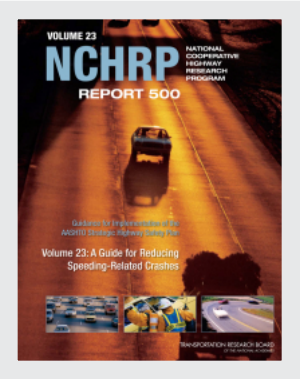

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 500

Guidance for Implementation of the AASHTO Strategic Highway Safety Plan

Volume 23: A Guide for Reducing Speeding-Related Crashes

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Subject Areas
Safety and Human Performance

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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FOREWORD

By Charles W. Niessner
Staff Officer
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The American Association of State Highway and Transportation Officials (AASHTO) has adopted a national highway safety goal of halving fatalities over the next 2 decades—or reducing the number of fatalities by 1,000 per year. 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 twenty-third volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* provides strategies that can be employed to reduce crashes involving speeding. 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. 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 twenty-third 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-the-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://safety.transportation.org. 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

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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 Ronald 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 and Vanessa Bond, also of CH2M HILL, served as technical specialists 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 speed guide:

- Kelly Hardy
  CH2M HILL

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, as well as additional reviews of the speed guide:

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SECTION I

Summary

Introduction

One of the hallmarks of the AASHTO Strategic Highway Safety Plan (SHSP) is to approach safety problems in a comprehensive manner. The range of strategies available in the guides covers various aspects of the road user, the highway, the vehicle, the environment, and the management system. The guides strongly encourage the user to develop a program to tackle a particular emphasis area from each of these perspectives in a coordinated manner. To facilitate this, the electronic form of the material uses hypertext linkages to enable seamless integration of various approaches to a given problem. As more guides are developed for other emphasis areas, the extent and usefulness of this form of implementation will become even more apparent.

The goal is to move away from *independent* activities of engineers, law enforcement, educators, judges, and other highway-safety specialists. The implementation process outlined in the guides promotes the formation of working groups and alliances that represent all of the elements of the safety system. In so doing, they can draw upon their combined expertise to reach the bottom-line goal of targeted reduction of crashes and fatalities associated with a particular emphasis area.

The six major areas of the AASHTO SHSP (Drivers, Vehicles, Special Users, Highways, Emergency Medical Services, and Management) are subdivided into 22 goals, or key emphasis areas, that impact highway safety. Though reduction of speeding-related fatalities is not specifically included in the list of SHSP emphasis areas, speeding is a contributing factor in many fatal crashes. Therefore this guide, which addresses speeding, complements the other guides in this series. Strategies discussed are applicable to high- and/or low-speed roadways and include education, enforcement, and engineering approaches to reducing speeding-related fatalities.

Speeding is among the most significant contributing factors to fatal collisions. Excessive speeds reduce a driver's ability to react and maneuver and require greater stopping distances. The severity of collisions, particularly those involving pedestrians, bicyclists, and motorcyclists, increases dramatically with the speed of collision. Speeding-related crashes are an issue that can be deterred with increased efforts in education, engineering, and enforcement. Currently there are many different efforts in the nation and around the world in practice to reduce these types of collisions.

Throughout this guide, problems and strategies associated with "low-speed" and "high-speed" roads are presented. AASHTO considers (AASHTO *Policy on Geometric Design of Highways and Streets, 5th Edition*) the upper limit for low-speed design (i.e., design speed) is 45 mph, and the lower limit for high-speed design is 50 mph.

Many of the strategies involve speed limits and advisory speeds (setting, posting, enforcing, etc.). As it is common practice for posted speed limits to be some nominal value less than the design speed (often 5 mph), this guide presents information on high-

and low-speed designs, with the definition being low-speed roads with speed limits of 40 mph or less (5 mph less than the highest AASHTO design speed) and high-speed roads with speed limits of 45 mph or greater (5 mph less than the lowest AASHTO design speed).

Grouping of strategies by speed range is done for convenience and focus. Users of this guide need not be constrained, however, by the definitions and groupings. A user may find that a strategy discussed in the low-speed guide may have application and value in a nominally high-speed condition. This is not only acceptable but considered good use of the guide. The strategies discussed are shown in Exhibit I-1.

General Description of the Problem

Excessive or inappropriate speeds result from two basic problems, both of which involve human factors considerations. Driver behavior (i.e., consciously choosing a clearly inappropriate speed) is one aspect of the problem. The second is associated with driver response to the environment (i.e., inadvertent selection of a speed that is inappropriate or unsafe, failure to adjust or change speeds, or failure to perceive the speed environment and as a result incur risk of a collision or conflict). It is both of these types of problems that this guide seeks to address.

Approximately 42,000 automobile-related fatalities occur each year in the United States, and historically, nearly one-third of fatal crashes involve speeding, as shown in Exhibit III-1. In *Traffic Safety Facts 2006—Speeding,* the National Highway Transportation Safety Administration (NHTSA) defines a speeding-related crash as a crash in which "the driver was charged with a speeding-related offense or if an officer indicated that racing, driving too fast for conditions, or exceeding the posted speed limit was a contributing factor in the crash" (NHTSA, 2006). This section details characteristics of speeding-related fatalities and fatal crashes obtained from a review of recent literature and the NHTSA Fatality Analysis Recording System (FARS) database.

In 2006, there were 42,708 traffic fatalities, 30 percent (13,113) of which involved speeding. Of these fatalities, 13,543 (32%) occurred as a result of a speeding-related crash. Only 13% of all speeding-related traffic fatalities occurred on Interstate roadways, while 72% occurred on non-Interstate roads. Of the crashes on non-Interstate roads, 29% occurred on low-speed non-Interstate roads (defined for the purpose of this report as roads with a speed limit of 40 mph or less), and 43% occurred on high-speed non-Interstate roads (roads with a speed limit of 45 mph or more). Roadways with unknown or no statutory speed limits accounted for 15 percent of speeding-related fatalities. These data are taken from *Traffic Safety Facts 2006–Speeding* (NHTSA, 2006). A further review of 2005 FARS data yields additional insights into fatal crash characteristics (NHTSA, 2005):

- Approximately 39 percent of speeding-related fatal crashes occurred on horizontal curves.
- Speeding-related fatalities occur primarily in single-vehicle crashes; 70 percent of speeding-related fatalities on low-speed roads, and 67 percent on high-speed roads occurred in this manner of collision.
- 38 percent of speeding drivers in a fatal crash were under the age of 25.
- 40 percent of drivers that were speeding in fatal collisions had a blood alcohol content (BAC) of at least 0.08.

Objectives of the Emphasis Area

The speeding-related safety issues discussed above are the basis for the inclusion of the strategies discussed in Section V. The strategies cover setting appropriate speed limits, improving driver awareness of speeding-related safety concerns, improving enforcement efforts, communicating appropriate speeds with drivers, and ensuring the roadway environment is designed and operated so as to encourage appropriate speeds. The strategies are grouped by objective—the safety concerns being addressed. Exhibit I-1 lists the objectives and the related strategies discussed in this guide. The strategies considered cover the full range of engineering, enforcement, and education:

- **Set appropriate speed limits**—Speed limits that appear inconsistent may be ignored by the majority of drivers and this may contribute to lack of respect for speed limit and other traffic laws. Setting speed limits to reflect the surrounding context of the roadway and meet with driver expectations can help improve driver respect for speed limits.
- **Heighten driver awareness of speeding-related safety issues**—Informing drivers of the risks—both to themselves and to other road users—associated with speeding is intended to encourage drivers to obey speed limits and drive at speeds safe for the roadway environment.

EXHIBIT I-1
Objectives and Strategies for Addressing Speeding-Related Fatalities

Objectives	Strategies
A. Set appropriate speed limits	A1 Set speed limits which account for roadway design, traffic, and environment
	A2 Implement variable speed limits
	A3 Implement differential speed limits for heavy vehicles if appropriate **(High Speed Only)**
B. Heighten driver awareness of speeding-related safety issues	B1 Increase public awareness of risks of driving at unsafe speeds
	B2 Increase public awareness of potential penalties for speeding
	B3 Increase public awareness of risks of not wearing seatbelts
	B4 Implement neighborhood speed watch/traffic management programs **(Low Speed Only)**
	B5 Implement Safe Community Programs
C. Improve efficiency and effectiveness of speed enforcement efforts	C1 Use targeted conventional speed enforcement programs at locations known to have speeding-related crashes
	C2 Implement automated speed enforcement
	C3 Increase penalties for repeat and excessive speeding offenders
	C4 Strengthen the adjudication of speeding citations to enhance the deterrent effect of fines
	C5 Increase fines in special areas

EXHIBIT I-1 (Continued)
Objectives and Strategies for Addressing Speeding-Related Fatalities

Objectives	Strategies
D. Communicate appropriate speeds through use of traffic control devices	D1 Improve speed limit signage
	D2 Implement active speed warning signs
	D3 Use in-pavement measures to communicate the need to reduce speeds
	D4 Implement variable message signs **(High Speed Only)**
E. Ensure that roadway design and traffic control elements support appropriate and safe speeds	E1 Use combinations of geometric elements to control speeds
	E2 Effect safe speed transitions through design elements and on approaches to lower speed areas
	E3 Provide appropriate intersection design for speed of roadway
	E4 Provide adequate change + clearance intervals at signalized intersections
	E5 Operate traffic signals appropriately for intersections and corridors (signal progression)
	E6 Provide adequate sight distance for expected speeds
	E7 Implement protected-only signal phasing for left turns at high-speed signalized intersections **(High Speed Only)**
	E8 Install lighting at high-speed intersections **(High Speed Only)**
	E9 Reduce speeds and/or volumes on both neighborhood and downtown streets with the use of traffic calming and other related countermeasures **(Low Speed Only)**

- **Improve the effectiveness of speed enforcement efforts—**Many crashes are caused or aggravated by drivers' noncompliance with traffic control devices or traffic laws. Effectiveness of enforcement can be increased if drivers perceive there is a significant chance they may be cited for speeding and may be given a hefty fine. Visible conventional or automated enforcement programs, increased fines for repeat offenders, and upholding of citations and levying of fines by courts can increase drivers' perceptions of the enforcement-related risks of speeding.
- **Communicate appropriate speeds through use of traffic control devices—**Information on appropriate speeds, including permanent speed limits, variable speed limits, and warning speeds, needs to be conveyed clearly to drivers and at appropriate locations. Pavement markings can be used to encourage drivers to proceed at appropriate speeds without actually posting the speed limit. Even though drivers have the responsibility to drive at a safe speed, they need to be able to receive cues from the roadway environment as to what that safe speed is.

- **Ensure roadway design and traffic control elements support appropriate and safe speeds—**Geometric design features of roadway sections and intersections, and operation of traffic signals, need to reflect the speeds desired of drivers. For example, roadway design elements sensitive to the context in which they will be located can encourage appropriate speed choices by drivers. Geometric elements which affect operating speeds, such as horizontal and vertical curves, can be designed in combinations to encourage appropriate speeds. Intersection types and designs should be appropriate for the context of the roadway. Providing a proper signal coordination through intersections along a corridor can create uniform speeds and reduce the need for drivers to stop at the intersections.

SECTION II

Introduction

Approximately 42,000 automobile-related fatalities occur each year in the United States. Nearly one-third of fatal crashes are speeding-related. In *Traffic Safety Facts 2006—Speeding,* NHTSA defines a speeding-related crash as a crash in which "the driver was charged with a speeding-related offense or if an officer indicated that racing, driving too fast for conditions, or exceeding the posted speed limit was a contributing factor in the crash" (NHTSA, 2006, p. 1). Excessive speeds reduce a driver's ability to react and maneuver, and require greater stopping distances. The severity of a collision, particularly those involving pedestrians, bicyclists, and motorcyclists increases dramatically with the speed of collision.

Excessive or inappropriate speeds result from two basic problems, both of which involve human factors considerations. Driver behavior (i.e., consciously choosing a clearly inappropriate speed) is one aspect of the problem. The second is associated with driver response to the environment (i.e., inadvertent selection of a speed that is inappropriate or unsafe, failure to adjust or change speeds, or failure to perceive the speed environment and as a result incur risk of a collision or conflict). It is both of these types of problems that this guide seeks to address.

Efforts to reduce speeding and speeding-related crashes need to be multi-disciplined in order to address all factors that contribute to a driver's choice of inappropriate speed or misunderstanding of what a safe speed would be. Speeding-related crashes can be reduced with increased efforts in education, engineering, and enforcement. Strategies in this guide are encouraged for implementation by state and local highway agencies, especially where there is a high frequency or rate of serious crashes that appear to involve inappropriate speeds.

Many of the strategies discussed in this guide are engineering-related. However, it is important to consider the need to involve stakeholders, and other safety professionals who will either be directly involved, or who can provide additional perspectives and expertise for implementing planned strategies. In some cases, implementation of the strategy will directly impact operations on the highway. In such cases, many elements of the safety community (e.g., law enforcement, EMS, fire departments, utilities companies, contractors, media, adjacent land users and owners) are best involved from early planning stages.

SECTION III

Type of Problem Being Addressed

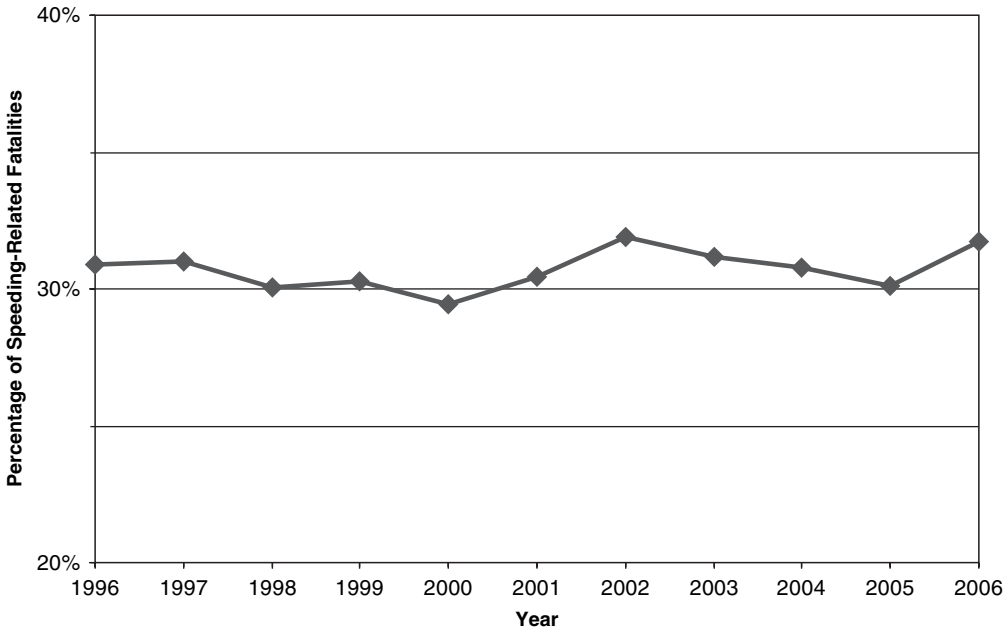
General Description of the Problem

Historically, approximately one-third of all fatal traffic crashes involve speeding, as shown in Exhibit III-1. Section III details characteristics of speeding-related fatalities and fatal crashes obtained from a review of recent literature and the NHTSA Fatality Analysis Recording System (FARS) database.

As shown in Exhibit III-2, there were 42,708 total fatalities on the roads in the United States in 2006; 13,543 (32 percent) of these fatalities occurred as a result of a speeding-related crash. Of these, only 13 percent of all speeding-related traffic fatalities occurred on Interstate roadways, while 72 percent occurred on non-Interstate roads, 29 percent occurred on low-speed non-Interstate roads (defined for the purpose of this report as roads with a speed limit of 40 mph or less), and 43 percent occurred on high-speed non-Interstate roads (roads with a speed limit of 45 mph or more). According to *Traffic Safety Facts 2006—Speeding,* roadways with unknown or no statutory speed limits accounted for 15 percent of speeding-related fatalities (NHTSA, 2006).

Of the speeding-related fatal crashes, 43 percent occurred in urban areas and 56 percent in rural areas. As an agency seeks to address speeding-related crashes, it may be necessary to coordinate implementation of strategies, especially education and enforcement strategies, with other agencies in neighboring jurisdictions or at a different governmental level.

EXHIBIT III-1
Historic Trend in All Fatalities That Are Speeding-Related
Source: FARS data (NHTSA, 2006a)



most common cause of speeding-related fatalities on low speed-roads (11%), while rear-end collisions were the second most common cause of speeding-related fatalities on high-speed roads (10%).

Non-Motorists

563 pedestrians were involved in speeding-related fatal crashes in 2006; 307 of these were on low-speed roadways, and 232 were on high-speed roadways.

EXHIBIT III-2
Fatal Speeding Crashes by Road Type and Speed Limit
Source: FARS data (NHTSA, 2006a)

Road Type	Speed Limit	Speeding-Related Traffic Fatalities	Percentage of Total Speeding-Related Traffic Fatalities
Interstate	Greater than 55 mph	1,373	10%
	Less than or equal to 55 mph	371	3%
Non-Interstate	Low (40 mph or less)	3,969	29%
	High (45 mph or more)	5,793	43%
Unknown	Unknown/No Statutory Limit	2,037	15%
Total		13,543	100%

Specific Attributes of the Problem

Much of the problem associated with speeding is behavioral. Unfortunately, there are cultural barriers to producing safe driving behavior. Speed is marketed to car buyers. Cars today can accelerate faster, reach higher speeds and handle more impressively than they could a generation ago (Schneider, 2004). Advances in technology have allowed auto manufacturers to produce efficient high-performance engines and lightweight parts (e.g., carbon fiber) that result in high-performance vehicles. Speeding is a traffic violation that seems acceptable to today's society. Exposure to high speeds, extreme driving and illegal racing in the media promote the wrong message to drivers, especially younger drivers. When such messages are combined with risks such as not wearing seatbelts, or driving under the influence of alcohol or drugs, the result can be deadly. This section reviews crash data and other research in order to better explain the nature of the speed- and speeding-related problems, and to help direct highway agencies' safety improvement efforts.

Speed-related crashes, where speeding is not a contributing factor, are hard to identify in crash databases. What characteristics of a crash identify speed as related to an improper response to the driving environment? For example, crash data may identify high-accident locations with relatively frequent run-off-road crashes where drivers were at or under the speed limit, giving the impression that speed was not a factor. Yet, the characteristics and pattern of the crashes could still indicate that speed was a contributing factor in the drivers' improper response to the driving environment. Analysis of an agency's crash data is an important step in the process for determining which safety improvements may be appropriate. It is important that efforts are made to investigate the characteristics of the crash data to identify all contributing factors so that the appropriate safety improvements are implemented to address the crash problems.

Several trends observed in nationwide crash data are summarized in this section. A review of characteristics of speeding-related crashes in an agency's jurisdiction can give insight into the appropriate elements for a comprehensive program to reduce speeding-related and speed-

related fatalities. Characteristics of drivers, the roadway environment, and involved vehicles should be analyzed. For example, analysis of age and gender can help identify a target audience for public information and education campaigns. Review of other contributing factors can indicate a benefit to combining programs; such as a seat belt safety education program that includes information on speed reduction. A prevalence of pedestrian involvement in speeding-related crashes may highlight a need for intersection lighting or pedestrian warning devices. An analysis of an agency's crash data should be performed in order to determine appropriate treatments that will address the specific safety concern. The strategies presented in this guide are included based on the analysis of crash data discussed below.

Driver Characteristics

Driver characteristics such as gender, age, impairment at the time of a crash, and seatbelt usage can contribute to the occurrence of crashes and the severity of injuries. Strategies to address the crash factors linked to these characteristics are typically more education- or enforcement-based than engineering-based, as these characteristics relate directly to driver perception and abilities. Knowledge of characteristics of the drivers involved in crashes can help an agency target the appropriate audience through the use of media outlets and formats that market research has shown to be popular among a specific group. Understanding the issues associated with the specific characteristics can help an agency identify strategies to address the associated crash problems.

Driver Gender and Age

To develop an effective driver education program, agencies should identify the target audience by examining crash data to determine if a particular type of driver is overrepresented in speeding-related crashes. A review of FARS data shows that one of the most obvious trends concerning these fatal collisions is the gender of the driver that was speeding.

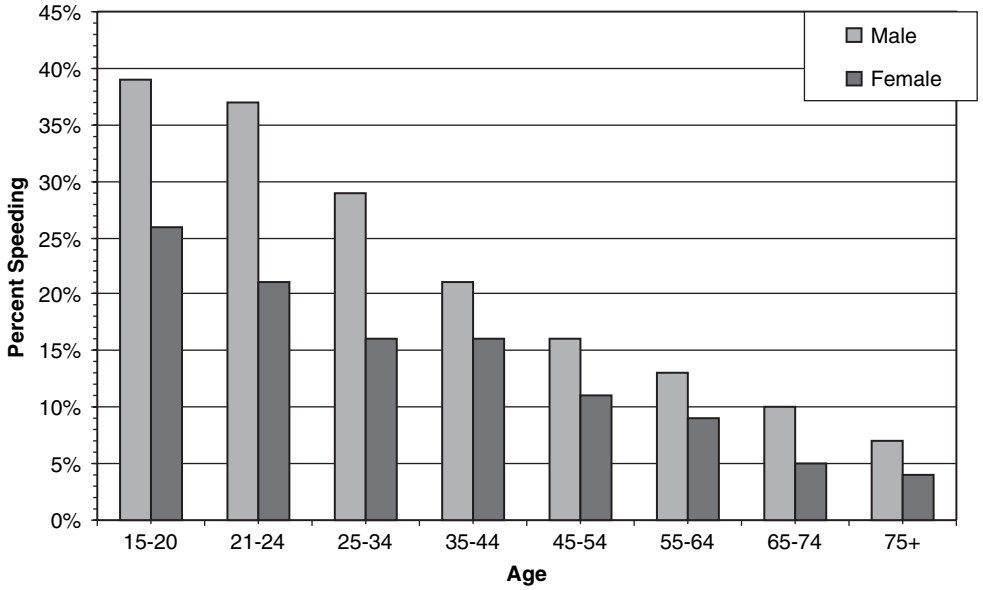
39 percent of 15- to 20-year old male drivers involved in fatal collisions were speeding compared with 26 percent of the female drivers of the same age group who were involved in fatal collisions. Each successively older age group of both males and females had a smaller percentage of speeding drivers when involved in a fatal crash, as illustrated in Exhibit III-3.

Even though a higher percentage of speeding drivers involved in a fatal crash are young, middle-aged drivers still represent a large portion of speeding drivers involved in fatal collisions. As illustrated above, though drivers under the age of 25 involved in fatal collisions speed more than drivers of other age groups involved in fatal collisions, 21 percent of male and 16 percent of female 35- to 44-year-old drivers involved in fatal collisions were speeding. An agency with similar trends in its crash experience may choose to target young male drivers in a public education campaign and in driver education courses, but education outreach to middle-aged drivers should not be overlooked.

Driver Impairment

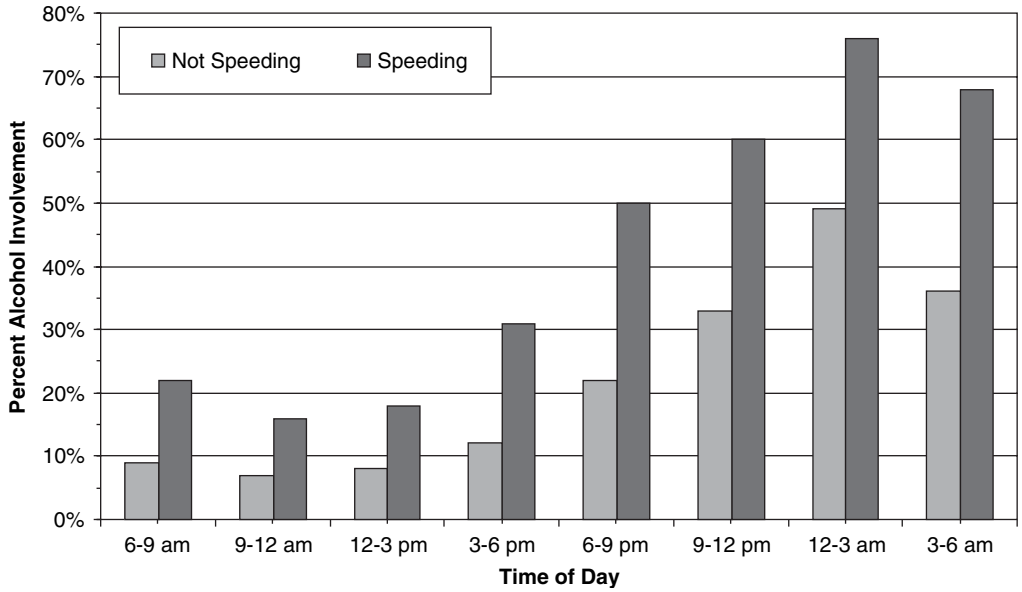
According to *Traffic Safety Facts 2006—Speeding,* approximately 41 percent of drivers with a blood alcohol content (BAC) of at least 0.08 who were involved in fatal crashes were speeding (NHTSA, 2006). Furthermore, 28 percent of the drivers 21 years or younger involved in a fatal speeding-related collision were intoxicated with a BAC of at least

EXHIBIT III-3
Age and Gender of Speeding Drivers Involved in Fatal Collisions, 2006
Source: Traffic Safety Facts 2006-Speeding, NHTSA



0.08. As shown in Exhibit III-4, as the evening progresses into night, the percentage of alcohol- and speeding-related fatal collisions increases. The association between driver impairment and speeding, and the increased incidence of fatalities associated with both impairment and speeding at night, poses a level of risk that demonstrates a likely need for a combination of strategies, such as public education and enforcement.

EXHIBIT III-4
Intoxicated and Speeding Drivers in Fatal Collisions by Time of Day (2006)
Source: Traffic Safety Facts 2006-Speeding, NHTSA



For both speeding and non-speeding drivers involved in fatal crashes, the percentage of those who had been drinking, with a BAC of 0.01 g/dL or higher, at the time the crash occurred was higher at night than during the day. Between midnight and 3:00 a.m., 76 percent of speeding drivers involved in fatal crashes had been drinking.

Occupant Protection

The availability and use of occupant restraints has a large influence on driver/passenger safety in the event of a speeding-related collision. According to NHTSA (2006), "air bags combined with lap/shoulder seatbelts, offer the most effective safety protection available today for passenger vehicle occupant." Yet, also according to NHTSA, in 2006, of drivers age 21 and older involved in fatal crashes, those who were not speeding were more likely to be wearing seatbelts than those who were speeding at the time of the crash. For drivers age 21 and older, the percentage of speeding drivers involved in fatal crashes who were using restraints at the time of the crash was 43 percent, but 73 percent of non-speeding drivers in fatal crashes were restrained.

Young adults, ages 16–20, generally exhibit lower voluntary seatbelt usage compliance than other segments of the population (refer to Exhibit III-1 of *NCHRP Report 500, Volume 11: A Guide for Increasing Seatbelt Use,* of this series). In 2006, only 45 percent of drivers under age 21 involved in a speeding-related fatal collision were wearing a seat belt at the time of the crash, whereas 69 percent of drivers over age 21 involved in a (non-speeding) fatal collision were wearing a seat belt. As young males also exhibit a tendency to drive at high speeds, and their driving skills are less refined than older drivers' skills tend to be, the combination of risky behaviors makes young males a particular target population for speeding-related education strategies.

Environmental Characteristics

The roadway environment can contribute to the incidence of crashes by presenting drivers with unexpected or unfamiliar situations that require a change in speed or other driving behavior. Lighting and weather conditions are examples of conditions of the roadway environment that can present additional challenges to drivers. Many times, a reduction in speed is needed to safely navigate a section of roadway. Several strategies in this guide incorporate advance warning of a need to reduce speeds, including for situations such as adverse weather.

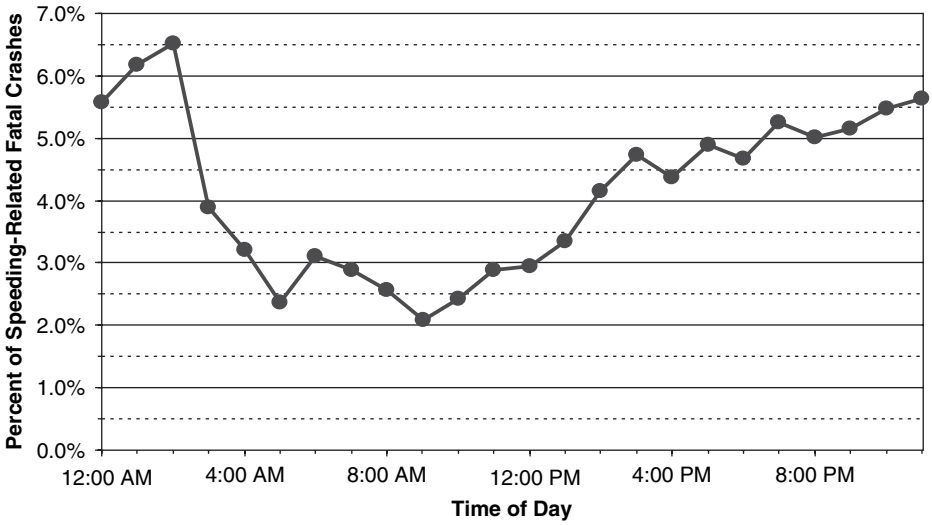
Time of Day

Speeding-related fatal crashes were more likely to happen late at night and into early morning. Between 10:00 p.m. and 3:00 a.m., each hour accounted for 5.5- to 6.5-percent of daily (24 hour) speeding-related fatal crashes (see Exhibit III-5). This is higher than any single hour during the day. Considering that traffic volumes decrease significantly late at night and through the early morning, this indicates that speeding fatalities are disproportionally high at night.

Weather Conditions

Speeding-related fatalities occurred most often under normal weather conditions. As shown in Exhibits III-6 and III-7, rain is the most common condition under which speeding-related

EXHIBIT III-5
Time-of-Day Distribution for Speeding-Related Fatal Crashes
Source: FARS Data (NHTSA, 2006a)



fatalities occurred on high- and low-speed roadways. Rainy/snowy/icy weather was present for 12% of the speeding-related fatalities on high-speed roadways, which suggests that high speeds and wet road conditions afford a fatal combination.

As illustrated by Exhibits III-6 and III-7, 93 percent of all fatalities on low-speed roadways and 86 percent of fatalities on high-speed roadways occurred under dry conditions. This

EXHIBIT III-6
Speeding-Related Fatalities on Low-Speed Roadways by Weather Conditions (2006)
Source: FARS Data (NHTSA, 2006a)

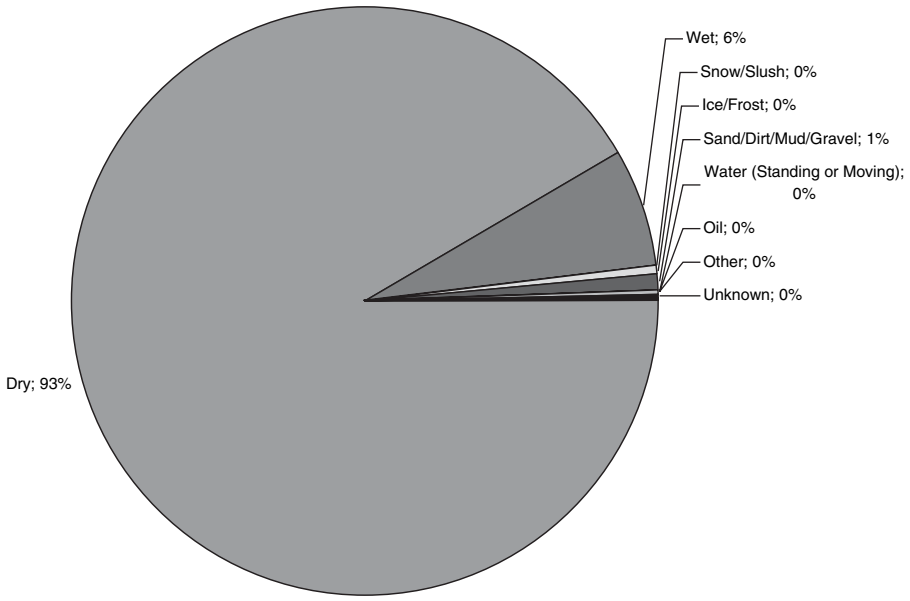
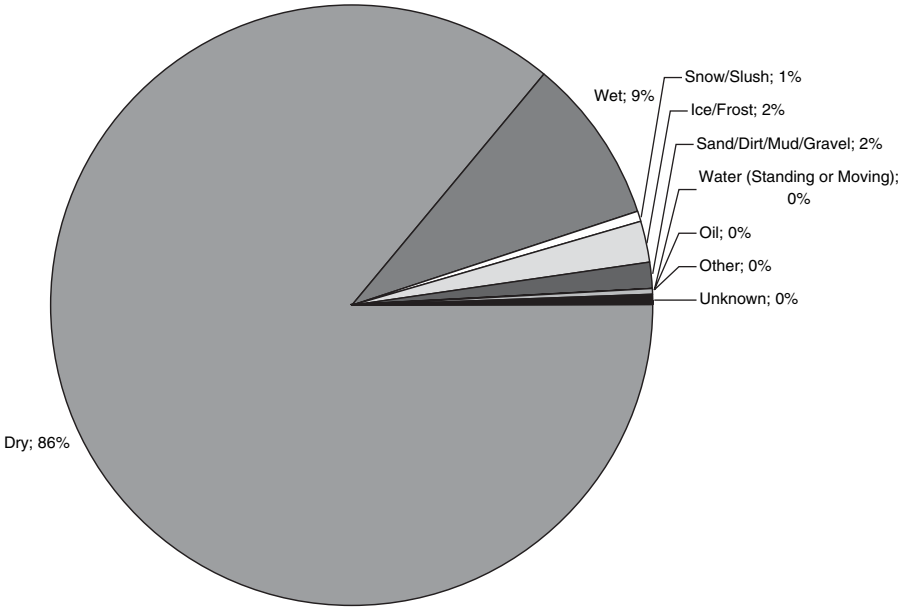


EXHIBIT III-7
Speeding-Related Fatalities on High-Speed Roadways by Weather Conditions (2006)
Source: FARS Data (NHTSA, 2006a)



indicates that adverse weather conditions are a larger problem on high-speed roadways than they are on low-speed roadways.

Construction/Maintenance Zones

In 2006, 37 percent of fatal crashes that occurred in construction/maintenance zones involved speeding (335 crashes). Of those crashes, 76 percent occurred on high-speed roadways, which is indicative of noncompliance with reduced work zone speeds on high-speed roadways.

Roadway Characteristics

Roadway elements can contribute to the speeds at which drivers feel comfortable as well as present drivers with situations they may not expect.

Relevance of Road Design and Type

Speeding-related fatalities were found to occur primarily on two-way, undivided roadways with 77 percent of speeding-related fatalities on low-speed roads and 62 percent of speeding-related fatalities on high-speed roads occurring on this roadway type in 2006. (Sixty-six percent of total speeding-related fatal crashes occurred on two-way, undivided roadways.) (See Exhibits III-8 and III-9.) In 2006, speeding-related fatal crashes accounted for 35 percent of all fatal crashes on low-speed roads, and 10 percent of all fatal crashes regardless of road type. For the same time period, speeding-related fatal crashes accounted for 30 percent of the high-speed road fatal crashes, and 21 percent of all fatal crashes.

EXHIBIT III-8
Speeding-Related Fatal Crashes on Low-Speed Roadways by Trafficway Flow (2006)
Source: FARS Data (NHTSA, 2006a)

Trafficway Flow	Speeding-Related Fatal Crashes on Low-Speed Roads	Percentage by Trafficway Flow	Total Fatal Crashes on Low-Speed Roads	Total Fatal Crashes on All Roads
Two-Way Undivided	2,918	77%	27%	8%
TWLTL	182	5%	2%	0%
Divide without Barrier	416	11%	4%	1%
Divide with Barrier	161	4%	1%	0%
One-Way	56	1%	1%	0%
Ramp	57	1%	1%	0%
Unknown	21	1%	0%	0%
Total*	3,811	100%	35%	10%

*Sums may not total accurately because of rounding.

Whereas speeding is particularly problematic on low-speed roads, there are more deaths on high-speed roads, as total travel (measured by VMT) is greater on high speed roadways.

Crash Type

Speeding-related fatalities occur primarily in single-vehicle crashes; 71 percent of speeding-related fatalities on low-speed roads and 70 percent on high-speed roads occurred in this manner of collision. (See Exhibits III-10 and III-11.) Right-angle collisions were the second

EXHIBIT III-9
Speeding-Related Fatal Crashes on High-Speed Roadways by Trafficway Flow (2006)
Source: FARS Data (NHTSA, 2006a)

Trafficway Flow	Speeding-Related Fatal Crashes on High-Speed Roads	Percentage by Trafficway Flow	Total Fatal Crashes on High-Speed Roads	Total Fatal Crashes on All Roads
Two-Way Undivided	4,916	62%	19%	13%
TWLTL	132	2%	0%	0%
Divide without Barrier	1,642	21%	6%	4%
Divide with Barrier	1,053	13%	4%	3%
One-Way	37	0%	0%	0%
Ramp	169	2%	1%	0%
Unknown	25	0%	0%	0%
Total*	7,974	100%	30%	21%

*Sums may not total accurately because of rounding.

EXHIBIT III-10
Speeding-Related Fatalities on Low-Speed Roadways by Manner of Collision (2006)
Source: FARS Data (NHTSA, 2006a)

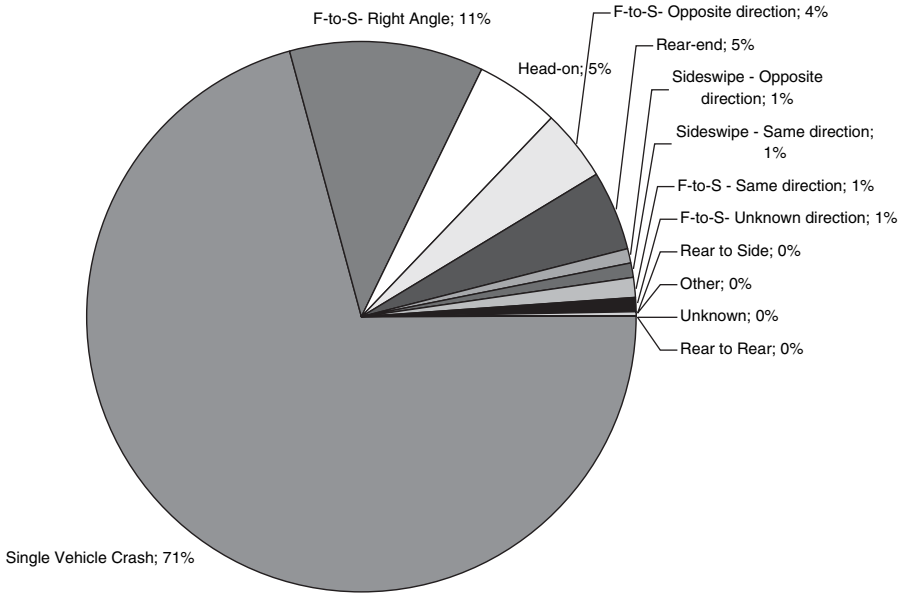
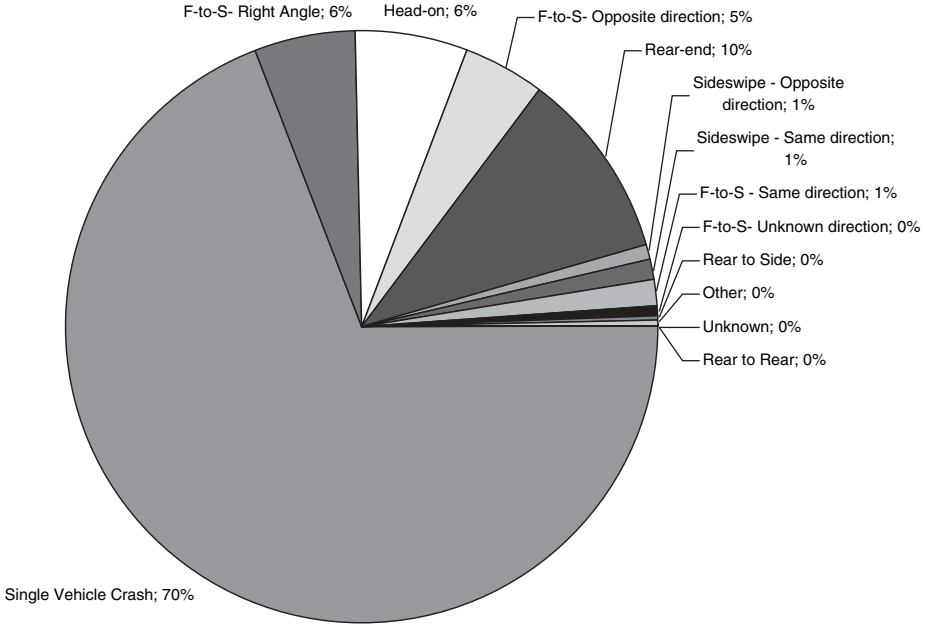


EXHIBIT III-11
Speeding-Related Fatalities on High-Speed Roadways by Manner of Collision (2006)
Source: FARS Data (NHTSA, 2006a)



SECTION IV

Index of Strategies by Implementation Timeframe and Relative Cost

A central tenet of the AASHTO Strategic Highway Safety Plan and its application at the state or local level is the time and cost to implement. Emphasis is on identifying strategies that are low cost (and hence able to be implemented on a broad or systematic basis), and take little time to implement. Time to implement addresses the urgency of achieving meaningful reductions in fatalities as quickly as is possible. In developing this and other similar guides, strategies that appear effective yet are clearly expensive and/or time-consuming were excluded.

Exhibit IV-1 provides a classification of strategies according to the expected timeframe required for implementation and relative cost to implement and operate each strategy for this emphasis area. In several cases, the implementation time will be dependent on such factors as the agency's procedures, the number of stakeholders involved, and the presence of any controversial situations. The range of costs may also be somewhat variable for some of these strategies, due to many of the same factors.

Placement in the table below is meant to reflect costs relative to the other strategies listed for this emphasis area only, rather than relative to strategies discussed in other guides in the *NCHRP Report 500* series. The estimated level of cost is for the commonly expected application of the strategy, especially one which does not involve additional right-of-way or major construction, unless it is an inherent part of the strategy.

EXHIBIT IV-1
Strategies Classified by Relative Cost and Time Necessary for Implementation

Relative Cost to Implement and Operate	Strategy
	Timeframe: Short (less than 1 year)
Low	A1 Set speed limits that account for roadway design, traffic, and environment
	A2 Implement variable speed limits
	A3 Implement differential speed limits for heavy vehicles if appropriate
	B2 Increase public awareness of potential penalties for speeding
	B3 Increase public awareness of risks of not wearing seatbelts
	B4 Implement neighborhood speed watch/traffic management programs
	C3 Increase penalties for repeat and excessive speeding offenders
	C4 Strengthen the adjudication of speeding citations to enhance the deterrent effect of fines

EXHIBIT IV-1 (Continued)
Strategies Classified by Relative Cost and Time Necessary for Implementation

Relative Cost to Implement and Operate	Strategy
	C5 Increase fines in special areas
	D1 Improve speed limit signage
	D2 Implement active speed warning signs
	E4 Provide adequate change + clearance intervals at signalized intersections
	E5 Operate traffic signals appropriately for intersections and corridors (signal progression)
Moderate	B1 Increase public awareness of the risks of driving at unsafe speeds
	B5 Implement Safe Community programs
	C1 Use targeted conventional speed enforcement programs at locations known to have speeding-related crashes
	D3 Use in-pavement measures to communicate the need to reduce speeds
Moderate to High	E8 Install lighting at high-speed intersections
High	
	Timeframe: Medium (1–2 years)
Low	
Moderate	
Moderate to High	C2 Implement automated speed enforcement
	D4 Implement variable message signs
	E3 Provide appropriate intersection design for speed of roadway
	E6 Provide adequate sight distance for expected speeds
	E7 Implement protected-only signal phasing for left turns at high-speed signalized intersections
	E9 Reduce speeds and/or volumes on both neighborhood and downtown streets with the use of traffic calming and other related countermeasures
High	E2 Effect safe speed transitions through design elements and on approaches to lower speed areas
	Time Frame: Long (more than 2 years)
Low	
Moderate	
Moderate to High	
High	E1 Use combinations of geometric elements to control speeds

SECTION V

Description of Strategies

Objectives

The main goal of this guide is the reduction of fatal and severe injury traffic crashes in which speeding or inappropriate speed is a factor. As is the case with most of the guidance in the AASHTO Strategic Highway Safety Plan, effectively addressing these types of collisions involves an interdisciplinary approach; a combination of education, enforcement and engineering measures will often be needed to obtain measurable improvements in safety.

Speeding-related fatalities can occur when drivers are traveling at speeds clearly in excess of the appropriate speed. Fatalities can also result when the selected speed is legal, yet local conditions warrant a lower speed. This guide suggests several objectives for addressing the problem of speeding and inappropriate speed choice.

Specific objectives include improvements in procedures for setting speed limits, driver education programs, speed enforcement programs and engineering features of the roadway environment. Exhibit V-1 lists the objectives and the related strategies for severe crashes that involve speeding or inappropriate speeds.

- **Set appropriate speed limits**—Setting speed limits to reflect the surrounding context of the roadway and that meet with driver expectations can help improve driver respect for speed limits. Speed limits that appear inconsistent may be ignored by the majority of drivers and this may contribute to lack of respect for speed limit and other traffic laws.
- **Heighten driver awareness of speeding-related safety issues**—Informing drivers of the risks—both to themselves and to other road users—associated with speeding is intended to encourage drivers to obey speed limits and drive at speeds safe for the roadway environment.
- **Improve the effectiveness of speed enforcement efforts**—Many crashes are caused or aggravated by drivers' noncompliance with traffic control devices or traffic laws. Effectiveness of enforcement can be increased if drivers perceive there is a significant chance they may be cited for speeding and may be given a hefty fine. Visible conventional or automated enforcement programs, increased fines for repeat offenders, and upholding of citations and levying of fines by courts can increase drivers' perceptions of the enforcement-related risks of speeding.
- **Communicate appropriate speeds through use of traffic control devices**—Information on appropriate speeds, including permanent speed limits, variable speed limits, and warning speeds, needs to be conveyed clearly to drivers and at appropriate locations. Pavement markings can be used to encourage drivers to proceed at appropriate speeds without actually posting the speed limit. Even though drivers have the responsibility to drive at a safe speed, they need to be able to receive cues from the roadway environment as to what that safe speed is.

- **Ensure that roadway design and traffic control elements support appropriate and safe speeds—**Geometric design features of roadway sections and intersections, and operation of traffic signals, need to reflect the speeds expected of drivers. For example, roadway designs sensitive to the context in which they will be located can encourage appropriate speed choices by drivers. Geometric elements which affect operating speeds, such as horizontal and vertical curves, can be designed in combinations to encourage appropriate speeds. Intersection types and designs should be appropriate for the context of the roadway. Providing a proper signal co-ordination through intersections along a corridor can create uniform speeds and reduce the need for drivers to stop at the intersections.

Ultimately, the goal toward which the objectives and strategies are directed is to improve safety for all road users by reducing the incidence of speeding and inappropriately high speeds. The strategies discussed in this section combine the elements of education, enforcement, and engineering. Strategies are suggested recognizing that, with few exceptions, programs that depend on only one of these elements are usually not as successful as those which incorporate a range of elements. Some strategies are aimed at general cultural and behavioral attributes of the driving public, while others are targeted at specific high-risk locations or portions of the population. The strategies listed in Exhibit V-1, which are

EXHIBIT V-1
Objectives and Strategies for Addressing Speeding-Related Fatalities

Objectives	Strategies
A. Set appropriate speed limits	A1 Set speed limits which account for roadway design, traffic, and environment (T)
	A2 Implement variable speed limits (T)
	A3 Implement differential speed limits for heavy vehicles if appropriate **(High Speed Only)** (T)
B. Heighten driver awareness of speeding-related safety issues	B1 Increase public awareness of the risks of driving at unsafe speeds (T)
	B2 Increase public awareness of potential penalties for speeding (T)
	B3 Increase public awareness of risks of not wearing seatbelts (T)
	B4 Implement neighborhood speed watch/traffic management programs **(Low Speed Only) (T)**
	B5 Implement Safe Community Programs (T)
C. Improve efficiency and effectiveness of speed enforcement efforts	C1 Use targeted conventional speed enforcement programs at locations known to have speeding-related crashes (P)
	C2 Implement automated speed enforcement (T)
	C3 Increase penalties for repeat and excessive speeding offenders (T)
	C4 Strengthen the adjudication of speeding citations to enhance the deterrent effect of fines (T)
	C5 Increase fines in special areas (T)

EXHIBIT V-1 (Continued)
Objectives and Strategies for Addressing Speeding-Related Fatalities

Objectives	Strategies
D. Communicate appropriate speeds through use of traffic control devices	D1 Improve speed limit signage (T)
	D2 Implement active speed warning signs (T)
	D3 Use in-pavement measures to communicate the need to reduce speeds (T)
	D4 Implement variable message signs **(High Speed Only)** (T)
E. Ensure that roadway design and traffic control elements support appropriate and safe speeds	E1 Use combinations of geometric elements to control speeds (horizontal and vertical curves, cross section), including providing design consistency along an alignment (T)
	E2 Effect safe speed transitions through design elements and on approaches to lower speed areas (T)
	E3 Provide appropriate intersection design for speed of roadway (T)
	E4 Provide adequate change + clearance intervals at signalized intersections (P)
	E5 Operate traffic signals appropriately for intersections and corridors (signal progression) (T)
	E6 Provide adequate sight distance for expected speeds (P)
	E7 Implement protected-only signal phasing for left turns at high-speed signalized intersections **(High Speed Only)** (T)
	E8 Install lighting at high-speed intersections **(High Speed Only)** (T)
	E9 Reduce speeds and/or volumes on both neighborhood and downtown streets with the use of traffic calming and other related countermeasures **(Low Speed Only)** (T)

categorized according to the objectives discussed above, are discussed in detail in this section. The order in which the strategies are listed does not imply a priority with which they should be considered.

Most of the strategies are relatively low-cost, short-term treatments for reducing speeding-related fatalities, consistent with the focus of the entire AASHTO Strategic Highway Safety Plan (SHSP). For each of these, a detailed discussion of the attributes, effectiveness, and other key factors describing the strategy is presented below. Several higher-cost, longer-term strategies which have been proven effective in reducing speeding are also presented in this section, but in less detail. While application of these is outside the implementation framework envisioned by the SHSP, their inclusion in this guide serves to complete the picture of proven, tried, and experimental strategies for reducing speeding-related fatalities. In addition, strategies that have been discussed in other guides in this series, such as some of those related to intersection improvements, are discussed in less detail in this guide, and the reader is encouraged to review the other pertinent volumes.

Types of Strategies

The strategies in this guide were identified from a number of sources, including recent literature, contact with state and local agencies throughout the United States, and federal programs. Some of the strategies are widely used, while a few have been subjected to only a limited number of trial applications to date. 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 thoroughly 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 that have been used in one or more locations and for which properly designed evaluations have been conducted which show them to be effective. These strategies may be employed with a good degree of confidence, but with the understanding that any application can lead to results that vary significantly from those found in previous experience. The attributes of the strategies that are provided will help the users make judgments about which may be 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 very likely to be a positive one. It is intended that as implementation of these strategies continues under the AASHTO Strategic Highway Safety Plan initiative, appropriate evaluations will be conducted. As more reliable effectiveness information is accumulated to provide better estimating power for the user, any given strategy labeled "tried" can be upgraded to a "proven" one.
- **Experimental (E)—**Those strategies representing ideas that have been suggested, with at least one agency considering them sufficiently promising to try them as an experiment in at least one location. These strategies should be considered only after the others have been determined not to be appropriate or feasible. Even where they are considered, their implementation should initially occur using a 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 or be identified as being ineffective and not worthy of further consideration.

Related Strategies for Creating a Truly Comprehensive Approach

The strategies listed in Exhibit V-1 and described in detail in the remainder of this section are either considered unique to addressing speeding and inappropriate speeds roadways, or are discussed in terms of their attributes specific to this. To create a truly comprehensive approach to the highway safety problems associated with speeding and inappropriately high speeds, agencies should consider including a variety of strategies as candidates in any program planning process. Appropriate strategies may be 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, which includes coordination with media outlets. 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, such as an individual corridor with a history of severe crashes that have involved speeding. While this is a relatively untried approach compared with area-wide campaigns, use of roadside signs and other experimental methods may be tried on a pilot basis.

  Within this guide, PI&E campaigns, where application is deemed appropriate, are usually used in support of some other strategy. In such a case, the description for that strategy will suggest this possibility (in the exhibits, see the attribute area for each strategy entitled "Associated Needs"). In some cases, where PI&E campaigns are deemed unique for the emphasis area, the strategy is explained in detail.

- **Enforcement of Traffic Laws—**Well-designed and well-operated law enforcement programs can have a significant effect on highway safety. It is well established, for instance, that an effective way to reduce the occurrence of crashes and their severity is to have jurisdiction-wide programs that enforce an effective law against driving under the influence of alcohol (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, by the nature of how they must be performed, are conducted at specific locations. The effect (e.g., lower speeds, greater use of seatbelts, and reduced impaired driving) may occur at or near the specific location where the enforcement is applied. This effect can often be enhanced by coordinating the effort with an appropriate PI&E program. However, in many cases (e.g., speeding 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). Where it is not clear how the enforcement effort may impact behavior, or where it is desired to try an innovative and untried method, a pilot program is recommended.

  Within this guide, where the application of enforcement programs is deemed appropriate, it is often in support of some other strategy. Many of those strategies may be targeted at either a whole system or a specific location. In such cases, the description for

that strategy will suggest this possibility (in the exhibits, see the attribute area for each strategy entitled "Associated Needs"). Since there are situations where enforcement programs can be designed or enhanced specifically for speeding, there are strategies that discuss this in detail.

- **Strategies to Improve Emergency Medical and Trauma System Services**—Treatment of injured parties at highway crashes can have a significant impact on the level of severity, survival rate, and length of time an individual spends in treatment. This is especially true when it comes to timely and appropriate treatment of severely injured persons. Thus, a basic part of a highway safety infrastructure is a comprehensive and well-based emergency care program. 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 there are improvements that can be made in how emergency medical services interact with other safety programs, especially for programs that are focused upon location-specific (e.g., corridors), or area-specific (e.g., rural areas) issues.
- **Strategies Directed at Improving the Safety Management System**—There should be a sound organizational structure in place, as well as an 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 often have jurisdiction over a large portion of the road system and are responsible for its related safety problems. They know, better than others, what the problems are. As additional guides are completed for implementation of the AASHTO Plan, the guides may address the details regarding the design and implementation of strategies for improving safety management systems.
- **Strategies Detailed in Other Emphasis Area Guides**—Several of these objectives, and many of the corresponding strategies, are applicable to other emphasis areas. Strategies that overlap between various guides in this *NCHRP Report 500* series are discussed briefly in this section, and the other guides (as noted) should be referenced for more details. For example, there are treatments for speeding that would improve safety for all intersection users. Any program targeted at the safety problem covered in this guide on speeding should be created with consideration given to potentially appropriate strategies in these other guides.

Objective A—Set Appropriate Speed Limits

The primary purpose for setting speed limits is to promote highway safety. In addition to safety considerations, decision makers must balance mobility against a need to provide road users with access to adjacent land. Thus, the posted legal limit informs motorists of the maximum driving speeds that decision makers consider reasonable and safe for a road class or highway section under favorable conditions. In addition, speed limits provide the basis for enforcement. Well-conceived speed limits provide law enforcement officers and courts with an indication of appropriate speeds for favorable conditions and thus help target enforcement and sanctions on those who drive at speeds that are excessive for conditions and likely to endanger others (Milliken et al., 1998).

Statutory speed limits, set by federal, state or local government with jurisdiction over roads, are general limits that apply to a given type of roadway. This encourages uniformity in speed limits as well as removes the need to perform engineering studies to determine speed limits for every section of roadway. In many cases, the statutory speed limit is the most appropriate speed limit, but in some situations the statutory limit may not be ideal. In these cases, studies are performed to determine the most appropriate limit for those speed zones. The 85th percentile speed of the current traffic is measured, and the speed limit is initially set at this level. When other factors, such as crash history and traffic and pedestrian volumes, are considered, it may be determined that the 85th percentile speed is not ideal, and the speed limit may be adjusted. A properly set speed limit prompts a reasonable balance between mobility (travel time) and safety (fewer crashes and conflicts) for a certain road class or a specific highway section (Lu et al., 2003).

Other factors should be considered when establishing appropriate speed limits. These are particularly important if a full speed study is not being conducted or if the speed limit is being established for a highway on new alignment or a highway under significant reconstruction that is not yet under traffic.

- What is the type or functional class of the highway (i.e., freeway, arterial, collector, local)?
- Is the roadway setting urban, suburban, or rural?
- What is the adjacent land use? What is the type and amount of development?
- What is the amount of access along the highway? What is the level of access control? Are certain movements restricted by medians or other methods?
- What is the design speed?
- What is the highway geometry—horizontally, vertically, and the cross section?
- What are the speed limits on adjacent roadways?
- What is the crash history? Have there been speeding-related crashes or crashes involving pedestrians?
- What is the level of pedestrian usage?
- Is parking allowed along the street or highway?
- Are there difficult-to-perceive risks or driving demands or violations of driver expectancy (e.g., isolated curves, heavy vehicle traffic)?

All of these issues define the roadway environment and subsequently provide guidance in choosing a speed limit that is reasonable for the typical, prudent driver.

Roadways classified as principal or minor arterials are primarily intended to provide for through traffic, in contrast to collector or local streets that mostly serve abutting land uses. The higher type facilities (arterials), which generally carry heavier traffic volume and traverse areas of commercial/industrial land uses, will usually warrant a higher speed limit than collector or local streets. For the latter, the adjacent land uses (i.e., residential, school zone, or playground); access density; and special users (i.e., pedestrians and bicyclists) dictate a slower safe speed.

Setting speed limits too high may be a contributing factor to an increase in the frequency and severity of crashes. Likewise, there are adverse effects when speed limits are set too low. This objective aims to set appropriate speed limits as a proactive approach to preventing the occurrence of speeding-related collisions on new or existing roads.

Strategy A1—Set Reasonable and Prudent Speed Limits That Account for Roadway Design, Traffic, and Environment (T)

In determining appropriate speed limits for each road type, decision makers should be guided by both the likely risks imposed on others by individual driver speed choices and the availability of information to enable drivers to make appropriate speed choices. They should take enforcement and practicality into consideration. The 85th percentile speed is widely recognized as the most used analytical method for selecting the posted speed limit. The basis of setting the speed limit near the 85th percentile speed is to include as many people traveling at or below the speed limit as is reasonable. Maximizing the number of people traveling at a similar speed helps to minimize speed differentials and conflicts between vehicles. In addition to the 85th percentile speed, decision makers should also request technical information on the following four factors to help guide their determination of appropriate legislated speed limits for a specific road class (Milliken et al., 1998):

- **Design speed,** that is the design speed of a major portion of the road, not of its most critical design features (e.g., a sharp curve);
- **Vehicle operating speed,** measured as a range of 85th percentile speeds taken from spot-speed surveys of free-flowing vehicles at representative locations along the highway;
- **Safety experience,** that is crash frequencies and outcomes; and
- **Enforcement experience,** that is, existing speed tolerance (i.e., allowance for driving above the posted speed limit) and level of enforcement.

Setting speed limits not only needs to be carefully considered for new roads, but it is also important to periodically review speed limits on existing roads to ensure they are appropriate for the current conditions, especially when there has been a change in the land use, access or traffic characteristics.

The *Manual on Uniform Traffic Control Devices* (MUTCD) offers the following guidance on evaluating speed limits on existing highways (MUTCD, 2003):

> At least once every 5 years, State and local agencies should reevaluate non-statutory speed limits on segments of their roadway that have undergone significant change in roadway characteristics or surrounding land use since the last review. . . . When a speed limit is to be posted, it should be within 5 mph (10 km/h) of the 85th percentile speed of free-flowing traffic.

The process to select the appropriate speed limit should also give consideration to unique or unusual design, traffic, or other environmental issues such as school zones, high percentage of trucks, heavy pedestrian volumes, frequent access or a concentration of elderly pedestrians. For more information, see http://www.mutcd.fhwa.dot.gov.

The speed limit for many new roads may already be defined by a state or local statute (i.e., statutory speed limit for residential areas). However the traffic, design and environmental characteristics of the roadway should still be considered to ensure that the roadway is appropriate for this general speed limit. An engineering study may determine that a speed zone should be established providing a different speed limit for a particular section of a road, or may identify changes in the roadway design to encourage drivers to travel at the appropriate speed. For example, a residential street with a wide cross section and sidewalks with large setback from the travel way may encourage higher speeds than intended by the speed limit, given the desired roadway setting and use. It may be desirable to alter these aspects of the design to encourage lower speeds to better match the context of the facility. See Exhibit V-2 for more information.

EXHIBIT V-2
Strategy Attributes for Setting Reasonable and Prudent Speed Limits That Account for Roadway Design, Traffic, and Environment (T)

Attribute	Description
Technical Attributes	
Target	All roads, both existing and planned, are the target for this strategy. The objective in establishing appropriate speed limits is to reduce the number and severity of crashes involving speeding. In addition to setting speed limits appropriately on new roads, speed limits on existing roads should be reviewed, especially if there has been a significant change since the speed limit was last posted. Changes may have been related to traffic (i.e., volumes, vehicle composition, travel speeds, and commuting patterns) or the adjacent land use (including land use type, density, and number of access points). These changes in the roadway environment may not have manifested in a crash experience linked to vehicle speeds yet, but the area may have a high potential for an increase in crash risk due to alterations in traffic and access.
Expected Effectiveness	It is expected that if drivers perceive a speed limit to be reasonable, they will be more likely to obey it. Many factors—such as traffic volumes, access, and offset to roadside objects—affect driver speed choice, and the speed limit should reflect these factors as well. Research has shown that unreasonably low speed limits significantly increase driver violation of speed limits. Also, lowering or raising speed limits has little effect on a motorist's speed selection. The majority of drivers (about 85 percent) travel at reasonably safe speeds for the various roadway conditions they encounter, regardless of speed limit signs (Parker, 1992). Setting the speed limit at an appropriate level, such as the 85th percentile speed, would then be expected to result in a majority of drivers obeying it. Research has shown that lowering a speed limit will not necessarily encourage people to drive more slowly and obey the new speed limit, at least not without visible enforcement, and that lower speed limits may not necessarily reduce crash rates (Parker, 1992). The effect of the enforcement on speeds does not last long after the enforcement ends. It is believed that the choice of speed limit, and planning and design of the roadway and its environment, should be considered simultaneously in order to best encourage drivers to proceed at the speed intended by the highway agency.

EXHIBIT V-2 (Continued)
Strategy Attributes for Setting Reasonable and Prudent Speed Limits That Account for Roadway Design, Traffic, and Environment (T)

Attribute	Description
Keys to Success	There are several keys to success associated with this strategy. For existing roadways, it is first appropriate to identify locations where speed limits need to be reevaluated. This may be an extreme horizontal curve or high peak hours of heavy trucks on a certain segment of road. Reviewing crash records for crashes related to speeding or speeds unsafe for conditions is a way to identify locations where speed limits should possibly be evaluated. At these locations, it may also be more appropriate to enhance the roadway or roadside design to better accommodate the speeds allowed by the speed limit. Law enforcement agencies may be another source of information regarding where speed limits need to be reevaluated. Another element of success is involvement of a wide array of agencies when determining appropriate speed limits. Professionals/groups to consider involving when setting speed limits include traffic engineers, law enforcement officials, judges, and public health officials (Milliken et al., 1998). Coordination with enforcement agencies and court systems is especially important if a speed limit will be changed. Clear communication of any changes in the speed limit to the public is important. Enhanced signing may be necessary in areas where the speed limit is changed. If new speed limits are implemented based on design, traffic, and environmental characteristics, some enforcement may be needed. If the speed limit is actually raised, there would be an expectation that fewer drivers would speed, but increased enforcement at these locations would also contribute to decreasing the number of vehicles traveling at excess speeds, at least while the enforcement is in effect. This strategy can be used in conjunction with technology such as variable speed displays or automated speed enforcement devices for better results. It is important that motorists view the speed limit on a specific segment of road to be reasonable and safe. The approach currently used widely in setting speed limits is that maximum speed limits are first legislated broadly by road class and geographic area, and in cases where the statutory limits do not fit specific roadway or traffic conditions, speed zoning practice is applied for that highway section based on engineering study (Lu et al., 2003). Speed limits should be set at levels that are largely self-enforcing or at the lowest speed the law enforcement officials are able to enforce (Milliken et al., 1998). The Federal Highway Administration has developed USLIMITS, a web-based expert systems for use in determining an appropriate speed limit. The tool is based on a similar Australian system, and calculates an appropriate speed limit based on existing operating speeds, crash history, road function, roadside development, pedestrian activity, access frequency, and other factors input by the practitioner. This system can be used by experienced traffic engineers as a source of a second opinion, or as a starting point for smaller agencies with little in-house traffic engineering experience. The output from USLIMITS includes a recommended speed and a list of issues that might be further investigated. USLIMITS is limited to determining appropriate speed limits in speed zones. USLIMITS does not address work zone speed limits, school zone speed limits, or variable speed limits that

EXHIBIT V-2 (Continued)
Strategy Attributes for Setting Reasonable and Prudent Speed Limits That Account for Roadway Design, Traffic, and Environment (T)

Attribute	Description
	change based on traffic and weather conditions. USLIMITS will be of particular benefit to local communities and agencies that do not have ready access to engineers with speed limit setting expertise. For experienced engineers, USLIMITS can provide an objective second opinion and increase confidence in speed limit setting decisions. Additional information on USLIMITS (and the newly developed USLIMITS2) and a link to the tool can be found online at http://safety.fhwa.dot.gov/speed_manage/uslimitsbrief.htm.
Potential Difficulties	One of the main difficulties identified with this strategy involves identifying and properly addressing all issues with setting speed limits. Involving all stakeholders in the process of identifying speed limit-related issues will help obtain all information needed to select the most appropriate speed limit. Another possible difficulty is gaining public acceptance of new speed limits, especially when the reason(s) for a lower speed limit may not be readily apparent. Though local residents and businesses may desire a lower speed limit, it will still likely be difficult to get most drivers to comply with the speed limit without consistent visible enforcement, especially drivers opposed to or unfamiliar with the speed limit changes. Public and political pressure may be applied to a highway agency to change the speed limit on an existing roadway to address a real or perceived safety concern to a limit that may not be optimal for traffic safety and operations. It is important to emphasize that research has shown that changing speed limits has little effect on speeds (Parker, 1992).
Appropriate Measures and Data	Key process measures include the numbers of existing roadways for which speed limits are reevaluated, and the numbers of new roadways for which speed limits are set considering design, traffic, environmental, and other factors. The number of roadways for which the speed limit is changed based on the reevaluation is another process measure. Measures related to gauging the effectiveness of a legislated speed limit are driver compliance with the speed limit and crash outcomes. Changes in external factors such as new land developments, changes in volume or composition of traffic, and increased (or decreased) cyclist or pedestrian activity also need to be considered in measuring the continued effectiveness of the speed limit. Before and after crash data and average travel speeds can be used to evaluate the effectiveness of changing speed limits. The amount of speed enforcement provided (i.e., patrol hours, vehicles stopped, citations written) before and after a speed limit change should also be recorded to monitor the change and the effort required to enforce such changes.
Associated Needs	It is important to educate the public—both drivers and residents—that speed limits are set based on the 85th-percentile speed, design factors, traffic conditions, and other related issues for safety purposes. Education and forewarnings may prevent future negative opinions of the speed limit established for a new road or revised speed limits on existing roads. It is very important to inform the public in advance if speed limits will be raised or lowered, as well as when there will be increased enforcement of the new speed

EXHIBIT V-2 (Continued)
Strategy Attributes for Setting Reasonable and Prudent Speed Limits That Account for Roadway Design, Traffic, and Environment (T)

Attribute	Description
	limits. This can be done during announcements at public meetings or utilizing the local media (television, radio, and newspaper) to notify the public of these changes. An example of materials that instruct the public on how speed limits are set, developed by the Minnesota Department of Transportation, is located online at: http://www.dot.state.mn.us/speed/SpeedFlyer2002.pdf. Coordination with responsible law enforcement agencies is needed to ensure that speed limits are enforced.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should establish procedures for setting speed limits that include consideration of the factors discussed in this section, and any additional factor that may be an issue in their jurisdiction. Documentation of these decisions should be included in the procedures, as should discussion of involving all interested stakeholders and possible enforcement and education efforts. It is important that law enforcement and traffic court judges perceive that speed limits are reasonable and enforceable (Milliken et al., 1998). Many drivers need to perceive the threat of being cited and of penalties being upheld by courts in order to feel compelled to obey the speed limit.
Issues Affecting Implementation Time	In most cases, it should take only several months to evaluate and, if necessary, change a speed limit. However, if there is significant disagreement among local residents and businesses regarding a speed limit change, the process might be lengthened significantly. Even so, one could still expect the time to evaluate and select a speed limit to take less than 1 year.
Costs Involved	Costs associated with this strategy include those related to collecting and analyzing vehicle speeds and crash histories, as well as the acquisition and installation of new speed limit signs. Additional costs might include automated or traditional law enforcement to enforce new speed limits, as well as public information campaigns to inform road users of the new speed limit.
Training and Other Personnel Needs	No extensive training or personnel should be needed for this strategy; however, someone with experience in selecting speed limits may need to provide assistance in special situations (i.e., school zones, high pedestrian areas, etc.).
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with all others discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy A2—Implement Variable Speed Limits (T)

Variable speed limits (VSL) are used to encourage drivers to proceed more slowly in certain areas or when driving conditions deteriorate, through the use of changeable message signs or other devices. For example, the speed limit can be lowered during winter driving conditions, when visibility becomes poor due to fog or snow, or when traffic incidents or crashes occur. Events like these that are unpredictable or difficult to predict with precision often require the use of cameras or detection equipment to determine when a speed limit should be changed and to gather data to determine what the speed limit should be.

VSL can also be used for more predictable time periods such as in school or construction zones. Near schools speed limits can be lowered during periods of the day when pedestrian activity is high. In many places throughout the United States, flashing lights mounted on a speed limit sign with a legend indicating "School Zone" are used to let the drivers know the change in speed limits near the school while the flashers are operating.

Use of VSL, specifically with respect to use in work zones, is discussed in greater detail in Appendix 2 of Volume 17 (Work Zones) of the *NCHRP Report 500* series. There is not much existing data to determine the effectiveness of this strategy (Milliken et al., 1998). Due to this uncertainty of effectiveness, in combination with high costs to implement, VSL have not been used widely in the United States for work zones. Their use is often limited to highways and freeways with high volumes of traffic and a frequent occurrence of adverse weather conditions (Milliken et al., 1998).

For non-work zone applications, VSL can be determined based on the average speeds on the stretch of roadway over which the limit would apply. Generally all VSL systems will require variable message signs and/or variable speed limit signs, sensors, and some sort of central processing unit to execute control actions. Equipment to detect volumes, speeds, and weather conditions is installed along the roadway, and the collected information is used to automatically determine the speed limit.

Several other countries such as the Netherlands, Germany, Sweden, and Australia have also tried VSL (Hines and McDaniel, 2002). VSL in Germany have been more widely accepted by the public than fixed speed limits (FHWA, 1995). Surveys have indicated that German drivers prefer roads with VSL, as it informs them of appropriate travel speeds, and other factors such as congestion, crashes, and lane closures. See Exhibit V-3 for further information.

Signs should be posted informing drivers of a reduced speed limit, but periodic enforcement will likely be needed to encourage drivers to slow down as they enter the area.

Strategy A3—Implement Differential Speed Limits for Heavy Vehicles if Appropriate (High Speed Only) (T)

Some agencies allow posting of a lower speed limit for heavy trucks in an effort to reduce the severity of collisions involving trucks. Differential speed limits are controversial and research is mixed in terms of their effectiveness in reducing crashes. *NCHRP Report 500, Volume 13:* "A Guide for Reducing Collisions Involving Heavy Trucks," contains a detailed discussion of differential speed limits for heavy vehicles.

EXHIBIT V-3
Strategy Attributes for Implementing Variable Speed Limits (T)

Attribute	Description
Technical Attributes	
Target	Roadways with conditions that may vary are potential locations for variable speed limits (VSL). VSL are most commonly used on highways with one or more of the following characteristics: • Traffic congestion • Incidents/crashes • Inclement weather (snow, ice, fog) • Smoke/fog from industrial activity • Construction zones • School zones
Expected Effectiveness	Studies on the effectiveness of VSL in the United States have had mixed results regarding impacts on safety (Milliken et al., 1998). Anecdotal information on the effectiveness of reducing speeds or crashes has been mixed, as well (Robinson, 2000). The use of variable speed limits in the Netherlands and Germany (autobahns) found that traffic flow can be improved by reducing travel times by 5 to 15 percent. Accident reductions of 25 to 50 percent have been reported with these systems according to the *FHWA Study Tour for Speed Management and Enforcement Technology* (FHWA, 1995).
Keys to Success	Keys to success include developing a procedure for identifying locations that are appropriate for use of VSL, as well as installing detection equipment that can quickly and accurately determine deteriorating driving conditions. Visible enforcement is necessary to encourage compliance with the speed limits. In order for VSL to be enforced, there must be proof of the violators' travel speeds (such as through the use of an enforcement officer patrolling the section of roadway, or through photo radar) and proof that the speeds displayed were visible (since they are often used in adverse conditions such as fog or snow) (Hines and McDaniel, 2002). Enforcing variable speeds can be difficult to implement since there are many different municipal and local jurisdictions that may be involved, which all have separate laws and regulations on the issue (Hines and McDaniel, 2002). The procedure for calculating speed limits should be carefully developed so as to reflect appropriate speeds for current conditions. Procedures developed for using VSL should include direction on how long to keep a reduced speed limit in effect. For weather- or traffic-related reasons for lowering a speed limit, procedures should be established to determine what information from the detectors indicates that it is appropriate to return the speed limit to normal. For scheduled changes in the speed limit, such as for a school zone, the VSL can be preset to begin and end at specific times, or can be controlled with cellular technology or manually on site. In some jurisdictions, school zone speed limits are in effect whenever children are present, and a supplemental plaque to the speed limit sign states this.

EXHIBIT V-3 (Continued)
Strategy Attributes for Implementing Variable Speed Limits (T)

Attribute	Description
Potential Difficulties	Installation and maintenance of changeable message signs and detection equipment can potentially be difficult, especially if equipment repairs need to be made during inclement weather. The cost of acquiring, installing, and maintaining changeable message signs and detection equipment can be high depending on the complexity of the system. Another potential problem for enforcement is that if a speed limit is changing, law enforcement must be aware of the speed limit currently in effect and also have a way to document this.
Appropriate Measures and Data	Key process measures include the number of existing roadways for which VSL are considered and implemented. Measures related to gauging the effectiveness of VSL are driver compliance with the speed limit and crash outcomes. Before and after crash data and average travel speeds can be used to evaluate the effectiveness of VSL. The amount of speed enforcement provided (i.e., patrol hours, vehicles stopped, citations written) before and after a speed limit change should also be recorded to monitor the change and the effort required to enforce such changes.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Agencies should establish guidelines that specify the conditions under which variable speed limits should be considered, and that specify how the speed limits should be established for various conditions.
Issues Affecting Implementation Time	Implementation costs will vary depending on the complexity of the system. A basic system for a school zone or work zone could be implemented in a relatively short timeframe, but a system involving equipment for detecting changing conditions and changeable message signs, or requiring significant data collection for analysis before designing the system, could take 6 months or more to implement.
Costs Involved	Also depending on the complexity of the system, this strategy could range from low to high cost. Factors increasing the cost of implementation include data collection and analysis, equipment for detecting incidents, congestion, weather, or other changing conditions, systems for analyzing conditions and determining the appropriate speed, and maintenance of equipment once installed.
Training and Other Personnel Needs	It may be necessary to train key staff and law enforcement staff on how to effectively use the respective VSL technology, depending on the complexity of the system.
Legislative Needs	Legislation may be needed to allow agencies to implement variable speed limits, and to establish who has the authority to change speed limits and under what conditions.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with all others discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Objective B—Heighten Driver Awareness of Speeding-Related Safety Issues

Increasing driver awareness is an important element in reducing speeding-related crashes. Public information and education campaigns that seek to inform drivers of the potential risks of driving at speeds considered excessive for the conditions or roadway environment may encourage drivers to select more appropriate speeds. Appealing to their sense of personal safety, by educating them about the risks involved with driving at high speeds, may help alter driver behavior. Making drivers aware of the monetary and safety-related costs of speeding can be an effective approach in reducing speeding-related crashes.

The strategies in this section are closely linked to the strategies in the next section that seek to improve the effectiveness of enforcement efforts. A driver education campaign can also reduce perceptions people have concerning the acceptability of speeding.

Strategy B1—Increase Public Awareness of Risks of Driving at Unsafe Speeds (T)

Many drivers will speed if they do not perceive there to be a chance of being cited for speeding; educating them about the risks involved with driving at unsafe speeds may help alter their behavior. Public information materials should concentrate on communicating specific concerns related to speeding in a way that is easily understood and captures the audience's attention, particularly for different age groups. There is much information on this issue that the public can readily access, however exposure may be limited without an education campaign designed to widely distribute the information. Such a campaign can include radio and television public service announcements, flyers and brochures, billboards, websites, and other various means of media communication appropriate for reaching the target audience.

Educational materials have been developed by several organizations for use in public information campaigns as well as for use by the general public. The National Highway Traffic Safety Administration (NHTSA) has such materials available for download from its website or in printed format. NHTSA's Traffic Safety Materials Catalog (http://nhtsa.gov/people/outreach/media/catalog/Index.cfm) includes brochures, pamphlets, books, fact sheets, posters, reports, stickers, CD-ROMs, etc. Additional materials from other sources are described below under the heading "Information on Current Knowledge Regarding Agencies or Organizations That Are Implementing This Strategy."

Educational programs and activities are good methods for informing young and inexperienced drivers. This is one of the most important groups to target, as less experienced drivers are often unaware of many of the risks associated with speeding, and the potential repercussions of driving at an unsafe speed. *NCHRP Report 500, Volume 19:* "A Guide for Reducing Collisions Involving Younger Drivers" provides more information on targeting this age group with information and education campaigns.

An agency may wish to target drivers of a specific roadway with an information campaign if speed is a contributing factor in crashes on a specific portion of that roadway. An example is the Virginia Highway Safety Corridor Program, discussed further in Strategy C1, where specific segments of Virginia highways are designated as safety corridors and increased fines and enforcement are used to target corridor-specific safety issues.

Elements of a jurisdiction-wide campaign would be applicable to a broader range of issues over a much larger area and the methods for implementing such a campaign would likely differ from a corridor-specific campaign. An agency may choose to incorporate variable message signs, billboards, or highway advisory radio to distribute information for a program of this type. See Exhibit V-4 for more information.

EXHIBIT V-4
Strategy Attributes for Increasing Public Awareness of Risks of Driving at Unsafe Speeds (T)

Attribute	Description
Technical Attributes	
Target	This strategy involves use of public information and education campaigns aimed at either the general public in an agency's jurisdiction, or a specific demographic or geographic part of the population for which unsafe speeds have been shown to be a factor in the area's crash experience.
Expected Effectiveness	The effectiveness of public information campaigns to increase driver awareness of the hazards of driving at unsafe speeds has not been quantified. Such programs, if well-designed to broadly distribute the information, would be expected to be successful in reaching the audience, and to lessen risky behaviors, though it may be difficult to relate a reduction in speeding-related crashes directly to a campaign. Well-designed public awareness campaigns heighten awareness of a problem and garner high approval ratings. Many agencies have indicated improving their public image and increasing goodwill with the public as a result of their public awareness campaigns. At times, the public information campaign may include notice of special emphasis on enforcement. Public information campaigns, done in conjunction with special enforcement, have been shown to enhance the effectiveness of the enforcement effort.
Keys to Success	One key to success is identifying the specific audience for the program. This can help in the design of campaign materials, the method for distributing the materials, and the evaluation of its effectiveness (through examination of crash data, surveys, or focus groups of the intended audience). Another key to success is identifying and reaching as large a percentage of the target audience as possible. Program materials should be created professionally and designed for the designated audience. Materials should focus on specific safety concerns related to unsafe speed choices or serve as an appeal to drive more slowly. Awareness can be promoted through driver education programs as well as public outreach activities. Adding general information on speeding and safe driving to booklets and pamphlets made available through the driver licensing agencies can add to the impact of this effort, since the time for license renewal is the one time when drivers' attention to such matters is at its height. The same principle applies to students in driver education courses. Those in charge of public information and education campaigns should cultivate and maintain good contacts with the print and broadcast media. Media representatives can be invited to planning meetings where campaigns are being designed. Means for receiving free space or time can be sought, as part of the media's responsibility to provide public service.

EXHIBIT V-4 (Continued)
Strategy Attributes for Increasing Public Awareness of Risks of Driving at Unsafe Speeds (T)

Attribute	Description
	Highway agencies should ensure that education and information programs are scheduled when most likely to maximize the exposure of the message to the target population (for example, rush hour or vacation season). Campaigns should focus on situations familiar to the intended target population. Radio public service announcements, billboards, ads in theater playbills, and messages on transit vehicles are effective methods for communicating with target populations at desired times.
Potential Difficulties	High quality and effective informational materials can be rather high in cost. Also, educational information can be difficult to display and communicate to the public without help from local officials, educators, important agency cooperation, etc. Public information and education campaigns may not reach a large portion of the targeted audience if appropriate dissemination methods are not used. A range of media should be used, including television, radio, newspaper, Internet, club, and association meeting presentations, and other measures deemed appropriate for a specific area or audience. Consideration should be given to people who may need materials in languages other than English or in alternative formats to accommodate disabilities.
Appropriate Measures and Data	Process measures include documenting the number, types of different programs used to disseminate information, frequency of different media used (radio ads, brochures, etc.), and measures of population exposed to the message. Level of expenditure is another possible process measure. The impact of a program on driver attitude, knowledge, and understanding, or on driver interpretation of devices, can be performed by assessing a sample of people in the target area. This assessment would require a measurement of attitudes, knowledge, and understanding at the start of the program and another at the conclusion so that comparisons could be made. Measurement may be done in a number of ways, including surveys (e.g., telephone, roadside, or mail interviews), and focus groups. It is not feasible to directly measure effectiveness of educational programs in terms of effect on crash experience, due to the many intervening variables. However, surrogate measures may be employed, including before and after test results, interviews, and observation of change in behavior.
Associated Needs	Studying attributes of drivers involved in speeding-related crashes may help identify areas of the population upon which to focus future campaign efforts. There is a need for cooperation among various media agencies to effectively implement this strategy. Skilled professionals are needed to create the materials employed in the training or information campaign and should be involved from the start of project planning. Use of those with expertise in listener and viewer characteristics will allow for optimal targeting of messages broadcast by various media outlets. If evaluations will be done using surveys, this will require expertise that may not be available within the agency. Survey specialists can be contracted to create the survey questions, administer the survey, and summarize and analyze the results.

EXHIBIT V-4 (Continued)
Strategy Attributes for Increasing Public Awareness of Risks of Driving at Unsafe Speeds (T)

Attribute	Description
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	A cooperative effort with driver educators and departments of motor vehicles is desirable. For campaigns targeted at local areas, the law enforcement agency with jurisdiction over the community may be the best organization to lead the program, since a department of public works or local highway agency may not be well-suited to leading implementation of education campaigns. At the very least, close coordination with local law enforcement and highway agencies is necessary. If public information campaign expertise is not available within an agency, it may be necessary to involve another agency or use a private media consultant. Since the cooperation of the media and other non-governmental organizations is so important, a mechanism is desirable for maintaining communication and involvement. If an agency has a public relations section, that office would be of help.
Issues Affecting Implementation Time	The time required to start the program will depend on the time needed to create or update media materials for public information campaigns, and secure time and space for the dissemination of materials. These programs should be well planned before implementation. The more time invested in the planning process, the greater the likelihood of success in reaching the target audience. The time to implement this strategy could be relatively short, depending on how much of the system is already in place, but 6 months (or more) could be required to design and launch a successful program. If a highway agency has previously worked with driver educators, departments of motor vehicles, and media outlets, this will reduce implementation time, and only the specific messages or materials will need to be developed once it is agreed that agencies will collaborate on the program. A longer-term public education and information campaign will be more likely to reach the most people and reinforce the message being sent.
Costs Involved	There would be costs involved in updating existing and/or developing new information materials. These costs could be variable depending on the nature of the materials being developed, and the extent of the materials that have already been developed. Dissemination of the information, including making drivers aware that new or updated materials are available, will add to the costs of implementation. Public service announcements on radio and television do not have airtime charges, but are generally more expensive to produce than other formats and may be aired at less than ideal times. Printed or billboard ads can be produced for less than broadcast messages, but there may be monthly charges for posting. The costs involved in a public information and education campaign can vary widely depending on the type of media distribution (e.g. television, radio, newspaper, website, other), intended length of the campaign, and the frequency with which the message is disseminated. Staff resources are needed to develop and manage the program.
Training and Other Personnel Needs	Driver trainers should be educated in the risks involved with speeding so they are better able to emphasize this in driver education curriculums.

EXHIBIT V-4 (Continued)
Strategy Attributes for Increasing Public Awareness of Risks of Driving at Unsafe Speeds (T)

Attribute	Description
	If public information campaign expertise is not available within an agency, it may be necessary to involve another agency or use a private media consultant. Some staff may have to go through a brief training course to make more effective public presentations on the topic.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies to reduce speeding-related fatalities on roadways.
Other Key Attributes to a Particular Strategy	None identified.

Information on Current Knowledge Regarding Agencies or Organizations That Are Implementing This Strategy

NHTSA created a Traffic Safety Marketing website that provides numerous references and ideas available for organizations to publicize the risks of speeding. Sample posters, billboards, radio spots and television advertisements are available on the website to provide ideas: http://www.trafficsafetymarketing.gov.

Advocates for Highway and Auto Safety is an organization comprised of consumer, insurance, and health and safety groups. Their primary objective is to improve awareness of safety issues and support federal and state policies that target traffic safety. The group has a website with safety information concerning speeding and related safety issues: http://www.saferoads.org/index.htm.

The *Insurance Institute for Highway Safety* primarily observes vehicle safety features and their effectiveness in the event of a crash. They have material available online concerning safety and speed related collisions: http://www.iihs.org/safety_facts/safety.htm.

Strategy B2—Increase Public Awareness of Potential Penalties for Speeding (T)

Appealing to a driver's concern for his/her own personal safety or informing of the risks (Strategy B1) associated with driving at unsafe speeds may be effective in addressing the issue of speeding with some drivers. However, for others, appealing to their pocketbook is the most effective means of changing behavior. Penalties for excessive speeding, including fines, points, potential loss of license and delay of full licensure in graduated licensing programs can be deterrents to speeding behavior. In addition to civil penalties, car insurance companies may charge their customers more after receiving citations for unsafe driving behavior. Making drivers aware of the direct costs associated with excessive speeding, whether directly related to a crash or not, can be an effective strategy.

As mentioned previously, one of the most effective ways to communicate potential speeding penalties is through education and information campaigns. The media can demonstrate potential penalties for speeding and provide examples of specific instances where such penalties were enforced. Newspaper and television news agencies are good sources for relaying information such as heightened speeding enforcement efforts and speeding penalties. Some local newspapers in smaller communities have a public safety log, with a description and driver information concerning accidents and traffic-related violations, such as speeding. This is an effective way to inform the public of such penalties, and can have a deterrent effect as well. School systems, particularly high school driver education courses, provide opportunities to educate younger drivers on local speeding penalties.

Differences in Speeding-Related Penalties

A variety of penalties can be imposed as a consequence of speeding. The most common penalty for drivers exceeding the posted speed limit is a fine, which is issued by the local police department and highway patrol officers. Laws governing speeding vary by state and local municipalities; however, it is important to inform drivers that they are susceptible to a speeding ticket if they are exceeding the speed limit, no matter by how little.

Although enforcement and penalties are not the only reason that drivers should not speed, this seems to be a deterrent, at least when the threat of being penalized is apparent. There are several studies based on surveys that indicate that the presence of enforcement can indeed reduce travel speeds. One particular study in Australia observed law enforcement presence and speeding behavior. Surveys from the study found that repeated law enforcement presence on roadways can reduce the proportion of speeding vehicles on a roadway by approximately two-thirds (Armour, 1986). The study also found that within moments following exposure to law enforcement officers, drivers tended to increase to their normal travel speeds when they felt the law enforcement presence was no longer visible. Based on results from this and similar studies, one can assume that people sometimes recognize the risk of a penalty, rather than safety risks.

Penalties vary depending on the state law. NHTSA has an online table indicating penalties and state laws for speeding violations (http://www.nhtsa.dot.gov/PEOPLE/INJURY/enforce/speedlaws501/summary_table.htm). Most states do not issue tickets exceeding $100 to first-time offenders (depending on state and local laws and the circumstances for which they were cited). However, depending on the circumstances, even first-time offenders can face jail time anywhere from 10 to 90 days. Drivers who are speeding and sanctioned with reckless driving, racing, under the influence of drugs or alcohol, or are repeat offenders are subject to increased fines, jail time, and license suspension. In cases where excessive speeding and reckless driving result in fatalities, drivers are subject to being charged with offenses such as vehicular manslaughter. In extreme cases, jail time and fines can be very high.

There are several approaches to monitor and deter repeat speeding offenders who regain or have not lost their licenses. One such method includes striping license plates; this has been used in some states for persons who are caught driving without a valid license. License plate striping is mentioned in *NCHRP Report 500, Volume 2:* "A Guide for Addressing Collisions Involving Unlicensed Drivers and Drivers with Suspended or Revoked Licenses." This method has been a proven strategy in certain states to minimize illegal driving. This method can be applied to repeat offenders of speeding violations, such that they would receive a

striped renewal sticker to place on their license plates. These stickers would serve as indicators (and reminders) to law enforcement and the driver that he/she is a repeat offender. The public should be informed of such programs, in order to convey the message that a fine may not be the only penalty for serious speeding offenses. Exhibit V-5 provides more information on this subject.

EXHIBIT V-5
Strategy Attributes for Increasing Public Awareness of Potential Penalties for Speeding (T)

Attribute	Description
Technical Attributes	
Target	This strategy targets all drivers, as well as specific groups such as younger drivers, repeat speeding offenders, and any other portions of the driving population in an agency's jurisdiction with a high proportion of speeding-related crashes.
Expected Effectiveness	Public awareness of speeding penalties is expected to have a deterrent effect; however, it is difficult to quantify effects of information campaigns on speeding behavior. Statistics from FARS and numerous other sources can be used to determine audiences for information on potential penalties, such as younger males. For young drivers, testing driver education students is a good tool to evaluate their knowledge of speeding penalties.
Keys to Success	This strategy requires the support of those responsible for law enforcement and adjudication, as well as driver education teachers. To contribute to the success of this strategy, officials should be proactive in advertising the penalties for speeding and the likelihood of receiving citations during speed limit enforcement efforts. Support and coordination among agencies is important for a successful campaign. It is important that the message of increased enforcement be communicated; however, whether specific details of speed checks are to be announced publicly is based on an agency's preference.
Potential Difficulties	Getting local judicial, law enforcement, and educational officials and professionals to cooperate and continuously educate and enforce speeding penalties can be difficult if the agencies have not established procedures for working together. Doing so will help ensure a successful program.
Appropriate Measures and Data	Data on speeding and enforcement should be reviewed before and after speeding penalty campaigns and should be a continuous effort. Analysis of citations and speeding-related crashes will indicate factors such as age and gender, information that can be used to help design a program. Results/trends found from speeding data should be shared with the court system, other law enforcement agencies, and driver education officials to indicate any changes that can to be made to improve upon the campaign.
Associated Needs	Coordination with enforcement agencies is important, so visible enforcement programs can be developed to help drivers perceive the potential for receiving citations.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Coordination between departments of transportation, departments of public safety, educators, and others will be an important aspect of developing a viable program with materials that effectively reach the intended audience.

EXHIBIT V-5 (Continued)
Strategy Attributes for Increasing Public Awareness of Potential Penalties for Speeding (T)

Attribute	Description
Issues Affecting Implementation Time	In order to develop an effective campaign, campaign details and event scheduling should be planned prior to distribution of the campaign materials. Likewise, coordination with other agencies involved in safety may take some time, and should be started at early stages of the speed penalty campaign.
Costs Involved	Cost for this strategy will vary depending on the extent of the campaign, the materials developed, and the size of the audience to reach. More detailed campaign materials in a variety of formats will increase costs, as will coordination among various agencies. If a campaign will be relatively small and target a small population, or if an agency has an established procedure for coordinating with other agencies, this strategy should be relatively low cost.
Training and Other Personnel Needs	For the speed penalty awareness campaign, there will likely not be much training needed if judicial, law enforcement, and educators are involved. They should already have great knowledge of such issues, and have information concerning different aspects of speeding penalties to contribute.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy B3—Increase Public Awareness of Risks of Not Wearing Seatbelts (T)

Informing the public of risks associated with driving at unsafe speeds was identified in Strategy B1 as one effective approach in heightening driver awareness of speeding-related safety issues. The risks associated with not wearing seatbelts are also an important aspect to highlight in public awareness campaigns. Though increased seatbelt use is not directly related to a reduction in speeding-related crashes, it is closely related to a reduction in serious injuries and fatalities as a result of speeding-related crashes. *NCHRP Report 500, Volume 11:* "A Guide for Increasing Seatbelt Use" covers strategies for increasing the use of seatbelts; therefore, an overview of the information is presented in this guide, and Volume 11 should be referenced for additional information.

In Volume 11, three objectives were identified for the occupant restraint area:

1. Initiate programs to maximize use of occupant restraints by all vehicle occupants;
2. Ensure that restraints for children of all ages are properly used; and
3. Provide access to appropriate information, materials, and guidelines for those implementing programs to increase occupant restraint use.

The information in Strategy B1 of this guide, though written in the context of programs related to speeding, also applies to public information campaigns on the importance of

seatbelt use. Information to convey to the public, which may help convince reluctant drivers to wear their seatbelts, could include the average seatbelt use rate for the targeted area and statistics on the improved chances for surviving crashes when restraints are used.

Strategy B4—Implement Neighborhood Speed Watch/Traffic Management Programs (Low Speed Only) (T)

Establishing a neighborhood speed watch committee, and posting signs alerting drivers to "watch their speed," can draw drivers' attention to their speeds as they travel through neighborhoods. Anecdotal evidence from law enforcement programs indicates that drivers speeding through neighborhoods are often people that reside in the neighborhood, and a traffic management program can provide information and education on the neighborhood level.

Neighborhood Traffic Management Programs

Neighborhood Traffic Management Programs (NTMPs) are being created all across the country. Cities develop these programs to assist residents in creating traffic management plans for their neighborhoods. This allows residents to provide input into traffic management issues in their communities. Through these programs, the city provides citizens with the resources to pursue solutions to their neighborhoods' traffic problems. Citizens are encouraged to create a neighborhood traffic safety committee. This committee will become the face of the neighborhood when dealing with the city government on traffic safety issues and can serve to facilitate communication between transportation departments when discussing traffic management options for a neighborhood. These committees are not only the liaisons between the neighborhood and the city, but they also can act as educators to the public. Public awareness campaigns are often started by neighborhood and community traffic safety committees, and are a way that residents can be involved in ensuring that their neighborhoods are a safe place for drivers, pedestrians, and bicyclists alike. The National Highway Traffic Safety Administration (NHTSA) has also created a helpful guide to starting a traffic safety committee. It is targeted towards a community wide committee but may also be useful to neighborhood committees as well. See http://www.nhtsa.dot.gov/portal/nhtsa_static_file_downloader.jsp?file=/staticfiles/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/810915.pdf for more information. Also, the NHTSA website is a valuable resource for information on speeding in general, as well as anti-speeding campaign materials.

Pace Car Program

Some Neighborhood Traffic Programs also include programs that encourage safe driving. One popular program is the Pace Car Program (Salt Lake City Corporation, 2000). The Pace Car Program is a citizen-based initiative that started in Boise, Idaho, and is being implemented in cities across the country, like Salt Lake City, Santa Cruz, and Boulder. The idea is quite simple: the program uses cars to calm cars, merely by encouraging motorists to abide by existing laws. The two elements of this program are a bumper sticker and a pledge. Pace Car drivers pledge to drive within the speed limit, stop to let pedestrians cross, walk when they can, and do something to their car to make others smile, with the goal of calming drivers rather than streets. They turn their car into a "mobile speed bump."

Pace car drivers set a prudent pace for the drivers behind them. If they drive within the speed limit, the cars behind them will do the same. The central core of this program puts the responsibility to drive responsibly in the hands of the motorists. In many cities the Pace Car Program is intended to be a city-wide program, however all the programs specifically emphasize obeying the speed limits and watching for pedestrians on residential streets.

Neighborhood Speed Watch Program

The Neighborhood Speed Watch Program is another program that encourages safe driving. Speed watch programs are used to address the issue of speeding along residential streets. It is a public awareness program involving the residents of the neighborhood. Typically the concerned residents will request that a speed watch be completed. These programs have been implemented in communities across the country, including in Seattle and Bellevue, Washington, Colorado Springs, and Salt Lake City. See City of Bellevue, Neighborhood Traffic Services (http://www.ci.bellevue.wa.us/traffic_calming.htm) for more information.

In Salt Lake City, Neighborhood Speed Watch Program requests are handled by the Transportation Division of the Salt Lake City government. The program was developed in Salt Lake City due to the frequent requests to address the speeding problem on residential streets. Once a request has been made, the Transportation Division loans a radar unit to one of the residents for a 48 hour period. The resident and one other person will then record the speeds of vehicles using the radar unit. Other information, such as license plate number of speeders and time and date of the offense is also noted. This information is then returned to the Transportation Division where it is processed. A letter from the Transportation Division is then sent to the registered owners of all matched vehicles. The letter advises them of the observed speed violation and asks them to encourage drivers of their vehicle to drive within the speed limit when traveling on neighborhood streets. No speeding citations are issued. The Salt Lake City Speed Watch program is fairly typical of all Neighborhood Speed Watch programs throughout the country, with slight variations existing (see Exhibit V-6).

EXHIBIT V-6
Strategy Attributes for Implementing Neighborhood Speed Watch/Traffic Management Programs (T)

Attribute	Description
Technical Attributes	
Target	This strategy is targeted at reducing speeding-related crashes on residential streets by encouraging residents to be actively involved. Anecdotal information indicates that offenders on residential streets are residents of those very streets, so they are both the problem and the solution in this strategy.
Expected Effectiveness	In general, this strategy relies on the assumption that if drivers are made aware of the fact that they are speeding, and of the concerns of the residents who live on those streets, they will reduce their speeds. Also, as part of the NTMP when all other methods are tried and have not succeeded, residents can request traffic calming solutions, such as speed humps or chicanes to mitigate the problem. For further exploration into traffic calming solutions see Strategy E3.

EXHIBIT V-6 (Continued)
Strategy Attributes for Implementing Neighborhood Speed Watch/Traffic Management Programs (T)

Attribute	Description
Keys to Success	A primary key to the success of neighborhood traffic safety programs is the willingness of the neighborhood residents to participate in these programs. Residents request and run the programs. They are responsible for distributing materials on the dangers of speeding in neighborhoods and are the people that meet with city officials to discuss the engineering and enforcement options for their streets. Transportation or enforcement agencies may need to publicize the availability of these programs in order to encourage interest in neighborhoods. In addition, once a program is started, transportation or enforcement agencies should periodically check in with the neighborhood committee to ensure that people remain motivated to participate.
Potential Difficulties	Difficulties include finding funds to run these neighborhood programs, especially if there is not a neighborhood association that generates funds already in existence. Also, apathy on the part of some of the neighborhood residents is a potential difficulty. In general, however, it can be assumed that if speeding is a problem in a neighborhood, residents will want to help mitigate the problem.
Appropriate Measures and Data	The number of neighborhoods that implement a program is an appropriate process measure for this strategy. Reduction of the number of speeding vehicles and reduction in crashes involving speeding are appropriate measures of the success of this strategy.
Associated Needs	It may be desirable to have periodic targeted enforcement of speed limits in the neighborhood, to draw further driver attention to the speed limit and to encourage people to obey it.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	These programs need active participation by the local department of transportation, local police department, and most importantly the residents of the affected streets. A procedure for coordinating among these groups should be developed.
Issues Affecting Implementation Time	This strategy can be implemented in a short amount of time. If a highway or enforcement agency does not have equipment, such as speed trailers, for neighborhoods to use, or if the program involves officers stationed in the neighborhood for a period of time to perform enforcement, implementation time will increase.
Costs Involved	Costs for implementing this strategy will be relatively low. Costs are related to pamphlets, flyers, posters, signs, or other materials that the residents use to get their message out to the other residents of the neighborhood, and those who drive the streets. Any equipment or enforcement activity would increase costs.
Training and Other Personnel Needs	Some of the residents will require training to participate in the Speed Watch program. The amount of training varies by city. In general, training in the use of a radar unit, general safety training, and program rules are required by most programs.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy B5—Implement Safe Community Programs (T)

The Safe Communities program model was developed by the National Highway Traffic Safety Administration (NHTSA). A Safe Community is one that promotes traffic injury prevention by involving citizens in addressing key problem areas. Data determines the focus areas and guides the implementation of programs. A multifaceted approach to each problem area includes interventions in each of the four E's—Education, Enforcement, Engineering and Emergency Medical Services. The Safe Communities approach represents a new way community programs are established and managed. All partners participate equally to develop solutions, share successes, assume risks, and build a community structure and process to improve the quality of life in the community through the reduction of injuries and costs. A Safe Community establishes community ownership and support for transportation injury prevention. In doing so, it expands resources and partnerships, and increases program visibility throughout the community.

The concept behind a Safe Community is that of collaboration. Many Safe Communities are coalitions. The coalition is made up of concerned citizens, law enforcement, medical staff, and educators combined with existing community groups and programs that have similar missions to that of the Safe Community. One organization typically cannot handle all the traffic safety problems that face a community—but a coalition has a better chance at success. A key to the success of a Safe Community is community involvement. Engaging these other community groups and public entities is critical to its success.

The Safe Community concept can be implemented on many different levels. It has been proven effective on the state, county, and community level. Examples of successful programs are the statewide program in North Dakota and a county program in Wright County, Minnesota. The North Dakota program provides resources and information for community programs and coalitions throughout the state. Their website (http://www.safecommunities.org) has a wealth of information available to community programs around North Dakota and the country. Safe Communities of Wright County (http://www.safecomm.org/) was formed in 1997 as a collaborative effort focused on reducing crashes in Wright County, Minnesota, through safety education and prevention. They have chosen to target commuters traveling on 55-mph roadways, and younger drivers. Driver inattention and speeding are two crash factors being targeted by this program. See Exhibit V-7 for further information.

EXHIBIT V-7
Strategy Attributes for Implementing Safe Community Programs (T)

Attribute	Description
Technical Attributes	
Target	This strategy targets speeding-related crashes that occur in communities as a whole. These programs require the combined efforts of citizens, law enforcement, public health, medical, injury prevention, education, business, civic and service groups, public works offices, and traffic safety advocates to provide program input, direction, and involvement in the Safe Community program. This also targets existing community programs that have aligning missions that wish to combine to create a coalition.

EXHIBIT V-7 (Continued)
Strategy Attributes for Implementing Safe Community Programs (T)

Attribute	Description
Expected Effectiveness	In Norwich, Connecticut, the creation of a Safe Community Coalition in 1997 had a profound effect on traffic crashes in the community. Objectives of this program were to increase public awareness of traffic safety laws, increase traffic enforcement and education efforts, decrease incidents of speeding, and promote safety belt, child safety seat, and bicycle helmet use. In doing so, Norwich experienced a reduction in traffic crashes of 12 percent in 1998 and safety belt use increased from 60 to 92 percent (NHTSA Traffic Safety Digest, Winter 1999). In Sacramento, California, a Neighborhood Traffic Management Program was developed involving eight neighborhoods that were experiencing high speed/high volume traffic that had diverted to their neighborhood streets. The objective of this program was to develop a multi-year plan of engineering, education and enforcement activities that addressed the issues of traffic safety. The citizens of the neighborhoods were involved in developing the program which included design and production of educational materials for both a Traffic Management Class and a Traffic Campaign as well as training for neighborhood leaders. Enforcement was increased, speed limit signs were installed, and new crosswalks were painted. These combined efforts led to an average reduction in speed of 10 mph and reduction of traffic volumes by 15 percent in one neighborhood (NHTSA Safe Communities Service Center). Though any individual treatment or aspect of a Safe Community program may be more effective than another, it is the combined efforts of the strategies and involved people that prove to be successful.
Keys to Success	A major key to the success of this strategy is the need for a champion, someone who will stick with this program and see that it succeeds. This person should be a part of the leadership team. A communicative and compatible team will be more effective in the long run. Efforts should be made to establish a strong working relationship among team members. Another key to the success of this strategy is citizen involvement. This is important because citizens ensure that local values and attitudes are considered during the process of identifying the injury problems and shaping successful solutions.
Potential Difficulties	The startup phase of a program such as this is the most critical and is the period when the program is most susceptible to failure. NHTSA provides an excellent guide for starting a Safe Community and what path to follow for success in the first 6 months (http://www.nhtsa.gov/portal/site/nhtsa/menuitem.404f848a3e46fc67ba8e5f8dcba046a0/). Garnering program funds, especially in smaller communities where funding may not be readily available, is a potential challenge.
Appropriate Measures and Data	The attainment of success may be measured both in terms of the existence of a Safe Community Program and the involvement within the community. The reduction in crashes, or of injury and fatal crashes, as well as speed reductions and reductions in traffic law violations, are measures of success as well.
Associated Needs	Educational and awareness programs will require the involvement of specific members of the community, such as the media, local schools, and the medical community.

EXHIBIT V-7 (Continued)
Strategy Attributes for Implementing Safe Community Programs (T)

Attribute	Description
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	The success of these programs will require the cooperation of several organizations and institutions, such as law enforcement, government, and local schools. A coordinated council, or team, will be needed to oversee the coalition.
Issues Affecting Implementation Time	The time to implement a program depends upon such factors as availability of funds and materials for startup meetings, the number of agencies and organizations to be involved, and the size of the community. The program could take 6 months to 1 year to establish a working team and begin implementing aspects of the program.
Costs Involved	Costs vary depending on the community and the goals and objectives of the program, but each individual aspect of the program should be relatively low in cost.
Training and Other Personnel Needs	The involvement of specialists in marketing, education, and leadership will be needed.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with all other strategies in this guide. All strategies that rely on public awareness and public education will benefit greatly from this strategy, including all the strategies within Objective B. Safe Community Programs provide the means to take on public campaigns, such as those related to increased enforcement programs, discussed in Strategy C1.
Other Key Attributes to a Particular Strategy	None identified.

Objective C—Improve Efficiency and Effectiveness of Speed Enforcement Efforts

Speed enforcement plays a large role in deterring drivers from traveling at excessive speeds. There are numerous methods that some law enforcement agencies currently use or are in the process of implementing in order to improve the efficiency and effectiveness of enforcing speed limits. Due to limited resources, the use of available funding and enforcement officers needs to be as efficient and effective as possible in order to have the greatest effect on highway safety.

Strategy C1—Use Targeted Conventional Speed Enforcement Programs at Locations Known to Have Speeding-Related Crashes (P)

Speed enforcement programs are launched by local and/or regional enforcement agencies. Speed campaigns typically target speeders through public awareness programs, as well as increased enforcement, providing increased enforcement at locations where a review of

current travel speeds, crash history, and officer and public input show the potential for improvement. When used in conjunction with public education/awareness campaigns to increase knowledge of enforcement efforts, speed enforcement programs have the most potential for deterring drivers from speeding.

When starting a speed enforcement campaign the enforcement agency, or agencies, administering the campaign should first focus on specific roads to target, when they should be targeted, and why they chose those particular locations and times. Typically speed enforcement programs identify roads to target based on review of crash history, speeding citations, and public complaints. Several road segments can be identified and prioritized based on speeding trends and past crash reports. Performing enforcement during the times of day when speeding has been most prevalent in the past or when safety issues are most likely will help increase the effectiveness of the program.

Consistent speed enforcement can be effective in deterring drivers from speeding. The more a driver is exposed to law enforcement presence, the less he/she is likely to speed. In the article, "The Effect of Police Presence on Urban Driving Speeds," Armour found that increased law enforcement presence does have an impact on travel speeds. The author's literature review concluded that there was good evidence that the presence of law enforcement will reduce vehicle speeds and that this reduction can be maintained for at least some time after the vehicles have passed the zone of law enforcement presence. The author also discussed the possibility of a "memory effect." A memory effect of enforcement is produced if drivers reduce their speed in areas where they have previously seen the presence of the law enforcement officials. It has been shown that a memory effect of enforcement can be produced in highway situations using high levels of enforcement, and in urban situations, this effect may last up to 2 days after the law enforcement presence has been removed (Armour, 1986). However, the study discussed in this article indicates that the deterrent effect of law enforcement presence is often location specific for most drivers on urban roads (less than 40 mph), in that they decrease travel speeds at locations where they know or think law enforcement might be present (based on previous experiences), but speed up after the enforcement zone. This can have a negative impact, as drivers may choose to travel different routes where law enforcement presence is less common. This emphasizes the importance of reevaluating the areas in need of law enforcement on a regular basis. As drivers choose different routes, based on law enforcement presence, speeding may become an issue at other locations. This should be monitored and adjustments in enforcement made as needed. This also indicates a need for a greater number of law enforcement, if an area-wide problem exists.

Public involvement and awareness of special speed enforcement programs result in elevated effectiveness of the program by enhancing the deterrent effect of enforcement. Public awareness campaigns can result in an enhanced deterrent effect. Vigorous publicity that accompanies an enforcement program may provide as many measurable results as the enforcement itself. The public involvement campaigns that accompany these enforcement programs do not necessarily need to be spearheaded by the enforcement agency. In fact, law enforcement agencies do not typically have the resources to generate the level of public awareness needed to create the general deterrence effect needed for the success of the program. Many communities, however, have concerned citizens and civic leaders who have both the talent and resources that are required to develop and implement effective program support activities.

There are a number of special enforcement programs that target an area-wide traffic safety problem. These programs target a number of different safety issues, including speeding.

NHTSA has a set of guidelines for developing a municipal speed enforcement program, available online at http://www.nhtsa.dot.gov/people/injury/enforce/program.htm. It provides guidance to both law enforcement and concerned citizens to assist with the development of traffic safety program support committees and the implementation of municipal speed enforcement and other special traffic safety programs. These implementation techniques were tested in both Modesto and San Bernardino, California. These communities, as a result of the programs they established, experienced declines in speeding-related crashes (For more information, see NHTSA, http://www.nhtsa.dot.gov/people/injury/enforce/program.htm). Both communities participated in a 6-month NHTSA study. Each community conducted speed enforcement programs in six special enforcement zones, while a third community refrained from implementing any special enforcement effort to act as a comparison site. In addition to increased enforcement, San Bernardino and Modesto organized safety program support committees to elevate public awareness of the special enforcement program. These committees were comprised of local leaders, concerned citizens, a law enforcement manager, and chaired by emergency department physicians. The public campaigns were widespread and covered every area of the media. The public campaign included press conferences, posters, brochures, bus bench display advertising, media events, and television and radio public service announcements (NHTSA, 1995). Both communities experienced a decrease in speed-related crashes, with San Bernardino being the most successful with a decrease of 11.3 percent over the 6 month period, while Modesto had just a 1.1 percent decrease. However, the comparison site had an increase in crashes of 3.4 percent, increasing the statistical significance of both study sites' decrease in crashes.

As an added benefit to the increased enforcement, both communities experienced a decline in other serious crimes. Larceny-theft crimes declined 11–12 percent in both communities, while statewide it decreased about 1.7 percent. Traffic enforcement stops conducted during this study resulted in more than 2,000 arrests for offenses ranging from assault to misdemeanor and felony warrants (NHTSA, 1995). These results stress the importance of "looking beyond the ticket" and serve as an added benefit of increased speed and traffic law enforcement. Albuquerque, New Mexico, experienced similar results in the Safe Streets Program in 1997.

The Smooth Operator Program, in the Washington, DC metropolitan area, has been combating aggressive driving since 1997. This program is both an education and enforcement program that has brought law enforcement agencies, trauma experts, government officials, and other professionals together to educate motorists about the risks involved with aggressive driving, and to stigmatize this behavior on the roads of Maryland, Virginia, and Washington, DC. Speeding is a major component of aggressive driving, especially excessive speeding. The enforcement component of the Smooth Operator Program takes place in four law enforcement waves, throughout the year. Each wave is 1 week long and vigorously targets speeding and aggressive drivers (Smooth Operator website). Similar programs are discussed further in the *NCHRP Report 500, Volume 1:* "A Guide for Addressing Aggressive-Driving Collisions." For more information on this specific program visit: http://www.smoothoperatorprogram.com/about.html.

In Virginia, the State Police, the Department of Motor Vehicles and the Department of Transportation have combined to develop a Highway Safety Corridor Program to address safety in high-crash locations on interstate and primary roads. Segments of interstate roadways have been identified as having higher than expected crash rates along with crash severity. The program development is an ongoing process as the agencies are currently in the process of establishing the Highway Safety Corridors based on crash data and public

comment around the state. In 2004, a 15-mile stretch of Interstate 81 (I-81) near Roanoke was designated a Highway Safety corridor. A telephone survey in 2005 revealed that one-half of the residents were aware of the designation and 40 percent of those who were aware of the designation had said they improved their driving behavior as a result. Prior to the designation of the safety corridor, the number of crashes on I-81 had consistently increased each year from 2000 to 2003. The number of crashes has leveled off since the stretch was designated in early 2004 (see Virginia DOT, http://www.virginiadot.org/comtravel/ct-highway-safety-corridor.asp). Highway Safety Corridors are discussed further in *NCHRP Report 500, Volume 20:* "A Guide for Addressing Head-On Collisions."

Another special law enforcement effort is saturation programs. The California Highway Patrol (CHP) often targets specific stretches of highways throughout the state to saturate with enforcement and engage in zero tolerance speed enforcement. On a given day, enforcement levels may be tripled to enforce this zero tolerance for speeding. Typically this special enforcement is conducted about 4 or 5 days each month, though it varies by area. Zero tolerance for speeding means the speed limit is strictly enforced. Anyone speeding, even just a few miles over the speed limit, can be pulled over and given a citation or warning. The primary goal of an enforcement saturation program is to increase the visibility of law enforcement, which is a deterrent for many would-be speeders. This generally decreases the average flow of traffic on busy roadways and therefore decreases the frequency and severity of crashes (Taylor, 2004, Hall, 2003).

These types of education and enforcement programs are an effective tool in increasing public awareness of the risks of driving at unsafe speeds, as discussed further in Strategy B1 of this guide; also see Exhibit V-8 for more information.

EXHIBIT V-8
Strategy Attributes for Using Conventional Speed Enforcement Programs at Locations Known to Have Speeding-Related Crashes (P)

Attribute	Description
Technical Attributes	
Target	This strategy aims at reducing excessive speeds through enforcement programs in targeted locations. Locations where speeding is known to occur or where there is a history of crashes, especially crashes involving speeding drivers, should be targeted.
Expected Effectiveness	Many studies indicate that increased law enforcement presence is a good way to deter drivers from speeding. A study in Australia found that law enforcement presence reduced the number of speeding vehicles on an urban road by approximately two-thirds (Armour, 1986). Likewise, a study in Korea found that the presence of automated speed enforcement devices reduced accidents by 29 percent and fatalities by up to 40 percent (Ha, Kang, and Park, 2003). Albuquerque, New Mexico, had great success with their Safe Streets Program in 1997. The program was composed of a number of different elements, including saturation patrols in local high-crime/high-crash areas, and freeway speed enforcement where two major highways intersect in the heart of Albuquerque, a total of 30 miles of urban interstate. All operations of the Safe Streets Program were highly visible and many publicity campaigns were created to let the public know of the increased enforcement and the dedication to increasing the safety on Albuquerque roads. During the program year, there was a 12 percent decrease in speeding-related

EXHIBIT V-8 (Continued)
Strategy Attributes for Using Conventional Speed Enforcement Programs at Locations Known to Have Speeding-Related Crashes (P)

Attribute	Description
	crashes, including a 34 percent decrease in fatal crashes and an 18 percent decline in injury crashes. In addition to the decline in vehicle crashes, the presence of highly visible law enforcement patrols aided in the decline of crime and many arrests also were made as a consequence of the special enforcement effort (Stuster, 2001). Communities may also experience an ancillary benefit in terms of reduction in crimes in the area with increased law enforcement presence.
Keys to Success	A successful speed enforcement program should involve local and regional enforcement agencies. Networking between enforcement agencies can greatly improve the success of any one speed enforcement program. More and better detailed data can be shared between the agencies. Having proper equipment is also an important key to the success of these programs. Having multiple agencies involved can help alleviate the costs of this equipment, by collectively purchasing and sharing the equipment. Crash history and speed studies should be reviewed and roads should be selected to target based on these studies. The TRB publication, *Special Report 254,* "Managing Speed, Review of Current Practice for Setting and Enforcing Speed Limits," identifies situations where speed enforcement programs in the United States have been most successful. Enforcement programs are most successful when deployed at specific locations and times when speeding is most likely to occur (e.g., nighttime), programs and enforcement are made easily visible to the public, and the program is administered for at least 1 year (Milliken et al., 1998). A successful speed enforcement program would also gain media attention, which is important to inform and gain public attention.
Potential Difficulties	One potential difficulty is lack of funding or personnel for proper equipment and law enforcement patrolling. To overcome this, some agencies have joined with neighboring jurisdictions to share officers and patrol cars in order to provide an enforcement program with greater coverage. Another potential difficulty involves the use of radar detectors by drivers in personal vehicles. Radar detectors in personal vehicles are illegal in only the District of Columbia and Virginia. They warn drivers of radar that is determining their speed, such as from a law enforcement vehicle or from an automatic speed enforcement device. The use of radar drones may be a possible option in combating their use. Radar drones emit a signal that sets off radar detectors, to cause the driver to think that there is a law enforcement officer or an automatic speed enforcement device within range and the driver will generally slow down. If used over a period of time in a specific location, the effectiveness of a radar drone will wear off as drivers with radar detectors frequently passing through the area become used to it. When used on a regular, but random, basis, drivers may become less reliant on their radar detector and more likely to obey the speed limit, at least in the area where radar drones are prevalent. Another possible solution to this is to outlaw the use of radar detectors. Radar detector detectors enable law enforcement officials to determine which drivers are using radar detectors. In jurisdictions where the use of radar detectors is illegal, drivers caught using these devices may be fined. Existing roadside geometrics can present law enforcement officers making traffic stops with a difficulty. Without an area with appropriate space for vehicles to pull out of the travel way, both officers and the drivers being stopped could be stopping in an

EXHIBIT V-8 (Continued)
Strategy Attributes for Using Conventional Speed Enforcement Programs at Locations Known to Have Speeding-Related Crashes (P)

Attribute	Description
	unsafe location. This can be especially true in work zones, where shoulders are often used for temporary travel lanes, resulting in no room for enforcement activities. Space available for enforcement activities should be considered when planning targeted enforcement programs. Also, in future road design, engineers should consider areas specifically for law enforcement.
Appropriate Measures and Data	Appropriate data includes average travel speeds and crash data collection before and after speed enforcement programs. Special attention should be paid to the fastest drivers, not just the average or 85th percentile speeds. These data can be used to determine if the speed enforcement program successfully reduced travel speeds and crashes along specific corridors. Detailed data, such as severity of crashes, age, and gender of drivers should be identified in order to target future speed enforcement programs.
Associated Needs	One of the most important associated needs identified with this strategy would be gaining public attention. Informing the public in advance of the program will likely contribute in deterring drivers from speeding if they know that law enforcement will be increased. Gaining public attention can be administered through flyers, brochures, posters, billboards, and radio or television advertisements.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Coordination between law enforcement agencies will be needed if agencies wish to join efforts to implement enforcement programs that share each other's resources.
Issues Affecting Implementation Time	Implementation time for a basic targeted enforcement program will be relatively short. If an enforcement agency needs to purchase equipment, apply for grants to help cover overtime labor costs, or coordinate with other agencies to share staff and equipment, the implementation time will lengthen. Making the public aware of upcoming and on-going enforcement programs will involve some planning and coordination with media outlets, which could lengthen implementation time as well.
Costs Involved	Costs to implement this strategy will be low to moderate, depending on the extent of enforcement coverage. Costs for this strategy include additional law enforcement personnel (if current personnel are not adequate for such a program) and technology, such as automated speed enforcement devices or state-of-the-art handheld radars. These items are optional, but they could contribute to an improved speed enforcement program. Other costs include any informational brochures or related media for public information.
Training and Other Personnel Needs	No extensive training would be required for this strategy. Current enforcement agencies might require additional personnel to support larger campaigns. These personnel would require training on making speeding-related stops. It may also be helpful to have a refresher course or training for law enforcement officers currently on the job. This can help ensure that speeding citations are properly filled out, which helps with adjudication and planning of future enforcement efforts.
Legislative Needs	Legislation may be necessary before implementing a speed enforcement program. The legislation is necessary to meet constitutional standards, state legal standards, and local jurisdiction standards. The National Conference of State Legislatures tracks status of legislation and speed laws (concerning radar) and provides examples of model legislation at: http://www.nhtsa.dot.gov/ncsl/Index.cfm.

EXHIBIT V-8 (Continued)
Strategy Attributes for Using Conventional Speed Enforcement Programs at Locations Known to Have Speeding-Related Crashes (P)

Attribute	Description
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with all others discussed in this guide.
Other Key Attributes to a Particular Strategy	None Identified.

Strategy C2—Implement Automated Speed Enforcement (T)

General Description

Law enforcement officers are not able to enforce speed limits on all roads at all times, and automated enforcement technologies offer the opportunity for increasing enforcement efforts and public perception that speeding citations are likely. The use of cameras to enforce red-light running is common practice in some jurisdictions, but their extension to applications involving speeding is more limited. Current technology can be used to deter drivers from speeding, and document them while traveling at speeds in violation of the posted speed limit. Such technology can be used without the presence of a law enforcement officer, if laws permit such use. This is ideal for high-speed roads where speeding is an issue that enforcement officials have difficulty controlling or on multi-lane roads with heavy traffic moving in both directions where it is often dangerous for officers to make traditional stops. Legislation enabling the citation of drivers recorded on camera is often needed for the technology to be employed. Studies in the United States indicate that speed cameras have been effective in reducing overall vehicle travel speeds and the proportion of drivers traveling in excess of posted speeds. However, it is common for the public to react negatively to the use of camera enforcement technology. Public involvement efforts are a significant portion of the implementation plans for automated enforcement programs.

Automated speed enforcement (ASE) devices are also known as speed cameras or photo radars. These devices comprise a speed measurement unit and a camera that work together to locate and identify drivers traveling at speeds above the posted speed limit. Speed cameras are generally located on roads with speeding issues and a history of speeding-related crashes. They are also often used in school zones, work zones and areas with large pedestrian volumes. The speed measurement unit on the camera measures the travel speed of vehicles on the roadway. When it detects vehicles exceeding the speed limit by a predetermined amount, the camera takes a photograph of the vehicle and records relevant information such as the travel speed, date, and time that the speeding violation took place. The speeds at which photo speed measurement units are triggered are determined by local enforcement agencies.

International Experiences with Automated Enforcement

Several countries report positive experiences with automated enforcement from both the traffic safety improvement and public acceptance perspective. Various reports published by

the Federal Highway Administration and Transportation Research Board, as well as reports by researchers in the countries using automated enforcement, document these experiences.

Automated speed enforcement combines radars with cameras to photograph speeding vehicles and issue tickets. About 75 countries rely on cameras to enforce speed limits, which reduces high travel speed and crashes (IIHS, 1999). The Insurance Institute for Highway Safety (IIHS) states that in some countries automated enforcement generates the majority of the speeding citations. In the United Kingdom, one-half of all the speeding citations resulted from automated enforcement.

British officials introduced an electronic system using loop detectors in all lanes to detect traffic volumes and speeds. Roadside processors analyze the data to detect where traffic is slowing and this information is used to post variable speed limits—ranging from 20 to 60 mph—on electronic signs. Speed limits are set to produce a uniform and safe traffic flow based on traffic and other conditions. When no variable limit is posted electronically, the speed limit reverts to the national maximum of 70 mph. Without proper enforcement, simply posting variable limits would not be effective in managing speeds. Enforcement is achieved by mounting cameras across the highway to detect and photograph speeding vehicles. First a radar measurement is taken, and speeding vehicles are photographed twice, each photo a half second apart. The distance traveled between the two photos is used to confirm the radar measurement. There were 28 percent fewer crashes involving occupant injuries during the first year of the program, and property-damage-only crashes went down 25 percent. Preliminary data for the second year indicate the improvements are being maintained (FHWA, 2005).

A study tour for speed management and enforcement was conducted by the FHWA in 1995. The tour observed automated enforcement devices in the Netherlands, Germany, Sweden and Australia. It was observed that photo radar devices were used to a certain extent in all of the countries visited. However, in each country the photo radar devices were used in conjunction with a law enforcement officer presence (FHWA, 1995). The reasoning for using ASE devices with law enforcement presence is to ensure that such devices are not used solely as revenue generators—a common allegation from people opposed to the use of ASE devices. The study found that implementation of photo radar was most successful in the Netherlands and Australia. The success, in both countries, is credited to the fact that legislation was enacted requiring citations be sent to the owner of the vehicle rather than the driver (FHWA, 1995). Currently, no equipment is commercially available that will consistently and reliably identify the driver of the vehicle. Consequently, the study team recorded that photo radar devices were not successful in Germany and Sweden; this is because laws in these countries require that tickets must be issued to the driver of the vehicle rather than the owner (FHWA, 1995). The speed management study team reported that photo radar devices were most successful when used with informational speed management programs/campaigns.

Overall, the FHWA study tour found that speed cameras were less effective in Germany, due to the current laws requiring positive identification of the driver. However, German officials did perform a long-term study in the 1970s on the A3 autobahn that did not require the driver's identification and the results were significant. In general, the autobahn does not have a speed limit, except in urban areas. Prior to this study at Elzer Mountain, between Cologne and Frankfurt, there was no posted speed limit on this hilly stretch of the autobahn. In 1971, before the study was conducted, 80 to 95 percent of passenger vehicles exceeded the recommended roadway design speed, 15 percent of which exceeded 150 km/h (93 mph) in

the left lane and 135 km/h (84 mph) in the middle lane, and 15 percent of trucks exceeded the design speed. In 1972, to reduce accidents and accident severity in this area, a 100 km/h (62 mph) speed limit was posted for passenger vehicles in the left and middle lanes and 40 km/h (25 mph) speed limit was posted for trucks in the right (truck) lane and a year later speed cameras were installed above each lane. The speed camera photographed all passenger vehicles exceeding the speed limit by 10 km/h and all trucks exceeding the truck speed limit by 5 km/h. The owners of the vehicles that were photographed were sent citations by mail. In addition to the speed cameras, law enforcement patrolled the segment of road to cite drivers for speeding. Immediately following the posting of the 100 km/h speed limit, a 30 km/h (19 mph) reduction in the average speed was observed. Following the installation of the speed cameras, an additional 20 km/h (12 mph) reduction in average speed was observed. The combination of setting a speed limit and the use of speed cameras resulted in a 91 percent reduction in crashes on that stretch of the autobahn. Ten years later, the reduced crash rate and lower speeds were considered sustainable. Just 7 percent of passenger vehicles in the left lane, 3 percent of passenger vehicles in the middle lane, and 10 percent of vehicles in the truck lane (right lane) were detected by the speed camera at speeds greater than 110 km/h for passenger vehicles and 45 km/h for trucks (Lamm and Kloeckner, 1984).

Another interesting automated enforcement method used in European countries is based on a concept of point-to-point automated speed enforcement. A product called the Speed Enforcement Camera System (SPECS) is a video system with automatic number plate reading digital technology consisting of two cameras. Each camera is set at a distance apart making it a speed-controlled zone. As a vehicle passes the two cameras its number plate is digitally recorded along with the time of entry and exit. The computer then calculates the speed based on the time and distance. This information is then transmitted to a central office or stored on discs in the cabinets at the roadside. If vehicles exceed the average speeds, a speeding violation is automatically generated. As the whole technology is digital it can run 24 hours a day with no film to change. Studies show that it has reduced fatalities in places where it was installed and also improved compliance with speed limits.

See Appendix 1 for further discussion on international experiences with automated speed enforcement.

Domestic Experiences with Automated Enforcement

As of April 2006, automated speed enforcement technology is used in about 20 communities in the United States (IIHS-Automated Enforcement Laws). Many jurisdictions that use automated enforcement are in states that have laws authorizing its use; however, not all states where automated enforcement is in use have such laws. Most automated enforcement programs and laws are for red light running; however, the use of automated enforcement for speed is increasing. The state laws that do exist vary from state to state; some authorize enforcement statewide, whereas others permit use only in specified communities. As of April 2006, New Jersey, West Virginia, and Wisconsin are the only states that prohibit any use of camera devices for enforcement purposes. Elsewhere in the United States, 25 states had no legislation regarding the use of any form of automated enforcement device, and 22 states and the District of Columbia had some legislation allowing the use of automated enforcement devices, either statewide or in select communities (IIHS-Automated Enforcement Laws).

There have been few studies in the United States that focus on the use of automated speed enforcement on high speed roads. A majority of the studies have been done in high-traffic, low-speed urban areas, like Washington, DC. They are also used in high pedestrian areas, where speeding is a serious issue, such as school and work zones. The studies that have been done in the United States indicate that speed cameras have been effective in reducing vehicle travel speeds. A study in 2002 found that speed cameras in the District of Columbia helped to reduce the number of vehicles traveling at 10 mph or more over the speed limit at enforced locations by 82 percent. This study also found that average travel speeds at enforced locations declined by 14 percent within 6 months of the speed cameras' implementation compared to nearby control locations (Retting and Farmer, 2003). This study is discussed further in Appendix 1. Likewise, a study in Garland, Utah, found that installing speed cameras, in conjunction with media coverage, helped reduce average travel speeds by 14 mph and reduce collisions in a school zone (IIHS-Automated Enforcement Laws). It may also be a cost effective solution since most enforcement agencies are constrained by staffing and funding limitations.

The results of a 1993 study in Riverside, California were reported at the 1998 TRB Annual Meeting (Bloch, 1998). The study evaluated the effectiveness of both photo radar and speed display boards. It concluded that both photo-radar and speed display boards can be effective in reducing vehicle speeds. Photo-radar reduced mean speeds 5.8 miles per hour (mph) where baseline speeds averaged 34–35 mph in 25-mph zones. It is common for the public to react negatively to such devices. Issues such as privacy rights are of concern to opponents of photo enforcement devices (Milliken et al., 1998). State and Supreme Court decisions have found that driving on public roads is not protected under the 4th Amendment of the Constitution (Milliken et al., 1998). As noted above, another issue among the public is owner versus driver of the vehicle in violation. Since the person driving the vehicle may not be the owner, most jurisdictions rely on the owner to divulge the name of the driver of the vehicle. However, in most jurisdictions, if the owner refuses then the citation is issued to the owner.

One problem that may pose issues concerning photo radar devices is the increasing market of anti-photo radar devices. There are vehicle devices available to consumers which detect photo radar devices to provide advance warning for drivers. Likewise, there are products available which are much lower in cost than photo radar detectors, including license plate covers, or spray cans that contain materials which produce glare or result in distorted photos of a vehicle's license plate. These items result in photos where the license plate is not readable, making it impossible to impose a penalty. If automated speed enforcement devices are implemented by an agency, measures to deter use of such products should be taken; see Exhibit V-9 for further discussion of these and other related issues. The state of North Carolina has targeted these issues by approving a bill that prohibits drivers from driving with an obscured license plate (NCSL, 2004).

Strategy C3—Increase Penalties for Repeat and Excessive Speeding Offenders (T)

Drivers who repeatedly flout speeding laws are a significant contributor to overall safety risk. All drivers convicted of speed limit violations are subject to penalties as determined by state and local laws. State laws vary on policy concerning license suspension, increased fines, and possible jail time for repeat speeding offenders and excessive speeding offenders, but these are strategies that could possibly deter convicted speeders from speeding in the future.

EXHIBIT V-9
Strategy Attributes for Implementing Automated Speed Enforcement (T)

Attribute	Description
Technical Attributes	
Target	Low- and high-speed roads where observations of crash histories indicate speeding problems, or where other factors indicate special risks (e.g. school and work zones), are target areas for installation of automated speed enforcement devices. This strategy is appropriate for consideration in locations where resources for manual enforcement are limited, or where manual enforcement poses a safety or operational concern for officers and the traveling public.
Expected Effectiveness	Based on national studies where automated speed technology has been used, the devices have been effective in reducing travel speeds and improving safety. In most cases, the studies found that automated speed enforcement had a positive impact on reducing speeding. As mentioned previously, the IIHS reported that automated speed enforcement reduced average travel speeds by 14 percent at actively enforced sites in the District of Columbia. Automated speed enforcement devices can produce better long-term effects along a roadway than manual targeted enforcement. Studies have found that traditional enforcement has a short-lived deterrent effect on drivers, where stationary automated speed enforcement devices would be present all the time for a long-term effect (Milliken et al., 1998). A 2-year test of automated speed enforcement in residential and school zones in Beaverton and Portland, Oregon, illustrated that speed cameras resulted in a decrease in vehicles exceeding the speed limit in these areas. In Beaverton, 4 months after the cameras were installed, 39 percent fewer vehicles exceeded the posted speed limit by 5 mph, and the average speed decreased by 4.6 percent. In Portland, data collected during a 4-month period on streets that received intensive photo radar enforcement showed the percentage of vehicles exceeding the posted speed limit by more than 10 mph decreased by 27 percent, while the average speed dropped by 2 mph. This study is discussed further in Appendix 1. Studies reported from the FHWA Study Tour for Speed Management and Enforcement Technology in Europe indicate effectiveness for certain countries. These are summarized below: • **Netherlands:** Studies found that 95 percent of law enforcement officer patrolling hours facilitated issuing tickets to approximately 30 percent of speeders; whereas, photo radar devices identified and issued tickets to approximately 70 percent of speeders with only 5 percent of the total law enforcement officer hours devoted to this task. • **Germany:** Photo radar devices were placed on the autobahn with speed limit signs reading 100 km/h (62 mph). This had immediate impacts, as it reduced average speeds by 30 km/h (19 mph). Longer term effects resulted in average speed reductions of an additional 20 km/h (12 mph). Implementation of photo radar devices yielded a 91 percent reduction in accidents along the segment of autobahn where photo radar devices were installed. • **New South Wales, Australia:** A public information campaign providing information on the implementation of photo radar devices was administered via radio, television, and informational pamphlets. Photo radar devices were then installed at numerous sites, typically sites with a poor crash history. The installation of ASE devices proved beneficial, as a 22 percent reduction in high severity collisions was observed. As well, a decrease in excessive speeding (10-20 km/h) was observed.

EXHIBIT V-9 (Continued)
Strategy Attributes for Implementing Automated Speed Enforcement (T)

Attribute	Description
	• **Victoria, Australia:** Automated speed enforcement devices were implemented in 1989 in Victoria. Photo radar devices were placed in locations where there were complaints of excessive speeding and locations with a history of high-severity collisions. Photo radar devices were used in conjunction with law enforcement patrolling and public information campaigns. Studies on the ASE devices found that after 5 years vehicles exceeding the speed limit declined from 23 percent to 3 percent.
Keys to Success	To successfully implement the use of automated speed devices it is important first to identify locations where they would be of best use. Having local officials, such as law enforcement officers and city engineers, identify roadways with speeding problems and ascertain the involvement of speeding in crashes helps to determine if and where the devices would be of best use. The public should be informed of the installation of the devices, how they work, and when they are going to go into effect. Public information may begin before or after site selection. Photo radar devices are good solutions where traditional law enforcement cannot be deployed effectively, or in locations where traditional enforcement is unsafe (Milliken et al., 1998). *Special Report 254:* "Managing Speed, Review of Current Practice for Setting and Enforcing Speed Limits" indicates that the success of automated speed enforcement depends on the way it is introduced to the public. Not only is it important to indicate appropriate locations for the devices, but it is just as important to deploy devices where the public perceives that speeding is a problem (Milliken et al., 1998). This will help gain public support on the issue. Educating the public about automated speed enforcement devices in advance of installation will help reduce confusion, questions, and concerns that they may have. Media advertising on the radio and television are good ways to inform and educate the public on speed cameras and deter negative feedback. In order to do this, officials such as law enforcement officers and judicial officials should be educated about automated speed enforcement devices concerning how they work and how they should be enforced. Informing appropriate officials will help them prepare for any feedback, questions, or comments from the general public. To avoid confusion concerning citations, legislation should be passed which indicates that vehicle owners be responsible for the speeding violations, rather than identifying the driver of the vehicle (FHWA, 1995).
Potential Difficulties	One of the difficulties in implementing automated speed enforcement is gaining public acceptance of use of the devices. The public will likely not accept the implementation of ASE devices if they feel that the devices are used solely to generate revenue. This can be countered through law enforcement patrolling at locations of ASE devices and identifying safety benefits to the public. People may feel that their right to privacy is being violated, which causes an issue for many opponents. Another issue concerns ticketing vehicle owners. The owner of the vehicle is ticketed, even if he/she is not the driver during the time of citation. A photo radar program in Victoria, Australia successfully targeted this problem by requiring vehicle owners to be liable for the penalty unless they can identify the person driving the vehicle (Milliken et al., 1998). There is a possibility that officials may not embrace the idea, and want to avoid automated speed technology based on negative feedback from the public. Cost for the devices may be an issue at first; however, potential for long-term savings should be evaluated and explained to both the public and decision-makers. Photo-radar detecting devices and products that distort images of license plates are also an issue since they are available.

EXHIBIT V-9 (Continued)
Strategy Attributes for Implementing Automated Speed Enforcement (T)

Attribute	Description
Appropriate Measures and Data	Key process measures include the number of locations where automated speed enforcement devices are implemented. Additional data to observe include changes in overall average speeds and crashes. Crash history and severity of speeding-related crashes should be observed before and after the installation of automated enforcement devices, to see if there were any resulting safety benefits. ADT data should also be measured before and after the installment of automated speed enforcement devices, to see if there are fewer vehicles along routes with these devices. If this is the case, this could likely result in decreased crashes, due to less vehicles and exposure to collision (depending on the amount of vehicles avoiding the road due to enforcement devices). This should be noted to address alternate routes where traffic is diverting.
Associated Needs	Associated needs include educational/informational awareness of officials and the general public on the implementation of automated speed devices. Studies from Europe observed that photo radar reduced travel speeds more significantly when used in conjunction with signs identifying the devices. To assure the public that ASE devices are used as safety measures, as opposed to revenue generators, such signing can be used, as well as law enforcement officers stationed near the devices.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Traffic enforcement and judiciary agencies should review the location and proper installation of the device. Likewise, the performance of the device should be tested before it is used for official enforcement. Policy concerning citations from automated enforcement devices should be communicated to officers and judicial system staff to help ensure appropriate application of the strategy.
Issues Affecting Implementation Time	If legislation needs to be enacted to enable an agency to use ASE, implementation time could take 1 year or more. Determining an effective policy for handling citations and developing a program to assure the public that the cameras are to be used to improve safety rather than generate revenue could take several months or more. If agencies are already using cameras for red-light enforcement, some of this work may already be done. Actual installation of the equipment is a short-term process.
Costs Involved	There are several different costs associated with automated speed enforcement devices. Costs include the acquisition, deployment, operation, and routine maintenance of automated speed enforcement devices (Milliken et al., 1998). Public information campaigns and outreach programs will add to the costs of implementing this strategy. These costs can be outweighed by the revenue gained from the cameras, as well as the potential for reduced collisions along a road, which could result in decreased crash severity. Examples of photo radar law enforcement costs and equipment are provided in *NCHRP Report 500, Volume 12:* "A Guide for Reducing Collisions at Signalized Intersections." The costs identified are shown below.

Type of Speed Control	Per Deployment	Per Hour of Deployment	Per 12 Hour Day	Per Driver Exposed
Photo radar (law enforcement costs only)	$155.00	$8.42	$119.23	$0.39
Photo radar (law enforcement and equipment)	$220.36	$11.98	$169.51	$0.55

Source: TranSafety, Inc., (1998).

EXHIBIT V-9 (Continued)
Strategy Attributes for Implementing Automated Speed Enforcement (T)

Attribute	Description
Training and Other Personnel Needs	Training for law enforcement officers responsible for camera operation and issuing citations would be needed to ensure that they know how the devices work. Information to include in training would be where to set the devices, such as what type of roads, where to locate them along the road, and how to set them to take photos at the speed desired. It is also important to provide training on how to retrieve the photos and identify the speeds of violators.
Legislative Needs	Legislation may be necessary before installing automated speed enforcement devices, as described in *NCHRP Report 500, Volume 12:* "A Guide for Reducing Collisions at Signalized Intersections." Legislation is necessary to meet constitutional standards, state legal standards, state vehicle code standards, and local jurisdiction standards. Any states enabling legislation should address the broad constitutional state and federal issues. This should be done within a framework that includes elements such as definitions of acceptable automated speed enforcement devices, restrictions of use, detailed description of acceptable photographic evidence concerning the vehicle driver and vehicle owners, and penalty provisions. Local jurisdictions should provide detailed legislation concerning requirements on automated speed enforcement devices. These details should include information concerning operating criteria, agencies responsible for camera operation and maintenance, restrictions to ASE in that jurisdiction, and requirements for advance notification. As stated previously, legislation can be passed to improve enforcement of ASE devices. As studies in the Netherlands have found, in order to avoid confusion concerning citations, legislation should be passed which indicates that vehicle owners be responsible for the speeding violations, rather than identifying the driver of the vehicle (FHWA, 1995). A summary of state legislation on automated enforcement may be found at: http://www.iihs.org/laws/automated_enforcement.aspx. The National Conference of State Legislatures tracks status of automated enforcement legislation and provides examples of model legislation at: http://www.nhtsa.dot.gov/ncsl/Index.cfm.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with all others discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Many states have laws that support increased fines for repeat offenders of driving under the influence of drugs or alcohol. For example, the state of Ohio increases penalties for repeat DUI offenders, with minimum fines, maximum license suspension time, and minimum jail time increasing with each successive conviction (Ohio Insurance Institute, 2001). Eleven states currently have increased fines for repeat speeding offenders. An increased fine is given to a driver who is cited for a speeding violation within a set timeframe (typically 1 year) of the previous citation. For instance, the state of California fines the first offense a maximum of $100, the second offense within 1 year of the first is fined up to $200, and any

subsequent offense within 1 year of the first offense is fined up to $250 (NHTSA, 2001). Further, upon the second conviction of the offense of driving greater than 100 mph on a highway within 3 years of the prior offense the amount of the fine increases to $1,000 and 2 or more prior convictions within 5 years results in a fine of $1,500 (NCSL, 2006). Also, most states have a demerit point system, where each violation earns demerit points, based on the severity of the violation. These demerit points are given for all moving traffic violations. Once a driver reaches the point threshold their driver license is suspended or, if available, the driver is given the opportunity to attend traffic school.

Thirty-six states offer traffic school or driver improvement courses to repeat traffic law offenders. The use of these courses varies among those states. Some use it as a penalty, requiring a habitual traffic law violator whose license has been suspended to take the course prior to reinstating his or her driving privilege. Other states offer it as an alternative to license suspension or to reduce demerit points. However, most states that offer these alternatives limit their use to once per year (NHTSA, 2001). For a driver whose speeding convictions would put him/her at the point threshold for traffic school more than once in a given time period, driver license suspension or revocation may be a more prudent action. There is potential for such courses to act as a deterrent to drivers who do not wish to subject themselves to such a course. Also, these courses have the ability to educate those drivers who speed repeatedly and excessively, and inform them of the real dangers of speeding.

A common excessive speeding problem, especially among young adults in urban areas, is illegal street racing. Illegal street racing is a form of auto racing that takes place on the streets and freeways. Speeds in these street races can reach in excess of 200 mph. Law enforcement officers attempt to stop these races, but because of their frequency and the ability of racers to change locations easily, this is a difficult task. This is a specific speeding problem in many larger cities around the country. A program in San Diego has been developed to combat the issue of illegal street racing, by providing an alternative location. RaceLegal.com was formed in 1998 by a professor at the San Diego State University's Graduate School of Public Health. A coalition was initiated with a grant from the California Office of Traffic Safety. This grass roots coalition involved city/county government, law enforcement, Bureau of Automotive Repair, Superior Court, City Attorney, District Attorney, and county probation. In short this program provides safer and sanctioned track alternative races at San Diego's Qualcomm Stadium. Drivers even have the opportunity to race against law enforcement officers in these sanctioned races. This provides a positive forum for interaction with law enforcement. The officers use this opportunity to foster relationships with young people, and encourage them to drive with safety in mind, including persuading drivers not to street race, always use seatbelts, and to lead a sober lifestyle. This program also uses public awareness methods to maintain a high level of community awareness of the incidence of local illegal street racing, as well as other traffic safety issues, such as safety belt usage and DWI. The RaceLegal.com program has had great success in reducing illegal street racing tragedies. According to the program's website, from 2002 to 2005 there has been a 94 percent improvement in crash fatalities due to illegal street racing. For more information on the RaceLegal.com program see Appendix 2.

Increasing state fines/penalties for repeat offenders is a potential strategy that might deter drivers from committing repeat offenses. Likewise, state laws could impose license suspension and potential for jail time, depending on the extent of offenses committed. Increased fines and penalties potentially deter people from committing a first offense, and more importantly potentially deter people from speeding again. See Exhibit V-10 for more information.

EXHIBIT V-10
Strategy Attributes for Increased Penalties for Repeat and Excessive Speeding Offenders (T)

Attribute	Description
Technical Attributes	
Target	Those drivers showing a history of speeding violations and excessive speeding.
Expected Effectiveness	There is a lack of studies that indicate the effectiveness of increasing penalties for repeat and excessive offenders. Studies for repeat DUI offenders vary; however, several suggest that heightened fines/penalties have resulted in a lower frequency of repeat offenders. The general finding from programs directed toward multiple traffic law offenders is that the programs show some effectiveness in reducing violations; however, these programs do not have a significant impact on crashes.
Keys to Success	For this strategy to work, state laws would need to be implemented to support increasing fines for repeat offenders and excessive speeders. Keys to success here would include getting local officials and public figures active and in support of such laws and implementing them. It is important to inform the public that increasing fines is in response to speeding and the associated safety risks it poses. It should be noted that increased fines are not implemented to generate additional revenue. Highway safety professionals may need to provide outreach to judicial agencies regarding the importance of upholding the increased fines and other penalties for speeding convictions, in order for the more severe penalties to have a deterrent effect on drivers.
Potential Difficulties	Inconsistent enforcement or adjudicating is a potential difficulty. It is important to enforce the speed laws consistently to effectively deter future speeding violations. Drivers must understand that the threat of penalty is real and likely if they speed. This requires consistency on the part of law enforcement officers as well as the judges who prosecute speed law violators (Milliken et al., 1998). See Strategy C4 on how to strengthen adjudication of speeding citations to enhance the deterrent effect of fines.
Appropriate Measures and Data	Appropriate data would include the number of repeat and excessive speed offenders before and after the implementation of increasing fines. Also, details such as age, gender and travel speed should be noted to indicate any trends to address in the future. The effectiveness of this law cannot only be observed through the decreased amount of speeders, it is important to indicate past and current severity and frequency of speed-related crashes that involve excessive speeds or repeat offenders.
Associated Needs	Associated needs include educational/information awareness to officials and the general public on the implementation of increasing penalties for repeat and excessive speed offenders. As mentioned previously, it is important to inform the general public that such measures are taken to eliminate speeding related crashes, rather than to gain increased revenue from issuing higher cost speeding tickets.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	As mentioned above, outreach to court officials is an important part of ensuring the success of this strategy. Highway agencies may want to develop a program for attending judicial meetings and conferences, or hold meetings with participation by enforcement and court officials.
Issues Affecting Implementation Time	Should legislation be needed to be able to impose increased penalties, implementation time could take 1 year or more. Once legislation is established, public outreach efforts may be needed, but implementation efforts would likely be completed in a relatively short timeframe.

EXHIBIT V-10 (Continued)
Strategy Attributes for Increased Penalties for Repeat and Excessive Speeding Offenders (T)

Attribute	Description
Costs Involved	Implementation costs should be low, but could vary depending on the amount of coordination with legislators and courts, as well as public outreach, needed. It is anticipated that the costs in the long run will be outweighed by the savings, due to the potential decrease in the number and severity of speeding-related crashes. Additional revenue may result from this strategy; however, it should be noted that this is not the purpose for increasing speeding fines.
Training and Other Personnel Needs	No additional training or personnel would be needed for this strategy. Existing law enforcement officials would be able to enforce the new law without additional training.
Legislative Needs	State and local laws concerning increasing penalties for repeat and excessive speed offenders may be needed.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with all other enforcement strategies in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy C4—Strengthen the Adjudication of Speeding Citations to Enhance the Deterrent Effect of Fines (T)

Court systems play an important role in the enforcement process for traffic citations. When speeding citations are thrown out or penalties/fines are reduced, the court system is downplaying enforcement (Milliken et al., 1998). There must be an agreement between enforcement officials and judges on the circumstances for which speeding citations will be written and the penalties that will be imposed. Likewise, it is equally important for the judicial system to treat speeding violations consistently, which can be done by establishing and following sentencing guidelines (Milliken et al., 1998).

There are many publications such as books, guides, and websites that investigate loopholes in state and municipal laws enforcing speeding violations. As a result, there are drivers guilty of speeding who find ways to dodge fines or penalties. Adjudication to address such issues can deter a driver from speeding if he/she is aware of the law, its consequences, and the ability of the judicial system to support law enforcement. There are many instances where court judges reduce fines/penalties or drop them completely if they feel that penalties are too harsh for conditions as stated in the citation (Milliken et al., 1998). This reduces the incentive for law enforcement officials to enforce the limits, and in turn reduces the deterrent effect of speeding penalties. It is important that law enforcement officials and court judges come to an agreement on enforcing speed limits uniformly and remove inconsistencies in penalizing violators (Milliken et al., 1998).

Adjudication can be strengthened through judicial outreach programs. These can be elaborate nationwide programs, such as college training courses, or local/regional initiatives. There are a number of judicial outreach initiatives targeted towards judges who preside over, and

prosecutors who prosecute DWI cases. Similar programs targeted towards judges who preside over speeding-related cases can be helpful in strengthening the adjudication of speeding citations. The purpose of these outreach programs is to educate prosecutors and judges about the importance of consistent penalties for speeding. This can be done by initially providing crash and other traffic data to exhibit the severity of the problem and thus the importance of consistently upholding fines and penalties to maintain the deterrent effect of said penalties. NHTSA, in collaboration with the Bureau of Justice Assistance, has identified similar strategies for "reducing obstacles to obtaining impaired driving convictions and applying sanctions in a consistent manner" which highlights the importance of consistent adjudication (NHTSA, 2003). In NHTSA's Report to Congress on the FY 2003 Expenditure of Funds for Judges and Prosecutors, they also highlighted key training programs that justices could take part in to prepare them for presiding over DWI and other traffic safety-related cases. Specifically the National Judicial College, a national judicial education and training institution, offers traffic safety courses developed with NHTSA funding (NHTSA, 2003).

Judicial outreach programs and training courses are educational tools that can be used to strengthen the adjudication of speeding citations, which in turn is expected to enhance the deterrent effect of fines and penalties. See Exhibit V-11 for more information.

EXHIBIT V-11
Strategy Attributes for Strengthening the Adjudication of Speeding Citations to Enhance the Deterrent Effect of Fines (T)

Attribute	Description
Technical Attributes	
Target	State and municipal judicial agencies should be targeted for improving adjudication of speeding citations. Agencies where there are inconsistencies in adjudication of speeding violations should be targeted.
Expected Effectiveness	The expected effectiveness cannot be quantified as there are currently no studies on improving adjudication for speeding violations and effectiveness. It is expected that once speeding penalties have been imposed consistently and frequently, public awareness of the threat of receiving sanctions for speeding will increase, enhancing the deterrent effect of speeding penalties.
Keys to Success	This strategy would include inter-agency cooperation between local law enforcement, highway agencies and judicial agencies. Likewise, informing the public of improvements in adjudication will help to improve the deterrent effect of the penalties. Judicial outreach is one important key to the success of this strategy. This outreach would entail showing justices/courts crash data and other traffic information to demonstrate the extent of the speeding problem and the role they play in mitigating this problem. They must be made aware of the need to consistently handle speed limit violations. This consistency is important not only for the deterrent effect, but also to prevent any public perception that traffic regulations for speeding are arbitrary or capricious (Milliken et al., 1998).
Potential Difficulties	Establishing a working relationship between judicial agencies and enforcement and highway agencies may be difficult if it is not understood at the outset by all participants that the goal is to improve highway safety and reduce fatalities, and that every organization has a part in this, rather than a situation in which courts feel the law enforcement and transportation departments are telling them how to do their job.

EXHIBIT V-11 (Continued)
Strategy Attributes for Strengthening the Adjudication of Speeding Citations to Improve the Deterrent Effect of Fines (T)

Attribute	Description
Appropriate Measures and Data	Appropriate data would include the number of persons caught violating posted speed limits before and after the implementation of improved adjudication. The effectiveness of such improvement cannot be quantified. However, there is a possibility that effectiveness can be observed through the number of speeding citations issued and the number of drivers who are found guilty of violations, as opposed to the number of drivers who are found not guilty of violations in the judicial process.
Associated Needs	The needs associated with this strategy include cooperation between judicial and law enforcement agencies.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Judicial agencies should review their speeding adjudication policies to ensure that speeding violators be properly fined based on their citation. Any judicial agency can participate in implementing this strategy, which is applicable to all areas (e.g. rural, urban, and suburban), particularly targeting high-speed arterials.
Issues Affecting Implementation Time	Implementation time is low for improving adjudication. Review of current adjudication, identifying areas for improvement, and implementing adjudication improvements is required, but would be expected to be able to be completed within several months.
Costs Involved	Costs for improving adjudication should be low. The main cost is getting professionals from judicial and enforcement agencies to implement new strategies for improving speeding adjudication. Educational or training costs may be necessary for those justices who choose to take educational training courses.
Training and Other Personnel Needs	Training for judges on sentencing guidelines for speeding penalties/fines is recommended to ensure that violations be treated on a consistent level.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with all other enforcement strategies in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy C5—Increase Fines in Special Areas (T)

General Description

Traffic violations in places like residential areas, work zones, and schools present a dangerous condition for both the roadway users traveling through these places and also to the workers, children and pedestrians within that area. Often violations, such as speeding or failure to obey flagger signals, are a factor in crashes in many of these places.

One method for reducing violations of traffic laws is to enforce laws and make fines significant enough to be a deterrent, and to encourage the judiciary to apply them consistently. Improving

the application of increased fines through more frequent visible enforcement activities will help change driver perception about the likelihood of being cited for violations. In addition to the possibility of being cited a large fine, the driver needs to have the perception that the fine will be large and the sanction will be upheld by the courts. Otherwise, the sanction will be reduced to the inconvenience of the court visit.

Forty-five states currently impose increased penalties for speed violations in work zones, and in some states those increased fines apply to all types of violations. Studies show that many drivers continue to violate the work zone speed limits in spite of these increased fines. Using a consistent approach to enforcing work zone traffic laws and adjudicating citations is a way to curb this trend. This will require seeking the cooperation of the judiciary. It can be facilitated by encouraging a partnership and making sure that judges understand the importance of this strategy for saving lives. More information on this strategy, with respect to use in work zones, is discussed in greater detail in *NCHRP Report 500, Volume 17* (Work Zones) of this series.

Doubling the fines in school zones may be one of the ways to improve compliance of speed limits in those areas. Signs may be posted around the school showing the message that speeding fines will be doubled. Public information campaigns may also be conducted to educate people about the penalty of speeding in school zones. Without proper enforcement, long-term effects may not be seen. More frequent enforcement activity may change drivers' perceptions and adherence to speed limits. Washington State enacted a state legislation in 1996 doubling the fines for speeding in school crosswalk and playground zones after a survey showed that 50 percent of drivers were not complying with reduced school zone limits and also speeds in excess of 50 mph were observed during the survey. One-half of the amount collected through doubling the fines was used for improving school zone safety like installation of signs, replacing existing school zone crossing signs with new fluorescent yellow-green signage. Similar strategies can be applied in problem locations in residential areas, hospitals and places with large elderly populations and numbers of pedestrians.

Objective D—Communicate Appropriate Speeds through Use of Traffic Control Devices

Traffic control devices are the primary means through which drivers are made aware of traffic laws. The most basic device is the speed limit sign, informing drivers of the maximum allowable safe travel speed, under any conditions. Variable message signs (VMS) provide more personalized, current information. Active speed warning signs display current travel speeds to drivers, and are intended to deter drivers from speeding and make them aware of the appropriate speed. In-pavement techniques can also be applied to the actual roadway to encourage safer speeds. The placement, visibility, and maintenance of all traffic control devices are important features in effectively communicating speed limits clearly. Poorly placed devices can have a negative effect on safety, and increase the chances of speeding-related collisions.

Strategy D1—Improve Speed Limit Signage (T)

The placement, visibility, and maintenance of speed limit signs are important features in effectively communicating speed limits clearly. A speed limit sign that has been misplaced, has low visibility, or is not properly maintained can result in ineffective communication of speed limits, which consequently can fail to encourage drivers to obey the speed limit. This can in turn have a negative effect on safety, and increase the chances of speeding-related collisions.

Location and frequency of speed limit signs are two key elements to properly communicating the speed limit. Speed limit signs need to be consistently placed at the proper locations (for example, following major intersections), which will reinforce a driver's expectation of when to look for a speed limit sign. This is especially important if there is to be a change in the speed limit from one section of the roadway to the next.

If a speed limit change occurs at a location where a driver may not be expecting one, then adding speed reduction signs should be considered. Along extended stretches of roadway where there are no changes in the speed limit, additional signing is still important as a reminder to drivers and also to inform drivers that may have entered the roadway at a minor intersection.

In Minnesota, "Reduced Speed Ahead" signs are used to give advance notice of reduced speed limits when the reduction is 15 mph or more. In urban areas, where speed reductions to 55 mph or less are required, speed reductions signs are to be erected on both sides of the roadway. This is to be followed by supplemental speed limit signs mounted on both sides of the roadways through the reduced speed zone. Supplemental speed limit signs, through all reduced speed zones, should be placed at intervals approximately equal to 60 seconds of travel time at the posted speed limit. Signs may need to be spaced closer in urban areas due to the increased number of access points. Minnesota sets 10 miles as the maximum spacing between speed limit signs in rural areas. In urban areas a speed limit sign should be placed at each interchange for traffic entering the mainline (Minnesota DOT, 2004).

As with placement, the driver's ability to see the sign is highly important if the driver is expected to obey the speed limit. Two factors that may affect the visibility include the mounting details (i.e., Is the sign properly mounted so that it is in a driver's field of vision?) and letter/border size (i.e., Was the appropriate letter and border size chosen for the speed limit such that a driver can easily read the sign?). For more information regarding the proper mounting and sizing of speed limit signs, refer to the current MUTCD.

Often overlooked, the context of the environment around a sign can impact its visibility. In urban areas where traffic signs and commercial signs may be abundant, a driver may need additional assistance with locating the speed limit signs. This assistance may take on different forms, but possibilities include using larger signs and removing or relocating unnecessary signs.

The issue of maintenance is an important factor in a sign's visibility. Poor maintenance can result in reduced visibility through many forms, including tree and shrub growth, vandalism, and reduction of the sign's retro reflectivity. See Exhibit V-12 for more information about improving speed limit signage.

Strategy D2—Implement Active Speed Warning Signs (Including Truck Rollover Warnings) at High Risk Locations Where Excessive Speeds and Potential Conflicts Are Expected (T)

Active speed warning signs, also known as radar speed displays, speed display signs or speed trailers, are similar to variable message signs (VMS), except they have radar technology that determines the traveling speed of vehicles. Active speed warning signs are intended to deter drivers from speeding and improve awareness that they need to obey the posted speed limit. Travel speeds are detected and then displayed on the message board.

EXHIBIT V-12
Strategy Attributes for Improving Speed Limit Signage (T)

Attribute	Description
Technical Attributes	
Target	This strategy is targeted at providing improved signing to communicate speed limits clearly and effectively, especially to drivers that are unknowingly speeding. The proper sign type, location, and routine inspection and maintenance of signs can deter speeding and facilitate enforcement by effectively communicating the proper speed limit to drivers. All agencies can implement this strategy. This strategy may be especially important where there is a higher percentage of older drivers, or the visibility of signs is often obscured by adverse weather, such as drifting snow.
Expected Effectiveness	There is a lack of studies evaluating the effect of proper signage and routine maintenance on preventing speeding; however, the general principle is that there is a higher likelihood that speed limits may be exceeded if drivers are unaware of the actual speed limit. Furthermore, clear and unambiguous communication of the speed limit to drivers is an important role of effective enforcement and prosecution of speeders, especially if law enforcement and the courts are to view speeding as a significant and preventable safety risk.
Keys to Success	The consistent and correct placement of speed limit signs is the first step towards effective communication. Further, selecting the proper design standards (i.e., lettering size) for the roadway is a fundamental requirement. Following deployment, the upkeep of speed limit signs is necessary, especially if minimum retro reflectivity levels are adopted by the highway agency. A GIS-based road sign inventory with links to maintenance records is one possible tool that can be used to track and manage sign maintenance activities and needs. Another key to the success of speed limit sign improvements is that the posted speed limit is reflecting an appropriate speed limit for the roadway. See Strategy A1 for setting appropriate speed limits.
Potential Difficulties	The biggest difficulties associated with this strategy are maintaining a sign inventory and routine inspection and maintenance of signs. This is especially difficult in urban areas where there are many signs on the roads. Likewise, this can be a difficult task for rural areas, where highway mileage with associated signage is high. Lack of personnel to take inventory and provide maintenance and repairs to correct signs can also be a potential difficulty for agencies that are understaffed for such duties.
Appropriate Measures and Data	Key process measures include the number of locations where poor signage was replaced, and the related effect it had on speeding vehicles. Additional data might include identifying locations with improved signage and using this to compare to locations with undesirable signage. Observing any negative effects that the adverse signs have on safety and speeding may provide beneficial results in identifying the effects of improved signage on speeding.
Associated Needs	None identified.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should review any policy concerning signage requirements to ensure that they meet the current MUTCD guidelines. Agreement among neighboring jurisdictions as to the policy, sign requirements (placement, letter height, etc.), routine inspection, and maintenance should be coordinated to ensure uniformity.

EXHIBIT V-12 (Continued)
Strategy Attributes for Improving Speed Limit Signage (T)

Attribute	Description
Issues Affecting Implementation Time	Implementation time for this strategy is short to moderate. Taking inventory of speed limit signage can be time-consuming, depending on the size of the municipality or jurisdiction. Once the inventory is taken, routine inspection should be geared to those signs identified as priority for improvements.
Costs Involved	This strategy should have a low implementation cost. Costs with this strategy include personnel to take inventory, inspect, and provide maintenance to signs. Other costs include the acquisition and installation of new signs. Development of a sign inventory system would increase costs.
Training and Other Personnel Needs	Additional personnel might be needed for jurisdictions where there is not adequate staffing to take on duties related to sign design, erection, and maintenance. Staff should also be properly trained to ensure consistent and effective signing practices.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with and oftentimes necessary for enforcement, education, and engineering strategies to be effective. Effective speed limit signing is an important issue when informing drivers of reduced speed zones (Strategy E2).
Other Key Attributes to a Particular Strategy	None identified.

Depending on the type of speed sign, some are capable of displaying additional text, such as "Slow," or they completely blank out when vehicles are driving at excessive speeds. This blank-out feature is intended to discourage drivers from speeding excessively to test the capabilities of the sign or their own driving audacity.

Active speed warning signs are similar to variable message boards and photo radar devices. They are different from automated speed enforcement devices in that they do not take photos and are not used for enforcement purposes. These signs differ from variable message boards as they have the radar technology to detect actual vehicle speeds. Speed warning signs can be used permanently at a location, or mounted on trailers and moved to different locations for temporary use.

Speed warning signs can be used permanently at a location, or mounted on trailers and moved to different locations for temporary use. One type of permanently mounted sign, used by King County in Washington, features a 12-inch high fluorescent yellow-green readout and is the same overall size and style as the existing speed limit sign. They are placed directly below the existing speed limit sign on the same post. These signs are ideal for neighborhoods as they are relatively small and do not stand out visually as much as a portable trailer would.

A study of the effectiveness of speed warning signs on speeding (for a roadway with a 25 mph posted speed limit) was reported by TranSafety, Inc., in May 1998, in the publication, *Road Injury Prevention and Litigation Journal*. Conclusions from this report are based on the study,

A Comparative Study of the Speed Reduction Effects of Photo-Radar and Speed Display Boards (Bloch, 1998). The use of a speed warning sign reduced the mean speed by 5.8 mph at the experimental site but had little effect 0.2 miles downstream (a 2.9 mph reduction in mean speeds). A speed warning sign used in conjunction with intermittent enforcement resulted in a 6.1 mph mean speed reduction at the experimental site and a 5.9 mph reduction in the mean speed downstream of the display.

The study found that speed warning signs were the major contributing factor in reducing the number of vehicles traveling at "excessive" speeds (i.e., at least 10 mph above the posted speed limit) by 34.9 percent (Bloch, 1998). The study also found that when used in conjunction with intermittent enforcement, speed display boards reduced the number of vehicles at "excessive" speeds by 31.8 percent (Bloch, 1998).

Speed display signs can be used as a deterrent to speeding, which may result in decreased speed-related crashes. Studies have found that these signs effectively contribute to decreased travel speeds while in place, with mixed long-term results. In combination with enforcement and other technology such as photo radar devices, speed display signs could have a greater potential to reduce speeding.

The technology for detecting vehicle speeds and providing a real-time warning to drivers can be applied to locations where there is a potential for heavy vehicle rollovers, such as a sharp curve. In addition to speed, warning systems may need to collect other information such as vehicle height and weight to determine the potential of a rollover crash. For information specific to the issue of speed warning signs as part of an interactive truck rollover warning system, refer to Strategy 12.1 E2 in *NCHRP Report 500, Volume 13:* "A Guide for Reducing Collisions Involving Heavy Trucks."

As in other community-wide solutions, such as traffic calming, highway and/or enforcement agency staff should host a neighborhood meeting to discuss the existing condition with interested parties and identify possible solutions. If active speed warning signs are the preferred mitigation method, an on-site investigation should be conducted to determine a physical range along the roadway where the signs would best meet the needs of the traveling public. See Exhibit V-13 for further discussion.

EXHIBIT V-13
Strategy Attributes for Implementing Active Speed Warning Signs at High Risk Locations Where Excessive Speeds and Potential Conflicts are Expected (T)

Attribute	Description
Technical Attributes	
Target	The target of this strategy is drivers who are willing to change their behavior when given information on their actual travel speeds, and has the added advantage of letting drivers know their speed is being monitored. Speed warning signs can be used in locations where speeding has been observed or may pose a safety risk (i.e., prior to a sharp horizontal curve, school zone, roadway section with a lower speed limit, and any location with a history of speed-related crashes). This strategy can also be used in cooperation with law enforcement efforts or as a substitute for enforcement at locations that cannot be adequately patrolled due to a lack of personnel.

EXHIBIT V-13 (Continued)
Strategy Attributes for Implementing Active Speed Warning Signs at High Risk Locations Where Excessive Speeds and Potential Conflicts are Expected (T)

Attribute	Description
Expected Effectiveness	Studies on speed warning signs have found the technology to be effective at reducing vehicle speeds while the signs are in place, especially for vehicles that are 10 mph or more above the posted speed limit (see discussion in the strategy introduction). Significant speed reductions were not sustained after the devices were removed. However, it was noted that one long-term, statistically significant effect occurred with the unenforced speed display board: a 1.7-mph decrease in speed continued at an experimental site after the display board was removed. Meyer (2000) noted that changeable message signs are unlikely to be able to reduce speeds by 10 mph or more in *A Literature Review of Perceptual Countermeasures to Speeding*.
Keys to Success	A key to the success of this strategy is identifying the locations that will have the greatest benefit from active speed warning signs (whether permanent or temporary). Locations should have a history of speeding and/or speed-related collisions. Observations from concerned citizens and law enforcement officials are often good sources for this information. Selected locations will likely have the greatest potential for success if both highway agencies and law enforcement agencies are involved in the process of determining locations to deploy the signs. Another important key to success is educating the public on the need for and benefits from speed warning signs in order to gain their acceptance. Likewise, it is important for local agencies, such as law enforcement and highway agencies to initially accept the need for speed warning signs.
Potential Difficulties	The public may initially be resistant to speed display signs, especially those accompanied with photo-radar or traditional enforcement. Because of the possibility for negative opinion, public outreach is needed early in the process so that the public understands the reasons for using the signs. It is especially important to inform drivers of where speed display signs are used in conjunction with enforcement.
Appropriate Measures and Data	A key process measure is the number of road segments where active speed warning signs are installed. A more detailed measure includes observing any changes in the number of speeding vehicles and in the speed profiles. When used in conjunction with photo-radar enforcement, data concerning the number of citations issued should be collected. Changes in the crash history and severity of speed-related collisions are good indicators of safety effectiveness. Data on speed-related crashes at locations of the speed displays should be collected before and after the installation of the signs. It is also important to monitor the long-term performance of the speed display sign to ensure that it remains effective.
Associated Needs	Informing the public on the use of speed displays is important. Informational materials should include: • Local issues with speeding • Safety advantages to using active speed warning signs • General locations where active speed warning signs are used

EXHIBIT V-13 (Continued)
Strategy Attributes for Implementing Active Speed Warning Signs at High Risk Locations Where Excessive Speeds and Potential Conflicts are Expected (T)

Attribute	Description
	• Whether speed warning signs are used in conjunction with photo-radar or traditional enforcement (if so, use of revenue from automated enforcement) Conveying this information to the public may help extend the period of effectiveness of the signs.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway and law enforcement agencies need to develop or review policy regarding the deployment of speed display signs, especially how the agencies will respond to a neighborhood's request to address a speed problem (perceived or actual). In the situation where the request is being made by the public, policies should also address which type of display will be used (permanent or temporary), how long temporary displays will be used at the location, and what actions an agency may take if the sign displays prove not to be effective at a particular location. Agencies should also consider developing guidelines and criteria to help in the identification of locations where speed display signs (with or without enforcement) would be warranted.
Issues Affecting Implementation Time	Implementation time for active speed warning signs can typically be performed in less than 1 year (especially for portable signs), but can vary depending on the level of public involvement, acquisition of signs, and additional personnel or studies needed.
Costs Involved	Costs will vary, but are expected to be low. The main costs are those which include data collection for prioritizing locations, acquisition, installation (does not apply to portable signs which can be placed in locations temporarily via truck and trailer), and maintenance. The acquisition and installation cost of permanent active speed warning signs is much higher compared to mobile ones.
Training and Other Personnel Needs	No significant training or increases in personnel should be needed for the installation, operation and maintenance of a speed warning sign.
Legislative Needs	Local legislation might cover requirements that address local needs for active speed warning signs such as operating criteria, agency responsible for operation and maintenance of signs, and restrictive uses (such as using in conjunction with photo-radar enforcement).
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with the others discussed in this guide. This strategy relies on the similar technology discussed in Strategy C2 (automated speed enforcement); therefore, these two strategies can be used in conjunction.
Other Key Attributes to a Particular Strategy	None identified.

Strategy D3—Use In-Pavement Measures to Communicate the Need to Reduce Speeds (T)

This strategy relies on the use of perceptual and in-pavement techniques to encourage drivers to proceed at a safe travel speed. This strategy can be applied along a roadway segment as well as at locations such as intersection approaches, work zones, toll plazas, ramps, and so on.

Perceptual Pavement Markings

Perceptual pavement markings give the driver the illusion of traveling faster than his or her actual speed in order to decrease the driver's comfort at excessive speeds. At locations where drivers are expected to reduce their speed, such as the beginning of a school zone, approach to an intersection, entrance to a residential neighborhood, or prior to a sharp horizontal curve, a converging pattern of pavement markings can be used to give the perception to the drivers that they are increasing their speed if they fail to slow down at a sufficient rate. Pavement markings can also be used for other perceptual applications, such as to give the illusion of lane narrowing. This method is intended to reduce a driver's comfort at an excessive speed while proceeding through the markings, as a way to encourage deceleration. This type of treatment has potential applications along the entire length of a corridor.

Perceptual pavement markings are good candidates for roads where speeding is known to play a role in either crash frequency or severity. Furthermore, perceptual techniques are expected to reduce travel speeds without the need for increased enforcement, and should be able to affect driver behavior regardless of whether a driver is intentionally or unintentionally speeding. Perceptual pavement markings can also encourage drivers to decelerate at an appropriate rate on the approach to an area with a reduced speed limit (i.e., school or work zone or intersection).

Perceptual pavement markings have several advantages over traditional speeding countermeasures. First, the cost of applying perceptual pavement markings is very low; however, the pavement markings must be routinely maintained in order to prevent a decrease in their visibility. Second, perceptual techniques are also very flexible since they can be used to target speeding specifically in high-risk areas, or for the whole length of a corridor. Finally, this strategy can be used for areas where law enforcement is not readily available, or can be used in conjunction with law enforcement for increased speed reductions.

Source: Katz, 2004

There are several different types of perceptual techniques. The following are examples of different perceptual pavement techniques that have been in use.

- **Transverse Lines:** Transverse pavement markings are dashed lines that span the width of a travel lane. These pavement markings can be used to create the illusion that lane widths are

decreasing or narrowing, an effect that is perceived when the driver is traveling at higher speeds. A study in Kansas found that using these pavement markings at work zones decreased speeds and reduced the variation in speeds, though the speed reductions were fairly small (Meyer, 2001).

- **Peripheral Transverse Lines:** Peripheral transverse lines are the same as the transverse lines discussed above but they are used at the edges of travel lanes rather than across the entire lane. A study, as cited in Katz's report *Pavement Markings for Speed Reduction,* found that peripheral transverse lines performed the same, and in some occasions better than, full-length transverse lines. Full-length transverse lines tend to decrease vehicle speeds upon entering the zone with transverse lines; however, vehicle speeds tend to rise again after time.
- **Converging Chevrons:** Chevrons can also be used in a converging pattern. This pattern is characterized by a series of chevrons on the pavement surface that are placed progressively closer together. The first chevrons encountered by a driver passing through the pattern are widely spaced; those later in the pattern are closer together. The intent of this pattern is to create the illusion that drivers are traveling faster than they really are and to foster the impression that the traffic lanes are narrowing. These are sometimes accompanied by a dashed edge line. This edge line may promote the perception in drivers that the traffic lane is narrower than it really is. This perception can encourage a driver to reduce his/her speed (Griffin and Reinhardt, 1995).

Source: Katz, 2004

Speed reduction can be further enhanced when these perceptual pavement techniques are combined with other in-pavement measures like rumble strips—discussed later in this strategy.

The *Manual on Uniform Traffic Control Devices* (2003) provides guidelines on the use of pavement markings as well as details concerning standard colors, dimensions, and placement.

Additional information can be found on the use of perceptual pavement markings in the discussion for Strategy 15.1 A4 in *NCHRP Report 500, Volume 6:* "A Guide for Addressing Run-Off-Road Collisions."

Rumble Strips

In addition to perceptual pavement marking techniques, in-pavement strategies, such as rumble strips, can be deployed as a means to reduce vehicle speeds and/or prevent crash types where speeding may play a significant role, like a lane departure crash, or a transition from a high-speed zone to a low-speed zone. Rumble strips can also be used as a traffic calming tool in high pedestrian areas, such as neighborhoods and school zones.

Rumble strips are grooves installed in the road surface intended to draw drivers' attention to the roadway environment—either that the vehicle is drifting out of the travel lane, or that

there is a situation ahead that requires more attention or deceleration. When a vehicle travels over a rumble strip, the driver is warned through the vehicle vibrations and the noise it produces.

There are three types of rumble strip applications.

- **Continuous Shoulder Rumble Strips:** This is the most common type of rumble strip that is typically applied to the shoulder of high-speed roads. These aim to prevent run-off-road accidents. The primary use of this type of rumble strip for speeding-related crashes is not to reduce vehicle speeds, but is instead to provide an additional warning to drivers leaving the roadway, especially those that are speeding.
- **Centerline Rumble Strips:** These are applied to the centerline of high-speed roads. Centerline rumble strips aim to prevent median crossing or head-on collisions. Again, this application's primary intent is not to reduce speeding (although they may provide the illusion of lane narrowing, which may slow drivers), but is instead to warn drivers they are crossing the centerline.
- **Transverse Rumble Strips:** These are used at intersection approaches, toll plazas, work zones, ramps, and extreme curves. The warning provided by the transverse rumble strips should help drivers recognize that they need to slow down, possibly even come to a complete stop depending on the situation.

For more information, see FHWA Research and Technology's *Priorities, Market-Ready Technologies and Innovations, Rumble Strips* at http://www.fhwa.dot.gov/rnt4u/ti/rumblestrips.htm.

Rumble strips are commonly applied on the side of rural roads to deter vehicles from leaving the traveled way, and are increasingly used at the centerline of high speed roads. On low speed roadways, transverse rumble strips are used to alert drivers of a speed zone transition. On a state highway, speed reduction will typically occur in a transition from rural to downtown conditions. Transverse rumble strips can be used on approaches to a main street where a speed reduction is desired and where speed limit or warning signs are already in place. They are used to target drivers that are inattentive, drowsy/fatigued, careless, or distracted (FHWA Research and Technology). Rumble strips are also safety measures during adverse weather conditions. Fog, snow, rain and related weather events can reduce the visibility of pavement markings and road signs (FHWA Research and Technology). Rumble strips have the advantage in these types of conditions of not relying on visibility to be effective; however, some states paint rumble strips to increase their visibility during favorable conditions (FHWA Research and Technology).

Intersections, work and school zones, neighborhoods, toll plazas, and freeway ramps are all locations that are vulnerable to speeding-related collisions and pose risks to drivers, workers, or pedestrians. Rumble strips are low-cost measures that can be taken to prevent collisions at these locations, by providing warning and increasing awareness of changes in the road environment to drivers.

NCHRP Report 500, Volume 6: "A Guide for Addressing Run-Off-Road Collisions" provides supplemental information on the application of shoulder rumble strips to decrease run-off-road collisions, while *NCHRP Report 500, Volume 4:* "A Guide for Addressing Head-On Collisions" provides a review of centerline rumble strips to prevent head-on crashes. Both

of these strategies are again reviewed in *NCHRP Report 500, Volume 7:* "A Guide for Reducing Collisions on Horizontal Curves." The use of transverse rumble strips was also reviewed in depth in *NCHRP Report 500, Volume 5:* "A Guide for Addressing Unsignalized Intersection Collisions." For additional information on the application and issues for rumble strips, refer to the mentioned guides.

Traffic operation personnel should consider rumble strips that are compatible with motorcycle and bicycle use. An abrupt rise in the roadway can present problems to bicyclists and motorcyclists. For this reason, there should be provisions made for cyclists to safely traverse through or around raised rumble strips. See Exhibit V-14 for more detail on this issue.

EXHIBIT V-14
Strategy Attributes for Using In-Pavement Measures to Communicate the Need to Reduce Speeds (T)

Attribute	Description
Technical Attributes	
Target	The perceptual pavement markings and transverse rumble strips are intended to give drivers a warning when entering a high-risk area at a potentially unsafe speed. Perceptual pavement markings can help a driver select a safe speed while transverse rumble strips are a warning that the driver is approaching a situation that requires more attention. Shoulder and centerline rumble strips are not intended as a speed reduction strategy, but instead will provide drivers with a warning when crossing the centerline or leaving the roadway, which are crash types in which speeding may play an important role. These strategies can be deployed on the approach to high-risk areas, such as sharp horizontal curves, intersections, school zones, work zones, neighborhoods, speed zone transitions and toll plazas, or can be deployed continuously along a high-speed corridor (such as freeway facilities and arterial highways).
Expected Effectiveness	It is expected that perceptual pavement marking techniques can reduce speeding and have the potential to reduce collisions. There are several studies on the effectiveness of perceptual pavement techniques that indicate successful applications in reducing vehicle speeds. Katz (2004a) reviewed the effects of perceptual techniques in the study, "Perceptual Pavement Marking Techniques as a Low-Cost Safety Improvement to Reducing Vehicle Speeds" at the 2004 Annual Meeting and Exhibit of the Institute of Transportation Engineers. His study indicated that perceptual techniques can provide results beneficial to safety and can also reduce speeding. Results from a study in Kansas indicated that optical speed bars cause reductions in mean speed, 85th percentile speed and speed variation (Meyer, 2001). A different study indicated that perceptual markings effectively decreased travel speeds where there was a high frequency crash history at a sharp curve in Kentucky (Agent, 1980). A study in Wisconsin found that chevron pavement markings that were placed at the exit ramp of a freeway reduced travel speeds by up to 17 mph after 20 months of installation (Drakopoulos & Vergou, 2003). However, the perceptual pavement markings have not always demonstrated the ability to reduce speeds over the long term. Furthermore, questions have been raised if the decrease in travel speeds was due to the speed illusion or simply because the drivers recognized the presence of pavement markings as a warning of a hazardous location (*NCHRP Report 500, Volume 6*).

EXHIBIT V-14 (Continued)
Strategy Attributes for Using In-Pavement Measures to Communicate the Need to Reduce Speeds (T)

Attribute	Description
	Perceptual techniques such as widening centerline markings (to provide the illusion of a narrower travel lane) and their effects have been studied in Europe. A study in the Netherlands found that applications along roads with posted speed limits of 80 kph (50 mph) produced speed reductions of 5 to 10 kph (3 to 6 mph). During this study a 36 percent reduction in crashes was observed for the roads where the application was used on a trial basis, while the control roads experienced an increase in crashes of 17 percent (FHWA, 1995). It can be expected that these speed reductions can be somewhat less on lower speed roads, depending on the severity of the speeding problem. Also, it should be considered that various pavement marking patterns may show relatively little effect on vehicle speeds but still serve to reduce the probability of traffic crashes. This is to say, even if perceptual pavement marking patterns do not dramatically reduce vehicle speeds, they may alert or rouse the driver into a heightened sense of awareness in which they are better prepared to avoid a crash (Griffin and Reinhardt, 1995). There are numerous studies that indicate the beneficial safety effects of the application of rumble strips in reducing run-off-road and head-on crashes. The FHWA has sponsored several studies that indicate rumble strips can reduce run-off-road collision by 20 to 50 percent (*NCHRP Report 500, Volume 6*). While there are many studies that indicate the safety benefits of shoulder rumble strips, there are also benefits to the application of transverse rumble strips. Portable rumble strips in rural work zones were found to have a positive impact on safety. Results from this study found that the average travel speed of passenger vehicles was reduced by 2 mph and the number of cars exceeding the speed limit decreased by up to 7 percent (Fontaine and Carlson, 2001). The same study found that rumble strips had a bigger impact on reducing average speeds of trucks, by up to 7 mph (Fontaine and Carlson, 2001). The Minnesota DOT reports that rumble strips have been used in work zones since the 1950's (Corkle, Marti, and Montebello, 2001). The study indicates that rumble strips in construction zones are typically used in conjunction with warning signs, flagging, and barricades. These devices likely add to the effectiveness of rumble strips.
Keys to Success	A key to the success of this strategy is identifying and prioritizing locations that can benefit from perceptual pavement markings, rumble strips or other in-pavement strategies. Identification of roadways for this application includes those where enforcement is not available, speeding is a problem at high speed limits, and there is a history of speed-related collisions. Provided that the use of transverse rumble strips is as effective as studies indicate, states should install them at locations as suggested. Further proof of effectiveness, through observing nationwide studies, is important prior to future installation of transverse rumble strips at intersections, school and work zones, neighborhoods, ramps, and toll plaza locations. A key to success for installation of transverse rumble strips is identifying locations where they would be most effective. In order to identify and prioritize these locations, it is important to look at crash history and severity, as well as travel speeds.

EXHIBIT V-14 (Continued)
Strategy Attributes for Using In-Pavement Measures to Communicate the Need to Reduce Speeds (T)

Attribute	Description
	Another key to success for the implementation of transverse rumble strips is using them properly and in conjunction with other safety measures. For example, rumble strips can be more effective when used with proper flagging and signage in work zones.
Potential Difficulties	The biggest issue for perceptual pavement markings is identifying locations where perceptual pavement techniques should be applied. Also, careful consideration needs to be given to the design of the pavement markings, especially converging patterns, in order to produce the desired effect and be consistent with requirements and guidelines in the MUTCD. Incompatibilities and issues may exist between rumble strips and certain motor bikes and bicycles. It is possible for cyclists to lose control while traveling over rumble strips (e.g. wheel catching in rumble strip). It is recommended by the FHWA in *Technical Advisory on Roadway Shoulder Rumble Strips* that they not be used in locations where there are bicycle paths or a high number of cyclists (FHWA, 2001). This is an issue since the transportation community encourages the use of bicycles. This strategy, therefore, targets toll plazas and freeway ramps, which are locations where bicycling is prohibited. Another possible issue with rumble strips is that they can produce additional risk. It has been found that it is common for drivers to merge into opposing lanes or swerve abruptly to avoid the rumble strips. This poses alarming risks to safety by providing exposure to head-on collisions or severely injuring workers at toll plazas or in work zones, or putting pedestrians and bicyclists at risk in downtown and residential areas. There are issues regarding adverse weather and rumble strips. Rumble strips can be ineffective when ice or snow builds up in them. Likewise, snow removal is difficult with conventional plows as they cannot pick up snow packed in the grooves of rumble strips. Rumble strips also can be a noise nuisance when placed in close proximity to residential areas. This may not be a well accepted alternative by residents. Public involvement must take place before rumble trips are installed in a residential area.
Appropriate Measures and Data	One key process measure is the number of corridors and locations where perceptual pavement markings and other in-pavement countermeasures have been applied. Identifying average travel speeds and crash history before and after the installation of the countermeasure can be used to determine the overall effect. Road characteristics should be noted, to indicate areas where this strategy might be more useful or at locations where it is not as successful, for the use of future applications. Other appropriate measures include gathering information and feedback from the public. For example, it is important to listen to concerns from the public on issues with rumble strips such as noise or use with bicycles.
Associated Needs	Information campaigns may be needed to inform the public of the purpose of the markings prior to the installation of pavement markings. As identified in *NCHRP Report 500, Volume 6,* there have been reports of persons mistaking the noise produced from rumble strips as car problems. Public information and educational campaigns can be used to reduce these misinterpretations.

EXHIBIT V-14 (Continued)
Strategy Attributes for Using In-Pavement Measures to Communicate the Need to Reduce Speeds (T)

Attribute	Description
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should have a design policy for perceptual pavement markings and other in-pavement countermeasures that can be used for speed zone transitions, neighborhoods, work and school zones, freeway ramps, toll plazas, and intersections. If highway agencies do not have a policy concerning these countermeasures, then these need to be developed first before the strategy is implemented. Many states have specific design and placement criteria concerning conventional rumble strip applications (shoulder rumble strips). Policy for transverse rumble strips should be implemented with design and placement criteria for speed zone transitions, neighborhoods, work and school zones, freeway ramps, toll plazas, and intersections.
Issues Affecting Implementation Time	Implementation time for this strategy is expected to be low. The process of identifying and prioritizing locations may lengthen implementation time.
Costs Involved	Costs for perceptual pavement markings will vary depending on the length of corridor to which the markings will be applied. The overall cost of perceptual pavement techniques is rather low compared to other speed reducing techniques, as pavement markings are inexpensive to install and maintain. Due to advances in construction technology and increased applications of rumble strips, the cost of installation has been on the decline. *NCHRP Report 500, Volume 6* reported that the New York Department of Transportation paid approximately $6.18 per linear meter of rumble strip in 1990. This decreased to only $0.49 per linear meter in 1998. The costs associated for transverse rumble strips, as described for applications in this strategy, would be much lower because ramps, toll plazas, work zones, and intersections do not require continual rumble strips at extensive lengths. Costs for maintenance of rumble strips are generally minimal.
Training and Other Personnel Needs	No additional training or personnel should be needed for this strategy.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	Use of enforcement with these countermeasures may help increase their effectiveness at reducing speeding and speeding-related crashes. Also, perceptual pavement markings can be used to help control speeds on approaches to reduced speed zones (Strategy E2) and can also be combined with geometric design elements to control speeds (Strategy E1).
Other Key Attributes to a Particular Strategy	None identified.

Strategy D4—Implement Variable Message Signs to Display Information on Appropriate Speeds for Current Conditions, As Well As Technologies to Monitor Conditions (High Speed Only) (T)

Variable message signs (VMS) are used to provide drivers information concerning the current and expected driving conditions. VMS display messages to drivers that will inform or warn them of conditions ahead that may prove beneficial to their safety or travel time. Examples of information commonly displayed by VMS are:

- Traffic conditions
- Work zone/construction areas
- Weather and surface conditions
- Detour/direction information
- Crashes and incidents
- Appropriate speed limits

There are several different types of VMSs, such as flip disk, light emitting diode (LED), and fiber optic displays (Wisconsin DOT, 2000). LED and fiber optic are two of the more common technologies in use today for the display of messages. VMS can be either permanent fixtures often mounted over the roadway or can be smaller, trailer mounted displays which are placed on the roadside. Both forms have a limited space for long messages with multiple text items; therefore, they are programmed to flash one item after another. The messages displayed on some VMS can be programmed on-site or remotely. This allows for a rapid update of information on current and expected travel conditions.

VMS displays provide advanced technology to indicate safe travel speeds to drivers. For certain conditions (i.e., congested roadways or inclement weather), the posted speed limit may not be a safe travel speed; however, drivers will often attempt to drive at the posted speed limit despite the safety problems this may create. A key element to this strategy's effectiveness is the support from enforcement and adjudication when speed limits are decreased due to conditions.

In addition to using ITS to display a safe speed for the driving conditions, ITS technology is needed to collect information on current conditions so that speed limits can be accurately set. Traffic conditions can be observed using video cameras and/or pavement loop detectors. Video can also be used to observe weather conditions, along with weather stations. Furthermore, in-pavement sensors are available for collecting information on actual pavement conditions, including pavement surface condition and temperature. Often this information can be gathered and then sent to a central location, such as a traffic management center in a large metropolitan area, for processing and display on VMS. See Exhibit V-15 for more information on how to use VMS.

EXHIBIT V-15
Strategy Attributes for Implementing Variable Message Signs to Display Information on Appropriate Speeds for Current Conditions As Well As Technologies to Monitor Conditions (T)

Attribute	Description
Technical Attributes	
Target	This strategy is targeted at reducing crashes related to traveling at speeds faster than what is appropriate for current conditions. Real-time communication of current conditions is provided to help drivers make better choices concerning their speed. VMS technology is ideal for high-speed roads such as freeways and arterials that have a history of speeding-related crashes (especially during congested conditions or adverse weather).
Expected Effectiveness	It is difficult to determine the effectiveness of this strategy in reducing crashes related to speeds higher than appropriate for conditions, as there are a variety of other factors that can affect the occurrence of crashes that are difficult to measure. There are a few studies which quantify the actual effectiveness of VMS presence and its ability to deter speeding. Studies indicate that VMS are effective in gaining travelers' attention. One particular study indicates that drivers feel VMS is reliable and provides them with helpful information while traveling (Ran et al., 2004). A survey by the Wisconsin DOT was administered to determine if VMS displays are effective ways to communicate information to travelers. Results from the survey (sample of 200+ respondents) indicated that the majority of the drivers are familiar with VMS, with 70 percent of the respondents indicating viewing VMS on their routine routes (Ran et al., 2004). From the total respondents, the collective attitude was positive, indicating that drivers feel the information displayed is reliable. They indicated that VMS were particularly informative concerning weather and traffic condition updates.
Keys to Success	The Wisconsin DOT's *Intelligent Transportation Systems Design Manual* identifies criteria that are useful for successful deployment of a VMS system (Wisconsin DOT, 2000). The manual indicates the following criteria for determining the use of VMS: • **Data Collection:** Data collection to determine where VMS would be most effective includes mapping of area, road alignment information, crash history, an inventory of existing signs, locating power sources along the road (to provide electricity to VMS). • **Determine Type of VMS:** Determining the type of VMS depends on the intended purpose for the signs. For displaying speed information it is important to consider VMS technology that is capable of displaying several lines of information. Some VMS signs are limited in the information that can be displayed. It is important to obtain a sign that is capable of displaying several lines of information concerning appropriate speed limits, traffic conditions, weather conditions and other related items that would have an effect on safe traveling speeds. • **Identify Locations to Install VMS:** Once data are reviewed, locations for VMS should be identified. This should be based primarily on the need for the signs. High-priority locations where VMS would be effective should be identified and exact locations to install the signs should be determined. Data collection is needed to know if a speed adjustment is warranted; this data is equally important to the effective and efficient location of VMS. Without timely and accurate data, drivers are more likely to disregard the suggested driving speeds.

EXHIBIT V-15 (Continued)
Strategy Attributes for Implementing Variable Message Signs to Display Information on Appropriate Speeds for Current Conditions As Well As Technologies to Monitor Conditions (T)

Attribute	Description
Potential Difficulties	Convincing drivers that they need to obey the suggested speeds could be one of the biggest difficulties. As with any speed limit or speed advisory sign, drivers will not necessary obey them, especially if the information is not up-to-date. Another potential problem may be legibility of the messages. Also drivers should not be overwhelmed with too much information which may cause distraction by taking too much reading time and causing vehicles to slow down. Another identified difficulty of this strategy is the costs associated with VMS. The acquisition, installation, and routine maintenance of variable message displays and the data collection equipment can be very costly.
Appropriate Measures and Data	As mentioned previously, data collection is important to determine effective locations to install VMS. Measures and data appropriate to determine the effectiveness of VMS at those locations include obtaining historical and current data concerning speeding at locations where VMS is installed. Crash data concerning speeding and various conditions such as weather and congestion are also important to identify, if available. These data items should be observed for current and future conditions after the VMS is installed, to determine the effectiveness of VMS.
Associated Needs	A public information campaign may be needed to inform drivers of the intent of VMS, especially if use of them in this manner is new to an area. A survey or other method of obtaining feedback from drivers can be a good way to gain information on the use, location, and other issues related to the signs. Technology to detect adverse conditions (high winds, snow, rain, fog, etc.) contributes to success in providing updated information displayed on variable message signs.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Policy guidance regarding the installation of VMS should be considered with the MUTCD as a reference.
Issues Affecting Implementation Time	Implementation time can vary depending on the process to identify proper locations and type of VMS to install. The data collection process is likely the longest task for this strategy. Acquiring and installing the VMS should not take long, especially if there is infrastructure to accommodate the signs (e.g., power supply or bridge to hang sign). In addition, the installation of data collection equipment can vary based on the size of the network observed and the technology selected.
Costs Involved	Costs for this strategy can be moderate to high, due to the detection and communication equipment needed. There are several different costs associated with this strategy. The major costs include the acquisition, installation, and routine maintenance of the VMS and data collection equipment. The costs are much higher if infrastructure to mount the signs (such as a bridge overpass) and a power supply does not exist.

EXHIBIT V-15 (Continued)
Strategy Attributes for Implementing Variable Message Signs to Display Information on Appropriate Speeds for Current Conditions As Well As Technologies to Monitor Conditions (T)

Attribute	Description
Training and Other Personnel Needs	No extensive training or additional personnel should be needed to implement this strategy. Personnel may need to be trained, however, concerning installation and maintenance of VMS and technologies used to collect field conditions. Also, an increase in law enforcement may be needed to improve compliance with the suggested driving speeds.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy will generally be compatible with other countermeasures.
Other Key Attributes to a Particular Strategy	None identified.

Objective E—Ensure Roadway Design and Traffic Control Elements Support Appropriate and Safe Speeds

While drivers have a responsibility to drive at a safe speed, they need to be able to receive clues from the roadway environment on what that speed should be. The design of a roadway and its traffic control devices should consider the speeds at which the agency wishes people to drive, as well as the speeds that can reasonably be expected.

A key element in safety is that road design and traffic control elements effectively communicate appropriate and safe speeds to ensure the safety of road users. This objective observes several different design and traffic control elements that are vital in providing safe travel at high speeds, and aims at correcting locations where current design elements are not appropriate. Strategies for this objective include:

- Combinations of geometric elements to control speeds
- Safe speed transitions through design elements
- Adequate sight distance for expected speeds
- Speeds on approaches to reduced speed zones
- Appropriate intersection design for speed of roadway
- Adequate clearance intervals at signalized intersections
- Appropriate operation of traffic signals for speed of intersections and corridors
- Protected-only signal phasing for left turns at high-speed signalized intersections

- Lighting at high speed intersections and high volume pedestrian/bicycle crossings
- Reduction of traffic speeds and volumes with traffic calming and other related countermeasures

Strategy E1—Use Combinations of Geometric Elements to Control Speeds (Horizontal and Vertical Curves, Cross Section), Including Providing Design Consistency along an Alignment (T)

Designing a roadway to influence drivers to travel at a particular "controlled" speed, and discourage them from traveling at an excessive or inappropriate speed, helps to prevent crashes from occurring and can also reduce severity when they do occur. Geometric elements, such as horizontal and vertical curves, affect operating speeds, and these elements can be designed in combinations to encourage appropriate speeds. This strategy aims at providing consistency in the design of roadway elements and selecting design elements that can be used to control vehicle speeds while providing for safe travel. Such road design elements may include the alignment, number of lanes, and width of lanes and shoulders. The provision of design consistency leads to roadway elements that meet drivers' expectations and result in consistent speeds along an alignment and fewer unexpected speed changes, factors which contribute to a reduced likelihood of crash occurrence.

Of the several design factors that influence driver speed and perception, two of the primary ones are the curve radius and the tangent length. Other important parameters include the length of spirals, the vertical grades and curves, the available sight distance, and the cross-section features.

Historically, the horizontal curve is the most critical geometric design element that influences driver behavior and has the most potential for crashes, and research has indicated that the average accident rate for horizontal curves is about three times the average accident rate for highway tangents and the average run-off-the-road crash rate for highway curves is about four times that of highway tangents (Lyles and Taylor, 2006).

Reasons for this increased crash frequency include restricted sight distance, driver inattentiveness, and speed estimation errors. To mitigate errors by the driver, it is important to convey a message to the driver as to what is the appropriate speed of the roadway. This can be done by providing a roadway that conforms to what a driver expects (from previous experience) and also provides clear clues as to what is expected of her/him on a particular roadway. This strategy thus aims at being consistent in the design of the roadway elements and selecting design elements that positively influence driver behavior and expectations, resulting in safer driving speeds and thus a reduced risk of collision.

The concept of design consistency is well documented and it is recognized that a consistent alignment will enable most drivers to operate safely at their desired speed along the entire alignment. Designs should thus strive to provide alignments that meet driver expectations, and avoid or minimize unexpected, unusual, or inconsistent design or operational situations. For example, large differences and sudden changes in horizontal alignment should be avoided, as these tend to increase driver workload and increase the likelihood of crashes. This includes situations such as the unexpected introduction of a relatively sharp curve at the end of a long tangent, where the higher speeds that may be encouraged by the long straight alignment could lead to driver error when the curve is encountered. One strategy is

to flatten the curve so that a driver can negotiate it at a higher speed which reduces the likelihood of someone over driving the curve. Research by Zegeer et al. (1992) indicated that curve flattening may reduce crash frequency by as much as 80 percent, depending on the central angle and the amount of flattening. Alternatively, providing a consistent design by the occasional introduction of a series of gentle curves may prevent speeds from getting too high on the tangent sections. This idea builds off the concept that is called a self-organizing road (Keith et al., 2005). Other design considerations include providing consistency in terms of sight distance availability, particularly to horizontal curves, again ensuring that the roadway meets the driver's expectations and does not surprise them (see Strategy E8).

A self-organizing road is essentially defined as a road that ". . . increases the probability that a driver will automatically select appropriate speed or steering behavior for the roadway without depending on road signs. The geometric features of the road encourage the desired driver behavior, and do not rely on the driver's ability or willingness to read and obey road signs." (Keith et al., 2005). The concept of a self-organizing, self-enforcing road is therefore to select distinctive features such that the appearance of the road leaves drivers in no doubt as to what sort of facility they are on. By providing a roadway that is planned and designed in such a way, an appropriate and "consistent" speed for each road category can be achieved. Distinctive features that "explain" the road include items such as number of lanes and lane width, presence or lack of cyclists and pedestrians, width of sidewalks, presence of medians, provision of on-street parking, and frequency of access. Simply, a self-organizing road is designed utilizing an aesthetic approach so that drivers will select an appropriate speed because it is comfortable and safe. In this way, the roadway environment provides positive enforcement by encouraging the driver to stay within the desired speed limit.

In addition to curvilinear alignments, other examples of a self-organizing road that can be used on low-speed roadways include lane width reduction (or lane narrowing), traffic calming measures, and roundabouts (Keith et al., 2005).

Narrower lane widths tend to reduce speeds since drivers are "encouraged" to slow down to maintain a comfortable position within the available lane width. Research carried out by an OECD Scientific Experts Group in 1990 reviewed impacts of lane width upon driver behavior and consistently found a reduction in speed with decreases in lane width and vice versa. Yagar and Van Aerde (1983) found that increasing lane width from 3.3 to 3.8 m was associated with a 2.85 km/h increase in speed. More recent work (Fitzpatrick et al., 2000) has corroborated these findings of very modest changes in speed associated with lane width.

Narrower lane widths can be implemented either by physically creating narrower travel lanes or by visually decreasing the available width, and may be supplemented by other measures within the driver's peripheral vision, such as landscaping and transverse lane markings, to reinforce the "slow down" message. This treatment may be a more effective tool for reducing speeds on rural roads and roads where there are more visual cues within the driver's peripheral vision.

As previously noted, the roadway width can be visually narrowed by such techniques as painting wider edge lines. The intention is that the driver will reduce speed to maintain a comfortable position within the narrower painted lanes. However, a study in a residential area by Lum (1984) indicated no impact on free speeds of narrowing lane widths from 5.5 m and 4.25 m to 2.7 m; thus, simply narrowing lane width without other measures, such as transverse

lane markings that have the effect of attracting the driver's peripheral vision, may not be particularly effective.

Regardless of the design technique used, the key is a consistent design so that the driver is not presented with an unexpected situation; Exhibit V-16 illustrates this point.

EXHIBIT V-16
Strategy Attributes for Using Combinations of Geometric Elements to Control Speeds, Including Providing Design Consistency Along an Alignment (T)

Attribute	Description
Technical Attributes	
Target	This strategy targets low-speed roads with inconsistencies in the alignment that may be a contributing factor to crashes, especially crashes where speeding plays a prominent role. Other components of this strategy also address using design elements to convince drivers to travel at a safe and reasonable speed. Providing consistent design and the appropriate use of design elements to reduce speeds and improve safety can be effective on low-speed roads.
Expected Effectiveness	Design inconsistencies, such as a sharp horizontal curve following a long tangent section, are known to have poor safety records. In this case, one of the best options would be to flatten the curve. The safety benefit from curve flattening was discussed above and reviewed in Strategy 15.1 A5 of the run-off-the-road guide (*NCHRP Report 500, Volume 6*). NCHRP Project 3-61, "Communicating Changes in Horizontal Alignment," indicates that the average crash rate for highway curves is 3 times higher compared to tangent highway alignments. The average rate of run-off-the-road crashes is four times higher at highway curves compared with the rate on straight alignments (Lyles and Taylor, 2006).
Keys to Success	Keys to success depend on the road type, traffic characteristics, traffic control devices, and safety elements. It is important to identify low-speed roads with inconsistent alignment or unsafe geometric elements. Improvements to these roads to reduce speeding is also most successful in reducing collisions when used in conjunction with traffic control devices, medians, barriers, and increased enforcement.
Potential Difficulties	One issue with this strategy is the cost of improvements. Roadway improvements requiring construction on new alignment can be costly. Costs will vary depending on the length of road segment to be improved and type of improvements being made.
Appropriate Measures and Data	Appropriate measures include the number of locations where geometric road improvements are made and the type of improvements (i.e., curve flattening or addition of gentle horizontal curves to a long tangent section). Vehicle speeds should be recorded before and after the project in order to determine if the project was successful in lowering vehicle speeds and making them more uniform. Impact measures also include the frequency or rate of collisions and severity of crashes that occur at these locations, especially those with speeding listed as a contributing factor. Comparison of crash data before and after improvements can help to identify the effectiveness of modifying different geometric design elements. Other measures include gaining public feedback to determine if the public is in favor of the revised road geometry.

EXHIBIT V-16 (Continued)
Strategy Attributes for Using Combinations of Geometric Elements to Control Speeds, Including Providing Design Consistency Along an Alignment (T)

Attribute	Description
Associated Needs	Needs associated with this strategy include informing the public that the road geometry will be improved. Signage and media announcements should indicate any changes prior to construction.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should have a current policy or adopt new policy on guidelines and criteria for road alignment. The AASHTO Green Book provides information on road design for reference.
Issues Affecting Implementation Time	Implementation time for this strategy will depend on the design selected. Minor improvements and changes (i.e., pavement markings) can often be implemented in 1 year or less. Major construction projects such as curve flattening and introducing occasional flat horizontal curves into a long tangent section will require several years to implement.
Costs Involved	Implementation costs will vary depending on the design alternative selected and the size of the area to be treated. For example, flattening a curve or series of curves can have a high cost due to design, right-of-way (ROW), and construction; whereas lane narrowing with pavement markings is a low-cost strategy.
Training and Other Personnel Needs	Highway personnel should receive training on the safe and proper use of design elements to control speeds. Such strategies have to be implemented carefully so as not to create a safety hazard while trying to address excessive speeds.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is one aspect addressing the overall design of a roadway. Other aspects of design specific to speed transitions, intersections, and sight distance are discussed in Strategies E2, E5 and E8 of this report.
Other Key Attributes to a Particular Strategy	None identified.

Strategy E2—Effect Safe Speed Transitions through Design Elements and on Approaches to Lower Speed Areas (T)

Reduced speed zones are areas where posted speed limits are reduced to safely accommodate traffic, pedestrians, and road conditions because there is a risk increase (perceived or actual) if traffic continues to travel at higher speeds. Reduced speed zones are generally used in school zones, high pedestrian areas, work zones, intersections and highway transitions from rural to urban areas. Work zones and rural to urban transitions are the most common type of reduced speed zones on high speed roads (45+ mph) such as freeways or major arterial highways. Reduced speed zones further lower speeds on low speed roads; typical applications include school zones, high pedestrian areas, work zones, and in residential or commercial neighborhoods.

This strategy aims at methods to encourage safe and effective speed transitions on the approaches to (and within) areas with a reduced speed limit. It may not be possible to ensure that all vehicles drive at or below the reduced speed limit; however, there are several methods and countermeasures that can be deployed to deter speeding in these zones.

To increase the effectiveness of speed transitions, signing, enforcement, pavement markings, and other safety elements should be used appropriately to deter drivers from speeding in these zones. Further, roadway designs sensitive to the context in which they will be located can encourage appropriate speed choice by drivers. Elements of the roadway, such as curvature and lane width, along with landscaping and other roadside features, can communicate the context of the roadway. For example, areas with high pedestrian activity may include raised or otherwise marked crosswalks and other physical features that draw drivers' attention to the nature of the area, which can both reduce their speeds and increase their awareness of pedestrians in the area. Visual cues that may encourage drivers to reduce vehicle speeds on approaches to lower speed areas include the introduction of sidewalks and curb and gutter, raised medians, landscaping, ornamental lighting, pedestrian signs, textured crosswalks or intersection pavement, banners and decorations, and other forms of street furnishings.

- **Enforcement:** There are different enforcement measures that can be taken and the best type of enforcement to implement depends on factors such as the extent of the speeding problem and the resources available for implementation. Enforcement methods to control speeds at these locations include:
  - Increasing law enforcement presence
  - More frequent ticketing of violators
  - Increasing fines (doubling or tripling fines in reduced speed zones)
  - Employing enforcement technology such as automated speed devices (e.g., photo radar which can be used in conjunction with speed display signs)

- **Transverse rumble strips:** Rumble strips are used to gain a driver's attention by producing an alarming noise and vibration throughout the vehicle. The use of transverse rumble strips in reduced speed zones may not efficiently control driver speeds; however, rumble strips used in conjunction with traffic control devices can provide an increased awareness of the importance of reducing speeds.

  Depending on the topography and the ambient noise levels, rumble strips can generate considerable noise over a large area. Consequently, they can be a more appropriate application in a rural environment and have only limited use in urban areas. Speed reductions from the use of transverse rumble strips alone are likely to be small and probably erode over time.

- **Advance warning signs:** It is important to use signs to provide drivers with advance warning of reduced speed locations. Previous versions of the MUTCD used a regulatory sign informing drivers of decreases in the posted speed limit ahead. The 2003 MUTCD allows a yellow diamond warning sign with either text or an arrow to show a reduced speed zone is ahead and what the speed limit is in that zone. Variable message signs used to display messages informing drivers of reduced speed zones and other relevant information are good to use in construction zones. Active speed feedback display signs can also be used to control speeds at reduced speed zones, as they typically gain a driver's attention, especially when the signs are used in conjunction with photo radar devices for enforcement.

- **Road design:** Changes can also be made to the alignment and cross-section of the roadway as a method to inform drivers they need to reduce their speeds. These changes could be something as simple as introducing curb and gutter or using pavement markings to give the illusion of lane narrowing. Other strategies to slow drivers may include channelization, raised medians, allowing on-street parking, the introduction of curvilinear alignments and the extension of the urban environment further into the transition area (for example, by the use of landscaping and lighting). With these design countermeasures, it is important that they are introduced in such a way that they do not become or create a safety hazard.

The use of distinctive road design features such as those noted above help to identify a change in the environment and can influence the driver's speed approaching, and in, the transition zone. Reference should be made to the discussion on self-organizing roads under Strategy E1 for further information regarding the use of physical and visual measures to achieve appropriate speed behavior.

As well as their use as an effective method of intersection control, roundabouts are often used to reinforce a change in environment (e.g., rural to urban) in conjunction with a change in speed. The roundabout also provides an opportunity to provide a "Gateway"—a device to mark such a transition from a higher speed facility to an environment requiring a lower speed and greater driver attentiveness, particularly if the driver had been driving on the "faster" facility for a relatively long time. The use of roundabouts is discussed further under Strategy E3, including the importance of providing ample warning to enable the driver to effect a safe speed transition on the approach to the roundabout (for example by the introduction of a raised median "splitter" island, or the introduction of a curvilinear alignment). One non-geometric method used in the United Kingdom, and found to be effective in reducing collisions associated with speed adaption, is to apply yellow transverse bar markings on high speed approaches to roundabouts. The transverse markings are typically placed at decreasing intervals on the roundabout approach to affect the driver's visual field and encourage the driver to slow down. Details of the United Kingdom markings and their spacing are provided in Chapter 5 of the United Kingdom's Traffic Signs Manual. Earlier research on trial markings at 42 roundabouts in the United Kingdom showed a 57% decrease in speed related crashes over a period of 4 years (Helliar-Symons, 1981).

Although traffic calming measures are more typically associated with an urban type setting, there may be opportunities to use such techniques in a rural environment to encourage a reduction in speed. These techniques may include lane narrowing (physical or visual), installation of median islands and other forms of channelization, and changes to the roadway surface. These techniques can be used in combination to reinforce the message to the driver that there is a change in the environment requiring a speed adjustment. In the United Kingdom, "Gateways" exist in a wide variety of forms to influence the driver's behavior on the approach to an area requiring a lower speed and greater attentiveness. The primary feature is a conspicuous vertical element at the side of the road (for example, enhanced signing, often with yellow backing boards; countdown signs on the approach to the gateway; vegetation; walls and fences; etc.). Other elements typically incorporated include lane narrowing (visual or physical), colored road surfacing, and special pavement markings (for example, speed "roundels" and "dragon teeth" lane edge markings). Using these measures in combination, and in conjunction with good sight lines, generally improves the Gateway conspicuity and its effect on reducing speeds. However, care should be taken to avoid introducing additional hazards (such as non-yielding signs and other roadside features), and consideration should also be given to possible visual

intrusion. Research in the United Kingdom (Wheeler et. al., 1994, Wheeler and Taylor, 1999) indicates typical average speed reductions of 1 to 2 mph from simple signing and marking; 5 to 7 mph from more comprehensive signing/marking with high visual impact; and about 10 mph with physical measures.

In another rural application (Steinbrecher, 1992), the district of Neuss, Germany implemented a combination of traffic calming measures on the approaches to 13 rural towns which included reducing the lane widths to about 5.5 m; adding strips of pavement stones to optically narrow the road further; installing refuge islands; and raising the road in asphalt. The road raising was achieved by constructing 3 m long ramps with slopes of about 35:1, which could be negotiated comfortably at speeds of 30 mph. Steinbrecher noted that the road raising aspect in combination with the refuge islands seemed to achieve the greatest effect of speed reduction. Results indicated speeds dropped in all 13 towns with before treatment speeds averaging between approximately 45 to 53 mph, and those after treatment averaging about 37 to 45 mph. The average speed reduction was just over 5 mph (varying between about 1 and 9 mph). The overall impact on average crash rate was a reduction from 1.1 per year to 0.6 per year.

Further information on traffic calming measures and their effectiveness is provided under Strategy E9 in this guide.

Construction zones are known to present increased challenges to drivers, as they typically form choke points requiring drivers to transition from a higher speed relatively unrestricted environment to a lower speed congested environment. This transition takes place on the approach to the work zone, and this area represents a particularly serious collision risk as some drivers do not respond well to the speed and lane changes that are required on the work zone approach, and often make unexpected or dangerous maneuvers. The key is to provide ample advance warning to enable drivers to reduce their speed on the approach to the work zone so that they can safely enter the zone and make any necessary lane changes or merges in a safe and efficient manner (it is also important that measures are implemented to guide drivers through the work zone itself). Reference should be made to the *Manual of Uniform Traffic Control Devices* and to *NCHRP Report 350* for further information regarding the standardization of work zone areas in terms of traffic control and work zone safety devices. Volume 17 of the *NCHRP Report 500* series, on reducing work zone fatalities, should also be referenced.

If a roadway has a speed transition into an area with a large number of pedestrians, possible design countermeasures include speed tables, pedestrian bulb outs, and raised crosswalks. These items are discussed in more detail in Strategy E3, Appendix 1, and Exhibit V-17.

EXHIBIT V-17
Strategy Attributes for Effecting Safe Speed Transitions through Design Elements and on Approaches to Lower Speed Areas (T)

Attribute	Description
Technical Attributes	
Target	This strategy targets drivers who fail to sufficiently slow down approaching and in reduced speed zones. The strategy specifically is designed to provide drivers with information on the presence of a reduced speed zone ahead and aims to deter drivers from speeding in these zones.

EXHIBIT V-17 (Continued)
Strategy Attributes for Effecting Safe Speed Transitions through Design Elements and on Approaches to Lower Speed Areas (T)

Attribute	Description
Expected Effectiveness	There are many studies that indicate the effectiveness of enforcement, rumble strips, signing, and design features to reduce travel speeds and improve safety. While there are not many studies that indicate the effectiveness of these techniques specifically for lowering speeds on transitions to reduced speed zones, there are many studies that indicate their effectiveness on high-speed roads. NHTSA conducted a survey to determine what countermeasures were effective in reducing speeding and unsafe driving. The survey results indicate that road design changes and speed bumps are considered to be effective in reducing speeding by 78 percent of respondents. Using transverse rumble strips on approaches to unsignalized intersections was reviewed as strategy 17.1 E6 in *NCHRP Report 500, Volume 5.* In this particular application, it was reported that there was no consensus on their effectiveness, but up to a 50% reduction in specific crash types (i.e., running the Stop sign) were reported. Other states have experimented on using movable rumble strips on approaches to work zones, but the response has generally not been favorable because of the difficulties of keeping the movable rumble strips in place. Studies on the effectiveness of rumble strips in the United Kingdom indicated average reductions in 85th percentile speeds of about 2 to 6 mph (Webster and Layfield, 1993, Barker, 1997). Injury collision reductions were reported, but found to be not statistically significant. There is little information relating the actual effectiveness of “reduced speed zone ahead” signs, but dynamic displays that show actual travel speeds have been studied and found to be effective. More information on this use of active speed warning signs is provided in Strategy D2. The use of design elements (perceptual or physical) to alter driver behavior has been reviewed in Strategies D4 and E1, and E3 of this guide. Final Report 2002-18, *Methods to Reduce Traffic Speed in High Pedestrian Area,* by the Minnesota DOT provides literature on devices that can be used in conjunction with safe speed transitions in pedestrian areas (Kamyab et al., 2002). Countermeasures included in this report include traffic calming, educational campaigns, law enforcement presence, rumble strips, lighting, pedestrian refuge islands, sidewalks, and signage. Refer to this document for further details.
Keys to Success	A key to success with this strategy is the identification of locations where drivers are failing to slow down on the approach to areas with posted reduced speed limits and are continuing to speed in the reduced speed zones. Typical ways to identify these locations are talking to law enforcement agencies, listening to concerned citizens, and reviewing crash histories. After a location has been identified as potentially having a speeding problem, then actual vehicle speeds need to be recorded to verify that drivers are indeed speeding. Each countermeasure may be more effective in certain situations than in others. Identification and prioritization of the appropriate countermeasure technique will rely on characteristics such as traffic volume, frequency and severity of crashes, average travel speeds, and alignment. Further, use of multiple countermeasures implemented at a single location may produce the best results in controlling speed. For example, reduced speed ahead signs could be used solely, but they could also be used in conjunction with rumble strips, flashing beacons, and increased enforcement at areas where speeding-related crashes pose a serious problem.

EXHIBIT V-17 (Continued)
Strategy Attributes for Effecting Safe Speed Transitions through Design Elements and on Approaches to Lower Speed Areas (T)

Attribute	Description
Potential Difficulties	One of the major difficulties with this strategy is the cost associated with controlling travel speeds. Of the countermeasures suggested, rumble strips and signs will have a relatively low implementation cost for each site. However, other strategies, such as increased enforcement, automated speed detectors, and road design changes, may have a high initial or recurring cost. Public acceptance of enforcement countermeasures, either traditional or automated, may not exist initially, but could grow through education and demonstration that the enforcement is preventing crashes.
Appropriate Measures and Data	Measures of implementation include the number of locations and type of countermeasures applied to speed transitions. Likewise, the type of reduced speed zone should be recorded (e.g., school zone, rural-to-urban transition, pedestrian activity, etc.). A key impact measure is whether vehicle speeds decrease. The frequency and/or rate of collisions and severity of crashes that occur at approaches or within reduced speed zones on high-speed facilities are additional areas to measure. Comparing before and after crash data will help determine the effect on safety. Other measures include gaining public feedback, to see if there is any negative or positive opinion concerning these countermeasures.
Associated Needs	Associated needs might include public information or educational campaigns, explaining why various changes in speed transition areas have been made.
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Highway agencies should adopt or review policy concerning criteria and guidelines for the use of speed reduction countermeasures specific to speed transition areas. Policies should identify attributes, such as the road type and placement, to ensure that countermeasures are used consistently and in the proper situations.
Issues Affecting Implementation Time	Implementation time varies depending on the type of countermeasure used. Some strategies that may be quickly implemented include increased enforcement, signage, or application of rumble strips. These types of countermeasures would typically take no more than 1 year to put into place. Strategies that require considerable policy decisions or design time usually take longer to implement.
Costs Involved	Costs vary depending on the countermeasures used for this strategy. Rumble strips and increased signage are a few of the lowest cost strategies for speed transition zones. Implementing variable message boards and/or automated speed enforcement devices is more expensive as the costs of acquisition, installation, and routine maintenance are higher. Redesigning the roadway to help encourage slower speeds would be a high-cost alternative.
Training and Other Personnel Needs	Highway agency personnel may need training to help them identify the proper circumstances for when to deploy each countermeasure technique and the effectiveness of these techniques when administered as part of normal operations. In order to provide the resources necessary for the traditional enforcement countermeasures, the responsible law enforcement agency may need to pay for overtime or redirect enforcement from other locations.
Legislative Needs	None identified.

EXHIBIT V-17 (Continued)
Strategy Attributes for Effecting Safe Speed Transitions through Design Elements and on Approaches to Lower Speed Areas (T)

Attribute	Description
Other Key Attributes	
Compatibility of Different Strategies	This strategy is one aspect addressing the overall design of a roadway, and it is compatible with the other strategies discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy E3—Provide Appropriate Intersection Design for Speed of Roadway (T)

Intersection design plays a large role in the safety of roads. According to *A Policy on Geometric Design of Highways and Streets,* "The efficiency, safety, speed, cost of operation, and capacity of the highway system depend on the design of its intersections" (AASHTO, 2004). The main objective of intersection design is to, "reduce the severity of potential conflicts between motor vehicles, buses, trucks, bicycles, pedestrians, and facilities, while facilitating the convenience, ease, and comfort of people traversing the intersections" (AASHTO, 2004). To provide safe intersections to road users, there are five elements that should be considered in the design (AASHTO, 2004):

1. Human factors
2. Traffic considerations
3. Physical elements
4. Economic factors
5. Functional intersection area

This strategy aims primarily at addressing traffic considerations and physical elements that apply to intersection design. Some of the important factors to consider for intersection design are the grade, angle, horizontal and vertical alignment, median type, turn lanes, corner radii, and traffic control devices at the intersection. See Appendix 1 for additional information on these design elements.

Roundabouts provide an important alternative to signalized and all-way stop-controlled intersections. Modern roundabouts differ from traditional traffic circles in that they operate in such a manner that traffic entering the roundabout must yield the right-of-way to traffic already in it. Roundabouts are a good option for low-speed roads, as they can serve moderate traffic volumes with less delay than signalized or all-way stop-controlled intersections because traffic can normally traverse the roundabout without stopping. It has been found that single-lane roundabouts operate more safely, and though not necessarily with fewer crashes, but with lower injury rates than two-way stop-controlled intersections. For further details regarding roundabouts, reference should be made to *NCHRP Report 500, Volume 5.*

Comprehensive details regarding the improvement of safety at both unsignalized and signalized intersections are provided in *NCHRP Report 500,* Volume 5 and Volume 12, respectively. Of particular relevance, the unsignalized intersection report (Volume 5) provides guidance on the choice of appropriate intersection control (Strategies 17.1.F1 through F3) and also on the use of geometric design improvements to reduce collision frequency and severity (Strategies 17.1.B1 through B18). The signalized guide (Volume 12) provides similar guidance (Strategies 17.2.B1 through B5). Because detailed discussion is contained in these other guides, the discussion in this guide will present an overview of speeding-related fatalities, and the other guides should be referenced for additional information. Also see Exhibit V-18 for further discussion of design issues.

EXHIBIT V-18
Strategy Attributes for Providing Appropriate Intersection Design for Speed of Roadway (T)

Attribute	Description
Technical Attributes	
Target	The target for this strategy is the appropriate and consistent design of intersections. This strategy relates to existing and future/planned intersections in rural, urban, and suburban areas.
Expected Effectiveness	While there are many different design features and related studies for intersection design, there are studies that identify the effectiveness of these individual elements. These are discussed in detail in Volume 5 (Non-signalized Intersections) and Volume 12 (Signalized Intersections) in this *NCHRP Report 500* series.
Keys to Success	A key to success for this strategy is to coordinate efforts of highway agencies and local agencies, as well as enforcement agencies. Their involvement is important in identifying design issues at intersections to help address current safety concerns and prevent the creation of new ones. The use of additional warning devices can help improve driver awareness of intersections. Examples include advisory signs (“yield,” “watch for cross traffic,” “reduce speeds”); flashing beacons; and rumble strips.
Potential Difficulties	Options for redesigning many intersections will be limited by difficult geometry, roadside development, high volumes, or other conditions. The high cost of reconstructing an intersection (such as to convert to a roundabout) may prohibit short-term implementation of such an improvement.
Appropriate Measures and Data	Process measures should include the number and locations of intersections where designs are reviewed, as well as intersections for which new design features are implemented. Impact measures include the frequency or rate of collisions and their severity. Observing crash data before and after intersection design improvements will help determine the effectiveness of the improvements.
Associated Needs	Coordination with the public to gain input and inform drivers of proposed changes is important. Providing drivers with information on future construction at intersections is important to ensure their safety and provide them with alternative routes if needed. It is also important to gain input from the public on intersections where they feel changes may be warranted. Information such as educational materials on intersection safety and how the elements of road design apply to safety should also be made available to the public.

EXHIBIT V-18 (Continued)
Strategy Attributes for Providing Appropriate Intersection Design for Speed of Roadway (T)

Attribute	Description
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Agency policy should address processes for changing an intersection design or elements of the intersection, including review of crash information to determine the most appropriate improvements.
Issues Affecting Implementation Time	Implementation time varies depending on the change made to an intersection design. Design and construction of a turn lane, for example, can be completed in less than 1 year if complicating right-of-way issues are not encountered. Conversion to a roundabout would likely take several years.
Costs Involved	As mentioned previously, it can be expensive to implement some of these key design elements. The costs are highest where major construction is required such as realignment of an intersection. Adding turn lanes, medians, or other precautionary safety measures is less costly compared to fully reconstructing an existing intersection. Likewise, maintenance costs will vary depending on the type of intersection. Operation and maintenance costs for roundabouts are somewhat higher than for unsignalized intersections, but less than those for signalized intersections.
Training and Other Personnel Needs	Intersection design improvements should be covered in normal agency training courses, with an emphasis on the appropriateness of designs for different roadway types.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with the others discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy E4—Provide Adequate Change + Clearance Intervals at Signalized Intersections (P)

Change + clearance intervals are the portion of a signal between the end of a green phase and the beginning of the next green phase for a conflicting movement. (Note: The "change + clearance" interval will simply be referred to as clearance interval for the remainder of this discussion.) Clearance intervals should be designed to account for expected approach speeds in order to reduce the potential for red-light-running collisions. Clearance intervals that are too short can result in drivers not being able to stop in time for the red signal, and intervals that are too long can breed disrespect for the signal in drivers familiar with the intersection. Either situation can result in red-light running, which increases the risk for angle collisions, the severity of which is compounded by speeding. Clearance intervals provide safe transitions in right-of-way (ROW) assignment between conflicting streams of traffic. Clearance intervals can include both yellow and all-red timing between conflicting green phases. *NCHRP Report 500, Volume 12:* "A Guide for Reducing Collisions at Signalized Intersections" covers material on

optimal clearance intervals in Strategy 17.2 A2; therefore, an overview of the information is presented in this guide, and Volume 12 should be referenced for additional information.

There is no specific standard for determining clearance intervals at an intersection. Clearance intervals are dependent on many factors, including operating speeds, intersection width, vehicle lengths, and driver characteristics such as reaction time and braking. ITE has developed an equation for determining the length of the change + clearance interval but some agencies may use a uniform clearance interval. See Appendix 2 of *NCHRP Report 500, Volume 12:* "A Guide for Reducing Collisions at Signalized Intersections" for more information on establishing clearance intervals. (http://safety.transportation.org/).

There are different issues with poor clearance intervals at high speed intersections. Clearance intervals that are too short in length result in drivers stopping abruptly, which may lead to rear-end collisions. Furthermore, a too short clearance interval could result in an angle collision involving vehicles traveling through the intersection after the end of a phase and vehicles entering the intersection on the subsequent phase. One study showed that the effect of clearance intervals shorter than those calculated using ITE guidelines had higher crash rates for rear-end and right-angle crashes (Zador et al., 1985). Clearance intervals that are too long may result in a growing problem of red-light violations as studies have suggested.

For more information on yellow and all-red intervals refer to Volume 12 of this series, as well as *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running.* (McGee, 2003). This can be accessed online at: http://www.ite.org/library/redlight/MakingInt_Safer.pdf

Strategy E5—Operate Traffic Signals Appropriately for Intersections and Corridors (Signal Progression) (T)

Traffic signals are timed and phased with the objective of providing efficient movement of traffic. The coordination of traffic signals, or signal progression, has been found to have many safety benefits. Signals that are properly coordinated produce platoons of vehicles that travel the road without having to stop at multiple signals. This results in less stopping and can be expected to reduce rear-end collisions at intersections.

Signal progression also improves turning movements at intersections. Signal progression creates platoons of vehicles, which creates more gaps in traffic and allows vehicles to make left turns and right turns onto the major street more easily. This is an important benefit for high speed roadways where larger gaps are needed for a vehicle to safely enter and accelerate, or cross the traffic stream. In addition, judging gaps at high speeds may be more difficult, especially for older and inexperienced drivers.

The topic of signal coordination is discussed in detail as part of Strategy 17.2 A4 in "A Guide for Reducing Collisions at Signalized Intersections" (*NCHRP Report 500, Volume 12*), and therefore the information is not repeated in this guide. The reader should refer to Volume 12 for additional details on this strategy.

Strategy E6—Provide Adequate Sight Distance for Expected Speeds (P)

Sight distance is a fundamental element in geometric design and reflects the driver's ability to see the road ahead and other road users so that the facility can be used in a safe and

efficient manner. The amount of sight distance provided to the driver is a function of the three-dimensional features of the highway—the cross-section (roadside), vertical alignment (grades and vertical curves), and horizontal alignment. The total sight distance requirement essentially comprises the distance traveled during two key events, often referred to as the perception-reaction time and the maneuver time. The former refers to the time needed for a driver to recognize an object or condition requiring a response and deciding what action is required (e.g., initiating contact with the brake), and the latter refers to the time from the initiation of the vehicle response to the completion of the driving maneuver (e.g., from the time the driver applies the brake to the time when the vehicle comes to a complete stop). These time periods, and hence distances, will vary depending on vehicle speeds and the types of maneuvers being undertaken, for example, stopping, turning, or passing. Roads designed with insufficient sight distance for the expected speed can not always provide drivers with adequate time to identify a hazardous situation, decide on a course of action, and then complete their maneuver.

Sight distance at curves (horizontal and vertical), intersections, passing zones and areas where drivers have to negotiate through a complex or unexpected situation (i.e., lane drop, toll plaza, etc.) should account for the speeds expected in those locations. Providing adequate sight distance can reduce rear-end crashes involving vehicles stopping suddenly when the driver views something unexpected, angle crashes related to drivers accepting gaps that are too small for their turning maneuver, and head-on, passing-related crashes. Clearing sight lines, removing roadside objects that block views, and possibly flattening curves are potential solutions for improving sight distance.

More information regarding sight distance is provided in Strategy 15.2 A3 of Volume 7 on horizontal curves, Objective 17.1 C of Volume 5 on unsignalized intersections, and in Strategy 17.2 C1 of Volume 12 on signalized intersections, as well as in Exhibit V-19 of this guide.

EXHIBIT V-19
Strategy Attributes for Providing Adequate Sight Distance for Expected Speeds (P)

Attribute	Description
Technical Attributes	
Target	This strategy targets roads with sight distance issues. A primary target for stopping, intersection, and passing sight distance issues is rural 2-lane highways, including intersections along these roadways. Passing sight distance is not applicable for expressway and freeway facilities; further, these facilities were typically designed to higher standards and likely meet stopping sight distance requirements. However, intersection sight distance is important for at-grade expressway intersections, and decision sight distance is very relevant to expressways and freeways at critical locations (i.e., lane drops, interchanges, toll plazas).
Expected Effectiveness	As described in *NCHRP Report 500, Volume 5* on unsignalized intersections (Objective 17.1 C), after a literature review by a group of safety experts, it was decided that if available sight distance in any quadrant of an unsignalized intersection is less than or equal to the design sight distance for a speed of 20 km/h (12 mi/h) less than the actual 85th percentile speed of the approach, the frequency of related crashes at the intersection would be increased by 5 percent (Harwood et al., 2000). Therefore, improving sight distance at an intersection may be 0 to 20 percent effective in reducing related crashes (angle- and turning-related crashes) depending on the number of quadrants with a sight distance restriction and the severity of the sight distance restriction.

EXHIBIT V-19 (Continued)
Strategy Attributes for Providing Adequate Sight Distance for Expected Speeds (P)

Attribute	Description
	Strategy 15.2 A3 of *NCHRP Report 500, Volume 7* (horizontal curves) reports that the safety effectiveness of improving the sight distance at a horizontal curve when the actual sight distance is slightly less than the required has not been adequately quantified. However, *NCHRP Report 400* indicates that there is a safety benefit to improving sight distance when there is a sizeable sight distance restriction (Fambro et al., 1997). FHWA's *Signalized Intersections: Informational Guide* (2004) provides estimates of expected reductions in the number of crashes per intersection per year when sight distance is increased. For example, for an ADT between 5,000 and 10,000 vehicles per day, an increase in sight distance between 50 and 99 feet could be expected to result in 1.30 fewer crashes at that intersection each year. For additional ADT and increased sight distance ranges, refer to the FHWA guide at http://www.tfhrc.gov/safety/pubs/04091/. A more recent FHWA report cites sight distance improvements as being one of the most cost-effective treatments (FHWA, 1996); see "Safety Benefits Associated with Sight Distance Improvements: Selected Findings" below. Fatal collisions were reduced by 56 percent and nonfatal injury collisions were reduced by 37 percent at intersections having sight distance improvements. **Safety Benefits Associated with Sight Distance Improvements: Selected Findings** ***Treatment*** — ***Implication*** *Sight distance improvements* — *56% estimated reduction in fatal collisions. 37% estimated reduction in injury collisions.*
Keys to Success	Evaluation of available sight distance should take into account both posted speed limits as well as actual travel speeds, in order to ensure that enough sight distance is provided for the speeds expected. Preferably, inadequate sight distance would be addressed by increasing the sight distance by either removing the sight obstructions or redesigning the roadway. If the sight distance cannot be increased, at a minimum, the location should be reviewed to determine if advance warning signs are appropriate.
Potential Difficulties	Effective solutions to sight distance limitations may include roadway realignment projects. The high cost of such projects may render them unfeasible for implementation. Highway agencies may need to carefully explore other lower-cost options to determine feasible treatments for specific locations. Some coordination with the public or residents near a roadway may be necessary in order to make clear why trees or other landscaping items are being removed.
Appropriate Measures and Data	Key process measures include the number of miles of roadway or intersection locations where sight distance was increased and the amount of increase in sight distance achieved. The crash frequency and severity, by crash type, are key measures of safety effectiveness. Separate analysis of crashes targeted by specific sight distance improvements is desirable for before and after the application.
Associated Needs	None identified.

EXHIBIT V-19 (Continued)
Strategy Attributes for Providing Adequate Sight Distance for Expected Speeds (P)

Attribute	Description
Organizational and Institutional Attributes	
Organizational, Institutional and Policy Issues	Agency policy should include guidance on low-cost, short-term treatments for improving sight distance adequate for expected speeds.
Issues Affecting Implementation Time	Implementation time varies depending on the specific sight distance issue. Projects involving the removal of roadside objects that are located on the highway right-of-way can often be implemented quickly, usually in a matter of days or a few months. Locations where roadside obstructions are on private property will require more time, especially if laws do not allow highway agencies to remove items on private property. Regardless of the authority of the highway agency, the property owner(s) must be contacted, informed of the problem, and come to an agreement to remove the object. Treatments for locations where sight distance issues exist due to the road alignment have a longer implementation time. This might include reconstructing the realignment which can take well over 1 year.
Costs Involved	Costs vary depending on the location and type of sight distance issue and chosen solution. Costs should be low in cases where objects need to be removed in the right-of-way. Locations where alignment reconstruction is needed will require higher cost improvements, especially if additional right-of-way is required. Potential funding sources include state and local highway agencies and, to the extent required by law, individual property owners.
Training and Other Personnel Needs	Training concerning sight distance issues for passing, stopping, decision, and intersections should be included in highway agency training concerning geometric design, highway safety, and maintenance.
Legislative Needs	The only potential legislative need identified is the legal authority of highway agencies to control sight obstructions on private property. In some jurisdictions, highway agencies may need the legislature to strengthen laws on this issue.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with the others discussed in the guide.
Other Key Attributes to a Particular Strategy	None identified.

Strategy E7—Implement Protected-Only Signal Phasing for Left Turns at High-Speed Signalized Intersections (High Speed Only) (T)

Protected-only left turn signals have a phase designated specifically for left-turning movements (known to be one of the highest risk movements at intersections), which is indicated with a green arrow. Protected-only phases are applicable on high speed roadways and/or in high traffic volume situations, where there may be a lack of adequate gaps to

complete turning movements. In addition to vehicle speeds and volumes, there are several factors that may warrant the use of protected-only "left turn" phases, such as delay, visibility, distance of the intersection, and safety at the intersection (e.g., crash history).

Benefits of protected-only left turns include increasing left-turn capacity and mitigating intersection delays for vehicles turning left (Brehmer et al., 2003). The use of protected left turn phases also improves safety by removing conflicts during a left turn movement. This characteristic can be especially important on high speed roadways where the prevailing speed can contribute to the crash severity and may play a role in the difficulty a driver has with identifying and selecting a safe gap.

Even though protected/permissive left-turn phases are warranted under certain conditions, this strategy focuses on protected-only left turn phases due to the increased safety benefits that can occur at high speeds.

To help in the selection of the appropriate left turn phasing (permitted, protected-only, and protected/permitted), several website sources that provide additional information on left turn signal phasing include:

- http://www.webs1.uidaho.edu/niattproject/
- http://www.dot.state.mn.us/metro/trafficeng/dsg_crse/chap21.html#_Toc429824696

Additionally, refer to *NCHRP Synthesis 225,* "Left-Turn Treatments at Intersections," for additional guidance on the type of left-turn phase to use (Pline, 1996).

Because protected-only left turn phasing was already reviewed as part of Strategy 17.2 A1 in "A Guide for Reducing Collisions at Signalized Intersections" (*NCHRP Report 500, Volume 12*), that guide should be referenced for an in-depth discussion of left turn phasing.

Strategy E8—Install Lighting at High-Speed Intersections (High Speed Only) (T)

High speed roads with unlit or poorly lit intersections, as commonly found in rural highways, can pose a hazard to drivers. Lighting is desirable at intersections of high speed roadways to provide drivers with adequate vision of other vehicles and obstacles which may pose safety issues, such as sight distance limitations, at intersection approaches. Intersection lighting has not been proven to prevent speeding nor is it intended to be a speed reduction strategy, but providing adequate lighting at high speed intersections is a proactive approach to avoiding collisions where speeding may play a role, particularly during nighttime and adverse weather conditions.

Studies have found that the installation of lighting at intersections is effective in reducing nighttime collisions. This strategy aims at preventing collisions along high speed roads, particularly at rural intersections by providing lighting. Lack of adequate lighting at high speed intersections can increase exposure to high severity collisions.

Because intersection lighting is discussed in detail in Strategy 17.1 E2 in *NCHRP Report 500, Volume 5,* "A Guide for Addressing Unsignalized Intersection Collisions," Volume 5 should be referenced for an in-depth discussion of lighting intersections.

Strategy E9—Reduce Speeds and/or Volumes on Both Neighborhood and Downtown Streets with the Use of Traffic Calming and Other Related Countermeasures (Low Speed Only) (T)

When implemented appropriately, traffic calming can alleviate speeding problems on neighborhood roads and downtown arterials, as well as on an area-wide scale. Divertive measures can control vehicular volumes on neighborhood roads by restricting access, and forcing vehicles to use the arterial roadways. There are many different traffic calming techniques that can be used to control vehicle speeds and are appropriate for low speed roadways. Descriptions of these strategies are described in more depth in *NCHRP Report 500 Volume 10:* "A Guide for Reducing Collisions Involving Pedestrians." Traffic calming may be applied at intersections, mid-block, or even along entire segments of a corridor.

When the purpose of a traffic calming measure is to control speeds, the specific traffic control device implemented may need to be repeated along the corridor. Otherwise, the drop in vehicle speeds is likely to be isolated to the vicinity of the device. Speeding traffic through residential neighborhoods is often a concern with the residents living in the area, especially when the traffic is (or at least is perceived to be) cut-through traffic. Drivers may choose to cut through a neighborhood to avoid busy sections of urban arterials, possibly even to avoid a single intersection, or to avoid residential collectors with existing traffic calming. When drivers leave higher speed arterials for the low speed residential streets, they may be unwilling to slow down and drive at the posted speed limit in the residential area. A combination of speed and volume control measures can help mitigate neighborhood speeds through either physical traffic calming elements, or by divertive/restrictive measures, which force vehicles to use the arterial roadways.

Jurisdictions across the country have implemented traffic calming measures to discourage drivers from using neighborhood shortcuts, and some have even prohibited vehicles from turning into residential areas by partially closing intersections or prohibiting access during peak periods. The goal of these approaches has been to make the shortcut a less attractive option or not an option at all. In doing so, it is important to improve the attractiveness (i.e., improving the operations) of the arterial streets or urban road system intended to provide mobility. This may be accomplished through a variety of measures, including adding through lanes, removing unnecessary signals, improving signal timing, and coordinating signal systems. These changes may involve improving a small area, or even a single intersection. However, changes may need to be implemented across a large portion of a system if there is significant congestion. For example, at a signalized intersection where vehicles are often delayed for more than one cycle length, consideration could be given to increasing capacity through the intersection by providing an auxiliary lane in advance of the intersection, and continuing it for sufficient distance downstream of the intersection to allow vehicles to adjust their speeds and safely merge back to the original lane configuration. Such a treatment should be implemented only where it will be clearly understood, and not where it may cause confusion to drivers which may introduce additional safety concerns.

Area-wide traffic calming programs implement these measures on a larger scale. Such a program could include conversion of one-way streets to two-way, or two-way streets to one-way; narrowing lanes; and installation of vertical and horizontal speed control measures on collectors and/or local streets throughout the area. Such programs have been tried in several European countries and in Japan, with some success in reducing vehicle speeds.

For further guidance, the Institute of Transportation Engineers provides a report entitled, "A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility," which includes a section on potential solutions for application to urban arterials. Details of these solutions, including descriptions, implementation issues, benefits and costs, example applications, and references, are included in the document (Meyer, 1997).

The various traffic calming measures used to control speeds and volumes are described in Appendix 3, including those that mitigate speeds by altering vertical and horizontal paths of vehicles, as well as those that control volumes, especially along residential collectors, by diverting or restricting traffic. Some strategies are discussed in Exhibit V-20 of this guide.

EXHIBIT V-20
Strategy Attributes for Reducing Speeds and/or Volumes on Both Neighborhood and Downtown Streets with the Use of Traffic Calming and Other Related Countermeasures (T)

Attribute	Description
Technical Attributes	
Target	This strategy targets the use of traffic calming measures to mitigate speeding along low-speed roads, including low-speed neighborhood and downtown arterial streets. The strategy also seeks to divert cut-through traffic from local collector roads back onto arterial streets, primarily by the improvement of operations on the arterial streets.
Expected Effectiveness	The effectiveness for each of the different traffic calming devices is discussed in further detail in *NCHRP 500, Volume 10*, "A Guide for Reducing Collisions Involving Pedestrians."
Keys to Success	It is important that traffic calming devices be applied along the appropriate streets for which they are intended, primarily low-volume residential, and low-speed collector and arterial streets. It must be noted that it may be necessary to repeat a measure along the corridor to effectively reduce speeds along the entire corridor. To discourage diverting traffic to another street that may not be able to handle additional traffic, traffic calming measures can be applied area-wide. Additionally, a real key to the success of these measures is residential input and consensus. Traffic calming devices can be designed to incorporate the needs of cyclists by including bicycle lanes in the design. Problems for visually impaired pedestrians can be avoided by using standard traffic calming designs that incorporate textured surfaces. Traffic calming strategies should be designed to accommodate emergency response vehicles. Average fire truck emergency response time is predicted to increase by 2 seconds in calmed areas; this impact is considered too small to quantify.
Potential Difficulties	In general it must be kept in mind that though traffic calming can be an effective strategy for reducing speeds, it may not be the most appropriate solution for all situations. Certain traffic calming applications are best suited to arterial roadways, some to local, and some to both. Some drivers who are unfamiliar with traffic calming devices may be confused, and drivers who currently exceed the speed limit can be expected to be frustrated by traffic calming measures. These are both considered short-term effects that should wane with time.

EXHIBIT V-20 (Continued)
Strategy Attributes for Reducing Speeds and/or Volumes on Both Neighborhood and Downtown Streets with the Use of Traffic Calming and Other Related Countermeasures (T)

Attribute	Description
	Roundabouts, traffic circles, and curb extensions typically involve landscaping. This will require additional watering and maintenance. It is not recommended to use brick pavers or grass, in lieu of proper landscaping–particularly on roundabouts and traffic circles, as this does not enable the approaching driver to have proper visibility of the traffic calming device. 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 measures can help reduce litigation problems.
Appropriate Measures and Data	The primary measure of effectiveness is the reduction of motor vehicle speeds and the reduction of speeding-related crashes. This includes localized uses of the strategy, in small-scale applications such as residential neighborhoods, as well as on a larger scale, as in area-wide traffic calming measures. Motor vehicle speeds alone are also a useful measure. The impact on motorist delay is an operational measure of interest.
Associated Needs	When traffic calming measures are being considered in a neighborhood, the residents of the neighborhood must be involved in the decision-making process. This may require a program providing public information and education about the various devices, as well as their importance to neighborhood safety and livability. Affected residents should have the opportunity to provide input on the change, or reduction in access, to ensure that the tradeoffs will be acceptable.
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. These parties should 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. It may be necessary to create new policies to address inclusion of these stakeholders.
Issues Affecting Implementation Time	It can take up to 1 year or more to implement some of these traffic calming measures. This time reflects what is required for conducting the necessary engineering studies, as well as for deliberations and discussions with all affected parties. Design and construction of such measures can take place within a short period of time, as long as no additional right-of-way is needed. Speed humps or tables may be installed rather quickly, if or when consensus among residents exists. Traffic engineers often conduct engineering studies to determine whether one or more of these measures are warranted at a specific location. The process includes working with affected parties, including residents, businesses, schools, the local police and fire departments, and others to address their concerns. This public involvement process may take a significant amount of time, especially if the proposed traffic calming measures 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.

EXHIBIT V-20 (Continued)
Strategy Attributes for Reducing Speeds and/or Volumes on Both Neighborhood and Downtown Streets with the Use of Traffic Calming and Other Related Countermeasures (T)

Attribute	Description
Cost Involved	The costs for installing traffic calming devices will vary, depending upon the type of improvement and the local conditions, particularly if additional right-of-way is needed. For further details, see Appendix 4.
Training and Other Personnel Needs	Agency personnel should be adequately trained in the proper selection, design, and implementation of such traffic calming devices. Training in consensus building and public involvement will also be helpful.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with the others discussed in this guide.
Other Key Attributes to a Particular Strategy	None identified.

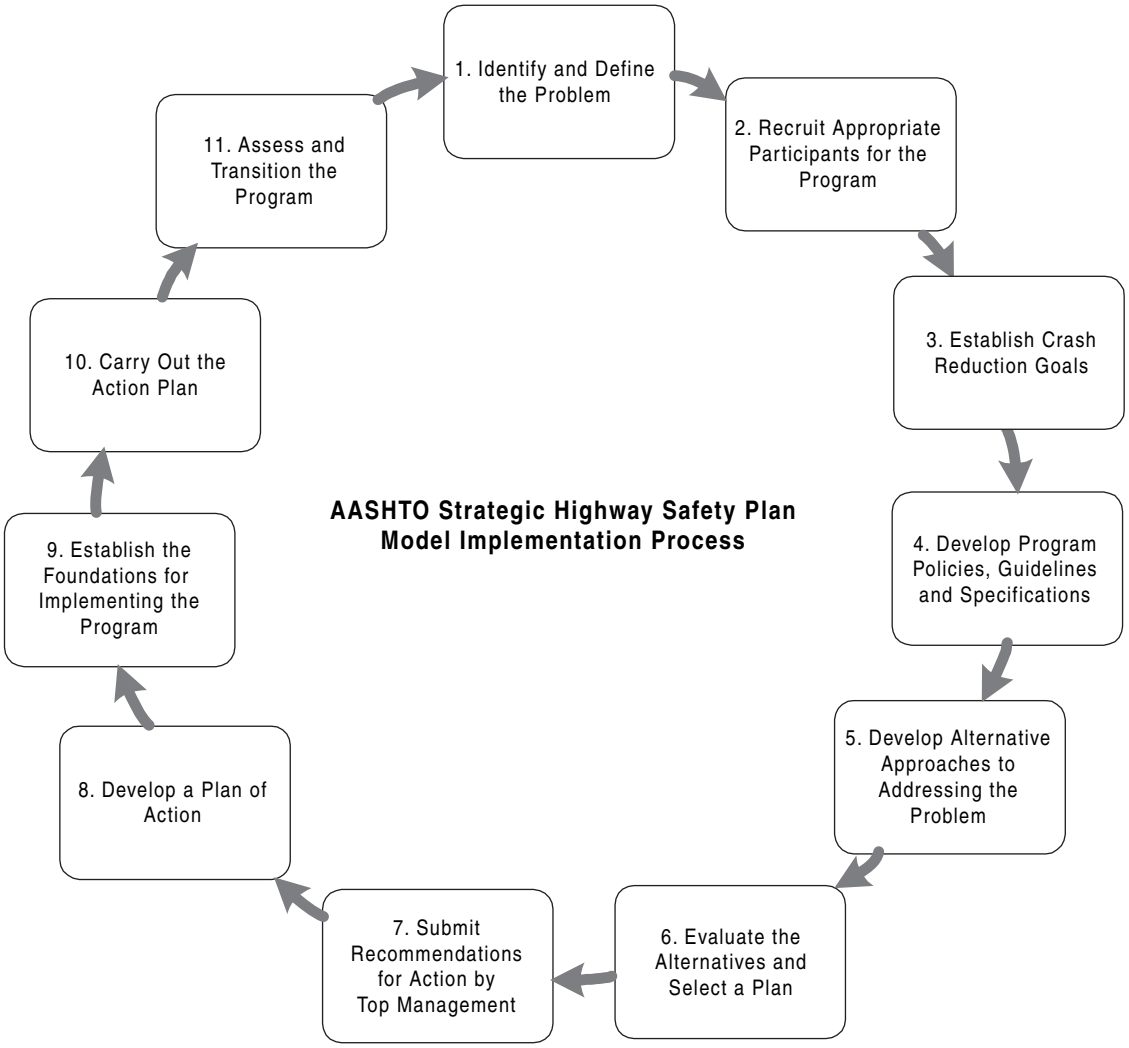
SECTION VI

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/reports/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 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 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/chhs/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://www.tc.gc.ca/finance/bca/en/Printable_e.htm.

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 are 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://safety.transportation.org.

1 International Automated Speed Enforcement
2 Race Legal
3 Safe Speed Transitions
4 Traffic Calming

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
S Comparisons of Benefit-Cost and Cost-Effectiveness Analysis
T Issues in Cost-Benefit and Cost-Effectiveness Analyses
U Transport Canada Recommended Structure for a Benefit-Cost Analysis Report
V Overall Summary of Benefit-Cost Analysis Guide from Transport Canada
W Program Evaluation—Its Purpose and Nature
X Traffic Safety Plan for a Small Department
Y Sample District-Level Crash Statistical Summary
Z Sample Intersection Crash Summaries
AA Sample Intersection Collision Diagram
BB Example Application of the Unsignalized Intersection Guide

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
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	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
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
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation