Guidance on Setting Speed Limits

Traffic Operations Division

Traffic Engineering Office

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TN TDOT Department of Transportation

Table of Contents

Glossary of Terms

85^{th} Percentile Speed – the speed that 85 percent of vehicles do not exceed.

Access controlled – a type of highway which has been designed for high-speed vehicular traffic, with all traffic flow and ingress/egress regulated. Also includes limited or partially controlled access, which allows for some at grade intersections.

Ball-bank Indicator – an inclinometer that is used for the specific purpose of determining safe (uniform advisory) curve speeds for horizontal curves.

FHWA – The Federal Highway Administration

ITE – Institute of Transportation Engineers

MUTCD – Manual on Uniform Traffic Control Devices

Speed Limit – the maximum speed at which a vehicle may legally travel on a particular stretch of road.

TDOT – The Tennessee Department of Transportation

Uncontrolled access – a type of highway that allows for ingress and egress at at-grade intersections rather than interchanges.

USLimits2 – a web based tool designed to help practitioners set reasonable, safe, and consistent speed limits for specific segments of roads.

Work Zone – an area of a highway with construction, maintenance, or utility work.

> **Short Term –** daytime work that occupies a location for more than 1 hour within a single daylight period.
>
> **Intermediate –** work that occupies a location more than one daylight period up to 3 days, or nighttime work lasting more than 1 hour.
>
> **Long Term –** work that occupies a location more than 3 days.

Chapter 1 – Introduction

1.1 Overview

Purpose

The purpose of this manual is to provide guidance for setting speed limits and advisory speeds on the state highway system.

Intended Users

This manual is intended for use by TDOT Regional Traffic Engineers in determining the need to recommend to the State Traffic Engineer a speed limit change or in establishing an advisory speed limit on the state highway system.

Local agencies are authorized to establish their own speed limits under certain conditions; however they are welcome to use this guide.

1.2 Background

Need for Guidance

The management of speed through establishing appropriate speed limits is an important component of highway safety. Proper speed limits are essential for effective and sustainable speed management. Speed limits should reflect the maximum reasonable and safe speed for normal conditions. The Manual on Uniform Traffic Control Devices (MUTCD) requires that speed limits be set on the basis of an engineering study. Speed limits should promote safe travel, and should be perceived by the public as safe and reasonable. If the public does not understand the consequences of speeding they are less likely to adjust speeds for traffic and weather conditions, or to comply with posted speed limits. State and local enforcement should focus on the types of drivers and situations where speeding has a significant impact on public safety. Voluntary compliance with speed limits can be improved through greater use of speed management devices and techniques that can be built into the existing highway system, as well as incorporated in the Intelligent Transportation System. A properly set speed limit will reduce differentials in speeds, thereby reducing the potential for conflicts.

Authority

The following statutes govern the establishment of speed limits in the State of Tennessee:

- 55-8-152 Speed Limits – Penalties.
- 55-8-153 Establishment of Speed Zones.
- 55-8-156 Special Speed Limitations – Penalties.

Tennessee Code Annotated sets statutory maximum speeds at 70 MPH for interstate highways, 65 MPH for all other public roads (TCA §55-8-152). TDOT has authority to reduce the speed limit on highways on the state transportation system below the statutory maximums (TCA §55-8-153). Municipalities are granted authority to lower the speed limits on any road within their jurisdiction, except for controlled access highways (TCA §55-8-153), but the speed may not exceed 55 MPH. Municipalities and counties have authority to set school speed limits in certain circumstances (TCA §55-8-152). TDOT has authority to set speed limits for bridges in Tennessee (TCA §55-8-156). In order to establish a limit lower than the statutory limit, an engineering investigation is required.

Controlled Access Highways

The maximum allowable speed limit on a controlled access highway is 70 MPH. The Tennessee Department of Transportation has sole authority to establish a speed limit lower than the statutory limit on controlled access facilities as needed based on an engineering investigation.

Non-Access Controlled Highways Outside Incorporated Municipalities

The maximum allowable speed limit on non-access controlled highways is 65 MPH. For roadways on the state highway system, but outside incorporated municipalities, TDOT has sole authority to establish regulatory speed limits lower than the statutory maximum. On non-state highways, outside an incorporated municipality, the county has the authority to lower the statutory speed limit by ordinance. Any reduction from the statutory maximum must be based on an engineering investigation.

Non-Access Controlled Highways within an Incorporated Municipality

The maximum allowable speed limit on non-access controlled highways is 55 MPH. For roadways within an incorporated municipality, the municipality has the authority to establish speed limits lower that the statutory limit as needed based on an engineering investigation.

1.3 Factors Influencing Driver Behavior

Introduction

This section discusses various factors influencing drivers and their perception of the safe speed at which to operate a vehicle. The AASHTO Green Book (A Policy on Geometric Design of Highways and Streets) identified the following 5 categories of factors that influence drivers' perception: physical factors of the highway, the amount of roadside interference, the weather, the presence of other vehicles, and the established speed limit. The factors within these categories should be considered as a whole and weighed accordingly in determining the optimal speed limit for a roadway.

Design and Physical Factors of the Roadway

The design and physical features of the roadway place limitations on the safe operating speed of vehicles. These factors include:

- Horizontal and vertical curves
- Hidden drives
- High driveway density
- Area type and level of development
- Availability of a shoulder and/or recovery area
- Lane width

- Turn lane availability
- Sight distance availability

The Vehicle

The mechanical condition of vehicles and their characteristics for accelerating, decelerating, stopping, and turning affects speed. The braking capabilities of different vehicles, such as passenger cars, buses, and various truck-trailer combinations can also vary. A vehicles shape and size affect the ability to navigate curves at certain speeds

The posted speed is typically set for highest percentage user, the design vehicle. However, in some locations it may be posted, for safety considerations, based a more vulnerable user.

The Driver

The abilities of drivers vary. The selection of speeds to be posted will be aimed at the ability and performance of the average driver.

Average driver ability is considered in the form of perception-reaction time (PRT) in the calculation of critical approach speeds to intersections, crosswalks, and locations with limited sight distance and in determining the posting distance for signs. The MUTCD establishes the reasonable value of PRT.

Weather Conditions

Speed limits are ordinarily set based on studies performed during optimal daytime weather conditions and dry pavement, however many of the design factors for highways are conservative due to vehicle performance on wet pavement.

Chapter 2 – Regulatory Speed Limits

2.1 What is a Regulatory Speed Limit?

Regulatory Speed Limit

A regulatory speed limit is the legal speed limit of a given route. A regulatory speed limit can be either statutory or posted.

2.2 How is a speed limit determined?

New Construction

The new or reconstructed roadways should be designed to accommodate operating speeds consistent with the roadway's highest anticipated posted speed limit based on the roadway's initial or ultimate function. The AASHTO Green Book provides that a design speed should be logical with respect to the anticipated operating speed, topography, adjacent land use, and functional class.

Existing Highway

A deviation from a statutory speed limit must be based on an engineering study. An engineering study may include a speed survey, safety study, geometrics, enforcement practices, roadside development, road and shoulder surface characteristics, and pedestrian and bicycle activity.

A speed study shall identify the 85th percentile speed and the average speed (see Figure 1), and these results should be considered along with other factors. A safety study shall consider crashes from the most recent 3 year period. Only crashes where speed may have been a contributing factor shall be considered. Distinct geometric conditions, such as driveway density or pedestrian volume shall be considered. The current enforcement practices shall be considered. If a highway has a speed problem but is not being enforced as is, then a lower limit will not solve this issue. If a highway is enforced to a greater degree than other like roads, then a speed survey should be performed to determine if the posted speed limit is too low. A regulatory speed limit should not be set lower than the average speed based off a speed survey.

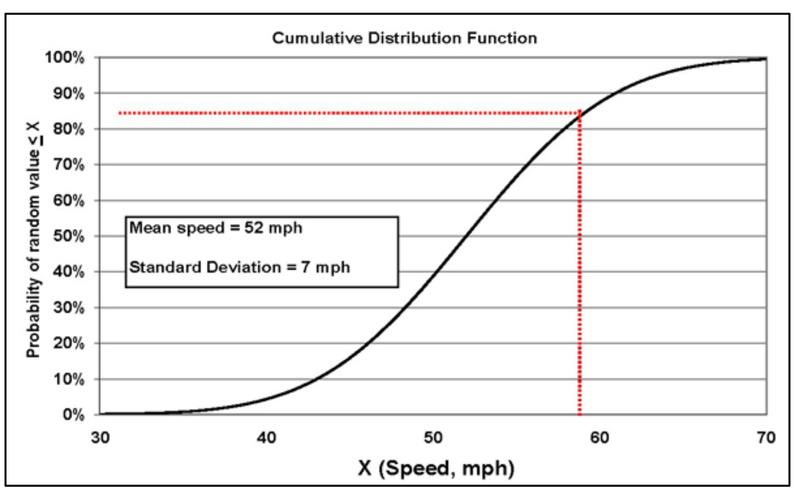


Figure 1: Example speed survey

Consistency

Whenever only a portion of the highway's speed is being evaluated, the speed limit in the approach to and departure from that section should being taken into consideration in order to ensure consistency. Unusually short sections should be avoided to maintain driver expectancy.

A speed zone should be at least half a mile when the limit is 40 MPH or higher and at least a quarter of a mile when the speed is less than 40 MPH. If the speed zone is a transition area dropping to a lower speed the length may be shorter depending on engineering judgement.

The speed limit from one speed zone to another should not change by more than is reasonable for a driver. A 5 or 10 MPH differences is recommended. The MUTCD requires a warning sign be posted in advance of a speed limit decrease of more than 10 MPH.

Speed Limits in Curb and Gutter Sections

Certain geometric situations provide some limitations on the maximum speed limit. The AASHTO Green Book specifies that roadway sections with a vertical curb should be only used on low speed roadways. The Green Book defines a low speed roadway as 45 MPH or less. However there are some situations where a higher speed may be allowed, and preferred, in sections with vertical curbs. In 2013, the TDOT Traffic Engineering Office developed a draft policy for when speed limits above 45 MPH would be allowed in curb and gutter sections based on a study completed by the University of Tennessee titled *Guidelines for Selecting Reasonable Speed Limits When Widening and Updating 55-mph Two-Lane Highways to Multilane Highways with Curbs and Gutters* and dated June 2012. This study and draft are currently being reevaluated.

2.3 How to request a speed limit change

To request a speed limit change, the Regional Traffic Engineer shall conduct an engineering study to determine the recommended limit. An engineering study could include a speed survey, crash review, etc. As part of the study, the regional traffic engineer may evaluate the section of road using USLimits2 (or later version) to evaluate their results. The results of the study shall be submitted to the State Traffic Engineer with a recommendation on the value of the recommended speed limit as well as the location. Any and all supporting data should be included. A present and proposed sign drawing may be required showing the highway under consideration.

2.4 Other Factors

Truck Speed Limits

In some areas, it may be necessary to have a lower truck speed limit due to safety or emissions. If a lower truck limit is used, it shall not be more than 10 mph lower than the posted speed limit for other vehicles. If a truck speed limit is desired, the Region Traffic Engineer shall request to the State Traffic Engineer using the procedures set for is section 2.3 above.

Variable Speed Limits

A variable speed limit is a regulatory speed limit that changes as traffic conditions change. A digital sign is installed and used to make changes along a section of highway during severe weather event or in times of heavy congestion.

TDOT currently utilizes variable speed limits on I-75 in region 2 in an area prone to fog issues. The normal regulatory limit is 70 mph, however if fog is present (and visibility is at least 32 feet) the speed will be reduced to 50 mph. Presence of fog and visibility limits will be determined in the field by the Tennessee Highway Patrol (THP), who will relay the information back to the TDOT Region 2 Transportation Management Center who will adjust the changeable speed limit signs. The THP will monitor the area and determine when the speed may return to the normal operating speed.

TDOT does not currently operate any congestion based variable speed limits. TDOT is currently reviewing this as a congestion mitigation and safety measure. If deployed, standard operating procedures will be developed.

Chapter 3 – Advisory Speeds

3.1 What is an Advisory Speed?

An advisory speed is defined in the MUTCD as a recommended speed for all vehicles operating on a section of highway and based on the highway design, operating characteristics, and conditions.

An advisory speed is not an enforceable speed limit. A vehicle not heeding an advisory speed may still be found at fault due to speed if a crash results from failure to follow the advisory speed.

3.2 How is an Advisory Speed Determined?

For Horizontal Curves

Certain roadways have a safe traveling speed for the majority of the road length with the exception of a curve section that may be unsafe at the same speed. In those situations, an advisory speed may be needed to warn drivers of the location were speed should be reduced. When needed, an advisory speed plaque shall be installed below the appropriate warning sign.

There are 6 FHWA approved methods to determine the safe driving speed through a curve or series or curves: direct method, compass method, GPS method, design method, ball-bank indicator method, and accelerometer method.

The direct method is based on filed measurements of vehicle speeds on the subject curve. There is disagreement on whether to use the 85th percentile, average, or median speeds and which vehicle type to consider (car, truck, or all).

The compass method is based on a single-pass survey technique using a digital compass, distance measuring instruments, and ball bank indicator. This method requires stopping of the vehicle in the travel lane in the curve, so therefore has some safety concerns. This method only works on curves that meet specific design criteria.

The GPS method utilizes a GPS receiver and a laptop computer to run the necessary software. The receiver is used to estimate curve radius and deflection angle. Data is collected with the GPS receiver and processed using the computer.

The design method is based on the use of curve geometry data: radius, deflection angle, and superelevation rate.

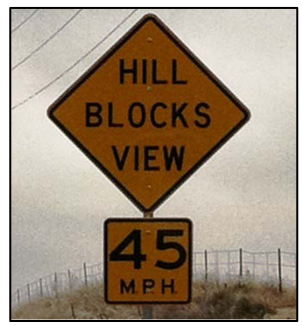
The ball-bank indicator method is based on a set of field driving tests to record indicator readings using a ball-bank and speedometer. There are varied criteria for establishing an advisory speed using this method. The MUTCD has the following criteria: 16 degrees of ball-bank for speeds of 20 mph or less, 14 degrees for speeds of 25-30, and 12 degrees for speed of 35 mph or greater. Electronic ball bank indicators make this method even simpler. This is the most common method to determine advisory speed because of its simplicity.

The accelerometer method uses an accelerometer, an electronic device which measured the later acceleration of a vehicle as it travels around a curve. This method is good in that it requires only 1 person to conduct the tests, however it requires special equipment.

Any approved method may be used to determine the appropriate advisory speed limit for horizontal curves, though the ball-bank indicator method is the most widely used method.

For Vertical Curves

An advisory speed limit may be needed when a vertical curve prevents adequate sight distance to driveways or intersections. The advisory speed plaque shall be installed below the appropriate warning sign (ie. Hill Blocks View, or Crossroads sign). The advisory speed should be based on stopping sight distance to the potential conflict point.



Truck Advisory Speeds

Trucks may need specific advisory speeds for curves or on steep grades. For curves, the advisory speed is calculated similarly to a passenger car, but uses a different design vehicle.

On steep grades, truck advisory speeds need to consider more than just deceleration rate for stopping sight distance. A truck’s brakes could overheat on steep grades causing brake failure if the truck was traveling to fast. The *Grade Severity Rating System* developed by FHWA is historically what has been used to make the determination on what speed was appropriate. Based off the trucks weight and estimated braking temperatures for various grades taken at various speeds, the system will evaluate the safe operating speeds to post on signs. That system however has not been updated since 1989 and truck designs have been significantly improved, so speeds may be slightly lower than what could safely be posted.

For Other Instances

Some roads have inconsistencies like dips or bumps in the pavement. Other roads have purposely installed speed bumps, speed humps, or speed tables. In either case it may be necessary to have an advisory speed limit to navigate this obstacle. The advisory speed that should be posted for natural bumps or dips should be determined by trial runs in the field. The advisory speed for installed speed bumps, speed humps, or speed tables should be based on the manufacturers' suggestion.

3.3 How to Post

Once the needed advisory speed is determined, you may need to post it in the field. The MUTCD requires that certain horizontal alignment signs and the advisory speed limit be posted when the difference between the posted speed limit and the advisory limit is 10 mph or greater. In instances, other than horizontal curves, where the difference in the posted speed limit and the advisory speed limit is 10 mph or great an appropriate warning sign and advisory speed plaque shall be installed. Guidance on the advanced placement of the warning sign can be found in Table 2C-4 of the MUTCD.

An advisory speed is displayed using either a yellow or orange supplemental sign plaque. Yellow is used as a warning in permanent situations, while orange is for use in temporary traffic control areas.

Chapter 4 – Work Zone Speed Control

4.1 Speed Control Types

A work zone speed is the speed motorists may safely travel through a work zone and can be either advisory or regulatory. The following table may be used to determine which speed control method is most appropriate. Choosing an appropriate speed limit is important, because compliance will be greater when motorists perceive that the limit is justified (*Methods and Practices for Setting Speed Limits: An Informational Report*, FHWA).

	Description	Examples
Advisory Speed	For driver and/or worker safety, warning signs with speed advisory plates, call for the reduction of speed by the driver to safely negotiate a potentially hazardous conditions caused by the work zone activity or worker proximity to the roadway for work taking less than 3 days. **Advisory speed limits should be the first consideration.**	Bumps, low shoulders, drop-offs, narrow lanes, no shoulder, sight distance restrictions, poor surface condition, maintenance operations at spot locations
Regulatory Speed Limit (Worker safety/Variable)	For worker safety, regulatory limit established in short-term projects during continuous worker activity **when the workers are present** and are adjacent to moving traffic.	Pavement repair, bridge repair, loop detector installation, turn lane installation, mill and overlay projects, concrete repair, etc
Regulatory Speed Limit (Continuous)	Regulatory speed limit in work zones intended for 24 hour continuous posting established in long term projects where it is **imperative for the motorist to reduce speeds in order to safely navigate** through hazards over the length of the project.	Bypasses, shoulder drop-offs, narrow lanes, grade separation, lane shifts, and pavement repair

Table 1: Speed Control Types

Advisory Speeds

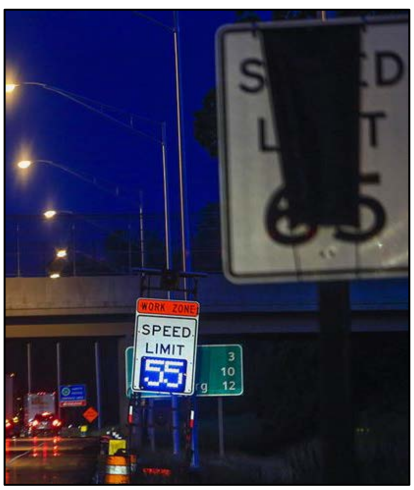
Warning signs with speed advisories should be used whenever an unexpected change in geometrics is caused by the work activity. Warning signs, with speed advisory plates, call for the reduction of speed by the driver to safely negotiate a hazard or potentially hazardous condition. Drivers will reduce their speed if they clearly perceive a hazard. **ADVISORY SPEEDS SHOULD BE THE FIRST CONSIDERATION WHEN ESTABLISHING SPEED LIMITS IN ANY WORK ZONE.**

Advisory speed limits are typically used to alert motorists to temporary road hazards. Some maintenance and operations activities pose little risk to motorists but may still warrant use of an advisory speed to enhance safety of workers.

Regulatory Speed Limits (Workers present/Variable)

Regulatory speed limits that change during periods of inactivity are generally established in intermediate and long term stationary construction or maintenance work zones only **when workers are present**. These limits are intended for use where the work area and workers are adjacent to traveled lane(s) open to vehicular traffic.

The speed limit signs shall only be posted in the work zone while workers are present performing construction or maintenance operations. Overuse of reduced speed limits will reduce their effectiveness; therefore, these must be prudently applied where the motorist can perceive the need to reduce speeds. During periods of no activity or when the traffic controls are removed from the roadway, the speed limit signs shall be covered or removed. This means installing signs at the beginning of a work shift and removing signs at the end of the shift. Alternatively, a changeable speed limit sign may be required in some circumstances, and the speed display adjusted at the start and end of each shift. The speed limit is only in effect when the signs are installed and visible to traffic. All sign installations shall conform to the MUTCD.



Improperly Covered Sign


Properly Covered Sign

Regulatory Speed Limits (Continuous)

Regulatory speed limits established for intermediate and long term construction and/or maintenance projects where there are continuous hazards to the motorist require a 24 hour, continuous posting. The speed limit goes into effect when the signs are posted.

Continuous regulatory speed limits should be used when the roadway construction environment will continuously dictate a reduced speed and it is imperative for the motorist to reduce speed in order to safely navigate hazards that may be encountered over the length of the project. Since the signs will be posted 24 hours a day, the primary reasons to establish the limit should also be present 24 hours a day. If the hazard to motorists is isolated to one phase of a long term project, after such phase is complete, the reduced speed should be lifted or made variable while workers are present.

4.2 How is Work Zone Speed Determined

Advisory Speeds in Work Zones

The work zone site supervisor may determine if an advisory speed limit is necessary for up to 10 mph lower than the posted speed limit. A supplemental advisory speed plaque may be added to other temporary traffic control warning signs in conformance to the MUTCD. When needed for worker safety, an advisory plaque in conjunction with the "Workers Ahead" warning sign may be used. This is intended for use at short term, spot locations. The size and placement of the signs shall conform to the MUTCD.

Regulatory Speed Limits

The Manual on Uniform Traffic Control Devices (MUTCD) gives guidance on speed limits in work zones. The MUTCD states, "Reduced speed zoning (lowering the regulatory speed limit) should be avoided as much as practical," and "Reduced speed limits should be used in only the specific portions of the work zone where conditions or restrictive features are present." The MUTCD further advises that a reduction of more than 10 mph should only be used when required by restrictive features of the work zone. The Federal Highway Association report from 2012 *Methods and Practices for Setting Speed Limits: An Informational Report* states, "Traffic control in work sites is designed on the assumption that drivers will only reduce their speeds if they clearly perceive a need to do so; therefore, reduced speed zoning ought to be avoided as much as practicable." This guidance is consistent with the guidance endorsed by ASSHTO as presented in the National Cooperative Highway Research Program (NCHRP) Research Results Digest # 192. This guidance will govern the decisions by TDOT of when a reduction to the speed limit is necessary.

The State Traffic Engineer's approval is required prior to making any regulatory speed adjustment. Typically a reduction of 10 mph will be the maximum that is warranted in a work zone absent any extenuating circumstances.

A contractor seeking a speed limit reduction shall make a request to the District Operations Engineer via the Speed Limit Reduction Request Form (located in Appendix B). The requestor shall identify if the requested reduction will be continuous reduction or only when workers are present reduction. A continuous reduction should only be used if the conditions warranting a reduction are present for an extended period (see Table 1 above for guidance). Using the procedures in the NCHRP Research Results Digest #192(located in Appendix A), the requestor shall identify which condition is satisfied (Figure 3 or 4 from NCHRP Digest #192) and which factor(s) (Table G-1 from NCHRP Digest #192) is present. If the Region Traffic Engineer and the District Operations Engineer agree that a reduction is warranted, the request shall be forwarded to the State Traffic Engineer for approval.

A designer seeking a speed limit reduction shall email the state traffic engineer. The designer shall identify if the requested reduction will be continuous reduction or only when workers are present reduction. A continuous reduction should only be used if the conditions warranting a reduction are present for an extended period (see Table 1 above for guidance). Using the procedures in the NCHRP Research Results Digest #192(located in Appendix A), the designer shall identify which condition is satisfied (Figure 3 or 4 from NCHRP Digest #192) and which factor(s) (Table G-1 from NCHRP Digest #192) is present.

Chapter 5 – School Speed Zones

5.1 What is a School Speed Zone?

What is a School Speed Zone?

The MUTCD defines a school zone as a roadway segment approaching, adjacent to, and beyond school buildings or grounds, or along which school related activities occur. A school speed zone is when the speed within the school zone is reduced from the normal operating speed when children may be present, such as arrival and dismissal time.

Tennessee state law says that for a school speed limit to be effective, it must be properly signed with flashers and only when children are present. It is the responsibility of the local agency to set a school speed limit if one is desired.

In Hawkins, Davidson, Hamilton, Knox, and Sullivan Counties a school zone in these counties is allowed on the roadway adjacent to or within ¼ mile to school grounds. In all other counties, a school zone is only allowed on the roadway adjacent to school grounds.

Why would a lower speed limit be desired?

A school speed zone is desirable when the pedestrian activity created by the school indicates a need for drivers to exercise greater care due to the higher than normal pedestrian volume or lower than normal pedestrian age.

Studies show that impact speed plays a critical role in the odds of survival of pedestrians struck by a car. The following figure graphs the results of 3 separate studies on the percent chance of a fatality resulting from a crash between a car and a pedestrian.

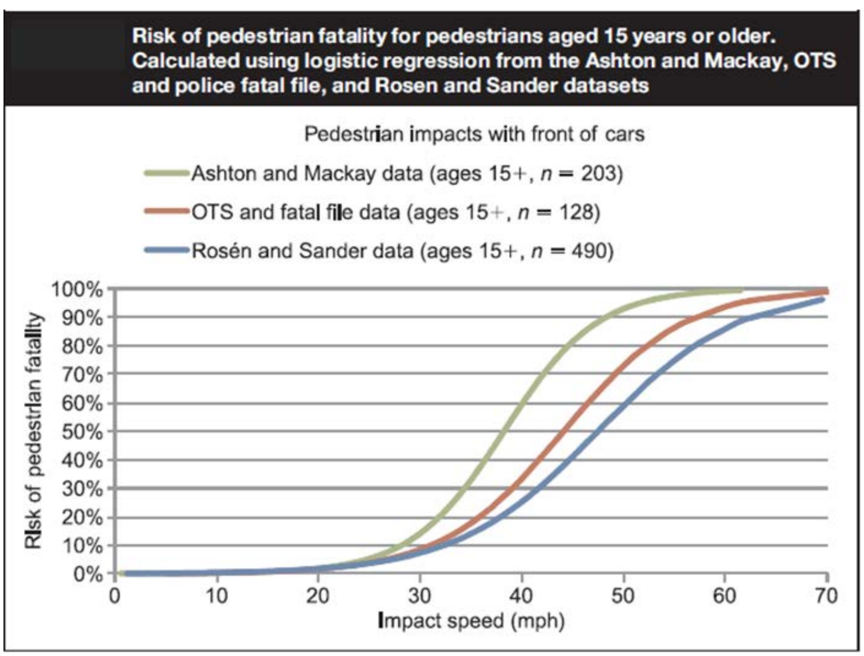


Figure 2: SOURCE: Road Safety Web Publication No. 16

5.2 How is an appropriate school speed limit determined?

The Federal Highway Administration (FHWA) recommends that school-age pedestrian activity be the motivating factor for implementing a school speed zone. Most state's school speed limit range from 15 to 25 miles per hour. In most instances, a decrease of more than 20 mph should be avoided. It is important to set an appropriate limit in order to maintain respect of the drivers as they traverse the school zone. A school speed limit should be determined based on an engineering study. Some common factors to consider are:

- Children walking along or crossing the roadway;
- Fencing around school property;
- Number and size of gaps in traffic for school-age pedestrians to cross the street;
- Presence of crossing guards;
- Student enrollment at the school;
- Location of the school property (i.e., abutting the road or visible from street); and
- Presence of sidewalks.

State law provides that the length of the school zone is authorized for the length of roadway adjacent to the school property, with some local agencies authorized to establish a school speed limit up to a quarter mile from the school. According to FHWA the length should be based on school-age pedestrian activity. An engineering study or investigation is required for any speed reduction. Table 2 below is the recommended distance to the start and end of the school zone area.

School Speed Limit (mph)	Distance to Crosswalk or First Driveway (ft.)
20	200
25	200
30	300
35	400

Table 2: Source: ITE Safe Routes to School Briefing Sheet

The length of a school speed zone should be based on engineering judgment rather than the exact location of the school property line or fence. The school speed zone should be centered at the location(s) where children cross the roadway. The beginning and ending points should be selected with appropriate consideration for the location of other traffic control devices and/or features that could affect the effective implementation of the school speed limit zone. The ITE Safe Routes to School Briefing states that, "Research has shown that speeds are approximately 1 mph higher for every 500 ft. driven within a school zone; therefore, longer school zones are associated with greater speed variability within the zone." TDOT prefers to limit the distance of a speed zone to 1000 feet where possible or 1800 feet if driveways are spaced far apart.

5.3 How is a school speed zone established and posted?

In order to establish a school speed limit, the local agency should pass a resolution setting the limit after the engineering study has been performed. A county needing to install flashers on a state route in conjunction with the speed limit must obtain, TDOT approval for the flasher.

Once the limit is determined and legally established, signing should be installed to convey to the motorists the new limit. The MUTCD provides signing requirements for a school zone.

Appendix A

National Cooperative Highway Research Program (NCHRP) Research Results Digest # 192

NCHRP
National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

September 1996 Number 192

These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may do so through contact with the Cooperative Research Programs Staff, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

Subject Areas: IIIC Maintenance, IVA Highway Operations, Capacity, and Traffic Control and IVB Safety and Human Performance

Responsible Senior Program Officer: Kenneth S. Opiela

Procedure for Determining Work Zone Speed Limits

This NCHRP digest summarizes the findings of NCHRP Project 3-41, "Procedure for Determining Work Zone Speed Limits," conducted by Graham-Migletz Enterprises, Inc. The digest, prepared by Lloyd R. Crowther and Kenneth S. Opiela, NCHRP Senior Program Officers, is an excerpt from the contractor's final report.

INTRODUCTION

The national *Manual on Uniform Traffic Control Devices for Streets and Highways* (*MUTCD*) (*1*) has no uniform guidelines for determining work zone speed limits. Consequently, work zone safety problems are aggravated by (1) inconsistencies in the methods used to determine work zone speed limits, (2) motorist noncompliance with the posted work zone speed limits, and (3) the growing practice of setting work zone speed limits through legislative or administrative decisions without the benefit of an engineering study. At their 1988 joint meeting, the AASHTO Highway Subcommittee on Traffic Engineering and the Maintenance Technical Committee of the National Committee on Uniform Traffic Control Devices unanimously concurred that research was urgently needed to establish a procedure for determining work zone speed limits to address these safety problems. The research reported here was initiated to meet this need.

THE PROBLEM AND ITS SOLUTION

The objective of this research was to develop a uniform procedure for determining work zone speed limits. The procedure had to be widely applicable and to accommodate, to the maximum extent possible, the often divergent interests of motorists, workers, and pedestrians. To meet this objective, the researchers sought to answer three fundamental questions: (1) Are work zones with reduced speed limits safer? (2) What are the compliance levels with various speed limit reductions? and (3) What roadway and traffic factors should be considered in determining a work zone speed limit?

To answer these questions, Graham-Migletz Enterprises, Inc. (GME) conducted a literature review and interviewed state and local highway agency officials in 12 states to learn about the procedures their agencies used to establish work zone speed limits and the perceived effectiveness of various speed limit reduction policies. In addition, the research included interviews and surveys to determine the attitudes of motorists, construction contractors, and construction liability insurance carriers concerning how work zone speed limits should be set. The results were considered in planning field data collection on vehicle speeds, traffic accidents, and traffic conflicts in work zones.

A candidate procedure for appropriate work zone speed limits was formulated early in the research and revised, as appropriate, throughout the remainder of the project. This procedure was based on an assessment of the hazards present in each individual work zone. It was tested and revised using vehicle speed and traffic accident data collected for actual work zone sites. In the process, GME compiled a 7-state, 68-site work zone research data bank that included 27 speed study sites and 66 accident-data collection sites.

The operational data—including vehicle speeds, but traffic volumes, and traffic conflicts—were collected at selected work zone sites where activities lasted 3 days or more. Speed data were generally collected during daytime off-peak hours, but at some sites, they were collected during daytime peak or nighttime periods or both.

The accident data included records of accidents that occurred both before and during the work activities at stationary construction zones. A minimum 1-month work period was established for accident study sites. The work at most sites lasted considerably longer.

The accident and speed data were analyzed to determine the effects of specific levels of speed limit reduction on sites with a variety of roadway, area, and work types. Particular care was taken to determine the work zone speed limit policies that (1) minimized the increase in speed variance from upstream of the work zone to the increase in speed variance within the work zone and (2) minimized the increase in the traffic accident rate from the period before construction to the period during construction.

FINDINGS

This section summarizes the findings of the research. It includes a description of the findings of the literature review, which addressed speed zoning and speed control, in general, and work zone speed zoning and control, in particular; a summary of state practices for establishing work zone speed limits; a summary of the field and accident data collection activities undertaken in the research; the results of the speed and accident studies; and the results of the surveys of motorists, construction contractors, and insurance carriers conducted during the research. A detailed explanation of these findings and the methods by which they were obtained is found in the appendixes of the final report. The subsequent Conclusions section addresses the interpretation of these findings, including a recommended procedure for determining work zone speed limits.

Literature Review Findings

The following discussion summarizes the findings of the literature review conducted during the research. The studies described here are presented in greater detail in Appendix A, which is not published herein.

Speed Zoning Overview

The establishment of speed zones is identified in the 1982 Federal Highway Administration (FHWA) "Synthesis of Safety Research Related to Traffic Control and Roadway Elements" as an important tool in promoting the safe and efficient operation of the highway system (*2*). Speed zones are established to encourage drivers to adopt safe travel speeds, to reduce the risk of accidents because of differences in vehicle speeds, and to allow the arrest of speed limit violators. Reasons for the establishment of speed zones can include urban development; small towns; poor horizontal or vertical geometrics; sight distance restrictions; intersections and driveways; congestion; adverse vehicle mix; pedestrian activity; and high accident rate. Speed zones established for these reasons are usually posted with regulatory speed limit signs. Speed zones may apply to specific areas, such as areas within city limits, without the need for speed limit signs.

The *Uniform Vehicle Code* (*3*) serves as a model for state traffic laws, but speed limit laws vary from state to state. Both absolute maximum and prima facie maximum speed limits are used in the United States. In addition to the national maximum speed limit, which has been adopted by every state, maximum speed limits have been adopted by individual state and local agencies for school zones, for specific vehicle classes (such as trucks), for specific times of day or lighting conditions (such as nighttime conditions), and for specific classes of highways (such as multilane, divided highways).

Advisory speed limits are posted for special situations such as sharp curves, grades, and intersections. Although advisory speed limits have been used in work zones, highway agencies are using regulatory speed limits more frequently in work zones, as described later in this section.

Virtually every traffic engineering reference work that addresses the principles of speed zoning or the installation of traffic control devices specifies the 85th percentile speed as the primary indicator of prevailing speeds to consider in establishing speed zones. Few of the standard traffic engineering references, including the *Transportation and Traffic Engineering Handbook* (*4*) and the *MUTCD* (*1*), however, offer any formal rationale for the use of the 85th percentile speed rather than some other measure of prevailing speed. Rowan and Keese (*5*) assert that the 85th percentile speed closely approximates a break point in most speed distribution curves above which speed ranges are associated with rapidly decreasing percentages of vehicles. Studies by Solomon (*6*) and Cirillo (*7*) indicate that accident involvement rates are lowest for vehicles traveling at approximately 8 to 10 mph above the average speed of traffic. This corresponds roughly to the 85th percentile speed of traffic.

Speed zoning criteria include other speed parameters and environmental factors; often, however, objective methods for assessing such criteria do not exist or are not used widely. For example, the pace—the 10-mph range containing the largest proportion of vehicles—is included in many speed zoning criteria, including the *MUTCD*, but an objective method for considering the pace speed range is seldom provided. One instance of an objective method for considering the pace, together with the 85th percentile speed, to establish maximum speed limits is provided by an Institute of Transportation Engineers (ITE) "Informational Report on Speed Zoning" (*8*) published in 1961.

The *MUTCD* incorporates other factors to be considered in establishing regulatory maximum speed limits, including road surface characteristics, shoulder condition, grade, alignment, sight distance, roadside development and culture, roadside friction, safe speeds for curves and other hazardous locations, parking practices, pedestrian activity, and reported accident experience; however, no guidelines for considering these factors are provided. Traffic engineers disagree on the extent to which such factors should be included. Some engineers stress the importance these factors have to safety, while others point out that these factors are reflected in prevailing speeds, whatever speed limits are applied. Perhaps all could agree on guidelines that stress the importance of considering these factors when their presence is not apparent to the driver.

Studies of isolated changes in speed limits have often found limits ineffective in reducing vehicle speeds (*9*, *10*, *11*, *12*, *13*). Some speed limit reductions have actually been counterproductive, resulting in increases in speeds (*14*). Other studies have confirmed that drivers respond to changing roadway conditions more than to posted speed limits (*15*, *16*). Such findings (1) reinforce the principle that speed limits should be strongly influenced by prevailing speeds and (2) point to the need to keep speed limits reasonable, because arbitrarily low speed limits may produce noncompliance and disrespect for speed limits and for traffic control devices in general. Even though many drivers supported the 55-mph speed limit, research shows they continued to violate it (*17*).

While isolated changes in speed limits may not always be effective, research results indicate that the more dramatic changes in speed control can reduce speeds. For example, some European experience showed a substantial speed reduction when speed limits were imposed for the first time (*18*, *19*). Research in another European country, however, found the introduction of a speed limit had no significant effect on traffic speeds or accidents (*20*). The researchers' experience with the national maximum 55-mph speed limit in the United States shows that, while it may not produce compliance, the imposition of the speed limit has reduced travel speeds.

A 1985 study by Parker (*21*) documented the results of an AASHTO survey on speed zoning practices. The engineering factors most frequently considered by U. S. and foreign highway agencies in setting maximum speed limits included 85th percentile speed, 10-mph pace, accident experience, and the type and amount of roadside development.

Recent FHWA research on speed zoning has confirmed many of the basic principles of speed zoning discussed previously (*22*). An analysis of travel speed and speed limit compliance concluded the following:

- Mean traffic speeds exceeded the posted speed limit by 1 to 8 mph.
- 85th percentile speeds ranged from 6 to 14 mph over the posted speed limit or 4 to 7 mph over the mean speed.
- Passenger cars travel 1 to 5 mph faster than trucks for all levels of speed limits.
- Most free-flow drivers (70.2 percent) did not comply with posted speed limits.
- Overall, 40.8 percent of drivers exceeded the posted speed limit by more than 5 mph, 16.8 percent exceeded the speed limit by more than

10 mph, and 5.4 percent exceeded the speed limit by more than 15 mph.
- In general, 85 percent compliance was achieved at speeds of 10 mph over the posted speed limit.
- Noncompliance was higher for passenger cars than for trucks at all speed limit levels.
- Excessive speeding (more than 10 mph over the posted speed limit) is more prevalent at night than during the day.

Research showed that the least amount of compliance with speed limits is on low-speed roads. On many roads, the posted speed limit has been set 8 or 12 mph below the 85th percentile speed, typically at a speed level that corresponds to about the 30th percentile speed of traffic (*23*).

Relationship of Speed and Speed Variance to Traffic Accidents

Solomon's (*6*), reported in 1964, is the most familiar study of the relationship between traffic accident involvement rate and deviation from average speed on two- and four-lane rural highways. Accident involvement rates were highest for vehicles at very low speeds, lowest at the average speed, and greater at the very high speeds. Cirillo (*7*) established a similar relationship for freeways. Recent FHWA research by Tignor and Warren (*23*) studied single-vehicle and multiple-vehicle accidents and found a similar pattern to that found by Solomon and Cirillo, with lowest accident involvement rates relatively close to the median speed of traffic. Another recent FHWA study by Harkey et al. (*22*) found a similar relationship that showed the speed at which accident risk was minimized occurred at the 90th percentile of the travel speeds observed, which was about 7 mph above the mean speed. Joscelyn et al. (*24*) found similar results to the other studies for higher speeds but did not find higher accident rates for lower speeds.

The relationships found by Solomon (*6*), Cirillo (*7*), Tignor and Warren (*23*), and Harkey et al. (*22*) show that accident rates increase with deviation from the average speed of traffic. This relationship between accident rate and deviation from mean speed implies that the speed variance is an important parameter because the percentage of vehicles traveling at speeds substantially greater than or less than the average speed increases with the speed variance.

The previously cited research on the relationship of speed variance and accident involvement rate shows that drivers who choose to travel faster than the average speed incur additional risk of an accident and increased accident severity for each increment of increased speed. Research by Jondrow, Bowes, and Levy (*25*) suggested that the speeds drivers choose represent their personal evaluation of the risk of a fatal accident and the relative values of travel time, fuel consumption, and loss of life. However, the risk that a driver incurs by choosing a particular travel speed includes a risk to other road users as well as the driver's personal or private risk. When the risk of others is considered, a social optimum speed, lower than the private optimum, can be determined. The social optimum speed could be thought of as a speed limit that would best represent the interests of all road users.

In a recent study, Garber and Gadirau (*26*) performed regression analysis of the relationship of accident rate to average speed and speed variance. They determined that speed variance will be minimum if the posted speed limit is between 6 and 12 mph lower than the design speed of the highway. Outside this 6- to 12-mph range, speed variance increases with increasing difference between the design speed and the posted speed limit. Garber and Gadirau (*26*) recommended that, in order to reduce speed-related accidents, speed limits should be posted 5 to 10 mph below the design speed for highways with design speeds of 50, 60, and 70 mph.

Using data from various countries and making several simplifying assumptions, Feldwick (*18*) found that the accident rate was related to rural speed limits. Roads with 45-mph speed limits had the lowest accident rates and roads with 80-mph speed limits had the highest accident rates.

The maximum speed limit in the United States was lowered to 55 mph in 1974 as a fuel-saving measure. The speed limits on most roads affected by the change were previously posted at 65 and 70 mph. Average speeds were reduced about 5 percent but varied according to road type and relative level of the speed limit (*19*, *27*). Speed data collected in 1979 showed that compliance with the 55-mph speed limit was poor (*27*). From 30 to 60 percent of motorists were exceeding the 55-mph speed limit on a statewide basis and up to 80 percent were violating the speed limit on rural freeways.

Beginning in 1987, state highway agencies were allowed to increase the posted speed limit from 55 to 65 mph on rural freeways. A recent AASHTO survey showed little difference in average speeds between states that raised the speed limit on rural freeways and those that did not (*28*).

Studies of the introduction of the 55-mph speed limit have produced mixed results. Some studies have reported that the fatality rate decreased, but the injury rate did not (*20*, *27*). Other studies have shown that highways most affected by the lower speed limit had the greatest reduction in fatality rates (*29*, *30*, *31*, *32*, *33*, *34*). However, 8 of the 17 states examined by Heckard et al. (*29*) had increases or no significant change in fatality rates in 1974 in comparison to past trends.

Advisory Speed Limits

Advisory speed limits are often used to aid drivers in selecting safe speeds for potentially hazardous locations such as curves, road work sites, intersections, and road sections with lower design speeds.

Lyles (*35*) found that 35-mph advisory and regulatory speed signs had little effect on speed compared to the standard curve sign. Drivers reached their minimum speed at approximately the same point in the curve regardless of the signing used.

Ritchie (*36*) found that drivers exceeded advisory speed limits of 15 to 35 mph but did not exceed 45- and 50-mph advisory speed limits.

Bezkorovainy (*37*) found that drivers were not influenced by raising or lowering advisory speed limits but were influenced by the sharpness of the curve.

Graham et al. (*38*) in a 1977 FHWA study found that 40- and 45-mph advisory and regulatory speed limits in freeway work zones had no significant effect on speed but did increase traffic conflicts. Work zones with advisory and regulatory speed limit signing had higher accident increases during construction compared to those without speed reductions.

Hanscom (*39*) observed average speed reductions of about 7 mph at locations where a changeable-message "SLOW TO 45 MPH" speed advisory was used at freeway lane closures; however, average speeds never dropped below the 45-mph advisory speed.

Webb (*40*) observed speed reductions of 2 to 6 mph where a changeable-message sign displaying a 50-mph advisory speed limit was used. Traffic speed averaged 66 to 70 mph without the advisory speed limit.

Drivers who use a highway repeatedly quickly learn the speed that curvature and road conditions will allow and advisory speeds can be expected to have little effect on them.

School Zone Speed Limits

Speed limits are frequently established for school zones in response to the public perception that lower speed limits are a major factor in school zone safety. Although the public considers reduced speed limits "safe," previous studies have found poor driver compliance with school zone speed limits (*41*, *42*, *43*, *44*, *45*) and no relationship between pedestrian accidents and school zone speed limits (*41*, *45*, *46*). A recent Nebraska study by McCoy (*47*) found higher speeds in school zones with 15- and 20-mph speed limits than in school zones with 25-mph speed limits.

The use of flashing beacons to supplement school zone speed limits has had mixed results. Several studies reported that flashing beacons in conjunction with a speed limit sign reduced the speed of traffic by less than 4 mph, although speed reductions up to 10 mph have been reported at some sites (*43*, *44*, *45*, *48*). Other studies, however, reported that vehicle speeds in school zones increased when the flashers were operating (*49*, *50*, *51*).

In summary, the available data show that school zone speed limits are ineffective in reducing vehicle speeds by more than 5 mph. Extremely low speed limits (15 and 20 mph) can be counterproductive and increase vehicle speeds above the levels found for higher school zone speed limits. In general, drivers do not feel constrained to obey speed limits that they consider unreasonable. Flashing beacons may be effective as a supplement to school zone speed limits, but the results are inconclusive.

Work Zone Speed Limits

For many years, most speed limits used in work zones were advisory speed limits. In recent years, however, many agencies have begun to use regulatory speed limits in work zones. Highway agency practices for work zone speed limits vary widely. These practices are reviewed in the following sections and in Appendix B, which is not published herein. The following discussion focuses on the results of research concerning work zone speed limits and their effects on vehicle speeds and on traffic accidents.

Effects on Vehicle Speeds

Most highway agencies that use regulatory speed limits in work zones believe that such limits will reduce vehicle speeds and prevent accidents. Published research reports and unpublished data indicate that regulatory speed limits are not very effective in reducing vehicle speeds in work zones (*38*, *52*, *53*).

A Minnesota work zone study by Jackels and Brannon (*54*) found that a regulatory 40-mph speed limit sign, on a normally 65-mph speed limit rural freeway, reduced the 85th percentile speed from 71 to 58 mph.

A recent study in Illinois by Benekohal (*55*) determined the speeds of free-flowing vehicles at several different locations in a rural freeway work zone. This work zone, on a freeway with a 65-mph speed limit for passenger cars and a 55-mph speed limit for heavy trucks, had 45-mph advisory speed limit signs in the advance warning area of the work zone and 45-mph regulatory speed limit signs in the work area. Passenger cars reduced their speed from 62.6 mph at the beginning of the taper to 49.3 mph at a work area where workers were present at a bridge repair site (4,400 ft downstream). Trucks reduced their speeds from 57.0 to 45.5 mph between the same locations. The standard deviation of speed for passenger cars was highest at the actual work area (9.28 mph), while trucks had their lowest standard deviation of speed at the work area (5.13 mph). These results showed that drivers do reduce speeds in work zones, especially when workers are present.

While the Benekohal study discussed previously did show a substantial reduction in vehicle speeds at one work zone site, this reduction in speed may have been partially because of the presence of workers as well as the posting of a regulatory speed limit. Most other studies of work zone speed limits have shown smaller effects (or no effect) of work zone speed limits on vehicle speeds. Research in Texas (*56*, *57*) resulted in recommendations of speed limit reductions in work zones ranging from 5 to 20 mph, depending on the type of highway. In an FHWA report, Parker (*21*) suggested that work zone speed limits should be no less than 25 mph and that the maximum speed limit reduction should be 15 mph below the normal speed of traffic.

Researchers that found reductions in work zone speed limits to be ineffective in reducing speeds, generally evaluated the effectiveness of other methods of reducing speeds.

A 1977 FHWA study by Graham et al. (*38*) found that the presence of a police vehicle using radar reduced mean traffic speeds by 2.5 to 4.9 mph, depending on the location within the work zone.

A 1985 Texas study by Richards et al. (*56*) found that flagging (19 percent speed reduction), law enforcement (18 percent speed reduction), changeable-message signs (7 percent speed reduction), and lane width reduction (7 percent speed reduction) were the most effective speed reduction methods for use in work zones.

The Minnesota study (*54*) discussed previously found that the presence of a police vehicle in the work zone reduced the 85th percentile speed by 13 mph (from 58 to 45 mph) and that a radar-activated information sign reduced the 85th percentile speed by 5 mph (from 58 to 53 mph). When the police vehicle left the work zone to pursue a speeder, the 85th percentile speed increased 22 mph (from 45 to 67 mph).

A study in Missouri (*58*) that evaluated radar-controlled speed matrix signs concluded that such signs did produce modest speed reductions, but the presence of law enforcement officers in the work zone was more effective than any type of sign currently available.

A 1989 FHWA study reported several applications of rumble strips in work zones (*59*). A Texas evaluation found rumble strips ineffective in reducing vehicle speeds (*60*). Pigman and Agent (*61*) found that rumble strips reduced vehicle speeds. A rumble strip vendor found that its rumble strips reduced speeds by 8 mph compared to standard warning signs and by 4.5 mph compared to standard construction warning signs in conjunction with a 35-mph regulatory speed limit (*62*). A 1987 Ohio study found that rumble strips reduced speeds 7 mph on the approach to a median crossover (*63*).

Speed reductions of 0 to 3 mph were produced by flaggers directing traffic to proceed through the work zone on a rural Texas two-lane, two-way highway where the flaggers were used to alternate one-way traffic through the work zone (*64*).

Effects on Safety

Only limited evaluations have been conducted of the effects of work zone speed limits on safety. The 1977 FHWA study of 79 construction zones by Graham et al. (*38*) found that urban projects showed a 14 percent increase in accident rate without speed limit reductions and a 60 percent increase in accident rate with speed limit reductions. Rural projects showed a 2.6 percent increase in accident rate without speed limit reductions and a 16.4 percent increase in accident rate with speed limit reductions.

One method of speed control discussed previously is the use of narrower lanes in work zones. An evaluation of a project where 9-ft lanes were used found that the total accident rate increased from 1.68 accidents per million vehicle-miles to 2.63 accidents per million vehicle-miles (*65*). Injury-accident rates increased as well. When 10- and 11-ft lanes were used, the total accident rate was closer to the preconstruction level and the injury-accident rate was below the preconstruction level.

Rouphail et al. (*66*) studied correlations between traffic control device layouts and speed variance at approach, transition, and lane closure areas. The greatest speed reductions were observed at the transition area (lane closure taper) because of congestion created by lane-changing maneuvers. At single-lane closures, speed reductions between the approach and transition areas were 5.45 and 7.19 mph below low- and high-volume conditions, respectively. Where two lanes were closed, speed reductions between the approach and lane closure areas were 9.64 and 14.58 mph, respectively. Under light volume conditions, speed recovery between the transition and lane closure areas was negligible. Under high-volume conditions, mean speeds increased by 1.5 mph for single-lane closures and by 10.8 mph for two-lane closures.

A speed analysis by Rouphail et al. (*66*) found that large speed variations were influenced by inconsistencies in traffic control devices. Sites with short taper lengths, missing arrow panels, and missing signs or that were of short duration had higher speed variations than other sites. This finding supports the importance of adhering to standards.

Highway Agency Work Zone Speed Limit Policies and Guidelines

The work zone speed limit policies and guidelines of each state highway agency were investigated to determine what methods are currently being used to establish work zone speed limits. This information was obtained from recent surveys conducted by the Florida Department of Transportation (DOT) and the Mississippi State Highway Department. A questionnaire was mailed to each of the 50 state highway agencies and to the District of Columbia and Puerto Rico; agencies were asked to confirm their work zone speed limit policies, as presented in the reports of the Florida and Mississippi surveys. Of the 52 highway agencies contacted, 45 responded.

The survey results indicated that three general policies are used by state highway agencies for establishing work zone speed limits: (1) policies based on avoiding the need for speed limit reductions whenever possible; (2) policies based on blanket speed limit reductions at all work zone sites; and (3) policies under which the need for a work zone speed limit reduction is established on the basis of specific factors.

Table 1 identifies which states use which policy categories. Eighteen states avoid reducing the work zone speed limit whenever possible. Five states have blanket work zone speed limit reduction; that is, they reduce the work zone speed limit in all or nearly all cases. (One of these five states uses a blanket speed limit reduction only in maintenance work zones; speed limits in construction zones are determined case by case.) Twenty-nine states followed an established procedure or an established set of factors in deciding whether to use a reduced work zone speed limit. The geographic distribution of the policies throughout the United States is illustrated in Figure 1.

The following sections discuss each of the work zone speed limit policy categories.

TABLE 1 Types of work zone speed limit policies

States that avoid reducing work zone speed limits whenever possible	States with "blanket" reduced work zone speed limits	States that reduce work zone speed limits based on an identified procedure or set of factors	
Alabama	Georgia	Arizona	Oklahoma
Alaska	Louisiana	Colorado	Pennsylvania
Arkansas	Michigan	Delaware	Rhode Island
California	Montana	Hawaii	South Carolina
Connecticut	Vermont	Idaho	Tennessee
District of Columbia		Illinois	Utah
Florida		Indiana	Texas
Iowa		Kansas	Washington
Maine		Kentucky	West Virginia
Maryland		Minnesota	Wisconsin
Massachusetts		Missouri	Wyoming
Mississippi		Nebraska	
Nevada		New Hampshire	
North Carolina		New Jersey	
Oregon		New Mexico	
Puerto Rico		New York	
South Dakota		North Dakota	
Virginia		Ohio	

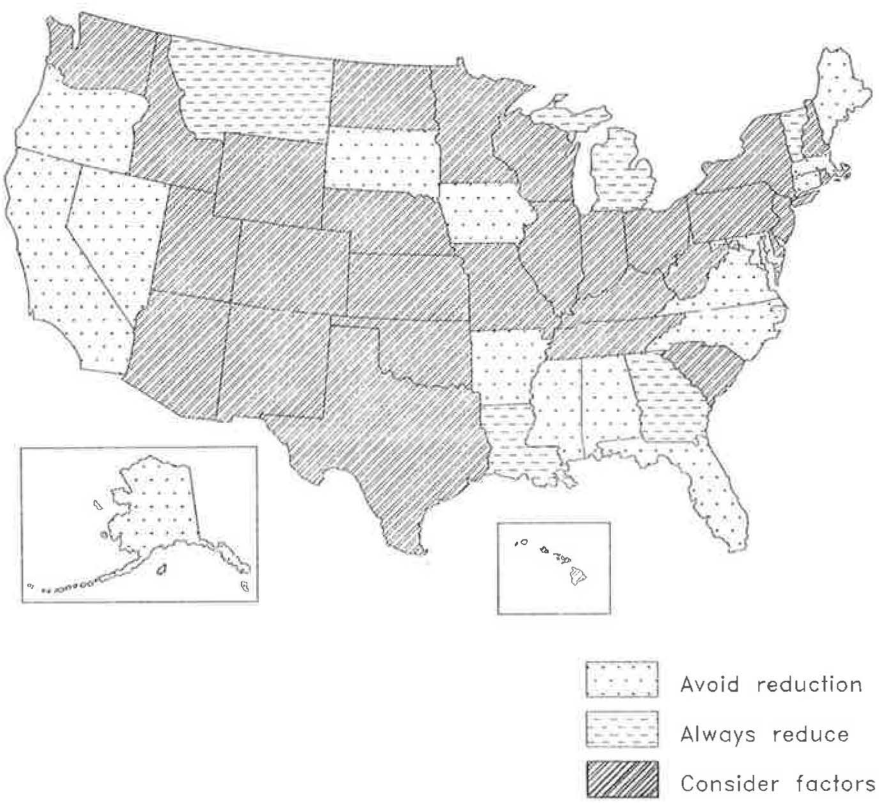


Figure 1. Work zone speed limit reduction policies.

Policies Based on Avoiding the Need for Speed Limit Reductions

Eighteen states have policies intended to avoid work zone speed limit reductions whenever possible. These states identified in Table 1 and in Figure 1, try to plan the work zone traffic control strategy and the geometric design of the work zone to operate safely at the existing posted speed limit. In situations where this is not possible, many of these agencies use a set of factors to determine if there is a need for a speed limit reduction. Of the 18 states, 13 listed specific factors that they consider in assessing the need for a speed limit reduction.

Of the 18 states, 15 use regulatory speed limit signing where they find it necessary to reduce the speed limit. The other three states (Connecticut, Massachusetts, and Mississippi) use advisory speed limits as the primary speed-reduction technique.

Both the California Department of Transportation (Caltrans) and the Florida DOT—in order to avoid reducing work zone speed limits whenever possible—require an engineering study if a regulatory work zone speed limit is to be implemented.

Caltrans uses reduced speed limits only in areas where the traveling public is affected by construction operations. Speed limit signs are moved as construction progresses. Caltrans believes that putting speed limits in areas where no construction is taking place encourages disrespect for the speed zone and reduces the effectiveness of the speed limit at locations where it is really needed.

The Caltrans policy for establishing work zone speed limits is based on its policy for establishing speed zones of all types. Thus, Caltrans establishes speed limits at or near the 85th percentile speed. The policy states that speed limits higher than the 85th percentile do not facilitate the orderly movement of traffic. Only when roadside development results in traffic conflicts or when unusual conditions are present and not readily apparent to drivers are speed limits below the 85th percentile warranted. Physical conditions—such as width, curvature, grade, and surface conditions or any other conditions readily apparent to the driver—in absence of other factors, would not require special speed zoning.

In contrast, the Florida DOT does not use the 85th percentile speed for work zone speed limits. Its policy states that changes to the existing speed limit should be made on actual or anticipated geometric, traffic volume, or work zone conditions but not on prevailing speeds.

The Florida DOT uses both regulatory and advisory speed limits and its policy is that the speed limit should not be reduced more than 20 mph below the normal posted speed limit. Advisory speed limits are enforceable in Florida as "careless driving." The Florida DOT requires that permanent speed limit signs are to be removed or covered when a regulatory work zone speed limit is in effect. The work zone speed limit signs must be removed as soon as the conditions requiring the reduced speed no longer exist. Once the regulatory work zone speed limit signs are removed, the preconstruction speed limit prior to construction automatically goes back into effect, unless the district traffic operations engineer issues a regulation to change the speed zone.

The objective of the Florida DOT is to move traffic through work zones in a manner comparable to normal highway conditions. The Florida DOT work zone speed limit procedure was used as the basis for the procedure developed in this research. The Florida DOT has developed guidelines for establishing work zone speed limits under the following seven conditions:

1. Activities that are more than 15 ft from the edge of pavement,
2. Activities that encroach on the area closer than 15 ft but not closer than 2 ft to the edge of pavement,
3. Activities that encroach on the area from the edge of the pavement to 2 ft from the edge of pavement,
4. Activities that encroach on the area between the centerline and the edge of pavement (lane closures),
5. Activities that require an intermittent or moving operation on the shoulder,
6. Activities that require construction of a temporary detour, and
7. Activities that encroach on the area beyond either the centerline of a roadway or a lane line of a multilane highway.

For each work zone condition, the Florida DOT guidelines present typical applications, duration of work, reduction of regulatory speeds, and the suggested amount of reduction.

The Iowa DOT is an example of a state highway agency that tries to avoid reducing work zone speed limits wherever possible. The Iowa DOT tries to avoid work zone speed limit reductions on rural freeways, with the exception of work zones where traffic in one direction is detoured onto another roadway, resulting in two-lane, two-way traffic operations. For freeway work zones with two-lane, two-way traffic operations, the work zone speed limit is reduced from 65 to 55 mph.

Policies Based on Blanket Speed Limit Reductions

Five states have blanket work zone speed reduction policies, that is, the speed limit is always or nearly always reduced in work zones. These states are identified in Table 1 and Figure 1.

Michigan uses a 45-mph regulatory speed limit in work zones. Georgia, Louisiana, and Vermont use 40-mph speed limits. Montana uses a 35-mph speed limit.

The 45-mph work zone speed limit in Michigan applies primarily to work zones with lane closures. A speed limit reduction is not mandated where work is on or outside of the shoulder or in work zones without lane closures—even those with narrow lanes or curvilinear paths. A statute to be introduced in the Michigan legislature will allow speed limits other than 45 mph, thus providing more flexibility to the agency in setting work zone speed limits.

Louisiana normally uses a 40-mph regulatory speed limit in work zones; however, Louisiana reduces the speed limit to 20 mph where traffic is close to workers. No exceptions to the policy were noted.

The Vermont blanket speed limit reduction to 40 mph applies to work zones on freeways and other limited access facilities. No speed reduction is recommended on other highway types.

Georgia uses a regulatory work zone speed limit of 40 mph. This blanket 40-mph speed limit generally is applicable only to maintenance work zones that involve work in the traveled way. Typically such projects only use the reduced speed limit during the day when work activities are in progress. The blanket 40-mph speed limit does not apply to speed limits in construction zones. Speed limits in construction zones are established on a case-by-case basis.

Montana typically posts its reduced 35-mph speed limit throughout the length of the project—not just in the work area. This policy is in contrast to those of California and Florida, which discourage reduced speed limits in inappropriate portions of the work zone. Montana believes that signing the entire project with a reduced speed limit reduces its potential liability for work zone accidents.

Policies with Speed Limit Reductions Based on Specific Factors

Twenty-nine states reduce speed limits in some work zones but not in others, on the basis of specific sets of factors. These states are identified in Table 1 and Figure 1. Eighteen of the states use regulatory speed limits when the work zone speed limit is reduced. Ten states use both regulatory and advisory work zone speed limits. Most of these 10 states have advisory speed limits that are enforceable. Pennsylvania is an exception where advisory speed limits are used in some cases although only regulatory speed limits are enforceable. West Virginia is the only state where work zone speed limits cannot be reduced with regulatory signs. All work zone speed limits in West Virginia are implemented with advisory signs.

Eight state agencies stated that they typically used 10-mph speed limit reductions in work zones. Four agencies stated that they typically used work zone speed limit reductions of 10 to 20 mph.

As in California and Florida, Texas policy states that regulatory speed limits in work zones should be posted only within the section of roadway where speed reduction is necessary for the safe operation of traffic and protection of construction personnel.

Two states require the speed limit to be documented in the project file or traffic control plan. Wyoming has a set of typical traffic control plans with reduced regulatory speed limit signs on them.

Illinois, Missouri, and Tennessee use reduced speed limit signs with flashers and a supplementary sign that indicates that the reduced speed limit is applicable "WHEN WORKERS ARE PRESENT." For example, Missouri uses flashing lights on their regulatory speed limit signs in work zones on divided highways to indicate that the speed limit is reduced to 45 mph. When workers are not present, the speed limit on such highways is typically 55 mph. One potential problem with this approach is that the flashing lights are occasionally left on by mistake at times when no work is being done and no workers are present in the work zone. At one location, the research team observed the flashing lights on speed limit signs in operation at night when no work was underway.

Some states require an engineering and traffic investigation to justify a speed limit reduction; others allow reductions without a formal study. Some states specify the work zone speed limit in the traffic control plan design phase, while others determine the speed limit at the job site. For example, the New York State DOT has two methods for establishing regulatory work zone speed limits for construction projects. One method used is to file an official department order with the secretary of state; this is a cumbersome procedure because work zone speed limits may change often. The other method is for the engineer-in-charge at the work site to set the speed limit under the restricted highway provision of state law; this does not require a separately filed order. There is no written policy for determining work zone speed limits under this procedure.

Table 2 summarizes the factors used by state highway agencies in establishing work zone speed limits. A total of 41 different factors were identified by 37 agencies. The frequency with which each factor was mentioned is an indication of its perceived importance by highway agencies. Lane width, alignment, and type of work zone were mentioned most often. Some responses mentioned lane widths of 10 or 11 ft as being critical in establishing work zone speed limits.

The consideration of alignment in determining work zone speed limits generally refers to the presence of horizontal and vertical curvature built or designed to standards less than that of the adjacent roadway. Some agencies have established a direct link between the design speed of the alignment and the posted work zone speed limit.

Type of work zone refers to the type of traffic control procedure or the location of the work activity. Work in the traveled way generally is considered more critical than work on the shoulder, and work on the shoulder is considered more critical than work outside of the shoulder.

Other common factors considered by highway agencies in setting work zone speed limits include sight distance, prevailing speeds, presence of workers, accident experience, presence of barriers, and roadway type.

Methods for Increasing Speed Limit Compliance

State highway agencies have used several methods to increase compliance with work zone speed limits. Although these methods were not a major focus of the research reported here, they may be essential for effective speed control at sites where reduced speed limits—reflecting engineering factors rather than prevailing speed—are employed. Table 3 lists work zone speed control methods. Flagging, law enforcement, changeable-message sign, and lane width reduction were found effective by the Texas Transportation Institute (TTI).

Accident and Traffic Operational Field Data Collection

The effectiveness of work zone speed limits was evaluated in this study through collection of traffic accident data and traffic operational field data at 68 work zones. These work zones were located in seven states that use various practices for determining work zone speed limits. Three of the states avoid reducing work zones speed limits whenever possible (i.e., California, Florida, and Iowa); two states use blanket speed limit reductions (i.e., Georgia for maintenance work zones and Montana for all work zones that involve work in the traveled way); and two states consider engineering factors in determining the need for speed limit reduction in work zones (i.e., Missouri and New York).

The sites were distributed among states as follows:

California	11 sites
Florida	7 sites
Georgia	9 sites
Iowa	14 sites
Missouri	4 sites
Montana	11 sites
New York	12 sites
	68 sites

The following roadway types, arranged in decreasing priority, were selected for the study:

TABLE 2 Factors used for establishing work zone speed limits

Factor	Frequency
Lane width	16
Alignment	14
Type of work zone	12
Sight distance	10
Prevailing speeds	9
Workers present	8
Accident experience	7
Presence of barrier	7
Roadway type	7
Driver expectancy/unexpected conditions	5
Traffic volume	5
Presence of pavement edge dropoff	4
Congestion	3
Construction equipment movements	3
Design speed	3
Engineering judgment	3
Road surface conditions	3
Duration of work	2
Existing speed limit	2
Lack of shoulder	2
Pedestrian activity	2
Presence of equipment	2
Approach speed	1
Distance from traffic to workers	1
Distance to barrier	1
Distance to work area	1
Erratic maneuvers	1
Lack of compliance with flagger	1
Length classification of roadway	1
Night classification of roadway	1
Night construction	1
Number of lanes	1
Other safety-related factors	1
Physical conditions	1
Preconstruction speed limit	1
Presence of flagger	1
Roadside development/driveway access	1
Roadside conditions	1
Temporary signalization	1
Undesirable working conditions	1
Vehicle mix (trucks)	1
Previous experience with similar work zones	1

TABLE 3 Speed control methods employed in work zones

Speed control methods
Flagging
Law enforcement
Changeable-message sign
Lane width reduction
Regulatory and advisory signing
Dynamic speed limit signing
Traffic-activated signing
Truck-mounted sign
Work zone deaths sign
Radar
Mock-up of a police car
Unused police car
Increased fines for infractions
Flashing lights on signs
High-visibility clothing
Iowa weave section
Rumble strips
Speed bumps and humps
Pacing
Pilot vehicle
Transverse striping
Colored or textured pavement
Traffic queue (congestion)
Highway advisory radio
Traffic signals

- Rural freeway or expressway,
- Urban freeway or expressway,
- Rural multilane or rural two-lane highway,
- Rural two-lane highway detour—free flow maintained, and
- Urban arterial.

These sites included work zones with speed limit reductions ranging from 0 to 30 mph.

Appendix C, which is not published herein, identifies the work zone sites studied; their speed limits; the type of area (e.g., urban or rural); the type of highway; and the location of the work relative to the traveled way. Table 4 summarizes the number of work zones studied for each combination of area type, highway type, and location of work.

Data collection and analysis activities in the study included the following:

- Traffic accident data were obtained and analyzed for 66 of the 68 work zones. The traffic accident studies included comparisons of accident rates before and during construction or maintenance at each work zone site.
- Traffic speed studies were performed in the field at 27 of the 68 study sites. Thirty-four speed studies were performed at these sites. The speed studies included 27 daytime off-peak, 3 daytime peak, and 4 nighttime studies, as well as special studies of changeable-message signs and radar effects. For all but four studies, vehicle speeds were determined by videotaping vehicles traversing a trap of known length (50 ft). Speeds at the remaining sites, where videotaping was not feasible, were measured with traffic radar. Each speed study involved the collection of speed data both upstream of and within each work zone.
- Traffic conflict and erratic maneuver counts were made during the speed study period at 14 work sites.

Figure 2 illustrates the typical locations for field data collection activities upstream of and within work zones. Speed data were collected at these locations by videotaping vehicles traversing a known distance. Speed studies were performed for both peak and off-peak conditions; in addition, speed studies were performed at night for selected sites. The following sections summarize the results of the analyses of these data.

Speed Data Analysis

This section summarizes the findings of the analysis of vehicle speeds performed with the field data. The analysis addressed the effect of work zones and work zone speed limits on mean speeds, speed limit compliance, 85th percentile speeds, and speed variance.

Analysis of Mean Speeds. An analysis was conducted to determine how effective work zone speed limits are in reducing the mean speed of traffic. Table 5 summarizes the results of the analysis of mean speeds upstream of and within highway work zones as a function of the magnitude of the speed limit reduction. This table reflects analysis of the daytime off-peak speed studies for 22 sites, which are referred to as the basic study sites.

The table shows that motorists do slow down in work zones, even at locations where there is no speed limit reduction. The mean speed of traffic in the work zone was less than the mean speed of traffic upstream of the work zone by a statistically significant amount for 19 of the 22 basic study sites. At sites where the speed limit was not reduced, the mean speed in the work zone for all vehicles was 5.1 mph less than the mean speed upstream of the work zone.

In work zones where the speed limit is reduced, the reduction in the mean speed of traffic in the work zone (relative to the mean speed of traffic upstream of the work zone) generally increases as the amount of the speed limit reduction increases. The size of the reduction in mean speed increased from 7.2 mph for a 10-mph speed limit reduction to 20.7 mph for a 30-mph speed limit reduction. However, the observed reductions in mean speed in the work zone were consistently less than the magnitude of the speed limit reduction. The mean speeds of motorists in work zones were reduced by 51 to 72 percent of the magnitude of the speed limit reduction and there is no evident relationship of this percentage to the magnitude of the speed limit reduction.

TABLE 4 Work zones studied by area type, highway type, and location of work

Location of Work	Rural				Urban				COMBINED
	Freeway	Multilane	Two-Lane	TOTAL	Freeway	Multilane	Two-Lane	TOTAL	
Traveled Way	20	0	9	29	7	1	0	8	37
Detour	10	0	0	10	1	1	0	2	12
Shoulder	2	0	3	5	5	0	1	6	11
Roadside	0	0	2	2	6	0	0	6	8
TOTAL	32	0	14	46	19	2	1	22	68

TABLE 5 Summary of reductions in mean speed between upstream and work zone locations

Speed Limit Reduction (mph)	Number of Sites	Reduction in mean speed (mph) between upstream and work zone location		
		All vehicles	Cars	Trucks
0	5	5.1	4.8	5.5
10	4	7.2	7.7	5.5
15	3	7.8	8.2	4.5
20	7	13.6	13.9	12.4
25	2	12.7	12.7	12.6
30	1	20.7	24.6	17.8

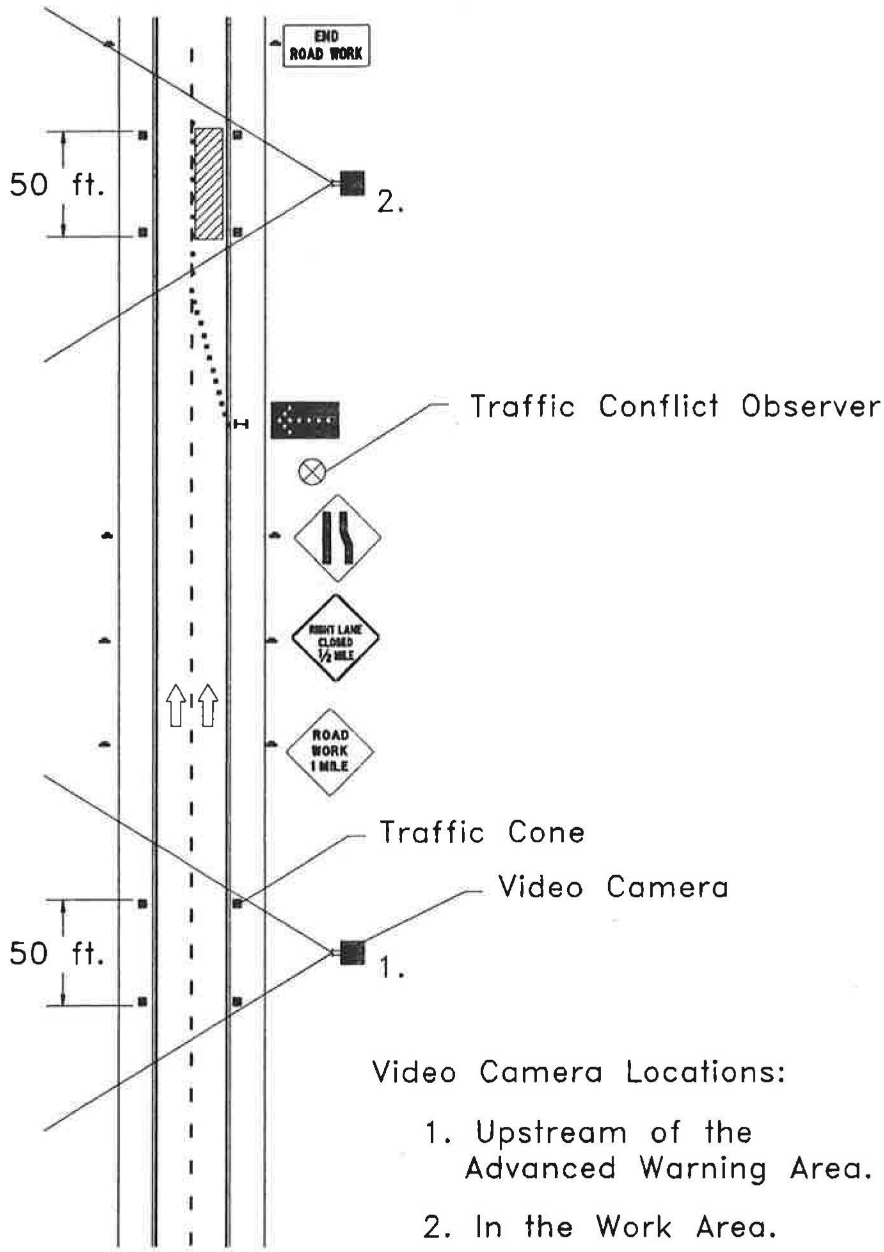


Figure 2. Data collection locations.

Work zones with a 10-mph speed limit reduction produced only slightly larger reductions in mean speed than the work zones with no reduction in speed limit (7.2 mph versus 5.1 mph). However, as will be shown later, work zones with a 10-mph speed limit reduction generally had smaller increases in speed variance than work zones with no speed limit reduction.

Work zones with a 15-mph speed limit reduction resulted in reduction in mean speed that was only marginally greater than for a 10-mph speed limit reduction (7.8 mph versus 7.2 mph).

Work zones with 20- and 25-mph speed limit reductions resulted in about the same reduction in mean speed (13.6 and 12.7 mph, respectively) and, at the one site with a 30-mph speed limit reduction, one of the largest reductions in mean speed (20.7 mph) was obtained.

Work zone speed limits less than the upstream speed limit generally resulted in slightly greater reduction in the speeds of passenger cars than trucks, although the differences are not large (usually less than 1 mph). At sites with no speed limit reduction, however, trucks actually slowed more than did passenger cars (5.5 mph versus 4.8 mph).

Analysis of Speed Limit Compliance. An analysis was conducted to determine the effect of work zone speed limits on speed limit compliance. It would be desirable to establish work zone speed limits in a manner that encourages compliance with speed limits. Table 6 shows the effect of work zone speed limits on the percentage of vehicles exceeding the speed limit upstream of and within work zones. The table shows the decrease in the percentage of vehicles exceeding the speed limit in the work zone in relation to the percentage of vehicles exceeding the speed limit upstream of the work zone.

At work zones with no speed limit reduction, the percentage of vehicles exceeding the speed limit is generally lower in the work zone than upstream of the work zone. The percentage of motorists traveling within the speed limit increased, on the average, by 21.7 percent from the upstream location to the work zone location. This finding follows very logically from the data in Table 5, which show that motorists travel about 5 mph slower in a work zone than they do upstream, even when the speed limit is not reduced.

For work zone sites with a 10-mph reduction in speed limit, it was found that speed limit compliance was, on the average, unchanged from upstream of the work zone to within the work zone. However, a review of the individual sites found that speed limit compliance increased substantially at two sites and decreased substantially at two other sites. This is an example of the high site-to-site variability that was found in the speed data.

For work zones with speed limit reductions of 15 mph or more, speed limit compliance was generally lower in the work zone than in the upstream area; in other words, speed limit noncompliance increases at higher speed limit reductions. This follows logically from the data in Table 5 which show that, on the average, motorists do not reduce their speeds by as much as the reduction in posted speed limit.

The same pattern found for all vehicles in Table 6 was also found for passenger cars. However, for trucks, speed limit compliance increased in work zones with no speed limit reductions but decreased in all work zones where the speed limit was reduced by any amount.

In summary, the level of speed limit compliance in work zones increased, compared to upstream sites, if the work zone speed limit is unchanged. Where the work zone speed limit is reduced by 10 mph, the level of compliance is the same, on the average, upstream of the work zone and within the work zone. Where the work zone speed limit is reduced by 15 mph or more, the level of speed limit compliance in the work zone is less than that upstream of the work zone.

Analysis of 85th Percentile Speeds. An analysis was conducted to determine how effective work zone speed limits are in reducing the 85th percentile speed of traffic. Table 7 summarizes the results of the analysis of 85th percentile speeds upstream of and within highway work zones as a function of the amount of the speed limit reduction.

The patterns observed in the 85th percentile speed data are very similar to the patterns reported previously for the mean speed data; the effect of work zone speed limit reduction on 85th percentile speed is generally about 2 to 3 mph less than the corresponding effect on mean speed. No formal statistical analysis of the 85th percentile speeds was

TABLE 6 Summary of change in percent of vehicles exceeding the speed limit between upstream and work zone locations

Speed Limit Reduction (mph)	Number of Sites	Change in percent of vehciles exceeding the speed limit between upstream and work zone location		
		All vehicles	Cars	Trucks
0	5	21.7	20.7	22.6
10	4	0.0	5.3	-19.4
15	3	-28.0	-26.7	-37.4
20	7	-3.1	-11.5	-10.8
25	2	-16.5	-11.5	-32.0
30	1	-33.0	-7.0	-70.0

NOTE: Positive changes indicate greater speed limit compliance in the work zone than upstream of the work zone
Negative changes indicate lower speed limit compliance in the work zone than upstream of the work zone

TABLE 7 Summary of reductions in 85th percentile speed between upstream and work zone locations

Speed Limit Reduction (mph)	Number of Sites	Reduction in 85th percentile speed (mph) between upstream and work zone location		
		All vehicles	Cars	Trucks
0	5	4.5	3.7	4.9
10	4	5.5	6.5	6.4
15	3	7.0	7.8	1.7
20	7	11.8	9.2	10.8
25	2	10.0	9.0	11.8
30	1	18.0	21.0	21.0

TABLE 8 Summary of speed variance results

Speed Limit Reduction (mph)	Number of Sites	Percent increase in speed variance between upstream and work zone location		
		All vehicles	Cars	Trucks
0	5	61.2	81.8	11.8
10	4	34.1	46.8	14.4
15	3	86.7	79.6	159.3
20	7	82.6	93.5	182.9
25	2	92.6	206.3	32.5
30	1	80.6	70.8	94.6

conducted, because the observed trends are so similar to the observed trends for mean speeds.

Analysis of Speed Variances. The analysis of speed variance data was very important to the research objectives. The literature shows that the speed variance is generally higher in the work zone than upstream of the work zone. The literature also indicates that speed variance is a potentially useful surrogate measure for safety. In interpreting the speed variance data, it should be kept in mind that the standard deviation of speeds, which may be more familiar to some readers, is the square root of the variance. In other words, if the speed variance is 29.9 mph^2, then the standard deviation of speed is the square root of 29.9, or 5.5 mph.

Table 8 summarizes the percent increase in speed variance between the upstream and work zone locations for the sites studied for each level of work zone speed limit reduction. The work zone speed variance was found to be significantly higher than the upstream speed variance at approximately half of the study sites. In most of the remaining cases, the speed variance in the work zone is higher than the upstream speed variance, but the difference was not large enough to be statistically significant. In none of the few cases in which the observed work zone speed variance was lower than the upstream speed variance was this difference statistically significant.

Table 8 has obvious implications for setting work zone speed limits in such a way as to minimize the increase in speed variance in the work zone. This percentage increase in speed variance appears to go through a minimum at a speed limit reduction of 10 mph. To summarize, it appears that, for work zones with speed limits that are not reduced, the speed variance in the work zone (for all vehicle types) is 61 percent higher than the upstream speed variance. For work zones with a 10-mph speed limit reduction, the increase in speed variance in the work zone is only 34 percent. Finally, for work zones with speed limit reductions of 15 mph or more, the increase in the work zone speed variance over the upstream speed variance ranges from 81 to 93 percent.

However, an important caveat in interpreting Table 8 is that none of the differences between the percent increases in speed variance that are shown in the table are statistically significant. Although disappointing, this finding reflects the diversity of conditions inherent in work zones. For example, the five work zones with no speed limit reduction, all of which happen to be located on freeways with 55-mph speed limits, had speed variance differences that ranged from a 19 percent upstream-to-work-zone reduction in speed variance to a 208 percent increase. Given motorist responses that are so highly variable, it is unlikely that statistically significant differences can be found.

Despite the lack of statistical significance, rational policies for setting work zone speed limits must be developed. The researchers consider it reasonable to use the speed variance results in Table 8 as a basis for policy if the accident analysis provides similar findings and if engineering judgement suggests that these findings are reasonable.

Accident Data Analysis

This section presents the findings of the analysis of traffic accidents performed in the research. The analysis addressed the effect of work zones and work zone speed limits on work zone accident rates. The literature indicates that traffic accident rates in work zones are generally higher than the traffic accident rates experienced at the same site during normal operations before the beginning of construction or maintenance. The accident analysis is based on the hypothesis that the most desirable policy for determining work zone speed limits is a policy that minimizes the increase in accident rate during the work period.

Table 9 summarizes the total length, exposure (million vehicle-miles of travel), number of accidents, and accident rates before and during construction for the 66 work zone sites included in the accident study. The table shows that the work zones in the study include 444.9 miles of roadway, or an average of 6.74 mi per site. The average length of site is relatively high because a number of the projects involved resurfacing extended sections of roadway.

The table shows that the accident database included over 3 billion vehicle-miles of travel in the study periods before construction and over 4 billion vehicle-miles of travel in the study periods during construction. The total exposure for the "during" periods is higher than for the "before" periods because some sites at which the construction extended for several years had a "before" period that was only a year or so in duration.

The database developed for the study consisted of 12,150 accidents, including 5,017 accidents in the "before construction" period and 7,133 accidents in the "during construction" period for the individual sites.

Table 9 shows that the total accident rate of the study sites was, on the average, 6.7 percent higher during construction than before construction, while the fatal and injury accident rate was, on the average, 6.9 percent higher during construction than before construction.

On the basis of preliminary analyses of the data, separate accident analyses were performed for groups of sites defined by the following factors:

- Area type (e.g., urban or rural),
- Highway type (e.g., freeway or two-lane), and
- Location of work (e.g., traveled way, detour, shoulder, or roadside).

Table 10 summarizes the percentage increase in accident rate (per million vehicle-miles) for each combination of these variables for which enough data were available for an analysis to be conducted. The results of these accident analyses are summarized below.

Analysis of Traveled Way and Detour Work Zones on Rural Freeways. The largest accident data set available for analysis consisted of 29 sites involving traveled way or detour work zones on rural freeways. Table 10 shows that, overall, these zones experienced an increase of 41.3 percent in total accident rate and of 30.7 percent in fatal and injury accident rate during the construction period.

Table 11 summarizes the mean percent increase in accident rate during the construction period as a function of speed limit reduction. The results presented in Table 11 are noteworthy because they show a characteristic pattern that is also present in the results of the speed variance analysis in Table 8. Specifically, the table shows that the minimum percent increase in accident rate during the construction period occurs for a 10-mph speed reduction. The differences between the mean percentage increase in accident rate for a 10-mph speed reduction and the other values shown in Table 11 are not statistically significant for total accident rate, but they are statistically significant for fatal and injury accident rate.

The findings presented in Table 11 imply that, at least for traveled way and detour work zones on rural freeways, a speed limit reduction of 10 mph will provide the minimum increase in accident rate.

Analysis of Traveled Way and Detour Work Zones on Urban Freeways. Table 10 shows that in traveled way and detour work zones on urban freeways, total accident rate increased by 34.2 percent and fatal and injury accident rate increased by 24.7 percent during the construction period. Table 12 summarizes the mean percent increase in accident rate during the construction period as a function of speed limit reduction.

The data in Table 12 imply that speed limit reductions up to 15 mph do not have an adverse effect on accident experience, but that accident rates increase substantially for a work zone speed limit reduction of 20 mph. However, the data for a 20-mph speed limit reduction are based on only one site and no conclusions can be drawn about the statistical significance of the difference in percent increase in accident rate between this site and the other sites. Despite this inability to test for statistical significance, the substantial increase in accident rate associated with the site that has a 20-mph speed limit reduction is consistent with the other results presented in this report.

Analysis of Shoulder and Roadside Work Zones on Rural Freeways. Only two of the study sites involved shoulder and roadside work on rural freeways. These data sites did not provide enough data to perform any meaningful analysis of speed limit practices.

Analysis of Shoulder and Roadside Work Zones on Urban Freeways. Table 13 compares the mean percent increase in accident rate for 10 sites with no speed reduction and one site with a 20-mph speed limit reduction. Because the 20-mph speed limit group includes only one site, no statistical conclusions can be drawn. However, the data imply that substantial increases in accident rate are associated with a 20-mph speed limit reduction. This observation is consistent with the results of the

TABLE 9 Summary of accident experience at study sites

	Before Period	During Period	Percent Increase
Total length of study sites (mi)	444.9	444.9	
Total exposure (MVMT)	3084.7	4112.0	
Total number of accidents in period	5017	7133	
Total number of fatal and injry accidents (see Note 1)	1743	2488	
Total accident rate (per MVMT)	1.63	1.73	6.7
Fatal and injury accident rate (per MVMT) (see Note 1)	0.57	0.61	6.9

Note 1: Excludes Site FL01 for which fatal and injury accident data were not available.

TABLE 10 Summary of percentage increase in accident rate by area type, highway type, and location of work

Area Type (Urban/ Rural)	Highway Type	Location of Work	Before Period					During Period					Percent Increase	
			Exposure (MVMT)	No. of Total Accs	Total Acc Rate	No. of F&I Accs	F&I Acc Rate	Exposure (MVMT)	No. of Total Accs	Total Acc Rate	No. of F&I Accs	F&I Acc Rate	Total Acc Rate	F&I Acc Rate
Rural	Freeway	Traveled Way/ Detour	792.29	661	0.83	209	0.26	1261.47	1487	1.18	435	0.34	41.3	30.7
Rural	Freeway	Shoulder/ Roadside	22.66	23	1.02	6	0.26	31.93	31	0.97	6	0.19	-4.3	-29.0
Urban	Freeway	Traveled Way/ Detour	746.60	836	1.12	347	0.46	940.05	1413	1.50	545	0.58	34.2	24.7
Urban	Freeway	Shoulder/ Roadside	1388.06	3049	2.20	1040	0.75	1707.15	3669	2.15	1313	0.77	-2.2	2.7
Rural	Two-lane	Traveled Way/ Detour	32.50	55	1.69	14	0.43	32.22	80	2.48	24	0.74	46.7	72.9
Rural	Two-lane	Shoulder/ Roadside	46.78	132	2.82	38	0.81	56.68	152	2.68	49	0.86	-5.0	6.4

TABLE 11 Percent increase in accident rate by speed limit reduction group for traveled way and detour work zones on rural freeways

Speed Limit Reduction (mph)	Number of Sites	Mean % increase in	
		Total Accident Rate	Fatal and Injury Accident Rate
0	5	59.5	98.6
10	9	42.3	4.1
15	4	54.4	147.9
20	6	99.8	112.5
25/30	3	(a)	(a)

NOTE: (a) insufficient data

TABLE 12 Percent increase in accident rate by speed limit reduction group for traveled way and detour work zones on urban freeways

Speed Limit Reduction (mph)	Number of Sites	Mean % increase in	
		Total Accident Rate	Fatal and Injury Accident Rate
0	5	-2.1	-8.7
10	1	8.3	-9.9
15	1	15.8	-17.1
20	1	76.1	51.1
25/30	---	---	---

TABLE 13 Percent increase in accident rate by speed limit reduction group for shoulder and roadside work zones on urban freeways

Speed Limit Reduction (mph)	Number of Sites	Mean % increase in	
		Total Accident Rate	Fatal and Injury Accident Rate
0	10	10.1	21.9
10	---	---	---
15	---	---	---
20	1	78.4	70.9
25/30	---	---	---

speed variance analysis and the rural freeway accident analysis.

Analysis of Traveled Way and Detour Work Zones on Rural Two-Lane Highways. Table 10 shows that in traveled way and detour work zones on rural two-lane highways, the total accident rate increased by 46.7 percent and fatal and injury accident rate increased by 72.9 percent during the construction period. Table 14 summarizes the mean percent increase in accident rate during the construction period as a function of speed limit reduction.

The sites on rural two-lane highways generally have so few accidents that no meaningful conclusions can be drawn. The data for total accident rate shown in Table 14 appear to confirm the finding that no speed limit reduction is better from a safety standpoint than a large speed limit reduction. The fatal and injury accident data are highly variable; most sites experienced only one or two fatal and injury accidents. None of the differences between the values shown in Table 14 are statistically significant.

Analysis of Shoulder and Roadside Work Zones for Rural Two-Lane Highways. Accident data are available for four shoulder and roadside work zones on rural two-lane highways. Only one of these four sites experienced a substantial number of accidents during the study periods. Table 15 presents the percent increase in accident rate by speed limit reduction group. Because of the small number of sites and the small number of accidents that occurred in those sites, no meaningful statistical conclusion can be drawn.

Analysis of Worker and Pedestrian Accident Data. The accident analyses presented here suggest conclusions that, at least for rural freeways, could form a basis for setting work zone speed limit policies. The analysis presented previously, however, does not address one of the specific issues of interest in the study: worker safety.

Both the accident analysis results and the speed variance analysis results suggest that it may be desirable to reduce work zone speed limits by 10 mph; however, consideration must also be given to the question of whether or not a speed limit reduction of 10 mph is adequate to provide for the safety of construction personnel who must work in exposed positions along the traveled way.

There is no information in the literature that indicates what reduction in speed limit or vehicle speed is required to provide for worker safety. The speed analysis results obtained in this study indicate that motorists do slow down more when they are adjacent to active work than when they are not.

The accident data for the 66 work zones in this study were reviewed for any indication of problems related to worker accidents. Because worker accidents cannot be explicitly identified in any of the accident data supplied by the participating states, this analysis focused on pedestrian accidents and accidents involving construction vehicles.

Fourteen pedestrian accidents (3 fatal accidents and 11 injury accidents) occurred on the study sites during the period before construction. In comparison, 24 pedestrian accidents (3 fatal accidents and 21 injury accidents) occurred during construction. This is equivalent to an increase of 29 percent in pedestrian accidents per million vehicle-miles of travel during the construction period. There is no indication that any of these pedestrian accidents involved construction workers and several were explicitly identified by the investigating officer as involving pedestrian violations.

During the construction period, three accidents involved construction vehicles. These accidents, which occurred in three different work zones, each involved collisions between a motorist and construction vehicle that resulted in an injury. There were no fatalities involving construction vehicles.

Although these data do not suggest any major safety problems involving construction workers in the work zones studied, the data do not indicate whether any of the injured parties in the accidents discussed previously were construction workers.

Motorist, Contractor, and Insurance Carrier Surveys

Motorists, construction contractors, and construction liability insurance carriers were surveyed to determine their experiences with and attitudes toward work zone speed limits. The results of the surveys are summarized in the following sections and are presented in more detail in Appendix F, which is not published herein.

Motorist Survey

A survey of motorist attitudes about work zones and speed limits was conducted near three work zones: two in Missouri and one in Georgia. Surveys were conducted at two rest areas and a service station located a few miles downstream of the work zones. Each survey lasted about 2 hours; 58 drivers were interviewed. Because speed data were collected at the respective work zones, the speed distribution from which the sample of drivers interviewed was selected was known. Two work zones had lane closures and the other was off the traveled way at a roadside weigh station. The two-lane closure work zones had the speed limits reduced from 65 to 45 mph and 65 to 40 mph, respectively. The roadside work zone had the speed limit reduced from 65 to 45 mph.

Results of Speed Studies in Work Zones Where Motorists Were Surveyed. Table 16 presents the speed data for the work zones where the motorist surveys were conducted. These data show that drivers reduce their speeds in work zones—but not to the posted speed limit. The percentage of drivers traveling at or below the speed limit in the work zone ranged from 4 to 18 percent. The standard deviation of speeds was higher in the work zone than at the upstream location. The fastest work zone speeds were observed in the roadside work zone.

Results of Motorists Interviews. The survey objectives were to determine whether drivers were aware that they had driven through a work zone; whether they could recall the features of a work zone, including the speed limit; and whether they understood the purpose of work zone traffic control.

Slightly more than one-third (38 percent) of the drivers had driven through the work zone before. About two-thirds of the drivers said that there was something about the work zone that caused them to change their driving. Ninety-one percent of all drivers (53 out of 58) said they saw the speed limit sign or reduced their driving speed or both. Of the 19 drivers who said there was nothing that caused them to change their driving, 14 drivers (74 percent) said they saw a speed limit sign.

Of the drivers at the lane closure sites that were asked about the appropriateness of the reduced speed limit, 73 percent (8 of 11) thought that the reduced speed limit was about right.

At the site where work was off of the traveled way, only 38 percent (3 of 8) thought that the reduced speed limit was about right. The negative respondents thought that the reduced speed limit was inappropriate because there wasn't any work being done that day. (No work was underway on the day of the survey.)

Drivers were shown a list of work zone situations and asked where drivers should reduce their speeds. The primary reasons that motorists thought would justify requiring drivers to reduce their speeds in work zones were workers in the road, lane closures, and stop-and-go traffic because of congestion.

A question was asked to determine if drivers who did not mention having seen the reduced speed limit sign actually knew the posted speed limit. Of those drivers who stated that they knew the speed limit, 76 percent (19 of 25) identified the speed limit correctly.

Ninety percent of the drivers (27 out of 30) in the lane closure work zones thought that a speed limit reduction was justified in that particular work zone; however, only 1 of 4 respondents in the roadside work zone thought that the speed limit reduction was justified.

The results of the motorist survey suggest that speed limit reductions are warranted when workers are in the road or a lane is closed. Some drivers thought that congestion was also a good reason to reduce speeds, but others stated that the congestion itself will reduce speeds. Motorists generally believed that, when work is off of the traveled way or when no work is being conducted, the speed limit should not be reduced.

Most of the drivers (91 percent) stated that they either saw the speed limit sign or reduced their speed or both. About three-quarters of the drivers correctly remembered the speed limit. These positive responses suggest that signing does help to reinforce the speed limit for drivers. Drivers reduced their speed by a greater amount in lane closure work zones than in the roadside work zone. The standard deviations of speeds increased from the open highway to the work area in all three work zones.

The survey results show that drivers have definite beliefs about work zone traffic and will

TABLE 14 Percent increase in accident rate by speed limit reduction group for traveled way and detour work zones on rural two-lane highways

Speed Limit Reduction (mph)	Number of Sites	Mean % increase in	
		Total Accident Rate	Fatal and Injury Accident Rate
0	1	–83.0	—
5	1	60.5	92.6
10	2	56.3	247.2
15	—	—	—
20	5	83.9	2.6
25/30	—	—	—

TABLE 15 Percent increase in accident rate by speed limit reduction group for shoulder and roadside work zones on rural two-lane highways

Speed Limit Reduction (mph)	Number of Sites	Mean % increase in	
		Total Accident Rate	Fatal and Injury Accident Rate
0	—	—	—
10	1	–21.0	12.0
15	2	26.6	–48.5
20	1	–30.9	46.8
25/30	—	—	—

TABLE 16 Vehicle speeds in work zones where drivers were surveyed (mph)

Site	Speed Limits	Mean Speed		Change in Mean Speed	Standard Deviation	
		Open Highway	Work Area		Open Highway	Work Area
MO04F	65/45	61	56	5	5	8
MO02	65/45	69	52	17	5	9
GA04	65/40	68	54	14	5	8

drive according to what they perceive the conditions in the work zone will permit.

Construction Contractor Survey

A survey of ten members of the Montana Contractor's Association was conducted. According to the Association, these firms surveyed performed about 80 percent of the highway construction work in Montana. The types of work done by these contractors include street and highway construction, bridge construction, asphalt, concrete, material supply, signing, pavement marking, lighting, traffic signals, guardrail, and traffic control.

The Montana Department of Highways uses a blanket 35-mph regulatory speed limit for most construction zones. Contractors believe that it is difficult to slow traffic, but that speed limits should be reduced in work zones, perhaps as low as a speed limit of 25 mph.

Contractors also believe that, although the presence of a police officer is effective in slowing traffic in work zones, vehicle speeds increase as soon as the officer leaves. Some contractors stated that police officers are not necessary in work zones, while others stated that officers should only be used for enforcement purposes and not for traffic control. Two contractors stated that flaggers should be given enforcement authority, even to the point of detaining offenders until a police officer arrives on site. One contractor stated that more people would comply with the speed limit if they thought they would be fined for speeding.

Factors for Determining the Need for Reduced Speed Limits. The factors that contractors mentioned most frequently as considerations in determining the need for reduced work zone speed limits were the type of work being performed and the need to perform work in the traveled way. These results suggest that contractors consider reduced speed limits justified when the work interferes with normal traffic flow. Contractors also cited safety of workers and motorists, and high traffic volumes as the reasons for reducing work zone speed limits. Other factors identified by contractors included presence of equipment, area type (e.g., urban or rural), common sense, length of work zone, road type, sight distance, size of work force, and width of road open to traffic.

Effective Speed Control Techniques. The effective speed control techniques that contractors mentioned most frequently were use of flaggers and proper traffic controls. Flashing lights and pilot cars also were mentioned frequently.

These techniques all pertain to traffic controls in the work zone. Use of police officers for speed control was not thought very effective, because speeds increase when the police officers leave the work zone. Contractors believe that established traffic control procedures can be used to control speed. Speed enforcement, including issuing speeding tickets, should supplement the traffic controls as needed.

Montana highway contractors believe that speeds should be reduced in highway work zones. The factors they consider important in establishing speed limits are also the factors considered by state highway agencies. The contractors think that there should be less reliance on police officers for traffic control in work zones. They also believe that work zone personnel should be given expanded authority to control speed in work zones.

Insurance Carrier Survey

Telephone interviews were conducted with selected insurance carriers that provide liability insurance to highway contractors to obtain the views of the carriers on work zone speeds and speed limits. Calls were made to insurance carriers in Connecticut, Minnesota, Nebraska, and Washington.

It was learned that insurance carriers suggest that contractors talk with persons knowledgeable about work zone traffic control or follow state guidelines when reviewing work zone traffic control procedures.

The survey found that insurance carriers do not require or promote reduced work zone speed limits and do not charge lower insurance rates for work zones with reduced speed limits.

CONCLUSIONS

A nationwide survey identified three types of work zone speed limit policies: (1) policies based on avoiding the need for speed limit reductions whenever possible, (2) policies based on blanket speed limit reductions at all work zone sites, and (3) policies under which the need for a work zone speed limit reduction is established on the basis of specific factors. The effectiveness of work zone speed limits was evaluated through accident and operational studies in seven states covcring these three types of policies for establishing work zone speed limits. Thc following roadway types, arranged in decreasing priority, were studied: (1) rural freeway or expressway, (2) urban freeway or expressway, (3) rural multilane or rural two-lane highway, (4) rural two-lane highway detour with free-flow maintained, and (5) urban arterial.

The speed studies showed that motorists reduce speed in work zones—even in work zones with no speed limit reduction. Mean speeds were approximately 5 mph lower within work zones with no speed limit reduction than they were upstream of the same work zones.

Speed limit compliance varied greatly from site to sitc. In general, compliance was greatest in work zones where the speed limit was not reduced, and compliance decreased where the speed limit was reduced by more than 10 mph.

The speed and accident study confirmed that large speed limit reductions in work zones are undesirable. Speed limit reductions to 10 mph below the preconstruction speed limit resulted in the smallest increase in speed variance within the work zone—relative to the speed variance upstream of the work zone—of any of the speed limit reduction strategies studied. Additionally, in rural freeway work zones involving work on or near the traveled way, a 10-mph reduction in the work zone speed limit minimized the accident rate increase from the preconstruction period to the construction period. The investigators conclude that

- Work zone speed limit reductions should be avoided whenever possible, particularly in work zones where all work activities are located in shoulder or roadside areas and when no work activities are underway.
- A 10-mph reduction below the normal speed limit is desirable as a work zone speed limit when:
  - Work takes place on or near the traveled way, particularly on rural freeways,
  - Personnel are required to work for extended periods in an unprotected position within 10 ft of the edge of the traveled way.
- Work zone speed limit reductions larger than 10-mph are undesirable and should be avoided except where required by restricted geometrics or other work zone features that cannot be modified.

Recommended *MUTCD* Revisions

On the basis of the findings of this research, GME has prepared recommended revisions to the *MUTCD*. The additional text would provide a general description of the research findings, which would be suitable for inclusion in other guidelines. GME also prepared a recommended procedure for determining work zone speed limits, which describes the steps that should be taken to properly implement the research findings. Both these sections of the research report are outlined in the following paragraphs.

Part VI of the *MUTCD* addresses the requirements for work zone traffic control. The only portion of Part VI that currently addresses the establishment of work zone speed limits is Section 6A-5 of the 1988 *MUTCD*, which enumerates the fundamental principles of work zone traffic control. The relevant portion of Section 6A-5 states:

> 2. Traffic movement should be inhibited as little as practicable.
>
> a. Traffic control in work and incident sites should be designed on the assumption motorists will only reduce their speeds if they clearly perceive a need to do so. Reduced speed zoning should be avoided as much as practicable.

Based on discussion between the research team and the National Committee on Uniform Traffic Control Devices, no change in these fundamental principles is recommended. The findings of this research identify factors that, if present in a work zone, may warrant a speed limit reduction. However, as implied by the fundamental principles, it would be desirable, whenever possible, to operate work zones that do not require speed limit reductions.

It may be appropriate to incorporate some additional guidance in Part VI of the *MUTCD* that identified engineering factors that may warrant speed limit reductions. Alternatively, such guidance could be incorporated in national guidelines such as the *Traffic Control Devices Handbook* or in guideline documents developed by individual highway agencies. The following text provides a general description of the findings of this research that is suitable for incorporation in a new section of Part VI of the *MUTCD* or in a separate guideline document:

> In accordance with the fundamental principles in *MUTCD* Section 6A-5 that motorists will reduce their speeds only if they perceive a clear need to do so. Reduced speed zoning should be avoided as much as practicable. Speed limit reduction of up to 10 mph from the normal or preconstruction speed limit may be implemented for work zones that involve traffic control devices placed in or very close to the traveled way, particularly on freeways. Speed zones with a reduction in speed limit up to 10 mph may also be appropriate in work zones where workers must work near the traveled way without the protection of a positive barrier for extended periods. Where the use of geometric elements with reduced design speeds cannot be avoided in a work zone, the speed limit should not exceed the design speed. Reduced speed limits should be used only during specific time periods and in the specific portion of the work zone where the factors identified previously are present. Reduced speed zoning should be avoided as much as practicable at sites where all traffic control devices and all work activ-ities are located on the shoulder or in roadside areas.

Other *MUTCD* sections that deal with work zone speed limits (e.g., Section 6B-6 which references the specifications for regulatory signing) would not need to be modified.

The research team has developed a recommended procedure for determining work zone speed limits. This procedure is presented in the next section. However, the research team does not recommend that this procedure be included in the *MUTCD*. A detailed procedure of this type is more appropriate for incorporation in handbooks, guidelines, and highway agency policy statements.

Recommended Procedure for Determining Work Zone Speed Limits

This procedure provides a rational method for considering engineering factors in selecting an appropriate work zone speed limit. The framework for the work zone speed limit procedure has been chosen because it provides an excellent method for classifying the work zone situations to which speed limits may be applied. The primary basis for the classification of work zones in this framework is the potential hazard present in the work zone (as represented by location of work activities in relation to the traveled way), rather than the prevailing speed of traffic in work zones. This approach is intended to establish speed limits on the basis of actual conditions in the work zone (that may not be apparent to drivers), rather than prevailing speeds, which are not known during the design stage and may change from day to day as the work progresses and the traffic control is changed accordingly.

On the basis of the present guidance in the *MUTCD*, the procedure starts with a default speed limit equal to preconstruction speed limit at the work site. The preconstruction speed limit is usually, but not necessarily, the same as the speed limit upstream of the work zone during the construction period.

The recommended procedure is based on consideration of speed limits for work zones on a site-by-site basis. Blanket policies—such as those that mandate the reduction of work zone speed limit to a fixed value—regardless of the pre-construction speed limit, the upstream speed limit, or the conditions in the work zone—are not recommended.

The need for a speed limit reduction is determined in the procedure through consideration of a number of factors related to the actual conditions in a specific work zone. At such locations where work activities are removed from the roadway by 10 ft or more, it is recommended that the work zone speed limit not be reduced. When work activities are closer to the roadway and other specific factors are present, speed limit reductions **may** be used. The word "may" is used, because the highway agency, through their design and field engineers, are in the best position to decide if a work zone speed limit reduction is appropriate for the conditions at the work site location.

In each situation where a work zone speed limit reduction may be appropriate, the recommended procedure indicates the maximum speed limit reduction that should be considered. On the basis of research findings from data gathered in work zones in seven states, a work zone speed limit reduction greater than 10 mph is not recommended unless the design speed of a geometric element is more than 10 mph below the normal speed limit.

Reduced speed limits are generally most appropriate for projects that last at least 24 hours, but there is nothing to constrain highway agencies from using reduced work zone speed limits for shorter projects, if appropriate.

Reduced work zone speed limits should be used only during specific periods and only in the specific portion of the work zone where the engineering factors identified in the work zone speed limit procedure are present. In developing work zone traffic control plans for specific sites, consideration also should be given to speed control techniques other than regulatory speed limits. For example, flaggers may be effective in slowing traffic at specific work sites where use of a regulatory speed limit throughout the entire work zone would be inappropriate.

Work Zone Speed Limit Procedure

The appropriate speed limit for any highway work zone can be determined from the procedure presented in this section. The procedure is applicable to stationary construction zones, maintenance zones, and utility operations; intermittent moving operations; and continuous moving operations. The recommended procedure has four steps:

- Step 1—Determine the existing speed limit,
- Step 2—Determine the work zone condition that applies,
- Step 3—Determine which factors for the appropriate condition apply to the specific site, and
- Step 4—Select the work zone speed limit.

Each step is discussed below. This procedure is illustrated by the flow chart in Figure 3. Figure 4 illustrates the seven work zone conditions that are addressed in Step 2.

Step 1—Determine the existing speed limit

The first step in the procedure is to determine the existing (preconstruction) speed limit for the work zone. The preconstruction speed limit is usually, but not necessarily, the same as the speed limit upstream of the work zone during the construction period. The preconstruction speed limit serves as the default value for the work zone speed limit. The speed limit in the work zone should be reduced only if such a reduction is warranted by the factors considered in the remainder of the procedure.

Step 2—Determine the work zone condition that applies

The work zone **condition** is determined by the location of work activities in relation to the traveled way. In general, speed limit reductions are more appropriate for work zones in which work activities take place in or near the traveled way than for work zones where work activities take place in shoulder or roadside areas well removed from the traveled way or behind a positive barrier.

The procedure addresses the following **conditions**:

1. Activities that are more than 10 ft from the edge of the traveled way (roadside activity),
2. Activities that encroach on the area closer than 10 ft but not closer than 2 ft to the edge of the traveled way (shoulder activity),
3. Activities that encroach on the area from the edge of the traveled way to 2 ft from the edge of the traveled way (lane encroachment),
4. Activities that require an intermittent or moving operation on the shoulder (moving activity on shoulder),
5. Activities that encroach on the area between the centerline and the edge of the traveled way (lane closure),
6. Activities that require a temporary detour roadway (temporary detour), and
7. Activities that encroach on the area on both sides of the centerline of a roadway or lane line of a multilane highway (centerline or lane line encroachment).

The conditions are discussed in greater detail later in this section.

Step 3—Determine which factors for the appropriate condition apply to the specific site

The third step in the procedure is to review the

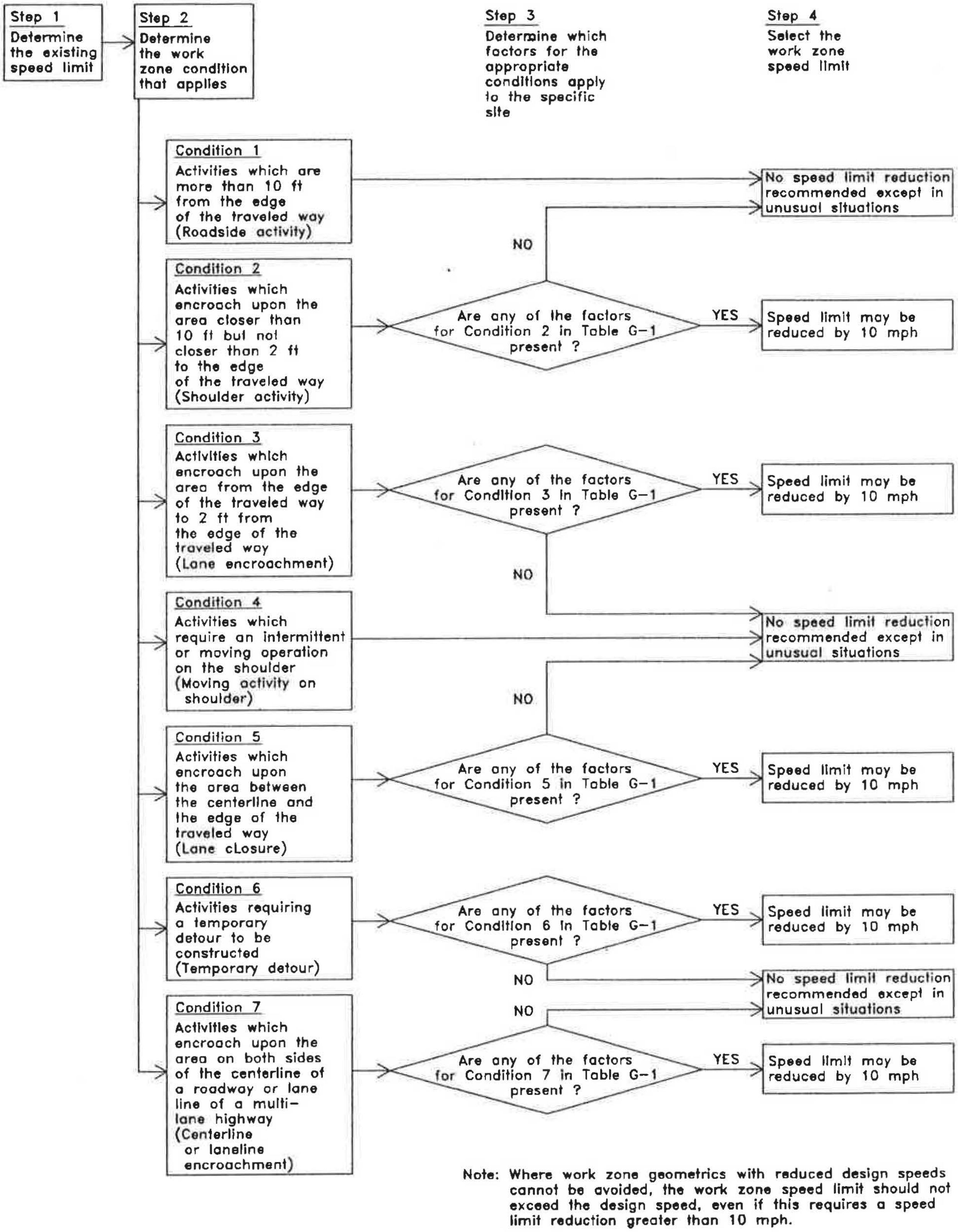


Figure 3. Work zone speed limit procedure flowchart.

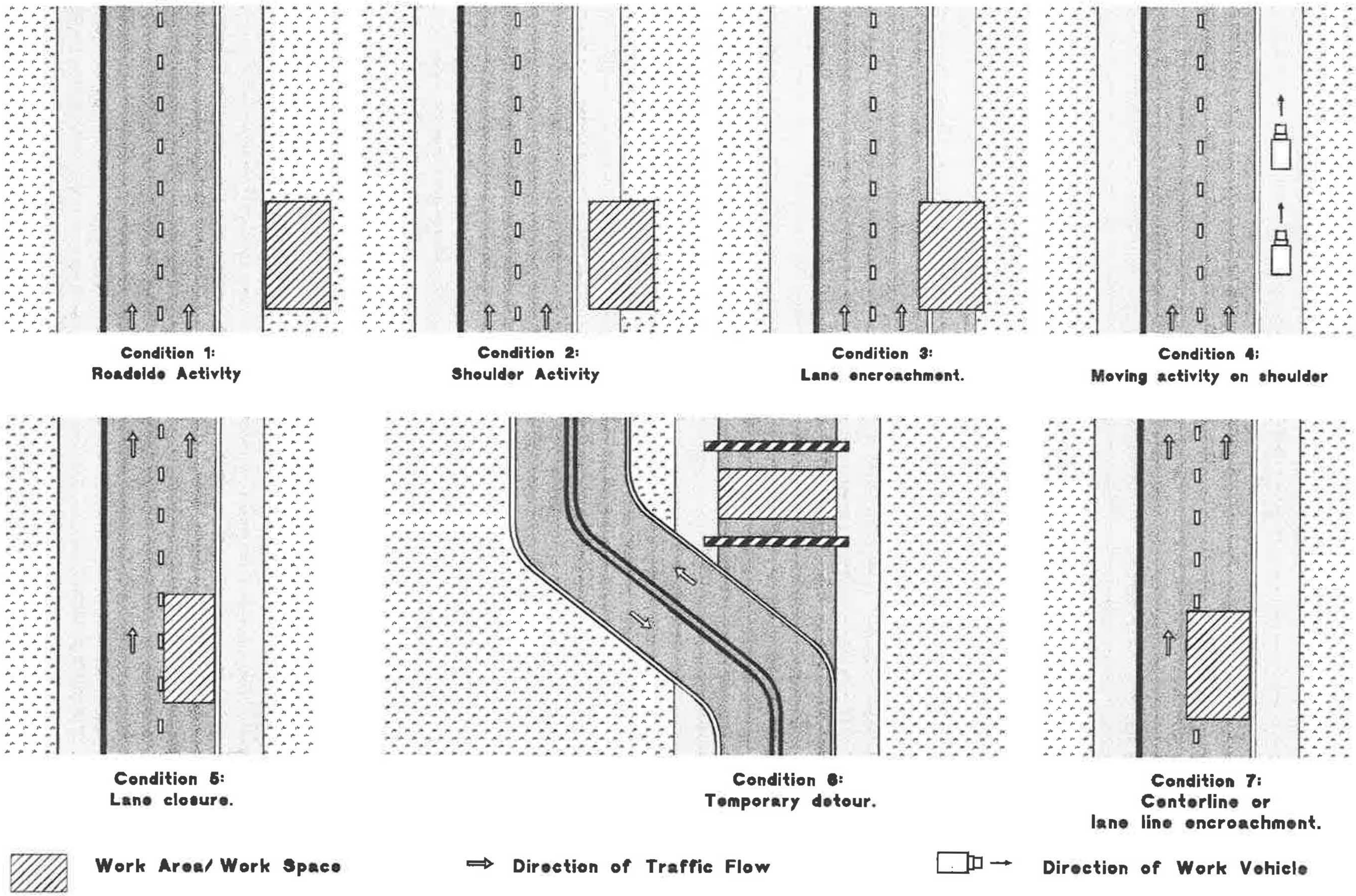


Figure 4. Work zone conditions.

portion of Table 1 applicable to the condition present in the work zone. Table 1 identifies the factors that should be considered in determining whether a speed limit reduction is appropriate for any given work zone condition. If any of the factors identified in the applicable portion of Table 1 is present, then a work zone speed limit reduction is warranted and **may** be implemented. Consideration of the factors in Table 1 is especially important at sites where the presence of these factors may not be apparent to motorists.

Step 4—Select the work zone speed limit

The work zone speed limit should be selected considering the factors presented in Table 1. The table includes guidelines on the maximum speed limit reduction that is recommended for each work zone condition. Speed limit reductions larger than the recommended 10-mph maximum should generally be considered only if restricted geometrics with a lower design speed are present in the work zone and modification of the geometrics to a higher design speed is not feasible.

Highway engineers responsible for each work zone should monitor the conditions in the work zone and ensure that the posted speed limit is appropriate for the actual conditions at any given time. For example, the presence of workers in an unprotected position within 10 ft of the traveled way for an extended period of time warrants a speed limit reduction of 10 mph. However, if worker protection is the only warrant for a speed limit reduction, the speed limit should be restored to its original value when the work activity at that location is completed. Use of work zone speed limits that are appropriate for the conditions that actually exist in the work zone is very important in maintaining motorists respect for speed limits. If motorists frequently encounter reduced speed limits that are not appropriate for the actual conditions in the work zone, they may lose respect for all speed limits and, thus, choose a speed that is too high in a situation where reduced speeds are truly necessary.

All work zone traffic controls should be evaluated at the beginning of the project and periodically through the life of the project to determine if the traffic controls are operating as intended. If problems, including traffic accidents, evidence of traffic accidents, such as debris, or near misses are occurring, the responsible person (resident engineer or traffic control specialist) should determine the cause of the problems so that the circumstances causing the problems can be corrected. Correction may require assistance from the traffic control designer, traffic engineer, or other knowledgeable person.

Condition 1

Activities that are more than 10 ft from the edge of the traveled way (roadside activity)

Typical Applications

Roadway construction
Cleaning drainage
Landscaping work
Structural work
Utility work
Reworking ditches
Fencing work

Reductions to Existing Regulatory Speed Limit

Should not be used*

Suggested Maximum Amount of Speed Reduction

None

Factors

None

The regulatory speed limit shall meet all requirements of the *MUTCD*.

*There should not be a reduction to the existing regulatory speed limit unless unusual situations create hazardous conditions for motorists, pedestrians, or workers.

Condition 2

Activities that encroach on the area closer than 10 ft but not closer than 2 ft to the edge of the traveled way (shoulder activity)

Typical Applications

Roadway construction
Culvert extensions
Guardrail installation
Cleaning drainage
Reworking ditches
Shoulder work
Utility work
Side slope work
Landscaping work
Structural work
Sign installation

Reductions to Existing Regulatory Speed Limit

May be used where **Factors** exist

Suggested Maximum Amount of Speed Reduction

10 mph

Factors

- Workers present for extended periods within 10 ft of traveled way unprotected by barriers
- Horizontal curvature that might increase vehicle encroachment rate (could include mainline curves, ramps, and turning roadways)

The regulatory speed limit shall meet all requirements of the *MUTCD*.

Condition 3

Activities that encroach on the area from the edge of the traveled way to 2 ft from the edge of the traveled way (lane encroachment)

Typical Applications

Roadway construction
Guardrail installation
Utility work
Shoulder work

Reductions to Existing Regulatory Speed Limit

May be used where **Factors** exist

Suggested Maximum Amount of Speed Reduction

10 mph

Factors

- Workers present for extended periods within 2 ft of traveled way unprotected by barrier
- Horizontal curvature that might increase vehicle encroachment rate (Could include mainline curves, ramps, and turning roadways.)
- Barrier or pavement edge dropoff within 2 ft of traveled way
- Reduced design speed for stopping sight distance
- Unexpected conditions

The regulatory speed limit shall meet all requirements of the *MUTCD*. Where work zone geometrics with reduced design speeds cannot be avoided, the work zone speed limit should not exceed the design speed, even if this requires a work zone speed limit reduction greater than 10 mph.

Condition 4

Activities that require an intermittent or moving operation on the shoulder (moving activity on shoulder)

Typical Applications

Roadway construction
Widening
Delineator installation
Shoulder and slope work
Utility work
Guardrail installation
Landscape work

Reductions to Existing Regulatory Speed Limit

Should not be used*

Suggested Maximum Amount of Speed Reduction

None

Factors

None

The regulatory speed limit shall meet all requirements of the *MUTCD*.

*There should not be a reduction to the existing regulatory speed limit unless unusual situations create hazardous conditions for motorists, pedestrians, or workers.

Condition 5

Activities that encroach on the area between the centerline and the edge of traveled way (lane closure)

Typical Applications

Roadway construction
Pavement repair
Utility work
Widening
Pavement resurfacing
Pavement marking
Bridge repair

Reductions to Existing Regulatory Speed Limit

May be used where **Factors** exist

Suggested Maximum Amount of Speed Reduction

10 mph

Factors

- Workers present for extended periods in the closed lane unprotected by barrier
- Lane width reduction of 1 ft or more with a resulting lane width less than 11 ft
- Traffic control devices encroaching on a lane open to traffic or within a closed lane but within 2 ft of the edge of the open lane
- Reduced design speed for taper length or speed change lane length
- Barrier or pavement edge dropoff within 2 ft of the traveled way
- Reduced design speed of horizontal curve
- Reduced design speed for stopping sight distance
- Traffic congestion created by a lane closure
- Unexpected conditions

The regulatory speed limit shall meet all requirements of the *MUTCD*. Where work zone geometrics with reduced design speeds cannot be avoided, the work zone speed limit should not exceed the design speed, even if this requires a work zone speed limit reduction greater than 10 mph.

Condition 6

Activities requiring a temporary detour to be constructed (temporary detour)**

Typical Applications

Roadway construction
Subgrade restoration
Bridge construction
Culvert repair

Reductions to Existing Regulatory Speed Limit

May be used where **Factors** exist

Suggested Maximum Amount of Speed Reduction

10 mph

Factors

- Lane width reduction of 1 ft or more with a resulting lane width less than 11 ft
- Reduced design speed for detour roadway or transitions (radius of curvature, superelevation, and sight distance)
- Unexpected conditions

The regulatory speed limit shall meet all requirements of the *MUTCD*. Where work zone geometrics with reduced design speeds cannot be avoided, the work zone speed limit should not exceed the design speed, even if this requires a work zone speed limit reduction greater than 10 mph.

**Detour and transition geometry with a design speed equal to or greater than the existing regulatory speed limit should be provided whenever possible.

Condition 7

Activities that encroach on the area on both sides of the centerline of a roadway or lane line of a multilane highway (centerline or lane line encroachment)

Typical Applications

Roadway construction
Pavement marking
Pavement resurfacing
Pavement repair
Widening
Crack sealing
Bridge repair

Reductions to Existing Regulatory Speed Limit

May be used where **Factors** exist

Suggested Maximum Amount of Speed Reduction

10 mph

Factors

- Workers present on foot in the traveled way or in the closed lane unprotected by barrier for extended periods
- Remaining lane plus shoulder width is less than 11 ft
- Reduced design speed for taper length or speed change lane length
- Barrier or pavement edge dropoff within 2 ft of the traveled way
- Reduced design speed of horizontal curve
- Reduced design speed for stopping sight distance
- Traffic congestion created by lane closure
- Unexpected conditions

The regulatory speed limit shall meet all requirements of the *MUTCD*. Where work zone geometrics with reduced design speeds cannot be avoided, the work zone speed limit should not exceed the design speed, even if this requires a work zone speed limit reduction greater than 10 mph.

DEFINITIONS OF WORK ZONE CONDITIONS

This section presents a discussion of the seven work zone conditions included in Table 1 that are considered in selecting an appropriate work zone speed limit.

Condition 1—Roadside Activity

The first condition relates to activities that are more than 10 ft from the edge of the traveled way. These operations are outside of the edge of the shoulder and typically include landscaping work, fencing, and ditching.

The report recommends that the speed limit should not be reduced for this condition. If all work activities are 10 ft or more from the edge of the traveled way, there should be no interference with traffic flow and minimal risk to workers on the roadside.

Condition 2—Shoulder Activity

This condition addresses activities that are less than 10 ft but more than 2 ft from the traveled way. Such work activities encroach on the shoulder but not on the traveled way. These activities have an effect on traffic but not as much effect as activities at the edge of the traveled way. Typical applications include culvert extensions, guardrail, structural work, and shoulder repair.

The report recommends that the speed limit should not be reduced for this condition; however, the speed limit may be reduced if one or more factors listed for this condition in Table 1 are present. The maximum speed limit reduction recommended for this condition is 10 mph, unless geometric design features require a larger speed limit reduction.

Highway agencies may choose to implement work zone speed limit reductions for this condition if the listed factors are present. In particular, a speed limit reduction may be considered if unprotected workers are present for an extended period within 10 ft of the traveled way.

Other than worker safety, for which no previous research was found, the factors recommended for consideration as part of this condition (and for the other conditions) are supported by research that documents their safety and operational effects. These include horizontal curvature and unexpected conditions within the work zone.

Horizontal curvature that might increase the vehicle encroachment rate constitutes another important factor that may be considered for shoulder work. Mainline curves and curves on ramps and turning roadways may each be considered. Consideration should include existing curves and curves introduced because of the construction activity. Shoulder areas adjacent to sharp horizontal curves are in many cases subject to run-off-the-road accidents, as evidenced by the amount of damaged guardrail and guardrail repair work at these locations. Any shoulder or roadside work in these areas is potentially subject to the same kind of accidents. Reduction of the work zone speed limit is warranted if the design speed of the horizontal curve is less than the existing speed limit.

Unexpected conditions within the work zone may also warrant a reduction in the work zone speed limit. For example, if construction equipment movements interfere with traffic, a reduction in the work zone speed limit may be warranted. However, if these movements occur during particular portions of the construction work, the speed limit reduction would be appropriate only during those portions of the work.

Condition 3—Lane Encroachment

A third work zone condition involves activities that encroach on the area from the edge of the traveled way to 2 ft from the edge of the traveled way. Thus, these activities are on the roadway shoulder very close to the traveled way. Typical activities for this condition are utility work, guardrail maintenance, and shoulder work.

The maximum speed limit reduction recommended for this condition is 10 mph, unless geometric design features require a larger speed limit reduction. Several factors, in addition to those of the previous condition, could warrant a reduced speed limit. As for Condition 2, the presence of unprotected workers, horizontal curvature, and unexpected conditions could each indicate the need for a reduced speed limit. The presence of unprotected workers within 2 ft of the traveled way would be an even stronger indication of the need for a reduced speed limit than it was for Condition 2 where the workers might be further from the roadway. Other factors that could warrant a speed limit reduction are the presence of a barrier, a pavement edge dropoff, or inadequate stopping sight distance.

Research has shown that a barrier within 2 ft of the edge of the traveled way reduces vehicle speeds and increases the likelihood that vehicles will shy away from the barrier. A pavement edge dropoff delineated with drums or other devices will have the same effect. Furthermore, a pavement edge dropoff presents a hazard to motorists who leave the roadway or try to return to it and this potential hazard typically increases with vehicle speed. Thus, the presence of a pavement edge dropoff may warrant a reduced speed limit when the dropoff is present.

The presence of limited stopping distance that does not meet the AASHTO Green Book criteria for a design speed equal to the existing speed limit is another justification for a speed limit reduction when work activities occur within 2 ft of the roadway. The presence of limited sight distance increases the possibility that a driver may be unable to see a stopped vehicle entering a roadway or an object in the roadway in time to stop. A driver who cannot stop is likely to attempt to avoid a collision by leaving the roadway, thus increasing the likelihood of entering the work area. This risk could be mitigated by reducing the speed limit—assuming that drivers would reduce their speeds in compliance with that speed limit.

Condition 4—Moving Activity on Shoulder

Activities requiring continuous or intermittent moving on the shoulder are beyond the scope of accident and field studies conducted for this research. This condition was included, however, to make the recommended procedure as complete as possible. No regulatory speed limit reduction is recommended for this condition.

Condition 5—Lane Closure

Activities that encroach on the area between the centerline or lane line and the edge of the traveled way, such as lane closures, are very critical because they directly interfere with existing traffic patterns.

A maximum speed limit reduction of 10 mph is recommended for Condition 5 sites, as it was recommended for Condition 3. A 10-mph speed limit reduction is desirable for work zones on rural freeways and may also be appropriate for other roadway types. Speed limit reductions greater than 10 mph are recommended only if required by restricted geometrics.

Most of the factors that may warrant speed limit reductions at lane closure sites (including the presence of unprotected workers, roadside barrier, pavement edge dropoffs, horizontal curvature, limited stopping sight distance, and unexpected conditions) have been discussed previously.

Taper and speed change lane lengths are critical geometric elements that should be designed to the speed limit or prevailing speed. In situations where it is not physically possible to do this, however, a reduced work zone speed limit may be warranted.

Traffic congestion created by a lane closure is another factor that may warrant a speed limit reduction. Traffic backups because of a decreased capacity of the roadway may lead to rear-end accidents. Traffic traveling at slower speeds will have more time to react to the rapidly slowing traffic immediately ahead. The presence of congestion, however, may provide greater justification for speed limit reduction upstream of the lane closure (where a standing queue may be present) than in the work zone itself.

Condition 6—Temporary Detour

Activities requiring temporary detours may warrant a reduced work zone speed limit of 10 mph below the existing speed limit. Where a detour roadway is provided, the speed limit in the detour should be appropriate for the design speed of the geometry of the detour roadway and the transition areas to and from the existing roadway. Geometric elements that should be considered include lane widths, horizontal curvature, and stopping sight distance. It is desirable to design the detour and transition areas to operate at the existing speed limit. Where this is not possible and the detour or transition areas must be designed for a lower speed, a reduced speed limit should also be used.

The presence of workers has not been listed as a factor to warrant a reduced speed limit on a detour roadway. A major objective of providing a detour roadway is to remove the traffic from the work area. Workers would be expected to be present only for very short periods (for example, when placing traffic control devices).

Condition 7—Centerline or Lane Line Encroachment

Activities that encroach on both sides of a centerline or lane line are considered in Condition 7. These include stationary activities that a lane and encroach on an adjacent lane or stationary activities that involve unprotected workers on foot in the traveled way. Moving operations, such as pavement marking, could also be considered as part of Condition 7. Moving operations, however, are beyond the scope of the accident and field studies conducted for this research. Regulatory speed limit reductions of up to 10 mph are recommended for this condition if workers are present on foot in the traveled way or in the closed lane unprotected by a barrier for extended periods, if the remaining lane and shoulder width is less than 11 ft, or if other unexpected conditions are present. The other factors listed for Condition 5 that justify a regulatory speed limit reduction also apply to Condition 7.

EXAMPLE APPLICATIONS OF THE WORK ZONE SPEED LIMIT PROCEDURE

Six examples that illustrate the application of the work zone speed limit procedure are presented herein.

Example 1

A truck weigh station on a rural, four-lane freeway is being reconstructed and is currently closed. The speed limit on that section of highway is 65 mph. The construction activity in the weigh station is well removed from the traveled way. Construction vehicles entering and exiting the weigh station use the existing ramps to and from the freeway.

1. **Determine the existing speed limit**
   The existing speed limit is 65 mph.
2. **Determine the work zone condition that applies**
   Because the work activity occurs off of the roadway, **Condition 1** applies.
3. **Determine the applicable factors**
   Table 1 shows that there are no factors that apply to Condition 1.
4. **Select the work zone speed limit.**
   Because there are no factors that apply to Condition 1, the work zone speed limit should remain at 65 mph.

Example 2

The same work zone described previously in Example 1 periodically requires fill material to be delivered to the work site. Dump trucks transport fill material from a borrow pit that is located a few miles from the work site. The borrow pit is located 300 ft from the roadway and is reached by a temporary road. The dump trucks receive a load of material and drive directly onto the traveled way through an opening in the right-of-way fence and transport the material to the work site.

1. **Determine the existing speed limit**
   The existing speed limit is 65 mph (see Example 1).
2. **Determine the work zone condition that applies**
   Condition 1 applies.
3. **Determine the applicable factors**
   There are no factors in Table 1 for Condition 1; however, slow-moving dump trucks entering the roadway create an unexpected condition for motorists, who may have to brake, change lanes, or swerve to avoid the dump trucks.
4. **Select the work zone speed limit**
   Because of the unexpected occurrence of a slow-moving dump truck entering the traveled way, a reduction in the work zone speed limit by 10 mph is warranted. The highway agency may reduce the speed limit from 65 mph to 55 mph. The reduced speed limit, however, should only be applied when dump trucks are delivering fill material to the work site. Under direction of the resident engineer, the 55-mph speed limits signs should be covered or removed when fill material is not being delivered.

Example 3

A six-lane-urban freeway is being resurfaced. The work activity requires lanes to be closed. The paving machine and channelizing devices frequently encroach into the adjacent lane. In addition to the equipment operators, there are a number of workers on foot in the closed lane. Throughout the day, dump trucks bringing paving material enter and leave the closed lane. The existing speed limit is 55 mph.

1. **Determine the existing speed limit**
   The existing speed limit is 55 mph.
2. **Determine the work zone condition that applies**
   Because a lane closure is required, **Condition 5** applies.
3. **Determine the applicable factors**
   The following factors from Table 1 apply:
   - Workers present in closed lane unprotected by barrier
   - Traffic control devices encroaching on the open lane

   In addition, the factors related to traffic congestion, lane width reduction, and unexpected conditions may also apply.
4. **Select the work zone speed limit**
   Because of the factors present in the work zone, a 10-mph speed limit reduction is warranted. The highway agency may reduce the work zone speed to 45 mph.

Example 4

The same resurfacing project described previously in Example 3 is governed by a contract clause that requires the contractor to reopen all lanes and remove all equipment from the roadway at the end of each working day. The work zone speed limit is reduced to 45 mph during the time work is in progress in the traveled way. What should the speed limit be set at when work is **not** in progress?

1. **Determine the existing speed limit**
   In this example, the existing speed limit refers to the preconstruction speed limit of the highway, which is 55 mph.
2. **Determine the work zone condition that applies**
   Because equipment is required to be stored off of the roadway when work is not progress, **Condition 1** applies.
3. **Determine the applicable factors**
   No factors apply to this condition.
4. **Determine the work zone speed limit**
   The 45-mph speed limit signs should be covered or removed when work is not in progress and replaced with 55-mph speed limit signs. At the start of the next work day, the 45-mph speed limit should be reactivated.

Example 5

The same work zone referred to in Examples 3 and 4 is experiencing minor rear-end accidents and many near misses on the approach to the lane closure areas because of congestion caused by the reduction in capacity created by the lane closure. The traffic backup often extends into the advance warning area beyond the reduced speed limit signs.

1. **Determine the existing speed limit**
   The existing speed limit in this case is 45 mph.
2. **Determine the work zone condition that applies**
   As in Example 3, **Condition 5** applies to this work zone.
3. **Determine the applicable factors**
   Traffic congestion caused by a lane closure is one additional factor that may apply.
4. **Select the work zone speed limit**
   Example 3 shows that lane closure work zones warrant a 10-mph speed limit reduction; in this case, the speed limit should be reduced from 55 mph to 45 mph. The presence of traffic congestion upstream of the lane drop taper is also a factor in Table 1 that warrants a 10-mph speed limit reduction. Because the 45-mph speed limit is already in place during the work period, the traffic congestion warrants extending that 45-mph speed limit further upstream beyond the end of the standing queue. In this way, motorists approaching the work zone will receive advance warning of the reduced speed limit before reaching the congested area.

Example 6

A bridge on a rural, two-lane highway is being replaced with a new bridge at the same location. A temporary bridge is being constructed adjacent to the existing bridge. The existing speed limit is 55 mph. The highway agency plans to build a temporary roadway to detour traffic onto the temporary bridge.

The highway agency would like to design the geometrics of the temporary roadway using a 60-mph design speed (to make the retention of a 55-mph speed limit appropriate), but the physical constraints of the site will only permit the roadway to be built at a 50-mph design speed.

1. **Determine the existing speed limit**
   The existing speed limit is 55 mph.
2. **Determine the work zone condition that applies**
   Because a temporary detour is to be constructed, **Condition 6** applies.
3. **Determine the applicable factors**
   The reduced design speed of the temporary roadway is a factor in Table 1 that warrants a reduced work zone speed limit for Condition 6.
4. **Select the work zone speed limit**
   Because the temporary detour will be built to a 50-mph design speed, the work zone speed limit should be reduced by 10 mph (from the existing 55-mph speed limit) to 45 mph.

FINAL REPORT

The overall objectives, research approach, findings, conclusions, and recommendations are presented in the main body of the agency final report for NCHRP Project 3-41 titled "Procedure for Determining Work Zone Speed Limits." Detailed descriptions of the surveys, procedures, analysis results, and final recommendations are presented in the Appendixes. Appendix A presents the literature review; Appendix B, the state highway agency work zone speed limit polices and guidelines; Appendix C, the data collection procedures; Appendix D, the speed data analysis results; Appendix E, the accident data analysis results; Appendix F, the motorist, contractor, and insurance carrier surveys; and Appendix G, the recommended procedure for determining work zone speed limits.

This agency report for Project 3-41 will not be published in the regular NCHRP report series. However, loan copies of the agency report are available by contacting: Transportation Research Board, National Cooperative Highway Research Program, 2101 Constitution Avenue, N.W., Washington, DC 20418.

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The staffs of seven state highway agencies located in California, Florida, Georgia, Iowa, Missouri, Montana, and New York made substantial contributions in the speed and accident data collection effort. The agencies discussed their work zone speed limit policies and procedures, identified active candidate construction zones, provided names of contact persons at each work zone, and provided computerized listings of traffic accidents during the period when work was being conducted and for an equal period before work began.

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We are also grateful to the 45 state and local traffic engineers who responded to a questionnaire on work zone speed limit policies and procedures.

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John Hodgkins	James W. Van Sistine
Sanford P. Lahue	J. Richard Young, Jr.
Virginia M. Lorenz	Howard H. Bissell

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Appendix B

Speed Limit Reduction Request Form

TN TDOT Department of Transportation

Speed Limit Reduction Request Form

Contract #: _________________________ Project #: ____________________________

County: ____________________________ Route #: _____________________________

Begining and Ending Log Miles: ____

TDOT Supervisor: ___________________________ Estimated Completion Date: ____________

Prime Contractor: ____

Reduction Request Type: _____Variable _____Continuous Existing Speed Limit: ____________

Requested Speed Limit: _____________ (**Note: Work zone speed limit reductions larger than 10 MPH are undesirable and should be avoided except where required by restricted geometrics or other work zone features that cannot be modified.)**

Description of work/ reason for requested reduction (identify condition and factors from Guidelines):

____

____

____

____

- Does the Construction activity occur within 10 FT of the edge of the travel way? ___________
- Are workers present for extended periods within 10 FT of the traveled way unprotected by barriers? ____________________
- Are barriers or pavement edge drop-offs present within 2 FT of traveled way? _____________
- Are lane widths being reduced? ________________ If yes, to what width? ________________
- Is traffic being shifted in the work zone? ____

_____________________________________ _______________________________________

TDOT Project Supervisor Approval Signature TDOT Reg. Traffic Engineer Approval Signature

Revised: 3/5/19