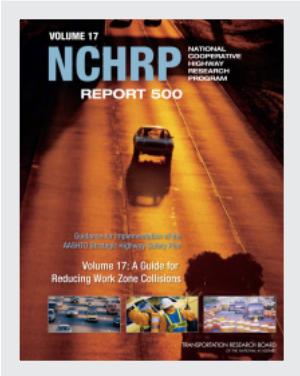


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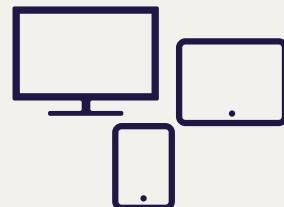
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 500

**Guidance for Implementation of the
AASHTO Strategic Highway Safety Plan**

***Volume 17: A Guide for
Reducing Work Zone Collisions***

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SUBJECT AREAS
Safety and Human Performance

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2005
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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FOREWORD

By Charles W. Niessner
Staff Officer
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Board

The goal of the AASHTO Strategic Highway Safety Plan is to reduce annual highway fatalities to 1.0 fatality per 100 million vehicle-miles of travel. 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 seventeenth volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* provides strategies that can be employed to reduce work zone crashes. The report will be of particular interest to safety practitioners with responsibility for implementing programs to reduce injuries and fatalities on the highway system.

In 1998, AASHTO approved its Strategic Highway Safety Plan, which was developed by the AASHTO Standing Committee for Highway Traffic Safety with the assistance of the Federal Highway Administration, the National Highway Traffic Safety Administration, and the Transportation Research Board Committee on Transportation Safety Management. The plan includes strategies in 22 key emphasis areas that affect highway safety. The plan's goal is to reduce the annual number of highway deaths by 9,000 by 2008. 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 seventeenth 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 and 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.

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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 Kevin Slack of CH2M HILL and Ron Pfefer. Timothy Neuman of CH2M HILL served as the overall project director for the team. Kelly Hardy, also of CH2M HILL, served as a technical specialist on the development of the guides.

The project team was organized around the specialized technical content contained in each guide, and the overall team included nationally recognized experts from many organizations. The following team of experts, selected on the basis of their knowledge of work zones, served as lead authors for the work zone guide:

- Nicholas D. Antonucci
CH2M HILL
- Kelly K. Hardy
CH2M HILL
- James E. Bryden
Highway Safety Engineer

Development of the volumes of *NCHRP Report 500* used 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 by providing material, participating in workshops and meetings, and providing input and comments during the development of the work zone guide:

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SECTION I

Summary

Introduction

The driving conditions of work zones differ from normal driving conditions. In addition, the driving conditions of each type of work zone (short-term, long-term, etc.) may differ from those of another type of work zone. These factors can result in violations of road user expectancy, which in turn can lead to congestion, erratic maneuvers, and ultimately crashes. Lack of driver knowledge of appropriate work zone driving actions, failure to obey traffic laws, and lack of awareness of work zones and/or workers also detract from work zone safety. As more and more of the nation's infrastructure reaches the end of its life cycle and fewer new roadways are constructed, work zones are becoming more and more prevalent on our roadways. This increased exposure to work zones increases opportunities for crashes to occur. Strategies that address all of these issues are presented and discussed in Section V.

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 will ultimately cover 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 coordination, 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 ever more apparent.

The goal of the SHSP is to move away from *independent* activities of engineers, law enforcement, educators, judges, and other highway-safety specialists and toward the *coordinated* formation of working groups and alliances that represent all of the elements of the safety system. In so doing, people 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. One of these goals addresses the improvement of safety in work zones. This implementation guide provides guidance to highway agencies that desire to implement safety improvements in work zones. It includes a variety of strategies that may be applicable to specific work zones or to agency procedures.

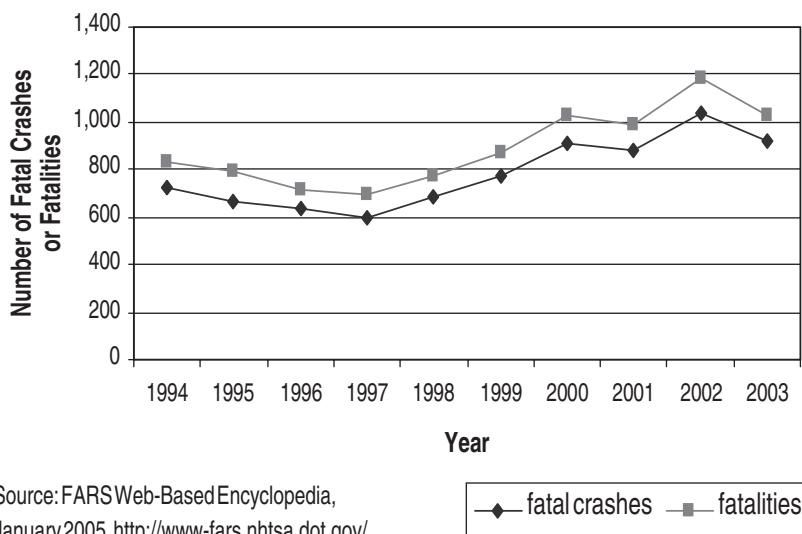
General Description of the Problem

In 2003, there were 919 fatal crashes (1,028 fatalities) and more than 40,000 persons injured in work zone crashes on America's highways (Fatal Accident Reporting System, or FARS, January 2005). Exhibit I-1 displays a trend of increasing deaths attributed to work zones from 1994 to 2003. During this timeframe, anecdotal evidence suggests that the number of

SECTION I—SUMMARY

EXHIBIT I-1

Number of Work Zone Fatal Crashes and Fatalities, 1994–2003



work zones have increased, although no definitive evidence or study encompasses all types of work zones. As more and more of the nation's infrastructure reaches the end of its life cycle, work zones are expected to remain a familiar sight on our roadways.

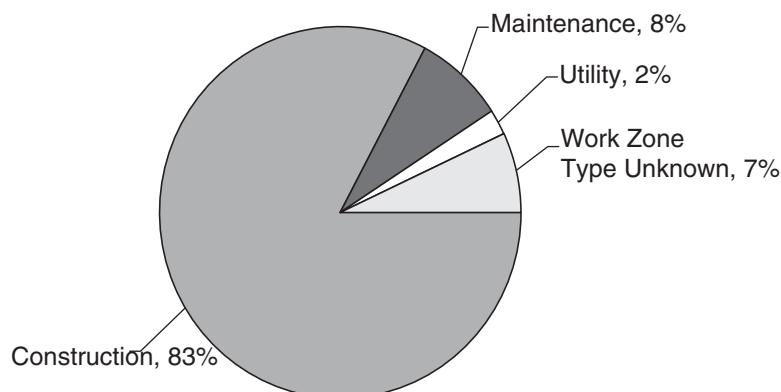
Exhibit I-2 shows the types of work zones in which fatal crashes occurred in 2003. The preponderance of crashes occurred in long-term construction zones. Issues faced may vary by type of work zone, but safety improvements for all types of work zones are considered in the strategies discussed in Section V.

A review of FARS data for 2003 yields additional insights into fatal crash characteristics in work zones:

- More than half of all fatal work zone crashes occurred during the day.
- More than twice as many work zone fatal crashes occurred on weekdays as on weekends.

EXHIBIT I-2

Work Zone Fatal Crashes by Work Zone Type in 2003



Source: FARS Web-Based Encyclopedia, January 2005 <http://www-fars.nhtsa.dot.gov/>

- Fatal work zone crashes occurred most often during the summer months.
- Almost 30 percent of fatal work zone crashes occurred on Interstate roadways.
- Almost 60 percent of fatal work zone crashes occurred on roads with a posted speed limit of 55 mph or greater.
- Single-vehicle crashes accounted for over half of all fatal work zone crashes.
- Rear-end fatal crashes were 25 times more common in work zones relative to all fatal crashes.
- Ten percent of work zone fatalities were pedestrians and bicyclists.
- Heavy trucks were involved in more than 20 percent of fatal work zone crashes.
- Alcohol was involved in almost 40 percent of fatal work zone crashes.

In addition to the trends identified in FARS, an American Road and Transportation Builders Association (ARTBA) review of federal data from the Bureau of Labor Statistics indicates that roadway construction workers are killed at a rate nearly three times higher than other construction workers and eight times higher than general industry workers.

Objectives of the Emphasis Area

The work zone safety experiences described above are the basis for the inclusion of the strategies discussed in Section V. The strategies are grouped by objective (i.e., safety concern). The objectives for improving work zone safety are explained below. Exhibit I-3 lists the objectives and the related strategies discussed in this guide. The strategies span the full range of engineering, enforcement, and education:

- 19.1 A Reduce the number, duration, and impact of work zones—Reducing the exposure of travelers to work zones and of workers to traffic will decrease the opportunities for crashes to occur. This exposure can be reduced by using maintenance and construction practices that increase pavement and bridge service life, accelerating construction and maintenance activities when they are needed, scheduling highway work to avoid periods of high traffic volumes, and providing adequate space for future road work in new project development.
- 19.1 B Improve work zone traffic control devices—Since work zones often present a higher driver-information and vehicular-control workload than nonwork areas present, the devices used to convey information to drivers and to alert them to the presence of workers and potential roadway hazards need to be visible and to have a clear and consistent meaning. Visibility of workers (especially flaggers) and their vehicles are necessary for the protection of both workers and highway users.
- 19.1 C Improve work zone design practices—Addressing safety for highway users and workers in the planning stages of a project can reduce the potential for crashes related to the work zone. Establishing work zone design guidance, including providing consistent design features across a jurisdiction, provides highway users with an environment that better meets their expectations. Positive separation between the traffic space and the work space can help reduce potential for conflicts between road users and/or workers. Consideration of all road users in the design of work zones can help improve safety for all users by providing cues to and accommodation of both motorized vehicles and nonmotorized travelers.

SECTION I—SUMMARY

- **19.1 D Improve driver compliance with work zone traffic controls**—Many crashes are caused or aggravated by drivers' noncompliance with traffic control devices or traffic laws in work zones. Enforcement campaigns (conventional or automated) have the potential to reduce undesirable driver behavior and improve safety in work zones. Signs that convey credible messages regarding speed limits or presence of workers contribute to driver compliance with traffic laws.
- **19.1 E Increase knowledge and awareness of work zones**—Training of highway users, designers, and workers can improve how work zones are designed, set up, and used. Public information and education campaigns can help improve driver skills in guiding vehicles through work zones. Training programs for agency staff and workers can help ensure that traffic control devices designed and set up in work zones are appropriate and provide positive guidance, rather than create additional clutter and driver confusion.
- **19.1 F Develop procedures to effectively manage work zones**—Work zone management practices, such as crash data system improvements, safety awards, interagency coordination, and inspections, can help bring about an improvement in work zone safety at an agency level.

EXHIBIT I-3
Emphasis Area Objectives and Strategies

Objectives	Strategies
19.1 A Reduce the number, duration, and impact of work zones	19.1 A1 Improve maintenance and construction practices (P) 19.1 A2 Utilize full-time roadway closure for construction operations (T) 19.1 A3 Utilize time-related contract provisions (P) 19.1 A4 Use nighttime road work (P) 19.1 A5 Use demand management programs to reduce volumes through work zones (P) 19.1 A6 Design future work zone capacity into new or reconstructed highways (T)
19.1 B Improve work zone traffic control devices	19.1 B1 Implement ITS strategies to improve safety (E) 19.1 B2 Improve visibility of work zone traffic control devices (T) 19.1 B3 Improve visibility of work zone personnel and vehicles (varies) 19.1 B4 Reduce flaggers' exposure to traffic (T)
19.1 C Improve work zone design practices	19.1 C1 Establish work zone design guidance (T) 19.1 C2 Implement measures to reduce work space intrusions (and limit consequences of intrusions) (T) 19.1 C3 Improve work zone safety for pedestrians, bicyclists, motorcyclists, and heavy-truck drivers (T)

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

Objectives	Strategies
19.1 D Improve driver compliance with work zone traffic controls	19.1 D1 Enhance enforcement of traffic laws in work zones (T) 19.1 D2 Improve credibility of signs (E) 19.1 D3 Improve application of increased driver penalties in work zones (T)
19.1 E Increase knowledge and awareness of work zones	19.1 E1 Disseminate work zone safety information to road users (T) 19.1 E2 Provide work zone training programs and manuals for designers and field staff (T)
19.1 F Develop procedures to effectively manage work zones	19.1 F1 Develop or enhance agency-level work zone crash data systems (T) 19.1 F2 Improve coordination, planning, and scheduling of work activities (T) 19.1 F3 Use incentives to create and operate safer work zones (T) 19.1 F4 Implement work zone quality assurance procedures (i.e., safety inspections or audits) (T)

(P) = proven; (T) = tried; and (E) = experimental. A detailed explanation of (P), (T), and (E) appears in Section V. Several strategies have substrategies with different ratings.

SECTION II

Introduction

Given the emphasis on maintaining and reconstructing existing infrastructure, the issue of work zone safety has become more prominent in recent years. Maintaining efficient and safe movement of traffic through work zones is a major challenge. Work zones, by their nature, require more attention than normal driving conditions because motorists are placed in special situations not encountered elsewhere on the roadway system. Work zone safety is an issue impacting motorists, other roadway users, and workers equally across all roadway types, regardless of the time of year, day of week, or time of day. In 2003, 1,028 people lost their lives in work zones on America's highways, and more than 40,000 others were injured. The strategies discussed in this guide focus on reducing fatalities in work zones, but their implementation will undoubtedly result in an overall reduction in work zone crashes.

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 will ultimately cover various aspects of the road user, the highway, the vehicle, the environment, and the management system. The guides strongly encourage the reader to develop a program to deal with a particular emphasis area from each of these perspectives in a coordinated manner. To facilitate this coordination, the electronic form of the material uses hypertext linkages to allow seamless integration of various approaches to a given problem.

The goal is to move away from *independent* activities of engineers, law enforcement, educators, judges, and other highway-safety specialists and toward a *coordinated* effort. The implementation process outlined in the guides (Section VI) promotes the formation of working groups and alliances that represent all of the elements of the safety system. The groups 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.

Many of the strategies discussed in this guide relate primarily to engineering. However, it is important to consider the need to involve stakeholders and other safety professionals who either will be directly involved or can provide additional perspectives and expertise for implementing planned strategies. In some cases, implementing the strategy will directly impact operations on the highway. In such cases, many elements of the roadway community and the safety community as a whole (e.g., law enforcement, emergency medical services [EMS], fire departments, utility companies, contractors, media, and adjacent land users and owners) are best involved at the earliest project planning stages.

The six major areas of the AASHTO SHSP (Drivers, Vehicles, Special Users, Highways, Emergency Medical Services, and Management) are subdivided into 22 goals that impact highway safety. Goal 19 addresses work zone safety issues. This guide provides direction to highway agencies to assist them in implementing safety improvements in highway work zones. Strategies discussed are intended to apply to a full range of highway functional classifications and work zone traffic control methods.

SECTION III

Type of Problem Being Addressed

General Description of the Problem

The safe and efficient flow of traffic through work zones is a high priority for transportation officials and the motoring public. In a recent survey, work zones were cited as second to poor traffic flow in causing dissatisfaction with roadway facilities (Keever et al., 2001). Exhibit III-1 indicates that work zones are estimated to contribute to 10 percent of the congestion in the United States. This is a rough estimate based upon a variety of congestion research sources. Although mobility may be the issue most often associated with work zones, mobility and safety are linked. The Federal Highway Administration has stated that as congestion builds within and approaching work zones, crash rates increase (FHWA, 1998).

In 2003, there were 919 fatal crashes (1,028 fatalities) and more than 40,000 persons injured in work zone crashes on America's highways (FARS, 2005). Exhibit III-2 displays a trend of increasing deaths attributed to work zones over the last 7 years. During this timeframe, anecdotal evidence suggests that the number of work zones have increased, although no definitive evidence or study encompasses all types of work zones. As more and more of the nation's infrastructure reaches the end of its life cycle, work zones are expected to remain a familiar sight on our roadways.

Exhibit III-3 shows the distribution of work zone types in which fatal crashes occurred in 2003. The preponderance of crashes occurred in long-term construction zones. Issues faced by drivers may vary by type of work zone, and safety improvements for all types of work zones are considered in the strategies discussed in Section V. Despite the large number of reported work zone fatalities, there is a general sense that the scope of the problem may be much worse, as there are many inconsistencies in defining and reporting work zone crashes from state to state.

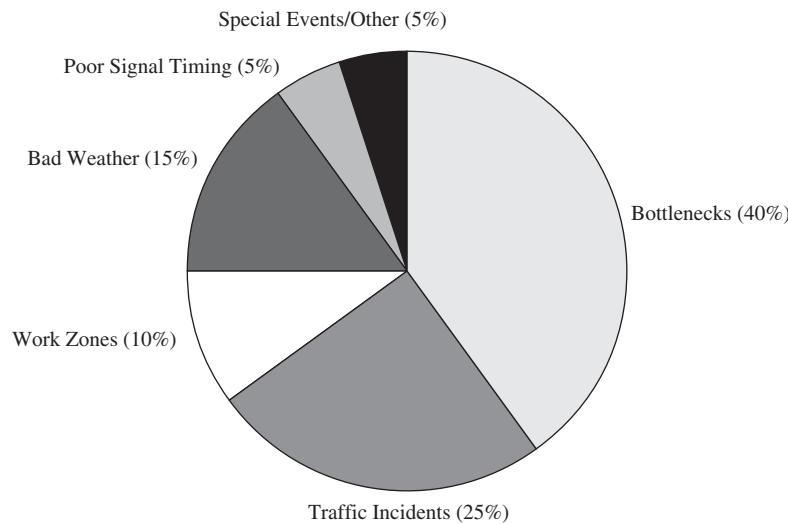
The safety of roadway construction workers in work zones is also of primary importance. According to an American Road and Transportation Builders Association (ARTBA) review of federal data from the Bureau of Labor Statistics, roadway construction workers are killed at a rate nearly three times as high as other construction workers and eight times as high as general industry workers. The fatality rate for roadway construction workers is 32 people for every 100,000 workers. By comparison, the rate for all construction is about 13 people per 100,000 workers, and the general industry rate is about 4 people per 100,000 workers (ARTBA, 2004).

The need for continued emphasis on work zone safety becomes more apparent because of the current emphasis on system preservation rather than construction of new facilities. Funding patterns support this point, as the U.S. Department of Transportation reports that the share of transportation capital funds used for system preservation rose from 47.6 percent in 1997 to 52.0 percent in 2000, and this percentage increase is expected to continue.

SECTION III—TYPE OF PROBLEM BEING ADDRESSED

EXHIBIT III-1

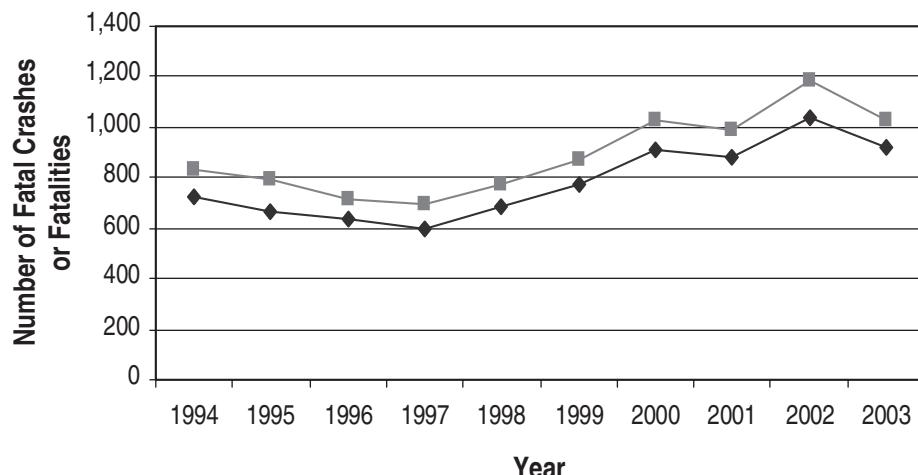
Sources of Congestion

Traffic Congestion and Reliability, 2004

System preservation—reconstruction of an existing roadway—is inherently more risky for both construction workers and roadway users than construction on new alignment. The prevalence of work zones on the roadway network may be best described by Wunderlich and Hardesty (2003), who report that about 20 percent of the National Highway System is under construction each year during the peak summer road work season, with the total number of highway work zones estimated to be more than 6,400. This study collected project information posted on agency websites, and these websites would most likely list only large projects rather than a complete list of all projects. Had

EXHIBIT III-2

Number of Work Zone Fatal Crashes and Fatalities, 1994–2003

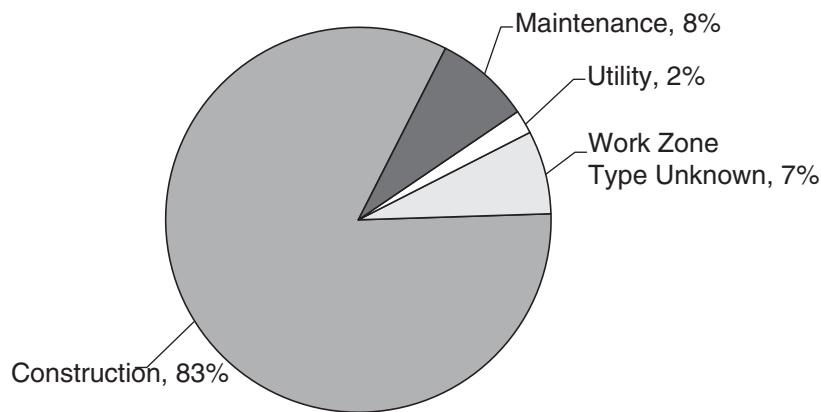


Source: FARS Web-Based Encyclopedia, January 2005, <http://www-fars.nhtsa.dot.gov/>

◆ fatal crashes ■ fatalities

EXHIBIT III-3

Work Zone Fatal Crashes by Work Zone Type in 2003



Source: FARS Web-Based Encyclopedia,
January 2005 <http://www-fars.nhtsa.dot.gov/>

the websites listed all projects, the types of work zones would be much more numerous, especially considering the presence of short-term work zones, including utility, maintenance, and emergency activities.

Specific Attributes of the Problem

Data from the Fatal Accident Reporting System (FARS) were reviewed in an attempt to characterize differences between work zone crashes and non-work zone crashes. Exhibit III-4 compares several factors that relate to work zone and non-work zone fatal crashes.

Based on a review of the above table, a few general statements can be made about the nature of work zones and their affect on traffic fatalities in 2003:

- More than half of all fatal work zone crashes occurred during the day. According to Wunderlich and Hardesty (2003), approximately 22 percent of the work zones that they found listed on agency websites were designated for night work, and two-thirds of all resurfacing and paving activity took place at night.
- More than twice as many work zone fatal crashes occurred on weekdays as on weekends.
- Fatal work zone crashes occurred most often during the summer months, followed by the fall and spring months, presumably when the majority of construction activities are taking place in large portions of the country.
- Almost 30 percent of work zone fatal crashes occurred on either urban or rural Interstates. Overall, slightly more fatal crashes occurred in rural work zones than in urban work zones.
- Almost 60 percent of work zone fatal crashes occurred on roads with a posted speed limit of 55 mph or greater.

SECTION III—TYPE OF PROBLEM BEING ADDRESSED**EXHIBIT III-4**

Comparison of Factors: Percentages of Work Zone and Non–Work Zone Fatal Crashes
Data from FARS (2003)

Factor	All Fatal Crashes	Work Zone Fatal Crashes
<i>Time of day</i>		
Night	49	47
Day	50	52
Unknown	1	1
<i>Day of week</i>		
Weekend	34	31
Weekday	66	69
<i>Season</i>		
Winter	22	16
Spring	24	26
Summer	27	31
Autumn	27	27
<i>Roadway function</i>		
Rural, Interstate	7	13
Rural, other	51	39
Urban, Interstate	6	15
Urban, other	35	32
Unknown	1	1
<i>Speed limit</i>		
1–50 mph	44	38
55–75 mph	52	58
Unknown	4	4
<i>Number of vehicles involved</i>		
One	57	53
Two	36	35
More than two	7	12
<i>Manner of two-vehicle collision</i>		
Rear-end	13	35
Head-on	26	21
Angle	32	22
Side-swipe, opposite direction	21	15
Side-swipe, same direction	6	7
Other or unknown	2	0

- Single-vehicle crashes accounted for more than half of all work zone fatal crashes.
- Rear-end fatal crashes were about 2.7 times as common in work zones as in all fatal crashes.

Other points regarding work zone safety include the following:

- Ninety percent of work zone fatal crashes involved vehicle drivers or occupants. Approximately 10 percent were pedestrians and bicyclists (FARS, 2003).
- Heavy trucks were involved in more than 20 percent of fatal work zone crashes (FMCSA, 2004).
- Alcohol was involved in 39 percent of fatal work zone crashes in 2003 (National Work Zone Safety Information Clearinghouse, <http://wzsafety.tamu.edu/index.stm>).

A broad range of engineering enforcement, education, and agency policy strategies are available (and discussed in Section V) and the potential to significantly improve work zone safety for workers, motorists, and other highway users. These safety strategies also link to guides in the *NCHRP Report 500* series already developed (or being developed) to address other priority areas in the SHSP.

Key References

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SECTION III—TYPE OF PROBLEM BEING ADDRESSED

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SECTION IV

Index of Strategies by Implementation Timeframe and Relative Cost

Exhibit IV-1 classifies strategies according to the expected timeframe required for implementation and the relative cost to implement and operate each strategy for this emphasis area. In several cases, the implementation time will depend 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 vary somewhat for some of these strategies because of 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 costs of the strategies are estimated on a project level. For programwide strategies, the costs are considered to be spread over multiple projects, as would realistically be the case for many of the strategies discussed in this guide.

EXHIBIT IV-1

Classification of Strategies According to Expected Timeframe and Relative Cost

Timeframe for Implementation	Strategy	Relative Cost to Implement and Operate			
		Low	Moderate	Moderate to High	High
Short (<1 year)	19.1 B2—Improve visibility of work zone traffic control devices			✓	
	19.1 B3—Improve visibility of work zone personnel and vehicles		✓		
	19.1 B4—Reduce flaggers' exposure to traffic		✓		
	19.1 C2—Implement measures to reduce work space intrusions (and limit consequences of intrusions)				✓
	19.1 D1—Enhance enforcement of traffic laws in work zones			✓	
	19.1 D2—Improve credibility of signs		✓		
	19.1 E1—Disseminate work zone safety information to road users			✓	
	19.1 E2—Provide work zone training programs and manuals for designers and field staff		✓		
	19.1 F4—Implement work zone quality assurance procedures (i.e., safety inspections or audits)			✓	

SECTION IV—INDEX OF STRATEGIES BY IMPLEMENTATION TIMEFRAME AND RELATIVE COST

EXHIBIT IV-1 (Continued)

Classification of Strategies According to Expected Timeframe and Relative Cost

Timeframe for Implementation	Strategy	Relative Cost to Implement and Operate			
		Low	Moderate	Moderate to High	High
Medium (1–2 years)	19.1 A1—Improve maintenance and construction practices			✓	
	19.1 A2—Utilize full-time roadway closure for construction operations*		✓		
	19.1 A3—Utilize time-related contract provisions			✓	
	19.1 A4—Use nighttime road work		✓		
	19.1 A5—Use demand management programs to reduce volumes through work zones			✓	
	19.1 B1—Implement ITS strategies to improve safety			✓	
	19.1 C1—Establish work zone design guidance		✓		
	19.1 C3—Improve work zone safety for pedestrians, bicyclists, motorcyclists, and heavy-truck drivers			✓	
	19.1 D3—Improve application of increased driver penalties in work zones	✓			
	19.1 F1—Develop or enhance agency-level work zone crash data systems		✓		
Long (>2 years)	19.1 F2—Improve coordination, planning, and scheduling of work activities		✓		
	19.1 F3—Use incentives to create and operate safer work zones		✓		
Long (>2 years)	19.1 A6—Design future work zone capacity into new or reconstructed highways			✓	

* Costs of improvements on parallel routes may be significant.

SECTION V

Description of Strategies

Objectives

The main goals of this guide are to reduce fatal work zone traffic crashes and to improve the overall work zone traffic safety for workers, motorists, and other highway users.

Specific objectives include improvements in work zone engineering practices; enforcement of traffic laws and regulations; education of drivers, designers, and highway workers; and improvement of agency policies and procedures. The objectives for improving safety in work zones are as follows:

- **19.1 A Reduce the number, duration, and impact of work zones**—Reducing the exposure of travelers to work zones and of workers to traffic will lessen the opportunities for crashes to occur. This can be accomplished using maintenance and construction practices that increase pavement and bridge service life, accelerate construction and maintenance activities where possible, schedule highway work to avoid periods of high traffic volumes, and provide adequate space for future road work in new project development.
- **19.1 B Improve work zone traffic control devices**—Work zones often present a higher driver-information and vehicular-control workload than nonwork zones. The devices used to convey information to drivers and to alert them to the presence of workers and potential roadway hazards need to be visible and have a clear and consistent meaning. Visibility of workers (especially flaggers) and their vehicles is necessary for the protection of both workers and highway users.
- **19.1 C Improve work zone design practices**—Addressing safety for both highway users and workers in the planning stages of a project can help reduce the potential for crashes related to the work zone. Establishing work zone design guidance, including providing consistent design features across a jurisdiction, provides highway users with an environment that better meets their expectations. Positive protection of the work space from the traffic separation can help reduce potential for conflicts between road users and/or workers. The design of work zones can help improve safety for all users by providing cues for, and accommodation of, both motorized vehicles and nonmotorized travelers.
- **19.1 D Improve driver compliance with work zone traffic controls**—Many crashes are caused or aggravated by drivers' noncompliance with traffic control devices or traffic laws in work zones. Enforcement campaigns (conventional or automated) have the potential to reduce undesirable driver behavior and improve safety in work zones. Signs that convey credible messages regarding speed limits or presence of workers contribute to driver compliance with traffic laws.
- **19.1 E Increase knowledge and awareness of work zones**—Training of highway users, designers, and workers can improve how work zones are designed, set up, and used. Public information and education campaigns can help improve driver skills in guiding vehicles through work zones. Training programs for agency staff and workers can help

SECTION V—DESCRIPTION OF STRATEGIES

ensure that traffic control devices designed and set up in work zones are appropriate and provide positive guidance, rather than create additional clutter and driver confusion.

- **19.1 F Develop procedures to effectively manage work zones**—Work zone management practices, such as crash data system improvements, safety awards, interagency coordination, and inspections, can help bring about an improvement in work zone safety at an agency level.

Exhibit V-1 shows the strategies of these objectives. The order in which the strategies appear does not imply a priority with which they should be considered. Ultimately, the goal toward which the objectives and strategies are directed is to improve work zone safety for road users and workers.

Most of the strategies are relatively low-cost, short-term treatments to improve safety in work zones, consistent with the focus of the entire SHSP. For each of these strategies, a detailed discussion of the attributes, effectiveness, and other key factors describing the strategy is presented below. Several high-cost, long-term strategies that have been proven effective in improving safety in work zones are also presented in this section, but in less detail. While application of these strategies is outside the implementation framework of the SHSP, inclusion of these strategies in this guide serves to complete the picture of proven, tried, and experimental strategies to improve safety in work zones.

EXHIBIT V-1
Emphasis Area Objectives and Strategies

Objectives	Strategies
19.1 A Reduce the number, duration, and impact of work zones	19.1 A1 Improve maintenance and construction practices (P) 19.1 A2 Utilize full-time roadway closure for construction operations (T) 19.1 A3 Utilize time-related contract provisions (P) 19.1 A4 Use nighttime road work (P) 19.1 A5 Use demand management programs to reduce volumes through work zones (P) 19.1 A6 Design future work zone capacity into new or reconstructed highways (T)
19.1 B Improve work zone traffic control devices	19.1 B1 Implement ITS strategies to improve safety (E) 19.1 B2 Improve visibility of work zone traffic control devices (T) 19.1 B3 Improve visibility of work zone personnel and vehicles (varies) 19.1 B4 Reduce flaggers' exposure to traffic (T)
19.1 C Improve work zone design practices	19.1 C1 Establish work zone design guidance (T) 19.1 C2 Implement measures to reduce work space intrusions (and limit consequences of intrusions) (T) 19.1 C3 Improve work zone safety for pedestrians, bicyclists, motorcyclists, and heavy-truck drivers (T)

EXHIBIT V-1 (Continued)
Emphasis Area Objectives and Strategies

Objectives	Strategies
19.1 D Improve driver compliance with work zone traffic controls	19.1 D1 Enhance enforcement of traffic laws in work zones (T) 19.1 D2 Improve credibility of signs (E) 19.1 D3 Improve application of increased driver penalties in work zones (T)
19.1 E Increase knowledge and awareness of work zones	19.1 E1 Disseminate work zone safety information to road users (T) 19.1 E2 Provide work zone training programs and manuals for designers and field staff (T)
19.1 F Develop procedures to effectively manage work zones	19.1 F1 Develop or enhance agency-level work zone crash data systems (T) 19.1 F2 Improve coordination, planning, and scheduling of work activities (T) 19.1 F3 Use incentives to create and operate safer work zones (T) 19.1 F4 Implement work zone quality assurance procedures (i.e., safety inspections or audits) (T)

(P) = proven; (T) = tried; (E) = experimental. An explanation of (P), (T), and (E) appears below. Several strategies have substrategies with different ratings.

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. Some strategies have been subjected to well-designed evaluations to prove their effectiveness, while other 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 that show the strategies 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 user make judgments about which strategies 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 been found no valid evaluations. These strategies, while in frequent or even general use,

SECTION V—DESCRIPTION OF STRATEGIES

should be applied with caution, carefully considering the attributes cited in the guide and relating these attributes to the specific conditions for which the strategies 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 SHSP, 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 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 considered unique to work zones or are discussed in terms of their attributes specific to work zones. To create a truly comprehensive approach to the highway safety problems associated with work zones, 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 (PI&E) Campaigns**—Many highway safety programs can be effectively enhanced with a properly designed PI&E campaign, which includes coordination with media outlets. The primary goal of PI&E campaigns in highway safety is usually 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 work zone in a corridor with a history of severe crashes. While this approach is relatively untried compared with areawide 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 work zone 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 crashes and their severity is to have jurisdictionwide 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. Enforcement of traffic laws 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 areawide or jurisdictionwide. 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 times, that other strategy is 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 work zones, 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 in which an individual spends 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 improvements can be made in how emergency medical services interact with work zones, 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, and so forth 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

SECTION V—DESCRIPTION OF STRATEGIES

for 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, apply to other emphasis areas, too. 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, treatments for work zones would improve safety for pedestrians, bicyclists, and older drivers. Any program targeted at the safety problem covered in this guide on work zones should be created with consideration given to potentially appropriate strategies in these other guides.

Objective 19.1 A—Reduce the Number, Duration, and Impact of Work Zones

The fewer times motorists encounter work zones, the fewer chances there are for work-zone-related crashes to occur. Reducing the number of work zones, the length of time during which work zones are set up, and the adverse impacts that work zones have on traffic will reduce the exposure of road users and workers to crashes. In that vein, strategies in this objective that are known to reduce traffic volumes through work zones are classified as “proven,” since the lower volume is expected to result in a lower crash experience.

Safety practitioners can reduce exposure to crashes by also using innovative practices to accelerate completion of construction and maintenance projects and bidding practices that strive to reduce the duration and impact of crashes on traffic. In addition, satisfactory safety records on previous projects may be a suitable criterion for contractors in the selection process.

The impacts of the various types of work zone traffic control plans on traffic operations should be thoroughly reviewed while planning the construction project and setting up the work zone. Decisions about what time of day that work will be performed and how traffic will be maintained through a work zone should be made with thorough knowledge of the traffic impacts that a particular alternative may have.

19.1 A1—Improve Maintenance and Construction Practices (P)

This strategy includes the following:

- Accelerating construction
- Better management of assets, including improving pavement maintenance
- Rehabilitation practices

General Description

Transportation entities are continually seeking innovative methods to design and construct their projects to be more efficient and to have less impact on the motoring public. While traditional methods can still be effective in certain applications, a number of new

practices can provide the same services in less time and for less money while reducing the duration of work zones and the exposure of workers to vehicle traffic. These new practices, however, are not without potential difficulties. While they certainly have the ability to add tremendous value to current construction practices, they also often come with greater bid cost. Planning and coordination among highway agencies, contractors, and other organizations involved in construction and highway safety can help reduce these risks.

Major areas of improvement are being targeted, including methods to accelerate construction and to improve management of assets (including pavement maintenance and rehabilitation). These areas of improvement have varying degrees of benefit, as well as varying degrees of risk. It is ultimately up to each individual transportation agency to determine which areas could be beneficial to its respective programs. A brief description of these methods is provided below:

- **Accelerated construction.** Accelerated construction techniques are being used more frequently across the country. The various methods of accelerated construction allow agencies the opportunity to do more construction in the same amount of time or less. Examples include prefabricated concrete elements and rapid-set or super-plasticized concrete. Accelerated construction techniques are applied for critical and/or high-volume facilities for which the societal costs of closure or loss of mobility are considered significant.
- **Better asset management.** Limited budgets and increased traffic volumes (resulting in increased difficulty in closing roadways or lanes for road work) lead highway agencies to improve management of their assets. The goal is to monitor the condition of roadway infrastructure elements so as to appropriately schedule improvement projects. This includes pavement management, described below, but also management of all roadway infrastructure elements so as to extend life cycles and increase the length of time between work zone setups on the same section of roadway. Better tracking of the condition of infrastructure elements allows agencies to cost-effectively target elements for preventative maintenance as well.

Improving pavement maintenance and rehabilitation is critically important to all agencies managing roadways because most agencies have an extremely large number of miles of pavement to manage. A pavement management program can help manage the tradeoff between minor pavement maintenance that can extend the life of a pavement and larger-scale repaving projects that would otherwise need to be performed more frequently. Developing and maintaining a system to consistently monitor the pavement conditions across the respective jurisdictions requires an efficient, well-coordinated plan. The goal is to schedule rehabilitation efforts to avoid rehabilitation that is either too early or too late, thereby reducing the number of times that maintenance will be performed on a section of highway and reducing exposure of road users and workers to work zone conditions.

Accelerated construction and better asset management may not initially be thought of as safety strategies. However, to the extent that they achieve the objective of reducing time exposure of workers and drivers to work zones, they clearly can be thought of as core strategies in promoting overall work zone safety.

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-2

Strategy Attributes for Improving Maintenance and Construction Practices (P)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>Improvement of maintenance and construction practices targets all types of work zone crashes by reducing traffic exposure to work zones. This is done by shortening the duration of the work or increasing the life of a roadway (and therefore reducing the frequency of maintenance and rehabilitation or replacement work). The strategy is aimed at improving existing practices, specifically methods by which the practices could be applied with greater efficiency and effectiveness.</p> <p>This strategy applies to a wide variety of project types, including both construction and maintenance operations, depending on the specific procedures discussed.</p>
Expected Effectiveness	<p>Construction and maintenance projects that are performed over shorter time periods and less frequently will reduce the exposure of traffic to the special dangers of driving in work zones. All other factors (traffic volumes, traffic control plan, weather conditions, etc.) being equal, the work zone operation completed in a shorter time would be expected to have fewer related crashes.</p> <p><i>Accelerated Construction:</i> Construction techniques that shorten the time during which a work zone is in place will reduce the exposure of traffic to the work zone and of workers to traffic. Materials designed for accelerating a work project (such as prefabricated elements or fast-cure concrete) will reduce construction time.</p> <p><i>Better Asset Management:</i> Cost-effective management of resources is an essential component of any infrastructure program. Research indicates that a systematic approach to maintaining comprehensive asset data (i.e., inventory and rating) enables the cost-effective optimization of those assets in the future, which would be expected to reduce the frequency of work zones needed to rehabilitate, repair, or reconstruct a given asset. Multicriteria decision making with regard to asset improvement has been shown to optimize the overall system given a limited amount of resources for improvement (Li and Sinha, 2004).</p> <p>Preventive pavement maintenance—when applied correctly and at the appropriate time for the given pavement condition, traffic constraints, and other design considerations—can reduce the rate of deterioration. Presently, no sufficient data are available to measure the effectiveness of pavement maintenance programs in reducing the need to rehabilitate pavement; however, the effect is expected to be substantial.</p>
Keys to Success	<p><i>Accelerated Construction:</i> Accelerated construction is attainable through several methods. The key to successfully applying any of these methods is continuous review and coordination between the design and construction disciplines. Coordination with the construction industry to obtain contractors' acceptance of the methods is essential, as well. Additionally, using the most appropriate method for each respective project will help to ensure success. Quality of materials is also a critical key to successful construction acceleration. The use of substandard practices or materials must not lower the quality of the product for the respective acceleration.</p> <p><i>Better Asset Management:</i> To optimize pavement and structure service lives, an effective asset management program is essential. Such a program should identify agency pavement and structure assets, track their condition over time, and program maintenance and rehabilitation to optimize overall service life.</p>

EXHIBIT V-2 (Continued)

Strategy Attributes for Improving Maintenance and Construction Practices (P)

Attribute	Description
Potential Difficulties	<p>Early preventive treatment is the key to successful maintenance and rehabilitation of pavement. Prevention treatments can be done on a time-based trigger or a condition-based trigger.</p> <p><i>Accelerated Construction:</i> Acceleration of construction should not sacrifice the quality of construction or design. Any process that is performed too quickly has the potential to sacrifice quality. This is particularly true in the application of prefabricated materials. Such materials can often be constructed offsite and out of the presence of construction inspectors. Thus, careful inspection of the respective materials is extremely important. Plant inspection agreements and fabrication certifications can be established to ensure this careful inspection.</p> <p>In addition, the lack of availability of enough skilled workers during accelerated schedules can potentially compromise the quality of the final product. Use of prefabricated elements may reduce the need for additional workers on projects with accelerated schedules.</p> <p>Weather conditions could also present potential difficulties to accelerated construction because adverse weather conditions will inevitably lengthen the time of construction. Projects with longer construction schedules will have a greater chance of experiencing adverse weather.</p> <p>The use of new or innovative techniques may run counter to an agency's standard specifications and work approaches. Contractors may offer higher bids to reflect the higher risk and greater demands on their staff.</p> <p><i>Better Asset Management:</i> Most highway agencies have a very large set of assets under their jurisdiction. Creating an inventory and rating system, as well as a future plan for those assets, is an effort that will require significant time, money, and personnel.</p> <p>If an agency is using predefined intervals for treatment of infrastructure elements, unforeseen changes in the highway environment may alter the need for treatment. If using threshold levels for initiating maintenance or rehabilitation, the threshold values should be continuously monitored and carefully interpreted to ensure that the correct treatments are provided at the correct times.</p>
Appropriate Measures and Data	<p>In general, the change in the number and type of crashes occurring in work zones will be the primary measure of effectiveness. Some reliance may have to be made upon other measures, such as the change in vehicle-miles or vehicle-hours of travel in work zones. Process measures may also be useful for measuring implementation of the strategy, including the number of work zones to which the desired practices are applied. Data needs are indicated below, according to the type of improved practice.</p> <p><i>Accelerated Construction:</i> Long-term monitoring of accelerated construction methods to ensure that the methods provide similar performance as, and have service lives equivalent to, those of conventional construction methods. Appropriate materials testing is needed to measure warranty criteria. To help to determine the acceptability of various methods to implement the required improvements, safety practitioners can conduct public surveys to gauge local public opinion regarding roadway improvements that will directly affect their daily standard of living.</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-2 (Continued)

Strategy Attributes for Improving Maintenance and Construction Practices (P)

Attribute	Description
	<i>Better Asset Management:</i> Maintaining up-to-date records and ratings for all assets would be required to determine need as well as to determine future asset improvements and maintenance requirements.
	Maintaining up-to-date pavement records and ratings would be required to determine need as well as to measure the effectiveness of maintenance application. Historical data can also be used to develop decision trees for use in future pavement and structure repair planning.
Associated Needs	Incentive programs, quality control programs, warranty programs, and onsite plant inspection are all needs associated with this strategy.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	<p>In general, it is likely that the implementation of several types of actions that are included in this strategy will require the issuance of new policy for one or more agencies within the jurisdiction.</p> <p><i>Accelerated Construction:</i> Since these forms of design and construction are often quite different from standard procedures, special procedures may need to be developed for each method. Coordination meetings among all of the different stakeholders affected by work zones (EMS workers, police officers, DOT staff, utility operators, commuter service operators, school districts, local businesses, media, etc.) are important in devising strategies for each of the respective services to continue its operations as seamlessly as possible during construction.</p> <p><i>Better Asset Management:</i> Usually this type of undertaking is done globally throughout an organization, which obviously requires tremendous resources and coordination. Developing a plan for asset management and communicating the plan throughout the organization are important aspects of this strategy.</p> <p>It is important for the respective agency to define its pavement preservation and rehabilitation priorities when establishing a pavement management system. For example, New Jersey recently went from a “worst first” approach to one that focuses on broad system preservation. Such a policy would be expected to reduce the impact of pavement repairs on network operation, including reduced work zone crashes.</p>
Issues Affecting Implementation Time	<p>Implementing improved construction and maintenance practices systemwide could take a significant amount of time, due primarily to the size of the roadway system. Training of agency personnel could also require significant implementation time, depending on the number of people who need to be trained and the uniqueness of the practices being implemented.</p> <p><i>Accelerated Construction:</i> Individual construction techniques that will accelerate work may involve only a short period of time to research and approve. Encouraging the construction industry to embrace the concept of accelerated construction so that accelerated construction becomes common across all agencies, contractors, and projects will take time. The amount of time may vary from contractor to contractor or from region to region and may be affected by traditional practices and economic factors.</p> <p><i>Better Asset Management:</i> Inventorying assets requires significant time, and the limited resources available will further lengthen implementation time. In any given organization’s jurisdiction, there exists a large area of pavement to be managed.</p>

EXHIBIT V-2 (Continued)

Strategy Attributes for Improving Maintenance and Construction Practices (P)

Attribute	Description
Costs Involved	<p>To effectively monitor and maintain the entire network will typically require significant time and resources. This is also true for the large number of structures under an agency's jurisdiction.</p> <p>Establishment of programs and procedures to implement improved maintenance and construction practices may involve significant agency resources. The need for training and the size of the roadway system can also increase costs. Cost elements may also include capital investment in new equipment and associated development costs.</p> <p><i>Accelerated Construction:</i> Costs of materials and/or labor may be greater for accelerated techniques, but greater initial costs of materials can often be justified using life cycle cost analysis. Several state DOTs, including New York and Ohio, use life cycle costs to evaluate benefits of accelerated construction practices. Significant risks are often at stake for the agency, the contractor, and/or the designer under most accelerated methods of construction. These risks are often time sensitive and come in the form of monetary disincentives for late completion, for failure to meet specifications, and so forth. In the case of payments for early completion, the responsible public agency may have to fund these payments, but benefits to the traveling public and perhaps to the agency (in the form of reduced time during which the agency will have to operate a facility under special procedures) may offset the associated cost. A contractor may also experience increased fixed costs because of the need to upgrade equipment. The contractor may also need to expend resources to retrain employees.</p> <p><i>Better Asset Management:</i> Depending on the amount of existing asset data available, significant resources may be required to fully develop a database that includes all data necessary for a complete program.</p>
Training and Other Personnel Needs	<p>Most individual aspects of this strategy involve introduction of new methods and procedures. Therefore, it is likely that a large portion of the personnel involved in these aspects of the agency's or contractor's operations will need training. However, this strategy will likely apply to a limited number of a given agency's projects, so the overall training need not be great.</p> <p>Software programs may be worthwhile investments to assist staff in developing treatment plans for pavement maintenance, rehabilitation, and/or reconstruction. One example is the Strategic Analysis of Pavement Evaluation and Repair (SAPER) software (Liu et al., 2004).</p> <p>The FHWA Office of Asset Management offers a training course to help improve skills in economic analysis and pavement and bridge asset management (see http://www.fhwa.dot.gov/infrastructure/asstmgmt/training.htm).</p>
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is broad and, as a result, compatible with many other strategies, particularly Strategies 19.1 A2, A3, A4, and A5.

SECTION V—DESCRIPTION OF STRATEGIES

Key References

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<http://www.dot.state.sc.us/doing/acceleratedselect.html>.

Washington DOT, *Asset Management: Pavement Assessment*.
<http://www.wsdot.wa.gov/publications/folio/PavementAssessment.pdf>.

Wei, C., and S. Tighe, "Development of Preventive Maintenance Decision Trees Based on Cost Effectiveness Analysis: An Ontario Case Study." *Transportation Research Record 1866*, Transportation Research Board, 2004.

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

Additional information on topics related to this strategy can be found on the following FHWA websites:

Office of Construction and Maintenance, "Accelerated Construction Technology Transfer":
<http://www.fhwa.dot.gov/construction/accelerated/index.htm>.

Office of Bridge Technology (including an Accelerated Bridge Construction Technology page): <http://www.fhwa.dot.gov/bridge/index.htm>.

Office of Pavement: <http://www.fhwa.dot.gov/pavement/index.cfm>.

Washington State DOT (WSDOT) has been rating its statewide pavement condition since 1969. According to FHWA, "WSDOT has an efficient data collection program using laser technology that provides high quality measurements for all road segments" (<http://www.wsdot.wa.gov/publications/folio/PavementAssessment.pdf>). Pavements in Washington are rated on pavement structural condition, rutting, and roughness. WSDOT uses a combination of pavement ratings to prioritize pavement rehabilitation needs based on lowest life cycle cost management. This management philosophy attempts to time rehabilitation efforts to avoid rehabilitation that is either too early or too late.

19.1 A2—Utilize Full-Time Roadway Closure for Construction Operations (T)

General Description

An agency may find that full closure of a roadway during construction operations may be the best option for performing the work in a safe and efficient manner. Full closure eliminates the potential for crashes in a work zone, especially crashes involving both vehicles and workers. By completely closing the roadway to traffic, the duration of the construction can be reduced, since the contractor does not need to interact with traffic and will likely have access to a larger work space. Both avoiding interaction with the traffic and having access to larger workspace will very likely increase the productivity of the contractor and reduce the duration of construction.

Additional reasons for considering full-time closure include potential to achieve a higher quality product, increased productivity (due to less interruption from traffic), and a need to complete a project before an upcoming event or season.

SECTION V—DESCRIPTION OF STRATEGIES

Full-time closure may be considered for relatively small projects with relatively short construction times, but also for major construction efforts such as what might occur on urban Interstate projects. One significant example of the latter is I-74 through downtown Peoria, Illinois. As of April 2005, a 1.5-mile segment of I-74 will be completely closed by the Illinois DOT to through traffic to enable the segment's complete reconstruction within one construction season. See <http://www.upgrade74.com/index.php>.

Significant requirements relating to the implementation of full-time closure and need to be met, beginning with the early planning stages of a construction project:

- Detour routes should be evaluated when road closure is being considered to determine if the alternative routes can handle traffic sufficiently, both from a capacity standpoint and from a safety perspective.
- There must be close coordination with property and business owners, as well as PI&E campaigns, to provide notice of the closure and alternative routes.
- Consider the effects of the road closure program on not just business owners, residents, and through travelers, but also other road users, such as school buses, transit systems, and emergency responders. Alternative routes that are relatively convenient for motorized road users may be inconvenient, difficult to use, or less safe for pedestrians and bicyclists. Early consideration of those impacted by full closure of a roadway can lessen the impact on all road users, as well as improve public relations throughout the construction.

In addition to long-term, full road closure, where traffic in either or both directions is detoured for the duration of the construction or maintenance activity, other methods for implementing road closure include:

EXHIBIT V-3
Full Road Closure



- Weekend closures
- Nighttime or off-peak closures
- Closure of the roadway to all but local traffic
- Short-term ramp closure
- Two-lane, two-way operations while one side of a multilane highway is closed
- Half closure of an interchange
- Closure of the mainline at a diamond interchange and routing of through traffic on the ramps

EXHIBIT V-4

Strategy Attributes for Utilizing Full-Time Roadway Closure for Construction Operations (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>This strategy targets all types of work zone crashes by allowing for an elimination of or reduction in traffic through the work zone. All of the traffic (or all except local traffic) during the period when the work is active is detoured to alternative routes. Because traffic is reduced or eliminated within the work zone, crashes involving through travelers and workers are eliminated.</p> <p>This strategy applies to many types of construction and maintenance activities and can be implemented on either a long-term basis or a short-term basis. Although some types of projects, such as complete bridge replacement, usually require long-term closure to traffic, the decision of whether and when to close a roadway to traffic is usually based on other factors, such as availability of alternative routes and the need to maintain access to abutting properties and businesses within the work zone.</p>
Expected Effectiveness	<p>A reduction in crashes would be expected in the work zones due to the decreased or eliminated volume in the work zones, but it would be difficult to determine whether an increase in crashes on a detour route is attributable to detoured traffic.</p> <p>Agencies that have implemented full road closure have cited improvements in safety, though this is difficult to measure. Workers report that eliminating their exposure to traffic increases the safety of the work zone, as well as their productivity (FHWA, 2003). Experience does not indicate that crashes increase significantly systemwide when full closure is used.</p> <p>Significant reductions in project duration can be achieved with full road closure (70- to 85-percent reductions were reported by the FHWA, 2003), which translates into less traffic exposure.</p>
Keys to Success	<p>Adequate alternative routes, public outreach programs, and provision of access to residences and businesses are keys to the successful implementation of full road closure.</p> <p>Alternative routes that can serve the needs of detoured travelers are crucial to the safety and mobility of the traveling public and the reduction of impacts on them. It is critical that the effect of increased volumes on detour routes be evaluated to determine what the best detour is and whether traffic signal timing or other operational, signing, design, or roadside features along the detour should be modified. An analysis of traffic on the network should be performed to determine the effect that full closure will have, as well as to determine the appropriate steps to take during closure to reduce the impact of the diverted traffic (such as re-timing of signals on the alternative routes). The FHWA's QuickZone software program aids in the estimation of work zone delay (see http://www.tfhrc.gov/its/quickzon.htm).</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-4 (Continued)

Strategy Attributes for Utilizing Full-Time Roadway Closure for Construction Operations (T)

Attribute	Description
	Road users should be encouraged to consider public transportation alternatives on detour routes, where available. Arranging special provisions or incentives for the traveling public to use public transportation can have a marked effect on highway operations. In addition, demand management techniques can be considered so that alternative highway routes are not overloaded. It may be possible to encourage trips normally made during peak periods through the corridor to be made at off-peak times, either by choice of the traveler or in conjunction with participation of large employers in the affected area. Refer to Strategy 19.1 A5 for additional discussion of demand management strategies.
	A traffic management plan that includes adequate signing to warn travelers of the closure and inform them of the alternative routes is also a key element. Though state agencies are generally not allowed to designate nonstate roadways as alternative routes without agreements with the local agencies with jurisdiction over the nonstate roadways, diverted traffic will still find its way to these other roadways. Thus, working with city, county, or other local officials may be an important element in planning a successful full road closure.
	The effect of full closure on the roadway network may depend to some extent on the duration of the project. For short-term projects where the road is closed during off-peak times (such as intermittent night or weekend closures), the traffic may be able to be easily accommodated on alternative routes if travelers are given enough advanced notice of the closure. For long-term closures where peak traffic will be affected, it may take more time for traffic to be redistributed on the network and among the alternative modes as road users find new commuting routes. Two of the projects profiled in the FHWA document <i>Full Road Closure for Work Zone Operations</i> (2003) reported that within 2 weeks after the full-closure operation began, traffic redistributed itself and the increased load on the network was balanced. The time to reach a new equilibrium would be expected to vary from project to project based on specific conditions. PI&E campaigns have played a significant role in successful full-closure projects. Elements of a successful PI&E campaign include:
	<ul style="list-style-type: none"> • Well-distributed closure announcements well in advance of and during construction • Announcement of the scheduled reopening • Route alternatives • Description of the benefits achieved by using full closure • Careful coordination with impacted residents and business owners
	In addition, real-time communication of traffic conditions in and approaching the work zone and on alternative routes is important. This can be provided through variable message signs, websites, telephone information lines, and radio traffic messages.
	Explanation of the reduced duration of the project and other benefits of full closure help increase driver understanding and patience and lead to increased public satisfaction, especially in cases where the public may initially perceive that the roadway will be closed for too long.
Potential Difficulties	Road closure should be scheduled around events that are expected to generate increased traffic or to significantly affect traffic flow in other ways. Festivals, sporting, or other entertainment events that draw traffic into a region or a specific site may be a factor in determining whether to use full closure. Long-term construction projects may need to be sequenced so as to allow temporary reopening of the roadway during special events.

EXHIBIT V-4 (Continued)

Strategy Attributes for Utilizing Full-Time Roadway Closure for Construction Operations (T)

Attribute	Description
	Rerouting may also affect public bus service, school bus service, and emergency vehicle access routes. Care should be taken to include these stakeholders in any closure planning.
	A well-publicized road closure increases schedule pressure, since the scheduled reopening of the roadway would also be well publicized.
	Businesses and residences located along the work zone will be affected by the closure, and these impacts should be considered during the planning process. A potential significant disruption to business is a strong reason for not using full closure. Meetings with business owners and home owners are useful in determining solutions to potential problems caused by the alternative access routes. A survey performed by the South Carolina DOT showed that the public would prefer a road to be closed in order to shorten the construction period. This type of survey would help an agency obtain feedback from people affected by a potential closure while deciding whether to close a road. The survey would also help with public relations.
	During full closure projects, work is often performed 24 hours a day, which will also impact nearby residences, as there is potential for noise and light impacts at night.
	While full closure of a roadway can reduce construction time, regulations governing construction practices may limit the time savings. For example, a recent revision to the Occupational Safety and Health Administration (OSHA) rule on Safety Standards for Steel Erection requires that shear studs be installed in the field in order to reduce tripping hazards unless full conventional fall protection is provided for highway workers (http://www.fhwa.dot.gov/construction/wash02/steel.htm). Such regulations can be expected to increase construction costs and times.
Appropriate Measures and Data	Key process measures include the number of construction or maintenance operations for which full road closure is used, as well as documentation of the completion of key steps in the preparation for, and operation of, the closure.
	Key safety effectiveness measures include crash frequency and severity, by type of crash. It is especially important to identify crashes related to the traffic diversion to alternative routes and to compare these crashes with the crashes that would have been expected had full closure not been used. Crash types on detour routes might include congestion-related crashes (such as rear-end crashes) or crashes caused by drivers making erratic maneuvers as they abruptly change paths (such as side swipes).
	Crash frequency and severity data are needed to evaluate the construction operation for safety effectiveness. Traffic volume data are needed to represent exposure, especially changes in volumes on alternative routes during the road closure. Delay data are needed to determine the operational impacts of the closure and to obtain an idea of how these impacts affect safety.
Associated Needs	While public information regarding the closure and alternative routes is necessary, the extent of the campaign can vary according to the familiarity of drivers with the roadway network. If the vast majority of drivers will be familiar with alternative routes, less information will need to be provided to them.
	It is important to involve emergency responders in planning a full road closure in order to determine how the responders will reach sites in areas with restricted access. Information on the best alternative routes will be of great importance to police, fire, and rescue personnel.

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-4 (Continued)**

Strategy Attributes for Utilizing Full-Time Roadway Closure for Construction Operations (T)

Attribute	Description
	<p>Availability of tow trucks and law enforcement along alternative routes can help quickly remove disabled vehicles and clear crashes, if needed, to maintain the maximum capacity possible on alternative routes.</p> <p>Planning activities should include consideration of how emergency evacuation routes or nearby parallel routes may be affected by closure of a roadway.</p>
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	<p>A policy and set of procedures related to handling of the issues described above need to be in place in the agency to ensure proper consideration of this alternative.</p> <p>Coordination and cooperation among a number of public, and possibly private, organizations will probably require oversight and facilitation from a high level in the jurisdiction. A type of joint management structure may be useful.</p> <p>Funding specifically for the PI&E campaign should be set aside to ensure that adequate information is provided to potential road users and nearby residents and businesses.</p>
Issues Affecting Implementation Time	<p>If agency policies and procedures are in place and there is no significant opposition to using full closure, decisions to use full closure will not involve significant time.</p> <p>Implementation of full closure for a specific project could take a year or two because of the need to plan for traffic control and public outreach. Public involvement programs and analysis of alternative routes will be needed, and the magnitude of each of these efforts may vary. Design of the work zone may involve less time because the traffic control plan will be simpler.</p> <p>The need for dissemination of information to the public about the closure and alternative routes will add to the implementation time of a project if these activities are not planned to occur at the same time as other planning activities. In addition, the need to plan a road closure around scheduled events may also affect the implementation time.</p>
Costs Involved	<p>Though costs for individual aspects of the project may be moderate or high for full closure, the total project costs may be lower. Full road closure may necessitate a more intensive, and therefore more costly, PI&E campaign than what may be needed for a project that does not involve full closure. Traffic control costs may be lower for the work area, but higher in other locations because adequate detour route signing will play an important role in the success of the project. Since the contractor would be able to work unimpeded, construction costs may be lower.</p>
Training and Other Personnel Needs	<p>No significant training efforts need to be undertaken, but the effect of road closure on traffic operations and the evaluation of traffic on alternative routes should be discussed in training for road designers who will be planning the construction sequencing and the construction traffic plan. Training programs should also include proper use of traffic control devices to close a roadway, as well as appropriate advanced warning signs for the closure and detour. Roll call information sessions may be needed for police, fire, and rescue personnel who will be affected by the closure.</p>
Legislative Needs	None identified.

EXHIBIT V-4 (Continued)

Strategy Attributes for Utilizing Full-Time Roadway Closure for Construction Operations (T)

Attribute	Description
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	Full closure would be compatible with other strategies detailed in this guide, especially those involving demand management, PI&E campaigns, and improvement of agency policies related to work zones. With increased traffic on detour routes, there may be a need to increase traffic law enforcement on those routes, and the strategies in Objective D should be reviewed. Full closure will be appropriate for only a specific range of conditions. Therefore, other strategies in this guide could be applicable for other conditions or types of projects.
Other Key Attributes to a Particular Strategy	Expected traffic conditions during the full closure project should be compared with the expected traffic conditions of other work zone traffic control options. The FHWA's QuickZone software program aids in the estimation of work zone delay (see http://www.tfhrc.gov/its/quickzon.htm) for various traffic mitigation options. Maryland State Highway Administration has modified the QuickZone program for its own use. Wisconsin DOT is developing a work zone delay estimation tool based on <i>Highway Capacity Manual</i> procedures for its own use.

Key Reference

Federal Highway Administration, *Full Road Closure for Work Zone Operations: A Cross-Cutting Study*. FHWA-OP-04-009. Washington, D.C. August 2003. <http://www.ops.fhwa.dot.gov/wz/resources/publications/FullClosure/CrossCutting/its.htm>.

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

The FHWA report *Full Road Closure for Work Zone Operations: A Cross-Cutting Study* describes several projects where full closure was chosen mainly as a means of expediting projects but also as a way to increase safety for travelers and workers.

The Ohio DOT developed a policy and map showing on which roadways a lane can be closed, based on traffic volumes. Additional information is available in the FHWA Work Zone Mobility and Safety Program website: http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?id=209&from=crossref&Category_id=18.

19.1 A3—Utilize Time-Related Contract Provisions (P)**General Description**

Time-related bidding methods are used to minimize the impacts of construction projects on road users. Encouraging contractors through financial incentives to be innovative and aggressive when developing project schedules can result in reduced user delay and improved traffic safety. A shorter construction period will minimize exposure of workers to traffic in the work zone, as well.

SECTION V—DESCRIPTION OF STRATEGIES

Although there are several concerns with time-related contract provisions, such as possibly compromising worker and traffic safety in order to accelerate work or pulling workers from other projects in order to meet or beat deadlines, these issues have been handled successfully by agencies using these bidding practices.

NCHRP Synthesis 215: Determination of Contract Time for Highway Construction Projects discusses procedures to determine construction contract time, including time-related contracts. The FHWA Office of Operations work zone website has information on best practices related to contracting and bidding procedures: <http://ops.fhwa.dot.gov/wz/practices/best/crossref.asp?ID=7>

The FHWA Making Work Zones Work Better Workshop includes a presentation by Stuart Thompson of the Utah Technology Transfer Center that provides a summary of lessons learned from states' experiences with innovative contracting types (<http://ops.fhwa.dot.gov/wz/workshops/originals/Stuart%20Thompson.ppt>). Examples of agencies that use these contracting practices can be found from these sources:

- AASHTO *Primer on Contracting for the Twenty-first Century*:
<http://www.transportation.org/download/ContractPrimer.pdf>
- FHWA Work Zone Mobility and Safety Program Best Practices Guide:
<http://ops.fhwa.dot.gov/wz/practices/best/crossref.asp?ID=7>
- Utah Local Technical Assistance Program (LTAP): <http://www.utaht2.usu.edu/>

Cost-Plus-Time Bidding (or A+B)

Bids consist of a component for contract items (A) as well as a component that considers the time to complete the project or a phase of the project (B). A cost is assigned to the proposed length of the construction project by multiplying the days to complete it by a cost per day that accounts for the effect on road users. This is added to the dollar amount for the work to be performed under the contract only for the purpose of awarding a contract. The A portion of the bid is the contract amount, and the B portion of the bid is used to determine incentive/disincentive provisions to include in the contract (see below for discussion on incentive/disincentive provisions). This contracting method can reduce the impacts of projects with high road user delay. As with other contracting types, some agencies use a warranty bond or a method of making future payments in order to factor quality into the bid. A+B bidding is appropriate for projects where traffic delays and inconveniences need to be minimized, such as projects on high-volume urban facilities; major reconstruction, rehabilitation, or bridge replacement projects; and projects on roadways with a poor level of service or high accident rate (NYSDOT, 1999).

Agencies should have well-defined procedures in place to provide guidance on which method to use in a given situation and what costs to assign, as well as well-written specifications to avoid contract disputes.

- The New York State DOT (NYSDOT) recommends that A+B bidding be used only in situations where the user delay costs of the work zone or the public benefit of the accelerated construction or completed project are significant. The NYSDOT uses a user cost of \$3,000 per day as a guide for determining whether incentive provisions are warranted (Kent, 2003).

- The agency's estimate of time to complete the contract should be as accurate and detailed as possible in order for the agency to be able to determine how reasonable a contractor's bid and construction schedule are. Incentives should be high enough to encourage innovation among contractors when working with tight schedules.
- A standard method of calculating user delay costs should be used. Several commercial software packages are available to assist with this calculation. Additional factors, such as loss of business for affected commercial establishments and changes to school bus and emergency vehicle routes, should be considered as well.
- The size of the B portion of the bid should be large enough to have an effect on the bidding. A bid for a project with a small time component (time multiplied by user cost per unit of time) would be less influenced by this B portion than would a project with a large time component. With more of a B portion, there is more incentive for a contractor to complete a project as quickly as possible.

Lane Rental

This method encourages minimization of impacts to road users when full road closure and detour routes are not feasible. The method involves charging a fee to a contractor while part of the roadway is occupied or obstructed. Fees can vary depending on whether the contractor uses the lane during peak hours, during off-peak hours, or at nighttime and depending on the road user costs associated with the contractor's use of the lanes. The fee is deducted from monthly payments to the contractor and is based on the estimated inconvenience or cost to road users. The fee can be assessed by day, hour, or part of an hour. Lane rental is most appropriate on high-volume roadways where intermittent lane closures are needed. Typical projects include pavement joint repair, paving, or replacement of overhead signs (NYSDOT, 1999).

Incentive/Disincentive Clauses

Contractors are compensated an additional set amount per day for early completion of all or a defined portion of the project, or the agency deducts a set amount per day from the payment to the contractor for late completion. When full road closure is being used, the incentive/disincentive clauses can be based on hours of early or late completion, rather than days. This method motivates contractors to minimize construction time and, therefore, impacts on traffic. Caps are often placed on the amount of the incentives that will be paid for a given project or project phase. A "no excuse" incentive compensates the contractor for early completion, but does not allow for consideration of weather, change orders, or other delays. This type of contract does not contain additional disincentives for late completion. Incentive/disincentive provisions can be included in A+B contracts and may be appropriate for projects of varying sizes where it is important to minimize the impact or delay to road users. Examples include resurfacing on minor or major roads, minor rehabilitation projects, or major reconstruction or Interstate rehabilitation projects (Ohio DOT, 2003).

Liquidated Damages

Agency and public costs attributed to late completion of work are recoverable from the contractor. These costs stem from additional engineering and inspection work, road use,

SECTION V—DESCRIPTION OF STRATEGIES

traffic control, police services, temporary easement or occupation charges, and maintenance work. Liquidated damages may not be appropriate for a project with an accelerated schedule, such as A+B bidding or incentive/disincentive clauses, since the lack of benefit to early completion does not offset the risk of late completion. Liquidated damages can be applied at interim milestones of the project if phases of work must be completed by a certain date.

EXHIBIT V-5

Strategy Attributes for Utilizing Time-Related Contract Provisions (P)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>Time-related bidding practices target all work zone crashes by working to reduce the exposure of vehicles traveling to, from, and through the work zone, as well as of the workers and equipment in the work zone.</p> <p>Projects at high-crash locations may be ideal locations for time-related contracts if there is a possibility that the features of the construction zone will make safety problems worse. Time-related bidding also attempts to reduce congestion-related crashes by reducing the severity and duration of the congestion.</p> <p>Time-related bidding is generally applicable to projects with major impacts on road users, businesses, and so forth. Projects on high-volume urban roadways, major bridge replacements, and projects that would otherwise have long detours for high volumes of traffic may be suitable applications of time-related bidding, as would projects that need to be completed by a certain date. Events that necessitate on-time completion of work may also be appropriate for time-related contract provisions.</p>
Expected Effectiveness	<p>Reducing the duration of work activities, when done in a manner that seeks to minimize the effect on traffic, should reduce the exposure of travelers to impacts of the work zone and should reduce the exposure of workers to risks associated with vehicles traveling through the work zone. Although valid evaluations of this strategy have not been conducted, the strategy is used with some frequency and is expected to reduce work zone crashes by reducing exposure.</p> <p>Ultimately, the desired reduction in work zone exposure time is best attained when the respective DOTs provide the contractors with incentives to complete the work as quickly as possible without sacrificing quality. The metropolitan Denver Transportation Expansion (T-Rex) project, a large urban freeway reconstruction and transit project, established an aggressive completion date of 2008, but contract incentivization has created an environment where the contractor is now on schedule to complete the project in 2006, 22 months ahead of plan (http://www.trexproject.com/).</p>
Keys to Success	<p>A key to the success of this strategy is to ensure that safety and mobility practices are not compromised in order to meet a tighter schedule. A traffic plan should be implemented and maintained to provide adequate information and route options for drivers and adequate protection for workers. As always, workers should adhere to regulations and guiding principles related to their safety.</p> <p>Several characteristics of projects involving time-related provisions may increase risk to workers, including higher numbers of workers present, the possibility of fewer lanes being closed (leaving less of a buffer between travel lanes and the work area), and the use of fewer or less effective traffic controls. For these reasons, strong worker safety measures are essential.</p>

EXHIBIT V-5 (Continued)

Strategy Attributes for Utilizing Time-Related Contract Provisions (P)

Attribute	Description
Potential Difficulties	<p>Projects on accelerated schedules could experience delays that projects with normal contracts would also experience, such as unanticipated site conditions. This work can be excluded from the time-related provisions of the contract, or additional design work could be done to attempt to minimize the impacts of unexpected issues on schedule. Contractors and agency staff should be prepared to address unforeseen additional work that could lead to delays. It may be desirable to use time-related provisions only on the most critical portions of the project or to use multiple types of time-related mechanisms on different phases of one project in order to minimize impacts.</p> <p>Rerouting may also affect public bus service, school bus service, and emergency vehicle access routes. Care should be taken to include these stakeholders in any closure planning.</p> <p>DOT staff can be burdened with having to respond quickly to contractors' questions, especially if there are multiple accelerated contracts going on at the same time.</p> <p>A contractor might transfer workers from other projects that are not time critical. The other projects may then sit idle while the accelerated project is being completed.</p> <p>For situations where it is to the contractor's advantage to turn back as much of the roadway as possible to traffic operations, a constrained work area may result, which could lead to increased accidents involving workers and work equipment.</p> <p>The public may perceive incentives as unnecessary unless traffic and safety benefits, or other reasons for accelerating work, are obvious or well explained. The public may also perceive noise and light pollution to be a problem if portions of the work are performed at night in order to meet deadlines.</p> <p>Economic factors can affect the practicality of time-related contracts. Material shortages (such as steel) can affect a contractor's ability to complete a project on a tight schedule. The length of a construction season for a given region should also be considered when developing time-related contract provisions.</p> <p>If highway agencies in the same region utilize time-related contracts extensively, it is possible that the supply of contractors available to perform work could be exhausted.</p>
Appropriate Measures and Data	<p>Key process measures include the number and percentage of contracts for which time-related provisions are used, by type of project on which they are used.</p> <p>Key safety effectiveness measures include crash frequency and severity, by type of crash. It is important to identify crashes related to the diverted traffic in order to examine the total safety effect that a time-related contracting method would have on a system. These crashes might include congestion-related crashes on the detour routes, such as rear-end crashes.</p> <p>Crash frequency and severity data are needed to evaluate the construction operation for safety effectiveness. Traffic volume data are needed to represent exposure, including changes in volumes on alternative routes during the construction. Delay data are needed to determine the operational impacts of the project on traffic flow.</p> <p>Another potential measure is the reduced exposure resulting from the shortened time during which the work zone is in operation. The time to complete a project can easily be tracked and compared with the expected time should time-related contract provisions not have been used.</p>

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-5 (Continued)**

Strategy Attributes for Utilizing Time-Related Contract Provisions (P)

Attribute	Description
	Other key non-safety-effectiveness measures are the completion time, user delay costs, and incentives/disincentives for work completed ahead or behind schedule. Adverse impacts on quality, such as premature failures, are another effectiveness measure.
Associated Needs	Software that assists in calculating user delay costs can help standardize the method of considering time in contract provisions. To determine traffic delays expected during construction, the FHWA QuickZone software can be used.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	While pilot projects can be performed without well-developed procedures and specifications, organizations need to develop policies, guidelines, and contract terms for using time-related contracts to implement this strategy on a wide scale. New York State's guidelines are available at http://www.dot.state.ny.us/cmb/consult/eib/files/ei99033.pdf . Example contract language is provided on this website.
Issues Affecting Implementation Time	Agencies may wish to establish policies and procedures for implementing time-related bidding practices. Development of these procedures will take some effort up front, but will make using the various types of contracts easier. Contractors will need to gain some experience with and confidence in time-related contract provisions for the effectiveness of this strategy to be realized.
Costs Involved	Efforts to develop procedures for using time-related contract provisions will be relatively low compared with project costs. Various agencies' experiences and available guidance should reduce efforts to develop procedures. Paying for overtime, nighttime, and multiple-shift work may increase both contractor and agency costs, but the increase can be offset by a shorter construction duration that results in reduced user costs. NYSDOT estimates that after using A+B bidding on more than 65 projects, 8,500 contract days have been saved because of the difference between actual construction time and contract bid time, thereby saving an estimated \$100 million in user delay costs (http://ops.fhwa.dot.gov/).
Training and Other Personnel Needs	Training for agency personnel will be needed to aid in understanding and managing time-related contract provisions. Contractors will also need to learn how time-related contract provisions work.
Legislative Needs	Laws related to bidding should be reviewed to be certain that time-related bidding practices are in accordance with laws under which a contracting agency operates.
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	Time-related bidding practices are compatible with the other strategies described in this guide.
Other Key Attributes to a Particular Strategy	Scheduling using the Critical Path Method can be performed with computer software such as Microsoft Project or Primavera Project Planner. This element is key in avoiding and resolving disputes that arise when an unexpected event causes the contractor to need more time. The National Highway Institute offers a training course called "Use of Critical Path Method for Estimating, Scheduling, and Timely Completion" (http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=1001).

Key References

American Association of State Highway and Transportation Officials, *Primer on Contracting for the Twenty-First Century*. Fourth Edition. Washington, D.C. 2001.
<http://www.transportation.org/download/ContractPrimer.pdf>.

Federal Highway Administration, Office of Operations Work Zone Mobility and Safety Website. Best Practice Policy, New York State DOT, “A+B Bidding.”
http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=198&from=crossref&Category_ID=18.

Kent, D.L., “Innovative Contracting Techniques That Consider Driver Impact: Use of A+B Bidding.” Presented at Federal Highway Administration *Making Work Zones Work Better Workshop* series, 2003. http://ops.fhwa.dot.gov/wz/workshops/accessible/Kent_MWZWB.htm.

New York State DOT, Engineering Instruction 99-033. 1999. <http://www.dot.state.ny.us/cmb/consult/eib/files/ei99033.pdf>.

Ohio DOT, Innovative Contracting Manual. 2003.
<http://www.dot.state.oh.us/construction/OCA/InnovativeContractingManualFinal.pdf>.

Utah LTAP Innovative Contracting website: <http://www.utaht2.usu.edu/>.

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

Many states are demonstrating that time-related contract provisions can be successful when applied and managed correctly.

NYSDOT has detailed guidelines for using A+B bidding, incentive/disincentive clauses, and lane rental. Engineering Instruction 99-033 (<http://www.dot.state.ny.us/cmb/consult/eib/files/ei99033.pdf>) includes guidelines on determining if these contracting methods apply to projects, identifying limits to incentives, and determining language for contracts that will include these features. This information will be included in the upcoming revised *Highway Design Manual*. Detailed information on the lessons learned by NYSDOT since beginning to use A+B bidding in 1994 is provided by Kent (2003). NYSDOT guidelines on time-related contract provisions are provided on the Internet at <http://www.dot.state.ny.us/cmb/consult/eib/files/ei99033.pdf>.

The AASHTO *Primer on Contracting for the Twenty-First Century* provides details on various contracting mechanisms, agencies that have used each method, and people to contact for additional information.

The Utah LTAP website (<http://www.utaht2.usu.edu/>) provides information on innovative contracting, including the various contract types and examples of state DOTs that have used the contract types.

Several DOTs have used lane rental, including Oklahoma and Oregon. A summary of these programs is provided on the FHWA Office of Operations work zone website (<http://ops.fhwa.dot.gov/wz/practices/best/topindex.asp?ID=103>).

SECTION V—DESCRIPTION OF STRATEGIES

The United Kingdom uses an active payment management mechanism. This technique motivates contractors to maximize the availability of travel lanes to traffic. Traffic volume and travel speeds are used to compare the conditions in the work zone with a standard defined in the contract, and incentives and disincentives are used to encourage contractors to minimize traffic delay. This practice could help reduce crashes related to congestion caused by work zones, as well possibly lead to development of work zones with reduced driver workload (AASHTO, 2001)

19.1 A4—Use Nighttime Road Work (P)

General Description

The use of nighttime road work offers several advantages:

- Less congestion would be expected at night.
- Less traffic would be exposed to any hazards related to driving through the work zone.
- Workers would be exposed to fewer passing vehicles, and this reduced exposure would lower the workers' risk of being struck.
- Road user costs may be lower.
- Work periods may be longer.
- Traffic control options may be more feasible.
- The concerns of high daytime temperatures may be avoided.
- Nighttime work may allow for better productivity, easier material delivery, and reduced equipment costs (Hancher and Taylor, 2001).
- Air pollution and fuel consumption is expected to be lower for nighttime work because of lower traffic volumes and less congestion at night.
- Lower temperatures may allow concrete to be placed and finished with a higher degree of quality.

The presence of lower nighttime traffic volumes should be confirmed during project planning because many urbanized areas do not see a substantial reduction in nighttime traffic volume.

For night construction to be considered advantageous:

- Traffic volumes should be lower than during the day and
- The setup and removal of traffic control devices on a nightly basis should be feasible to allow for restoration of normal traffic patterns during the day.

Economic, social, and environmental issues should also be considered when determining whether to perform work at night (Bryden and Mace, 2002, *NCHRP Report 475*). The effect of daytime construction on businesses may also be a reason for choosing night alternatives. Climate issues, such as a tendency for rain to occur at certain times of the day or night, could also be a factor in deciding whether to perform work at night.

EXHIBIT V-6
Nighttime Road Work

Nighttime construction has associated safety issues:

- Although workers are exposed to less traffic, there is less visibility of workers, equipment, and roadside hardware in the work zone.
- Nighttime traffic speeds will tend to be higher because drivers are less likely to expect to encounter work zones.
- A greater proportion of the vehicles encountered at night will include alcohol- or drug-impaired drivers.

Strategies 19.1 B3 and B4 discuss improvements in visibility of signs and workers, and this material should be reviewed when considering night construction. Drivers may be less alert at nighttime than during the day, and drivers and pedestrians are more likely to be impaired. These concerns present additional safety challenges in performing nighttime work. *NCHRP Report 476* (Bryden and Mace, 2002) discusses designing and operating nighttime work zone traffic control and improving the visibility of workers and vehicles. The report should be referenced when night work is planned. Cottrell provides recommendations as well, based on a review of night work zones in Virginia (Cottrell, 1999). *NCHRP Report 498* (Ellis et al., 2003) provides illumination guidelines for night work and is another key reference for planning night work. An additional source of information is CRP-CD-50: *NCHRP Training for Night Road Work to Improve Safety and Operations*, which was developed to accompany *NCHRP Report 475* and *NCHRP Report 476*.

Local residents may experience noise and light pollution, as well as vibration disturbances, during night construction. These potential impacts should be considered when the use of night work is being evaluated.

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-7

Strategy Attributes for Using Nighttime Road Work (P)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>Performing work at night targets all types of work zone crashes by allowing for work to occur when traffic volumes are lower, thereby reducing potential exposure to conflicts between vehicles and between traffic and workers.</p> <p>Night work is appropriate at projects sites that have lower traffic volumes at night than during the day, when work may be easier and/or safer. The primary objectives of work zone traffic control are ensuring an acceptable level of safety for workers and road users, minimizing adverse impacts on traffic flow and the community, and allowing the project to be completed on schedule and at an acceptable level of quality. If these objectives cannot be met during daytime construction, nighttime work may be appropriate (Bryden and Mace, 2002, <i>NCHRP Report 475</i>).</p>
Expected Effectiveness	<p>The effectiveness of performing work at night to improve safety is difficult to assess. Lower traffic volumes would be expected to contribute to fewer crashes, assuming concerns such as adequate visibility of traffic control and workers are addressed, but the advantage associated with less traffic may be offset by reduced visibility, higher speeds, and an increase in impaired and drowsy drivers. Due to the unique conditions in each work zone and the varying traffic volumes at each site, the appropriateness and feasibility of night construction varies from project to project. Crashes would be expected to decrease while traffic volumes are lower and while there are fewer congestion-related problems. The ability to close extra lanes allows for an increased buffer between work activities and traffic. It may also be possible to use additional traffic control devices and safety features that cannot be accommodated during daytime work.</p> <p>NCHRP Project 17-30 is an ongoing project that is examining the crash experience of nighttime and daytime road work, as well as the types of crashes related to performing daytime and nighttime work. The project will also develop management practices to improve safety in work zones and recommendations to improve data collection for work zone crashes. The project is scheduled for completion in 2006.</p>
Keys to Success	<p>For night work to be advantageous, traffic volumes must be lower at night, and setup and removal of traffic control on a nightly basis must be easy enough to be performed frequently. The work must also be able to be performed in nightly time increments so the roadway can be restored to normal capacity each day. Other factors include traffic congestion, safety, control considerations, productivity, quality of construction, social issues, economic and environmental considerations, and public relations. These factors are discussed in more detail in <i>NCHRP Report 475</i> (Bryden and Mace, 2002).</p> <p>Park et al. (2002) report results of an Oregon survey that show that congestion, traffic control, and safety are the most important factors in determining whether to perform work at night or during the day. A detailed planning phase is critical to the successful operation of a nighttime construction zone due to challenges related to performing work at night.</p> <p>The traffic control plan should discuss how community concerns will be addressed, in addition to how the traffic will be handled. The plan should address adjustments to traffic control, restrictions (including those for work hours, equipment storage, and length of lane closures), inspection and supervision, communications, setup and takedown, monitoring flow and safety, and speed control.</p>

EXHIBIT V-7 (Continued)

Strategy Attributes for Using Nighttime Road Work (P)

Attribute	Description
	<p>Development of an operational plan will ensure that all factors involved in safe and efficient operation of the work zone have been considered and that appropriate resources and procedures are available. <i>NCHRP Report 476: Guidelines for the Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction</i> recommends that contractors be required to submit a plan for agency review before work can begin on all but very simple night work projects. Some agencies currently require this. If work is performed by an agency rather than a contractor, a written operational plan must still be developed.</p> <p>The operational plan should address the following issues:</p> <ul style="list-style-type: none"> • Staffing - Though tasks performed may be similar to those performed under daytime conditions, additional staff may be needed to address traffic control and lighting demands. • Worker training - Workers need to be aware of additional risks associated with night work; therefore, additional safety training may be needed before night work is started. A survey of Kentucky contractors showed that most contractors placed a higher emphasis on safety when performing night work, and workers wear additional reflective clothing (Hancher and Taylor, 2001). • Project site patrol - Traffic control devices should be reviewed at night to ensure they are in proper condition and are visible under night conditions. • Material availability - Arrangements for obtaining materials and servicing equipment need to be made in advance of beginning work, since these materials and servicing equipment might be difficult to obtain at night. • Setup and takedown procedures - Adequate time is needed to allow for proper installation and removal of traffic control devices in a safe and efficient manner. Coordination with enforcement agencies is desirable, as they may be able to provide vehicles with flashing lights to increase visibility of the workers or may have other suggestions for improving the safety of the situation. The setup and takedown tasks can be at least partially automated, and a number of commercially available devices can accomplish this. One example is the vehicle developed by the Advanced Highway Construction and Maintenance Technology group at the University of California at Davis. This vehicle sets and picks up cones. CalTrans has used this vehicle (http://www.ahmct.ucdavis.edu/index.htm?pg=Cones). • Work zone lighting - Adequate and appropriately placed lighting contributes to a safe environment for both workers and road users and contributes to worker productivity. • Overhead power lines - Reduced visibility and worker fatigue during nighttime work increase the opportunities for contact with high-voltage power lines. Care is needed during specific operations where tall vehicles or equipment may be used near power lines. • Emergencies and contingencies - Potential emergencies and disruptions, along with procedures for handling them, should be identified in the operational plan. <p>A plan for agency oversight and inspection is needed, as well. This plan should address staffing needs for inspection, technical oversight, and administrative support. Addressing community complaints and handling accidents should be detailed in the plan.</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-7 (Continued)

Strategy Attributes for Using Nighttime Road Work (P)

Attribute	Description
	<p>Law enforcement services and public awareness activities are also elements of night construction that should be addressed during the planning stage.</p>
	<p>Certain tasks can be performed at night without any negative effects on quality and/or productivity, such as deck pouring, rock excavation, asphalt paving, and traffic control. Rough grading can easily be performed at night, but final grading is more difficult.</p>
	<p>Traffic control should be used to minimize the risk to the travelers and workers. Visibility and smooth traffic flow are two key issues in the determination of appropriate traffic control. Enforcement of the work zone traffic control and speed limits may be needed to help ensure that traffic operates smoothly. This enforcement may be the most successful method for slowing traffic and increasing driver attention to work zone signing and safety.</p>
Potential Difficulties	<p><i>NCHRP Report 475</i> discusses factors that impact nighttime work and the potential difficulties that nighttime work presents:</p> <ul style="list-style-type: none"> • Traffic queues may still occur even if volumes are lower. There is potential for a reduced safety experience (specifically, more rear-end crashes) if drivers do not expect to encounter queues. In this situation, daytime work or full closure may be more appropriate options. • There is a potential for a reduction in productivity due to difficulty communicating with supervisors and technical support staff during nighttime hours as well as the longer times needed to set up and take down traffic control devices and lighting. These concerns should be addressed during the planning stages. This productivity loss may be offset by an increase in productivity due to longer work shifts and less disruption from traffic. • Additional traffic control, lighting, material, equipment repair, and worker pay costs will increase construction costs, but these may be offset by an increase in productivity and decrease in road user delay costs. The cost of accidents may be higher or lower due to performing work at night. Individual projects will have conditions (especially traffic) that contribute to an increase or decrease in the risk of work-zone-related crashes. Impacts on businesses would be expected to be less during night work than during day work due to the typical decrease in business activity at night. • At night, there is more likely to be a higher incidence of fatigued or impaired drivers and pedestrians. Traffic control can be enhanced to help account for reduced alertness. Sleep patterns of workers are disrupted, and this may have an adverse effect on safety and productivity on the project as well as in the workers' family and social lives. • Night work may have a significant effect on the community in which it is performed. There is a potential for complaints about noise, light, and vibration from work zones from people living nearby the work zone. Work activities may need to be suspended while community events are being held. In some jurisdictions, use of the audible back-up alarms on warnings for work equipment is prohibited at night, which could present worker safety concerns. <p>The availability of materials for delivery at night may be limited, as may be the availability of people to perform equipment repairs and to provide other support services.</p>

EXHIBIT V-7 (Continued)

Strategy Attributes for Using Nighttime Road Work (P)

Attribute	Description
Appropriate Measures and Data	<p>A key process measure is the number of projects on which night work is used, as well as documentation of how the key elements of good nighttime operations were implemented.</p> <p>Key safety effectiveness measures include crash frequency and severity, by type of crash. It is important to consider crashes related to the presence of the work zone, especially those occurring at night, as well as crashes related to traffic diversion to an alternative route. These crashes might include the relative number of congestion-related crashes on the detour routes, such as rear-end crashes, compared with what would have been expected had work occurred during the day.</p> <p>Crash frequency and severity data are needed to evaluate the construction operation for safety effectiveness. Traffic volume data are needed to represent exposure, including changes in volumes on alternative routes during the construction. Delay data are needed to determine the operational impacts of the project on traffic flow.</p> <p>Citations in the work zone may be an appropriate surrogate measure of safety.</p> <p>Other key non-safety-effectiveness measures include the proportion of projects with on-time completion that can be credited to night work.</p>
Associated Needs	<p>PI&E campaigns informing travelers of night work will be needed in order to improve driver awareness of the work zone and potential for queues. PI&E campaigns, using a variety of media outlets, can help address concerns that local residents may have with the potential for disruptions from noise, light, and vibrations. Information regarding alternative routes should also be conveyed during PI&E campaigns. Visible enforcement of traffic laws in work zones will contribute to safety of a night work zone, as well as daytime construction activities.</p>

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	<p>A standard procedure is desirable for comparing the impacts of night work against those of day work, including impacts on safety and traffic. <i>NCHRP Report 475</i> provides a procedure for comparing nighttime and daytime alternatives.</p> <p>Nighttime operations may require the use of law enforcement and other personnel at times and in numbers not normally scheduled. Therefore, it will be important to involve these and similar stakeholders as early as possible in the planning process.</p>
Issues Affecting Implementation Time	<p>Agencies may need to develop specifications for performing night work if they have not already done so. Implementation time for night construction projects may be longer for jurisdictions not familiar with performing construction at night than for jurisdictions that are. PI&E campaigns may need to be more extensive to alert drivers to the plans for nighttime operations, and development of agency staffing plans may also initially take more time.</p>
Costs Involved	<p>While actual construction costs, such as delivery of materials and labor, will be higher for night work, the increase can be offset by reduced road user costs and increased overall productivity on the project (Bryden and Mace, <i>NCHRP Report 475</i>). However, while increased worker productivity will lessen the impact of the increased material and labor costs, the material and labor costs will be covered by a different funding source than that which covers road user costs and productivity.</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-7 (Continued)

Strategy Attributes for Using Nighttime Road Work (P)

Attribute	Description
Training and Other Personnel Needs	Training in nighttime safety concerns and practices may be needed for workers who have not had such training or who have not had such training recently. Planners, designers, and field staff of both the highway agencies and the contractor involved are appropriate participants in training for nighttime work zone safety. Periodic briefing sessions may be appropriate at times throughout the project, as well. NCHRP has developed a training program on nighttime construction to supplement <i>NCHRP Report 475</i> and <i>NCHRP Report 476</i> (additional details are available in <i>NCHRP Research Results Digest 293</i> , http://trb.org/news/blurb_detail.asp?id=4474).
Legislative Needs	Existing noise and other restrictions on night work will need to be addressed.
Other Key Attributes	
Compatibility of Different Strategies	This strategy is compatible with others discussed in this guide, especially 19.1 B2 and B3, which discuss visibility of traffic control devices, workers, and work vehicles, and D1 and E1, which discuss law enforcement and public awareness.

Key References

American Association of State Highway and Transportation Officials (AASHTO). *Primer on Contracting for the Twenty-First Century*. Fourth Edition. Washington, D.C. 2001. <http://www.transportation.org/download/ContractPrimer.pdf>.

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19.1 A5—Use Demand Management Programs to Reduce Volumes through Work Zones (P)

General Description

Transportation demand management (TDM) programs are one part of a comprehensive traffic management approach aimed at improving safety and reducing delays in work zones. TDMs apply mostly to significant construction projects (involving major capacity reduction for an extended time period) in urban areas. The primary objective of TDMs is to reduce potential delay for all corridor uses by reducing vehicular volume through the work zone. A significant secondary benefit of effective programs is the reduction in vehicular exposure, which should translate into a reduction in work zone crashes.

These programs encompass a wide range of trip reduction approaches and systems based on intelligent transportation systems (ITS) to control traffic, manage demand and operation, and provide information to the public. TDM programs can be utilized to enhance the safety of motorists and highway workers by reducing the number of trips through work zones and by providing drivers with up-to-date information. Employing TDM programs aimed at lessening peak-period traffic through a work zone is expected to have the greatest safety and operational benefit.

It may also be desirable to design TDM programs that encourage long-haul trucks to use alternative routes that avoid work zones on major roads. A plan for outreach to the trucking industry would be a necessary component of this aspect of a TDM program.

ITS technology is often used in conjunction with TDM programs and is often critical to the programs' success. While there is overlap between this strategy and the ITS programs discussed in Strategy 19.1 B1, this section focuses specifically on TDM as a traffic congestion and crash mitigation tool for use during road construction.

TDM Programs

A few TDM programs that can be used to reduce travel demand through work zones include:

- Carpooling: more than one person traveling in a car.
- Vanpooling: eight to 15 people traveling in a van.
- Transit: use of shuttles, buses, and rail.

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- Toll subsidies: encourage diversion to toll facilities.
- Bicycling and walking.

In addition, the following TDM strategies are intended to provide business employees who are impacted by a project with flexible work schedules to ultimately decrease transportation system demand, especially during peak commuting hours:

- Telecommuting: working from home or from a facility designed to accommodate remote working
- Variable work hours: shifting employee work schedules to avoid peak travel times

Features of TDM programs that indirectly influence the success of the programs (as identified by the Colorado DOT's *Transportation Demand Management & Corridor Projects*) include:

- Parking management: providing preferential parking at places of employment for carpoolers and vanpoolers, allowing nondrivers to "cash out" the value of the parking space provided by an employer, and charging for parking.
- Rideshare matching: a service that identifies people living and working near one another to offer either full-time or occasional commuting partners.
- Incentives and subsidies: reducing the cost of transit passes or vanpool fares or rewarding commuters with cash, prizes, time off, or recognition.
- Marketing and promotions: advertising these programs and offering promotional offers (such as reduced introductory fares) to encourage commuter participation.
- Guaranteed ride home: providing carpoolers, vanpoolers, or those utilizing alternative transportation modes with a ride home by taxi or rental car in case of an emergency or when working late.
- Value pricing: using market-based transportation strategies to enhance mobility options (e.g., parking pricing, and peak-hour tolls).
- Onsite amenities and TDM-friendly site design: designing facilities to support a wide variety of convenient transportation options.

Benefits of TDM

TDM strategies offer several advantages to roadwork projects, including:

- Accurate, up-to-date information on work zone conditions reduces congestion.
- Driver confusion resulting from lack of information is reduced.
- Less traffic is exposed to any hazards related to driving through the work zone.
- Because workers are exposed to fewer passing vehicles, they have a lower risk of being struck.
- Response time of emergency vehicles to crashes is reduced.
- Travelers are provided with up-to-date information on available travel routes, detours, and traffic incidents.

- Delays caused by congestion in work zones are reduced, which in turn reduces road user costs.
- Traffic control options are more feasible.

The Wisconsin DOT has instituted a TDM program associated with the multiyear reconstruction of the Marquette Interchange in downtown Milwaukee. Elements of the program include a freeway bus transit program and extensive driver information, including a unique website offering up-to-date information on ramp closures, detours, and upcoming construction stages. See <http://www.mchange.org/>.

Several conditions must be in place for TDM strategies to be considered advantageous within work zones:

- Alternative commuting options must exist and be publicized, such as transit, carpooling, vanpooling, bicycling, walking, and telecommuting.
- PI&E programs must be in place to inform travelers about alternatives, particularly alternatives related to ride share matching, marketing and promotions, and guaranteed rides home.
- Travel times for the alternative commuting modes must be competitive with travel times for single-occupancy vehicles.
- Travel alternatives must be convenient and comfortable for users.
- Incentives related to use of the alternatives may be necessary, particularly incentives related to travel cost advantages. This condition may be met through incentives and subsidies, value pricing, and/or parking management programs (*CDOT, Transportation Demand Management & Corridor Projects, 2002*; http://www.dot.state.co.us/CommuterChoice/Files/TDM_Corridor_Project_Complete_File.pdf).

The types of work zones that may be appropriate for TDM strategies include:

- Work zones located in densely populated areas that support a variety of transportation choices;
- Projects located in areas with an employment base large enough to impact travel demand by offering telecommuting, staggered work hours, flex-time, compressed work weeks, and so forth;
- High-volume roadways where congestion-related delays may be common or where detours will be used;
- Work zones that will be in place for a significant amount of time; and
- Long-term projects (because the system costs will be easier to justify).

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-8**

Strategy Attributes for Using Demand Management Programs to Reduce Volumes through Work Zones (P)

Attribute	Description
<i>Technical Attributes</i>	
Target	Use of TDM programs should target all potential users of the road under work zone control. The strategy, therefore, should impact all types of work zone crashes by reducing traffic volumes, thereby reducing vehicle-vehicle and vehicle-worker conflicts.
Expected Effectiveness	According to the Colorado DOT's <i>TDM Toolkit</i> (2002), it is difficult to separate out the effectiveness of individual TDM strategies within a TDM program because individual strategies are not mutually exclusive or cumulative. As noted in the FHWA publication, <i>Meeting the Customer's Needs for Mobility and Safety During Construction and Maintenance Operations</i> (1998), few studies have been conducted on work zone crashes and work zone issues. Applying TDM to work zones is a relatively new idea, and there is little evidence to prove TDM's effectiveness for reducing work zone crashes. However, information from a limited number of work zones on which TDM was used suggests that traffic volumes were decreased. It is expected, therefore, that a reduction in volume through a work zone would reduce the crash experience of that work zone. Examples of TDM programs effective in reducing volumes are provided at the end of this strategy under the heading, "Information on Current Knowledge Regarding Agencies or Organizations That Are Implementing This Strategy."
Keys to Success	A detailed planning phase is critical to the successful implementation of a TDM plan for construction projects. Developing a TDM plan requires selecting the most appropriate strategies and obtaining a commitment from partners. As noted in Colorado DOT's <i>TDM Toolkit</i> (2002), development of TDM plans often includes the following steps and considerations. An operational plan should be developed to ensure that all factors involved in a TDM program have been considered and that appropriate resources and procedures are available. Additionally, a partnership should be formed with organizations and businesses in the community. Transit agencies should be approached to determine how existing transportation facilities and services may be utilized during construction and what additional transit services may be needed. Employers near the work zone should be contacted to provide traveler information and to develop transportation alternatives, such as transit, vanpooling, flexible work hours, and telecommuting. Additional partnerships with private transportation providers, schools, and neighboring communities may also be considered.
Potential Difficulties	Finding the most effective organizational "home" is one of the biggest hurdles to a TDM program. It will be difficult to get the attention and involvement of the variety of the desired agencies and other affected entities. Support from a high level in government in the affected area is important. If the project involves a lengthy period of time and several stages, it will be important to keep the stakeholders updated on a regular basis.

EXHIBIT V-8 (Continued)

Strategy Attributes for Using Demand Management Programs to Reduce Volumes through Work Zones (P)

Attribute	Description
Appropriate Measures and Data	<p>The Colorado DOT's <i>TDM Toolkit</i> (2002) and the Houston-Galveston Area Council's <i>Transportation Demand Management and Corridor Planning Guidebook</i> (2003) both outline measures of TDM effectiveness. These measures include a wide range of quantitative and qualitative information, such as:</p> <ul style="list-style-type: none"> • Crashes in the work zone (compared with comparable projects); • Traffic congestion in the work zone (measured by traffic volumes, hours of delay, or level of service); • Public awareness of transportation or route alternatives; • Public awareness of TDM incentives or transit pass programs; • Number of vanpools operating in the corridor; and • Number of transit passes sold at area employment sites. <p>The TDM program should also include clearly stated, realistic goals established prior to implementation. As noted above, a likely goal would be to reduce traffic volumes through work zones. Initially, it is necessary to document baseline conditions. Future evaluations of TDM programs should include a comparison against baseline conditions to effectively measure results.</p>
Associated Needs	<p>ITS tools will be needed to provide information to travelers on a variety of transportation modes. The advanced warning of construction activities and delays can allow travelers to plan their trip to minimize the impact of a work zone on their commute. ITS tools also help travelers find the most efficient modes and routes of travel for their trips, and this help complements the TDM programs discussed in this strategy.</p> <p>PI&E campaigns that use a variety of media outlets are needed to reach a wide range of travelers to inform them of alternative mode choices and travel routes. The campaign should be focused in part on reaching large employment centers near the project. Part of this effort may involve creation of a project website, which will include a TDM section.</p>

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	<p>As noted in the FHWA report, <i>Mitigating Traffic Congestion</i> (2004), the scope of the TDM effort should be considered when determining the organizational home for a TDM program. Determining key staff or organizational responsibility for overseeing implementation and evaluation of TDM plans is key to the success of a program. The Colorado DOT's <i>TDM Toolkit</i> (2002) provides detailed information about developing an implementation plan for TDM programs. A variety of organizational options exist for implementing TDM plans, including the creation of a Transportation Management Association (TMA). TMAs are organizations created to be responsible for implementing commuter and TDM assistance programs within a given area. TMA activities typically include promoting various trip reduction strategies, as well as working with local transit providers to improve routing and services.</p> <p>Interagency agreements may be needed to deal with issues of joint use of personnel and handling of subsidies.</p>
Issues Affecting Implementation Time	<p>Developing and implementing a TDM program could take a year or two, as some aspects of the program may need to be bid into a specific project for a relatively short term. Development includes creating viable partnerships with stakeholders impacted by the project. Coordination with stakeholders (including transit agencies, employers,</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-8 (Continued)

Strategy Attributes for Using Demand Management Programs to Reduce Volumes through Work Zones (P)

Attribute	Description
	private transportation providers, schools, neighborhood groups, and city and county governments) should continue throughout the project. How the TDM program will be organized and run will also impact implementation time. Lastly, the need for dissemination of information to the public about the closure and alternative routes and modes of transportation will add to the implementation time of a project if these activities are not planned at the same time as other planning activities occur.
Costs Involved	The issues that affect implementation time also affect costs involved with implementing and maintaining the strategies. There are also costs associated with specific TDM strategies, such as costs for improvements on alternative routes or provision of alternative transportation modes. Staff resources are needed to run and manage the program, and project-level staff involved with the construction project will need to provide project-specific information to the agency staff running the TDM program. Ongoing costs will also include the PI&E campaign. These costs can vary widely depending on the type of media distribution (e.g., television, radio, newspaper, and website), the intended length of the campaign (or the project), and the frequency with which the message is disseminated.
	The Colorado DOT's <i>Draft 2030 Statewide Transportation Plan</i> (2004) indicates that the costs of TDM programs may be reduced through federal assistance given to states to relieve congestion and reduce air pollution by promoting alternative modes. Two of the largest sources of revenue for TMAs are dues (34 percent) and grants (49 percent). By utilizing TDM strategies that make the most efficient use of existing transportation facilities, public- or private-sector employers can promote alternative modes, increase vehicle occupancy, reduce travel distances, and ease peak-hour congestion. The annual budget for TMAs ranges between \$75,000 and \$2 million.
	The Colorado DOT and associated agencies dedicated \$3 million dollars to the TransOptions program, including transit and vanpool subsidies, money for community outreach and education, and money for maintaining a project website. The Springfield Interchange Project in Virginia included \$28 million for a congestion management program, including provisions for fire and rescue equipment and staff, additional travel options for commuters, improved highway routes around the interchange, and increased capacity and regularity of park-and-ride and light rail alternatives. Another \$6 million was spent to build and operate the nation's first retail information center in the Springfield Mall. This center was developed to meet the needs of people concerned about the impact of the project. Since 1999, more than 230,000 people have visited the center to obtain up-to-date construction information (FHWA, 2004).
Training and Other Personnel Needs	Staff may benefit from training to learn about successful TDM programs associated with other construction projects.
Legislative Needs	None identified.
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	TDM-related strategies are discussed in other sections of this report. Strategy 19.1 B1 discusses ITS strategies to improve safety within work zones. Strategy 19.1 E1 discusses methods to disseminate work zone safety information to road users. The material in Strategies 19.1 B1 and 19.1 E1 should be reviewed in combination with TDM strategies discussed in this section.

Key References

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

Several examples of TDM programs for major reconstruction projects are described in Appendix 1.

The FHWA report, *Mitigating Traffic Congestion—The Role of Demand-Side Strategies* (2004) reports that the Colorado DOT's T-REX project—a 5-year design-build project on I-25 and I-225 to add 19 miles of light rail and improve 17 miles of highway—successfully implemented a TDM program, called TransOptions. This program offers mode choices, including transit and vanpools, and route choices. An audit of the project's first 2 years (2001 and 2002) showed that TDM strategies collectively reduced daily VMT by 74,800.

The same FHWA report indicated that TDM strategies used to enhance mobility during reconstruction of U.S. Highway 101 in central California led to a reduction of approximately 300 cars per day from the highway, translating into approximately 8,000 fewer VMT. Average auto occupancy on the highway rose from 1.206 to 1.266. This program used increased commuter bus services, special vanpool promotions and subsidies, and carpool incentives. An evaluation of the program showed that the carpool incentives were the most cost-effective means among the three programs used for removing cars from the highway.

As noted in Colorado DOT's *TDM Toolkit* (2002), development of TDM plans often includes the following steps and considerations:

1. Defining the problem and identifying potential solutions increases the understanding of existing services and programs and helps to identify TDM strategies that will enhance what is already in place.
2. Creating effective partnerships with public and private participants who are likely to be affected by a construction project will help to ensure the ultimate success of a TDM

SECTION V—DESCRIPTION OF STRATEGIES

program. Testing possible TDM strategies to determine the likelihood of success might be done by interviewing employers and commuter focus groups. TransOptions, the TDM program created for the T-REX project in Colorado, is an example of a successful partnership between the Colorado DOT, Regional Transportation District, FHWA, and Federal Transit Administration. This program has assisted employers and commuters in dealing with challenges of traveling through work zones.

3. TDM strategies should be selected in conjunction with community partners.
4. Parties should be selected to be responsible for implementing, overseeing, and evaluating the TDM program.
5. Funding must be secured to implement the TDM program. Funding should be available for marketing and promotions, including incentives to reward people for their use of TDM options (e.g., cash, prizes, time-off, and recognition).
6. An evaluation plan should be developed that compares conditions prior to implementing a TDM program with conditions after implementing the program in order to effectively measure results.

19.1 A6—Design Future Work Zone Capacity into New or Reconstructed Highways (T)

General Description

Anticipating future work zone requirements and incorporating them into the planning and design process for new roadways (or roadways currently undergoing reconstruction) is one way to ensure that space and operational needs of future work zone operations are accommodated, thereby minimizing the conflict between traffic and future maintenance activities. Adequate planning can address the needs of a range of work zone operations, from short-term work zones, such as traffic barrier repair and pothole patching, to major repaving and reconstruction work.

Mobility and safety in work zones are linked, and providing optimum conditions for work zone operations can potentially reduce traffic queues approaching a work zone as well as reduce work-zone-related crashes. Ensuring that future work zone operations can be performed effectively is one way to reduce the duration and impact of future work zone operations. There are several ways to be certain that future work zone operations are considered early in the project process:

- *Make work zone considerations an explicit tradeoff in decision making for both new construction and reconstruction projects.* Many competing goals and required tradeoffs are part of a roadway project. Explicitly including work zones as part of the evaluation process will ensure that the needs of future maintenance and construction activities are evaluated against other project drivers and issues.
- *Incorporate work zone needs into agency design policies and processes.* For example, if minimum shoulder widths are required to provide for traffic or pedestrian needs in work zones, there should be additional scrutiny when lesser values are proposed on a project. Wisconsin DOT builds wider shoulders on Interstate bridges to allow room for future construction and maintenance needs. When South Carolina DOT constructed the

Cooper River bridge, additional funding was obtained for a lane for pedestrians and future work activities so a lane would not have to be closed to perform work. Another example is the provision for adequate space to allow positive barriers to be placed between traffic and the work area. Physical barriers are discussed further under Strategy 19.1 C2.

Many DOTs have developed guidelines on how many lanes will be required to be maintained during construction based on facility type or traffic volumes. Ohio DOT has developed a “Permitted Lane Closure Map” for its network of freeways and expressways. This map highlights the number of lanes that are present and the number of these lanes that can be closed without exceeding a maximum allowable queue length. North Carolina DOT uses established work zone capacity values for rural, suburban, and urban facility types in assessing work zone operational requirements. This maintaining information can be used to determine the effect that lane closures and other work zone traffic control will have on capacity and delay. The information will help agency staff who plan roadways to be able to address future work zone needs.

- *Be aware of the long-term vision of roadway corridors.* For example, if a four-lane facility is being constructed, but the plan ultimately calls for six lanes, consideration should be given to the future widening project, and the design of that work zone should be considered during development of the four-lane project. The Ohio DOT is developing guidelines on constructing a full-depth shoulder on roadways where work may be planned within a certain time period.

Objective 19.1 B—Improve Work Zone Traffic Control Devices

Traffic control devices are used to communicate with drivers in advance of and within work zones. It is critical that the devices are understandable and visible and provide useful information. Since work zone conditions vary from typical roadway conditions, it is important to inform the driver of the desired actions and the correct path through the work zone. In addition to use of conventional signing and media outlets, route decision making can be enhanced using ITS to inform drivers of delays and alternative routes. Traffic signs, pavement markings, and work vehicles should be well maintained and visible in both daytime and nighttime conditions. Visibility of workers is also a key issue in work zone safety.

19.1 B1—Implement ITS Strategies to Improve Safety (E)

General Description

ITS tools—such as traffic monitoring, advanced travel time, delay, and route information—can improve safety and mobility for travelers in work zones and on the approaches to work zones. This improvement is accomplished through communication with travelers and between elements of the system, which includes agency personnel. The information gathered from the roadway environment is transmitted to agency personnel and road users to allow them to make better safety and mobility decisions.

Using ITS in work zones can improve traffic safety by alerting drivers to the presence of the work zone and real-time conditions in the work zone. This advanced notice can warn drivers that they may need to reduce their speed or stop. Because travelers have advanced

SECTION V—DESCRIPTION OF STRATEGIES

information regarding delays in the work zone, as well as information on alternative routes or detours, the drivers can make route choices in advance of the work zone. Thus, mobility is improved. The length of the backup, as well as an estimated travel time, can be communicated to travelers. ITS can be used to convey work zone speed limit information, as well as messages on increased enforcement or higher fines in the work zone. With the data collected by a system, agency personnel can better respond to incidents and relay messages to the public as needed. Detection of accidents can allow faster action by appropriate emergency response personnel, and this faster action can in turn minimize the impacts of accidents on traffic flow, including potential for secondary crashes. Messages conveying the location of an accident can be relayed to travelers quickly.

ITS can be used for functions that typically have been performed manually. It is possible to incur lower project costs by using ITS to automate transfer of information to agency personnel and travelers. Remote sensors collect data on traffic volume, speed, and/or queues and relay this information to a central control center. The data are processed and communicated to transportation agency staff and travelers. Agency staff are able to override messages relayed to the public if adjustments are needed. Portable system elements may be appropriate for rural or short-term installations.

New ITS technologies are developing at a fast pace. Some of the more common technologies applied to work zones are shown in Exhibit V-9.

Several systems have a specific focus on improving safety in work zones and are described in further detail in the FHWA's *Intelligent Transportation Systems in Work Zones* (FHWA, 2002):

- **Dynamic message signs** advise drivers of slower downstream speeds and travel times. This technology has been effective in reducing speeds in congested flow conditions, but not during uncongested flow. The technology can offer the road users information that may minimize frustration and associated aggressive driving.
- **A highway advisory radio** broadcasts advisory messages to drivers. A sign (dynamic or fixed message) informs drivers of the correct radio station, and messages regarding traffic delays, detours, road closures, and other travel conditions in the area can be broadcast.

EXHIBIT V-9Example System Components for Use in Work Zones

ITS Components for Data Collection and Processing: Central controller/sensors

Closed circuit television cameras

Remote sensors

ITS Components for Communication with Travelers: Dynamic/changeable message signs (portable or fixed)

Internet

Highway advisory radio

Telephone information line

In-vehicle navigation systems

- **A citizens band radio channel** broadcasts advisory messages. A survey showed that a majority of truckers, whom the system targets, hear the message and think it is a worthwhile method of communicating.
- **Portable signs** define the length of a dynamic no-passing zone based on the length of a traffic queue. As a queue lengthens, the next upstream “DO NOT PASS” sign lights up. This is a regulatory (and therefore enforceable) sign.
- **A portable trailer** measures vehicle speeds and displays the speeds for the driver. In a study based on a limited amount of data, this system was shown to reduce speeds and variations in speeds in the work zones where deployed and, on occasion, downstream of the work zone (Maze et al., 2000).
- **Variable work zone speed limits** reduce speed limits when workers are present. This strategy is experimental; therefore, the effectiveness of it in reducing crashes is unknown. A work zone speed limit may vary depending on whether workers are present or on other factors; therefore, the speed limit may vary in long work zones. Legislative authority may be needed for an agency to implement this strategy. Appendix 2 discusses variable speed limits in more detail.
- **Speed warning systems** communicate average downstream speeds to drivers on variable message signs. This technology warns drivers that they may soon need to slow down or stop.
- **Web cameras** provide real-time visual traffic condition information. Video cameras used to monitor traffic can provide images to be broadcast on a website or on television stations. Traffic reporters can use these images, and drivers can check the website for an update on traffic conditions before beginning their travel.

Illinois DOT has instituted a program of speed-monitoring cameras in work zones similar to other applications (e.g., red-light running cameras).

ITS strategies are generally more applicable to larger projects on high-volume facilities over long construction periods. Such projects are in one sense beyond the focus of the SHSP. However, in the context of an agency changing its practices and methods for all projects moving forward, the strategies are appropriate.

EXHIBIT V-10

Strategy Attributes for Implementing ITS Strategies to Improve Safety (E)

Attribute	Description
<i>Technical Attributes</i>	
Target	ITS strategies target crashes related to congestion caused by work zones—speeding, aggressive driving, and unexpected conditions—as well as crashes that may be related to driver confusion or lack of information, such as last-minute correction of navigation errors (i.e., swerving). Related crash types include rear-end crashes, side swipes, or head-on crashes. ITS strategies warn drivers of the potential need to decelerate or stop and provide drivers with alternative route information.

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-10 (Continued)

Strategy Attributes for Implementing ITS Strategies to Improve Safety (E)

Attribute	Description
	<p>The types of work zones that may be appropriate for ITS applications include:</p> <ul style="list-style-type: none"> • High-volume roadways where delays may be common or where detours will be used, • Work zones that may involve changes in travel patterns, and • Work zones where high speeds are expected or have been experienced.
	<p>Long-term projects are more ideal situations for ITS use, since the system costs will be more easily justified. Any situation that necessitates communication with drivers while they are in or approaching the work zone may be appropriate for ITS applications. ITS systems are more likely to be used to improve mobility in urban work zones and to improve safety in rural work zones.</p>
Expected Effectiveness	<p>The complex and individual nature of work zones creates difficulty in evaluating the effectiveness of specific technologies and applying the estimated safety improvements to other projects. Although no studies conclusively prove that ITS technologies reduce work-zone-related crashes, anecdotal information from a variety of work zones on which ITS strategies were used suggests that the crash rates were lower than expected. A reduction in volume through a work zone should reduce the crash experience of that work zone, and use of ITS to provide information on downstream traffic conditions and alternative routes can help divert traffic from the work zone to other routes, thereby lowering exposure and reducing crashes.</p> <p>The FHWA report <i>Intelligent Transportation Systems in Work Zones: A Cross Cutting Study</i> (2002) states that the New Mexico State Highway and Transportation Department reported a smaller increase in crashes (7 percent) than expected during the rebuilding of the I-40 and I-25 interchange, as compared with the crash experience before the construction project began. Secondary crashes were reduced as well, and this is thought to be due to a reduction in the time to clear incidents. A PI&E campaign, increased enforcement, and ITS were likely the main contributors to an initial 32-percent decrease in crashes during the first 3 months of construction. Other projects reported in the FHWA study experienced low numbers of crashes as well.</p> <p>Wisconsin DOT evaluated the accuracy of travel time messages for a work zone displayed on variable message signs. Traffic flow data were collected using roadside sensors, and this information was used to estimate travel times. Variable message signs were placed in locations where drivers had the opportunity to exit the freeway under construction (or not to enter it) if they chose. A comparison of these calculated times with actual travel time data showed that the travel times displayed on the variable message signs were relatively accurate. The difference between actual and predicted travel times was 2 to 3 minutes, on average. Fewer injury crashes were experienced on this section of the freeway after the travel time messages were put into use than in the control section of the roadway (a similar work zone in the opposite direction of travel). (These data were collected for approximately 2 months and the results should be used with caution.) (Notbohm et al., 2001).</p> <p>It is also expected that drivers in congested conditions will experience less frustration and be less inclined to take aggressive action if informed about the length of the congestion, in terms of both time and distance.</p> <p>Emergency response times – and, potentially, crash survivability – may also be improved when ITS strategies are used to detect incidents and determine the appropriate types of responders.</p>

EXHIBIT V-10 (Continued)

Strategy Attributes for Implementing ITS Strategies to Improve Safety (E)

Attribute	Description
Keys to Success	<p>Keys to success are related to planning and administration of the system to be implemented and technical details related to information provided to travelers and agency personnel.</p> <p>As a system is being developed, the transportation agency implementing the system should coordinate with other stakeholders, such as emergency responders. One issue to consider is how information will be shared with police and emergency medical providers so that resources are used appropriately and efficiently when incidents occur. The public is another key stakeholder to consider during planning, and a PI&E campaign should inform the public of the technologies that will be used and their benefits, as well as the information that will be provided by the ITS. Throughout the project, accurate information is needed (FHWA, 2002).</p> <p>A plan for handling problems with the system components will need to be developed with consideration for placing staff on-call during nonbusiness hours to handle problems. The reliability of the communications system should be confirmed before implementation. The schedule will need to include some time for startup of the system, which includes activities such as calibration of traffic detectors and accounting for traffic scenarios that may not have been initially programmed into the system. Periodic—possibly daily—checks on system performance will need to be performed (FHWA, 2002).</p> <p>It is important that variable message signs information be provided to travelers far enough in advance of the back of the queue for them to be able to take alternative routes. The advance warning signs should also be appropriately spaced so that drivers do not encounter a queue before they reach the sign warning them of the queue.</p> <p>A portable system remotely operated by cell phone may be more appropriate for a rural work zone, where a traffic command center would not be available or needed. Portable systems are applicable in situations where a system is needed for a relatively short time (such as for a planned event). These systems can work with sensors and without the need for an operator.</p> <p>Providing accurate and up-to-date information to drivers is important as well. Should drivers repeatedly find information to be old or inaccurate, they will learn to disregard the information.</p> <p>Adequate planning is needed for the system, especially larger complex ones, since the system will need to be customized for the specific situation (such as setting up web cameras). Contractors will often lease the system from a vendor, so time and planning are needed to allow for this. Having a separate contract for the ITS portion of the project can allow the planning for and implementation of the system to proceed separately from the construction contract to ensure that the system is in place before construction begins.</p>
Potential Difficulties	<p>Costs associated with the purchase or lease of ITS components can be significant.</p> <p>Agencies should make efforts to reduce difficulties with system components during startup and initial periods of system use. Comprehensive testing of the system should be performed.</p> <p>Lack of cell phone coverage may limit the applicability of systems intended for use in rural areas in which sign messages are controlled by cell phones.</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-10 (Continued)

Strategy Attributes for Implementing ITS Strategies to Improve Safety (E)

Attribute	Description
	Typical weather conditions that may be expected during the duration of the work should be considered when choosing systems that detect traffic queues or incidents. For example, video detection of incidents may be hampered during periods of heavy fog.
Appropriate Measures and Data	A key process measure is the number of projects on which ITS technology is used. The types of systems and quantities of each, as well as system malfunctions, should be used to measure the implementation process. Key safety effectiveness measures include crash frequency and severity, by type of crash. It is important to consider crashes related to the presence of the work zone, as well as to identify crashes related to traffic diversion to an alternative route. These might include congestion-related crashes on the detour routes, such as rear-end crashes.
	Crash frequency and severity data are needed to evaluate the construction operation for safety effectiveness. Traffic volume data are needed to represent exposure, including changes in volumes on alternative routes during the construction. Changes in traffic volume in the work zone can be used to determine the exposure of traffic to the work zone and the exposure of workers to traffic. Delay data are needed to determine the operational impacts of the project on traffic flow.
	Citations in the work zone may be an appropriate surrogate measure of safety. Changes in the number of citations for speed violations, from before construction to during construction, can be used to evaluate possible changes in the level of safety.
Associated Needs	The deployment of specific ITS equipment may require skills not present among the personnel of the highway agency. Therefore, private contractors may be needed to implement and/or maintain the system.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Coordination with other agencies—such as emergency response providers, local jurisdictions, and land users adjacent to the work zone that may be affected by the project—should be a part of the planning process, and this coordination should continue throughout the project. Some education may be required so that personnel from these other agencies are aware of how the ITS work zone system works. Stakeholders with incident management responsibilities should have a significant role in determining how the system is used for and affects emergency response. New policies and procedures may be required to guide the application of ITS technologies in the jurisdiction.
Issues Affecting Implementation Time	Agencies should not need to spend significant effort to begin using ITS on construction projects. It may be desirable to establish a procedure for comparing the costs of various systems with the benefits. Much of the equipment needed may not be available and would need to be ordered in advance of a project. This would add to the initial implementation time. If an ITS contractor/consultant is required for a construction project, it may require additional time to finalize a contract. It may be desirable to install already-planned permanent or long-term ITS before a construction project begins. In such a case, a separate system would not be needed during construction. This would also be a good time to update an existing system. Installing the ITS technology before the construction begins can either increase

EXHIBIT V-10 (Continued)

Strategy Attributes for Implementing ITS Strategies to Improve Safety (E)

Attribute	Description
	implementation time (if the installation was scheduled to occur some time after the construction project) or decrease implementation time (if the system is nearly ready to be installed and does not need to be added to the construction contract).
	PI&E campaigns for the construction project should include an element to make travelers aware of the ITS technologies being used. In some cases, the ITS technologies will need to be fully operational before construction can begin, and this will need to be planned into the implementation time for individual projects.
Costs Involved	Establishing procedures for including ITS in work zones will be of minimal cost. ITS components can be purchased or leased, and the cost will depend on the complexity of the system and the individual technologies included in the system. The FHWA (2002) reports that ITS work zone systems cost less than 1 to 10 percent of the total project cost for the construction projects highlighted in the document.
	An analysis of over 100 planned ITS projects in Nebraska led to development of benefit/cost (B/C) ratios for the system deployments. The systems studied were planned for permanent use, rather than work zones. The projects were expected to have an average B/C ratio of 1.5. Types of ITS programs with the highest expected B/C ratios were tourism and traveler information systems, commercial vehicle operation systems, and traveler safety and security systems (McCoy et al., 1998).
Training and Other Personnel Needs	Agency design staff will need to be trained on what technologies are available and in what situations they are applicable and appropriate. If support of the ITS components is not included in the vendor's contract, agency personnel will most likely need to be trained by the vendor so that they can operate and maintain the system.
Legislative Needs	None identified.
Other Key Attributes	
Compatibility of Different Strategies	Most technologies that fall into the broad category of ITS are compatible with other strategies discussed in this guide and may enhance the effectiveness of other strategies.
Other Key Attributes to a Particular Strategy	In addition to lessening the impact of the work zone on road users, cooperation with stakeholders such as the public and emergency response providers can improve relations with these groups and improve the confidence that these groups have in agency personnel and programs. Examples of these benefits are documented by FHWA (2002).
	Agencies should consult legal personnel to determine whether certain data, such as camera images, should be archived.

Key References

Carlson, P.J., M. Fontaine, H.G. Hawkins, K. Murphy, and D. Brown, "Evaluation of Speed Trailers at High-Speed Temporary Work Zones." Paper No. 00-1475. Transportation Research Board, Compendium of Papers CD-ROM, Washington, D.C. 2000.

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SECTION V—DESCRIPTION OF STRATEGIES

Federal Highway Administration, *Intelligent Transportation Systems in Work Zones: A Cross Cutting Study*. Report No. FHWA-OP-02-025. Washington, D.C. 2002.
http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13600.html.

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Maze, T., A. Kamyab, and S. Schrock, "Evaluation of Work Zone Speed Reduction Measures." Iowa State University Center for Transportation Research and Education. Ames, Iowa. April 2000.

Notbohm, T. , A. Drakopoulos, and A. Horowitz, *Smart Work Zone Deployment Initiative Summer 2001 Travel Time Prediction System*. 2001. http://www.eng.mu.edu/~drakopoa/web_documents/TIPS/Tipswisconsin.pdf.

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

The FHWA report *Intelligent Transportation Systems in Work Zones: A Cross Cutting Study* (2002) describes construction projects that used ITS in the work zones to successfully provide real-time travel information to travelers, reduce delay, and reduce time to clear incidents.

19.1 B2—Improve Visibility of Work Zone Traffic Control Devices (T)

General Description

Visibility of traffic control devices can be limited by poor retroreflectivity, obstructions, sight distance, weather conditions, wear, and other factors. Lack of visibility of traffic control devices can contribute to crashes in work zones. Providing adequate visibility of traffic control devices aids in drivers' advance perception of the travel path through the work zone, especially at night. Poor visibility of signs and markings may result in drivers unintentionally violating the intended message of a regulatory or directional sign. Also, drivers' attention may be focused on other objects in the work zone or work activities in an adjacent lane rather than on signing. The visibility of signs, markings (including raised

pavement markers), and channelizing devices may also be affected by degradation of the reflectivity of the device, the interference of physical objects (e.g., equipment, other vehicles, dirt, or road sludge), atmospheric conditions (e.g., fog), and darkness. Maintenance of traffic control devices is important to the visibility of the devices. If visibility of traffic control devices is considered to be a potential factor in crashes that have occurred, field reviews may be regularly performed, especially at night, to determine if part of a device's message is obscured, obliterated, or blocked, as well as to check the retroreflectivity of the device.

In addition to potentially restricting driver sight lines, signs not associated with the driving task and a large numbers of appurtenances in the vicinity of a work zone can impose a high workload on drivers. The need for numerous traffic control devices in work zones, combined with the presence of existing signs and devices, plus background clutter created by advertising signs, street lighting, and so forth often make it difficult to select and locate temporary traffic control devices to ensure adequate visibility in work zones. It is therefore essential to adhere to the *Manual on Uniform Traffic Control Devices* (MUTCD) guidance to ensure that all work zone traffic control devices are properly selected, designed, and located to provide adequate visibility and driver comprehension. An analysis of driver information workload may be needed to identify potential problem areas.

State agencies are encouraged to adopt their own visibility standards for work zone traffic control devices. The standards would apply not only to signs and pavement markings, but also to barricades and channelizing devices such as cones and barrels. The American Traffic Safety Services Association (ATSSA) has recommended guidelines for the condition of temporary traffic control devices, and many states follow these or equivalent standards (available online at <http://www.atssa.com/resources/statepolicies.asp>). In addition, FHWA is developing standards for retroreflectivity.

Frequent inspections are needed to ensure that an agency's visibility standards are met in work zones. Agencies are encouraged to require that a person certified in development and implementation of traffic control plans oversee the traffic control in work zones. It is important to follow up with contractors to make sure traffic control supervisors are being used on projects where this is recommended or required. It may be desirable to have more than one supervisor, possibly at least one on the contractor's staff and one from the highway agency staff, to be able to monitor more of the time when the work zone is active, especially when work is occurring for long periods (such as 24-hour operations). The recent FHWA rule on work zone safety and mobility requires contractors and state highway agencies to designate a trained person to be responsible for "implementing a transportation management plan and other safety and mobility aspects of the project." Beginning in January of 2005, South Carolina DOT has required all construction work bids to have a certified work zone traffic control supervisor. Certification is obtained during a 3-day training course.

Nighttime visibility is an important consideration when determining appropriate traffic control devices to use in a work zone. Drivers and pedestrians at nighttime tend to be less alert and are more often driving under the influence of alcohol or drugs than during daytime. "A significant problem with night work, then, is that drivers need more visibility at a time when conditions reduce visibility" (Bryden and Mace, 2002, *NCHRP Report 476*). The clues that drivers are able to pick up from the roadway environment that help them steer their vehicles along the appropriate path are not as evident at night, and reliance on signs and markings increases. Increased conspicuity of signs and markings provides more

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information to drivers at a greater distance, and this is especially important at night. *NCHRP Report 476* and *NCHRP Report 498* should be consulted for additional information about nighttime visibility of traffic control devices.

Older drivers are particularly susceptible to involvement in work zone crashes due to their often increased difficulty in responding to situations that violate driver expectancy and due to their significantly decreased visual acuity, especially in periods of reduced visibility such as night and poor weather. Decreased visual and other functional capabilities compound the issues related to the unique nature of every work zone. The older driver guide in this *NCHRP Report 500* series (Volume 9) should be consulted for additional information on improving work zones to accommodate older drivers. In addition, the FHWA *Older Driver Highway Design Handbook* (1998, available at <http://www.fhwa.dot.gov/tfhrc/safety/pubs/older/home/index.htm>) should be consulted to ensure that improvements to visibility of traffic control devices will be appropriate for older drivers. Also, see Appendix 3 for a brief summary of some research on traffic sign visibility, performed by the United States Sign Council, with emphasis on the mounting height.

Methods for improving visibility of signs, pavement markings, and channelizing devices include:

- Implement visibility (i.e., retroreflectivity) standards (or ATSSA condition guidelines or the equivalent).
- Upgrade sign sheeting materials. Use of highly reflective or fluorescent sign sheeting can provide improved visibility for work zone signs. Use fluorescent orange sign sheeting where low-light conditions are expected during the work zone operation. Fluorescent sheeting does not provide much additional value during bright daylight or nighttime conditions and therefore may not be appropriate for work zones that are set up and taken down daily.
- Provide larger signs on high-speed roadways where clutter is not a concern. Where sign density is higher (such as on urban roadways), temporary signs need to fit in with existing traffic control and cannot block other devices. Larger letter height and stroke width can help increase visibility as well. Crash experience on a roadway can be used to determine if larger signs may be appropriate for a work zone on that roadway.
- Provide redundancy in signs on high-speed rural roadways and for critical signs.
- Increase sign spacing on high-speed roadways to allow more time for drivers to process the information on the signs and to prepare for the required maneuver.
- Provide artificial lighting on work zone signs.
- Provide flags and/or warning lights on work zone signs.
- Increase the size of channelizing devices.
- Decrease the spacing of channelizing devices.
- Avoid using Type III barricades near intersections and ramps, except for full road closures (where Type III barricades are required). Other channelizing devices, such as Type II barricades, drums, and vertical panels, especially if closely spaced, can provide equivalent path guidance to drivers without blocking sight lines.

EXHIBIT V-11

Positive Guidance: Excellent Temporary Marking and Channelizing Devices



- Install highly reflective temporary pavement markings to delineate intended travel paths; a material with high visibility in both dry and wet conditions is ideal. A wet reflective tape product is available that provides increased visibility in wet conditions. Refer to the section entitled “Information on Current Knowledge Regarding Agencies or Organizations That Are Implementing This Strategy” for one agency’s experience with this product.
- Ensure adequate visibility of signs and markings on detour routes. Improvements need to be made as appropriate to accommodate increased volumes of traffic anticipated due to diversions from the work zone.
- Improve the display of sign messages through changes in colors, contrast, pictorial or text messages, font style, letter height, and stroke width. Reduction of glare from signs and adjusting mounting height and location relative to travel way as appropriate can improve visibility of signs.

Another aspect of visibility of traffic control devices relates to the obliteration of temporary markings when the control plan changes in a work zone. Construction and maintenance may be done in stages so that vehicles are directed over different paths at various stages of work. When the paths change, the temporary and permanent markings that are present for a

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EXHIBIT V-12

Excellent Channelization at Night—Large Devices (Drums), Closely Spaced, in Good Condition



previous stage need to be obliterated so that the driver has a clear definition of the currently desired path. Means for obliteration sometimes involve covering paint with black paint or material. This may not achieve the desired affect if the material still maintains a contrast with the underlying pavement. Even more important, the material may become highly reflective of headlight or overhead lighting at night under wet road conditions. Under such conditions, the driver may not be able to distinguish a color and can be mislead. In addition, previous markings are sometimes covered with a temporary material that can loosen and come off under certain atmospheric, weather, and traffic conditions. The most appropriate and latest marking materials will be needed to overcome this, along with frequent inspections of the site.

EXHIBIT V-13

Strategy Attributes for Improving Visibility of Work Zone Traffic Control Devices (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>This strategy is targeted at crashes that occur because drivers are unable to see traffic control devices in work zones sufficiently in advance of a required maneuver. This can lead to crashes caused by path errors, such as lane deviation, roadside encroachment, work space intrusion, and failure to adhere to flagger instructions. Crash types that may result would include rear-end, side swipe, angle, run-off-road, and head-on crashes, depending on work zone configuration.</p> <p>Work zones of all sizes and duration would be appropriate sites for improving visibility of signs, markings, and channelizing devices.</p>

EXHIBIT V-13 (Continued)

Strategy Attributes for Improving Visibility of Work Zone Traffic Control Devices (T)

Attribute	Description
Expected Effectiveness	Improved visibility and awareness of traffic control information are expected to reduce conflicts related to drivers not being able to see the devices well or soon enough to comply with the sign message or follow the appropriate path. While studies have not yet proven that improving visibility will reduce crashes, anecdotal experience from examination of work zone crash reports clearly shows that poor visibility of traffic control devices is often a contributing factor and that improving drivers' expectancy of the roadway conditions should improve safety.
Keys to Success	<p>While there is a visibility standard of the American National Standards Institute and the International Safety Equipment Association (ANSI/ISEA) for work zone personnel, development of a national standard for visibility of signs and markings is not yet completed (for an overview of this effort, refer to http://safety.fhwa.dot.gov/index.htm). It is important for agencies to establish their own standards for minimum levels of visibility and ensure that traffic control devices used in work zones at least meet their minimum. <i>NCHRP Report 476</i> and <i>NCHRP Report 498</i> should be consulted for information on sign visibility, and ATSSA provides recommendations on the condition of traffic control devices.</p> <p>Visibility and clarity of the traffic control devices should be improved without creating additional confusion for drivers. Additional signs providing warning or guidance messages to drivers should not clutter the roadway and should not present confusing or conflicting messages to drivers.</p> <p>A traffic control supervisor and an aggressive traffic control inspection program can help ensure adequate visibility of work zone traffic control devices. Frequent checks of the work zone should be performed to ensure that traffic control devices are in proper place and visible under all expected operating conditions, including night and poor weather. Signs should be examined at different times of day in order to examine the visibility of signs under varying daylight and nighttime conditions. Signs can be hit during crashes, barrels can be knocked out of place, and so on. Dirt and dust from work activities can obscure traffic control devices, as well. Care should be taken to identify such problems with traffic control devices and to correct them as soon as possible.</p>
Potential Difficulties	<p>Better traffic control devices can be more expensive to purchase and can take more time to install and maintain, which will also add to a project's cost. If these traffic control devices are not maintained properly, the expected benefits may be lost.</p> <p>Care should be taken to ensure that new or relocated signs do not present additional sight distance, roadside, or driver distraction hazards.</p>
Appropriate Measures and Data	<p>A key process measure is the number of projects on which traffic control device visibility is inspected and improved. The types of improvements and the number of applications of each should be used to measure the implementation process as well.</p> <p>Key safety effectiveness measures include crash frequency and severity, by type of crash. It is important to consider crashes related to visibility of signs and markings in the work zone.</p> <p>Traffic volume data are needed to represent exposure. Citations in the work zone may be an appropriate surrogate measure of safety. Observations of driver behavior, especially with respect to the compliance with work zone signing, may also be considered as a surrogate measure.</p>

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EXHIBIT V-13 (Continued)

Strategy Attributes for Improving Visibility of Work Zone Traffic Control Devices (T)

Attribute	Description
Associated Needs	A quality control plan for inspecting visibility of traffic control devices is recommended. Refer to Strategy 19.1 F4 for additional information. Guidelines on the condition of traffic control devices (such as those developed by ATSSA) are needed as well. Removing signs and other items contributing to roadside clutter may require public involvement activities.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	Highway agencies should ensure that their design and field practices are consistent with the MUTCD and should review their traffic engineering and design policies regarding use of traffic control devices to ensure that appropriate action is being taken on routine projects. Agencies should also strive for consistency with work zone signs and markings in nearby jurisdictions. Any highway agency can participate in implementing this strategy, which is applicable to work zones in rural, urban, and suburban areas for all project sizes and types.
Issues Affecting Implementation Time	Time required to prepare to use new methods and materials should be relatively short. Improving existing procedures for work zone sign and marking visibility should be factored into estimates of implementation time. Even with those considerations, implementation time would still be expected to be short. Time to inspect work zone signs and markings, install new signs or markings, improve existing devices, and remove or relocate signs is expected to be relatively short.
Costs Involved	Costs will be low to develop or update procedures for installing or upgrading signs and markings and to improve visibility and awareness of the traffic control devices. Ongoing maintenance costs should be included when considering use of these devices. Costs to upgrade retroreflective materials and device sizes may be significant. Using more devices (for redundancy or closer spacing) will increase costs. Implementation of field inspections may add to overall inspection costs.
Training and Other Personnel Needs	Visibility of traffic control devices should be addressed in highway agency training concerning work zone traffic control installation and human factors. The training is needed both in the design office and for operations and maintenance personnel. ATSSA offers a variety of training programs on work zone safety, including distance learning. See http://www.atssa.com/rsti/default.asp .
Legislative Needs	None identified.
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	Actions taken to improve visibility of work zone signs and markings are compatible with other strategies to improve work zone safety.

Key References

American Traffic Safety Services Association (ATSSA), *Quality Standards for Work Zone Traffic Control Devices*. 1995.

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Federal Highway Administration, *Manual on Uniform Traffic Control Devices (MUTCD)*. Washington, D.C. 2003.

Federal Highway Administration, "Work Zone Safety and Mobility," final rule. *Federal Register*, Vol. 69, No. 174, September 9, 2004. <http://a257.g.akamaitech.net/7/257/2422/06jun20041800/edocket.access.gpo.gov/2004/04-20340.htm>.

Staplin, L., K. Lococo, and S. Byington, *Older Driver Highway Design Handbook*. Report No. FHWA-RD-97-135. Federal Highway Administration. Washington, D.C. January 1998.

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

Wisconsin DOT used wet reflective tape in a work zone and evaluated its visibility in both day and nighttime dry conditions and during wet nighttime conditions. Wisconsin DOT found the tape to be more visible than traditional pavement markings. The DOT recommends that the tape be considered for use in work zones where visibility in all weather conditions is necessary. Additional information can be found online at <http://www.dot.wisconsin.gov/library/research/docs/finalreports/tau-finalreports/reflectivetape.pdf>.

19.1 B3—Improve Visibility of Work Zone Personnel and Vehicles (Varies)

General Description

Visibility of workers, vehicles, and equipment is a key element of work zone safety. Being visible is important not only for flaggers and other personnel directly exposed to traffic—or in parts of the work area where public traffic may intrude—but also for workers who are exposed to construction traffic in the work area. In a report titled *Building Safer Highway Work Zones*, the National Institute for Occupational Safety and Health provides recommendations for preventing injuries to workers (Pratt et al., 2001). In the report, over half of the fatal crashes involving workers also involved work vehicles and equipment in and around the work zone.

Visibility of Work Zone Personnel

Several strategies can help improve worker visibility (effectiveness rating is shown in parentheses):

- **Appropriate location of flagger station (T):** The location of the flagger station should provide as much sight distance from drivers to the flaggers as possible. This is especially important to consider at crest vertical curves and horizontal curves (NYSDOT, 2005). The flagger station should be far enough upstream of work space to allow motorists to respond to the flagger commands before reaching the work area. With this in mind, flaggers should be placed as close to the work area as possible to minimize delay in one-lane sections, which will help reduce the risk of congestion-related crashes.

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- **Flag trees (T):** Flag trees are high-level devices that provide additional warning that flaggers are present. They may be less effective in urban or congested areas than in rural areas due to visual clutter of the background. However, flag trees in urban areas may be more visible than flaggers since they can be taller than flaggers and more easily seen over taller vehicles. Flag trees may not be feasible for mobile or short-term work where frequent moving of the trees is needed.
- **Additional advance warning of flagger presence (E):** Centerline cones may be placed upstream of a flagger station to alert drivers to the presence of a flagger in the roadway. This may not be ideal on narrow roadways or where drivers may be confused by the cones and may drive on the left side of them (NYSDOT, 2005).
- **Flashing stop/slow paddles (E):** Another method for increasing flagger visibility is to use stop/slow paddles with flashing lights. The paddles have high-intensity lights on the “stop” side that flaggers can activate when needed (i.e., when it appears that a driver has not noticed the flagger and sign). Alerting a driver to the presence of a flagger and sign should increase the chances of the driver stopping or slowing and avoiding crashes. Information on states’ experiences with flashing paddles can be found on the FHWA website at <http://www.fhwa.dot.gov/winter/roadsrv/byproduct.htm> (listed under “flashing stop/slow paddle”).
- **High-visibility apparel (T):** Flaggers generally stand facing traffic, but this is not always true for workers performing other tasks. Therefore, they need to be visible from all directions in any position (stooping, facing away from traffic, and so on). This means that since it is unpredictable which part of the body will need to be visible to traffic and other construction personnel, there is a great need for a worker’s entire body to be visible. At night, flaggers are often illuminated by headlights and therefore can be made more visible with retroreflective clothing, but other workers not directly exposed to traffic cannot rely on retroreflectivity. Light-colored clothing, in addition to retroreflective vests and hard hats, should be worn to make workers visible under both headlights and more diffused work lighting (Bryden and Mace, 2002). Encircling hard hats with high-visibility tape will help improve visibility of workers as they are positioned sideways with respect to oncoming traffic and as they therefore have a smaller cross section of high-visibility apparel facing traffic.



The American National Standard for High-Visibility Safety Apparel (ANSI/ISEA 107-2004) established three levels, or conspicuity classes, of high-visibility apparel for workers. This is a consensus standard developed by ISEA through ANSI and is not currently included in the latest version of the MUTCD. The level of apparel a worker needs to wear (per these standards) is dependent upon the type of work, vehicular traffic, hazards, and other activities in the work zone. Class 3 apparel is the most visible in a wide range of weather and lighting conditions and is appropriate for use where traffic speeds are 50 mph or greater. Additional discussion of the classes of apparel is available on the Center for Disease Control and Prevention website at <http://www.cdc.gov/elcosh/docs/d0600/d000627/d000627.html>.

In order for workers to be visible against the background of construction equipment and vehicles, clothing with a striped pattern, rather than a solid color, may provide additional

EXHIBIT V-14

Highly Visible Flagger at Night—Apparel, Temporary Lighting



visibility (Bryden and Mace, 2002). Use of yellow-green colors in worker apparel may help improve worker visibility against a background of orange construction equipment, signs, and barricades. Fluorescent apparel can enhance visibility during dawn and dusk. Varying apparel colors by season to ensure that workers stand out against the foliage background is suggested by Pratt et al. (2001). For example, South Carolina DOT does not use yellow-green apparel because workers wearing that color do not stand out well against the pine forest background commonly found in the state.

Visibility of Work Zone Vehicles

Improvements to visibility of work zone vehicles include:

- **Use more visible paint colors, conspicuity tape, or retroreflective materials or backup alarms to increase road user and worker awareness of work zone vehicles (T):** Increased visibility of work vehicles will provide road users with more warning that vehicles either are present or may be entering the traffic lanes.
- **Use backup alarms or video cameras to increase worker awareness of work zone vehicles and driver awareness of other workers (T):** Backup alarms are used to alert people in the vicinity of a vehicle that it is backing up. These alarms are sometimes objectionable to residents in the vicinity of a work zone, and an alternative can be an observer who signals to a vehicle operator when it is safe to proceed in reverse. Video cameras can be used to provide the view behind the vehicle as the operator is backing up.
- **Use advance warning vehicles to alert drivers to the presence of a work zone (T):** The AASHTO 2002 *Roadside Design Guide* discusses appropriate use of advance warning vehicles (shadow and barrier vehicles) and truck-mounted attenuators. Advance warning vehicles should be equipped with warning lights, such as rotating

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beacons or strobe lights. Strobe lights, however, can be fatiguing to workers in nighttime conditions (in addition, strobe lights can trigger seizures in some people with epilepsy). Arrow panels are recommended for use on shadow and barrier vehicles as an effective means of warning drivers that a lane is closed. These panels should be mounted as high as possible on the vehicles and should be as large as possible to provide the most visibility. The arrow panels should be dimmed at night to a maximum of 50 percent of full intensity to avoid glare problems for approaching drivers.

- **Use combinations of warning light colors (T):** A combination of colors for warning lights may convey a message of greater hazard warning to drivers. A study of several freeway sites in Texas showed a 5- to 6-mph decrease in speed of vehicles approaching maintenance vehicles with a combination of yellow and blue warning lights at two of five sites. This color combination resulted in an increase in brake usage as well and an even greater increase when red-yellow-blue warning lights were used. Different color lights did not have a significant impact on the tendency of drivers to change lanes as they approached the maintenance vehicle with the warning light. The presence of a law enforcement vehicle was shown to influence drivers to brake more frequently than a TxDOT courtesy patrol vehicle (Ullman, 2000). Warning lights in colors other than yellow should be used only when a specific need exists for these lights and only when permitted by the jurisdiction in which the work zone is located (Bryden, 2003).

Nighttime Visibility

Nighttime visibility of workers and vehicles is an important consideration when determining whether to perform work during the day or night. Visibility is reduced at night, and there are also concerns related to driver expectancy and the potential for fatigued or otherwise impaired drivers.

EXHIBIT V-15

Visible Work Vehicle at Night—Arrow Board, Reflective Signs and Markings, Warning Lights



Retroreflective material on apparel and vehicles will improve their visibility. Strobe lights are highly visible and less costly than incandescent flashing/rotating lights for vehicles, but are believed to be more difficult for drivers to determine both the distance to them and the rate at which the distance is closing. Light bars provide good visibility but may be difficult to be visible from 360° around a large vehicle. Additional guidance on use of warning lights at night is provided by Bryden (2003).

For nighttime construction, adequate lighting is necessary to allow workers to complete their tasks efficiently as well as increase the visibility of workers and vehicles. Care should be taken to minimize the glare experienced by both workers and drivers. Consideration of glare-free light balloons is suggested by Pratt et al. (2001).

EXHIBIT V-16

Strategy Attributes for Improving Visibility of Work Zone Personnel and Vehicles (Varies)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>The principal targets are worker and vehicle visibility, which affect crashes that occur when drivers either are not aware of the presence of workers or vehicles or fail to see them due to distractions or reduced visibility. Such crashes would involve either a vehicle striking a worker (whether a flagger or other worker directly exposed to traffic) construction vehicle or a vehicle intruding on the work space. Also, lack of worker or equipment visibility could contribute to a collision between vehicles traveling through the work zone should drivers make erratic maneuvers to avoid a worker or work vehicle that was not seen. These crash types would include rear-end crashes and possibly side-swipe, angle, and head-on crashes, depending on work zone configuration.</p> <p>Work zones of all types would be appropriate sites for improving visibility of workers and vehicles.</p>
Expected Effectiveness	<p>It can be expected that improvements in visibility will have a positive effect on crash experience. Methods for improving visibility of work zone personnel and vehicles have been evaluated, and treatments such as high-visibility apparel and warning lights have been shown to be effective in improving visibility. While it is difficult to quantify the effectiveness in terms of crash reduction in work zones, it is known that a substantial number of work zone crashes involve vehicles traveling through the work zone that strike a worker or work vehicle/equipment. It is reasonable to expect improved visibility to reduce the number of such crashes.</p>
Keys to Success	<p>One key to success is to have well-developed agency guidelines for the use of apparel and other methods to improve worker and vehicle visibility.</p> <p>Another key to the success of visibility improvements is frequent inspection of worker clothing, vehicle warning lights, and other enhancements to ensure that the devices are clean, functioning, well maintained, and providing an appropriate level of visibility.</p>
Potential Difficulties	<p>If high-visibility materials are not maintained properly, the expected benefits may be lost.</p> <p>It is important to ensure that any lighting that improves visibility of workers and equipment does not create glare for drivers passing through the work zone, workers, or drivers of construction vehicles.</p>
Appropriate Measures and Data	<p>The existence—or development, if necessary—of a clear policy on worker and work vehicle visibility is a primary process measure. Another key process measure is the</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-16 (Continued)

Strategy Attributes for Improving Visibility of Work Zone Personnel and Vehicles (Varies)

Attribute	Description
	project on which worker and vehicle visibility is improved. The types of improvements and the number of applications of each should be used to measure the implementation process as well.
	Key safety effectiveness measures include crash frequency and severity, by type of crash. It is important to consider crashes related to visibility of workers and work vehicles in the work zone.
	Crash frequency and severity data are needed to evaluate the construction operation for safety effectiveness. Traffic volume data are needed to represent exposure.
Associated Needs	None identified.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	Highway agencies should review and revise, as appropriate, policies regarding worker and vehicle visibility to facilitate appropriate action being taken on routine projects. Good quality control/quality assurance procedures and practices at the project level are also necessary.
	Nearly any highway agency can implement this strategy, which is applicable to work zones on any facility type in rural, urban, and suburban areas where work occurs either during the day or at night.
	Complete cooperation of contractors and all field staff is important. Contract provisions should clearly specify the visibility requirements for both personnel and equipment used on the project.
Issues Affecting Implementation Time	Implementation time will be relatively short for procedures to improve visibility, such as installing markings or lights on vehicles or lighting for the work area, and for workers to begin wearing high-visibility apparel.
Costs Involved	Costs will be low for most procedures to improve visibility and awareness of the work zone personnel and vehicles. Ongoing maintenance costs should be included in cost considerations. Cost elements will include apparel purchases, painting of vehicles, and installation of appropriate lighting fixtures.
Training and Other Personnel Needs	Visibility of work zone personnel and vehicles should be addressed in highway agency training concerning work zone safety. Contractors may also need to undergo training that includes discussion of ways to improve worker and vehicle visibility.
Legislative Needs	Use of different combinations of colored warning lights (such as yellow and blue) may require enabling legislation.
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	Actions taken to improve visibility of work zone personnel and workers are compatible with other strategies to improve work zone safety.

Key References

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Ullman, G.L., "Special Flashing Warning Lights for Construction, Maintenance, and Service Vehicles: Are Amber Beacons Always Enough?" *Transportation Research Record* 1715. Transportation Research Board. Washington, D.C. 2000.

19.1 B4—Reduce Flaggers' Exposure to Traffic (T)

General Description

Though many workers are exposed to traffic-related hazards in the work zone, flaggers are in a particularly hazardous position since they are constantly near moving traffic and frequently to two or more different streams of traffic. Many times, however, a two-way, one-lane operation is the only viable traffic control option. Making the flagger more visible (discussed in Strategy 19.1 B3) is one method to improve flagger safety. Additional strategies, discussed in this section, include using signals, remote control flagging systems, and pilot cars.

Road closure is an alternative to using flaggers and two-way, one-lane operations and will eliminate crashes where vehicles strike flaggers. Refer to Strategy 19.1 A2 for additional details. Another alternative is use of a temporary roadway that allows for two-way, two-lane operation.

Temporary Signals

Temporary traffic signals can be used instead of flaggers, thereby reducing the exposure to traffic of the workers who would perform the flagging task. Temporary signals may be considered for work zones where other traffic control options include flaggers, stop or yield

SECTION V—DESCRIPTION OF STRATEGIES

signs, or warning signs or lights. In some situations (such as on low-volume roadways), these other options may be sufficient.

Work zone types on which temporary signals may be appropriate include:

- Pavement and bridge repair,
- Roadside maintenance, and
- Emergency repairs.

A warrant for the use of temporary signals does not exist, and decisions to use them are generally made on a case-by-case basis. As with the installation of permanent signals, traffic conditions and physical characteristics of the work zone should be examined to determine if use of a signal is appropriate.

Portable Signals

Portable traffic signals can replace flaggers to allow work zone personnel to perform other critical tasks. In order to avoid fatigue, flaggers need to be relieved periodically, such as every 2 hours. Workers need to be able to perform multiple functions and need to rotate into and out of the flagger task. By automating the task of flagging, workers can be freed to focus on other tasks for longer periods and are removed from direct exposure to traffic at the flagger station.

Portable signals are mounted on trailers at both ends of the area where one-way operations occur. Communications between the signals are provided by hard wiring, by a radio frequency transceiver, or by a preset timing. An operator inputs the cycle information, such as minimum and maximum green time, yellow and red intervals, and green extension. The portable nature of the signals on trailers allows for easier setup and removal than stationary signals, making them an appropriate option for projects of relatively short duration. Portable

EXHIBIT V-17

Portable Signal System to Reduce Flagger Exposure



signals also may be appropriate for use in long work zones. If temporary signals malfunction and switch to flashing red operation, drivers must be able to see whether there is another vehicle on the opposite approach. Portable signals will more likely be used on operations where workers are present the entire time and where, therefore, flaggers could replace the signals until the signals are repaired.

Automated Flagger Assistance Devices

An automated flagger assistance device, which is a remote control sign or signal, can be also be used instead of a flagger. These devices typically require only one worker to operate, and this worker does not need to be stationed in the roadway or on the shoulder. The FHWA has issued interim approval for the use of these devices in temporary traffic control zones and provides technical provisions for these devices (see <http://mutcd.fhwa.dot.gov/resources/afads.htm>). However, each jurisdiction must receive a specific approval from the FHWA by submitting a written request to the FHWA stating the location where the device will be used and agreement to comply with the terms.

Approval for use of these devices must be received from FHWA.

There is some concern that drivers will misinterpret the meaning of a remotely controlled stop/slow paddle. It is possible that a driver will stop at the stop sign and then proceed, rather than wait for the slow sign. Additional signing could address this.

A brief description of the Minnesota DOT experimental use of such a device is provided on the FHWA Work Zone Mobility and Safety Program website at http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=140&from=topindex&Category_ID=124. Minnesota limits the use of these devices to work zones less than 1,000 feet long on low-volume, two-lane roadways. A similar device is a remote controlled red/amber signal that replaces a flagger or is used in coordination with a flagger positioned out of the traffic stream. The system includes a gate that lowers during the red signal.

Wisconsin DOT has used a remote flagging device with success; an evaluation is provided in Appendix 4.

EXHIBIT V-18

Strategy Attributes for Reducing Flaggers' Exposure to Traffic (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	This strategy targets crashes in which vehicles strike flaggers. Other crash types, such as rear-ends that occur when a driver's view of a flagger is blocked by another vehicle, may also be reduced. This strategy is applicable to any work zone where two-way, one-lane operations are necessary, though some of the alternatives may be more costly than can be warranted on smaller projects.
Expected Effectiveness	While thorough studies have not yet been performed to show the effectiveness of this strategy, replacing flaggers with temporary or portable signals or remote-controlled signs would be expected to eliminate crashes where vehicles strike flaggers, should

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-18 (Continued)

Strategy Attributes for Reducing Flaggers' Exposure to Traffic (T)

Attribute	Description
	the flaggers be able to be stationed a distance away from through traffic. It is possible that rear-end crashes may initially increase as drivers become familiar with new devices.
Keys to Success	<p>If a flagger is replaced with a signal or sign, the traffic control device needs to be installed and used in such a way that it is clear to drivers what action they are supposed to take. In addition to advanced warning signs, supplemental signing at the signal or an arm that lowers during a red phase of a signal (see Appendix 4) to provide this information, a PI&E campaign may be necessary to communicate to drivers how the signal operates and how drivers are expected to proceed through the work zone. This is especially true for the new or experimental systems that are being developed and becoming more frequently used.</p> <p>The devices must be visible to approaching motorists, and at least the minimum amount of sight distance should be provided. Care should be taken to ensure adequate sight distance to the traffic control device on approaches where permanent features, such as horizontal or vertical geometry, or temporary conditions, such as work vehicles and equipment, may restrict the drivers' view of the device.</p> <p>Appropriate timing of the temporary or portable signals is critical to the success of this strategy. Excessive wait time can lead to driver confusion and frustration, possibly resulting in violation of the signal. A maximum reasonable wait time is considered to be 4 minutes (Daniels et al., 2000, and NYSDOT, 2005). Factors to consider when determining signal timing include length of the work zone, traffic volume, approach speed, range of speeds in the work zone, and amount of buffer time between traffic departing the work zone and traffic entering the work zone (Daniels et al., 2000). Driveway and intersections, pedestrians, and parking should also be considered (NYSDOT, 2005).</p>
Potential Difficulties	<p>It is important to ensure that replacement of flaggers with remote control of two-way traffic on a one-way facility does not present greater safety problems for drivers, due to low visibility of the system or confusion that the new system may create.</p> <p>Design of a signal timing plan, if it does not consider all appropriate factors, can negatively impact traffic flow and safety through the work zone. Conditions at the site should be studied before implementing the signal.</p> <p>In the event of malfunction of a traffic signal or of an automated flagging device, flaggers must take over responsibility of directing traffic immediately. It is possible that work zone personnel would not be immediately aware of the malfunction unless stationed nearby and watching for such situations or unless the system has an alarm to warn workers that there has been a malfunction. Such an issue could result in serious head-on crashes as well as place workers within the area at greater risk to collision.</p> <p>As with traditional manual flagging operations, work zones with driveways or intersections in between the signals or automated flagging devices will present additional challenges to safe handling of the alternating one-way operations. It is preferable to locate the one-way operations so that they do not include intersections and high-volume driveways so that automated flaggers or portable or temporary signals are controlling all the vehicles that enter a work zone.</p> <p>For work zones that involve very short-term, one-way operations or projects with a location that moves frequently, flaggers may be a better choice than temporary or portable signals, since the benefits gained by using portable signals may not be offset by the repeated efforts to set up, take down, and move the signals.</p>

EXHIBIT V-18 (Continued)

Strategy Attributes for Reducing Flaggers' Exposure to Traffic (T)

Attribute	Description
Appropriate Measures and Data	<p>A key process measure is the number of projects on which flaggers are replaced with temporary or portable signal systems or with experimental remote control flagging systems. Documentation of the type of system and the manner in which it is deployed is also needed as part of the process evaluation data collection.</p> <p>Key safety effectiveness measures include crash frequency and severity, by type of crash. It is important to consider crashes involving flaggers in the work zone.</p> <p>Crash frequency and severity data are needed to evaluate the construction operation for safety effectiveness. Traffic volume data are needed to represent exposure. Delay data are needed to determine the operational impacts of the project on traffic flow.</p>
Associated Needs	<p>A PI&E campaign is an important part of implementing a device for controlling two-way, one-lane operation that may be new or potentially confusing to drivers. Drivers need to know how to respond when they encounter the situation, especially if it is relatively new to an area. It is important to communicate with the public on the use of remote control flagging systems, as these are experimental and it is very likely that a high percentage of drivers will not be familiar with them.</p>

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	<p>Agencies using temporary signals need to determine whether alterations to the procedure for adjusting the timing of temporary signals are needed. While temporary signals are in use, agencies will want to establish a procedure for adjusting the settings. It should be determined who will be responsible for determining the changes, and it is important to consider how this will be accomplished during nonbusiness hours if the signal will be operating at night.</p> <p>An agency desiring to use this strategy may need to develop a set of policies and guidelines on the use of the devices. In some cases, legislation may be needed for a control device to be used. Another key issue is the development of operational procedures for these devices to ensure that each setup provides adequate sight distance. Proper signal timing for specific temporary and portable signals should also be determined using established policies or guidelines.</p> <p>Since remote control flagging systems are experimental traffic control devices, FHWA approval may be needed before they can be used. An evaluation plan should be in place as well to assess the effectiveness of the system.</p>
Issues Affecting Implementation Time	<p>Implementation of temporary or portable signals or remote control flagging systems can be achieved in a relatively short time, once any necessary authorization is received. The “authorization,” however, may involve passing legislation, establishing policies and guidelines, and receiving FHWA approvals. In such cases, the time could be extended to beyond a year.</p>
Costs Involved	<p>The cost of the improvements and devices described above could be amortized over several projects. To implement such measures in all applicable locations would have a significant impact on overall budget and cost of projects. Many agencies will purchase one or more sets of equipment and use these sets on projects where they will provide the greatest benefit. One advantage to having several of these systems is that by freeing a flagger to perform other tasks, efficiency is increased on the project and the number of personnel needed is reduced.</p> <p>Example costs of a temporary signal are provided in Appendix 5.</p>

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-18 (Continued)**

Strategy Attributes for Reducing Flaggers' Exposure to Traffic (T)

Attribute	Description
Training and Other Personnel Needs	Highway agency personnel (specifically traffic signal engineers) and contractors should be trained in the process of developing a signal timing plan for temporary and portable signals (including appropriate location of the devices in order to ensure adequate sight distance) and use of the system, as appropriate for the tasks for which the personnel are responsible. Training will also be needed for flaggers who are operating remote control systems and proper procedures for serving this function.
Legislative Needs	None identified.
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	Use of temporary or portable signals or remote control flagging systems is compatible with other strategies discussed in this guide.

Key References

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NYSDOT, *Highway Design Manual*. June 24, 2005. <http://www.dot.state.ny.us/cmb/consult/hdmfiles/hdm.html>.

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

Texas DOT has used portable signals on several projects. Use of the signals is evaluated by Daniels et al. (2000).

Washington DOT has identified Unilight traffic signals as a top-rated ITS application to avoid stationing flaggers close to traffic (<http://www.betterroads.com/articles/brjun00c.htm>).

Objective 19.1 C—Improve Work Zone Design Practices

Changes in the basic approach used to design work zones and the specific design features included in work zones provide a number of opportunities to improve overall safety and reduce the risk of fatalities. Agencies can best ensure consistently high-quality work zone designs by developing and implementing specific design guidance and procedures for use by designers and planners. Design features intended to reduce the risk and consequences of work space intrusions and to accommodate the needs of other roadway users can contribute to the overall safety of work zones.

Greater attention to the design of work zones may enhance some of the other objectives proposed in the guide. It may lead to a more efficient overall operation of the work zone, in terms of both traffic operations and safety.

19.1. C1—Establish Work Zone Design Guidance (T)

General Description

Experience shows that inappropriately designed work zones are common. Work zone design guidance has been established in some states, but other states do not have set guidelines for designers to follow. Adoption of design guidelines is an initial step to ensuring a level of quality and consistency in work zones under an agency's jurisdiction. Periodic updating of work zone design guidelines is recommended to ensure that the latest knowledge related to work zone safety is reflected in the guidelines.

Work zone conditions differ from normal driving conditions. Drivers familiar with a roadway encounter different conditions when driving through work zones, and violations of driver expectancy may result. Space limitations, when combined with the challenge of configuring a work zone to allow continuation of traffic operations while work is underway, often result in less than ideal geometry. In addition, since every situation is different, it is common to have a significant amount of variation in design among work zones. Designing work zones according to established guidelines for layout geometry and use of materials will contribute to meeting driver expectations by providing consistency between work zones, resulting in less violation of driver expectancy and safer work zone operation.

Several examples of design elements for which guidelines would be desirable are:

- **Lane transitions.** Ideally, lane transitions would be designed so as to reduce or eliminate uncomfortable deceleration as well as speed variance in the work zone. While optimum transitions are desired, it is not always possible to implement them due to existing constraints in the project area.
- **Lane widths.** Designers would benefit from information on which to base selection of lane width for a specific project.
- **Ingress and egress of work vehicles.** Guidelines for providing space for acceleration and deceleration of trucks as they enter and exit the work zone, as well as for provision of periodic interruption of traffic in at least one lane, would be useful.
- **Pavement edge drop-offs.** Guidance on use of signs, channelizing devices, or barrier can help designers provide more consistency in work zones (see Appendix 6).

SECTION V—DESCRIPTION OF STRATEGIES

NCHRP Project 3-69 is developing a methodology to help transportation professionals choose appropriate design and traffic control elements for work zones on high-speed roadways. This is expected to be completed in 2006.

EXHIBIT V-19

Strategy Attributes for Establishing Work Zone Design Guidance (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	The principal target of this strategy is the agency designer who will develop plans for the work zone. Proper design guidance is expected to affect all types of work zone crashes by reducing road user and worker exposure to potentially unsafe work zone conditions. This is done by developing and applying design guidelines to ensure safe design practices and consistency among work zones.
	A wide variety of project types, including both construction and maintenance operations, would benefit from being designed according to established guidelines.
Expected Effectiveness	It is expected that establishing and using work zone design guidelines will improve work zone safety, though it is not feasible to do a valid measurement of an impact from a support function that is somewhat removed from the road operation. Providing easily accessible materials can promote the awareness of staff with agency policies and procedures.
Keys to Success	A key to the success of this strategy would be conduct of (1) quality-control reviews to ensure that work zones are designed properly and (2) safety audits or inspections of the work zones to ensure that they are installed as planned. Agency personnel should receive training in any newly adopted design guidelines. Staff who do not design work zones frequently may need to repeat training when those skills are needed.
Potential Difficulties	Review of work zone designs and inspections of work zones will increase the workload on agency staff who would be assigned responsibility for these tasks.
	To address potential liability concerns and provide a basis for future decisions made during the development of work zone design, guidelines should be documented so that a record is kept of (1) the information used to develop the guidelines, (2) decisions on what to include or leave out, and (3) discussions on various topics.
Appropriate Measures and Data	Process measures would include the existence of the design policies, the frequency of review of these policies, and the number of work zone projects to which they are applied. It is not feasible to measure the safety effectiveness of this type of support activity. Impact should be measured, instead, in terms of the improvement in safety-oriented design features of work zones.
Associated Needs	None identified.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	Support for this effort is best attained from the highest levels in the agencies to improve agencywide acceptance and implementation of new guidelines. It is also important to involve all interested parties within an agency in developing guidelines, or at least in planning discussions and review efforts. Ultimately, it is desirable that the design guidelines be adopted as agency policy.

EXHIBIT V-19 (Continued)

Strategy Attributes for Establishing Work Zone Design Guidance (T)

Attribute	Description
	Interagency agreements may be needed in order to ensure participation of people outside the highway agency with interest in work zone safety, such as police departments.
Issues Affecting Implementation Time	Implementation may take some time, since development of the guidelines may require research into work zone safety and operations issues, the state of the practice, and federal and other agency policies. Guidelines would also need to undergo an extensive review within the agency, including a review by risk management personnel.
Costs Involved	A key cost is the personnel time that would be needed to develop and review the guidelines. Publication of the guidelines (whether in printed or electronic format) and development of training for agency personnel and contractors should be considered when estimating development costs. The cost to develop guidance could be significant, but per-project cost would be low.
Training and Other Personnel Needs	Agency personnel should be trained in the application of the design guidelines, as should personnel from any contracted organizations that will be designing work zones.
Legislative Needs	None identified.
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	This strategy is compatible with the others discussed in this guide. Strategy 19.1 F4, regarding safety inspections, is directly related to this strategy.

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

Several agencies have their work zone design guidance traffic control manuals available online:

- Illinois DOT's Virginia Work Area Protection Manual:
<http://www.dot.state.il.us/desenv/bdemanual.html>.
- Indiana DOT's Design Manual:
<http://www.in.gov/dot/div/contracts/standards/dm/>.
- Virginia DOT's Work Area Protection Manual:
<http://www.virginiadot.org/business/resources/1-%20WEBwapmCOVER.pdf>.
- Washington State DOT's Design Manual:
<http://www.wsdot.wa.gov/fasc/EngineeringPublications/manuals/Designmanual.pdf>.

In an effort to improve design and operation of future work zones, Oregon DOT holds a debriefing meeting at the end of construction projects. Oregon DOT is also looking into developing a traffic control plan database and providing traffic control plan development training for staff and consultants in order to facilitate statewide consistency.

19.1.C2—Implement Measures to Reduce Work Space Intrusions (and Limit Consequences of Intrusions) (T)

General Description

Vehicles traveling through work zones are near workers, work activities, and equipment in the work space. Work space intrusion crashes may occur when vehicles for one reason or another leave the traffic space and enter the work space. These crashes have high potential for resulting in severe injuries or fatalities, especially for workers not inside construction vehicles and occupants in vehicles colliding with heavy equipment. Bryden et al. (2000) found that intrusion crashes represent approximately 9 percent of all work zone crashes. Many factors can contribute to these crashes, including excessive speed, driver fatigue, impairment, inattention, reduced visibility, adverse weather, conflicts with other vehicles in the traffic space, or inadequate traffic control.

Positive protection is defined as a device that contains and redirects vehicles in accordance with *NCHRP Report 350*, thereby preventing vehicles from intruding into the work space. Providing positive protection separation between the traffic and the work space, while not always achievable, has the potential to reduce crash frequency and severity for both workers and road users. NCHRP Project 20-7, Task 174, produced a final report on the use of positive protection in work zones (copies of this final report are available upon request from the NCHRP).

When physical barriers cannot be provided, it is imperative to provide the necessary measures to keep drivers alert and traveling at an appropriate speed. Strategies to reduce work space intrusions where positive protection cannot be used are based on improving the visibility of the work space, increasing driver awareness of the work zone, reducing speeds, and reducing roadway departures. While these treatments cannot physically prevent an intrusion, such measures may reduce the risk of an intrusion event occurring. It is important to note that not all work space intrusions can be eliminated. In such cases, it is imperative that the consequences of such an intrusion, especially to the workers within the work zone, be limited.

Physical Separation Measures

Methods for reducing work space intrusions include:

- Portable concrete barrier,
- Shadow vehicles with or without truck-mounted attenuators or arrestor nets, and
- Vehicle arrestor barriers.

Providing physical barriers that separate traffic in the active lanes from the transition area, work space, and/or buffer space is the cornerstone in positive protection. In nearly all cases, such barriers eliminate the possibility for intrusion into the respective work zone areas. Portable concrete barriers are the preferred barriers for such protection.

Water-filled barriers can be used for some of the same applications as portable concrete barriers and can be easier to move. Low-speed roadways and situations where deflection control is not critical are examples of where water-filled barriers may be appropriate.

Moveable barriers may be a good physical separation option in situations where a lane can be or needs to be closed and reopened frequently. An example of a situation where this may

be appropriate is when there is a significant difference in the peak volume traveling in each direction through a work zone. A lane can be closed in the off-peak period and reopened for the peak period in that direction of travel. Also, moveable barriers may be appropriate for nighttime projects in which a lane needs to be closed on a nightly basis. Application of moveable barriers is discussed in the MUTCD, Part 6H, Typical Application 34 (<http://mutcd.fhwa.dot.gov/pdfs/2003/Ch6H.pdf>).

Speed Control Measures

Excessive speed is a significant contributor to intrusion accidents. During construction, space to which traffic can be diverted is often limited. In many cases, the design of the temporary traveled way uses design criteria applicable for lower design speeds in order to maximize the space available for the respective traveled way. Lane shifts and median crossovers usually require vehicles to travel at significantly lower speeds due to shorter tapers and sharper curves. A barrier will often be placed near the traveled way as well, providing less room for errant vehicles going off the traveled way. The applications of low-speed design criteria demand that every effort be made to reduce the speed with which vehicles travel through the work zone. The implementation of measures to reduce such speeds can consequently reduce the number of speed-related intrusion crashes. Such measures include speed limit reductions, police enforcement, drone radar, rumble strips, variable message signs, and pilot vehicles.

Pilot cars may be used to lead drivers through the work zone and to help drivers follow flagger instructions. An advantage to using pilot cars is that they can control the speed of the vehicles proceeding through the work zone and provide a form of positive guidance to assist drivers in navigating the work zone. Pilot cars are more feasible in long work zones than in short ones.

Intrusion Mitigation Measures

Strategies to limit the consequences of work space intrusions include intrusion alarms and spotters/flaggers. Intrusion alarms provide an audible warning to workers when a vehicle enters the work space. The purpose is to provide workers with an additional window of time to move to a safer location. Alarms can sound warnings when impacted or when a detector is triggered. The alarm device can detect the intrusion using infrared beams, microwave beams, or pneumatic tubes. Intrusion alarms are either stand-alone or attached to cones, plastic drums, and other channelizing devices used to separate traffic space from work space. Flaggers can also be provided with alarms to sound if a vehicle disobeys the signal and enters the work zone. Several alarms can be used together to provide warning over long distances.

Positive Guidance Measures

Channelizing devices, such as drums, can be used to separate a work area from traffic. This does not, however, provide a physical barrier between the traffic lanes and the work area. Reducing the spacing of the devices provides additional positive guidance for drivers. Wider gaps in devices can be used to allow work vehicles to enter and exit the work space.

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-20

Type III Barricade Spaced at Intervals in Closed Lane to Reduce Intrusion Risk

**EXHIBIT V-21**

Strategy Attributes for Implementing Measures to Reduce Work Space Intrusions (and Limiting Consequences of Intrusions) (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>Implementation of measures to reduce work space intrusions targets crashes involving traffic intruding into the work space and/or buffer space. Such crashes include those of vehicles striking work vehicles, construction equipment, workers on foot, excavations, unprotected bridge dropoffs, bridge piers, falsework, and any other construction feature.</p> <p>This strategy is applicable to any work zone, as it is always desirable to separate traffic from work. Short-duration work zones may not offer cost-effective applications of the more expensive methods of preventing intrusions, such as portable barriers.</p>
Expected Effectiveness	<p>Experience has shown that measures to reduce work space intrusions have been very effective. The use of portable concrete barriers as a physical separation between the active travel lanes and the work zone areas can eliminate most intrusions. Truck-mounted attenuators are also effective in developing positive protection through the work zone.</p> <p>One must remember that a collision with a portable concrete barrier or truck-mounted attenuator is a crash also and may involve damage and injury. However, the resulting damage and injury is expected to be of a lesser degree than not providing this positive protection. The effectiveness in speed reduction strategies is often minor or relatively short-lived, but there may be some benefit in increasing driver awareness of the work zone.</p>

EXHIBIT V-21 (Continued)

Strategy Attributes for Implementing Measures to Reduce Work Space Intrusions (and Limiting Consequences of Intrusions) (T)

Attribute	Description
Keys to Success	<p>Guidance on the use of positive protection may be needed for the agency that is investigating use of the strategy. An example of one DOT's guidance can be found online at http://wzsafety.tamu.edu/files/guideline.stm.</p> <p>Devices used for positive protection should be maintained. Regular inspections of the work zone should be performed to determine if any repositioning or repairs are needed.</p> <p>Visibility of any devices used to control the speed of traffic is a key issue. When flaggers are used in work zones for speed reduction, improving the visibility of the flaggers can further assist drivers in identifying and reacting to areas of slowed or stopped traffic (see Strategy 19.1 B3).</p>
Potential Difficulties	<p>It is often not possible to provide positive protection for the entire length of a work zone. Access to and from the active travel lanes may be required intermittently throughout the area of construction for construction vehicles, thereby leaving those areas vulnerable to intrusion from vehicles in the active lanes. In addition, the use of portable concrete barriers may contribute to increased severity of crashes between through traffic vehicles when one vehicle side swipes the portable concrete barriers and is consequently deflected into an adjacent travel lane. With portable concrete barriers in the clear zone, run-off-road crashes will be more likely, since there will be less recovery space for errant vehicles. Some studies have recommended the use of portable concrete barriers only when absolutely necessary to provide protection from a sensitive area in the work zone. Portable concrete barriers are not practical for short-term work zones, especially where the location of the work changes frequently (as with resurfacing projects). Placement and removal of portable concrete barriers involves risk for both workers and traffic.</p> <p>It is possible for water- or sand-filled drums or cones to be misused by not using the proper amount of ballast and/or not placing it in the proper position filled or anchored. This misuse would prevent the devices from performing as designed and could create a hazard if struck by a vehicle.</p> <p>The implementation of truck-mounted attenuators will not eliminate intrusion crashes, and collisions with truck-mounted attenuators can result in serious injuries. As noted previously, the purpose of the shadow vehicle with a truck-mounted attenuator is to stop an intruding vehicle in a controlled manner before it strikes workers or encounters more serious hazards. There are instances where a vehicle will penetrate portable concrete barriers and enter the work space. Experience with both portable concrete barriers and truck-mounted attenuators shows both devices to be very effective in stopping or controlling errant vehicles without high risks to vehicle occupants. However, when impact conditions exceed the design capability of the devices, more serious consequences may result.</p> <p>Devices used to limit the consequences of intrusions should not be placed so that they adversely affect sight distance in the work zone, create additional visual clutter, or confuse drivers.</p> <p>Workers must find intrusion alarms credible. Too many false alarms will significantly lessen the value of the alarms since workers may begin to ignore them. The intrusion alarms need to differentiate between work vehicles entering the work space and actual intrusions by errant vehicles.</p>

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-21 (Continued)

Strategy Attributes for Implementing Measures to Reduce Work Space Intrusions (and Limiting Consequences of Intrusions) (T)

Attribute	Description
Appropriate Measures and Data	<p>A key process measure is the number or percentage of projects on which this strategy is implemented, along with the type of method used and the manner in which it is deployed.</p> <p>Key safety effectiveness measures include crash frequency and severity, by type of crash. It is especially important to identify crashes related to the protection measures themselves. These might include side-swipe crashes with the portable concrete barriers or crashes caused by drivers making erratic maneuvers as they (1) get too close to or are deflected from the portable concrete barriers or (2) attempt to avoid entering the work zone.</p> <p>Crash frequency and severity data are needed to evaluate the construction operation for safety effectiveness. Traffic volume data are needed to represent exposure, including changes in volumes on alternative routes during the construction.</p>
Associated Needs	A PI&E campaign may be needed if a project will involve use of a new device that may cause driver confusion.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	Portable concrete barriers effectively protect the work zone from traffic intrusion, but they can contribute to the occurrence of collisions in the traffic lanes. Agencies may need to evaluate this issue in greater detail to establish appropriate policies and guidelines for the application of portable concrete barriers.
Issues Affecting Implementation Time	Speed control measures that include special law enforcement efforts will need to be carefully arranged and coordinated with the appropriate agencies, including provision for space in which law enforcement vehicles may be placed for surveillance, as well as for stopping violators without negatively affecting traffic operations.
Costs Involved	<p>It may take several months to develop guidelines for the use of the various means for achieving positive protection and limiting the consequences of intrusions. Once guidelines are in place and agency personnel have been trained, actual installation time of positive protection devices will be short, but will vary depending on the specific devices used. Installation time for some devices, like intrusion alarms and drums or cones that improve the positive guidance, will be relatively short.</p>
Training and Other Personnel Needs	Positive protection guidelines, intrusion alarms, and other methods for reducing intrusions or limiting the consequences of them should be covered in agency training on work zone design and traffic control. Training on the proper uses for and setup of equipment used for these purposes should be provided to agency personnel and contracted workers.
Legislative Needs	None identified.

EXHIBIT V-21 (Continued)

Strategy Attributes for Implementing Measures to Reduce Work Space Intrusions (and Limiting Consequences of Intrusions) (T)

Attribute	Description
<i>Other Key Attributes</i>	
Compatibility of Different Strategies	Reducing work space intrusion and limiting the consequences of intrusions are strategies compatible with other improvements to work zone safety.

Key References

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19.1 C3—Improve Work Zone Safety for Pedestrians, Bicyclists, Motorcyclists, and Heavy-Truck Drivers (T)

General Description

Work zones should continue to accommodate the road users who were using a roadway before construction began. Work zones present additional workload not only to drivers of passenger vehicles and heavy trucks, but also to pedestrians, bicyclists, and motorcyclists. In addition to providing well-designed facilities for these other road users, agencies should notify drivers of the presence of these people and vehicles and design the work zone for drivers to be able to see and avoid these users. Accommodation of pedestrians, bicyclists, motorcyclists, and heavy-truck drivers should be planned before work begins. In addition, regular inspection of conditions for these road users should be performed in order to ensure that these users are being accommodated safely.

SECTION V—DESCRIPTION OF STRATEGIES

Roadway sections in work zones open to public travel should be free from surface irregularities and construction debris that present hazards to any road user expected. Uneven and cluttered surfaces can cause motorcyclists or bicyclists to fall and can present tripping hazards to pedestrians. This includes pavement edges, large or deep ruts, metal plates, and pavement and other surfaces with low skid resistance. The travel path should be continuous and hard. Loop detectors on existing roadways should continue to be accessible during the project.

Additional strategies beyond those briefly discussed in this section are covered in other volumes of the *NCHRP Report 500* series:

- Pedestrians (Volume 10)
- Bicycles (forthcoming)
- Motorcycles (Volume 18)
- Heavy-truck drivers (Volume 13)

Pedestrians

The MUTCD should be consulted for information on accommodating pedestrians in work zones and on reducing pedestrian-vehicle conflicts. In addition, many of the strategies for improving pedestrian safety discussed in Volume 10 (relating to pedestrian crashes) of this series can be applied to work zones.

Careful consideration should also be given to the needs of pedestrians with disabilities, especially when there is evidence that the regular users of this area include pedestrians with special needs. The level of accessibility of existing pedestrian facilities should be maintained during the work period to the extent practical. The MUTCD provides guidance on providing accessible facilities in work zones, including consideration of pedestrians with either visual or mobility disabilities. The changes made to a pedestrian's path, due to work zones, will interrupt the routine of a person with visual disabilities whose route goes through the affected area. Visually impaired pedestrians need clear guidance through the work zone, and this can be provided through detectable obvious barriers and edges on channelizing devices, guide rails, audible warning devices, or even audible spoken messages activated by push buttons.

Several treatments that affect pedestrian safety are detailed below.

- **Pedestrian Paths:** Pedestrian paths should be continuous, smooth, hard, and located out of hazardous areas. Chadda and McGee (1984) discuss pedestrian considerations in work zones. Maintaining pedestrian access to adjacent properties throughout construction may be required. While undesirable, it may be necessary for practical reasons to allow for pedestrian travel through the work zone. If pedestrian travel paths will be obstructed or made more hazardous by ongoing work, the traffic control plan should provide an alternative, safer route. This may be accomplished with:
 - *Existing pathways:* pedestrians can be directed to use alternative pathways already existing in the work zone. This may include sidewalks on the other side of the street.
 - *Bypasses:* temporary bypass routes can be provided where unobstructed and nonhazardous space is available in the right-of-way. Bypasses may be established in parking lanes or grass buffers in the work zone.

- **Detours:** pedestrians can be instructed to use a detour route when it is not possible to use other existing pathways
- **Traffic Plans:** When establishing pedestrian traffic plans, the origins and destinations of the pedestrians should be considered, as well as the ideal (typically shortest) routes through the work zone. Access to bus stops and cross walks should be maintained, or temporary relocation of both should be considered. Pedestrians will be using the paths during all lighting and weather conditions; therefore, messages (both visual and audible) should be clear at all times. The FHWA Office of Safety website has a checklist of pedestrian-related items to consider when developing a traffic control plan:
<http://safety.fhwa.dot.gov/wzs/sa03047/wzp3.htm>.
- **Channelization:** Pedestrians should be encouraged to use the safest path and to cross roadways in the appropriate location. One way to accomplish this is through channelization, which can help reduce conflicts with work activities and vehicular traffic. Any devices or barriers used to channelize pedestrian movements should not obstruct the sight distance for motorists. Barriers can also serve as protection from vehicular traffic when the two travel paths are close.
- **Public education:** Educating pedestrians on appropriate behaviors when walking through work zones, as well as on the meanings of traffic control devices, can contribute to their safe use of pedestrian facilities in work zones. FHWA has several pedestrian information sheets, one of which covers walking through work zones:
<http://www.tfhrc.gov/safety/pedbike/issues/issues.htm>.

The pedestrian guide (Volume 10 of this series) discusses strategies for improving pedestrian safety in more detail.

EXHIBIT V-22
Work Zone Pedestrian Walkway



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Bicyclists

Consideration should be given to the needs of bicyclists as work zones are being designed and set up and as work is being performed. Pavement edge dropoffs or longitudinal joints can present hazards to bicyclists, as can surface debris and low-traction areas.

Warning signs increase driver awareness of bicycles in work zones. Standard MUTCD bicycle warning signs should be used to alert drivers to the presence of bicyclists. PennDOT installed orange warning signs to inform drivers that bicyclists may be using the travel lanes in a construction zone with heavy bicycle traffic. The “Bicycles in Roadway” signs have flashing lights to increase their visibility and are supplemented with changeable message signs at the ends of the work zone. (Additional information can be found online at http://www.222connections.com/lehigh/news_story.cfm?news_item=48).

The bicycle guide (forthcoming in this series) will provide details on improving safety for bicyclists.

Motorcyclists

Many of the work zone design features that improve safety for drivers of passenger cars and trucks will improve safety for motorcyclists. One example is paved shoulders, which can be used by motorcycles in case of break downs, as well as other vehicles. Motorcycles should be explicitly considered when making decisions about other design features, such as barrier type, and pavement marking materials that could reduce traction. Temporary pavement marking materials can be shorter or provide a gap free of the material for motorcycles to pass through in order to reduce low-traction surfaces. Sewer caps that temporarily sit above the pavement level, edge drop offs, and other surface conditions commonly found in work zones can present more significant hazards to motorcycles than other vehicles. Agencies may wish to require that longitudinal joints be closed up once work is completed for the day. Advance warning signs can be used to inform motorcyclists of conditions in the work zone, such as wet pavement, longitudinal joints, or steel plates in the roadway. Refer to the motorcycle guide (Volume 18 of this series) for additional details on these and other strategies.

Heavy-Truck Drivers

The physical and operational characteristics of heavy vehicles vary from those of passenger cars and should be considered in work zones on roadways where trucks typically travel. Several heavy-truck characteristics to consider include:

- **Acceleration and deceleration capability:** This plays a role in many aspects of a work zone design and its operation. Temporary entrance and exit ramps and flagging operations are two examples. Restriction of trucks to the right lane of a multilane roadway may not be desirable if there are entrance and exit ramps within the work zone.
- **Rollover potential:** Design of radii on ramps, crossovers to temporary roadways, and lane shifts should consider the higher center of gravity of trucks.

- **Vehicle size:** Lane width and placement and height of barriers should accommodate the larger vehicles.
- **Turning:** Intersection corners should account for both the minimum turning radii of large trucks and the off-tracking of the wheels.

See the heavy-truck guide (Volume 13 in this series) for strategies for improving heavy-truck safety in more detail.

Key References

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Objective 19.1 D—Improve Driver Compliance with Work Zone Traffic Controls

Good compliance with traffic laws and regulations in work zones is essential to maintaining a high level of safety and orderly, efficient traffic flow. Frequent and visible enforcement is generally accepted as highly effective in gaining compliance with traffic laws and regulations in work zones. Enforcement issues include how and where work zone enforcement is most effective, as well as the administrative arrangements needed to ensure that adequate enforcement is available when needed. Adding to the effectiveness of adequate enforcement are increased penalties for work zone violations. Finally, drivers need to have a high level of respect for work zone laws and regulations, which can be achieved by maintaining driver credibility for regulations posted in work zones.

The physical presence of a law enforcement officer in the work zone is the most effective way to maximize compliance. This should be considered prior to commencement of a project in order to better plan for the associated costs. Design of the work zone should accommodate space needed for enforcement activities in order to make the activities safer and more efficient.

SECTION V—DESCRIPTION OF STRATEGIES

19.1 D1—Enhance Enforcement of Traffic Laws in Work Zones (T)

General Description

Enforcement of traffic laws in work zones can be enhanced using four key methods:

- Targeted conventional enforcement,
- Automated enforcement,
- Improved efficiency of enforcement, and
- Improved administrative procedures for work zone police services.

Targeted Conventional Enforcement

Targeted conventional enforcement in work zones, where officers present in the work zone enforce speed limits and other traffic laws, can help improve the safety in the work zone by reducing the occurrence of violations and increasing driver awareness of the work zone. Though a direct correlation to a reduction in fatal crashes cannot be made, it can be expected that increased enforcement will lead to a reduction in speeds and a safer work zone for both drivers and workers. Evidence suggests that the effect of the enforcement (i.e., the reduction in violations) does not last long after enforcement ends unless a pattern of targeted enforcement occurs over a period of time. Coordination among transportation agencies, law enforcement agencies, and traffic courts in the jurisdiction is important to the success of this strategy. Refer to Volume 5 of this series (the guide for unsignalized intersections), for additional details on providing targeted enforcement.

EXHIBIT V-23

Police Enforcement During Night Work – Targeted Enforcement



Automated Enforcement

Automated enforcement of traffic laws is increasingly common in the United States, and there are opportunities to use this technology in work zones. Automatic speed enforcement systems, in particular, would be appropriate for work zones, allowing police officers to focus efforts in other areas. Cameras can be placed in locations where targeted enforcement by officers is difficult due to limited space for stopping violators, such as in congested areas, on bridges, in tunnels, or on detours or temporary lanes with challenging geometry. The cameras can be turned on only when the work zones are active and workers are present.

Due to institutional issues, however, these systems are not frequently used in work zones. As with automated red-light running enforcement, automated speed enforcement is often viewed by the public as a revenue generator. Some enforcement agencies view the loss of public contact (when providing manual enforcement and writing citations) as a negative reflection of the agency. Other political issues include concerns about how speed limits are set and tolerances in enforcing them. In addition, state traffic laws may need to be changed to allow use of automated enforcement. If these issues can be addressed, it is possible that automated speed enforcement can be implemented and can have a positive effect on work zone safety. A well-designed PI&E campaign can explain the safety-related reasons for using automated enforcement and how traffic laws such as speed limits are set, resulting in increased public support of the cameras. Using the proceeds from fines to purchase items such as safety equipment or to assist injured workers could also help improve public sentiment.

Illinois will be using speed cameras in areas designated as “work zones” on major freeways. To improve safety in work zones, Illinois has passed an act for automated traffic control systems in highway construction or maintenance zones (available online at <http://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=2619&ChapAct=625%26nbsp%3BILCS%26nbsp%3B7%2F&ChapterID=49&ChapterName=VEHICLES&ActName=Automated+Traffic+Control+Systems+in+Highway+Construction+or+Maintenance+Zones+Act%2E>). Refer to the signalized intersection guide (Volume 12 of this series) for additional details on automated speed and red light enforcement.

Improved Efficiency of Enforcement

Lack of adequate space for vehicles to pull off of the road often results in inefficient traffic law enforcement through the work zone. Police enforcement in work zones can be difficult where there is not an adequate shoulder or pull-off area for enforcement activities, such as monitoring speeds or pulling over drivers. This difficulty forces the police officer to follow a violator through the work zone. Use of emergency lights while following a vehicle in a work zone may cause a driver to stop in the travel lane and block traffic rather than proceeding through the work zone. Designing space for enforcement activities into a work zone would make police officers’ tasks easier and safer. Maintaining adequate shoulder areas to keep them available for making traffic stops free of debris also aids in effective enforcement.

Improved Administrative Procedures for Work Zone Police Services

Developing administrative procedures at the police and highway agency level can be highly effective in helping to ensure that police services are incorporated where necessary in any

SECTION V—DESCRIPTION OF STRATEGIES

given work zone. A procedure should be established for a highway agency to request enforcement help from the police agency. These procedures would be useful for working with both state and local law enforcement agencies. On a project level, in order to make efficient use of limited police resources to enforce traffic laws in work zones, the need for police services should be considered in the planning stages of the project. In addition to enforcement activities, incident response activities should be considered. Schrock et al. (2002) conducted a survey of 20 state law enforcement agencies throughout the country. Less than a third of the respondents to the survey indicated that their agency was involved in the planning stages of the traffic control plans for the work zone. Additional discussion on developing administrative procedures is provided in Appendix 7.

NCHRP Project 3-80 will develop guidelines for applying law enforcement strategies for work zones on high-speed roadways.

EXHIBIT V-24

Strategy Attributes for Enhancing Enforcement of Traffic Laws in Work Zones (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	This strategy targets traffic law violators in work zones. Crashes of all types may result from various violations. Speeding is an obvious concern in work zones, and rear-end crashes would be a common crash type related to speeding (as well as to tailgating).
	This strategy is applicable to all work zones. Administrative procedures would need to be developed only once and then could be applied to all work zones. Work zones short in length or duration may not need space for enforcement activities designed into them, but enforcement can be an element of any work activity.
Expected Effectiveness	Previous research has shown that the presence of police in a work zone is associated with a small but measurable reduction in the speed of motorists, but that this effect does not remain long after enforcement has ended. While research has not conclusively proven that improving the efficiency of police enforcement reduces fatal and severe crashes in work zones, it can be assumed that enforcement will have some positive effect on crash rates, at least while the enforcement is occurring. Improving conventional enforcement, implementing and improving automated enforcement, increasing the efficiency of enforcement, and implementing administrative procedures that facilitate the presence of police should lead to an even greater reduction in traffic law violations through the work zone.
Keys to Success	Coordination with law enforcement agencies is the principal key to success. Police presence and enforcement at work zones typically involves one of the following three strategies: stationary, traffic controller, or mobile (Schrock et al., 2002). In the case of stationary enforcement, police officers are stationed within their patrol car within the work zone or within a reasonable distance in advance of the work zone. In the case of traffic controller enforcement, police direct traffic from outside their vehicles. This strategy is less common than the other two strategies. Mobile enforcement involves police officers circulating back and forth within the zone. Previous work seems to indicate that the stationary strategy is more effective than the mobile strategy in reducing speeds (Benekohal et al., 1992).

EXHIBIT V-24 (Continued)

Strategy Attributes for Enhancing Enforcement of Traffic Laws in Work Zones (T)

Attribute	Description
	If shoulders will not be available during a construction or maintenance project, it is desirable to design pullouts into the work area. These pullouts could be used for both enforcement and emergency stops or breakdowns (see http://ops.fhwa.dot.gov/wz/workshops/sheet1.htm) A pullout length of approximately 0.25 mile is adequate for acceleration and deceleration on high-speed facilities.
	Though a traditional automated enforcement system (i.e., cameras), specifically one for speed enforcement, may not be suitable for a given work zone, it is possible to employ technology to aid officers in enforcing speeds. A video-based system can capture speeding vehicles and transmit the image to a patrol car downstream of the work zone. The officer can then use this image to stop violators. Automated enforcement would be more appropriate for larger work zones that will last a longer period, due to the system costs and other implementation issues.
	Kamyab et al. (2003), in their survey, found that states use various criteria in determining the need for police services during work zone operations. Most states use traffic volume and road classification in making this determination and use police services in long-term work zones. Peak congestion, lane closures, night work, risk to construction workers, crash history, work zone speeds, special events, and inclusion in a safety corridor are other factors being considered.
Potential Difficulties	Construction or maintenance activities may conflict with enforcement activities, mainly with respect to the space needed to perform each activity. Officers need shoulders or pullouts for stopping vehicles, and at the same time shoulders could be used for construction or maintenance activities. Shoulders may be of insufficient width for stopping or may not be present on the temporary roadway. A balance between these competing space needs is desirable, and coordination between the highway and police agencies is essential in determining the extent to which each agency will be able to use the space in question.
	The spacing of pullouts is an important consideration: too many pullouts may interfere with contractor operations, and too widely spaced pullouts are less likely to be useful to police officers. A survey by Ullman et al. (undated) concluded that distances of 2 to 3 miles between pullouts would be a compromise between these conflicting needs.
	Speed limit “tolerances” can present difficulty in attempting to improve enforcement. If drivers believe they can exceed the posted limit by 5 to 10 mph without being ticketed, they likely will do it.
	Automated enforcement devices have the potential to malfunction or break in the field. The use of automated enforcement requires careful consideration of maintenance and repair of the equipment.
	Two other potential difficulties include the availability of adequate police resources to perform enforcement and the legality of speed limit postings so they can withstand court challenges.
Appropriate Measures and Data	Process measures include the documentation of the number and type of targeted enforcement campaigns put into effect on specific work zones or in specific jurisdictions, the number of projects on which enforcement is considered during design, and the number of jurisdictions (state level or district level) that have established administrative procedures for coordination with law enforcement personnel.

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-24 (Continued)**

Strategy Attributes for Enhancing Enforcement of Traffic Laws in Work Zones (T)

Attribute	Description
	<p>Key safety effectiveness measures include crash frequency and severity, by type of crash. It is especially important to identify crashes related to traffic law violations. This information can also help guide enforcement activities.</p> <p>Actual speeds measured in work zones and the number of citations measured in work zones, both before and after an enforcement activity, will provide insight into the effectiveness of the enforcement activities. Traffic volume data are needed to represent exposure. Data on recidivism rates for work zone traffic law violators could help measure the effectiveness of this strategy, as well as provide insight on ways to further improve enforcement procedures. Data on conviction rates and types will provide further insight.</p>
Associated Needs	<p>PI&E campaigns informing drivers of increased enforcement activities or automated enforcement should accompany these programs. Refer to Strategy 19.1 E1 for additional information.</p>

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	<p>Coordination between highway and enforcement agencies is at the heart of this strategy. Once procedures for this coordination are established, they should be communicated throughout the highway agency so that personnel involved with work zones will know the appropriate steps for coordinating enforcement efforts. Discussions between highway and enforcement agencies are needed to determine the most appropriate locations for targeted enforcement activities, speed or red-light running cameras, and work zone shoulders or pullout areas.</p> <p>The FHWA recommends that highway agencies coordinate with law enforcement to develop written policies and guidelines addressing the following (FHWA, 2001):</p> <ul style="list-style-type: none"> • Situations where uniformed police officers are recommended; • The work zone traffic control planning process; and • Officer pay, work procedures, supervision, and so forth. <p>In some cases, funding for police services can also be channeled through a construction contract. The state of Oklahoma currently has such a system in place. In this case, the contractor pays for the police services and submits the costs (with profit and overhead) as an expense to the highway agency. This allows police services to be acquired at short notice. However, this type of arrangement typically will be more expensive due to contractor overhead and profits (Bryden and Mace, 2002). Refer to Engineering Instruction 93-30: Dedicated Police Services on Department Construction Projects (available online at http://www.dot.state.ny.us/cmb/consult/eib/files/ei93030.pdf).</p>
Issues Affecting Implementation Time	<p>The implementation time for the various aspects of this strategy should be relatively short. Once an administrative procedure is in place, efforts to coordinate with police agencies for enforcement in specific work zones should be an ongoing effort. Installation of automated enforcement systems could take some time, since testing of the system will be necessary. If legislation needs to be passed in order to implement automated enforcement, the process could take significantly longer. Consideration of work zone design elements that make enforcement activities safer and more efficient will not add significant time to the design of a work zone and its traffic control plan, if considered during the planning and design stages of a project rather than after these steps are completed. Availability of funding for providing enforcement could potentially</p>

EXHIBIT V-24 (Continued)

Strategy Attributes for Enhancing Enforcement of Traffic Laws in Work Zones (T)

Attribute	Description
	affect implementation time. This is another reason for the inclusion of law enforcement agencies in the earliest stages of planning the work zone activity. Insufficient funding for the components of this strategy will likely result in slower implementation.
Costs Involved	Targeted conventional enforcement in work zones may involve higher costs than in non-work-zone areas, since highway agencies often fund enforcement activities at overtime rates for officers and reimburse the law enforcement agencies for supervision, patrol cars, and other related services. Although the use of officers working on overtime for enforcement in work zones is more expensive, it provides greater flexibility in deployment and more focused targeting of problem areas. The cost of an automated enforcement system may be significant. Designing and constructing enforcement areas into work zones would involve nominal additional costs. Development of administrative procedures will take some effort, but costs associated with this will be balanced by the efficiencies gained in having a previously established procedure each time the highway agency needs to coordinate with the police agency for enforcement activities in a work zone.
	Example funding mechanisms may include state and/or federal money provided within the construction contract; state and/or federal money provided through a statewide umbrella program; and state and/or local enforcement agency commitment to the effort without any external funding source (i.e., either using additional local funds or working within existing budgets).
Training and Other Personnel Needs	<p>Considering that law enforcement personnel assigned to work zones have a broader responsibility than just speed enforcement, a training program addressing work zone traffic laws and their enforcement would be useful. Since 1994, the state of New Jersey has developed a unique program through which a unit of 35 officers who are dedicated to work zone enforcement is maintained (Schrock et al., 2002). This unit coordinates the placing of officers on work zones and supervising other officers who are assigned to work zones on an overtime basis. In addition, officers in this unit:</p> <ul style="list-style-type: none"> • Are certified Occupational Safety Health Administration (OSHA) safety inspectors, • Review traffic control plans, • Attend work zone planning meetings, and • Work with contractors to ensure that the proper traffic control devices are present at work zones. <p>These functions could also be performed by highway agency employees.</p> <p>A recent survey conducted by Kamyab et al. (2003) indicates that several other states—including Maryland, Missouri, South Dakota, Washington, Tennessee, and New Hampshire—have instituted special training programs for law enforcement officers who are assigned to work zones.</p> <p>In response to a recommendation by the National Transportation Safety Board, FHWA is developing a work zone enforcement course for police officers.</p>
Legislative Needs	Legislation to allow use of automated enforcement may be needed, if it does not already exist in a state.

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-24 (Continued)

Strategy Attributes for Enhancing Enforcement of Traffic Laws in Work Zones (T)

Attribute	Description
<i>Other Key Attributes</i>	
	<p>Although enforcement of speeds is an important task in many work zones, depending on the needs of a particular work zone project, other enforcement functions could be considered. Following is a list of functions mentioned in NYSDOT's Engineering Instruction 93-30 (NYSDOT, 1993; Bryden and Mace, 2002):</p> <ul style="list-style-type: none"> • Coordinate and provide appropriate police services when an incident occurs. • Assist in keeping travel lanes clear of illegally parked or stalled vehicles. • Assist in controlling illegal turning movements that restrict capacity at intersections. • Assist in directing traffic in congested situations. • Assist in traffic control for special construction events, such as bridge steel erection, changes in traffic patterns, and blasting. • Provide warning of heavy congested or stopped traffic in advance of problem areas, such as lane closures. • Observe and report traffic problems on state highways or detour routes to the appropriate engineering staff. • Enforce speed and other restrictions in or near the work zone area. • Aid in traffic control during the daily setup and takedown activities for operations that are conducted only during nighttime hours. • Preventing intrusions into closed lanes, exits, and so forth. <p>Functions that police perform in other states are summarized by Kamyab et al. (2003).</p>

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

CalTrans has an agreement with the California Highway Patrol for enforcement efforts in work zones. The Construction Zone Enforcement Enhancement Program (COZEEP) provides CalTrans with funds for police officers and vehicles. The need for COZEEP must be assessed on all projects where lane closure is planned. Contractors can request additional enforcement support, but it is the contractors, rather than CalTrans, that would fund this additional support. The CalTrans construction manual discusses risk factors that may render COZEEP desirable for a given work zone (http://www.dot.ca.gov/hq/construc/manual2001/chapter2/chp2_2.pdf). The Maintenance Zone Enforcement Enhancement Program (MAZEEP) is a similar collaborative effort between CalTrans and the California Highway Patrol.

New York State DOT has a procedure for coordinating work zone and enforcement activities (NYSDOT, 1993). Refer to Engineering Instruction 93-30: Dedicated Police Services on Department Construction Projects (<http://www.dot.state.ny.us/cmb/consult/eib/files/ei93030.pdf>).

Illinois is initiating the use of automated enforcement in work zones (<http://www.illinois.gov/PressReleases>ShowPressRelease.cfm?SubjectID=1&RecNum=3304>).

19.1 D2—Improve Credibility of Signs (E)

General Description

"Misinformation" provided to drivers on outdated signing can lead to a lack of respect for all work zone signing. If signs convey credible messages, drivers may be more likely to follow the instructions provided on the signs.

Standardized signs and channelizing devices will contribute to successful interpretation by drivers. Sign legends or symbols and channelizing conventions can vary even within

SECTION V—DESCRIPTION OF STRATEGIES

a state and may not meet MUTCD recommendations. Standardized communication with drivers will remove uncertainty and speed response time for those driving into and through work zones.

Types of messages with potential credibility concerns are found on the following types of signs:

- Speed signs
 - Speed advisories
 - Nonvariable speed limits
 - Variable speed limits
- Warning signs
 - Work zone
 - Flagger
 - Lane closure
- Other informational signs
 - Incorrect or nonessential changeable message signs
 - Congestion/delay/queue warnings

The following sections provide recommendations for the above types of signs. Because recommendations for speed signs are less commonly available than those for warning signs or other informational signs, the reader may find the information on speed signs more necessary than the information for warning signs or other informational signs. Thus, the speed sign section below is more detailed than the sections on warning signs and other informational signs.

Speed Signs

- **Speed Advisories.** A common way to inform drivers about work zone conditions is to use advisory supplemental speed signs to inform drivers of the appropriate speeds. Advisory speed plaques supplement warning signs and should be considered before deciding to lower the speed limit. If drivers do not perceive a hazard, they will not reduce their speeds. Similarly, if the advisory speed seems excessively low, drivers will not slow to that speed. Of greater concern, they will lose confidence in other signs where the speed may be realistically posted, thus failing to adhere to the advisory speed where it is particularly important to do so. Test-driving the work zone will help determine if the advisory speed is reasonable (Stidger, 2003). To maintain credibility, the stated speeds should be increased or decreased as actual work conditions change.
- **Nonvariable Speed Limits.** According to the MUTCD, if drivers perceive a need to reduce their speed, they will reduce their speed. However, speed limits perceived to be too low can breed noncompliance in drivers. In order to improve compliance with speed limits, work zones should be designed for the desired speed. Existing speeds, work zone design speeds, and the interaction of workers and equipment with traffic are factors to consider when determining work zone speed limits. The speed limit should not be significantly lower than what drivers expect; otherwise, drivers will lose respect for the limit (McGee et al., 1988). Work zone reduced speed limit signs should also be placed reasonably close to the work area to which they apply.

Since geometric and traffic conditions in the work zone may change frequently, the speed limit should be based on these factors rather than on prevailing speeds, which also may change on a daily basis and are unknown during the design stage. Determination of an appropriate work zone speed limit should include consideration of the existing speed limit, the location of work activities in relation to the travel way, and additional factors such as presence of workers, horizontal alignment, lane width, lateral offsets to objects (e.g., barriers), pavement edge dropoffs, limited stopping sight distance, and traffic congestion caused by a lane closure (Migletz et al., 1993). Speed limit reduction signs should be covered or removed when the condition for which they are posted no longer exists.

- **Variable Speed Limits.** Changeable signs can be used to alter the speed limit as conditions in a work zone change (e.g., as workers are present or weather deteriorates). Variable speed limits can be implemented in work zones, but the posted speed should be reasonable, or it will breed driver disrespect as do permanent speed limit signs. If a variable speed limit sign lowers the speed limit because workers or other hazardous conditions are present, the hazards should be evident to drivers. Enforcement agencies need to be informed of changes in the speed limit in order to effectively provide speed limit enforcement and to document the speed limit that is in place when the citation is issued.

Warning Signs

If warning signs are posted a significant amount of time before work starts, left up after work is completed, or posted too far in advance of a work zone, drivers may begin to believe the signs are not correct and may disregard the warnings.

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"Workers Present" Sign in Tennessee



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For example, an active work zone sign (“Lights Flashing When Workers Present”) with flashing lights can alert drivers to the possibility of encountering workers or equipment near the roadway, but if drivers repeatedly see the sign on but do not see any workers, they will doubt its validity.

Indiana found that a reduced speed limit implemented when workers were present was not obeyed for the entire length of a work zone when work was occurring in only a small section of the work zone (FHWA Work Zone Safety and Mobility Program Best Practices website, http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=150&from=crossref&Category_ID=18). Ensuring that signs communicate accurate information and realistic regulations and warnings should encourage drivers to follow them.

Other Informational Signs

Signs that provide drivers with information on downstream traffic conditions can increase driver awareness of work zones, queues, and other conditions. As with changeable message signs used for non-work-zone applications, incorrect or unnecessary information can be expected to contribute to driver disregard for the information on the signs. A changeable message sign with a work zone warning on it that is not cleared when the work zone is removed can lead drivers to question the validity of messages they see in the future.

Key References

Federal Highway Administration. Work Zone Safety and Mobility Program Best Practices website: http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?ID=150&from=crossref&Category_ID=18.

McGee, H.W., D.B. Joost, and E.C. Noel, “Speed Control at Work Zones.” *ITE Journal*. Institute of Transportation Engineers. January 1988.

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19.1 D3—Improve Application of Increased Driver Penalties in Work Zones (T)

General Description

Traffic violations in work zones present a dangerous condition for both the highway users traveling through the work zone and the workers within the work zone. Violations, such as speeding or failure to obey flagger signals, are often a factor in crashes in the work zone.

One method for reducing violations of traffic laws is to enforce work zone laws and make penalties and fines significant enough to be a deterrent and to encourage the judiciary to apply the penalties consistently. Improving the application of increased fines in work zones 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 also needs to perceive 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 approach requires the cooperation of the judiciary and can be facilitated by encouraging a partnership and making sure that judges understand the importance of this strategy for saving lives.

Specific examples of increased penalties implemented by states include:

- Increased fines,
- Short-term suspension of the driver's license for speeding in a work zone,
- Increased points applied to the driving record for work zone speeding, and
- Jail time for causing the death of a worker.

These examples are discussed below under the "Information on Current Knowledge Regarding Agencies or Organizations That Are Implementing This Strategy" heading.

EXHIBIT V-26

Combination Sign for Increased Fine and Worker Safety Awareness



SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-27**

Strategy Attributes for Improving Application of Increased Driver Penalties in Work Zones (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>This strategy principally targets drivers who violate the law. It is intended to reduce all types of crashes caused in part by violations of traffic laws in work zones, such as speeding or failure to obey flagger signals.</p> <p>This strategy is applicable to all work zones. Work zone traffic law enforcement can be performed as part of regular traffic law enforcement activities, and dedicated programs may be desirable for larger, long-term work zones.</p>
Expected Effectiveness	<p>The effectiveness of improving the application of driver fines and penalties in an effort to increase work zone safety has been studied, and the results of the studies vary. However, general trends exist. While policies of increased fines and other penalties are very popular (45 states have adopted such legislation), the policy seems to do little to reduce speeds or fatalities through the work zone (Ullman et al., 2000). The effectiveness of this strategy can be improved by using a consistent and visible approach to enforcing work zone traffic laws and adjudicating citations that result in drivers believing that they will receive citations and fines for violations.</p> <p>An Oregon DOT survey showed that 79 percent of drivers responding to the survey reported that double fine signs in work zones influenced their choice of speed either “a lot” or “some” (Jones et al., 2002).</p> <p>Increased fines in work zones (and signing to this effect) can be effective in increasing driver awareness of hazards in work zones. Although the effectiveness of the strategy in reducing violations may not be significant, increased awareness of work zone safety issues could be enough of a benefit for states to pursue this strategy.</p>
Keys to Success	<p>Identifying keys to success for this strategy is somewhat elusive because the strategy has not been implemented with significant success. Evaluating potential reasons for failure, however, allows for speculation of what may generate successful implementation in the future. Observed reasons for lack of effectiveness include the following:</p> <ol style="list-style-type: none"> 1. Lack of Credibility Given to Work Zone Speed Limits. The intent of the increased driver penalties is primarily to reduce crashes by reducing excessive speeds in the work zone, but at most of the sites examined, the increased fines had little effect on speeds. Regardless of whether the limits were regulatory or advisory, the motoring public generally did not view the work zone speed limits as credible. The Oregon DOT study reviewed literature regarding increased penalties for work zones and other violations (Jones et al., 2002). The results suggest that violations do not decrease significantly if drivers do not perceive a threat of being cited. 2. Little Change in Enforcement and/or Court Dismissals. Because the majority of drivers ignore work zone fine increases, one would expect more revenue to be generated as more citations were issued. However, the studies found little difference in revenue before and after the implementation of increased work zone driver fines. This finding indicates that either traffic laws are not being enforced in work zones or the judicial systems are not imposing the increased fines. <p>Given these reasons for failure, it seems that the following actions could help: (1) fines and penalties in the areas studied need to be more severe to fully deter work zone traffic violations, (2) strict enforcement of the increased driver fines in work zones should be implemented in order to cause the motoring public to view the work zone</p>

EXHIBIT V-27 (Continued)

Strategy Attributes for Improving Application of Increased Driver Penalties in Work Zones (T)

Attribute	Description
	penalty increase as credible, (3) the cooperation of the judiciary should be sought through meetings and seminars that educate the judiciary on the serious safety problems associated, and (4) judicial discretion should be limited in applying the increased fines.
Potential Difficulties	<p>Many states have already adopted legislation to increase fines, and this is usually an item popularly supported by legislators, but monitoring and enforcing the legislation consumes extensive resources if done enough to deter violations of traffic laws in work zones. Increased enforcement efforts could create an excessive burden on local judicial systems until driver behavior changes and violations (and therefore citations) decrease.</p> <p>In states where workers must be present in the work zone in order to apply higher penalties for violations, signs with flashing lights (“Workers Present When Flashing”) can be used to alert both drivers and police officers to the presence of workers in a work zone. This informs drivers that higher fines will be given for violations, but can also create problems for officers who must verify that the lights are flashing before issuing citations.</p> <p>Increased fines may help to deter speeding in some instances, but they do not invoke the respect or fear that more severe penalties (such as jail time or license revocation) do. Implementation of more severe penalties may not be practical, however, since the courts may be less likely to impose the penalties.</p>
Appropriate Measures and Data	<p>Design of work zones should allow for safe and efficient enforcement in work zones. In work zones that have limited space available for pulling over violators, enforcement officers are more reluctant to do so because of the risk of increasing congestion and potentially creating a greater risk of crashes through the work zone</p> <p>Process measures include the existence of supporting legislation, degree of law enforcement activity and productivity, and court resolution of appeals.</p> <p>Key safety effectiveness measures include crash frequency and severity, by type of crash. It is especially important to identify crashes related to excessive traffic violations.</p> <p>Citation frequency and the magnitude of the violations (i.e., the number of miles per hour over the speed limit) data are needed to evaluate the increased penalty for safety effectiveness. Traffic volume data are needed to represent exposure.</p> <p>Data on recidivism rates for work zone traffic law violators could help measure the effectiveness of this strategy, as well as provide insight on ways to further improve application of increased fines.</p>
Associated Needs	<p>The effectiveness of increased fines and penalties is likely to be improved if signing informs drivers of the increased fines, a visible enforcement program exists, and the highway agency conducts outreach to members of the judiciary system.</p> <p>Interagency coordination can help communicate the nature of work zone safety concerns and the needs for enforcement and adjudication to emphasize work zone safety. South Carolina DOT has traffic safety meetings to which magistrates, attorneys, contractors, contractor associations, police officers, city officials, and others are invited. Some highway agencies attend meetings and conferences with court officials to communicate the importance of upholding fines and penalties for work zone traffic law violations. There may be several sections of the law under which work zone traffic citations can be written, and if the correct section is not used, a citation can be thrown out in court. Education efforts for officers enforcing traffic laws may be needed.</p>

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-27 (Continued)**

Strategy Attributes for Improving Application of Increased Driver Penalties in Work Zones (T)

Attribute	Description
	Improved enforcement in work zones and credible signs are needed for successful implementation of this strategy. Refer to Strategies 19.1 D1 and 19.1 D2.
	Use of the media to advertise enforcement programs and consequences increases the visibility and can influence effectiveness. A PI&E campaign to emphasize increased enforcement and judicial activities could have a positive influence in speed reduction through work zones. In addition, if legislation allowing for increased penalties is new, information will need to be provided to the public on what this means to them, such as when increased enforcement will begin and the details on the increased fines.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	Coordination within the highway agency—as well as with enforcement, judicial, and licensing agencies—is necessary for the successful implementation of this strategy. Establishment of and commitment to an enforcement program; a commitment from courts to impose increased penalties; and efforts by licensing agencies to collect information on violations, penalties, and recidivism are needed to ensure success of this strategy. Policies and enforcement should be firm enough to encourage more driver compliance.
Issues Affecting Implementation Time	Implementation of this strategy may take a moderate amount of time, and if new legislation is needed to allow for increased penalties, a significant amount of time may be required (widespread support of a bill to increase fines may allow it to pass quickly). Development of enforcement programs and training of law enforcement personnel will add to implementation time, as will coordination with courts and driver licensing agencies.
Costs Involved	The issues listed above that will affect implementation time will also affect costs involved in implementing the strategy, including increased public education on any new laws passed, though costs will be relatively low once the program is implemented. Increased enforcement would be expected to lead to increased citations, which in turn would increase court costs. Ideally, at least some of these costs would be offset by the increased fines.
	The costs will also depend on the extent to which enforcement efforts are increased. Targeting every work zone full time will not be practical, but a higher frequency and level of enforcement (i.e., number of officers) will result in higher costs. Agencies can apply for grants from NHTSA for work zone enforcement programs. Highway agencies can provide supplementary funding for increasing work zone enforcement. An example of an agency that does this is the Oregon DOT.
Training and Other Personnel Needs	Increased penalties and fines would need to be discussed in training and/or communications with police officers and judicial system personnel. Programs would be needed to improve the applications of increased fines, such as enforcement campaigns.
Legislative Needs	If current laws prohibit increased fines in work zones, agencies will need to work with legislators to change these laws. In states where this policy is mandated through legislation, the aforementioned notes under Organizational, Institutional and Policy Issues should apply.

EXHIBIT V-27 (Continued)

Strategy Attributes for Improving Application of Increased Driver Penalties in Work Zones (T)

Attribute	Description
<p>In the section below entitled “Information on Current Knowledge Regarding Agencies or Organizations That Are Implementing This Strategy,” several examples are provided citing legislative measures aimed at controlling speed in work zones. While no data are yet available regarding the effectiveness of such measures, the approaches certainly seem to be aggressive and may be of interest to other legislators.</p>	
Other Key Attributes	
<p>Compatibility of Different Strategies This strategy is compatible with other strategies in this guide, especially 19.1 D1 (Enhance Enforcement of Traffic Laws in Work Zones), 19.1 D2 (Improve Credibility of Signs), and 19.1 E1 (Disseminate Work Zone Safety Information to Road Users). Increased fines and improved application of increased fines may add to the success of other strategies discussed in this guide.</p>	

Key References

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http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/EffectDoubleFines.pdf.

Pratt, S.G., D.E. Fosbroke, and S.M. Marsh, *Building Safer Highway Work Zones: Measures to Prevent Worker Injuries from Vehicles and Equipment*. National Institute for Occupational Safety and Health. 2001. <http://www.cdc.gov/niosh/2001128.html>.

Ullman, G.L., P.J. Carlson, and N.D. Trout, “Effect of the Work Zone Double Fine Law in Texas.” *Transportation Research Record* 1715. Transportation Research Board. Washington, DC. 2000.

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

Pennsylvania has implemented a penalty program that will suspend a driver’s license for 15 days if the driver exceeds the work zone speed limit by 11 mph or more.

Michigan uses a “point system” in which licenses are restricted, suspended, and/or revoked (depending on the number of violations) when the maximum point reduction threshold is exceeded. The point reductions are increased for work zone speeding. Michigan has also passed legislation (“Andy’s Law”) that applies a penalty of 1 year in prison for drivers who hit a construction worker and up to 15 years in prison for killing a construction worker.

Ohio requires mandatory jail time for drivers causing injury or death in construction zones.

Illinois passed legislation allowing a charge of reckless homicide to be made against speeders who kill construction workers. Illinois has also passed a 14-year prison term and \$10,000 maximum penalty for drivers who kill a construction worker. It also has increased

SECTION V—DESCRIPTION OF STRATEGIES

its fines for work zone violations. (<http://www.tmemag.com/tme/index.cfm/powergrid/rfah=%7Ccfap=/CFID/297083/CFTOKEN/85264747/fuseaction/showNewsItem/newsItemID/6857>).

Objective 19.1 E—Increase Knowledge and Awareness of Work Zones

Training regarding work zones and work zone safety is important for drivers, workers, and agency personnel. PI&E campaigns can be used to educate drivers on work zone safety issues at both a high level and a project level. Drivers should know how to interpret visual cues as they approach and drive through work zones. Training programs for staff—both office staff who may design work zones and traffic control plans and field staff—are important elements in a program to reduce work zone crashes.

19.1 E1—Disseminate Work Zone Safety Information to Road Users (T)

Communication of work zone safety information to road users is an important aspect of improving the ways in which road users interact with work zones. Three types of communication are needed.

- Driver education and training: educating drivers, pedestrians, and other road users on the meaning of work zone traffic control devices and appropriate actions to take in work zones.
- Safety awareness campaigns: creating an awareness among road users that work zones require more caution than nonwork areas.
- Real-time work zone condition communication: media reports, advanced traveler information systems, websites, and telephone information lines to alert road users about the conditions in a given work zone and alternative routes or modes.

Driver Education and Training

A failure to understand and interpret the traffic control provided in a work zone could result in driver error and potentially a crash. This is especially true for older and younger drivers. Research indicates that driver understanding of work zone traffic control is lacking. For example:

- Huddleston et al. (1982) conducted a lab study to evaluate driver understanding of work zone flagger signals. The study indicated that most of the signals that involved the use of a stop/slow sign paddle and/or hand motion were understood by the drivers, but the signals in which a flag alone was used were less effective.
- Swanson et al. (1997) have indicated that older drivers have difficulty in detecting, reading, and understanding symbolic traffic signs. Comprehension for some symbols is as high as 90 percent, but for others, less than half of drivers understand the meaning.
- Hoyer and Familant (1987) suggest that older drivers could be particularly disadvantaged by changes in roadway geometry and operations such as those found in construction zones.

- Ford and Picha (2000) indicated that surveyed teenage drivers understood traffic control devices to only a moderate degree. Of 53 traffic control devices tested (which included construction warning signs), only 9 were understood by more than 80 percent of the respondents.

As such, driver education courses should include instruction on what actions drivers are to take when they encounter specific traffic control devices. This information should be included not only in courses for new drivers and refresher courses for more experienced drivers, but also in driver manuals and other instructional materials distributed to drivers.

Informational brochures on the meanings of work zone traffic control devices can be distributed at department of motor vehicle offices and rest areas, as well as at events where DOT personnel, department of public safety personnel, police officers, or others interact with the public. These materials should also be distributed where pedestrians, bicyclists, and transit users will be and to residences and businesses in the vicinity of a planned work zone.

Work zones deserve special consideration during design of the traffic control plan because of their strong potential to violate a driver's expectations. Signs and channelizing devices will contribute to successful interpretation by drivers. Sign legends or symbols and channelizing conventions can vary even within a state and may not meet MUTCD recommendations. Standardized communication with drivers will remove some of the guesswork from driving into and through work zones.

Safety Awareness Campaigns

PI&E campaigns for work zones are typically intended to promote an understanding of broad work zone safety issues and an awareness among drivers and other road users that (a) their personal safety will depend on having good knowledge of work zone operations and controls and (b) driving carefully in work zones requires more caution than in nonwork areas.

Perhaps the most visible program highlighting work zone safety issues is the National Work Zone Awareness Week (<http://safety.fhwa.dot.gov/wzs/nwzswk04.htm>), which is designed to bring widespread attention to the problem of work zone safety and mobility. The event is co-sponsored by the FHWA, the American Association of State Highway and Transportation Officials, and ATSSA, with the cooperation of the American Road and Transportation Builders Association and the Associated General Contractors. Refer to Appendix 8 for the 2004 National Work Zone Awareness Week poster.

PI&E campaigns may target such work zone safety problems as flagger instructions, early merging, and driver awareness and comprehension of work zone messages. Focus groups have identified public service announcement campaigns as a potential means to improve driver behavior in work zones (King et al., 1999).

Real-Time Work Zone Condition Communication

Notifying road users about what impacts a given work zone will have on travel and what travel alternatives there are can help road users make appropriate decisions regarding travel through a particular work zone. Many DOTs have been providing updated work zone information on their websites so that people can better plan their trips and anticipate the

SECTION V—DESCRIPTION OF STRATEGIES

conditions that they will encounter. Media alert bulletins, changeable message signs with route information, brochures, and toll-free telephone numbers are examples of methods for communicating work zone traffic and safety information to highways users. This type of communication is discussed in more detail in Strategy 19.1 B1, the strategy in which use of ITS in work zones is covered.

EXHIBIT V-28

Strategy Attributes for Disseminating Work Zone Safety Information to Road Users (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	<p>The principal targets of this strategy are all road users. This strategy should help reduce crashes where contributing factors may be lack of knowledge of the meaning of traffic control devices, lack of awareness of the need for additional caution in work zones, and lack of knowledge of conditions in a given work zone or alternatives to driving through the work zone.</p> <p>A failure to adequately determine the desired action either in advance of or while traveling through a work zone can cause erratic maneuvers that can lead to crashes. Rear-end, side swipe, and head-on crashes are common crash types that occur when drivers suddenly stop or suddenly change lanes or paths. Motorists and pedestrians who travel in work zones can benefit from being able to better interpret work zone traffic control.</p> <p>This strategy is appropriate for all work zones. Driver education programs are intended to provide knowledge needed to travel through all work zones. PI&E campaigns and real-time work zone condition updates can be designed for individual projects and therefore can be customized to the project type, duration, drivers, and any new or different technologies used in the work zone.</p>
Expected Effectiveness	<p>Improved dissemination of work zone safety information to road users has not been proven to be effective, and it will be difficult to do so. However, it is expected that increasing driver knowledge about what to expect in work zones and how to react to traffic control devices will lessen risky behaviors. While there is evidence that misunderstanding traffic control devices can lead to crashes, there is no published evidence that this strategy is effective for work zones. However, the strategy is expected to improve safety in the work zone. Providing updated information on work zone activities and potential delays can reduce driver frustration and result in increased goodwill for an agency.</p> <p>Good PI&E campaigns heighten awareness of a problem and garner high approval ratings. Many agencies have indicated that their public image has been enhanced as a result of their PI&E campaigns. At times, the PI&E campaign may include special emphasis on enforcement. PI&E campaigns, done in conjunction with special enforcement, have been shown to enhance the effectiveness of the enforcement effort.</p>
Keys to Success	<p>A 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 issues and behaviors in work zones, appeal to drivers to drive differently in a work zone, or discuss alternatives to driving through a given work zone as appropriate for the intended goals of the information dissemination program. Focus groups and public surveys can help identify the target audiences.</p>

EXHIBIT V-28 (Continued)

Strategy Attributes for Disseminating Work Zone Safety Information to Road Users (T)

Attribute	Description
	<p>Motorists should be given specific information on how to handle work zone driving tasks. Awareness can be promoted through driver education programs as well as public outreach activities. Adding general information on work zone safety to booklets and pamphlets made available through the driver licensing agencies can add significantly to the impact of this effort, since drivers' attention to such matters is at its height during license renewal. The same principle applies to students in driver education courses. It will be easier to educate the public with an educational brochure if there is a standardized set of signs, markings, and channelizing devices in the jurisdiction rather than if there are so many variations that the driver gets confused.</p> <p>Those in charge of PI&E campaigns should cultivate and maintain good contacts with the print and broadcast media. Media representatives can be invited to planning and stakeholder meetings. Means for receiving free space or time can be sought as part of the media's responsibility to provide public service.</p> <p>Highway agencies should ensure that PI&E programs are scheduled when most likely to maximize the exposure of the message to the target population (i.e. during construction season). Campaigns should center on local conditions and situations familiar to the intended target population. In addition, work zone information provided to the roadway user needs to be updated and accurate. 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.</p>
Potential Difficulties	<p>PI&E campaigns may not reach a large portion of the targeted audience if appropriate dissemination methods are not used. A range of media may be needed, including television, radio, newspaper, Internet, club and association meeting presentations, and other measures deemed appropriate for a specific project or a particular area of the country. Consideration should be given to people who may need materials in languages other than English or in alternative formats to accommodate disabilities. Ensuring that updated and reliable information on work zone activities is provided to the motorist can be time consuming.</p>
Appropriate Measures and Data	<p>Process measures include documenting the number and types of different programs used to disseminate information, the frequency of different media used (radio ads, brochures, etc.), and the population exposed to the message. Level of expenditure is another possible process measure.</p> <p>The impact of a program on driver attitude, knowledge and understanding, or interpretation of devices can be assessed by analyzing a sample of people in the target area. This analysis 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.</p> <p>Because of many intervening variables, it is not feasible to directly measure the effectiveness of educational programs in terms of effect on crash experience. However, surrogate measures may be employed, including before and after test results, interviews, and observation of change in behavior.</p> <p>Crash frequency and severity are key safety effectiveness measures and should be measured both before and after a <i>specific</i> campaign. However, these direct safety impacts are not feasible to measure in a valid manner for general information campaigns, because many variables come into play.</p>

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-28 (Continued)**

Strategy Attributes for Disseminating Work Zone Safety Information to Road Users (T)

Attribute	Description
	Traffic volume data are also needed to represent exposure. Studying attributes of drivers involved in work zone crashes may help identify areas of the population upon which to focus future campaign efforts.
Associated Needs	State driver handbooks and driver instruction manuals may need to be revised to clarify the meaning and intent of work zone traffic control devices.
	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 PI&E campaign and should be involved from the start of project planning. Use of people with expertise in listener and viewer characteristics will allow for optimal targeting of messages broadcast by various media outlets.
	Managing information from multiple work zones across a wide geographic area may require additional data management strategies for an agency.
	If evaluations will be done using surveys, the necessary expertise 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. Quite often, universities and colleges offer a survey service.

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	A cooperative effort with driver educators and departments of motor vehicles is desirable. Revising existing signs to improve comprehension requires changes to the agency's traffic control device manual. This will usually require that the modifications have been adopted by the National Committee on Uniform Traffic Control Devices. This involves a major rule-making process at the federal level and may require rule making at the state level. This process may take years before changes can be implemented on a widespread basis. If PI&E 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 nongovernmental 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 update and disseminate materials for training, prepare media materials for PI&E campaigns, secure time and space for the dissemination of materials, or put a system in place for providing real-time information to the traveling public. These programs should be well planned before implementation. The more time invested in the planning process, the greater the likelihood of the strategy reaching the target audience and being effective. 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 launch a successful program. If a highway agency has previously worked with driver educators, departments of motor vehicles, and media outlets, then the implementation time will be reduced, and only the specific messages or materials will need to be developed once it is agreed that agencies will collaborate on this program as well. If an advanced traveler

EXHIBIT V-28 (Continued)

Strategy Attributes for Disseminating Work Zone Safety Information to Road Users (T)

Attribute	Description
	information system is already in place on a roadway for which work is planned, or if the system is planned as part of the work, implementation time will be reduced, and it is the specific wording of the messages and the alternative routes that will be needed.
	Implementation of changes to signs and other traffic control devices may take a long time.
Costs Involved	There would be costs involved in updating existing and/or developing new training 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 materials are available, will add to the costs of implementation.
	Public service announcements on radio and television do not have airtime charges, but are more expensive to produce than other formats and may be aired at less than ideal times. Printed or billboard ads and ads on transit vehicles can be produced for less than broadcast messages, but there may be monthly charges for posting. Another option for communicating with the targeted audience that may be cost-effective is messages placed in playbills at theaters in the area of a work zone.
	The costs involved in a PI&E campaign can vary widely depending on the type of media distribution (e.g., television, radio, newspaper, or website), the intended length of the campaign or project, and the frequency with which the message is disseminated.
	Costs are also associated with specific projects, such as changeable message signs, toll-free telephone information numbers, and websites. Staff resources are needed to run and manage the program, and project-level staff will need to provide project-specific information to the agency staff running the information program.
Training and Other Personnel Needs	Driver trainers should be educated in the meaning and intent of traffic control devices and in driving safely through work zones so they are better able to emphasize this in driver education curriculums.
	If PI&E 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 improve safety in work zones, especially Strategy 19.1 B1 and the strategies in Objective 19.1 D.
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SECTION V—DESCRIPTION OF STRATEGIES

Key References

Federal Highway Administration and American Association of State Highway and Transportation Officials, *Work Zone Operations Best Practices Guidebook*. FHWA-OP-00-010. Washington, D.C. April 2000.

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King, L.E., M.R. Kane, and M.L. Carpenter, *Motorists' Perception of Work Zone Safety*. ITE International Conference Proceedings, March 1999.

Staplin, L., K. Lococo, S. Byington, and D. Harkey, *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians*, FHWA Publication No. FHWA-RD-01-051, May 2001. <http://www.fhrc.gov/humanfac/01105/cover.htm>.

Swanson, H.A., D.W. Kline, R.E. Dewar, "Guidelines for Traffic Sign Signals." *ITE Journal*, Vol. 67, No. 5, May 1997.

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

The FHWA/AASHTO report *Work Zone Operations Best Practices Guidebook* (2000) describes public relations, education, and outreach activities pursued by several states. A description of each practice, benefits realized, and applicable project locations are provided. Prominent activities and the DOTs conducting them include the following:

- **Development of media partnerships (Oregon DOT).** Regular contacts with state and local media have provided an opportunity for consistent dialogue on work zone safety issues. These regular contacts have increased the likelihood of coverage of work zone safety issues in the media as well as kept motorists better informed of DOT construction and maintenance activities and the effect of these activities on travel plans.
- **Media outreach program for construction and maintenance work zones (Mississippi DOT).** Radio, television, newspapers, and faxes are used to notify the public of upcoming construction and maintenance projects. The purpose of the program is to reduce traffic delays for the motoring public. The program has created good will for the DOT, and it is believed that the information provided has increased safety for the motoring public as well as the workers.
- **"Wizard" citizens band (CB) radio transmissions (Pennsylvania DOT).** These transmissions provide traffic safety and work zone information message broadcasts on CB radio channels. As such, the activity is geared primarily at long-haul truckers. The "Wizard" monitors CB transmissions on one or more frequencies. When it

detects a lull in activity, the “Wizard” will broadcast a safety message. This system provides truck drivers with information on work zones and any changes in traffic patterns.

- **Dissemination of work zone information at rest areas, welcome stations, truck stops, motels, and restaurants (Wyoming DOT).** This activity allows for motorists to plan trips around construction schedules and potential roadway closure, providing the opportunity for reducing driver exposure to work zones. The Pennsylvania DOT also disseminates brochures highlighting safe driving trips when driving through construction areas and work zones.
- **Use of a public relations firm (Iowa DOT).** A contracted public relations firm has raised awareness and educated drivers about the dangers of work zones by “getting the word out” via television and radio spots. The campaign, geared toward improving work zone awareness and safety, has improved the DOT’s image and increased driver awareness of work zone issues.
- **Public outreach through neighborhood liaisons (Massachusetts Highway Department).** Depending on the size and scope of the project, liaisons can be assigned to neighborhoods affected by construction. In Massachusetts, the liaisons became the “face” of the project by organizing community meetings and serving as a conduit for information exchanges between the Massachusetts Highway Department and the community at large. This program has helped the community members feel that they have an influence in decision making and gives them confidence that their concerns will be heard.
- **A public relations handbook for contractors (Colorado DOT).** The effort was undertaken to provide guidance for construction site managers to improve their image. The handbook provides guidance on appropriate notifications, media releases, press tips, crisis management strategies, and a checklist for public relations.

There are additional public outreach activities detailed in the *Work Zone Operations Best Practices Guidebook*. Additional information can be found at <http://ops.fhwa.dot.gov/wz/practices/bestpractices.htm>.

The National Work Zone Safety Information Clearinghouse also provides links to work zone safety tips and information on outreach efforts, public awareness, and public education campaigns related to work zone safety issues. Additional information can be found at <http://wzsafety.tamu.edu/>.

Many, if not all, states have areas on their websites highlighting efforts and providing information on work zone safety. An example website is the North Carolina DOTs website, which provides statistics on North Carolina and national work zone safety, safe driving tips for work zones, information about statewide and national work zone safety events, clips of multiple public service announcements related to work zone safety, and information on current work zone activities throughout the state. More information can be found at <http://www.doh.dot.state.nc.us/safety/workzone/>.

Virginia DOT also provides updated information on current work zone activities across the state as part of its 511 Travel Information Service. Additional details can be found at <http://www.511virginia.org/>.

SECTION V—DESCRIPTION OF STRATEGIES

19.1 E2—Provide Work Zone Training Programs and Manuals for Designers and Field Staff (T)

The recent FHWA rule (<http://a257.g.akamaitech.net/7/257/2422/06jun20041800/edocket.access.gpo.gov/2004/04-20340.htm>) requires that work zone personnel receive training appropriate to their positions. Training programs for office and field staff (agency, contractor, and utility company staff) are important elements of a program to reduce work zone crashes, and evidence of the importance of training can be found in the MUTCD.

Many highway agencies have developed work zone safety training programs for their own staff and for contractor staff. Although some agencies have not done the same, courses are available through the FHWA. Courses are also often available through labor unions. Problems with offering courses are often more related to funding and scheduling than to availability of training materials and instructors.

The MUTCD discussion of temporary traffic control fundamentals states that everyone performing tasks related to temporary traffic control should receive training for the respective tasks and that only people with training should supervise the selection, placement, and maintenance of temporary traffic control devices. In addition, the recently finalized FHWA rule on managing the safety and mobility impacts of work zones demonstrates the need for training of people with work zone responsibilities.

Many education and training options are available to address work zone safety issues. Workshops, training videos, and single- to several-day courses are provided by many organizations and transportation departments across the country.

A review of the National Work Zone Safety Clearinghouse website (<http://wzsafety.tamu.edu/>) reveals that the work zone safety training database contains almost 1,200 records of description for videos, courses, workshops, conferences, materials, and certification programs that deal with topics of work zone safety. Many, if not all, states have specific work zone training programs and courses geared toward specific policies and procedures. Many prominent training programs are also produced on a national basis from organizations such as the American Road and Transportation Builders Association, ATSSA, the Associated General Contractors of America, the FHWA (through the National Highway Institute), and the National Association of County Engineers.

With all of the work zone training options available, highway agencies should identify the gaps in training available to their personnel and contractors, as well as identify the staff who have not yet received the appropriate training. The missing materials need to be developed and a program needs to be established to ensure that personnel receive the most up-to-date training appropriate for their levels of responsibilities.

Development and use of work zone field manuals for staff are important components of a training program. Many states, as well as ATSSA, provide field manuals. Providing easily accessible materials to staff in the field can further promote the awareness of, and familiarity with, existing agency work zone processes. Agencies can develop field versions of full-scale policies and procedures or tailor the field manuals to address specific areas of concern with work zone setups.

EXHIBIT V-29

Strategy Attributes for Providing Work Zone Training Programs and Manuals for Designers and Field Staff (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	The principal target of this strategy is the staff in an agency whose responsibilities involve design and operation of work zones. Targeted crashes are those where a contributing factor is work zones that were improperly or inappropriately designed or implemented. Implementation of this strategy will involve personnel in the design and operation of work zones. This includes highway designers, maintenance and construction field staff, and utility company workers. All work zones can benefit from this strategy.
Expected Effectiveness	It is expected that providing focused work zone training to office and field staff will improve work zone safety, though it is not feasible to do a valid measurement of an impact from a support function that is relatively far removed from the road operation. Providing easily accessible materials can promote staff awareness of agency policies and procedures.
Keys to Success	<p>A key to success is agency pairing of the development of courses and materials with a program to ensure that appropriate personnel are exposed to them. Such a program would include course attendance, independent study, and testing of knowledge and attitudes. Appropriate employees for the program include field personnel, designers, inspectors, maintenance personnel, and others who would be involved in work zone design or operation.</p> <p>Ohio DOT requires all design consultants to take an Ohio-specific work zone design course (focusing mainly on design of freeway work zones) and pass a test. The Ohio DOT Traffic Academy conducts the course and charges consultants the direct costs for training personnel from their offices. This process helps speed the project development process.</p> <p>Consideration should be given to making training materials (e.g., computer-based materials) available for self-study if an agency considers this an effective means of training for a given topic. Mandatory attendance at training classes or certification requirements should be considered for some work zone activities; many states require contractors to provide trained or certified work zone supervisors and flaggers. Personnel may be tested to ensure that the desired impacts have been achieved on knowledge and attitudes. In addition, testing will provide guidance on how to improve the effectiveness of the training initiative. Offering incentives to successfully complete the training should also be considered.</p> <p>All training programs should be adapted to an agency's particular needs, thereby addressing the agency's own specific experiences and issues and providing consistency with the agency's policies and procedures.</p> <p>Agencies should consider making the training and manuals available to local jurisdictions that will be designing and operating work zones. This will help ensure consistency in work zone design and traffic control in a region.</p>
Potential Difficulties	Potential difficulties include getting personnel to attend and successfully complete courses and independent study programs. Most agencies are experiencing a lack of availability of staff to do the basic work of the agency without even considering time taken for training. Also, many staff members are not inclined to spend time in a classroom or study in front of a computer. Without adequate support for the program from upper management, including incentives for successful completion, it may be difficult to achieve the desired results. Obtaining resources for holding training and for workers to travel to training is also a potential difficulty, as is finding adequately trained staff to teach courses.

SECTION V—DESCRIPTION OF STRATEGIES

EXHIBIT V-29 (Continued)

Strategy Attributes for Providing Work Zone Training Programs and Manuals for Designers and Field Staff (T)

Attribute	Description
	<p>It is often the case that personnel who have been involved in any area of activity (e.g., design or operation of work zones) for a long time will have developed habits and opinions that may not be optimal. Therefore, it should be expected that there will be some resistance to new ideas and procedures. To help overcome this resistance, it may be useful to monitor the change in performance of personnel after they return to their work.</p> <p>In order to minimize the negative effects on new personnel of out-of-date or inappropriate practices and attitudes among existing staff, new personnel should participate in training at the start of their employment or soon thereafter.</p> <p>Contractors may also be reluctant to invest in training for workers who are only employed for short periods (such as a flagger who will only be needed for 1 day). Availability of contractor staff for training is a potential difficulty, as well. Many contractors work in several states in a region, and it would be burdensome to make their workers meet training requirements for all of the states in which they will work. Oregon DOT has a reciprocal program with neighboring states to accept flagger certifications. New York State DOT will accept valid up-to-date certification from ATSSA, unions, or other organizations providing training.</p> <p>In areas where a significant portion of the workers speak English as a second language, training materials may need to be offered in languages other than English in order to increase the likelihood that workers will be able to benefit from the training.</p>
Appropriate Measures and Data	<p>Process measures of program effectiveness include the number and type of training courses given, the number and type of attendees at training events, and the number of field manuals distributed to staff.</p> <p>It is not feasible to measure effectiveness of training programs in terms of effect on crash experience because of the many intervening variables. However, surrogate measures may be employed, including before-and-after test results and interviews and observation of change in personnel performance. The involvement of improper traffic control setup or practice in work zone crashes should be compiled by agencies and used to identify training needs.</p>
Associated Needs	<p>The development, presentation, and assessment of training materials require the involvement of persons having educational training and experience. Some agencies may have to arrange for external contractors to help with this effort, should they desire to develop their own materials instead of using what has been developed and tested.</p>

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	<p>A plan should be established for alerting agency personnel and contracted field staff to the availability of training materials and field manuals. There will be a need for upper-level management to actively support a plan for training agency personnel.</p> <p>To ensure that contractors' personnel are adequately trained, the agency may consider implementing a training certification process. It may be possible to include this requirement of certification in contracts.</p> <p>The agency developing the materials should consider ways to work cooperatively with local jurisdictions to develop opportunities for providing training and field manuals to appropriate local staff.</p>
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EXHIBIT V-29 (Continued)

Strategy Attributes for Providing Work Zone Training Programs and Manuals for Designers and Field Staff (T)

Attribute	Description
Issues Affecting Implementation Time	Implementation time for this strategy could be short because there are a substantial number of existing training courses available. Development and design of new educational materials will lengthen the implementation time. This strategy is envisioned to be ongoing and long term because materials will be developed and revised.
	There is time involved in establishing certification systems and maintaining a database of certified personnel. The Oregon DOT contracts this task to a community college that also provides the training.
Costs Involved	Costs to attend existing training courses vary but should be relatively low unless agencies are training large numbers of staff. There would be additional costs involved in developing and printing new training materials and field manuals. These costs could vary highly depending on the length of the training course and the nature of the materials being developed.
Training and Other Personnel Needs	Special personnel may be needed to conduct the desired training. Contractor and utility company staff need training in addition to agency staff, and field manuals should also be distributed to them.
Legislative Needs	None identified.

<i>Other Key Attributes</i>	
Compatibility of Different Strategies	This strategy can be used in conjunction with other strategies to improve safety in work zones.

Key References

Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO), *Work Zone Operations Best Practices Guidebook*. FHWA-OP-00-010. Washington, D.C. April 2000.

Federal Highway Administration (FHWA), *Manual on Uniform Traffic Control Devices* (MUTCD). Washington, D.C. 2003.

National Highway Institute courses: <http://www.nhi.fhwa.dot.gov/>.

National Work Zone Safety Information Clearinghouse website: <http://wzsafety.tamu.edu/>.

Virginia DOT website: <http://www.virginiadot.org/business/trafficeng-default.asp>.

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

Several state DOTs offer work zone-related training courses. A few examples are available online:

- Minnesota: <http://www.dot.state.mn.us/const/wzs/training.html>
- Ohio: <http://www.dot.state.oh.us/traffic/>

SECTION V—DESCRIPTION OF STRATEGIES

Major activities and courses sponsored by the FHWA are listed below:

- A course on the Design and Operation of Work Zone Traffic Control. This course provides participants with information on the safest and most efficient work zone traffic controls. This includes the application of effective design and installation concepts, using signs and markings for detours, construction zones, and maintenance sites. For additional information, visit <http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=145>.
- A course on the Design, Construction, and Maintenance of Highway Safety Appurtenances and Features. The course covers the design, construction, and maintenance of highways, as well as the purpose and performance requirements of state-of-the-art highway safety features, such as breakaway sign supports, breakaway utility poles, traffic barriers, impact attenuators, traversable terrain, and hardware features such as drainage inlets. The course describes how features function, what can go wrong, and how to recognize and correct improper installations. Additional information can be found online at <http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=149>.
- A course on Work Zone Traffic Control for Short-Term Maintenance Operations (<http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=152>). The course addresses typical short-term maintenance activities occurring on two-lane rural highways and multilane urban streets and highways. The course covers the applicable standards for work zone protection contained in the MUTCD, the need for proper application of devices, and liability issues of highway agencies and individuals.
- A course on Construction Zone Safety Inspection (<http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=154>). This course provides training in the management of traffic control plans and the inspection of construction zone safety devices. Topics covered include traffic control plan review, inspection of traffic control procedures and safety devices, and the resolution of discrepancies from the traffic control plan, as well as deficiencies in safety hardware maintenance.
- Hosting of Making Work Zones Work Better Workshops (<http://ops.fhwa.dot.gov/wz/workshops/workshops.htm>). These workshops promote the use of innovative practices, technologies, and products that have the potential to improve work zone mobility and safety. The workshops also include an open forum for discussion and information sharing to enhance the body of work zone knowledge and improve future work zone programs.
- *CRP-CD-50: NCHRP Training for Night Road Work to Improve Safety and Operations.* Training materials were developed as part of NCHRP Project 17-17 to complement NCHRP Reports 475 and 476. The training covers the night work decision process, project conceptual design, traffic control plan design, traffic control devices and safety features, and night work operations. Additional information can be found in *NCHRP Research Results Digest 293* (http://trb.org/news/blurb_detail.asp?id=4474).

Other courses are currently being developed by the FHWA and are expected to be available in 2005. This includes an advanced work zone training class.

Additional training courses are also available through other organizations, such as ATSSA (<http://www.atssa.com/rsti/ci.asp>) and the American Road and Transportation Builders Association (http://www.artba.org/artba_store/).

Several states have also developed field manuals for construction staff and others dealing with work zone setup and operation. Minnesota DOT has developed a field manual dealing specifically with the layout of temporary traffic control zones. The manual provides typical layouts for many temporary traffic control zone situations and provides other safety and regulatory guidance to field staff.

Minnesota's Temporary Traffic Control Zone Field Manual can be viewed at <http://www.dot.state.mn.us/const/wzs/training.html>.

Virginia DOT has also developed field manuals for staff in the area of work area protection and work zone safety guidelines for temporary traffic control. Both of these manuals can be found at <http://www.virginiadot.org/business/trafficeng-default.asp>.

The Missouri DOT Traffic Control for Field Operations manual is available online at <http://www.modot.state.mo.us/business/manuals/trafficcontrol.htm>.

Objective 19.1 F—Develop Procedures to Effectively Manage Work Zones

Implementing programs and procedures at the agency level can help bring about an institutional change in the emphasis placed on work zone safety and on the use of strategies to improve work zone safety. Work zone management practices, such as crash data system improvements, coordination and planning of activities, safety awards, and inspections or audits, can help improve work zone safety from an agency level.

Strategy 19.1 F1—Develop or Enhance Agency-Level Work Zone Crash Data Systems (T)

General Description

Crash data systems provide the basic information necessary for effective highway and traffic safety decisions and improvements by any level of government. Crash data are used to identify highway safety problem areas, establish objectives and performance measures, determine how resources should be allocated, and determine the effectiveness of programs that have been implemented. A future guide in the *NCHRP Report 500* series will discuss data needs, sources, and analysis, while this strategy discusses data issues specific to work zones.

Rather than just a crash database, a system for collecting and using all work zone safety information is important to effectively plan, improve, and manage work zone safety. In addition to crash data, other information is needed to help transportation professionals make informed decisions about whether improvements need to be made in a specific work zone or in the way an agency designs and operates all work zones. Information related to all roadway users, including drivers, pedestrians, bicyclists, and highway work zone workers, should be included in a work zone safety information system. Such information would include both volumes and attributes of roadway users involved in crashes. Medical information can be obtained from medical records on hospital emergency rooms to help

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assess the location and type of injuries sustained and the frequency and nature of work zone crashes.

Improvements in work zone crash data systems will allow agencies to assess where safety improvements are needed and will provide insight into what types of improvements are appropriate (engineering, enforcement, or education).

Accurate and timely reporting of work zone crashes is a joint effort between highway and law enforcement agencies. A working arrangement between law enforcement agencies and the highway agency is needed to ensure that safety data are entered into the database as soon as possible. Since agency personnel will be onsite at many work zones, they can collect the information needed on the crash, work zone design, and traffic control in place at the time of the crash. In many states, there is significant time lag (6 months or more) between the occurrence of a crash and the entering of the data into a crash database. To reduce this lag, some states have started conducting pilot tests using personal digital assistants (PDAs) and devices with global positioning systems (GPS) to record the crash data electronically for transmission to a central database. Other states have adopted forms that can be scanned into electronic format, which eliminates the manual coding that is usually the major source of delay in the data management operation.

Ultimately, the data collected are of no use if it cannot be made available to decision makers in a timely fashion. Many current systems do not allow for timely delivery of information, especially when it is not the basic preprogrammed type that is included in annual summary reports or standard site summaries. There is a need for interactive analysis by the end user, rather than fixed report formats produced by agency information technology departments.

Two important considerations in developing crash data systems are the specific data that need to be collected when crashes occur and exposure data that help describe the extent of the crash problem.

Crash Data Elements

The Model Minimum Uniform Crash Criteria (MMUCC) recommends a list of data elements that should be collected when a crash occurs (see Appendix 9). Many states are recording detailed information about crashes that occur at or near work zones. There is still debate among researchers and practitioners on the precise definition of a work zone crash, especially under situations where there is no apparent ongoing work in the work zone. For crashes that occur before the first work zone warning sign, some judgment may be required in deciding whether it is work zone related (such as a crash that occurred in a queue that extended upstream of the first work zone warning sign).

New York State has developed a program to collect detailed work zone crash information (see Appendix 10). Florida DOT has developed a crash reporting form that collects the detailed information it needs to evaluate work zone safety (see Appendix 11).

Any changes to crash reporting forms and procedures will be of interest to a number of stakeholders. Therefore, it will be highly desirable to form a representative group to oversee the process and give changes a final approval or recommendation. An agency's information

technology department can play an important role in the development of new forms and procedures.

Training will be needed for both law enforcement officers and agency personnel on any new crash reporting forms or data collection methods. The details of the training will depend on a variety of factors, including who is primarily responsible for reporting work zone–related crashes (usually law enforcement agencies) and coding these crashes.

Exposure Information

To better understand the nature of safety problems in a given work zone, it is important to have exposure information. Exposure information can include traffic counts and details about the design and operation of the work zone, such as

- Work zone lengths,
- Hours of activity (including details on day and nighttime activities),
- Duration of work zone,
- Length and duration of lane closures or significant capacity reductions,
- Purpose of the work zone, and
- Traffic control plans used.

This exposure information may be difficult to obtain. Recently, Ullman et al. (as part of NCHRP Project 17-30, which is currently underway) conducted a study to explore the quality and quantity of work zone data available in five regions of the United States. Data from several states were collected by examining state DOT construction and maintenance management databases, traffic control plans, and project diary information from 75 work zone contracts. None of these work zone projects were recording traffic volumes while the work was occurring.

Key References

Ullman, G.L., A.J. Holick, and S.M. Turner, "Work Zone Exposure and Safety Assessment," Federal Highway Administration, Washington, D.C. (in press).

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

Ohio DOT has a program to collect work zone crash data on major freeway projects on a regular basis and soon after crashes occur. Twice a month, crash reports are manually picked up from police agencies. Without this proactive effort, the crash reports would not be received by Ohio DOT for approximately a year, after many of the work zones are gone. Obtaining the reports earlier allows for review of the work zone and implementation of improvements during the work if improvements would be appropriate. Ohio DOT uses the crash reports to look at half-mile segments of larger work zones and determine if there are problems with the design or traffic control that may contribute to the crash.

Strategy 19.1 F2—Improve Coordination, Planning, and Scheduling of Work Activities (T)

General Description

In order to improve communication among agencies whose work is affected by work zones and to find ways to reduce the negative impacts of construction activities, some states and metropolitan areas coordinate among the various parties to reduce impacts on traffic and incident response efforts. The goal is to

- Coordinate among agencies whose functions will be affected by the presence of the work zone,
- Coordinate the schedules of multiple projects on the same section of roadway to minimize impacts (i.e., schedule projects to occur at the same time or one right after the other), and
- Plan work zones in a corridor or area to have the least impact on safety and mobility.

Coordination may involve highway agency personnel representing different divisions (e.g., maintenance, construction, design, and traffic), other highway agencies with jurisdiction over the area (county and local), contractors, police and other emergency responders, and representatives from regional FHWA offices. Examples of selected initiatives from states and cities are summarized in Appendix 12.

Coordination with emergency responders is a key consideration when planning and scheduling work zones. It is important for police, fire, and emergency medical service agencies to be aware of alternative routes around work zones and possible congestion. These agencies should also have plans for how best to respond to incidents in work zones. Incident management plans can help reduce delays and secondary incidents caused by crashes, breakdowns, or other problems in work zones. Elements of an incident management plan could include emergency pull-outs, help patrols, onsite towing services, onsite personnel trained in collecting work zone data relative to crashes, and crash investigation teams stationed at park-and-ride lots near work zones

Major work zone projects in high-volume corridors can affect an entire corridor; lead to increased delays for motorists; and impact many facilities, such as hospitals, schools, recreation facilities, and shopping centers. Work zones and utility work should be coordinated, planned, and scheduled in such a way that traffic runs smoothly, safely, and effectively with the least amount of inconvenience to motorists. Minimizing the effect of work zones on traffic will help minimize the adverse safety impacts of the work zone.

Activities should be scheduled so as to overlap or not overlap, as appropriate. Work activities occurring on two parallel corridors may reduce the alternative route choices for travelers, which could increase congestion caused by work zones. Such projects should be scheduled at different times. Separate projects on the same route (for example, utility work and resurfacing work) should be scheduled to occur at the same time or as close together as possible in order to minimize disruption to traffic and to take advantage of the work zone traffic control already in place.

EXHIBIT V-30

Strategy Attributes for Improving Coordination, Planning, and Scheduling of Work Activities (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	The principal targets of this strategy include all those who are involved in planning and managing work zone activities. All crash types would be targeted by this strategy, which seeks to reduce the impact that work zones have on a community.
Expected Effectiveness	It is not feasible to measure the safety effectiveness of a support activity of the type being discussed here. However, this strategy is expected to have a beneficial impact on safety related to all types of work zones by potentially reducing traffic congestion, reducing exposure of highway users to work zones and workers to traffic, and improving emergency response and enforcement of work zone traffic laws. Agencies that have focused on improving coordination, planning, and scheduling of work activities have had positive experiences.
Keys to Success	<p>The effort will have a greater chance of success if all agencies in the corridor operation, even the agencies that are not expected to be affected by the work zones, are involved in interagency communication. This includes various departments of a highway agency (construction, maintenance, surveying, etc.) and local highway agencies, as well as emergency responders and law enforcement agencies. Various contractors and utility companies planning work in an area should be included in coordination efforts.</p> <p>State DOTs and metropolitan areas need to develop procedures that will ensure that proper coordination, planning, and scheduling occurs and that all concerned parties are involved.</p>
Potential Difficulties	<p>There may be “turf” issues and other political problems to solve between offices in the involved agencies. It is important that coordination and communication be stipulated at the highest levels of the agencies involved.</p> <p>Different agencies may have different policies and procedures. Some degree of flexibility will be needed so that cooperation can be maintained and coordination efforts can proceed effectively.</p>
Appropriate Measures and Data	<p>Process measures would include documentation of policy changes that have been implemented because of improved coordination, planning, and scheduling. Documentation of the nature of coordination may also be included. Measures of scheduling would include documentation of how projects have been scheduled considering other projects in the area.</p> <p>It is not feasible to measure the safety effectiveness of a support activity of the type being discussed here. Impact should be measured, instead, in terms of the change in process and the estimated change in the degree of cooperation attained. In terms of scheduling, it might be useful to count the number of conflicting projects identified and avoided.</p>
Associated Needs	None identified.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	There may be a need to modify institutional policies to allow for the establishment of task forces to work on coordination activities that include individuals from outside the highway agency.

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-30 (Continued)**

Strategy Attributes for Improving Coordination, Planning, and Scheduling of Work Activities (T)

Attribute	Description
	Support for this effort is best attained from the highest levels in the agencies involved. Interagency agreements may have to be established to cement the desired relationships.
Issues Affecting Implementation Time	Depending on each agency's practices and relationships with other stakeholders, implementation time may vary. Strong relationships and good communication practices must be developed.
Costs Involved	A key cost is the personnel time that may be needed to develop policies for effective coordination, planning, and scheduling of work zones, as well as the time spent in these coordination and control activities. There may be additional costs if new systems (such as an online database) are developed to support this.
	Another potentially substantial cost is the time and resources for coordination during design and construction of individual projects once the policy is in place.
Training and Other Personnel Needs	It may help to train some management staff on how to deal with organizational change.
Legislative Needs	None identified.

Other Key Attributes

None identified.

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

Ohio DOT developed a policy and a map that shows the roadways on which a lane can be closed based on traffic volumes. Additional information is available in the FHWA Work Zone Mobility and Safety program website: http://ops.fhwa.dot.gov/wz/practices/best/view_document.asp?id=209&from=crossref&Category_id=18.

Strategy 19.1 F3—Use Incentives to Create and Operate Safer Work Zones (T)**General Description**

Some state agencies and other highway organizations have established incentive or award programs to encourage work zone personnel to strive for safer work zones. Such programs are intended to raise awareness of safety issues and improve the morale among their employees and contractors, which in turn is expected to lead to safer work zone practices and improved work zone safety. Incentives or awards can be presented to individual highway agency or contractor employees, to construction firms, or to other individuals or organizations involved in work zone activities.

An example association award is an award program sponsored by the American Road and Transportation Builders Association and the National Safety Council. These groups jointly present annual awards for what they consider to be the best outreach and training programs

and technical innovations. These awards are given to government and private organizations in an attempt to recognize efforts to improve work zone safety. A description of the winners of the awards for 2004 is available online at http://www.artba.org/news/press_releases/2004/11-08a-04.htm.

EXHIBIT V-31

Strategy Attributes for Using Incentives to Create and Operate Safer Work Zones (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	The principal targets of this strategy are people and organizations in highway agencies, contracting companies, vendors, and any other organization involved in work zones. All crash types would be targeted by this strategy, which seeks to improve the overall work zone safety experience by improving the level of awareness and performance of the individuals and organizations involved.
Expected Effectiveness	Safety incentives are instituted in order to raise awareness on work zone safety issues and improve morale. Anecdotal evidence indicates that such programs are effective in accomplishing this, though a direct link to a reduction in crashes has not been identified.
Keys to Success	<p>For planning incentive programs and selecting the award recipients, the agency should adopt a structured process that is acceptable to agency staff and contractors throughout the agency's jurisdiction.</p> <p>It is also important that the recognition of incentive or award recipients be made from the highest possible level in the organization.</p> <p>The nature of the incentive or award (certificate of recognition, monetary bonus, etc.) may affect the enthusiasm with which people work to earn the award. In addition, incentive programs should be directed at the entities (individuals, project teams, etc.) directly responsible for the areas in which work zone safety improvements are desired.</p>
Potential Difficulties	There may be difficulties in acquiring both the necessary staff time to manage an award program and the funds for the awards.
Appropriate Measures and Data	<p>Process measures include documentation of the procedures that are established to identify award recipients, the number of awards issued, and what the recipient individual or team did to earn the awards.</p> <p>Impact measures include the effect of these measures on employee morale, awareness of work zone safety issues, and the frequency and severity of crashes in work zones. Evaluation of changes in staff attitudes may be made through the use of surveys, interviews, focus groups, observations of personnel behavior, and changes in safety practices.</p>
Associated Needs	None identified.
<i>Organizational and Institutional Attributes</i>	
Organizational, Institutional and Policy Issues	The process for selecting award recipients should be developed to ensure that it is acceptable to those to whom the program is directed.

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-31 (Continued)**

Strategy Attributes for Using Incentives to Create and Operate Safer Work Zones (T)

Attribute	Description
	The program should be initiated and supported at the highest level possible in the organizations involved.
	The involvement of commercial sponsors may be useful for award programs run by contractors or contractor associations (e.g., as “safety partners”), especially if the sponsors can provide prizes of value for the winners in exchange for exposure for marketing.
Issues Affecting Implementation Time	The time required to implement this type of program will depend on the practices in each agency. Decisions will need to be made regarding the criteria for offering incentives or choosing award recipients, the resources that an agency can commit to incentive awards, the number of awards that are to be issued, the frequency of issuance, and whether a “prize” or bonus will be included with the award.
Costs Involved	Costs to develop an incentive or award program could be moderate, as contractors may expect to recover costs associated with the awards they give. Any bonuses distributed as part of awards would increase the costs. However, even modest awards or prizes are probably adequate to achieve the goal of this strategy in terms of supporting good awareness and enthusiasm for work zone safety.
Training and Other Personnel Needs	None identified.
Legislative Needs	None identified.
<i>Other Key Attributes</i>	
None identified.	

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

New York and Minnesota are two states that have implemented work zone safety award programs. Refer to Appendix 13 for a description of these programs.

Strategy 19.1 F4—Implement Work Zone Quality Assurance Procedures (i.e., Safety Inspections or Audits) (T)**General Description**

This strategy deals with the implementation of work zone quality assurance programs (i.e., safety inspections or audits) that are intended to gather information about the adequacy of work zone traffic control procedures and identify areas where improvements are necessary. This strategy addresses three issues: agency work zone procedures, implementation at the individual project level, and management at project and program levels. Safety audits are performed at various stages in the design and construction process. Safety inspections performed during construction are necessary to ensure that the design and operation of work zones provide adequate consideration of the needs of road users and workers. The

idea behind both is to elevate the consideration of work zone safety and to ensure that work zones provide adequate safety for workers and road users. The recent FHWA rule on work zone safety and mobility recommends that states “develop and implement systematic procedures to assess work zone impacts in project development, and to manage safety and mobility during project implementation.” It may be desirable for an agency to perform independent assessments of the effectiveness of their procedures to gain an objective view of the success of their programs.

Safety inspections can be used to determine whether the design, operation, installation, and maintenance of various traffic control devices conform to the standards prescribed by the MUTCD and the standards or guidance prescribed by a state or jurisdiction. Inspections should also evaluate whether the traffic controls in place are adequate to meet the safety and mobility needs of the project. Much of the guidance and standards in the MUTCD and elsewhere allow extensive flexibility and latitude in choice of devices and how they are implemented. To provide any real value, these inspections need to consider how well the traffic control setup is actually working, not simply whether it complies with the MUTCD.

Following are examples of features that need to be covered as part of an inspection program:

- *Advance warning:* Evaluate the quantity, condition, and placement of signs, including nonstandard signs, and the placement of arrow boards.
- *Channelization:* Evaluate the condition and effectiveness of channelization.
- *Pavement markings:* Evaluate the condition of pavement markings and whether they are easily understandable to road users.
- *Flagging:* Evaluate whether flaggers are clearly visible to the approaching traffic, whether the numbers of flaggers is adequate, whether there is proper coordination among the flaggers, whether the flagging technique is appropriate, and whether the attire used by the flaggers is appropriate.
- *Roadside safety:* Evaluate whether the type of barrier is appropriate, whether the barrier meets NCHRP Report 350 requirements and is installed correctly, whether the barrier is in good condition, whether flared end treatments or impact attenuators are necessary, whether the barrier is delineated appropriately, whether adequate clear zone is available, and whether other roadside features (such as slopes and unprotected fixed objects) present safety hazards.
- *Nighttime traffic control:* Evaluate temporary traffic control devices at night and during dawn and dusk to ensure that they are visible at these times.
- *Miscellaneous traffic control:* Evaluate whether the equipment and/or operations in the roadway are adequately protected, whether temporary signal operations are effective, whether the posted speed limit is appropriate, whether access control is adequate, whether pedestrians have adequate travel path and are adequately protected from hazards, and whether emergency responders are able to access incidents in the work zone as well as travel through the work zone when responding to incidents.
- *Law enforcement programs:* Evaluate the feasibility and effectiveness of programs for enforcing traffic laws in a given work zone. Consideration should be given to whether officers have space to stop violators and whether a law enforcement agency has been

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able to provide enforcement at agreed-upon levels. Issues to be reviewed include the communication of enforcement officers with project personnel, the particular law enforcement strategy used (stationary, mobile, multiagency, etc.), and whether project personnel perceive benefits to the enforcement program.

Examples of work zone inspection forms are shown in Appendix 14.

It is important to understand that any results of a safety inspection represent only a point sample of the project when the inspection was conducted. Hence, any recommendations that are developed should strive to assess how effectively the traffic control system will function under all reasonably expected traffic conditions and during adverse conditions, such as darkness and rain.

EXHIBIT V-32

Strategy Attributes for Implementing Work Zone Quality Assurance Procedures (i.e., Safety Inspections or Audits) (T)

Attribute	Description
<i>Technical Attributes</i>	
Target	All crash types would be targeted by this strategy, which seeks to improve the quality of work zone traffic controls, both on individual projects and programwide. Designers, maintenance personnel, contractors, utility personnel, and all others involved in work zones would be affected by safety inspections, but the strategy would be implemented by an individual or small group. This strategy would have a beneficial impact on all types of work zones, regardless of size or duration.
Expected Effectiveness	It is not feasible to directly measure the safety effectiveness of a support activity of the type being discussed here. Surrogates may be used as indicators, however. NYSDOT instituted its work zone inspection program in the late 1980s. NYSDOT's experience shows an overall improvement in work zone quality and a decrease in serious work zone crashes throughout the 1990s. While a direct correlation between crash reduction and quality improvement cannot be established, the improvement in quality is believed to contribute to the crash reduction (Bryden and Andrew, 2001).
Keys to Success	<p>Experience from the inspection program in New York has indicated that for the program to be successful, the inspection team needs to include individuals from a small core group with extensive experience in work zone inspections to ensure that procedures are consistently followed in different parts of the state. A representative from the state's highway safety office would provide a useful perspective during evaluations and inspections.</p> <p>Continuous monitoring of work zones is needed to ensure that traffic control devices are maintained in good condition, that appropriate devices are set up and/or removed as work progresses and as the work zone layout changes, and that recommended improvements are implemented.</p> <p>The agency and contracting community must support program findings, and there must be good procedures for disseminating and implementing findings.</p> <p>Inspections can be either announced or unannounced. Inspections should not be used as a report card on an individual's performance, although the results should be used</p>

EXHIBIT V-32 (Continued)

Strategy Attributes for Implementing Work Zone Quality Assurance Procedures (i.e., Safety Inspections or Audits) (T)

Attribute	Description
	<p>to improve the performance of individuals by informing them of the inspection results through debriefings and by providing additional training as needed. The intent should be to gather information about the adequacy of work zone traffic control procedures and identify areas where improvement is necessary.</p> <p>The program should be initiated carefully, using a few pilot field visits to test procedures. This will allow for issues to be resolved before major investments of resources are made.</p>
Potential Difficulties	<p>Establishing support for safety inspections and providing adequate resources for performing inspections are the primary issues with implementing this strategy. There may be a natural hesitancy of an internal group to be too critical about its own agency's performance. In addition, if the group is entirely internal, there may not be special expertise. For example, human factors specialists who could help identify continuing problems may not be readily available in an agency. Therefore, it may be productive to include people from outside the agency who have the desired expertise. The potential for inspector hesitancy to be critical of an agency's actions or practices should be considered when deciding whether internal or external personnel should perform inspections. There needs to be an awareness that hesitancy to report problems can not only increase risk to the public, but also negatively affect risk management issues (such as increased potential for crashes if work zone traffic control devices are not visible).</p> <p>It may be difficult to draw general conclusions from a series of case studies based upon some selection process. Use of a rating system may help establish a quantitative basis for evaluation.</p>
Appropriate Measures and Data	<p>Process measures include the number of safety inspections or audits performed and documentation of the types of problems identified.</p> <p>Direct evaluation of effectiveness can be measured in terms of the improvements in design, development, and operation of work zones based on safety inspections.</p>
Associated Needs	<p>There may be a desire to include outside expertise, such as human factors specialists, on the quality control team.</p>

Organizational and Institutional Attributes

Organizational, Institutional and Policy Issues	If a state has not already done so, it will need to institute new policies and procedures to create a basis for inspection and rating programs. Also, states may want to review existing policies and procedures. The development and acceptance of these will be needed from various offices within an agency. Therefore, this must be accomplished from a high level within the agency.
Issues Affecting Implementation Time	Arrangements will be needed across offices in the agency to arrange for the availability of personnel to participate in the quality assurance teams.
	Some time will be necessary to institute policies and procedures to establish inspection and rating programs, but much of this strategy could be implemented relatively quickly. The specific implementation time will depend on the agencies' existing policies and procedures, the nature of the organization, and the degree of complexity desired.

SECTION V—DESCRIPTION OF STRATEGIES**EXHIBIT V-32 (Continued)**

Strategy Attributes for Implementing Work Zone Quality Assurance Procedures (i.e., Safety Inspections or Audits) (T)

Attribute	Description
Costs Involved	The major cost of this strategy will be providing staff to conduct inspections, analyze results, and manage the safety inspection program. Training for inspectors will be an additional lesser cost.
Training and Other Personnel Needs	Personnel involved in the inspection process should undergo a training program so that the purpose of the inspection program is understood and so that the inspection program is performed consistently at all locations.
Legislative Needs	None identified.
<i>Other Key Attributes</i>	
None identified.	

Key References

Bryden, J.E., and Andrew, L.B., "Quality Assurance Program for Work-Zone Traffic Control," *Transportation Research Record* 1745, Transportation Research Board, 2001.

FHWA Work Zone Safety and Mobility Rule. Federal Register. 2004.
<http://a257.g.akamaitech.net/7/257/2422/06jun20041800/edocket.access.gpo.gov/2004/04-20340.htm>.

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

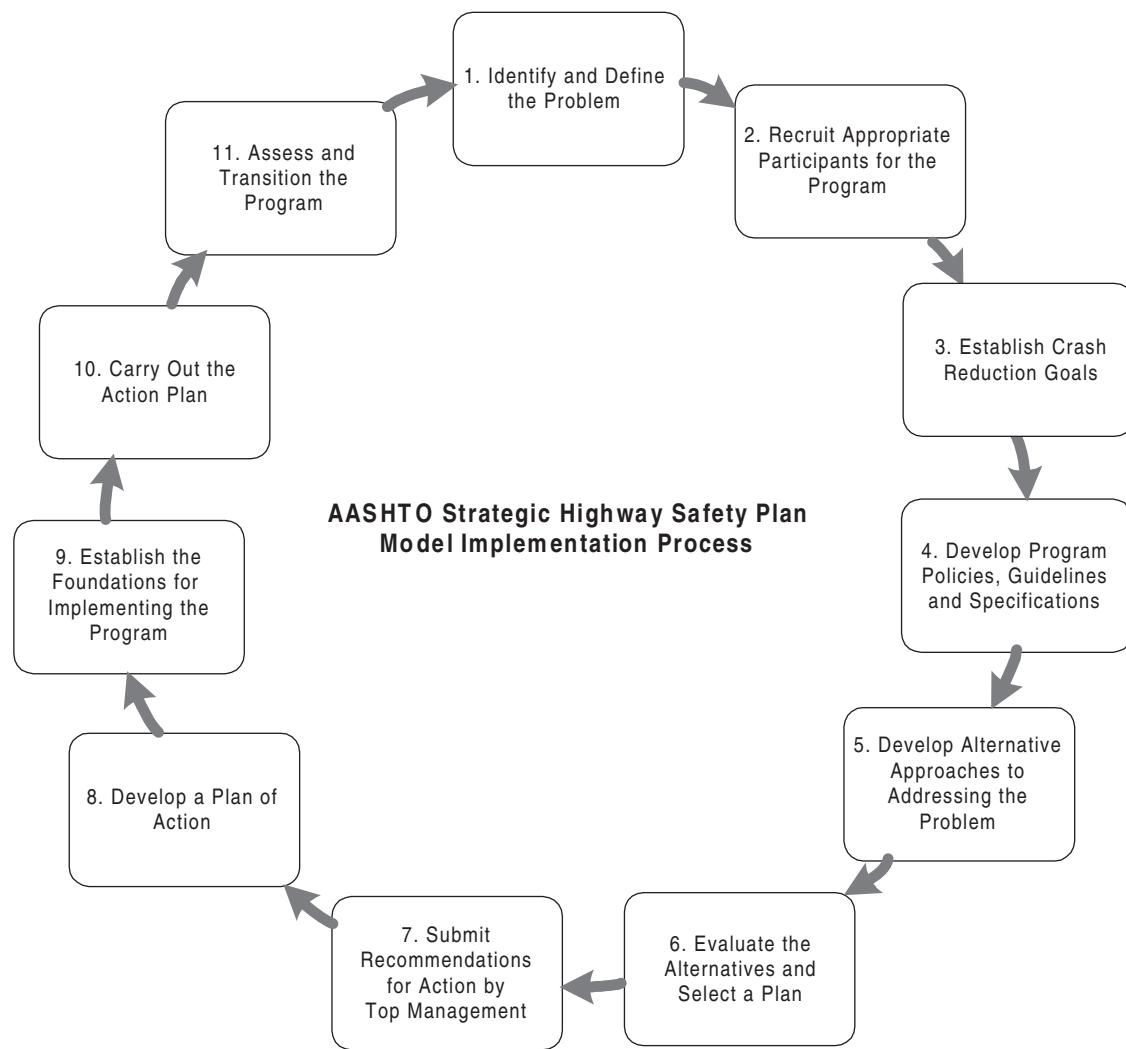
Examples of agency inspection forms, including a rating system used by one agency, are shown in Appendix 14.

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:

SECTION VI—GUIDANCE FOR IMPLEMENTATION OF THE AASHTO STRATEGIC HIGHWAY SAFETY PLAN

- 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

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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 Appendices Y, Z and AA for examples of what some states are doing)

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- 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 (*approvals 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

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- 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 a support for funding programs for its achievement. Therefore, it is desirable to establish, within each emphasis area, one or more crash reduction targets.

These may be dictated by strategic-level planning for the agency, or it may be left to the stakeholders to determine. (The summary of the Wisconsin DOT Highway Safety Plan in [Appendix A](#) has more information.) For example, Pennsylvania adopted a goal of 10 percent reduction in fatalities by 2002,¹ while California established a goal of 40 percent reduction in fatalities and 15 percent reduction in injury crashes, as well as a 10 percent reduction in work zone crashes, in 1 year.² At the municipal level, Toledo, Ohio, is cited by the U.S. Conference of Mayors as having an exemplary program. This included establishing specific crash reduction goals (http://www.usmayors.org/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/review performance and process measures
 - 6.2. Establish data collection and reporting protocols
 - 6.3. Develop data collection and reporting instruments
 - 6.4. Measure baseline conditions

Implementation Step 10: Carry Out the Action Plan

General Description

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

Specific Elements

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

Implementation Step 11: Assess and Transition the Program

General Description

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

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

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

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

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

Specific Elements

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

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

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Appendices

The following appendixes are not published in this report. However, they are available online at <http://safety.transportation.org>.

- 1 Examples of Projects Utilizing Travel Demand Management in Work Zones
- 2 Variable Speed Limits in Work Zones
- 3 Sign Visibility Conclusions
- 4 Evaluation Report on RC Flagman Remote Flagger
- 5 Costs of Temporary Signal
- 6 Pavement Edge Drop-Offs
- 7 Developing Administrative Procedures for Traffic Law Enforcement in Work Zones
- 8 NWZAW Poster
- 9 Work Zone Crash Data Elements
- 10 New York State Department of Transportation Work Zone Crash Data Collection
- 11 Florida Crash Reporting Form
- 12 State Examples of Work Zone Coordination
- 13 Work Zone Safety Awards
- 14 Examples of Inspection Forms Used by Different Agencies

- 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

APPENDIXES

- 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 used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
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	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
NCHRP	National Cooperative Highway Research Program
NCTRTP	National Cooperative Transit Research and Development 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