mounting the beacon on a housing that contains the pedestrian symbol (Van Houten et al., 1999b). The second problem is more difficult to remedy.

Electronic Signs That Indicate the Direction Pedestrians are Crossing. Data also show that overhead electronic LED pedestrian signs (Exhibit V-31) that show the driver the direction the pedestrian is crossing and remind him or her to look for pedestrians is an effective way to increase driver yielding behavior (Nee and Hallenbeck, 2003; Van Houten et al., 1999a). One study compared this sign with a yellow flashing beacon at a site where both devices were installed (Van Houten et al., 1999a). The findings showed that the proportion of drivers that yielded to pedestrians was always higher at times when the electronic sign was activated than at times when the flashing beacon was activated.

EXHIBIT V-31
Electronic signs that show the direction that pedestrians are crossing is an effective way to increase driver yielding behavior. (Photo by Ron Van Houten)

There are probably several good reasons why the electronic signs, which show the

direction the pedestrian is crossing, were more effective than the flashing beacon. First, this type of sign is associated with pedestrians because it uses the pedestrian symbol to signal when a pedestrian is in the crosswalk. Second, it shows the direction the pedestrian is crossing the street. This information helps the driver to better assess whether there is a pedestrian crossing the street or whether the pedestrian has already finished crossing, because it cues the driver what to look for (someone crossing from the right or left). Hence, if the signal indicates someone is crossing from the right, and a vehicle is stopped in the lane on the driver's right, or a delivery truck is parked on the driver's right, the driver will be better warned to proceed cautiously until it is ascertained that the pedestrian is not being screened. Third, the device also signals when pedestrians are crossing from both directions. The LED pedestrian sign also has animated eyes to instruct the motorist to look for the pedestrian, or pedestrians, crossing from a particular direction.

In-Pavement Lighted Markers at Uncontrolled Crossings. Both sides of the crosswalk are lined with encased raised pavement markers. Many treatments include LED strobe lighting in the raised pavement markings (Exhibit V-32). This system involves reinstallation each time the road is resurfaced or affected by utility repairs. The markers tend to be seen only by the first vehicle in a platoon; and when there is also a high volume of traffic in the other direction, it limits a driver's view of the entire crossing. Another disadvantage of in-pavement lighted markers is that they do not show the direction the pedestrian is crossing or whether pedestrians are crossing from both sides of the roadway. Studies in California and Washington State have shown these signs to be effective, but similar results have not been obtained in Florida.

Other Measures at Uncontrolled Crossings. In addition to the measures discussed above, there are experimental measures where less is known about their real-world effects. Many of these measures are discussed in the 2001 report, *Alternative Treatments for At-Grade Pedestrian Crossings* (Institute of Transportation Engineers, 2001a).

Exhibit V-33 shows a crosswalk on a multilane road at a T-intersection. The crosswalk is installed along the path between two bus shelters on the side of the intersection with the fewest conflicts with turning vehicles. The installation includes electronic signs indicating when pedestrians are crossing (along with the direction they are crossing), advance yield markings reminding drivers to yield in advance of the crosswalk, and a cut through the refuge island which forces pedestrians to look in the direction of approaching vehicles before crossing the second half of the roadway.

EXHIBIT V-32
In-pavement markers typically include LED strobe lighting in raised pavement markings. (Photo by Michael Ronkin)

EXHIBIT V-33
Crosswalk on a multilane road at a T-Intersection.

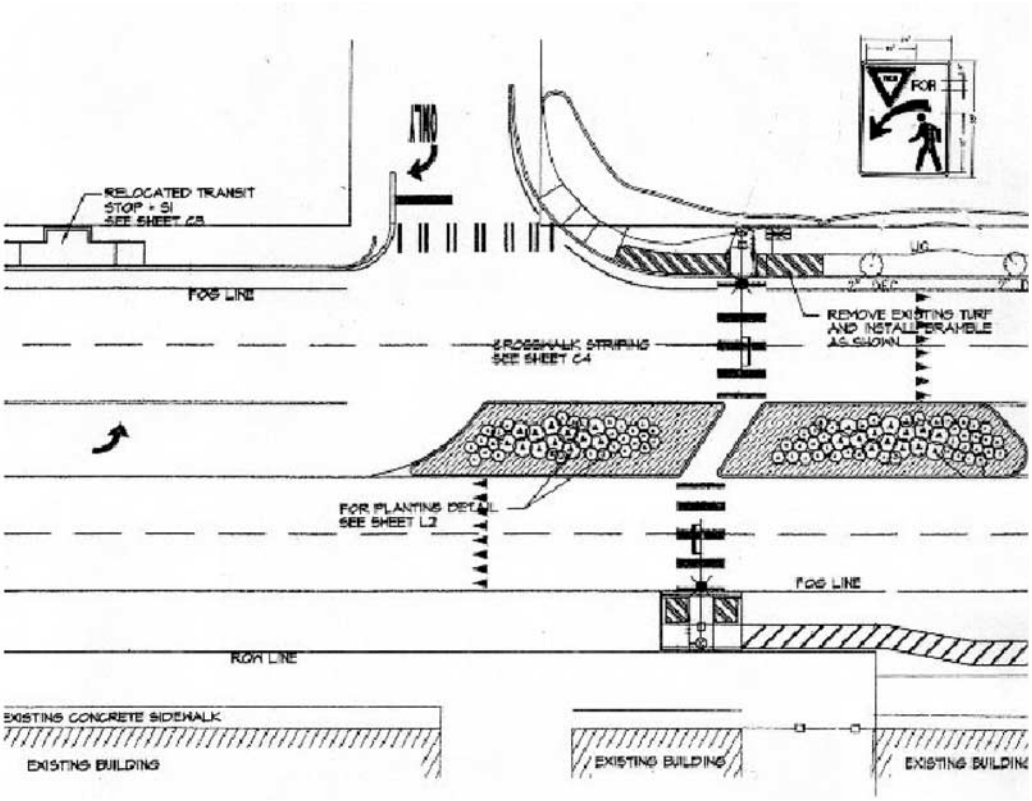


EXHIBIT V-34
Strategy Attributes for Signals to Alert Motorists that Pedestrians Are Crossing

Attribute	*Description*
Technical	
Target	This strategy is directed at drivers who are approaching a crosswalk where pedestrians are crossing.
Expected Effectiveness	Studies have shown that alerting motorists when a pedestrian is crossing the street can increase yielding behavior and reduce conflicts between motorists and pedestrians (Nee and Hallenbeck, 2003; Van Houten and Malenfant, 2001; Van Houten et al., 1999b). Compliance with these signals varies from location to location. The electronic sign indicating the direction the pedestrian is crossing shows considerable promise.
Keys to Success	A basic key to success is having a mechanism for identifying problem locations and programming improvements. This can be a combination of active agency field review along with provision for input from law enforcement and the community. Design guidelines and criteria are needed to help identify inadequate situations, as well as to arrive at effective applications of the strategy.

EXHIBIT V-34 (Continued)
Strategy Attributes for Signals to Alert Motorists That Pedestrians Are Crossing

Attribute	*Description*
	Where a new control, such as this, is to be employed, it will be important to educate the public on its meaning and appropriate behaviors toward it.
Potential Difficulties	Adequate lighting is needed at the crosswalk in addition to these devices. This may not always be available. However, evaluations are underway of some of these devices that can also illuminate the crosswalk from above.
	Maintenance of these devices is critical. The more complex the device, the more things that can go wrong. Maintenance personnel will need to be trained on the special repair requirements, and a program of monitoring will need to be established.
	Unless a pedestrian symbol appears on the yellow-beacon installation, it may not be clear to the driver that the warning involves a pedestrian in the crosswalk. Furthermore, the beacon does not indicate in which direction the pedestrian is crossing.
	In-pavement lighted markers at uncontrolled crossings may not be effective under conditions having vehicle congestion.
Appropriate Measures	The primary measure of effectiveness would be the change in the number of crashes, by type, including crossing pedestrians and rear-end. Pedestrian-vehicle and vehicle-vehicle conflicts might be used as surrogates for early evaluation of the program. Process measures include the number of improvements made and the number of pedestrians affected by the improvements made.
Associated Needs	Prohibited parking in advance of the crosswalk, advance yield markings, and raised pedestrian refuge islands may be supplements, particularly at high-volume multilane sites.
Organizational and Institutional Attributes	
Organizational Issues	New policies and criteria may be needed for selecting, designing, implementing, and maintaining these devices.
Cost Involved	This treatment is somewhat less expensive than a traffic signal and does not significantly impact motorist or pedestrian delay. If an overhead sign is selected, installation on a mast arm will reduce maintenance costs. Pedestrians get an immediate response when they are detected by an automatic sensor or press a button signed “PRESS BUTTON TO ALERT MOTORISTS,” and the motorist need only slow or stop long enough to let the pedestrian cross their portion of the roadway.
Training and Other Personnel Needs	It will be important for agency staff and others who do this work for the agency to be trained in identifying the conditions in the field under which these devices are appropriate, how to design the installation, and how to properly maintain them.
Legislative Needs	None.

Strategy 9.1 B5: Improve Reflectorization/Conspicuity of Pedestrians

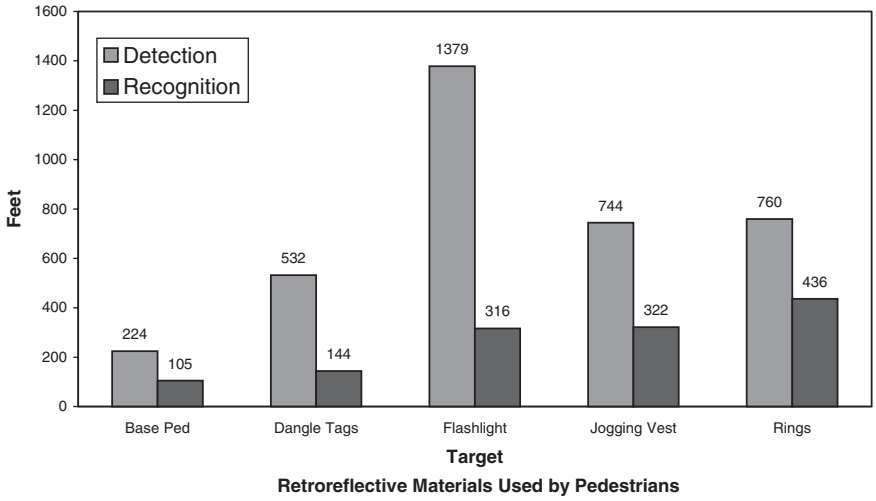
EXHIBIT V-35
Reflectorized vests and other clothing for pedestrians can increase the visibility of a pedestrian at night by a factor of five.

Retroreflective materials are required for roadway markings such as crosswalks, stop lines, and lane markings. These materials reflect light from vehicle headlights and from roadway illumination using specially designed glass beads. Vests and other clothing for pedestrians have also been made with reflective materials (Exhibit V-35). Studies have found that reflectorization can increase the visibility of a pedestrian by a factor of five. However, some retroreflective clothing can lose its reflective properties after repeated washings. Retroreflective material has been used on shoes, backpacks, jackets, and other clothing. The Standard Specification for Nighttime Photometric Performance of Retroreflective Pedestrian Markings for Visibility Enhancement is set by ASTM International (American Society for Testing and Materials International, 2003). For access to ASTM standards, visit the ASTM Web site, www.astm.org.

EXHIBIT V-36
Strategy Attributes for Improving Reflectorization/Conspicuity of Pedestrians

Attribute	Description
Technical Attributes	
Target	This strategy is directed at pedestrians who are walking at night near motor-vehicle traffic.
Expected Effectiveness	A study by Blomberg et al. (1984) investigated the effectiveness of countermeasures to improve the conspicuity of pedestrians and bicyclists. Nighttime field tests were conducted on baseline pedestrians (i.e., wearing a white tee shirt and blue jeans), walking on a test track, compared with pedestrians with dangle tags, a flashlight, jogger's vest, and rings (retroreflective material on headband, wristbands, belt, and ankle bands). The detection and recognition distances are shown in the figure below. In a later 1994 study, Owens et al. (1994) conducted an experiment in which retro-reflective materials were placed on different body locations. Pedestrians wearing reflective materials on knees, waist, elbows, and shoulders were seen more readily. Authors stated that "biological motion" was an important part of detection and recognition by drivers. Seen at night, such motions of the reflectorized materials are more pronounced and are more readily interpreted as human motion.
Keys to Success	*The keys to success include the following:* Working with manufacturers of clothing or shoes to incorporate reflective materials.

EXHIBIT V-36 (Continued)
Strategy Attributes for Improving Reflectorization/Conspicuity of Pedestrians

Attribute	Description
	Pedestrians' awareness that they are not always visible to motorists at night and that factors such as sun glare can interfere with their being detected during the daytime. An accompanying educational/awareness campaign on high risks for pedestrians at night and the need for providing retroreflective materials for pedestrians. The availability of clothing with retroreflective material or retroreflective patches considered stylish enough by the user to want to wear it.  **Retroreflective Materials Used by Pedestrians**
Potential Difficulties	There are difficulties to overcome, such as convincing people of the need to be more visible at night as pedestrians and that they should wear retroreflective clothing (e.g. jacket) when walking at night.
Appropriate Measures and Data	A reduction in the frequency of nighttime pedestrian crashes is a prime measure of effectiveness. A surrogate measure is the percentage of pedestrians wearing more visible or retroreflective clothing at night.
Associated Needs	There is a need for an education/awareness campaign to convey the importance of being visible at night while walking near streets and highways and how to do increase visibility.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	This strategy should also include programs for employees of construction companies, utility companies, or others that routinely work at night in or near the street system to encourage or mandate the use of reflectorization when in the work environment.
Issues Affecting Implementation Time	None.
Cost Involved	Costs for retroreflective materials are minimal for a single person. The implementing agency may experience costs associated with a public-information and education campaign.

(*continued on next page*)

EXHIBIT V-36 (Continued)
Strategy Attributes for Improving Reflectorization/Conspicuity of Pedestrians

Attribute	Description
Training and Other Personnel Needs	None.
Legislative Needs	None.
Other Key Attributes	
	None.

Objective 9.1 C—Reduce Vehicle Speed

As noted in Section III in the general description of the pedestrian crash problem, motor-vehicle speed is an important factor both in the occurrence of pedestrian crashes and the severity of injury sustained by the pedestrian. A later strategy (Strategy 9.1 D2) addresses the role of enforcement in reducing vehicle speeds. The strategies below all focus on speed reduction through roadway or engineering measures.

Strategy 9.1 C1: Implement Road Narrowing Measures

Road narrowing can reduce vehicle speeds along a roadway section and enhance pedestrian movement and safety. Bicycle travel will also be enhanced, and bicyclist safety might improve when bicycle lanes are added.

Roadway narrowing can be achieved in several ways:

- By reducing lane widths (to 3.0 or 3.4 m [10 or 11 ft]) (excess pavement can be striped for use as a bicycle lane or shoulder)
- Through travel lanes can be removed or converted into medians or bike lanes (see Exhibit V-37)
- The street can be narrowed by extending sidewalks and landscaped areas and/or by adding on-street parking within the former curb lines

If no sidewalks exist along the roadway, they normally should be added. If sidewalks exist, and there is adequate width, a landscaped buffer is desirable to provide a buffer area between pedestrians and motor vehicles.

Some roads have more travel lanes or pavement width than necessary and are difficult to cross largely because of their width. Reducing the number of lanes on a multilane roadway will reduce crossing distances for pedestrians and may also slow vehicle speeds. A good example of this measure is to reduce a four-lane undivided road to three lanes (e.g., one lane in each direction with a center turn lane). Such a road conversion, sometimes called a "road diet" can provide positive safety benefits to pedestrians and motorists.

EXHIBIT V-37
This roadway section was converted from a four-lane undivided road to a three-lane road with sidewalks and bike lanes. (Photo by Dan Burden)

Reducing the number of lanes may result in lower vehicle capacity and increased delay. However, the existence of significant levels of left-turn traffic can prevent a four-lane street from realizing considerably lower delay, than for a three-lane section (two through lanes plus a center turn lane). This is because drivers waiting for an adequate gap to turn left, on a four-lane street, may cause delay to through traffic. Under most ranges of volume that have been tested, reducing from four lanes to three lanes results in minimal effects on level of service to vehicles. This is because left-turning vehicles use the center lane of a three–lane section to wait to complete their maneuver.

For Average Daily Traffic (ADT) above approximately 20,000 vehicles per day (vpd) on three-lane roads, traffic congestion may increase to the point of causing motorists to divert to alternative routes. This can create problems on the alternative routes, especially if they are through a residential neighborhood. An analysis should be done of the level of service to determine whether the number of lanes on a roadway is appropriate.

This strategy is usually applied to a roadway section of significant length. There are also spot narrowing improvements that may be implemented at intersection or midblock locations. These include curb extensions and chokers, which are discussed under intersection traffic calming measures (Strategy 9.1 A3).

In deciding whether road narrowing measures are an appropriate strategy for reducing pedestrian crashes, one must always consider potential tradeoffs with respect to vehicular operations and crashes. For example, lane narrowing can make heavy truck and/or emergency vehicle access difficult, and the addition of on-street parking can increase the number of backing-related crashes. Factors such as development type (urban, rural, etc.), vehicle mix (numbers and types of large trucks), vehicle speeds and volumes, pedestrian volumes, roadway function, and availability of alternate routes should be considered when evaluating this tradeoff.

Additional information on road narrowing measures can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Roadway Design—Road/Lane Narrowing, http://www.walkinginfo.org/de/curb1.cfm?codename=9b&CM_maingroup=Roadway%20Design
- Project for Public Spaces (PPS), Traffic Calming 101, http://www.pps.org/buildings/info/how_to/livememtraffic

EXHIBIT V-38
Strategy Attributes for Implementing Road Narrowing Measures

Attribute	*Description*
Technical Attributes	
Target	Roadway narrowing improvements have the objective of slowing vehicle speeds along routes where pedestrians may be crossing the street.
Expected Effectiveness	Lower vehicle speeds are associated with shorter stopping distances. Lower-speed vehicles are also more likely and more able to yield to a pedestrian. Narrowing roadways is believed to result in slower vehicle speeds and a corresponding reduction in pedestrian crashes. However, there are no valid evaluations of this presumption.
Keys to Success	When narrowing a roadway or lane, one must consider the need to service trucks and school buses, as well as provide access for emergency-service vehicles. On multilane roadways, it may be desirable to narrow only the left lanes and leave the right lanes wider, for use by larger vehicles and bicycles. Before reducing the number of lanes, roadway capacity and other aspects of road safety need to be considered. Level of service analysis of intersections should consider alternative treatments for the section of roadway. For example, a four-lane undivided road can be converted to one through-lane in each direction, with a center left-turn lane, or with a combination of raised median, left-turn lanes, and bicycle lanes. Turning lanes may not be needed at all intersections. When considering road-narrowing measures, it is highly desirable to include the entire neighborhood in the decision-making process. This will allow input from the entire affected area and will help prevent the level of road safety in one part of the neighborhood from being sacrificed to benefit another part. It is important to keep residents and businesses informed of what is being proposed, how it can benefit them, and what the likely tradeoffs are. A public-information and education program is thus important to the success of such projects. The affected residents and businesses should be able to provide input so that their concerns can be addressed
Potential Difficulties	Some traffic may divert to other local streets in neighborhoods. Also, narrowing a roadway can have adverse effects on bicyclists if insufficient space is designated for their travel.
Appropriate Measures and Data	Reduction in vehicle speed may be used as a surrogate measure of effectiveness along a route that has undergone roadway narrowing. It may be desirable to use more than one measure of speed (e.g., mean and 85th percentile, or proportion exceeding a given speed). Reduction in crashes and/or crash severity involving crossing pedestrians is an ultimate measure of effectiveness. Pedestrian- and vehicle-volume data are needed for estimating exposure and calculating crash rates.
Associated Needs	Public-Information and education activities are needed, as noted above.

EXHIBIT V-38 (Continued)
Strategy Attributes for Implementing Road Narrowing Measures

Attribute	*Description*
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	Lane widths must conform to national, state, and local guidelines. Narrowing lanes runs counter to many agencies' design standards. A design exception may be needed; in any event, there may be institutional reluctance to reduce lane width. New policies may need to be developed.
Issues Affecting Implementation Time	Narrowing a roadway by reconstruction and addition of channelization may take a minimum of 2 years to achieve, due to the time to receive design and funding approvals.
	Re-striping roadways, to have narrower lanes and/or fewer lanes is often done in conjunction with resurfacing and therefore results in little or no additional cost.
Cost Involved	Costs will vary depending upon the manner in which the narrowing is achieved. Reconstruction that involves channelization will be much more costly than reconstruction that only requires a change in pavement markings. The inclusion of road narrowing in the context of a broader reconstruction effort will minimize overall costs. See Appendix 12 for estimates of cost for the use of pavement markings.
Training and Other Personnel Needs	No particular training is needed to re-stripe roadways (e.g., after resurfacing projects) to narrow the width or reduce number of lanes.
Legislative Needs	None.
Other Key Attributes	
Legislative Needs	A typical three-lane configuration (two travel-lanes and a center turn-lane) also has safety advantages for motorists. Through traffic can maintain a fairly constant speed, while left-turning drivers can enter the center turn lane to wait. (Federal Highway Administration, 2002)

Strategy 9.1 C2: Install Traffic-Calming—Road Sections

Continued growth and decentralization throughout the United States have increased the volume of vehicles on streets and highways. Many neighborhood residents and local officials have expressed interest in undertaking traffic calming to reduce the speed and number of cars on their streets.

Traffic-calming encompasses a series of physical treatments that are meant to lower vehicle speeds and volumes by creating the visual impression that certain streets are not intended for high-speed or "cut-through" traffic. Thus, traffic calming may improve conditions for pedestrians. While many of the road narrowing measures discussed under Strategy 9.1 A1 can also effectively "calm" traffic along a section of roadway, the measures discussed under this section have the broader goal of improving the overall safety and attractiveness of the roadway environment for pedestrians and bicyclists, including children and the elderly.

Traffic-calming measures are generally of two types: either they require motorists to change their direction of travel (i.e., move to the left or right), or they require motorists to change elevation (i.e., go up and down). Traffic-calming treatments need to be well designed and based upon information currently available about their applications and effects. Information on U.S. experiences with various traffic-calming treatments can be found in ITE/FHWA's

Traffic Calming: State of the Practice (1999) (available online at http://www.ite.org/traffic/tcstate.htm#tcsop).

This strategy includes four traffic-calming measures that can be used along mid-block segments of local streets and some low-volume collector streets or commercial-area streets. More information can also be found in ITE/FHWA's *Traffic Calming: State of the Practice* (1999) and in FHWA's *Pedestrian Facilities Users Guide* (Federal Highway Administration, 2002).

When considering measures to reduce vehicle speeds on road sections, one important factor relates to the placement of trees and other roadside features. The key factor is to balance the needs of pedestrians, bicyclists, motorists, and transit vehicles with the operational expectations for a specific type of street and area. For example, placing trees relatively close to the street might be acceptable, or even desirable, on low-speed, low-volume neighborhood streets; high-speed arterial streets should typically have greater setbacks of trees, utility poles, and other roadside objects to reduce the chance of fixed-object crashes. More discussion on this topic is given in the companion guides on tree crashes, run-off-road crashes, and utility pole crashes.

Serpentine Street

A serpentine street uses a winding pattern with built-in visual enhancements (Exhibit V-39). These allow through movement but not fast driving. Landscaping can be used to create a park-like atmosphere. Serpentine street-design needs to be coordinated with driveway access and parking. Where cost is a concern, lower-cost but equally effective traffic-calming strategies may be preferable.

EXHIBIT V-39
A serpentine street uses a winding pattern to slow down vehicle speeds. (Photo by Cara Seiderman)

Additional information on the use of serpentine streets can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Calming—Serpentine Design, http://www.walkinginfo.org/de/curb1_print.cfm?codename=31d&CM_maingroup=Traffic+Calming&1.x=7&1.y=6
- City of Palo Alto, Neighborhood Traffic Calming Program, http://www.cityofpaloalto.org/transportation/ntcp/

Chicane

A chicane consists of alternately placed curb extensions into the street (Exhibit V-40). This design creates a horizontal shift in traffic and also narrows the traveled way down to one lane (or two narrow lanes). As a result, motorists are forced to slow down as they maneuver through the chicane. Good

visibility can be maintained by planting only low shrubs or trees with high canopies. The design of a chicane needs to ensure that bicyclist safety and mobility are not diminished. Also, like the serpentine street above, a chicane needs to be coordinated with driveway access and parking.

EXHIBIT V-40
A chicane consists of alternatively placed curb extensions into the street which creates a horizontal shift in traffic and reduced vehicle speeds. (Photo by Dan Burden)

Additional information on the use of chicanes can be found at the following Web sites:

- Project for Public Spaces (PPS), Traffic Calming 101, http://www.pps.org/buildings/info/how_to/livememtraffic
- PBIC, Walking Design and Engineering: Traffic Calming – Chicanes, http://www.walkinginfo.org/de/curb1_print.cfm?codename=22d&CM_maingroup=Traffic+Calming&1.x=5&1.y=5
- EcoCity Cleveland, Transportation Choices, http://www.ecocitycleveland.org/transportation/traffic/tools/chicanes.html
- Quality of Life Collegeville, Traffic Calming, http://www.cwdnet.com/qlc/tc_narrowing.htm
- Fehr and Peers Transportation Consultants, Traffic Calming.Org, http://www.trafficcalming.org/toolbox/chicanes.html
- City of Los Altos, CA, Traffic Plan, http://www.ci.los-altos.ca.us/publicworks/trafficplan/41-44.pdf

Choker

Chokers are curb extensions that narrow a street by widening the sidewalks or planting strips (Exhibit V-41). The street is narrowed from two lanes to one lane (or two narrow lanes). Motorists are forced to slow and, in some cases, allow an oncoming vehicle to pass. The minimum width should be wide enough to accommodate fire and sanitation trucks.

EXHIBIT V-41
Chokers narrow a street and force motorists to slow down. (Photo by Dan Burden)

Additional information on the use of chokers can be found at the following Web sites:

- Project for Public Spaces (PPS), Traffic Calming 101, http://www.pps.org/buildings/info/how_to/livememtraffic
- PBIC, Walking Design and Engineering: Traffic Calming—Choker, http://www.walkinginfo.org/de/curb1_print.cfm?codename=20d&CM_maingroup=Traffic+Calming&1.x=14&1.y=5
- Fehr and Peers Transportation Consultants, Traffic Calming.Org, http://www.trafficcalming.org/toolbox/chokers.html

Speed Humps and Speed Tables

EXHIBIT V-42
Flat-top speed humps are referred to as speed tables. (Photo by Dan Burden)

The purpose of speed humps is to reduce vehicle speeds. Speed humps should not be confused with speed bumps, which are sometimes used in parking lots. A speed hump is an elongated hump with a circular-arc cross-section (round-top) or flat-top. Speed humps generally do not have a negative effect on bikes and should be built through any bike lanes present on the roadway so that motorists do not swerve into the bike lane to avoid the hump. Flat-top speed humps are also referred to as speed tables (Exhibit V-42).

Additional information on speed humps and speed tables can be found at the following Web sites:

- Project for Public Spaces (PPS), Traffic Calming 101, http://www.pps.org/buildings/info/how_to/livememtraffic
- PBIC, Walking Design and Engineering: Traffic Calming—Speed Hump, http://www.walkinginfo.org/de/curb1_print.cfm?codename=24d&CM_maingroup=Traffic+Calming&1.x=6&1.y=10
- ITE—Traffic Calming Measures: Speed Table, http://www.ite.org/traffic/table.htm

Woonerf

Woonerf is a Dutch word that translates as "living street." It is typically used only on residential streets. A woonerf is a space shared by pedestrians, bicyclists, and low-speed motor vehicles. It is typically a narrow street without curbs or sidewalks. Vehicles are slowed by placing trees, planters, parking areas, and other obstacles in the street. Motorists must travel at very low speeds, below 10 mi/h. Thus, a woonerf creates a public space for

social and possibly commercial activities, as well as a play area for children (Exhibit V-43). A woonerf identification sign is placed at each street entrance. It is important to allow access by fire trucks, school buses, and other service vehicles, if needed.

EXHIBIT V-43
A woonerf is a "living street" that is shared by pedestrians, bicyclists, and low-speed motor vehicles. (Photo by Michael Ronkin)

Additional information on the use of woonerfs can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Calming—Woonerf, http://www.walkinginfo.org/de/curb1_print.cfm?codename=32d&CM_maingroup=Traffic+Calming&1.x=11&1.y=12
- EcoCity Cleveland, Transportation Choices, http://www.ecocitycleveland.org/transportation/traffic/tools/woonerf.html
- SWOV—Institute for Road Safety Research (Netherlands), http://www.swov.nl/. Click on English. Search for SWOV publications. Search for traffic+calming Schagen. Follow links to the report, *Traffic Calming Schemes* (van Schagen, 2003).

Other traffic calming countermeasures can be used at intersections. These are discussed under Strategy 9.1 A3.

EXHIBIT V-44
Strategy Attributes for Installing Traffic Calming—Road Sections

Attribute	***Description***
Technical Attributes	
Target(s)	Motorists: These countermeasures seek to reduce the speed of motor-vehicle traffic, make the driver aware of the presence and priority of pedestrian traffic, and may help reduce cut-through traffic.
Expected Effectiveness	*Curb Extension or Bulbout* Anne Arundel County, Maryland, has used a combination of medians and bulbouts near intersections. The medians narrow the traveled way and provide a sheltered storage area, while the bulbouts force drivers to make a lateral deflection as they enter the narrowed area. Medians with lateral deflection reduced the 85th-percentile speeds by 2 to 5 mi/h (Walter, 1995). In Ontario, Canada, Macbeth (1995) reported speed reductions on five raised and narrowed intersections and seven midblock bulbouts, in conjunction with lowering the speed limit to 30 km/h. The proportion of motorists who exceeded 30 km/h was 86 percent before the devices were built, but only 20 percent afterwards.

(*continued on next page*)

EXHIBIT V-44 (Continued)
Strategy Attributes for Installing Traffic Calming—Road Sections

Attribute	*Description*
	In De Meern, Netherlands, two bulbouts were placed opposite one another to narrow the width of the traveled way. A significant reduction in the 85th-percentile vehicle speed was observed (Replogle, 1992). Bulbouts had little effect on reducing vehicle speeds in two Australian cities, Keilor (Queensland) and Eltham (Victoria). However, in Concord, New South Wales, a comparison of a street with both bulbouts and marked parking lanes versus an untreated street showed that the crash rate on the treated street was only one-third of that of the untreated street. It was not stated how many of these crashes involved pedestrians, nor how the streets compared prior to treatment (Hawley et al., 1992). *Speed Humps and Speed Tables* Speed humps have been evaluated and found effective in many cities in terms of reducing vehicle speeds. Eight studies were reviewed for this Guide and are listed in the References section. These studies found that 85th-percentile speeds decreased by 4 to 23 mi/h after the speed humps were installed. Fewer crashes occurred in Omaha, Nebraska, and Montgomery County, Maryland, as a result of adding speed humps. Other studies did not address the effects of speed humps on crashes. Traffic volumes fell by up to one half in three Australian cities and also fell in Bellevue, Washington. Traffic volumes remained constant in Agoura Hills, California, though. The other studies did not address traffic volumes. A more detailed review of these studies can be found in the Pedestrian Synthesis by Campbell et al. (2002). See also Appendix 13. Very limited evaluations of crash impacts have been made of the other types of measures being considered here. However, they are being implemented on the assumption that pedestrians benefit because motorists are traveling more slowly and therefore have more time to react to the presence of pedestrians. This means less risk of a crash, fewer and less-severe conflicts, and perceptions of greater safety by pedestrians. These countermeasures are static, so they must be appropriate at all hours of the day and night.
Keys to Success	It is important to apply these strategies along the types of streets for which they are intended, primarily low-volume residential and, occasionally, collector streets. Ideally, they should be applied area-wide rather than in one or two isolated spots. Resident input and consensus is also a key to their success. In addition, adequate street lighting is important. *Choker* In order to function effectively, the street must be narrowed enough so that two cars that are approaching from opposite directions do not have enough room to pass. Emergency vehicles must be accommodated. *Woonerf* The design is intended to keep vehicle speeds below 10 mi/h, so that the street is safe for children. Woonerfs are typically low-volume, narrow neighborhood streets or specially designated streets in downtown areas. They frequently have special pavement texturing and are signed as special streets for pedestrians, as well as for motor vehicles. Speed humps may or may not be used on such streets. A woonerf may be an exception to “normal accepted practice,” so revisions may need to be made in local or state design policies. These countermeasures should be used as part of an overall neighborhood strategy. It is highly desirable to include the entire neighborhood in the decision-making process. It will help prevent the level of road safety in one part of the neighborhood from being sacrificed to benefit another part. It is important to keep residents and

EXHIBIT V-44 (Continued)
Strategy Attributes for Installing Traffic Calming—Road Sections

Attribute	*Description*
	businesses informed of what is being proposed, how it can benefit them, and what the likely tradeoffs are. A public-information and education program is thus important to the success of such projects. The affected residents and businesses should have the opportunity to provide input into the change or reduction in access to ensure that the tradeoffs will be acceptable to them.
Potential Difficulties	Traffic-calming devices are not a panacea, guaranteed to improve conditions for pedestrians. These devices, by themselves, cannot ensure that motorists will slow down and yield to pedestrians, nor that pedestrians will cross safely. Enforcement campaigns can be undertaken in conjunction with traffic calming (see Strategy 9.1 D2).
	Moreover, traffic-calming devices have their disadvantages. For example, these treatments, if not designed properly, can hinder activities such as street cleaning and snowplowing, may impede emergency vehicle access, and may affect drainage. A test period can be used to identify potential problems for residents, as well as emergency and school access. Adjustments can then be made to take care of any unanticipated problems. Care should be taken that traffic is not diverted onto a parallel local street. The ITE/FHWA *Traffic Calming* (1999) and FHWA *Pedestrian Facilities User Guide* (2002) provide further information on such issues.
	Chicane
	Chicanes may reduce the ability to allow on-street parking.
	Speed Humps and Speed Tables
	Noise may increase, as vehicles slow down and go over the humps and tables.
	Speed humps and speed tables may create drainage problems on some streets.
	Speed humps can increase the cost and complexity of resurfacing streets, since they either need to be removed and replaced after resurfacing, or the old surface on either side of the hump must be ground out to maintain the same “hump effect.” Simply resurfacing over the hump can create long-term street-drainage problems. Also, restriping of the humps must be closely coordinated with resurfacing, so that the humps are not left unmarked for any period of time.
	Speed humps can also be problematic for bicyclists if they are not well lit and should never be used on an unlit down grade, where bicyclists are approaching the hump at a high rate of speed.
Appropriate Measures and Data	Motor-vehicle speed is a useful surrogate safety measure. Conflicts between motor vehicles and pedestrians may also be used as a surrogate measure of safety. The primary measure of effectiveness is crashes. The impact on motorist delay is an operational measure of interest.
Associated Needs	A public-information and education program may need to be conducted.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	In addition to neighborhoods, other parties that may be affected include businesses, schools, the local fire and police departments, and others. These parties should also be included in the decision-making process.
	Some agencies may have design policies or standards that do not include traffic-calming techniques or that would inhibit their use. New policies may be needed.

(*continued on next page*)

EXHIBIT V-44 (Continued)
Strategy Attributes for Installing Traffic Calming—Road Sections

Attribute	*Description*
Issues Affecting Implementation time	It may take 1 or more years to implement some of these countermeasures. This time reflects that required for conducting the necessary engineering studies, as well as for deliberations and discussions with all stakeholders. Design and construction of such measures can take place within a short timeframe as long as no additional right-of-way is needed. Speed humps or speed tables may be installed rather quickly, if consensus amongst residents exists. Traffic engineers often conduct engineering studies to determine whether one or more of these countermeasures are warranted at a specific location. The process includes working with affected residents, businesses, schools, the local police and fire departments, and others to address their concerns. This public involvement process may take a while, especially if the proposed countermeasures prove to be controversial. The types of traffic calming, and the locations within a neighborhood, may need to be modified. The availability of funds to cover the costs of installation depends upon local and state funding cycles. Depending upon local climatic conditions, installation may be feasible year-round, or only during the warmer months. Once the appropriate groundwork has been laid, speed humps can actually be installed fairly quickly. For example, in Glendale, Arizona, speed humps are typically placed within 30 days, following receipt of a signed petition showing consensus. The speed of installation, coupled with their relatively low cost (see below), has made them the most popular type of traffic-calming treatment requested.
Costs Involved	Costs will vary depending upon the degree of new construction required and the specific type of treatment being applied. For further details, see Appendix 14. The cost to implement a woonerf design in retrofit may be quite high, but the marginal cost would be nominal if, instead, it was implemented as part of a new construction.
Training and Other Personnel Needs	Agency personnel should understand traffic-calming measures so they can be appropriately selected and installed.
Legislative Needs	As with any traffic control measure, there has been litigation related to various traffic-calming devices. Having clear policies, guidelines, and practices for selection and use of various traffic-calming devices can help reduce litigation problems.
Other Key Attributes	
	None.

Strategy 9.1 C3: Install Traffic-Calming—Intersections

Continued growth throughout the United States has increased the number of cars on streets and highways. Many neighborhood residents and local officials have expressed interest in traffic-calming projects to reduce the number and speed of cars on their streets.

Traffic-calming encompasses a series of physical treatments that are meant to lower vehicle speeds and volumes by creating the visual impression that certain streets are not intended for high-speed or "cut-through" traffic. Thus, traffic calming may improve conditions for pedestrians.

Traffic-calming treatments should be well designed and applied under appropriate conditions, to maximize their effectiveness. Local officials and engineers will benefit by maintaining information on the applications and their effects. Information on U.S. experiences with various traffic-calming treatments can be found in ITE's *Traffic Calming: State of the Practice* (1999).

This strategy includes five traffic-calming measures that can be used at intersections:

Curb Radius Reduction

One of the common pedestrian crash types involves a pedestrian who is struck by a right-turning vehicle at an intersection. Large curb radii encourage motorists to make right turns at higher speeds. Reducing the curb radius creates a tighter turn and results in motorists making right turns at lower speeds (Exhibit V-45). Other important benefits are shorter crossing distances for pedestrians and improved sight distances between pedestrians and motorists. However, large curb radii have been determined to be helpful for older drivers (see the guide on crashes involving older drivers). Therefore, care should be taken when applying this strategy. Larger vehicles, such as fire trucks, school buses, moving vans, and delivery trucks also need to be accommodated.

EXHIBIT V-45
Reducing the curb radius creates a tighter turn and results in motorists making right turns at lower speeds. (Photo by Peter Lagerwey)

There are sources providing information on appropriate design standards for curb radius:

- Salt Lake City Public Works Department, Division of Transportation, http://www.ci.slc.ut.us/transportation/Design/pdf/E1.g1.pdf
- Portland Department of Transportation, Pedestrian Design Guidelines, http://www.trans.ci.portland.or.us/DesignReferences/Pedestrian/SECTIONB.PDF

Additional information on the use of curb radius reduction can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Roadway Design—Curb Radius Reduction, http://www.walkinginfo.org/de/curb1.cfm?codename=14b&CM_maingroup=RoadwayDesign
- Mission Pedestrian, http://www.missionped.org/curbrad.html
- City of Alameda, Calif., Traffic Calming Toolbox, http://www.ci.alameda.ca.us/publicworks/pdf/toolbox.pdf (last accessed April 22, 2004)

Mini-Circle

Mini-circles are raised circular islands constructed in the center of residential street intersections. They are intended to reduce vehicle speeds by forcing motorists to maneuver around them (Exhibit V-46). Mini-circles may be appropriate at intersections where traffic volumes do not warrant a signal or STOP sign. A series of intersections along a local street should be treated as part of a neighborhood traffic improvement program. Tight curb radii

EXHIBIT V-46
Mini-Circles are raised circular islands constructed in the center of residential intersections. (Photo by Dan Burden)

should accompany mini-circles, to discourage motorists from making high-speed right turns. Mini-circles with cuts in splitter islands make crossing easier for pedestrians, especially those in wheelchairs. Larger vehicles, such as fire trucks and school buses, can be accommodated by creating a mountable curb on the outer portion of the circle. Mini-circle landscaping should not block sight distance. Yield controls should be used.

Additional information on the use of mini-circles can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Calming—Mini Circle, http://www.walkinginfo.org/de/curb1_print.cfm?codename=23d&CM_maingroup=Traffic+Calming&1.x=10&1.y=4
- ITE—Traffic Calming Measures: Neighborhood Traffic Circle, http://www.ite.org/traffic/circle.htm

Curb Extension

Curb extensions, also known as bulbouts or neckdowns, extend the sidewalk or curb line out into the parking lane, thereby reducing the effective street width. These serve to shorten the pedestrian crossing distance, narrow the roadway, and improve the ability of pedestrians and motorists to see each other (Exhibit V-47). Curb extensions also prevent motorists from parking in, or too close to, a crosswalk, or from blocking a curb ramp. Curb extensions should only be used where there is a parking lane. Larger vehicles, such as fire trucks and school buses, need to be able to make right turns. On the other hand, it is not necessary that a vehicle be able to turn from a curb lane to another curb lane. Instead, vehicles can often encroach into adjacent lanes safely when traffic volumes and/or speeds are low. Street furniture and landscaping should not block sight distance. Curb extensions should be designed to facilitate adequate drainage.

Additional information on the use of curb extensions can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Calming—Curb Extensions, http://www.walkinginfo.org/de/curb1_print.cfm?codename=19d&CM_maingroup=Traffic+Calming&1.x=6&1.y=9

EXHIBIT V-47
Curb extensions extend the sidewalk or curb line out into the parking lane, thereby reducing the effective street width. (Photo by Dan Burden)

- Portland Department of Transportation, Traffic Calming, http://www.trans.ci.portland.or.us/trafficcalming/devices/Peds/CURBEXT.HTM
- City of Austin, Texas, http://www.ci.austin.tx.us/roadworks/curb.htm

Raised Intersection

Raised intersections are intended to slow all vehicular movements through the intersection. It is built by raising the entire intersection to the level of the sidewalk (Exhibit V-48). The crosswalks on each approach may also be elevated, so that pedestrians cross at the same level as the sidewalk, without the need for curb ramps. Raised crosswalks can be an urban design element through the use of special paving materials. Detectable warning strips mark the boundary between the sidewalk and the street for pedestrians with vision impairments.

EXHIBIT V-48
Raised intersections are intended to slow all vehicle movements through the intersection. (Photo by Dan Burden)

Additional information on the use of raised intersections can be found at the following Web sites:

- PBIC, Walking Design and Engineering: Traffic Calming—Raised Intersection, http://www.walkinginfo.org/de/curb1_print.cfm?codename=26d&CM_maingroup=Traffic+Calming&1.x=7&1.y=13
- ITE—Traffic Calming Measures: Raised Intersection, http://www.ite.org/traffic/raised.htm
- Fehr and Peers Transportation Consultants, Traffic Calming.Org, http://www.trafficcalming.org/toolbox/raisedint.html
- City of Edgewood, Wash., http://www.ci.edgewood.wa.us/Cops/Safe%20Journey/Library/countermeasures/29-30.htm

Modern Roundabout

A modern roundabout is built with a large, often circular, raised island located in the center of the intersection of a street with one or more crossing roadways (Exhibit V-49). Motorists enter the circle, travel around in a counterclockwise direction, and then turn right onto the desired street. All entering traffic yields (Yield signs placed on each approach) to vehicles approaching from within the roundabout. A roundabout is intended to be applied where vehicular delay can be maintained at or below levels experienced under stop- and signal-control. Because of this, they can sometimes be installed on two-lane roadways in lieu of a road widening to four lanes. More details on roundabouts may be found under Strategy 17.1 F3 in the unsignalized intersections guide. In addition, the following Web sites provide numerous resources on the topic:

- http://roundabout.kittelson.com/
- http://www.ksu.edu/roundabouts/
- http://www.rpi.edu/dept/cits/roundabouts.html

EXHIBIT V-49
A modern roundabout is built with a large, often circular, raised island located in the center of the intersection of an arterial street with one or more crossing roadways. (Photo by Dan Burden)

Design guidelines for pedestrian crossings at roundabouts are provided at the following Web site:

- FHWA, Office of Safety, http://safety.fhwa.dot.gov/roundaboutsummit/rndabtatt7.ppt

Modern roundabouts can be relatively friendly to pedestrians if they have "splitter" islands on each approach to the roundabout and are designed to slow traffic prior to entering the roundabout. The splitter islands can serve as a refuge for pedestrians and make crossing safer. There is still, however, concern about safety for visually impaired pedestrians at roundabouts.

Accessible pedestrian signals and truncated domes placed at splitter islands can assist visually impaired pedestrians with gap selection and "wayfinding." In larger roundabouts, an off-road bicycle path may be necessary to allow bicyclists to use the pedestrian route.

Other traffic countermeasures can be used on midblock roadway sections. These are discussed under Strategy 9.1 A4.

EXHIBIT V-50
Strategy Attributes for Installing Traffic Calming—Intersections

Attribute	***Description***
Technical Attributes	
Target(s)	Motorists: These countermeasures are intended to reduce the speed of motor-vehicle traffic and make the driver aware of the presence and priority of pedestrian traffic.
Expected Effectiveness	*General* Pedestrians are believed to benefit because motorists are traveling more slowly and with a greater expectancy of the presence of pedestrians and therefore have more time to react to their presence. This means potentially less risk of a crash, fewer and less-severe conflicts, and greater perceived safety for the pedestrian. Raised intersections and curb extensions also improve sight distances between pedestrians and motorists and can help prevent vehicles from blocking the crosswalk. *Raised Intersection* The Australian "wombat" crossing usually consists of a raised crosswalk and bulbouts. It is designed to slow motorists, shorten pedestrian exposure to motor vehicles, and increase pedestrian visibility to motorists. Wombat crossings have generally reduced 85th-percentile vehicle speeds by about 40 percent (Hawley *et al.,* 1992). At one intersection in Cambridge, Massachusetts, about 10 percent of motorists yielded to pedestrians crossing before a raised intersection was installed. The yield rate increased to 55 percent after the raised intersection was installed (City of Cambridge, 2000). *Mini-Circle* Mini-circles have been found to reduce motor-vehicle crashes by an average of 90 percent in Seattle, Washington (Institute of Transportation Engineers, Federal Highway Administration, 1999). *Modern Roundabout* A before-and-after study of 8 roundabouts in the United States found that roundabouts reduced the total number of crashes by 51 percent, and the number of injury crashes

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EXHIBIT V-50 (Continued)
Strategy Attributes for Installing Traffic Calming—Intersections

Attribute	*Description*
	by 73 percent (Jacquemart, 1998). These roundabouts had diameters of 121 ft or less. The sample of pedestrian crashes was not adequate for determining those effects. Before-and-after studies in other countries have also found crash reductions. For example, a study of 73 roundabouts in Victoria, Australia, found that the rate of injury crashes fell by 74 percent (Troutbeck, 1993). The number of injury crashes per year fell by 78 percent at 83 roundabouts in France (Centre D'Etudes Techniques de L'Equipment de l'Ouest, 1986). In the Netherlands, a study of 181 roundabouts found that the total number of crashes fell by 51 percent, and the number of injury crashes, by 72 percent (Schoon and van Minnen, 1994). However, the specific impact on pedestrian safety was not determined.
Keys to Success	As with the midblock traffic-calming treatments, adequate lighting is important for reducing nighttime collisions, including drivers running into the various treatments (mini-circles and curb extensions especially). *Curb Radius Reduction* Nearby land uses and types of road users should be considered when designing intersections so that curb radii are sized appropriately. *Mini-Circle* Signs should be installed to direct motorists to proceed around the right side of the circle before passing through or making a left turn. Mini-circles must be properly designed to slow vehicles and benefit pedestrians and bicyclists, without creating an obstacle for fire trucks, school buses, and other large vehicles. *Modern Roundabout* Street widths and available right-of-way need to be sufficient to accommodate a properly designed roundabout. On two-lane roadways, splitter islands at the approaches slow entering vehicles and allow pedestrians to cross one lane of traffic at a time. The design speed of the vehicle entry, vehicle deflection around the roundabout, and the vehicle exit must be approximately equal to be effective.
Potential Difficulties	The reader is cautioned that traffic-calming devices are not a panacea that is guaranteed to improve conditions for pedestrians. These devices by themselves can not ensure that motorists will slow down and yield to pedestrians, nor that pedestrians will cross in the crosswalk. Enforcement and education campaigns can be undertaken in conjunction with traffic calming (See also Strategy 9.1.D2). Moreover, traffic-calming devices have their disadvantages. For example, these treatments can hinder activities such as street cleaning and snowplowing, may impede emergency vehicle access, and may affect drainage. *Curb Radius Reduction* If a curb radius is made too small, large trucks or buses may ride over the curb, placing pedestrians at risk. *Mini-Circle* When traffic does not stop, it is harder for pedestrians with vision impairments to find an adequate gap to cross.

EXHIBIT V-50 (Continued)
Strategy Attributes for Installing Traffic Calming—Intersections

Attribute	*Description*
	Larger vehicles, such as fire trucks and school buses, may need to make left turns in front of the circle.
	Modern Roundabout
	To ensure adequate sight distances, and to allow room for cars exiting the roundabout to yield/stop for pedestrians without blocking traffic flow on the roundabout, crosswalks may need to be placed some distance from the roundabout entry/exit points. Thus, pedestrians may need to travel out of their way to cross the intersection safely. However, proper design of roundabouts provides for pedestrians to cross at the splitter islands, which can reduce crossing problems for most pedestrians. Care should also be taken that landscaping is maintained (trimmed) to ensure adequate visibility between motorists and pedestrians.
	Roundabouts may be difficult for some pedestrians to cross, including persons with visual impairments, young children, and the elderly
	Bicyclists may not be able to share the road comfortably with motorists, unless there is only one approach lane, speeds are slow, and traffic volumes are light to moderate.
	Roundabouts typically involve landscaping, with continued water and maintenance needs. Grass, decomposed granite, or brick pavers are generally unacceptable, since they do not incorporate a vertical element in the traffic-calming device. Trees, bushes, and other vertical elements make the roundabout visible to approaching drivers and less likely to be hit.
Appropriate Measures and Data	The primary measure of effectiveness is crashes and the severity of these crashes. Motor-vehicle speeds may be used as a surrogate measure of effectiveness. Other surrogate measures include the number of motorists who yield to pedestrians, conflicts between motor vehicles and pedestrians, and motorist delay.
Associated Needs	When considering traffic-calming measures, the entire neighborhood must be included in the decision-making process. This may require a program of public information and education about the various devices, as well as their importance to neighborhood safety and livability. The affected residents should be able to provide input into the change, or reduction in access, to ensure that the tradeoffs will be acceptable to them.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	In addition to neighborhood residents, other parties that may be affected include businesses, schools, the local fire and police departments, and others. All these parties should be included in the decision-making process.
	New policies may be required for guiding the design and implementation of some of these strategies.
Issues Affecting Implementation Time	It may take 1 or more years to implement these countermeasures. Traffic engineers often conduct engineering studies to determine whether one or more of these countermeasures should be used at a specific location. The process includes working with affected residents, businesses, schools, the local police and fire departments, and others, to address their concerns. This public-involvement process may take a while, especially if the proposed countermeasures prove to be controversial. The

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EXHIBIT V-50 (Continued)
Strategy Attributes for Installing Traffic Calming—Intersections

Attribute	*Description*
	types of traffic calming, and the locations within a neighborhood, may need to be modified. The availability of funds to cover the costs of installation depends upon local and state funding cycles. Depending upon local climatic conditions, installation may be feasible year-round, or only during the warmer months.
Costs Involved	Costs will vary, depending upon the type of improvement and the local conditions, especially if additional right-of-way is required. See Appendix 15 for further details.
Training and Other Personnel Needs	Adequate training in the proper selection, design, and implementation of such devices is needed. Training in consensus building and working with the public in group meetings is also helpful
Legislative Needs	None identified.
Other Key Attributes	
	None identified.

Strategy 9.1 C4: Provide School Route Improvements

A variety of roadway improvements are available to increase the safe travel of children in school zones. Sidewalks or separated walkways are essential for a safe trip from home to school on foot or by bike. Ideally, schools should be sited in locations where it is easy and safe for students to walk or bike. If an elementary school is in an unsafe location (such as fronting a high-volume arterial street), it is virtually impossible to make the school pedestrian-trip safe and walkable. Conversely, a well-sited school will encourage higher levels of walking and bicycling and contribute to reduced traffic congestion near the school.

A new EPA study details the relationship between school location and travel choices. For more information, see the publication titled *Travel and Environmental Implications of School Siting* at http://www.epa.gov/smartgrowth/pdf/school_travel.pdf.

Other beneficial measures include well-trained adult crossing guards (Exhibit V-51), parking prohibitions on approaches to intersections, increased child supervision, and the use of signs and markings (e.g., school advance warning sign and school speed limit sign). Schools should develop "safe routes to school" plans (including creating school walking-route maps that can be sent home to parents) and work with local agencies to identify and correct problem areas and locations. School administrators and parent-teacher organizations should educate students and parents about school safety and access to and from school. A combination of education, enforcement, and a well-designed street system are needed to encourage motorists to drive appropriately.

EXHIBIT V-51
Well-trained adult crossing guards can be an effective traffic control measure in school zones. (Photo by Dan Burden)

One of the most frequently experienced operational problems in the vicinity of schools involves parents dropping off and picking up their children. There are two immediate solutions to this problem: (1) there needs to be a clearly marked area, with adequate capacity, where parents are permitted to drop off and pick up their children, and (2) drop-off/pick-up regulations must be provided to parents on the first day of school. Drop-off areas must be located away from where children on foot must cross streets or access points. Parent drop-off zones must also be adequate in length and separated from bus drop-off zones. If parents can be trained properly at the start of the school year, they are likely to continue appropriate behavior throughout the year.

This strategy could also include safer school-bus routing. Selection of safer school-bus stop locations are important, since this can affect the number and types of streets children must cross to get to the bus stop.

NHTSA has sponsored the development of a guide: *Safe Routes to School;* see http://www.nhtsa.dot.gov/people/injury/pedbimot/ped/saferouteshtml/overview.html.

This guide contains a comprehensive set of information, including guidelines, materials, curriculum ideas, and an assessment of the impact of traffic-calming measures.

These and other resources are cited and discussed further under Strategy 9.1 D1, "Provide Education, Outreach, and Training."

In addition, several strategies in this guide address engineering approaches for providing safe street crossings for pedestrians of all ages. In particular, the user is referred to Strategy 9.1 B1, "Provide Crosswalk Enhancements," Strategy 9.1 A2, "Install or Upgrade Traffic and Pedestrian Signals," and Strategy 9.1 B4 "Signals to Alert Motorists That Pedestrians Are Crossing."

EXHIBIT V-52
Strategy Attributes for Providing School Route Improvements

Attribute	*Description*
Technical Attributes	
Target(s)	This strategy is targeted toward motorists who drive through school zones (including parents who drop their children off at school), children who walk or ride a bike to school, and parents of school-age children.
Expected Effectiveness	There has been almost no evaluation of the overall effectiveness of these programs with regard to primary crash measures. However, the methods and procedures for this strategy are widely used and considered beneficial to safety. Regulatory school flashers (SPEED LIMIT 25 MPH WHEN FLASHING) were found to reduce vehicle speeds by an average of about 4 mph (Zegeer et al., 1978), based on 48 school-zone locations in Kentucky. Vehicle speeds were predominantly 35 to 45 miles per hour without the flasher. Only two of the 48 locations experienced speed reductions of 10 mph or more. At rural locations, speed variance (and thus, the potential for rear-end crashes) increased during the flashing periods. Overall, only 18 percent of all motorists complied with the 25-mph speed limit. The presence of crossing guards was found to be the most effective measure in terms of motorists complying with the regulatory flashing speed limit sign. Police enforcement also contributed to improved motorist speed compliance.
Keys to Success	For a longer-term solution, it is preferable to create a network where children can walk or bicycle safely to school. Safety must be a combined effort between local traffic officials, school officials, police, parents, and students to be successful.
Potential Difficulties	Barriers to be overcome include getting the cooperation of school officials to implement an effective child-pedestrian safety-education program, coordination and funding of a sufficient number of well-trained adult crossing guards, and obtaining selective-enforcement efforts near schools.
Appropriate Measures and Data	Child-pedestrian crash reduction in a neighborhood, or area of town or city, is the primary measure of effectiveness. Surrogate measures include vehicle speeds in school zones (particularly during morning or afternoon crossing time) and the number of children walking or bicycling to school.
Associated Needs	Proper training and monitoring of adult crossing guards is essential. Guards should also be equipped with a bright and reflective safety vest and a STOP paddle. Increased police enforcement in school zones may be needed, particularly in situations where drivers are speeding and/or not yielding to children in crosswalks. Public-information and education campaigns and methods are needed to ensure that parents know safe routes to school and how to properly drop off and pick up their children at the school. Education is also needed to teach children how to cross safely. A community in western Canada provides Internet-based information on trips to school, see http://www.mapleridge.org/community/school_district/safe_route_school.html. Clark County, Nevada, provides GIS based maps which can be used to plan safe routes to school (see http://www.accessclarkcounty.com/Pubworks/Neighborhood/School_Safe_Route.htm). The Los Altos School District uses a walkability checklist to improve school safety; see http://www.nhtsa.dot.gov/people/injury/buses/GTSS/case5.html.

EXHIBIT V-52 (Continued)
Strategy Attributes for Providing School Route Improvements

Attribute	*Description*
	See also Strategy 9.1 D1, Provide Education, Outreach, and Training.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	Parents and school officials need to be involved in developing safe-route-to-school plans and in identifying barriers to safe walking and bicycling. Other issues include who will pay for adult crossing guards and for needed engineering improvements.
Issues Affecting Implementation Time	Budget issues affect the implementation of various countermeasures in school zones. Organizing the stakeholders and getting their cooperation can also consume significant time.
Costs Involved	Costs depend upon the school-zone treatment selected.
Training and Other Personnel Needs	Adult crossing guards must be well trained to be effective, and a system should be in place for monitoring their performance. Student guards must also receive proper training and monitoring.
Legislative Needs	In some states and local jurisdictions, increased legislative support may be needed to strengthen laws and increase penalties for breaking laws related to children's safe travel to and from school
Other Key Attributes	
	None identified

Objective 9.1 D—Improve Pedestrian and Motorist Safety Awareness and Behavior

Strategy 9.1 D1: Provide Education, Outreach, and Training

An educational strategy should do much more than provide information—the goal is to *motivate* a change in specific behaviors to reduce the risk of pedestrian injuries. The most successful educational messages encourage people to think about their own travel attitudes and behaviors and help them to make informed (i.e., better) choices (Exhibit V-53). The ways

EXHIBIT V-53
The most successful educational messages encourage people to think about their own travel attitudes and behaviors and help them make better choices. (Photo by Dan Burden)

in which travel attitudes and behavior are influenced are now being referred to as "soft" policies, in contrast to "hard" policies that force change (e.g., changes in infrastructure or traffic laws). An integrated, multidisciplinary approach that links hard and soft policies and addresses both pedestrians and drivers has the greatest chance of success.

For example, if a jurisdiction were to install new countdown pedestrian signals at a congested intersection, an effective public awareness campaign would explain how the countdown sequence works and would also try to convince pedestrians of the personal benefit derived in complying with the new countdown signals. Drivers would need to be targeted with a complementary message that stresses how this new technology could improve their interaction with pedestrians and the consequences if they do not practice more cautious behaviors. In other words, it would address a key decision-making question for both pedestrian and driver: *Is this worth changing my behavior?*

A comprehensive coordinated program incorporates both broad approaches and targeted campaigns.

Broad Approaches[1]

There are a number of educational strategies that can be conducted with modest resources or within existing resources. Many of these focus on ongoing actions at the state level but can be adapted for use in local agencies as well. They include the following:

- **Highlight pedestrian features when introducing new infrastructure—**Seize opportunities to create public awareness. For example: Redding, California, built a new pedestrian bridge, conducted a media campaign, and held public events to commemorate the new bridge. More importantly, the city used this as an avenue to discuss the value of linking pedestrian-friendly destinations—raising the profile on a new asset in the community and encouraging residents to use it.
- **Improve pedestrian data—**Re-examine existing data to better describe the nature of the problem. For example, the California Department of Transportation (Caltrans) reframed its pedestrian injury problem by stating that pedestrians represented only 2 percent of its constituency, but they represented nearly 20 percent of the roadway fatalities. Caltrans has cultivated partners, such as public health and emergency medical services, to help them to more fully describe pedestrian crash circumstances and their associated costs. For further information on improving data, refer to *Bicycle and Pedestrian Data: Sources, Needs, and Gaps,* available on The Bureau of Transportation Statistics Web site at http://www.bts.gov/publications/bicycle_and_pedestrian_data/.
- **Conduct internal campaigns within the organization to build staff support for pedestrian safety programs—**Incorporate pedestrian safety issues wherever appropriate, such as inviting proponents for alternative modes to exhibit or present issues at staff meetings, generate in-house newsletter articles that cite successes, address as appropriate in strategic planning, etc.

[1] Adapted from *A Model for Changing Travel Attitudes and Behaviour*, produced by the INPHORMM project, December 1998. INPHORMM is a research project funded by the Commission of the European Communities, Directorate General for Transport.

- **Incorporate pedestrian safety messages into public relations efforts—**Draft news releases, disseminate fact sheets for local elected officials, incorporate pedestrian issues into reports or policy documents, or launch new grant programs with a press event that highlights the importance of pedestrians as part of the road-user mix.
- **Develop relationships with sister state agencies and statewide consumer groups—** Provide leadership by convening a task force or conducting an ad hoc meeting to discuss issues in common and to share current and potential activities that merit collaboration. Pedestrian safety is of interest to many governmental agencies as well as constituency groups (e.g., Departments of Public Health, Motor Vehicles, Education, Aging, State Police, as well as state auto clubs, senior mobility advocates, etc.).
- **Market alternative travel modes—**Place emphasis on alternative modes for employees within the organization. Ensure that there are employee transportation coordinators, provide information on ride sharing and incentives for walking as part of commute, etc.

The following Web site offers tips on marketing alternative modes for travel to work:

- ValleyMetro Phoenix, http://www.valleymetro.org/Rideshare3/3Marketing/Index.html

Educational Campaigns and Programs

Choosing the most effective educational strategy depends on the objectives, the audience, and the messages to be conveyed, as well as what funding is available for this effort. A critical first step is determining who the audience will be. Is the program reaching out to individuals to change personal practices; to organizations and institutions, such as local school districts, to change their policies; or to an even broader audience, such as when the program is working to create a shift in how pedestrians are viewed by the community-at-large? Even within a given level, the type of educational strategy selected depends on how ready the targeted group is to make a change. For example, a very different message is needed to create awareness in someone who has never contemplated letting his or her children walk to school versus someone who feels that walking to school is an important activity and simply wants to know more about safer routes to and from the campus.

The following section briefly describes three different approaches. They work best in concert and are more powerful when they are part of a long-term program versus a project designed to achieve some immediate short-term changes.

Public Awareness Campaigns

These "lay the groundwork" for subsequent pedestrian safety initiatives, increasing the likelihood of their success. They also garner public support and begin the process of changing public attitudes toward pedestrian safety issues. Good public awareness campaigns will increase knowledge and motivate changes in behavior.

The Federal Highway Administration recently launched a broad-based *Pedestrian Safety Campaign* aimed at (1) sensitizing drivers to the fact that pedestrians are legitimate road users and should always be expected on or near the roadway, (2) educating pedestrians about minimizing risks to their safety, and (3) developing program materials to explain or enhance the operation of pedestrian facilities, such as crosswalks and pedestrian signals. A

Pedestrian Safety Campaign Toolkit containing a planning guide, TV and radio public service announcements, posters, brochures, cinema slides, press releases, and newspaper articles is being made available to safety practitioners and pedestrian advocates who have the resources to implement a campaign. For further information, see the campaign Web site at http://safety.fhwa.dot.gov/pedcampaign.

Other examples of public awareness campaigns may be found in Appendix 16.

Campaigns to Targeted Groups and Settings

Educational materials that target specific groups (school age children, older adults, motorists) or specific settings (school zones, crosswalks, or pediatricians' offices) most often are intended to change knowledge and behaviors. Since behaviors generally do not change easily, and since the audience itself is always changing (e.g., preschoolers growing into school age children, adults becoming new parents), these campaigns generally should be considered ongoing efforts that need to be institutionalized within the organizations and communities. Examples of targeted pedestrian education campaigns include Safe Routes to School and The Walkability Checklist. These and other campaigns are highlighted in Appendix 16.

Individual Campaigns

Like targeted campaigns, individual campaigns usually target a specific audience. However, they differ in that the audience is reached through an intermediary. For example, pediatricians may be recruited to educate parents about the dangers posed by vehicles backing out of driveways, or school safety guards may be asked to instruct children in safe crossing behavior. The intervention actually occurs at a one-on-one level. Examples of individual level pedestrian safety education materials are *A Message for Parents of Preschool Children* and *Rules of the Road for Grandchildren: Safety Tips* (see Appendix 16 for details).

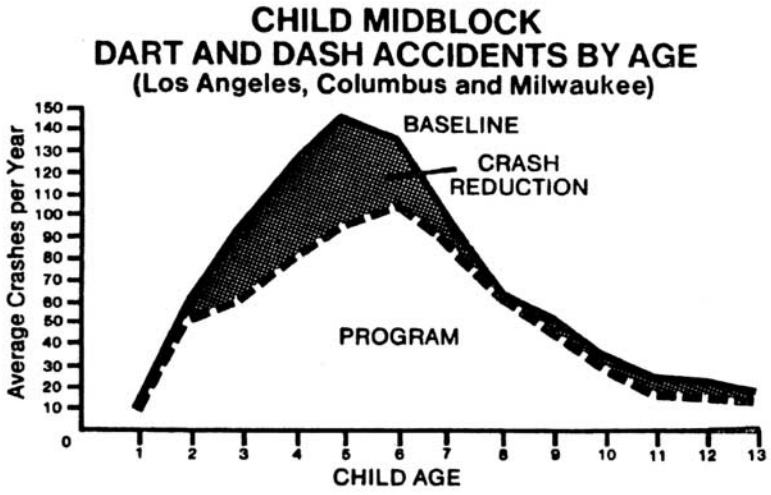
In summary, these three approaches—general public awareness, targeted campaigns, and individual campaigns—provide a range of options for increasing knowledge and for changing attitudes and behaviors that will strengthen pedestrian safety programs in local communities.

EXHIBIT V-54
Strategy Attributes for Providing Education, Outreach, and Training

Attribute	Description
Technical Attributes	
Target	Educational measures are directed at both drivers and pedestrians to improve their behavior and compliance to laws and ordinances. Effects of Willie Whistle Educational Campaign on Pedestrian Accidents (Source: Blomberg et al., 1983)

EXHIBIT V-54 (Continued)
Strategy Attributes for Providing Education, Outreach, and Training

Attribute	Description
Expected Effectiveness	Numerous studies have been conducted to evaluate efforts of educational programs on pedestrian behavior. For example, the NHTSA film on WILLIE WHISTLE (Blomberg et al., 1983) is aimed at grades kindergarten through 3 and teaches children the safe way to cross streets. After extensive testing in Los Angeles, Columbus, and Milwaukee, an observed reduction in dart and dash crashes by more than 30 percent among 4- to 6-year-old children was attributed to the film (exhibit below).



A 15-minute follow-up educational film called *And Keep On Looking* (Preusser and Lund, 1988) was later developed by NHTSA to convey street crossing advice to older children (grades 4 through 7) such as crossing busy streets, safety in parking lots, and crossing at signalized locations. The effectiveness of this film was examined through testing in Connecticut, Seattle, and Milwaukee. In a 2-year test in Milwaukee of the film's effects, the number of 9- to 12-year olds involved in pedestrian crashes decreased by more than 20 percent. Positive results were also found in Seattle in terms of children's observed behavior and in Connecticut through retained information after viewing the film.

NHTSA is currently evaluating the effectiveness of a comprehensive pedestrian safety program being conducted in Miami/Dade County, Florida, involving education, enforcement, and engineering approaches to increasing pedestrian safety.

In general, although specific education programs might be shown to change targeted behaviors, attitudes, or knowledge levels—and even crashes in large-scale evaluations such as those described above—they are viewed by NHTSA as important components in pedestrian safety initiatives *even if they have not been formally evaluated and proven effective*. This is because of the important role they play in increasing public awareness and complementing engineering and enforcement activities.

(*continued on next page*)

EXHIBIT V-54 (Continued)
Strategy Attributes for Providing Education, Outreach, and Training

Attribute	Description
Keys to Success	The keys to success are to make pedestrian education an ongoing component of traffic safety education activities; to implement comprehensive, long-term programs; and to use appropriate, well-designed, educational programs and materials for pedestrians and motorists in conjunction with engineering and enforcement programs. Hiring a public information firm, or working with the public-information office within the agency, can help ensure that appropriate materials are developed and appropriate contacts are made when working with the media. In addition, care must be taken to develop programs and materials that are appropriate and effective for the particular ethnic or cultural group, age level, etc. being targeted. The focus should be on developing materials that people want, need, and will use more than once. An example would be high-quality neighborhood walking and bicycling maps that incorporate educational messages.
Potential Difficulties	It may be difficult to make the necessary contacts and secure the support needed to ensure a comprehensive educational program. Also, care must be taken in developing safety messages that are targeted to the major pedestrian crash causes and in identifying the best approaches (Public Service Announcements [PSAs], educating drivers, classroom training, parental education, etc.) for delivering the identified message to the targeted audience. With school-based traffic-safety education programs, there may also be difficulty getting into established school curriculums.
Appropriate Measures and Data	Frequency of crashes between motorists and pedestrians (especially of the type targeted by the program) is the primary safety measure. Surrogate safety measures include conflicts between pedestrians and vehicles; observed behaviors by motorists (e.g. failing to yield to pedestrians in crosswalks, speeding) and pedestrians (e.g. violating the pedestrian signal); as well as changes in knowledge and attitudes (for example, measured by safety surveys).
Associated Needs	Identifying and arranging the appropriate vehicles for the educational program requires involvement of specific members of the community, such as the media, local schools, and the health community (e.g., pediatricians and family physicians).
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	A successful public information program will require the cooperation of several organizations and institutions. A coordinating council, or other type of group, might be needed to oversee the effort.
Issues Affecting Implementation Time	Education messages directed at school children are most effective if targeted just before high-crash months, so that fall and early spring are typically appropriate times for such messages. The time to implement a program depends upon such factors as the availability of materials, the number of agencies and organizations to be involved, and the size of the target population.
Cost Involved	Costs vary widely, depending upon the type of educational program.
Training and Other Personnel Needs	Staff should be appropriately trained to conduct the program. Specialists in education and marketing will be needed.
Legislative Needs	None.

EXHIBIT V-54 (Continued)
Strategy Attributes for Providing Education, Outreach, and Training

Attribute	Description
Other Key Attributes	
None identified.	

Useful Web Sites

The Pedestrian and Bicycle Information Center (PBIC), a national clearinghouse for information about health and safety, engineering, advocacy, education, enforcement, and access and mobility—http://www.walkinginfo.org/.

National Highway Traffic Safety Administration's pedestrian safety programs—http://www.nhtsa.dot.gov/people/injury/pedbimot/ped/. Also, http://www.nhtsa.dot.gov/safecommunities/.

Pedestrian Safety Roadshow. FHWA web site. http://safety.fhwa.dot.gov/roadshow/walk/ (last accessed April 22, 2004)

The Association of Pedestrian and Bicycle Professionals (APBP)—http://www.apbp.org. Provides online resources and publications, links to other Web sites.

Partnership for a Walkable America—http://www.walkableamerica.org/. Download Walkable America Checklist. Also, http://www.iwalktoschool.org (official Web site of International Walk to School Day).

Bureau of Transportation Statistics—U.S. DOT provides information on bicycle, pedestrian, and crash data—http://www.bts.gov

Strategy 9.1 D2: Implement Enforcement Campaigns

Police enforcement is essential to preserve pedestrian right-of-way and promote a safe environment for pedestrians. A combination of well-publicized enforcement campaigns, strategically installed traffic signs and devices, and public education programs can effectively increase driver awareness of the obligation to share the roadway with pedestrians and bicyclists. Police enforcement of the traffic code is also the most potent means of giving credibility to traffic control devices and traffic safety educational programs (Exhibit V-55). Traffic safety educational programs can sensitize and inform the general public of the need and benefits of observing traffic regulations. Unfortunately, knowing what to do and why to do it is often not enough. Good and bad driving behavior is much more a function of direct and immediate consequences that follow driver behavior.

Police forces throughout the United States have a long history of enforcing the law as it pertains to speeding, driving under the influence, and red-light running. They have developed very effective ways to observe, measure, and apprehend drivers who engage in these behaviors. Their observation and measurement procedures and accompanying devices have been validated, are socially acceptable, and are generally well accepted for evidentiary

EXHIBIT V-55
Police enforcement is essential to preserve pedestrian right-of-way and promote a safe environment for pedestrians. (Photo by Michael Ronkin)

purposes. This may not be the case when it comes to the enforcement of crosswalk laws. Enforcement of right-of-way legislation presents a more daunting challenge for most police forces. The nature of the offense (not yielding to pedestrians, for example) appears at first glance to be a more subjective infraction of a shared responsibility. Police departments may not assign priority to enforcement of pedestrian right-of-way laws and/or may not provide officers adequate training in the enforcement of these laws.

Enforcement can increase driver compliance at crosswalks, increase driver awareness and/or mindfulness of pedestrians, and give credibility to engineering interventions. See Appendix 17 and Appendix 18 for details on example enforcement programs. Some additional considerations for conducting an enforcement campaign are found in Appendix 19. Some of the enforcement effort needed will require special legislation to establish the basis for the enforcement actions. Model ordinances have been developed to help communities adopt the necessary legal infrastructure. Further details on these ordinances can be found in Appendix 20. Information on enforcement related to pedestrian safety may also be found at www.walkinginfo.org/. In addition to special enforcement activities directed at improving motorists yielding to pedestrians in marked and unmarked crosswalks, law enforcement officials should also be encouraged to strictly enforce speed limit laws in locations where pedestrian traffic is high and/or where analysis of crash data suggests that speeding may be a contributing factor in pedestrian crashes.

Downtown business areas, shopping centers, school zones, college campuses, hospitals, senior centers, parks and recreation facilities, etc. are all locations that may warrant special attention by law enforcement officials to discourage speeding and encourage proper behavior for yielding to pedestrians crossing roadways. Locations where red-light running poses a risk to pedestrians should also be targeted for special enforcement, including consideration of automated (photo) enforcement where law allows.

EXHIBIT V-56
Strategy Attributes for Implementing Enforcement Campaigns

Attribute	*Description*
Technical Attributes	
Target	This strategy is primarily directed at motorists who fail to give pedestrians proper right-of-way at crosswalks. It also targets some of the most serious risk-taking traffic violations by pedestrians.
Expected Effectiveness	No quantitative studies are known that have determined the specific effect of various types of police enforcement on pedestrian-related traffic injuries and fatalities. The effect of enforcement alone on pedestrian crashes is difficult to quantify because of the multitude of factors that affect pedestrian crashes. For most jurisdictions, pedestrian injuries and fatalities occur at a wide variety of crosswalks and at frequencies that do not permit the establishment of causal relationships between those crashes and enforcement operations. Enforcement programs increase the percentage of motorists yielding to pedestrians and also motorist awareness of pedestrians. They can also target drivers that are speeding or those that pass vehicles that are yielding to pedestrians. Malenfant and Van Houten (1989) measured large increases in yielding behavior in three Canadian cities employing enforcement complemented with educational outreach and several engineering interventions. Although safety may have been greatly influenced by the engineering interventions, the enforcement component increased yielding behavior. Exhibit V-57 shows the increase in yielding behavior produced in three cities. More recently, this program has been applied to increase yielding behavior in Miami Beach, Florida. Data collected to date show that yielding has increased in both corridors following the introduction of the program and that maintenance strategies are working to maintain the increase in yielding behavior. Data also indicated that enforcement of pedestrian right-of-way at marked crosswalks at uncontrolled locations generalized to other crosswalks. Generalization was noted at (1) uncontrolled locations where enforcement had not been scheduled, (2) crosswalks at traffic signals that did not receive enforcement, and (3) intersections at uncontrolled locations without crosswalk markings. Britt *et al.* (1995) reported similar findings from an enforcement campaign on motorist compliance with new stricter crosswalk laws in Washington State. The new policy encouraged officers to write two tickets for motorist violations to every jaywalking citation. Evaluating willingness of drivers to stop at uncontrolled intersections for pedestrians before and after the enforcement campaign, researchers found that motorists were much more likely to stop in areas made up of multifamily housing units and small retail businesses than in nonresidential areas. It should be noted that enforcement can yield fast results in small, tight-knit communities. To produce similar results in larger communities requires a more sustained effort over a longer period of time.
Keys to Success	To be effective, police enforcement campaigns must be well planned and organized. They also must be sensitive to the special needs and characteristics of the neighborhood, age group, ethnic group, etc. being targeted by the campaign. In the case of enforcement of pedestrian right-of-way at crosswalks, participating police officers need to be trained beforehand, since this type enforcement is unlike typical enforcement operations. Police officers should have senior staff support. It is best to work in a small team. Police authorities should inform prosecutors and judges prior to introducing the campaign, as well as promote media and public support. Pedestrian safety enforcement operations should focus on the more serious violations of both drivers and pedestrians. Most often this will mean giving priority to enforcement of

(*continued on next page*)

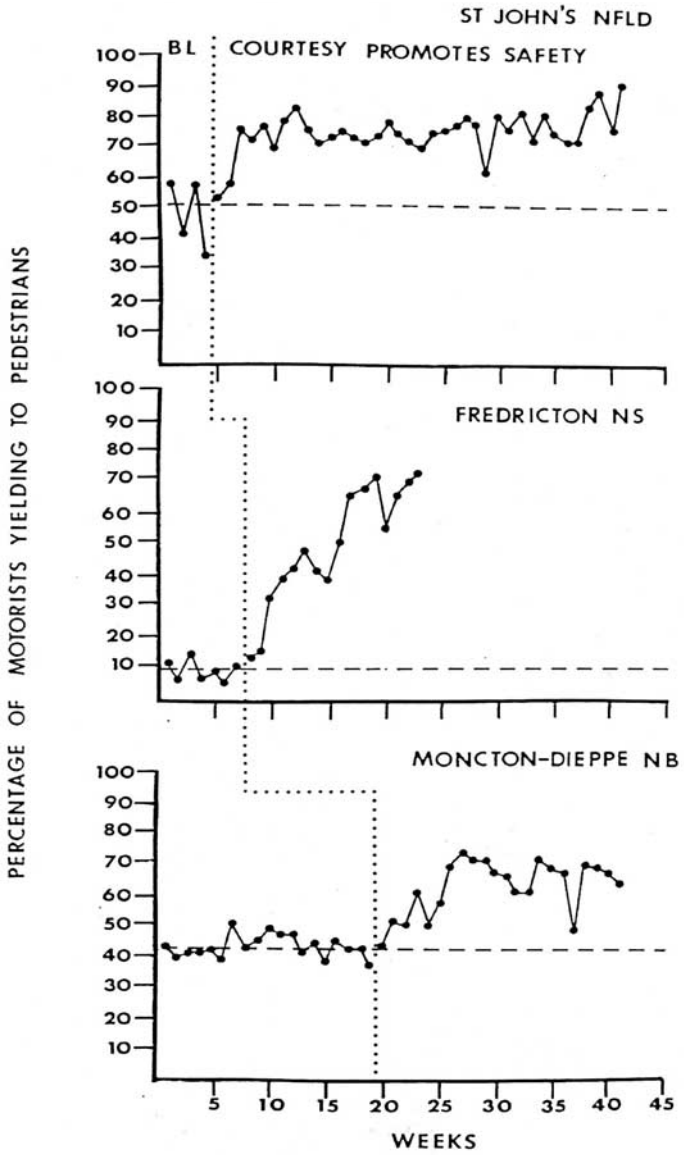
EXHIBIT V-56 (Continued)
Strategy Attributes for Implementing Enforcement Campaigns

Attribute	*Description*
	driver behavior. In the beginning stages, enforcement operations should be scheduled very frequently and gradually reduced, but sustained over the long term, particularly at problematic locations. Police forces without a history of such enforcement operations should begin with warnings and enforcement flyers before introducing citations. Finally, enforcement of pedestrian violations should be kept for last, or until a large majority of drivers maintain a high level of yielding to pedestrians at crosswalks.
Potential Difficulties	Police enforcement can result in public relations problems if it is not well planned and if officers are not properly trained for this special type of operation. Other problems will arise if the enforcement team does not have the full support of senior police administrators, political officials, and the media.
Appropriate Measures and Data	Reducing pedestrian-related traffic crashes is the ultimate objective of the enforcement operations. However, such crashes are distributed over a large area and typically at low frequency at a given location. They cannot be used to evaluate specific enforcement procedures. Appropriate measures should focus on higher-frequency pedestrian-safety-related behaviors, such as yielding to pedestrians at crosswalks, speeding by drivers at crosswalks, and drivers stopping too close to, or in, crosswalks. Other safety-related behaviors that occur at sufficiently high frequency to evaluate the effectiveness of an enforcement operation include the frequency of pedestrians thanking drivers that yield right-of-way, stepping into traffic without warning, and crossing against the walk signal.
Associated Needs	Valuable components to support police enforcement include clearly marked crosswalks with advance crosswalk signs; prompting signs for pedestrians; and, if possible, large feedback signs to inform the public of the campaign and of the implied surveillance. Public education (e.g., using a 20-minute lesson plan for school-aged pupils) and information flyers for the general public (especially the elderly) have the potential to greatly enhance the visibility and required public support for police enforcement of crosswalks.
Organizational and Institutional Attributes	
Organizational, Institutional, and Policy Issues	The establishment of a “Triple E” committee (Education, Enforcement, and Engineering), to develop and direct the effort, significantly increases the probability of success of any of these initiatives. Representation should include city or county administrators, their public relations departments, the police or sheriffs’ departments, engineering departments, neighborhood associations, and crossing guards. Police enforcement operations must be well understood, and they should not work in isolation, but as integral members of a strong, well-organized, multidisciplinary municipal or county Triple E team.
Issues Affecting Implementation Time	Although enforcement of pedestrian right-of-way at crosswalks can be introduced at any time, enforcement campaigns are most timely just prior to summer holidays when the number of school-aged children on roadways increases. It is also timely to introduce such campaigns at the beginning of a new school year, when kindergarten and first graders are at greater risk because of their inexperience at getting to and from school. Furthermore, if a Triple E committee is to be organized, a planning process followed, and a new PI&E campaign created to accompany it, the entire venture could take at least 1 year before implementation can start.
Cost Involved	Cost varies, depending on the type, intensity, and duration of the enforcement effort. Some state governors’ highway safety offices may provide grants for targeted enforcement programs, e.g., at schools or to stop red-light running.

EXHIBIT V-56 (Continued)
Strategy Attributes for Implementing Enforcement Campaigns

Attribute	*Description*
Training and Other Personnel Needs	Police training is needed regarding the proper procedures to carry out the enforcement campaign.
Other Key Attributes	
	None.

EXHIBIT V-57
Illustration of motorist yielding behavior from pedestrian enforcement program



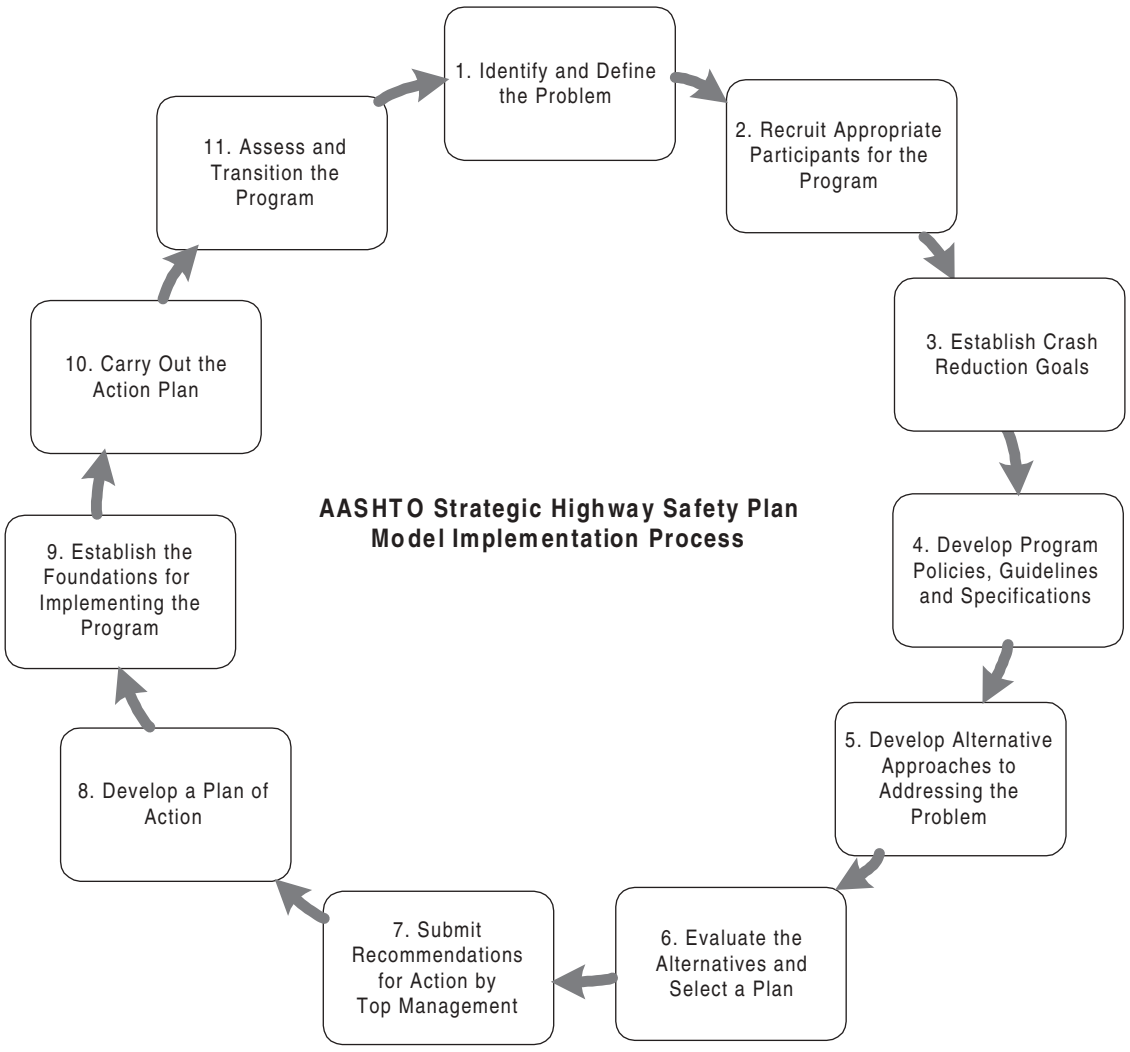
SECTION VI

Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

Outline for a Model Implementation Process

Exhibit VI-1 gives an overview of an 11-step model process for implementing a program of strategies for any given emphasis area of the AASHTO Strategic Highway Safety Plan. After a short introduction, each of the steps is outlined in further detail.

EXHIBIT VI-1



Purpose of the Model Process

The process described in this section is provided as a model rather than a standard. Many users of this guide will already be working within a process established by their agency or working group. It is not suggested that their process be modified to conform to this one. However, the model process may provide a useful checklist. For those not having a standard process to follow, it is recommended that the model process be used to help establish an appropriate one for their initiative. Not all steps in the model process need to be performed at the level of detail indicated in the outlines below. The degree of detail and the amount of work required to complete some of these steps will vary widely, depending upon the situation.

It is important to understand that the process being presented here is assumed to be conducted only as a part of a broader, strategic-level safety management process. The details of that process, and its relation to this one, may be found in a companion guide. (The companion guide is a work in progress at this writing. When it is available, it will be posted online at http://transportation1.org/safetyplan.)

Overview of the Model Process

The process (see Exhibit VI-1, above) must be started at top levels in the lead agency's organization. This would, for example, include the CEO, DOT secretary, or chief engineer, as appropriate. Here, decisions will have been made to focus the agency's attention and resources on specific safety problems based upon the particular conditions and characteristics of the organization's roadway system. This is usually, but not always, documented as a result of the strategic-level process mentioned above. It often is publicized in the form of a "highway safety plan." Examples of what states produce include Wisconsin DOT's Strategic Highway Safety Plan (see Appendix A) and Iowa's Safety Plan (available at http://www.iowasms.org/toolbox.htm).

Once a "high-level" decision has been made to proceed with a particular emphasis area, the first step is to describe, in as much detail as possible, the problem that has been identified in the high-level analysis. The additional detail helps confirm to management that the problem identified in the strategic-level analysis is real and significant and that it is possible to do something about it. The added detail that this step provides to the understanding of the problem will also play an important part in identifying alternative approaches for dealing with it.

Step 1 should produce endorsement and commitments from management to proceed, at least through a planning process. With such an endorsement, it is then necessary to identify the stakeholders and define their role in the effort (Step 2). It is important at this step to identify a range of participants in the process who will be able to help formulate a comprehensive approach to the problem. The group will want to consider how it can draw upon potential actions directed at

- Driver behavior (legislation, enforcement, education, and licensing),
- Engineering,

- Emergency medical systems, and
- System management.

With the establishment of a working group, it is then possible to finalize an understanding of the nature and limitations of what needs to be done in the form of a set of program policies, guidelines, and specifications (Steps 3 and 4). An important aspect of this is establishing targets for crash reduction in the particular emphasis area (Step 3). Identifying stakeholders, defining their roles, and forming guidelines and policies are all elements of what is often referred to as "chartering the team." In many cases, and in particular where only one or two agencies are to be involved and the issues are not complex, it may be possible to complete Steps 1 through 4 concurrently.

Having received management endorsement and chartered a project team—the foundation for the work—it is now possible to proceed with project planning. The first step in this phase (Step 5 in the overall process) is to identify alternative strategies for addressing the safety problems that have been identified while remaining faithful to the conditions established in Steps 2 through 4.

With the alternative strategies sufficiently defined, they must be evaluated against one another (Step 6) and as groups of compatible strategies (i.e., a total program). The results of the evaluation will form the recommended plan. The plan is normally submitted to the appropriate levels of management for review and input, resulting ultimately in a decision on whether and how to proceed (Step 7). Once the working group has been given approval to proceed, along with any further guidelines that may have come from management, the group can develop a detailed plan of action (Step 8). This is sometimes referred to as an "implementation" or "business" plan.

Plan implementation is covered in Steps 9 and 10. There often are underlying activities that must take place prior to implementing the action plan to form a foundation for what needs to be done (Step 9). This usually involves creating the organizational, operational, and physical infrastructure needed to succeed. The major step (Step 10) in this process involves doing what was planned. This step will in most cases require the greatest resource commitment of the agency. An important aspect of implementation involves maintaining appropriate records of costs and effectiveness to allow the plan to be evaluated after-the-fact.

Evaluating the program, after it is underway, is an important activity that is often overlooked. Management has the right to require information about costs, resources, and effectiveness. It is also likely that management will request that the development team provide recommendations about whether the program should be continued and, if so, what revisions should be made. Note that management will be deciding on the future for any single emphasis area in the context of the entire range of possible uses of the agency's resources. Step 11 involves activities that will give the desired information to management for each emphasis area.

To summarize, the implementation of a program of strategies for an emphasis area can be characterized as an 11-step process. The steps in the process correspond closely to a 4-phase approach commonly followed by many transportation agencies:

- Endorsement and chartering of the team and project (Steps 1 through 4),
- Project planning (Steps 5 through 8),
- Plan implementation (Steps 9 and 10), and
- Plan evaluation (Step 11).

Details about each step follow. The Web-based version of this description is accompanied by a set of supplementary material to enhance and illustrate the points.

The model process is intended to provide a framework for those who need it. It is not intended to be a how-to manual. There are other documents that provide extensive detail regarding how to conduct this type of process. Some general ones are covered in Appendix B and Appendix C. Others, which relate to specific aspects of the process, are referenced within the specific sections to which they apply.

Implementation Step 1: Identify and Define the Problem

General Description

Program development begins with gathering data and creating and analyzing information. The implementation process being described in this guide is one that will be done in the context of a larger strategic process. It is expected that this guide will be used when the strategic process, or a project-level analysis, has identified a potentially significant problem in this emphasis area.

Data analyses done at the strategic level normally are done with a limited amount of detail. They are usually the top layer in a "drill-down" process. Therefore, while those previous analyses should be reviewed and used as appropriate, it will often be the case that further studies are needed to completely define the issues.

It is also often the case that a core technical working group will have been formed by the lead agency to direct and carry out the process. This group can conduct the analyses required in this step, but should seek, as soon as possible, to involve any other stakeholders who may desire to provide input to this process. Step 2 deals further with the organization of the working group.

The objectives of this first step are as follows:

1. Confirm that a problem exists in this emphasis area.
2. Detail the characteristics of the problem to allow identification of likely approaches for eliminating or reducing it.
3. Confirm with management, given the new information, that the planning and implementation process should proceed.

The objectives will entail locating the best available data and analyzing them to highlight either geographic concentrations of the problem or over-representation of the problem within the population being studied.

Identification of existing problems is *a responsive approach*. This can be complemented by a *proactive approach* that seeks to identify potentially hazardous conditions or populations.

For the responsive type of analyses, one generally begins with basic crash records that are maintained by agencies within the jurisdiction. This is usually combined, where feasible, with other safety data maintained by one or more agencies. The other data could include

- Roadway inventory,
- Driver records (enforcement, licensing, courts), or
- Emergency medical service and trauma center data.

To have the desired level of impact on highway safety, it is important to consider the highway system as a whole. Where multiple jurisdictions are responsible for various parts of the system, they should all be included in the analysis, wherever possible. The best example of this is a state plan for highway safety that includes consideration of the extensive

mileage administered by local agencies. To accomplish problem identification in this manner will require a cooperative, coordinated process. For further discussion on the problem identification process, see Appendix D and the further references contained therein.

In some cases, very limited data are available for a portion of the roads in the jurisdiction. This can occur for a local road maintained by a state or with a local agency that has very limited resources for maintaining major databases. Lack of data is a serious limitation to this process, but must be dealt with. It may be that for a specific study, special data collection efforts can be included as part of the project funding. While crash records may be maintained for most of the roads in the system, the level of detail, such as good location information, may be quite limited. It is useful to draw upon local knowledge to supplement data, including

- Local law enforcement,
- State district and maintenance engineers,
- Local engineering staff, and
- Local residents and road users.

These sources of information may provide useful insights for identifying hazardous locations. In addition, local transportation agencies may be able to provide supplementary data from their archives. Finally, some of the proactive approaches mentioned below may be used where good records are not available.

Maximum effectiveness often calls for going beyond data in the files to include special supplemental data collected on crashes, behavioral data, site inventories, and citizen input. Analyses should reflect the use of statistical methods that are currently recognized as valid within the profession.

Proactive elements could include

- Changes to policies, design guides, design criteria, and specifications based upon research and experience;
- Retrofitting existing sites or highway elements to conform to updated criteria (perhaps with an appropriate priority scheme);
- Taking advantage of lessons learned from previous projects;
- Road safety audits, including on-site visits;
- Safety management based on roadway inventories;
- Input from police officers and road users; and
- Input from experts through such programs as the NHTSA traffic records assessment team.

The result of this step is normally a report that includes tables and graphs that clearly demonstrate the types of problems and detail some of their key characteristics. Such reports

should be presented in a manner to allow top management to quickly grasp the key findings and help them decide which of the emphasis areas should be pursued further, and at what level of funding. However, the report must also document the detailed work that has been done, so that those who do the later stages of work will have the necessary background.

Specific Elements

1. Define the scope of the analysis
    - 1.1. All crashes in the entire jurisdiction
    - 1.2. A subset of crash types (whose characteristics suggest they are treatable, using strategies from the emphasis area)
    - 1.3. A portion of the jurisdiction
    - 1.4. A portion of the population (whose attributes suggest they are treatable using strategies from the emphasis area)
2. Define safety measures to be used for responsive analyses
    - 2.1. Crash measures
        - 2.1.1. Frequency (all crashes or by crash type)
        - 2.1.2. Measures of exposure
        - 2.1.3. Decide on role of frequency versus rates
    - 2.2. Behavioral measures
        - 2.2.1. Conflicts
        - 2.2.2. Erratic maneuvers
        - 2.2.3. Illegal maneuvers
        - 2.2.4. Aggressive actions
        - 2.2.5. Speed
    - 2.3. Other measures
        - 2.3.1. Citizen complaints
        - 2.3.2. Marks or damage on roadway and appurtenances, as well as crash debris
3. Define measures for proactive analyses
    - 3.1. Comparison with updated and changed policies, design guides, design criteria, and specifications
    - 3.2. Conditions related to lessons learned from previous projects
    - 3.3. Hazard indices or risk analyses calculated using data from roadway inventories to input to risk-based models
    - 3.4. Input from police officers and road users
4. Collect data
    - 4.1. Data on record (e.g., crash records, roadway inventory, medical data, driver-licensing data, citations, other)
    - 4.2. Field data (e.g., supplementary crash and inventory data, behavioral observations, operational data)
    - 4.3. Use of road safety audits, or adaptations
5. Analyze data
    - 5.1. Data plots (charts, tables, and maps) to identify possible patterns, and concentrations (See Appendixes Y, Z and AA for examples of what some states are doing)

5.2. Statistical analysis (high-hazard locations, over-representation of contributing circumstances, crash types, conditions, and populations)
5.3. Use expertise, through road safety audits or program assessment teams
5.4. Focus upon key attributes for which action is feasible:
    5.4.1. Factors potentially contributing to the problems
    5.4.2. Specific populations contributing to, and affected by, the problems
    5.4.3. Those parts of the system contributing to a large portion of the problem

6. Report results and receive approval to pursue solutions to identified problems (a*pprovals being sought here are primarily a confirmation of the need to proceed and likely levels of resources required*)
    6.1. Sort problems by type
        6.1.1. Portion of the total problem
        6.1.2. Vehicle, highway/environment, enforcement, education, other driver actions, emergency medical system, legislation, and system management
        6.1.3. According to applicable funding programs
        6.1.4. According to political jurisdictions
    6.2. Preliminary listing of the types of strategies that might be applicable
    6.3. Order-of-magnitude estimates of time and cost to prepare implementation plan
    6.4. Listing of agencies that should be involved, and their potential roles (including an outline of the organizational framework intended for the working group). Go to Step 2 for more on this.

Implementation Step 2: Recruit Appropriate Participants for the Program

General Description

A critical early step in the implementation process is to engage all the stakeholders that may be encompassed within the scope of the planned program. The stakeholders may be from outside agencies (e.g., state patrol, county governments, or citizen groups). One criterion for participation is if the agency or individual will help ensure a comprehensive view of the problem and potential strategies for its resolution. If there is an existing structure (e.g., a State Safety Management System Committee) of stakeholders for conducting strategic planning, it is important to relate to this, and build on it, for addressing the detailed considerations of the particular emphasis area.

There may be some situations within the emphasis area for which no other stakeholders may be involved other than the lead agency and the road users. However, in most cases, careful consideration of the issues will reveal a number of potential stakeholders to possibly be involved. Furthermore, it is usually the case that a potential program will proceed better in the organizational and institutional setting if a high-level "champion" is found in the lead agency to support the effort and act as a key liaison with other stakeholders.

Stakeholders should already have been identified in the previous step, at least at a level to allow decision makers to know whose cooperation is needed, and what their potential level of involvement might be. During this step, the lead agency should contact the key individuals in each of the external agencies to elicit their participation and cooperation. This will require identifying the right office or organizational unit, and the appropriate people in each case. It will include providing them with a brief overview document and outlining for them the type of involvement envisioned. This may typically involve developing interagency agreements. The participation and cooperation of each agency should be secured to ensure program success.

Lists of appropriate candidates for the stakeholder groups are recorded in Appendix K. In addition, reference may be made to the NHTSA document at http://www.nhtsa.dot.gov/safecommunities/SAFE%20COMM%20Html/index.html, which provides guidance on building coalitions.

Specific Elements

1. Identify internal "champions" for the program
2. Identify the suitable contact in each of the agencies or private organizations who is appropriate to participate in the program
3. Develop a brief document that helps sell the program and the contact's role in it by
    - 3.1. Defining the problem
    - 3.2. Outlining possible solutions
    - 3.3. Aligning the agency or group mission by resolving the problem
    - 3.4. Emphasizing the importance the agency has to the success of the effort

   3.5. Outlining the organizational framework for the working group and other stakeholders cooperating on this effort
   3.6. Outlining the rest of the process in which agency staff or group members are being asked to participate
   3.7. Outlining the nature of commitments desired from the agency or group for the program
   3.8. Establishing program management responsibilities, including communication protocols, agency roles, and responsibilities
   3.9. Listing the purpose for an initial meeting
4. Meet with the appropriate representative
   4.1. Identify the key individual(s) in the agency or group whose approval is needed to get the desired cooperation
   4.2. Clarify any questions or concepts
   4.3. Outline the next steps to get the agency or group onboard and participating
5. Establish an organizational framework for the group
   5.1. Roles
   5.2. Responsibilities

Implementation Step 3: Establish Crash Reduction Goals

General Description

The AASHTO Strategic Highway Safety Plan established a national goal of saving 5,000 to 7,000 lives annually by the year 2003 to 2005. Some states have established statewide goals for the reduction of fatalities or crashes of a certain degree of severity. Establishing an explicit goal for crash reduction can place an agency "on the spot," but it usually provides an impetus to action and builds a support for funding programs for its achievement. Therefore, it is desirable to establish, within each emphasis area, one or more crash reduction targets.

These may be dictated by strategic-level planning for the agency, or it may be left to the stakeholders to determine. (The summary of the Wisconsin DOT Highway Safety Plan in Appendix A has more information.) For example, Pennsylvania adopted a goal of 10 percent reduction in fatalities by 2002,[1] while California established a goal of 40 percent reduction in fatalities and 15 percent reduction in injury crashes, as well as a 10 percent reduction in work zone crashes, in 1 year.[2] At the municipal level, Toledo, Ohio, is cited by the U.S. Conference of Mayors as having an exemplary program. This included establishing specific crash reduction goals (http://www.usmayors.org/uscm/uscm_projects_services/health/traffic/best_traffic_initiative_toledo.htm). When working within an emphasis area, it may be desirable to specify certain types of crashes, as well as the severity level, being targeted.

There are a few key considerations for establishing a quantitative goal. The stakeholders should achieve consensus on this issue. The goal should be challenging, but achievable. Its feasibility depends in part on available funding, the timeframe in which the goal is to be achieved, the degree of complexity of the program, and the degree of controversy the program may experience. To a certain extent, the quantification of the goal will be an iterative process. If the effort is directed at a particular location, then this becomes a relatively straightforward action.

Specific Elements

1. Identify the type of crashes to be targeted
    - 1.1. Subset of all crash types
    - 1.2. Level of severity
2. Identify existing statewide or other potentially related crash reduction goals
3. Conduct a process with stakeholders to arrive at a consensus on a crash reduction goal
    - 3.1. Identify key considerations
    - 3.2. Identify past goals used in the jurisdiction
    - 3.3. Identify what other jurisdictions are using as crash reduction goals
    - 3.4. Use consensus-seeking methods, as needed

[1] Draft State Highway Safety Plan, State of Pennsylvania, July 22, 1999
[2] Operations Program Business Plan, FY 1999/2000, State of California, Caltrans, July 1999

Implementation Step 4: Develop Program Policies, Guidelines, and Specifications

General Description

A foundation and framework are needed for solving the identified safety problems. The implementation process will need to be guided and evaluated according to a set of goals, objectives, and related performance measures. These will formalize what the intended result is and how success will be measured. The overlying crash reduction goal, established in Step 3, will provide the context for the more specific goals established in this step. The goals, objectives, and performance measures will be used much later to evaluate what is implemented. Therefore, they should be jointly outlined at this point and agreed to by all program stakeholders. It is important to recognize that evaluating any actions is an important part of the process. Even though evaluation is not finished until some time after the strategies have been implemented, it begins at this step.

The elements of this step may be simpler for a specific project or location than for a comprehensive program. However, even in the simpler case, policies, guidelines, and specifications are usually needed. Furthermore, some programs or projects may require that some guidelines or specifications be in the form of limits on directions taken and types of strategies considered acceptable.

Specific Elements

1. Identify high-level policy actions required and implement them (legislative and administrative)
2. Develop goals, objectives, and performance measures to guide the program and use for assessing its effect
    - 2.1. Hold joint meetings of stakeholders
    - 2.2. Use consensus-seeking methods
    - 2.3. Carefully define terms and measures
    - 2.4. Develop report documenting results and validate them
3. Identify specifications or constraints to be used throughout the project
    - 3.1. Budget constraints
    - 3.2. Time constraints
    - 3.3. Personnel training
    - 3.4. Capacity to install or construct
    - 3.5. Types of strategies not to be considered or that must be included
    - 3.6. Other

Implementation Step 5: Develop Alternative Approaches to Addressing the Problem

General Description

Having defined the problem and established a foundation, the next step is to find ways to address the identified problems. If the problem identification stage has been done effectively (see Appendix D for further details on identifying road safety problems), the characteristics of the problems should suggest one or more alternative ways for dealing with the problem. It is important that a full range of options be considered, drawing from areas dealing with enforcement, engineering, education, emergency medical services, and system management actions.

Alternative strategies should be sought for both location-specific and systemic problems that have been identified. Location-specific strategies should pertain equally well to addressing high-hazard locations and to solving safety problems identified within projects that are being studied for reasons other than safety.

Where site-specific strategies are being considered, visits to selected sites may be in order if detailed data and pictures are not available. In some cases, the emphasis area guides will provide tables that help connect the attributes of the problem with one or more appropriate strategies to use as countermeasures.

Strategies should also be considered for application on a systemic basis. Examples include

1. Low-cost improvements targeted at problems that have been identified as significant in the overall highway safety picture, but not concentrated in a given location.
2. Action focused upon a specific driver population, but carried out throughout the jurisdiction.
3. Response to a change in policy, including modified design standards.
4. Response to a change in law, such as adoption of a new definition for DUI.

In some cases, a strategy may be considered that is relatively untried or is an innovative variation from past approaches to treatment of a similar problem. Special care is needed to ensure that such strategies are found to be sound enough to implement on a wide-scale basis. Rather than ignoring this type of candidate strategy in favor of the more "tried-and-proven" approaches, consideration should be given to including a pilot-test component to the strategy.

The primary purpose of this guide is to provide a set of strategies to consider for eliminating or lessening the particular road safety problem upon which the user is focusing. As pointed out in the first step of this process, the identification of the problem, and the selection of strategies, is a complex step that will be different for each case. Therefore, it is not feasible to provide a "formula" to follow. However, guidelines are available. There are a number of texts to which the reader can refer. Some of these are listed in Appendix B and Appendix D.

In addition, the tables referenced in Appendix G provide examples for linking identified problems with candidate strategies.

The second part of this step is to assemble sets of strategies into alternative "program packages." Some strategies are complementary to others, while some are more effective when combined with others. In addition, some strategies are mutually exclusive. Finally, strategies may be needed to address roads across multiple jurisdictions. For instance, a package of strategies may need to address both the state and local highway system to have the desired level of impact. The result of this part of the activity will be a set of alternative "program packages" for the emphasis area.

It may be desirable to prepare a technical memorandum at the end of this step. It would document the results, both for input into the next step and for internal reviews. The latter is likely to occur, since this is the point at which specific actions are being seriously considered.

Specific Elements

1. Review problem characteristics and compare them with individual strategies, considering both their objectives and their attributes
    - 1.1. Road-user behavior (law enforcement, licensing, adjudication)
    - 1.2. Engineering
    - 1.3. Emergency medical services
    - 1.4. System management elements
2. Select individual strategies that do the following:
    - 2.1. Address the problem
    - 2.2. Are within the policies and constraints established
    - 2.3. Are likely to help achieve the goals and objectives established for the program
3. Assemble individual strategies into alternative program packages expected to optimize achievement of goals and objectives
    - 3.1. Cumulative effect to achieve crash reduction goal
    - 3.2. Eliminate strategies that can be identified as inappropriate, or likely to be ineffective, even at this early stage of planning
4. Summarize the plan in a technical memorandum, describing attributes of individual strategies, how they will be combined, and why they are likely to meet the established goals and objectives

Implementation Step 6: Evaluate Alternatives and Select a Plan

General Description

This step is needed to arrive at a logical basis for prioritizing and selecting among the alternative strategies or program packages that have been developed. There are several activities that need to be performed. One proposed list is shown in Appendix P.

The process involves making estimates for each of the established performance measures for the program and comparing them, both individually and in total. To do this in a quantitative manner requires some basis for estimating the effectiveness of each strategy. Where solid evidence has been found on effectiveness, it has been presented for each strategy in the guide. In some cases, agencies have a set of crash reduction factors that are used to arrive at effectiveness estimates. Where a high degree of uncertainty exists, it is wise to use sensitivity analyses to test the validity of any conclusions that may be made regarding which is the best strategy or set of strategies to use. Further discussion of this may be found in Appendix O.

Cost-benefit and cost-effectiveness analyses are usually used to help identify inefficient or inappropriate strategies, as well as to establish priorities. For further definition of the two terms, see Appendix Q. For a comparison of the two techniques, see Appendix S. Aspects of feasibility, other than economic, must also be considered at this point. An excellent set of references is provided within online benefit-cost guides:

- One is under development at the following site, maintained by the American Society of Civil Engineers: http://ceenve.calpoly.edu/sullivan/cutep/cutep_bc_outline_main.htm
- The other is *Guide to Benefit-Cost Analysis in Transport Canada*, September 1994, http://www.tc.gc.ca/finance/bca/en/TOC_e.htm. An overall summary of this document is given in Appendix V.

In some cases, a strategy or program may look promising, but no evidence may be available as to its likely effectiveness. This would be especially true for innovative methods or use of emerging technologies. In such cases, it may be advisable to plan a pilot study to arrive at a minimum level of confidence in its effectiveness, before large-scale investment is made or a large segment of the public is involved in something untested.

It is at this stage of detailed analysis that the crash reduction goals, set in Step 3, may be revisited, with the possibility of modification.

It is important that this step be conducted with the full participation of the stakeholders. If the previous steps were followed, the working group will have the appropriate representation. Technical assistance from more than one discipline may be necessary to go through more complex issues. Group consensus will be important on areas such as estimates of effectiveness, as well as the rating and ranking of alternatives. Techniques are available to assist in arriving at consensus. For example, see the following Web site for an overview: http://web.mit.edu/publicdisputes/practices/cbh_ch1.html.

Specific Elements

1. Assess feasibility
    - 1.1. Human resources
    - 1.2. Special constraints
    - 1.3. Legislative requirements
    - 1.4. Other
    - 1.5. This is often done in a qualitative way, to narrow the list of choices to be studied in more detail (see, for example, Appendix BB)
2. Estimate values for each of the performance measures for each strategy and plan
    - 2.1. Estimate costs and impacts
        - 2.1.1. Consider guidelines provided in the detailed description of strategies in this material
        - 2.1.2. Adjust as necessary to reflect local knowledge or practice
        - 2.1.3. Where a plan or program is being considered that includes more than one strategy, combine individual estimates
    - 2.2. Prepare results for cost-benefit and/or cost-effectiveness analyses
    - 2.3. Summarize the estimates in both disaggregate (by individual strategy) and aggregate (total for the program) form
3. Conduct a cost-benefit and/or cost-effectiveness analysis to identify inefficient, as well as dominant, strategies and programs and to establish a priority for the alternatives
    - 3.1. Test for dominance (both lower cost and higher effectiveness than others)
    - 3.2. Estimate relative cost-benefit and/or cost-effectiveness
    - 3.3. Test productivity
4. Develop a report that documents the effort, summarizing the alternatives considered and presenting a preferred program, as devised by the working group (for suggestions on a report of a benefit-cost analysis, see Appendix U).
    - 4.1. Designed for high-level decision makers, as well as technical personnel who would be involved in the implementation
    - 4.2. Extensive use of graphics and layout techniques to facilitate understanding and capture interest
    - 4.3. Recommendations regarding meeting or altering the crash reduction goals established in Step 3.

Implementation Step 7: Submit Recommendations for Action by Top Management

General Description

The working group has completed the important planning tasks and must now submit the results and conclusions to those who will make the decision on whether to proceed further. Top management, at this step, will primarily be determining if an investment will be made in this area. As a result, the plan will not only be considered on the basis of its merits for solving the particular problems identified in this emphasis area (say, vis-à-vis other approaches that could be taken to deal with the specific problems identified), but also its relative value in relation to investments in other aspects of the road safety program.

This aspect of the process involves using the best available communication skills to adequately inform top management. The degree of effort and extent of use of media should be proportionate to the size and complexity of the problem being addressed, as well as the degree to which there is competition for funds.

The material that is submitted should receive careful review by those with knowledge in report design and layout. In addition, today's technology allows for the development of automated presentations, using animation and multimedia in a cost-effective manner. Therefore, programs involving significant investments that are competing strongly for implementation resources should be backed by such supplementary means for communicating efficiently and effectively with top management.

Specific Elements

1. Submit recommendations for action by management
    - 1.1. "Go/no-go" decision
    - 1.2. Reconsideration of policies, guidelines, and specifications (see Step 3)
    - 1.3. Modification of the plan to accommodate any revisions to the program framework made by the decision makers
2. Working group to make presentations to decision makers and other groups, as needed and requested
3. Working group to provide technical assistance with the review of the plan, as requested
    - 3.1. Availability to answer questions and provide further detail
    - 3.2. Assistance in conducting formal assessments

Implementation Step 8: Develop a Plan of Action

General Description

At this stage, the working group will usually detail the program that has been selected for implementation. This step translates the program into an action plan, with all the details needed by both decision makers, who will have to commit to the investment of resources, and those charged with carrying it out. The effort involves defining resource requirements, organizational and institutional arrangements needed, schedules, etc. This is usually done in the form of a business plan, or plan of action. An example of a plan developed by a local community is shown in Appendix X.

An evaluation plan should be designed at this point. It is an important part of the plan. This is something that should be in place before Step 9 is finished. It is not acceptable to wait until after the program is completed to begin designing an evaluation of it. This is because data are needed about conditions before the program starts, to allow comparison with conditions during its operation and after its completion. It also should be designed at this point, to achieve consensus among the stakeholders on what constitutes "success." The evaluation is used to determine just how well things were carried out and what effect the program had. Knowing this helps maintain the validity of what is being done, encourages future support from management, and provides good intelligence on how to proceed after the program is completed. For further details on performing evaluations, see Appendix L, Appendix M, and Appendix W.

The plan of action should be developed jointly with the involvement of all desired participants in the program. It should be completed to the detail necessary to receive formal approval of each agency during the next step. The degree of detail and complexity required for this step will be a function of the size and scope of the program, as well as the number of independent agencies involved.

Specific Elements

1. Translation of the selected program into key resource requirements
    - 1.1. Agencies from which cooperation and coordination is required
    - 1.2. Funding
    - 1.3. Personnel
    - 1.4. Data and information
    - 1.5. Time
    - 1.6. Equipment
    - 1.7. Materials
    - 1.8. Training
    - 1.9. Legislation
2. Define organizational and institutional framework for implementing the program
    - 2.1. Include high-level oversight group
    - 2.2. Provide for involvement in planning at working levels
    - 2.3. Provide mechanisms for resolution of issues that may arise and disagreements that may occur
    - 2.4. Secure human and financial resources required

3. Detail a program evaluation plan
    - 3.1. Goals and objectives
    - 3.2. Process measures
    - 3.3. Performance measures
        - 3.3.1. Short-term, including surrogates, to allow early reporting of results
        - 3.3.2. Long-term
    - 3.4. Type of evaluation
    - 3.5. Data needed
    - 3.6. Personnel needed
    - 3.7. Budget and time estimates
4. Definition of tasks to conduct the work
    - 4.1. Develop diagram of tasks (e.g., PERT chart)
    - 4.2. Develop schedule (e.g., Gantt chart)
    - 4.3. For each task, define
        - 4.3.1. Inputs
        - 4.3.2. Outputs
        - 4.3.3. Resource requirements
        - 4.3.4. Agency roles
        - 4.3.5. Sequence and dependency of tasks
5. Develop detailed budget
    - 5.1. By task
    - 5.2. Separate by source and agency/office (i.e., cost center)
6. Produce program action plan, or business plan document

Implementation Step 9: Establish Foundations for Implementing the Program

General Description

Once approved, some "groundwork" is often necessary to establish a foundation for carrying out the selected program. This is somewhat similar to what was done in Step 4. It must now be done in greater detail and scope for the specific program being implemented. As in Step 4, specific policies and guidelines must be developed, organizational and institutional arrangements must be initiated, and an infrastructure must be created for the program. The business plan or action plan provides the basis (Step 7) for this. Once again, the degree of complexity required will vary with the scope and size of the program, as well as the number of agencies involved.

Specific Elements

1. Refine policies and guidelines (from Step 4)
2. Effect required legislation or regulations
3. Allocate budget
4. Reorganize implementation working group
5. Develop program infrastructure
    - 5.1. Facilities and equipment for program staff
    - 5.2. Information systems
    - 5.3. Communications
    - 5.4. Assignment of personnel
    - 5.5. Administrative systems (monitoring and reporting)
6. Set up program assessment system
    - 6.1. Define/refine/revise performance and process measures
    - 6.2. Establish data collection and reporting protocols
    - 6.3. Develop data collection and reporting instruments
    - 6.4. Measure baseline conditions

Implementation Step 10: Carry Out the Action Plan

General Description

Conditions have been established to allow the program to be started. The activities of implementation may be divided into activities associated with field preparation for whatever actions are planned and the actual field implementation of the plan. The activities can involve design and development of program actions, actual construction or installation of program elements, training, and the actual operation of the program. This step also includes monitoring for the purpose of maintaining control and carrying out mid- and post-program evaluation of the effort.

Specific Elements

1. Conduct detailed design of program elements
    - 1.1. Physical design elements
    - 1.2. PI&E materials
    - 1.3. Enforcement protocols
    - 1.4. Etc.
2. Conduct program training
3. Develop and acquire program materials
4. Develop and acquire program equipment
5. Conduct pilot tests of untested strategies, as needed
6. Program operation
    - 6.1. Conduct program "kickoff"
    - 6.2. Carry out monitoring and management of ongoing operation
        - 6.2.1. Periodic measurement (process and performance measures)
        - 6.2.2. Adjustments as required
    - 6.3. Perform interim and final reporting

Implementation Step 11: Assess and Transition the Program

General Description

The AASHTO Strategic Highway Safety Plan includes improvement in highway safety management. A key element of that is the conduct of properly designed program evaluations. The program evaluation will have been first designed in Step 8, which occurs prior to any field implementation. For details on designing an evaluation, please refer to Step 8. For an example of how the New Zealand Transport Authority takes this step as an important part of the process, see Appendix N.

The program will usually have a specified operational period. An evaluation of both the process and performance will have begun prior to the start of implementation. It may also continue during the course of the implementation, and it will be completed after the operational period of the program.

The overall effectiveness of the effort should be measured to determine if the investment was worthwhile and to guide top management on how to proceed into the post-program period. This often means that there is a need to quickly measure program effectiveness in order to provide a preliminary idea of the success or need for immediate modification. This will be particularly important early in development of the AASHTO Strategic Highway Safety Plan, as agencies learn what works best. Therefore, surrogates for safety impact may have to be used to arrive at early/interim conclusions. These usually include behavioral measures. This particular need for interim surrogate measures should be dealt with when the evaluation is designed, back in Step 8. However, a certain period, usually a minimum of a couple of years, will be required to properly measure the effectiveness and draw valid conclusions about programs designed to reduce highway fatalities when using direct safety performance measures.

The results of the work is usually reported back to those who authorized it and the stakeholders, as well as any others in management who will be involved in determining the future of the program. Decisions must be made on how to continue or expand the effort, if at all. If a program is to be continued or expanded (as in the case of a pilot study), the results of its assessment may suggest modifications. In some cases, a decision may be needed to remove what has been placed in the highway environment as part of the program because of a negative impact being measured. Even a "permanent" installation (e.g., rumble strips) requires a decision regarding investment for future maintenance if it is to continue to be effective.

Finally, the results of the evaluation using performance measures should be fed back into a knowledge base to improve future estimates of effectiveness.

Specific Elements

1. Analysis
    - 1.1. Summarize assessment data reported during the course of the program
    - 1.2. Analyze both process and performance measures (both quantitative and qualitative)

   1.3. Evaluate the degree to which goals and objectives were achieved (using performance measures)
   1.4. Estimate costs (especially vis-à-vis pre-implementation estimates)
   1.5. Document anecdotal material that may provide insight for improving future programs and implementation efforts
   1.6. Conduct and document debriefing sessions with persons involved in the program (including anecdotal evidence of effectiveness and recommended revisions)
2. Report results
3. Decide how to transition the program
   3.1. Stop
   3.2. Continue as is
   3.3. Continue with revisions
   3.4. Expand as is
   3.5. Expand with revisions
   3.6. Reverse some actions
4. Document data for creating or updating database of effectiveness estimates

SECTION VII

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Appendixes

The following appendixes are not published in this report. However, they are available online at http://transportation1.org/safetyplan..

1 Matrix of Pedestrian Crash Types and Corresponding Strategies
2 PEDSAFE Case Studies Available On-Line
3 Triple E Committees
4 Countermeasures Used to Prevent Pedestrian Alcohol Deaths
5 Guidelines for Sidewalk and Curb Ramp Design
6 Guidelines for New Sidewalk and Walkway Installation
7 Typical Costs for Sidewalks and Curb Ramps
8 Costs of Typical Traffic and Pedestrian Signal Upgrades
9 Costs of Typical Pedestrian Refuge Islands and Raised Medians
10 Typical Costs for Vehicle Restriction/Diversion Measures
11 Key Results of a Major Study of Crosswalk Safety
12 Cost Considerations for Road Narrowing Using Pavement Markings
13 Details on Evaluations of Speed Humps
14 Cost Estimates for Common Traffic Calming Actions for Road Sections
15 Typical Costs for Traffic Calming Installations at Intersections
16 Public Awareness Campaigns
17 CERS Enforcement Program
18 Redmond, Washington Police Department Pedestrian Right-of-Way Enforcement Program
19 Considerations for Implementing a Pedestrian Enforcement Program
20 Model Municipal and County Pedestrian Ordinances

A Wisconsin Department of Transportation 2001 Strategic Highway Safety Plan
B Resources for the Planning and Implementation of Highway Safety Programs
C South African Road Safety Manual
D Comments on Problem Definition
E Issues Associated with Use of Safety Information in Highway Design: Role of Safety in Decision Making
F Comprehensive Highway Safety Improvement Model
G Table Relating Candidate Strategies to Safety Data Elements
H What is a Road Safety Audit?
I Illustration of Regression to the Mean
J Fault Tree Analysis
K Lists of Potential Stakeholders
L Conducting an Evaluation
M Designs for a Program Evaluation
N Joint Crash Reduction Programme: Outcome Monitoring
O Estimating the Effectiveness of a Program During the Planning Stages
P Key Activities for Evaluating Alternative Program
Q Definitions of Cost-Benefit and Cost-Effectiveness
R FHWA Policy on Life Cycle Costing

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation