State of the Practice: Setting Speed Limits and Using Dynamic Speed Feedback Signs

Final Report and Guidelines
November 2019

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16. Abstract

Speeding, defined as exceeding the posted speed limit or driving too fast for conditions, contributes to approximately one-third of all traffic fatalities and costs society about $40.4 billion each year.

These guidelines focus on two strategies to reduce speeding:

- Setting proper speed limits, which is key to ensuring reasonable and safe speeds
- Using dynamic speed feedback sign (DSFS) systems, traffic control devices that have been used successfully to reduce speeds

The guidelines include a summary of the current state of the practice and best practices for setting speed limits and a summary of best practices for using DSFS and recommendations on their use.

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STATE OF THE PRACTICE: SETTING SPEED LIMITS AND USING DYNAMIC SPEED FEEDBACK SIGNS

Final Report and Guidelines
November 2019

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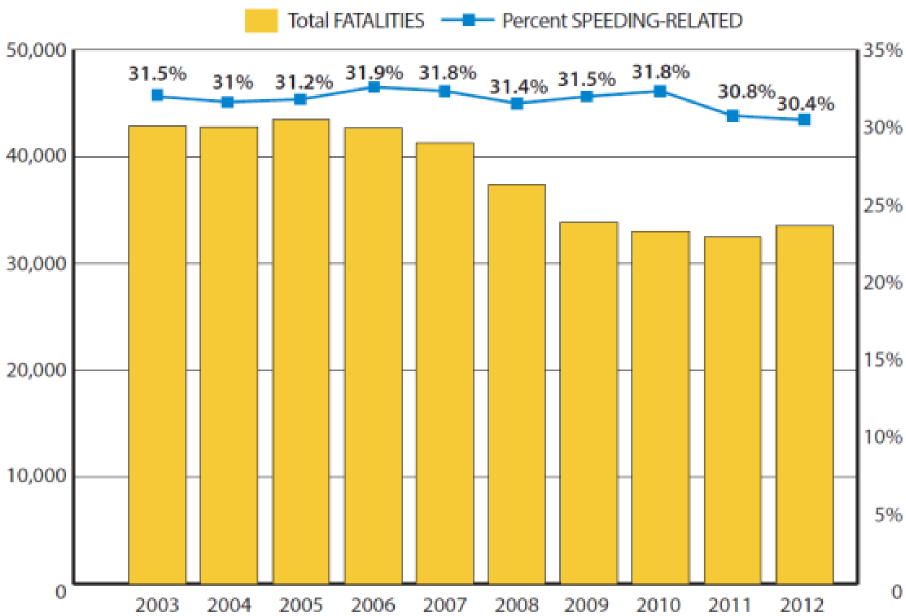
1. INTRODUCTION

1.1 Background

Speeding, defined as exceeding the posted speed limit or driving too fast for conditions, contributes to approximately one-third of all fatalities and costs society about $40.4 billion each year (NHTSA 2014). Although fatal crashes in general have decreased over the last 10 years, the proportion of speeding-related fatal crashes has remained constant over that same period, as shown in Figure 1.



Neuner et al. 2016/Leidos, Brudis & Associates, Inc., Center for Transportation Research and Education at Iowa State University, and Sam Schwartz Engineering
Source: FARS 2003 to 2012

Figure 1. Speeding-related fatal crashes in the United States

A number of strategies have been used to address speeding. These guidelines focus on two in particular:

- Setting proper speed limits. This is key to ensuring reasonable and safe speeds.
- Dynamic speed feedback sign (DSFS) systems. These are traffic control devices that have been used successfully to reduce vehicle speeds.

1.2 Project Objectives

The objectives of this project were as follows:

- Assess the current state of the practice and best practices for setting speed limits
- Summarize the best practices for using DSFS and provide recommendations on their use

1.3 Existing Practices for Setting Speed Limits

Several approaches are used to set speed limits in the United States, including the following:

- *Statutory*: Speed limits are legislated by state or local governments.
- *Engineering*: A process based on data collection and analysis is used to determine a reasonable and safe maximum speed limit; the speed limit is often set according to the 85th percentile speed, the roadway design speed, or other criteria.
- *Expert System*: A knowledge-based computer program is used to recommend speed limits based on data such as road type, site features, traffic volumes, and crash characteristics.
- *Safe Systems*: Speed limits are set according to the crash types that are likely to occur.
- *Optimization*: Speed limits are set in a way that minimizes total transport cost, which may include costs associated with vehicle operation, crashes, travel time, noise, and air pollution.

Methods used by various states for setting speed limits, setting speed zone lengths, using transition zones, and setting school speed limits are summarized in Chapter 3, with a brief synopsis provided in Tables 1 through 4.

Table 1. Summary of state practices for setting speed limits

State	Statutory	85th percentile	Engineering judgment	Factors Considered
Iowa	√	√	√	• Road type • Traffic control • Crashes • Volume • Sight distance • Pedestrian activity
Arizona		√	√	• Road characteristics • Alignment • Sight distance • Crashes • Parking practices • Pedestrian activity • Signal progression
California			√	• Follows MUTCD
Florida	√	√	√	• Cannot be more than 8 mph lower than 85th • Speed pace • Road characteristics • Signal progression • Sight distance
Georgia			√	• Speed • Roadway characteristics • Crashes
Kentucky		√	√	• Speed • Location • Crashes
Louisiana			√	• High enforcement areas • Geometric restrictions • Inadequate shoulders
Massachusetts	√	√	√	• Speed • Roadway characteristics • Crashes • Must be at least 7 mph lower than 85th

State	Statutory	85th percentile	Engineering judgment	Factors Considered
Missouri	√		√	• 85th, upper limit of 10 mph pace or average test run • Roadway characteristics • Fatal/major injury crashes • Pedestrian • Parking • Land use
Montana			√	• 85th, pace and speed profile • Roadway characteristics • Crashes/hazardous conditions • Pedestrian/school/senior center • Parking • Land use • Volume • Seasonal factors
North Carolina		√	√	• Roadway characteristics • Roadway alignment • Land use • Intersections • No more than 35 mph for roadside development and greater than 75% for unimproved roads
Oregon	√		√	• 85th, average speeds • Crashes • Roadway alignment • Pedestrians • Land use • Enforcement • Volume • Public testimony • Access
Texas		√		• 85th, even when higher than inferred design speed • New roads designed for the highest anticipated posted speed

State	Statutory	85th percentile	Engineering judgment	Factors Considered
Wisconsin	√		√	• 85th and 50th speeds • Crashes • Roadway characteristics • Access points • Parking • Pedestrian/bicycle • Winter maintenance
Wyoming	√	√	√	• Roadway characteristics • Crashes • Parking • Pedestrian • May not be below the 50th or lower limit of 10 mph pace

Table 2. Summary of state practices for setting speed zone length

State	Speed Zone Length Criteria
Alaska	• Greater than or equal to distance traveled in 25 sec at existing speed limit
Louisiana	• Greater than or equal to 1,000 feet for speed limits 35 mph or higher • Greater than or equal to 2,500 feet for speed limits 40 mph or lower
Massachusetts	• Greater than or equal to 0.5 miles • Rural: normally 0.2 miles
Missouri	• Should have logical beginning and end points • Greater than or equal to 2 miles for unincorporated or rural areas
Oregon	• Greater than or equal to 0.25 miles
Wisconsin	• Greater than or equal to 0.3 miles

Table 3. Summary of state practices for using transition zones

State	Criteria
Colorado	• Speed limit difference greater than or equal to 15 mph
Kentucky	• Normal transitions of 55 mph to 45 mph and 35 mph to 25 mph
Louisiana	• Allow sufficient distance to slow to new speed • Transition speed no more than 10 mph lower than higher speed
Maine	• Greater than or equal to 0.25 miles
Massachusetts	• 40 mph for undivided highways outside of densely settled/business areas for 0.5 miles • 50 mph for divided highways outside of densely settled/business areas for 0.25 miles
North Dakota	• Speed limit difference greater than or equal to 15 mph
Oregon	• Greater than or equal to 1,000 feet • Speed limit difference between adjoining roadways at least 10 mph
Texas	• Speed limit difference greater than or equal to 15 mph • Greater than or equal to 0.2 miles
Virginia	• Use on 65 mph roads • Use 60 mph to 55 mph transition zones near city limits
Wisconsin	• Less than or equal to 0.3 miles • Consider if physical characteristics of road change • No more than two transition zones on a given road • Only use when 85th percentile speeds indicate a need

Table 4. Summary of state practices for setting school zone speed limits

State	Criteria
Florida	• Age of children • Normal approach speed • Sight distance • Traffic volume • Street width • Presence of other traffic control • Use of adult crossing guards
Georgia	• Presence of multiple grades and school enrollment of at least 250
Kentucky	• 10 mph lower than normal posted speed limit • Should not be less than 25 mph or greater or greater than 45 mph • Sight distance, roadway conditions, crash history may also be considered
Massachusetts	• 20 mph • Used near K–8 schools • Used when school property abuts public row, school children have direct access from school, or a marked ADA-compliant crosswalk is present
North Carolina	• Not allowed on Interstates or controlled-access highways • Allowed on lower functional classes abutting school property • 10 mph less than 85th percentile speed • Speed limits under 20 mph are not allowed
Oregon	• 20 mph by statute • Applies to roadways adjacent to schools and designated crosswalks
Texas	• When school is visible from roadway • Engineering study is used to determine need
Wisconsin	• 15 mph when conditions are met
Wyoming	• 20 mph when conditions are met

1.4 Effectiveness of Dynamic Speed Feedback Signs

DSFS systems are traffic control devices used to reduce vehicle speeds. DSFS systems consist of a speed measuring device, which may use either loop detectors or radar, and a message sign that displays feedback to those drivers who exceed a predetermined speed threshold. The feedback may be the driver's actual speed, a message such as SLOW DOWN, or activation of some warning device, such as beacons or a curve warning symbol.

The utility of this traffic control device is that it specifically targets drivers who are speeding rather than affecting the entire driving population. In this way, the system interacts with an individual driver and may lead to better compliance because the message appears to be more personalized.

When drivers encounter a lower speed section of roadway after traveling at a higher speed for some time, their adaptation to the higher speed causes them to underestimate their speed. In these situations, DSFS are particularly useful to remind drivers of their own speed and the speed reduction (Forbes et al. 2012).

Effectiveness of DSFS

Although DSFS have been generally shown to be effective, agencies prefer select application of these devices for several reasons. Although their cost is relatively low, i.e., $2,500 or more, this amount is still a significant outlay of resources for a small agency. Additionally, these signs require regular maintenance, including calibration and monitoring to ensure that they are positioned properly. Some agencies are also concerned that, without guidelines for using these devices, requests by citizens for their application will escalate. Another concern is that overuse of the devices may cause drivers to pay less attention to them.

A number of studies have been conducted to assess the effectiveness of DSFS in various settings, as noted in Section 4.1. In general, studies have noted that the devices are effective and that speed reductions over time have been consistent. A summary of the various studies on DSFS by type of roadway is provided in Table 5.

Table 5. Summary of DSFS studies

Type of Roadway	Mean Speed (mph)	85th Percentile Speed (mph)	Distance (feet)	Exceeding Speed Limit (%)
Urban arterials (2)	-1.0 to -2.0	-1.0 to -3.0	Within 900 ft downstream	
Rural arterial curve (3)	-0.0 to -10.9	-2.0 to -3.0		-14.4 to -26.2%
Rural arterial (1)	No change		Decreases noted from 1,200 ft upstream to 300 to 500 ft downstream	
Multi-lane divided (1)	-2.6			
Collectors (4)	-0.3 to -2.2	-1.0 to -8.0		
School zones (6)	2.0 to -9.2	0.0 to 10.0		up to -92.8%
Transition zones (2)	-0.4 to -7.6	0.0 to -9.0		up to -71.1%

The number of studies for each type of roadway is indicated in parentheses. For instance, two studies were available that assessed DSFS on urban arterials. Results between the two studies indicated reductions of 1 to 2 mph in mean speed.

One study (Hallmark et al. 2013a) developed the crash modification factors (CMFs) presented in Table 6 for DSFS on rural curves.

Table 6. CMFs for dynamic speed feedback signs on rural curves

Crash Type	CMF
All in both directions	0.95
All in the direction of the sign	0.93
SV in both directions	0.95
SV in the direction of the sign	0.95

Source: Hallmark et al. 2013a

Driver Attitudes Toward DSFS

Several surveys have been conducted to assess drivers' attitudes towards DSFS. Jeihani et al. (2012) conducted a survey about attitudes toward and reactions to DSFS in Baltimore, Maryland. They found that 70.1% of drivers reduced their speed when encountering a DSFS on a 25 mph roadway while only 35% to 38% reduced their speed on a 35 or 45 mph roadway. The majority of respondents (63%) indicated that they reduced their speed after passing a DSFS because they believed they may receive a speeding ticket, and 37% slowed down after passing a DSFS because they did not realize they were speeding and the DSFS reminded them of their speed. While the DSFS did appear to positively impact driver behavior, almost half of the respondents (48%) said that they would increase their speed if their speed was lower than the speed limit. Around 55% of drivers believed that DSFS increase safety, and 25% believe they improve both safety and traffic flow.

A study was conducted in Vermont (Addison County 2013) to assess driver behavior near DSFS in school zones. Drivers were asked to rank five different factors that influenced their speed in a school zone (presence of children, presence of law enforcement, presence of a crossing guard, presence of a DSFS, and flashing beacons on school zone speed limit signs). The presence of children had the highest impact followed by flashing beacons on school zone speed limit signs and then presence of law enforcement. Presence of a crossing guard was ranked fourth and presence of a DSFS was ranked last. This low ranking for DSFS may be due to the fact that drivers regularly encounter the first four factors but encounter DSFS less frequently. Drivers were also asked how helpful DSFS were in informing them of their speed. Over 85% of drivers ranked them as very helpful, helpful, or sometimes helpful; over 72% of drivers responded that they are effective in warning of a danger ahead; and 84% indicated that they were effective in making drivers slow down.

Summary of Guidelines for Use of DSFS

DSFS have been shown to be effective in reducing speeds. However, the devices need to be installed on roadways where conditions warrant their use. Although these devices cost relatively little, i.e., $2,500 or more, this amount is still a significant outlay of resources for a small agency, and the signs do require maintenance. Without guidelines, some agencies are concerned that citizens will request that these signs be placed on every roadway and that overuse may reduce compliance.

A number of agencies have developed guidelines for the use of DSFS. In some cases, these guidelines have included specifications governing size, the message displayed, or other technical details. Several agencies have developed recommendations on where to use DSFS, as summarized in Section 3.4 and presented in brief in Table 7.

Table 7. Summary of factors considered by agencies when placing DSFS

Metric	Considerations for Use
85th percentile speed	• Greater than 5 mph over the posted speed limit • Greater than the posted speed limit plus 5 mph (3 mph in a school zone)
Mean speed	• Greater than 5 mph over the posted speed limit
Average daily traffic (ADT)	• Greater than 500 vehicles per day (vpd)
Crash experience	• Correctable speed-related problem exists within a recent period
Pedestrian presence	• Within 500 yards of a major pedestrian generator • Primarily a residential or heavily traveled pedestrian area • Pedestrian-based crash problem exists
Posted speed limit	• Studies have proposed using DSFS both only where speed limits are over 25 mph and only where speed limits are 35 mph or less • High-speed signalized intersection approaches where speed limit is greater than 45 mph
Other traffic control	• More effective with other indicators, such as school zone speed limit beacon, signal change warning, etc. • More effective with regulatory than advisory speed limit • The DSFS supports a driver information system that provides a clear and real need to reduce speeds • Less effective at locations with an overabundance of driver information
Other roadway characteristics	• More effective if sight distance less than decision sight distance • More effective on two-way two-lane or one-way one-lane roads, where lead vehicles that slow impact the following vehicles • Discouraged in non-residential areas • Not appropriate on freeways or major arterials except in work zones
Transition zones	• High to low speed • Change in speed greater than 10 mph
Work zones	• Work zone speed limit greater than 35 mph • Mean speed greater than 10 mph over posted speed limit • 85th percentile speed greater than 10 mph over posted speed limit • When speed-related crashes have occurred
School zones or parks	• Within 0.5 miles of school zone or park • Posted speed limit at school zone or park greater than 15 mph • 85th percentile speed greater than 5 mph over posted speed limit OR mean speed greater than 5 mph over posted speed limit OR ADT greater than 500 vpd OR supplement to advisory or conditional speed limit is already in place

The Iowa DOT has specific guidance for use of DSFS, as summarized in Section 3.4.

In general, most of the guidance suggests that the use of these devices be limited to locations where there is a demonstrated speed issue. One study suggested that DSFS are more effective when the perception of regular enforcement exists. It should be noted that most of the guidance does not appear to be based on the results of studies, and in many cases the rational for the guidance was not stated.

Permanent Versus Temporary Installation

Countermeasures whose primary purpose is to get a driver's attention may lose effectiveness over time as drivers become habituated. It has been suggested that this applies to DSFS.

A psychologist examined the phenomenon of habituation to speed feedback signs (Burkley 2019). The author notes that unlike static traffic signs, DSFS provide an individualized message, which psychologists call a feedback loop. A feedback loop consists of an action, feedback, and then a reaction. In this case, the sign provides information to a driver about his/her action (i.e., "You are speeding"), the driver sees his/her speed (or other message), and then the driver reacts (slows down), which creates a positive response in the brain. The author suggests that feedback loops are highly effective in modifying behavior because the human brain is hardwired to respond to them. Burkley (2019) also suggests that DSFS provide drivers with a personalized message about their behavior in relation to the posted speed limit. In particular, the author notes that drivers consistently overestimate their driving skills and underestimate how much they speed. As a result, drivers may be less likely to become habituated to DSFS than static countermeasures.

1.5 Recommendations for Use of DSFS

As a speed management countermeasure, DSFS can be effective in both short- and long-term installations. However, DSFS messages have a limited reach downstream from the location of the sign.

The following recommendations are sourced from other agencies' practices and the research team's expertise in both speed management and evaluation of DSFS for various projects. These recommendations exclude the special considerations required for work zones.

Demonstrated Speeding Problem

When a location is being considered for application of a DSFS, the first consideration should be the adequacy of the existing posted or advisory speed limits and sign placement.

DSFS are most likely to be effective when a demonstrated speeding problem exists, as evidenced by any of the following conditions:

- The 85th percentile speed is 5 mph or more over the posted limit.
- There is a documented history of speed-related crashes in the area.

Traffic Volume Threshold

Several agencies recommend that DSFS only be used on roadways that meet a traffic volume threshold (e.g., more than 500 vpd). However, if a demonstrated speeding problem exists, choosing the appropriate volume threshold should be at the discretion of the agency.

Roadway Type

Based on sign visibility, DSFS work best on one- or two-lane roadways. When a DSFS is placed at a location with more than one lane in the travel direction, it is difficult to target the message to a particular driver, unless signs are installed on both sides of the road. For example, a driver in one lane may be speeding, causing the sign to activate and display a message, while a driver in the adjacent lane who is not speeding receives the same message. Additionally, if a DSFS is used on only one side of a multi-lane roadway, it can add to larger speed differentials. When DSFS are used on multi-lane facilities, a unique DSFS per lane should be used.

Other Traffic Control

Specific recommendations for the use of DSFS with other traffic control include the following:

- DSFS are more likely to be effective when used with regulatory rather than advisory speed limits.
- Posted speed limit signs should be used in conjunction with a DSFS to remind drivers of the target speed.
- The decision to place a DSFS should be made in consideration of the other traffic control present in an area. Sign clutter or over-use of traffic control may lessen the impact of a DSFS.

School Zones

In school zones, additional consideration may be given to what constitutes a demonstrated speeding problem. The criteria may include the following:

- The 85th percentile speed is 3 mph or more over the posted speed limit.
- Speed-related crash problem

Roadway Context

The characteristics of the surrounding roadway should be considered, including the following:

- Sight distance
- Horizontal/vertical curvature
- Whether right of way or shoulder/side characteristics impact the ability to place signs as recommended by the manufacturer

Other

Before installing an electronic radar-based sign, consider a progressive approach to applying countermeasures, starting with lower cost alternatives.

2. TERMINOLOGY

85th percentile speed*:* Speed at or below which 85% of drivers are traveling

Advisory speed: Recommended speed for a specific condition where there is a need to reduce the travel speed below the posted speed limit

Annual average daily traffic (AADT): Estimate of the average 24-hour traffic volume for a location

Crash modification factor (CMF): A multiplicative factor to estimate the expected number of crashes given the effects of a specific countermeasure at a particular location

Countermeasure: Treatment applied to a roadway to achieve some positive impact such as a speed or crash reduction; the terms "device," "strategy," or "feature" are sometimes also used in practice

Design speed: The selected speed used to determine the various geometric design features of a roadway

Manual on Uniform Traffic Control Devices (MUTCD): Standards for installation and maintenance of traffic control devices on all public streets, highways, bikeways, and private roads that are open to public travel

Mean speed: Average speed of all vehicles at a particular point

Measure of effectiveness: A metric used to assess how well a countermeasure is performing

Operating speed**:** Speed at which vehicles are operating during free-flow conditions

Posted speed: Maximum lawful speed for a particular location

Road safety audit: A formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team

Rural transition zone: The area between a high-speed roadway and rural town or village where speeds are stepped down to transition drivers to the lower posted speed limits within the community

Severity: Worst severity sustained by an individual in a motor vehicle crash

Speeding*:* Typically defined as a driver exceeding the posted speed limit or traveling too fast for conditions

Speed management: Strategies or countermeasures to achieve a desired speed for a particular facility; used interchangeably with traffic calming

Speed zone: Continuous section of roadway to which a speed limit applies

Statutory speed: Numerical speed limit established by state law that applies to various classes or categories of roads in the absence of posted speed limits

Town center: Central part or main business and commercial area of a town

Transition zone: An area where drivers are alerted that the roadway conditions are changing in an effort to give them time to react and slow down to the appropriate speed

Volume: The number of vehicles on a roadway at a particular point in time (e.g., vehicles per hour)

Figure 2 illustrates various speed limit zones.

FHWA 2016a

Figure 2. Graphical representation of speed limit zones

3. EXISTING PRACTICES FOR SETTING SPEED LIMITS

3.1 Background

The primary purpose of a speed limit is to set the maximum reasonable and safe speed at which a normal driver can react to driving situations under favorable weather and visibility conditions to avoid conflicts. Appropriately set speed limits can result in more uniform traffic flow and an appropriate balance between safety and mobility. Speed limits serve as the basis for enforcement when drivers exceed the maximum speed limit, and they provide fairness and context for traffic laws (FDOT 2019, Forbes et al. 2012).

Several approaches are used to set speed limits in the United States (Kim et al. 2019), as described in the following sections.

Statutory

Speed limits are legislated by state or local governments.

Engineering

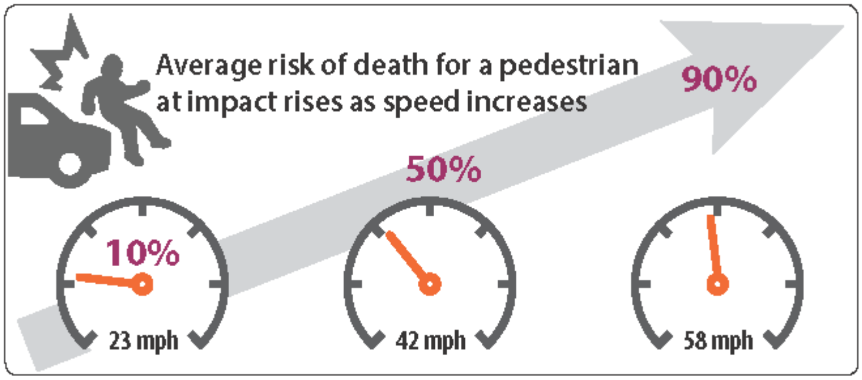
Speed limits are set through a process based on data collection and analysis to determine a reasonable and safe maximum speed limit. This process relies on engineering judgement. In general, base speed limits are set according to the 85th percentile speed, the roadway design speed, and/or other criteria. This base speed limit is then adjusted in consideration of contextual factors such as roadway geometry, traffic volume, or pedestrian presence (Forbes et al. 2012).

Expert System

A knowledge-based computer program is used to assist practitioners in selecting speed limits based on data such as road type, site features, traffic volumes, and crash characteristics. Two systems are used in the United States: USLIMITS and USLIMITS2.

Safe Systems

The safe systems approach sets speed limits according to the crash types that are likely to occur. The primary criterion is the safety of all road users, including pedestrians and bicyclists, who are much more vulnerable to injury and death when hit by a vehicle (see Figure 3).



FHWA 2016a; data source: Teft 2011/AAA Foundation for Traffic Safety

Figure 3. Relationship between vehicle speed and fatality risk for pedestrians

In general, the safe systems approach results in lower speed limits compared to other approaches (ITE 2019).

While this approach has been widely used in Europe, it is not common practice in the United States. A CMF is used to compute the expected number of crashes after implementing a countermeasure on a roadway or intersection. The Federal Highway Administration (FHWA) (Forbes et al. 2012) suggested the following relationship between speed and safety, which is based on a meta-analysis conducted by the Norwegian Institute of Transport Economics. The relationship is for speeds from 15 mph to 75 mph. The relationship does not account for speed variance.

$$CMF = (V_a/Vb)^x$$

Where:

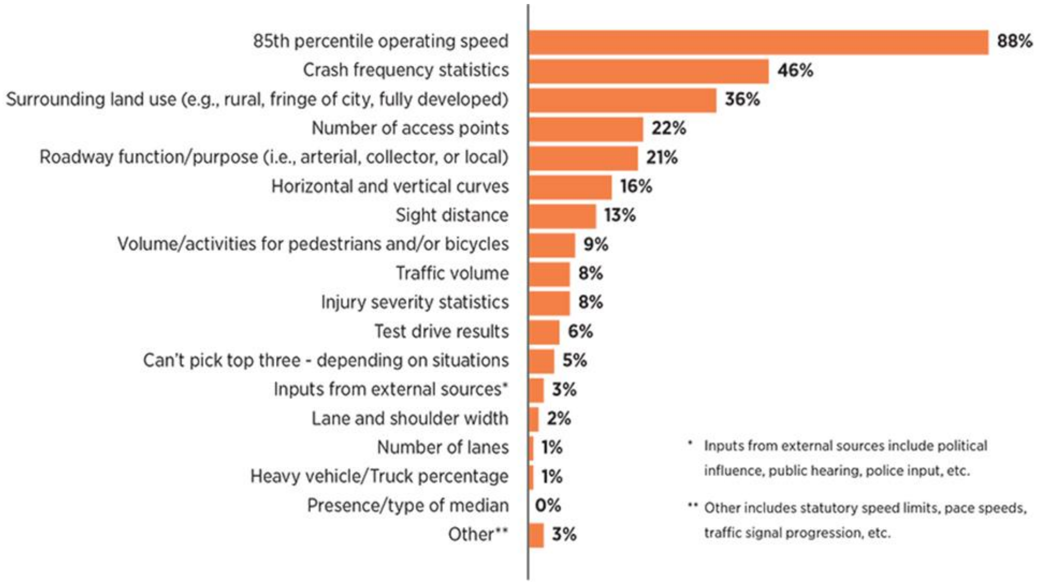
V_a = mean speed after speed reduction countermeasure is applied
Vb = mean speed before speed reduction countermeasure is applied
X = 3.6 for fatal crash frequency
2.0 for injury crash frequency
1.0 for property damage-only crash frequency
4.5 for fatalities
2.7 for personal injuries

Optimization

The optimum speed limit approach minimizes total transport cost, which may include costs associated with vehicle operation, crashes, travel time, noise, and air pollution. The approach favors society as a whole over individual drivers.

Survey of Practices on Factors for Setting Speed Limits

Kim et al. (2019) conducted an online survey to determine current practices for setting speed limits in the United States. Figure 4 illustrates factors that traffic professionals primarily consider when setting speed limits.



Kim et al. 2019/AAA Foundation for Traffic Safety, used with permission

Figure 4. Factors considered in setting speed limits

As shown, 88% of professionals consider 85th percentile operating speeds while 46% consider crash frequency when setting speed limits. Reasons for changing speed limits include the following:

- Changes in infrastructure, network, land use, or road function (63%)
- Public requests to improve mobility (41%)
- Public requests to improve safety (76%)
- Political decisions (47%)
- Existing speed limits too high or low based on 85th percentile speed (26%)

When changing speed limits, 28% of professionals indicated that they often or always consider implementing speed management strategies such as countermeasures or enforcement, 58% sometimes consider implementing speed management strategies, and 14% never consider implementing speed management strategies.

When asked about USLIMITS or USLIMITS2, 30% of professionals had never heard of or had no understanding of these expert systems. Almost half of respondents who were knowledgeable about either of these systems indicated that they never base their decisions on USLIMITS or USLIMITS2. In general, 25% of respondents felt that their own system was easier to use, more effective, or more comprehensive than USLIMITS or USLIMITS2, and 19% indicated that their agency does not recommend the systems. Lastly, around 10% of respondents felt that the systems require data that are not available, and 14% felt that the systems' recommendations are unrealistic or not applicable.

3.2 National Dialog on Setting Speed Limits

In January 2018, the National Committee on Uniform Traffic Control Devices (NCUTCD) developed a task force to assess the recommendations outlined in *Reducing Speeding-Related Crashes Involving Passenger Vehicles* by the National Transportation Safety Board (NTSB). The task force conducted a survey of 740 professionals to identify practices and attitudes related to setting speed limits. Respondents included consultants (27%), state agencies (18%), smaller cities (17%), county/regional agencies (16%), and larger cities (9%) (McCourt et al. 2019). Based on the responses, the task force made the following recommendations to the NCUTCD Council (quoted verbatim from McCourt et al. 2019):

- Use of speed distribution in setting of speed zones is important but is only **one** of the factors in setting speed zones.
- Reinforce that the other factors **should** be considered in conducting speed zone studies and a change from option (may) to guidance (should) should be made (returning it to its historic status).
- The inclusion of **bicycle activity** as one of the factors both in terms of road context and road users.
- Clarify factors to include lane widths, medians, driveways, land use, and past study data. Past studies provide valuable insights into understanding if or how speed distribution may have changed over time (speed creep).
- To clarify the use of the 85th percentile speed, limit the **specificity** of setting speed zones within 5 mph (8 km/hr) of the 85th percentile for freeways, expressways, and rural highways.

The survey responses indicate that industry use and knowledge of USLIMITS2 is limited, and the task force noted the need to determine why. The task force noted that requiring the use of a specific process is not appropriate for the MUTCD. Instead, a process should be included in national guidance documents for agencies to utilize in establishing their policies. Furthermore, the task force noted that setting reasonable speed zones should include consideration of many factors, some of which are not well defined in the MUTCD. The task force recommended that these definitions be included in national guidance documents to allow interpretation by individual agencies rather than being explicitly defined in the MUTCD (McCourt et al. 2019).

Based on the results of the survey and other studies, the NCUTCD voted in January 2019 to send a ballot item to the FHWA to revise the language in the MUTCD regarding setting speed limits (quoted verbatim from McCourt et al. 2019) as follows:

Standard:

01 Speed zones (other than statutory speed limits) shall only be established on the basis of an engineering study that has been performed in accordance with traffic engineering practices.

Guidance:

01a Factors that should be considered when establishing or reevaluating speed limits within speed zones are the following:

A. Speed distribution of free-flowing vehicles (such as current 85th percentile, the pace, review of past speed studies)
B. Reported crash experience for at least a 12-month period relative to similar roadways
C. Road characteristics (such as lane widths, curb/shoulder condition, grade, alignment, median type, sight distance)
D. Road context (such as roadside development and environment including number of driveways, land use, functional classification, parking practices, presence of sidewalks/bicycle facilities)
E. Road users (such as pedestrian activity, bicycle activity)

01b When a speed limit within a speed zone is posted on freeways, expressways, or rural highways, it should maximize the percentage of vehicles in the pace and should be within 5 mph of the 85th percentile speed of free-flowing vehicles.

3.3 State DOT Practices for Setting Speed Limits

The establishment of speed limits varies by state, and within each state the establishment of speed limits can vary by agency (department of transportation [DOT], city, county, etc.). Table 8 provides a summary of practice for several state DOTs.

Table 8. Summary of state practices for setting speed limits

State	Statutory	85th percentile	Engineering judgment	Factors considered
Iowa	√	√	√	• Road type • Traffic control • Crashes • Volume • Sight distance • Pedestrian activity
Arizona		√	√	• Road characteristics • Alignment • Sight distance • Crashes • Parking practices • Pedestrian activity • Signal progression
California			√	• Follows MUTCD
Florida	√	√	√	• Cannot be more than 8 mph lower than 85th • Speed pace • Road characteristics • Signal progression • Sight distance
Georgia			√	• Speed • Roadway characteristics • Crashes
Kentucky		√	√	• Speed • Location • Crashes
Louisiana			√	• High enforcement areas • Geometric restrictions • Inadequate shoulders
Massachusetts	√	√	√	• Speed • Roadway characteristics • Crashes • Must be at least 7 mph lower than 85th

State	Statutory	85th percentile	Engineering judgment	Factors considered
Missouri	√		√	• 85th, upper limit of 10 mph pace or average test run • Roadway characteristics • Fatal/major injury crashes • Pedestrian • Parking • Land use
Montana			√	• 85th, pace and speed profile • Roadway characteristics • Crashes/hazardous conditions • Pedestrian/school/senior center • Parking • Land use • Volume • Seasonal factors
North Carolina		√	√	• Roadway characteristics • Roadway alignment • Land use • Intersections • No more than 35 mph for roadside development and greater than 75% for unimproved roads
Oregon	√		√	• 85th, average speeds • Crashes • Roadway alignment • Pedestrians • Land use • Enforcement • Volume • Public testimony • Access
Texas		√		• 85th, even when higher than inferred design speed • New roads designed for the highest anticipated posted speed

State	Statutory	85th percentile	Engineering judgment	Factors considered
Wisconsin	√		√	• 85th and 50th speeds • Crashes • Roadway characteristics • Access points • Parking • Pedestrian/bicycle • Winter maintenance
Wyoming	√	√	√	• Roadway characteristics • Crashes • Parking • Pedestrian • May not be below the 50th or lower limit of 10 mph pace

The following sections describe practices for setting speed limits in states where additional information was available.

Iowa Department of Transportation (Iowa DOT)

Legal speed limits are set by Iowa Code Section 321.285 (Iowa DOT 2010). The most common statutory speeds include the following:

- 20 mph in business districts
- 25 mph in residential and school districts
- 45 mph in suburban districts
- 55 mph on rural highways
- 65 mph on selected multi-lane highways
- 70 mph on rural Interstate highways

Whenever statutory speed limits are not appropriate for a specific section of a highway, speed limits on state and federal highways are based on an engineering study that considers several factors, such as the following:

- Road type and surface (curve, hill, etc.)
- Location and type of access points (intersections, entrances, etc.)
- Existing traffic control devices (signs, signals, etc.)
- Crash history
- Traffic volume
- Sight distances

- Pedestrian activity
- Results of a field review and speed study

The speed analysis includes determining the 85th percentile speed.

Arizona Department of Transportation (ADOT)

ADOT uses *Traffic Engineering Policies, Guidelines, and Procedures* (ADOT 2015). Speed zoning is based on the principle of setting the speed limit as near as practical to the 85th percentile speed. An engineering and traffic investigation is used to evaluate reasonableness and includes the following:

- Length of section
- Alignment
- Roadway width and shoulders
- Surface condition
- Sight distance
- Traffic volume
- Accident experience
- Maximum comfortable speed on curves
- Side friction (roadside development)
- Parking practices and pedestrian activity
- Signal progression

Florida Department of Transportation (FDOT)

FDOT and other Florida agencies use *Speed Zoning for Highways, Roads, and Streets in Florida* (FDOT 2019). Florida has a statute for allowable speed limits on various types of roads, such as the following:

- 65 mph for four-lane divided highways outside an urban area (a population center of more than 5,000)
- 60 mph for county roads

Changing speed limits requires an engineering study, which includes the 85th percentile speed, the upper limit of the 10 mph pace, and an average test run speed. The manual used in Florida stresses uniform speed zoning and enforcement throughout the state. A speed limit 4 to 8 mph lower than the 85th percentile speed may be used when warranted by an engineering study based on factors such as roadway characteristics, crash history, signal progression, or sight distance. Additional consideration may be given when other standard signs and markings are ineffective. Speed limits cannot be set more than 8 mph below the 85th percentile speed. The posted speed limit cannot exceed the design speed.

No minimum speed zone length is specified, but the driver should be able to slow to comply with the speed limit. Exceeding a 10 mph change from one zone to another is discouraged.

School zones are set based on an engineering study for the specific site. Factors to consider include the following:

- Age of children
- Normal approach speed
- Sight distance
- Traffic volume
- Street width
- Presence of other traffic control
- Use of adult crossing guards

Georgia Department of Transportation (GDOT)

GDOT guidelines suggest considering factors such as speed data, roadway geometric design, crash history, and other roadway conditions to set speed limits. The standard process is to conduct a thorough speed study for both directions of travel and to consider three years of crash data. Additionally, GDOT conducts test drives to assess a driver's feel and expectations for the roadway. GDOT also uses the FHWA's online tool USLIMITS to corroborate the results of its engineering studies (FHWA 2016b).

Speed limits below 25 mph are not allowed along state routes; the minimum allowed is 35 mph.

Kentucky Transportation Cabinet (KYTC)

KYTC uses the *Kentucky Traffic Operation Guidance Manual* (2005), which recommends engineering studies that consider the 85th percentile speed, crash history, and location. Speed limits are expected to be regularly reviewed by the districts.

Louisiana Department of Transportation and Development (Louisiana DOTD)

The Louisiana DOTD uses the *Engineering Directives and Standards Manual* (Louisiana DOTD 2014) for state-owned highways. Speed limits are primarily set using the 85th percentile speed except for areas with high enforcement, geometric restrictions, or inadequate shoulders.

Massachusetts Department of Transportation (MassDOT)

MassDOT uses *Procedures for Speed Zoning on State and Municipal Roadways* (MassDOT 2005). Statutory speed limits are used in the absence of special speed regulations. An engineering and traffic investigation is required, which is in compliance with established traffic engineering practices. Speed limits are set in consideration of the 85th percentile speed, roadway conditions, and crash history. For instance, at locations that have a high crash rate attributable to speeding, the speed limit may be set up to 7 mph lower than the 85th percentile speed.

Missouri Department of Transportation (MoDOT)

MoDOT uses the *Missouri Speed Limit Guidelines* (MoDOT 2010). Maximum speed limits are governed by state statutes. For instance, Interstates and freeways in rural areas are set at 70 mph and in urban areas are set at 60 mph.

Prevailing speed is the first consideration for setting speed limits, which is defined as the 85th percentile speed, upper limit of the 10 mph pace, or average test run speed. Speed limits are set at 5-mph increments, but the speed limit cannot be more than 3 mph over the prevailing speed.

Other factors may be considered in selecting the prevailing speed, but the speed limit cannot be set lower than the 50th percentile speed. These other factors, each of which has specific criteria for consideration, include the following:

- Fatal and major injury crash rate
- Total crash rate
- Pedestrian traffic
- Parking
- Adjacent development
- Roadway characteristics

Montana Department of Transportation (MDT)

MDT uses the *Montana Traffic Engineering Manual* (MDT 2007). A speed study is required to change speed limits. The primary factors to consider in determining speed limits are the 85th percentile speed, pace, and speed profile. Other factors that should be considered when selecting speed limits include roadside development, transition zones, adjacent sections, crashes/hazardous conditions, highway geometrics, pedestrian/school/senior centers, parking, traffic mix, and seasonal factors.

North Carolina Department of Transportation (NCDOT)

NCDOT uses the *North Carolina Guidelines for the Establishment of Restrictive Speed Limits* (NCDOT 1995). A traffic study is recommended for speed limits different than the statutory limits. The guidelines also suggest consideration of the following factors:

- 85th percentile speed

- Roadway characteristics, including surface and shoulder characteristics
- Roadway alignment
- Roadside development
- Intersections

The guidelines also recommend using a speed limit of 35 mph or less on a road if the roadside development is 75% or more. Additionally, a speed limit of 35 mph or less is recommended for unimproved roads.

Oregon Department of Transportation (ODOT)

ODOT uses a set of statutory speed limits as follows:

- 15 mph: Alleys and narrow residential roadways
- 20 mph: Business districts, school zones, and some residential districts
- 25 mph: Residential districts, public parks, and ocean shores
- 55 mph: Some open rural highways and trucks on some Interstate highways
- 60 mph: Trucks on some Interstate and open rural highways
- 65 mph: Passenger vehicles, light trucks, motor homes, and light duty commercial vehicles on some Interstate highways, some open rural highways, and trucks on some Interstate highways
- 70 mph: Passenger vehicles, light trucks, motor homes, and light duty commercial vehicles on some Interstate highways

The *Oregon Department of Transportation Speed Zone Manual* (ODOT 2017) describes the process for setting speed limits. Engineering studies are required by statute. A study should consider free-flow speed (average, 85th percentile, and 50th percentile), geometric features, pedestrians and bicyclists, adjacent land use, enforcement, crash history, public testimony, traffic volume, and access.

Texas Department of Transportation (TxDOT)

TxDOT uses *Procedures for Establishing Speed Zones* (TxDOT 2011). The manual contains various traffic engineering studies that have been conducted, the speed zone approval process, and advisory speeds that can be applied by agencies. Speed limits are set based on 85th percentile speed, even when the inferred design speed is lower than the resulting posted speed limit. New roads should be designed for the highest anticipated posted speed limit based on the roadway’s initial or ultimate function.

Wisconsin Department of Transportation (WisDOT)

The Wisconsin Department of Transportation uses *Statewide Speed Management Guidelines* (WisDOT 2009). State statute establishes speed limits for roadways, but state and local governments have administrative authority to change the speed limit. Factors considered in setting speed zones include the following:

- Speed (85th percentile, 50th percentile)
- Crash history
- Roadway geometry (lane width, curves, roadside hazards, sight distances, etc.)
- Density and roadside development (number of driveways and access points)
- Roadway and shoulder characteristics
- Presence of on-street parking
- Pedestrian and bicycle activity
- Level of winter maintenance

Wyoming Department of Transportation (WYDOT)

WYDOT uses the *WYDOT Traffic Studies Manual* (WYDOT 2011). Speed limits are set by state statute as follows:

- 20 mph in school zones
- 30 mph in urban districts
- 30 mph in residential districts
- 30 mph in subdivisions
- 75 mph on Interstate highways
- 65 mph on all other paved roadways
- 55 mph on all other unpaved roadways

Other speed limits require an engineering study, which includes an analysis of free-flow speeds. In general, 85th percentile speeds are used, but other factors such as roadway characteristics, land use, parking, pedestrian activity, and crash history are also considered. When a speed limit below the 85th percentile speed is justified, the speed limit may not be below the 50th percentile speed or the lower limit of the 10 mph pace.

3.4 State DOT Practices for Establishing Speed Zone Lengths

Speed zones are continuous segments of roadway that have the same speed limit. The practices for establishing the length of these zones vary from state to state. A summary of state DOT practice is provided in Table 9.

Table 9. Summary of state practices for setting speed zone length

State	Speed Zone Length Criteria
Alaska	• Greater than or equal to distance traveled in 25 sec at existing speed limit
Louisiana	• Greater than or equal to 1,000 feet for speed limits 35 mph or higher • Greater than or equal to 2,500 feet for speed limits 40 mph or lower
Massachusetts	• Greater than or equal to 0.5 miles • Rural: normally 0.2 miles
Missouri	• Should have logical beginning and end points • Greater than or equal to 2 miles for unincorporated or rural areas
Oregon	• Greater than or equal to 0.25 miles
Wisconsin	• Greater than or equal to 0.3 miles

The following sections describe practices for setting speed zone lengths in states where additional information was available.

Alaska Department of Transportation and Public Facilities (Alaska DOT&PF)

The minimum speed zone length is equal to the distance traveled in 25 seconds at the existing speed limit (Forbes et al. 2012).

Louisiana Department of Transportation and Development (Louisiana DOTD)

The minimum speed zone length is 1,000 feet for speed limits less than or equal to 35 mph and 2,500 feet for speed limits greater than or equal to 40 mph (LaDOT 2014).

Massachusetts Department of Transportation (MassDOT)

The minimum speed zone length is 0.5 miles. In rural areas, each zone in a series of graduated speed zones is normally 0.2 miles. If the speed limit changes by 15 mph or more from one zone to the next, a REDUCED SPEED AHEAD sign is used (Forbes et al. 2012).

Missouri Department of Transportation (MoDOT)

MoDOT suggests that speed zones should have logical beginning and end points (i.e., city limits, intersection). A length of at least two miles is suggested for unincorporated or "non-community" areas (MoDOT 2010).

Oregon Department of Transportation (ODOT)

Specifies speed zones should be at least 0.25 miles (ODOT 2019).

Wisconsin Department of Transportation (WisDOT)

Speed zones should be at least 0.3 miles (WisDOT 2009).

3.5 State DOT Practices for Using Transition Zones

Transition zones provide an area where drivers are alerted that the roadway conditions are changing in an effort to give them time to react and slow down to the appropriate speed. In order to gain motorist compliance, it is critical to establish transition zones that are properly designed with realistic speed limits. The physical extent of the transition zone is based on the distances needed to achieve a speed reduction, the posted speed limits, and the characteristics of the surrounding area, which may be obtained from direct observation, discussions with local residents or businesses, or a review of the area's speed and crash history (Torbic et al. 2012).

The need for a transition zone, along with its length and speed limit, is typically determined through an engineering and traffic investigation (TxDOT 2015). The following may also be considered:

- Roadway operating speeds in advance of the speed reduction
- Safety or operational issues that are due to posted speed limit differentials
- History of aggressive braking at the entrance to the reduced speed limit area
- Lack of speed compliance in the lower speed limit area
- Whether motorists are expected to comply with the transition speed zone

Forbes et al. (2012) recommends estimating transition zone speed limits by dividing the overall speed reduction by 50% (Forbes et al. 2012). For instance, the transition zone along a 60 mph roadway entering a community with a posted speed limit of 30 mph produces a difference of 30 mph. This 30 mph divided in half results in 15 mph. So, the transition zone speed limit would be 30 mph plus 15 mph, or 45 mph in total, through the transition zone.

Transition zone practices vary among agencies and states. Table 10 provides a summary of these practices.

Table 10. Summary of state practices for using transition zones

State	Criteria
Colorado	• Speed limit difference greater than or equal to 15 mph
Kentucky	• Normal transitions of 55 mph to 45 mph and 35 mph to 25 mph
Louisiana	• Allow sufficient distance to slow to new speed • Transition speed no more than 10 mph lower than higher speed
Maine	• Greater than or equal to 0.25 miles
Massachusetts	• 40 mph for undivided highways outside of densely settled/business areas for 0.5 miles • 50 mph for divided highways outside of densely settled/business areas for 0.25 miles
North Dakota	• Speed limit difference greater than or equal to 20 mph
Oregon	• Greater than or equal to 1,000 feet • Speed limit difference between adjoining roadways at least 10 mph
Texas	• Speed limit difference greater than or equal to 15 mph • Greater than or equal to 0.2 miles
Virginia	• Use on 65 mph roads • Use 60 mph to 55 mph transition zones near city limits
Wisconsin	• Less than or equal to 0.3 miles • Consider if physical characteristics of road change • No more than two transition zones on a given road • Only use when 85th percentile speeds indicate a need

The following sections describe practices for using transition zones in states where additional information was available.

Colorado Department of Transportation (CDOT)

CDOT suggests the use of a transition zone when the speed limit difference is 15 mph or more (Hildebrand et al. 2004).

Kentucky Transportation Cabinet (KYTC)

KYTC uses normal transitions of 55 mph to 45 mph and 35 mph to 25 mph (KYTC 2005).

Louisiana Department of Transportation and Development (Louisiana DOTD)

Transition zones are not required. If they are used, they should allow sufficient distance for a driver to slow to the new speed. The speed limit in the transition zone should not be more than 10 mph lower than the speed limit in the higher speed area (Louisiana DOTD 2014).

Massachusetts Department of Transportation (MassDOT)

MassDOT suggests a transition zone speed limit of 40 mph for undivided highways outside of a densely settled area or business district for 0.5 miles or 50 mph on a divided highway outside of a densely settled area or business district for 0.25 miles MassDOT (2017).

Maine Department of Transportation (MaineDOT)

MaineDOT suggests a transition zone of at least 0.3 miles (Hildebrand et al. 2004).

North Dakota Department of Transportation (NDDOT)

Transition zones should be used when the speed limit difference is 20 mph or more (NDDOT 2015).

Oregon Department of Transportation (ODOT)

Transition zones should be at least 1,000 feet and should have at least a 10 mph speed limit difference from the adjoining roadways (ODOT 2019)

Texas Department of Transportation (TxDOT)

Texas suggests the use of a transition zone when the speed limit difference is 15 mph or more and suggests a length of 0.2 miles (TxDOT 2015).

Virginia Department of Transportation (VDOT)

VDOT suggests using transition zones on 65 mph roads. A transition from 60 mph to 55 mph is used within or near city limits (Hildebrand et al. 2004).

Wisconsin Department of Transportation (WisDOT)

Transition zones are generally not recommended. When used, they should be less than 0.3 miles in length. Transition zones should be considered if the physical characteristics of the roadway change (i.e., rural to urban, a minimal number of driveways to a significant number of driveways). No more than two transition zones should be used on a given section of roadway. Transition zones should also only be considered when 85th percentile speeds indicate a need (WisDOT 2009).

3.6 State DOT Practices for Setting School Zone Speed Limits

Most states use a school zone speed limit of 15 to 25 mph in urban and suburban areas. Since school zone speed limits are only active for a small portion of the day, Forbes et al.

(2012) recommend that the school zone speed limit be no more than 12 mph below the speed limit on the corresponding roadway. A summary of state practices regarding school zone speed limits is provided in Table 11.

Table 11. Summary of state practices for setting school zone speed limits

State	Criteria
Florida	• Age of children • Normal approach speed • Sight distance • Traffic volume • Street width • Presence of other traffic control • Use of adult crossing guards
Georgia	• Presence of multiple grades and school enrollment of at least 250
Kentucky	• 10 mph lower than normal posted speed limit • Should not be less than 25 mph or greater or greater than 45 mph • Sight distance, roadway conditions, crash history may also be considered
Massachusetts	• Can be posted with approval on non-state roads • 20 mph • Used near K–8 schools • Used when school property abuts public row, school children have direct access from school, or a marked ADA-compliant crosswalk is present
North Carolina	• Not allowed on Interstates or controlled-access highways • Allowed on lower functional classes abutting school property • 10 mph less than 85th percentile speed • Speed limits under 20 mph are not allowed
Oregon	• 20 mph by statute • Applies to roadways adjacent to schools and designated crosswalks
Texas	• When school is visible from roadway • Engineering study is used to determine need
Wisconsin	• 15 mph when conditions are met
Wyoming	• 20 mph when conditions are met

The following sections describe practices for setting school zone speed limits in states where additional information was available.

Florida Department of Transportation (FDOT)

School zone speed limits are set based on an engineering study, with the following factors considered (FDOT 2018):

- Age of children
- Normal approach speed
- Sight distance
- Traffic volume
- Street width
- Presence of other traffic control
- Use of adult crossing guards

Georgia Department of Transportation (GDOT)

To establish a school zone speed limit, multiple grades must be present, and the school's enrollment must be 250 or more, including all students and staff.

Kentucky Transportation Cabinet (KYTC)

The *Kentucky Traffic Operation Guidance Manual* (KYTC 2005) recommends a school zone speed limit that is 10 mph lower than the normal posted speed limit. The school zone speed limit should not be less than 25 mph or greater than 45 mph, but factors such as sight distance, roadway conditions, and crash history may be considered in setting the speed limit.

Massachusetts Department of Transportation (MassDOT)

Safety zone speed limits can be adopted by municipalities with approval on non-state highway roads. Safety zone speed limits are 20 mph and are used in areas with vulnerable populations, such as playgrounds, senior citizen housing, hospitals, high schools, and daycares. School zone signs are used near kindergarten through 8th grade (K–8) schools.

School zone speed limits are set at 20 mph during the hours when children are accessing school grounds. They are used on roadways where the school property abuts the public right of way, school children have direct access to the road from the school proper, or there is a marked ADA-compliant crosswalk (MassDOT 2005).

North Carolina Department of Transportation (NCDOT)

School zones are not allowed along Interstates or controlled-access highways. School zones are allowed on lower functional class roadways if the school property abuts the roadway. The maximum suggested length of the school speed zone is 500 feet upstream and downstream of the school. The *North Carolina Guidelines for the Establishment of Restrictive Speed Limits* recommends a school zone speed limit that is 10 mph less than the 85th percentile speed. However, speed limits less than 20 mph are not allowed (NCDOT 1995).

Oregon Department of Transportation (ODOT)

School zone speed limits of 20 mph are set by statute and apply to roadways adjacent to schools and designated crosswalks. Oregon also uses the *A Guide to School Area Safety* for school zone recommendations (ODOT 2017).

Texas Department of Transportation (TxDOT)

School speed zones are used during the hours when children are going to or from school on roadways where the school is adjacent to or visible from the roadway. An engineering study should be used to determine the need for a school speed limit and to select appropriate traffic control devices (TxDOT 2015).

Wisconsin Department of Transportation (WisDOT)

State statute sets school zone speed limits at 15 mph when appropriate conditions are met (WisDOT 2009).

Wyoming Department of Transportation (WYDOT)

State statute sets school zone speed limits at 20 mph when appropriate conditions are met (WYDOT 2011).

4. EFFECTIVENESS OF DYNAMIC SPEED FEEDBACK SIGNS

DSFS systems are traffic control devices that have successfully been used to reduce vehicle speeds. DSFS systems consist of a speed measuring device, which may use either loop detectors or radar, and a message sign that displays feedback to those drivers who exceed a predetermined speed threshold. The feedback may be the driver's actual speed, a message such as SLOW DOWN, or activation of some warning device, such as beacons or a curve warning symbol.

The utility of this traffic control device is that it specifically targets drivers who are speeding rather than affecting the entire driving population. In this way, the system interacts with an individual driver and may lead to better compliance because the message appears to be more personalized.

When drivers encounter a lower speed section of roadway after traveling at a higher speed for some time, their adaptation to the higher speed causes them to underestimate their speed. In these situations, DSFS are particularly useful at these locations to remind drivers of their own speed and the speed reduction (Forbes et al. 2012).

Speed feedback signs are used both as permanent and temporary traffic control devices. It has been suggested that when DSFS are left in a location for a long period of time, drivers may become acclimated and the device may lose its effectiveness. However, as noted in Section 4.4 and in several of the studies summarized in Section 4.1, DSFS have been shown to be effective long-term solutions.

Typical DSFS configurations include the following:

- A blank display when no vehicles are approaching
- A steady message (e.g., a driver's speed) or a blank display when the approaching vehicle's speed is at or below the posted speed limit
- A flashing message (e.g., a driver's speed) or a targeted message such as SLOW DOWN if the approaching vehicle's speed exceeds the posted speed limit by a certain threshold (e.g., 5 mph over the posted speed limit)

Speed display matrices are often capped to avoid drivers racing against the sign.

In reality, a DSFS may include any traffic control device that measures a driver's speed and then provides a message only when a certain speed threshold is exceeded. These devices include different sign configurations, as shown in Figure 5, or activated light-emitting diodes (LEDs), as shown in Figure 6.

Hallmark et al./CTRE

Figure 5. Typical DSFS sign configurations

Hallmark et al./CTRE

Figure 6. LED-enhanced speed limit sign

Other applications of DSFS include dynamic sequential chevrons, as shown in Figure 7 (left), which are placed on curves and set to activate for drivers traveling over a certain speed threshold, as noted in a study by Smadi et al. (2014).

Smadi et al./CTRE (left) and Hallmark et al./CTRE (right)

Figure 7. Sequential dynamic chevrons (left) and stop sign beacon (right)

Other electronic traffic control devices have also been set to display only at target speeds. A study by Hallmark et al. (2018) evaluated stop sign beacons equipped with a radar (see Figure 7, right). These devices measured drivers' speeds, and the beacon only activated when drivers approached the rural stop at a threshold exceeding the speed at which a driver could reasonably be expected to stop safely.

4.1 Effectiveness

DSFS systems have been shown to successfully reduce vehicle speeds. A number of studies on DSFS are summarized in Table 12 and described in more detail in the following sections.

Table 12. Summary of DSFS studies

Type of Roadway	Mean Speed (mph)	85th Percentile Speed (mph)	Distance (feet)	Exceeding Speed Limit (%)
Urban arterials (2)	-1.0 to -2.0	-1.0 to -3.0	Within 900 ft downstream	
Rural arterial curve (3)	-0.0 to -10.9	-2.0 to -3.0		-14.4 to -26.2%
Rural arterial (1)	No change		Decreases noted from 1,200 ft upstream to 300 to 500 ft downstream	
Multi-lane divided (1)	-2.6			
Collectors (4)	-0.3 to -2.2	-1.0 to -8.0		
School zones (6)	2.0 to -9.2	0.0 to 10.0		up to -92.8%
Transition zones (2)	-0.4 to -7.6	0.0 to -9.0		up to -71.1%

Arterials

DSFS have been evaluated on arterials by several researchers. Jeihani et al. (2012) and Karimpour et al. (2019) conducted evaluations of DSFS on urban arterials. Both studies found modest decreases in speed immediately after installation, while the Karimpour et al. (2019) study found that speeds in general increased at four months after installation.

Several studies have evaluated the use of DSFS along rural arterials. The majority of findings show that speeds decreased after installation and that these decreases were sustained over time. One study noted that the signs were the most effective at a distance of 1,400 feet upstream to a point 500 feet downstream of the DSFS.

Urban Arterial Applications

Jeihani et al. (2012) evaluated the effectiveness of DSFS on an urban arterial (three-lane roadway with a speed limit of 45 mph). The DSFS was a 1.5- by 3-foot dynamic sign that displayed speed with a static YOUR SPEED sign. Speeds were evaluated before and three months after installation at five locations downstream of the DSFS (10, 900, 1,130, 2,390, and 4,060 feet). The authors found that the speed reductions were only sustained for up to 900 feet downstream of the sign.

Karimpour et al. (2019) assessed four existing DSFS on a major arterial (with a 45 mph speed limit) in Tucson, Arizona. The DSFS were installed in advance of signalized intersections. Data were collected for four weeks, and then the signs were disabled for two weeks. The authors found that the 85th percentile speeds were 1 to 3 mph lower and that the mean speeds were 1 mph lower when the signs were active during weekdays. They also found that the mean speeds decreased 1 to 2 mph and that the 85th percentile speeds decreased 1 to 3 mph during the weekend.

Rural Arterial Applications

Ullman and Rose (2005) evaluated DSFS along arterials with sharp horizontal curves. On US 277, the posted speed limit was 30 mph with an advisory speed of 20 mph. The site had experienced issues with large trucks entering the curve too fast and overturning. Rumble strips were already present upstream of the curve. DSFS were installed in both directions of travel, and data were collected immediately after the curve.

In the northbound direction, a 3.5 mph reduction in the mean speed and a 2 mph reduction in the 85th percentile speed were found. Additionally, the percentage of drivers exceeding the posted limited decreased from 91.9% to 65.7% (a decrease of 26.2%). Data were also collected around four months after installation, and no change in any of the speed metrics was found.

In the southbound direction, the mean speed decreased by 2.1 mph, the 85th percentile speed decreased by 3 mph, and the percentage of drivers exceeding the speed limit decreased by 12.2% immediately after installation. Four months after installation, the mean speed was 2.4 mph lower, the 85th percentile speed was 3 mph lower, and the percentage of drivers exceeding the speed limit was 14.4% lower than before installation.

The DSFS' impact on heavy trucks was also measured. In the northbound direction, the mean speed decreased by 0.6 mph, the 85th percentile speed decreased by 2 mph, and a 28.7% decrease in drivers exceeding the posted speed limit was found. Four months after installation, these speed metrics had improved (5.2 mph for the mean speed, 2 mph for the 85th percentile speed, and 11.5% for the percentage of drivers exceeding the posted speed limit).

In the southbound direction, the truck mean speed decreased by 2.3 mph, the 85th percentile speed decreased by 1 mph, and the percentage of truck drivers exceeding the speed limit decreased by 24% immediately after installation. At four months after installation, these speed metrics changed to show an increase of 1.3 mph in the mean speed, a 2 mph increase in the 85th percentile speed, and a 9.1% increase in the percentage of drivers exceeding the speed limit.

Kamyab et al. (2002) evaluated a dynamic speed feedback sign along a rural roadway that passed through a recreational/residential area. Speed data were collected for passenger vehicles before and at one month and two months after installation. Speeds were found to be either unchanged or to exhibit minor increases (about 1 mph).

Santiago-Chaparro et al. (2012) evaluated speeds along a rural corridor in Washington County, Wisconsin, at several locations where DSFS were installed. This two-lane highway had 6-foot paved shoulders, an ADT of 7,000 vpd, and a posted speed limit of 55 mph. DSFS were installed at four locations to complement periodic enforcement. The signs were estimated to be visible for a distance of 2,525 feet upstream of the signs. Speeds were monitored at a point upstream and a point downstream of each of the signs. Vehicle profiles were collected, and data were recorded. The point at which drivers reduced their speed by 1 mph was noted, along with the point where they increased their speed by 1 mph. The most significant reductions were found to occur 1,200 to 1,400 feet upstream of the signs, and speeds began to increase again at 300 to 500 feet downstream of the signs.

Hallmark et al. (2015) conducted a national demonstration project to evaluate the effectiveness of two different DSFS in reducing speeds and crashes on curves at 22 sites on rural two-lane roadways in seven states. One sign displayed a simple speed feedback message when drivers exceeed the posted or advisory speed limit (Figure 8, left), and the other displayed the corresponding speed advisory sign when drivers exceeded the posted or advisory speed limit (Figure 8, right).

Figure 8. Dynamic speed feedback signs on curves

Data were collected before and at 1, 12, and 24 months after installation of the DSFS. On average, most sites exhibited decreases in mean speeds, with decreases of up to 10.9 mph noted at both the point of curvature (PC) and the center of the curve (CC). Most sites experienced decreases in 85th percentile speeds of 3 mph or more at the PC, with the majority of sites exhibiting a decrease of 2 mph at the CC. The number of vehicles traveling 5, 10, 15, or 20 mph over the posted or advisory speed limit were also compared before and after installation. Large reductions in the number of vehicles traveling over the posted or advisory speed limit occurred for all of the periods after installation at the PC and CC, indicating that the signs were effective in reducing high-end speeds, as well as average and 85th percentile speeds.

A before-and-after crash analysis was also conducted, and CMFs were developed. CMFs ranged from 0.93 to 0.95 depending on the crash type and direction of the crash, as shown in Table 13.

Table 13. CMFs for dynamic speed feedback signs

Crash Type	CMF
All in both directions	0.95
All in the direction of the sign	0.93
SV in both directions	0.95
SV in the direction of the sign	0.95

Source: Hallmark et al. 2013a

Bertini et al. (2006) studied the effectiveness of a DSFS system on I-5 near Myrtle Creek, Oregon, on a curve with an AADT of 16,750 vpd and an advisory speed of 45 mph. The system consisted of two displays that provided different messages to drivers based on the speed detected. For instance, one sign displayed CAUTION when vehicles were traveling under 50 mph and SLOW DOWN when vehicles were traveling over 50 mph.

The DSFS systems were put in place alongside one of the existing signs in both the northbound and southbound directions (see Figure 9). Each system consisted of the actual dynamic message sign, a radar unit, a controller unit, and computer software.

Bertini et al. 2006, Portland State University

Figure 9. DSFS on a curve

The results indicated that after installation of the DSFS system, passenger vehicle speeds decreased by 2.6 mph and commercial truck speeds decreased by 1.9 mph, with the results being statistically significant at the 95 percent confidence level. The results of a driver survey indicated that 95 percent of drivers surveyed said that they noticed the DSFS system and 76 percent said that they slowed down due to the system.

Preston and Schoenecker (1999) evaluated the safety effects of a DSFS on County Highway 54 in Minnesota, which is a two-lane rural roadway with a speed limit of 55 mph and an AADT of 3,250 vpd. The curve has an advisory speed of 40 mph.
The DSFS system had a changeable message sign and radar unit. The researchers conducted a field test over a four-day period with a unit that consisted of a closed-circuit

television camera, a VCR, and a personal computer (a portable trailer housed the entire system).

The sign displayed the following:

- CURVE AHEAD from 6 to 10 a.m., 11 a.m. to 2 p.m., and 4 to 7 p.m.
- No message during other times of the day unless activated

The team randomly evaluated whether vehicles negotiated the curve successfully based on the curve messages. Vehicles that crossed a left or right lane line on one or more occasions were identified as not navigating the curve successfully.

The team found that about 35 percent of the drivers who received the static message were unable to negotiate the curve successfully. Vehicles that received the CURVE AHEAD message were more likely to negotiate the curve successfully than vehicles that received no message, but the difference was not statistically significant. Only 26 percent of vehicles that received the activated CURVE AHEAD – REDUCE SPEED message were unable to negotiate the curve successfully, and the difference was statistically significant at the 90 percent confidence level.

Tribbett et al. (2000) evaluated dynamic curve warning systems for advance notification of alignment changes and speed advisories at five sites, which ranged from 7,650 to 9,300 vpd, in the Sacramento River Canyon on I-5 in California. Messages used by the researchers included curve warnings (shown in Figure 10) and driver speed feedback.

Tribbett et al. 2000, Western Transportation Institute, Montana State University

Figure 10. Curve warning sign in the Sacramento River Canyon

Decreases in mean truck speeds (from 1.9 to 5.4 mph) occurred at three sites, and decreases in mean passenger speeds (from 3.0 to 7.8 mph) occurred at four sites.

Collectors

Several studies have evaluated the use of DSFS along collector roadways. Although it was not consistently stated in the studies, these applications were typically in urban environments.

Chang et al. (2004) evaluated the use of DSFS at several locations along a two-lane collector and found mean speed reductions from 0.3 to 1.7 mph at 1 month and from 0.4 to 2.2 mph at 22 months after installation. Decreases in 85th percentile speeds from 1.0 to 1.9 mph and from 2.6 to 6.3 mph were observed at 1 month and 22 months, respectively, after installation of the treatments.

The City of Bellevue, Washington (2009), evaluated DSFS systems on urban two-lane roads with 25 to 35 mph speed limits (see Figure 11).

City of Bellevue, Washington 2009

Figure 11. DSFS system in Bellevue, Washington

For segments with a 25 mph speed limit, the city found a 2.3 mph reduction in 85th percentile speeds on average at one year after installation and a 3.1 mph reduction in a longer term evaluation. The average reduction in 85th percentile speeds for segments with speed limits from 30 to 35 mph was 4.0 mph at one year after installation and 5.7 mph in a longer term evaluation.

The City of Englewood, Colorado (2013), installed DSFS at several locations along collector streets in response to speeding concerns. The speed limit on these roads was typically 30 mph. The average decrease in 85th percentile speeds at 12 months after installation was 4.5 mph.

Jeihani et al. (2012) evaluated the effectiveness of DSFS on an urban collector (a three-lane road with a speed limit of 35 mph). The DSFS was a 15- by 18-inch dynamic sign that displayed the approaching vehicle’s speed with a static YOUR SPEED message. Speeds were evaluated before and after installation. The evaluation revealed a 2.9 mph reduction in mean speed and a 5 mph reduction in 85th percentile speed.

Addison County, Vermont (2013), evaluated DSFS in three rural communities. All were regular DSFS that displayed the approaching vehicle’s speed. At the first site (a 25 mph zone), a fluorescent pedestrian warning sign was also installed. The evaluation found a 4 to 7 mph reduction in mean speed and a 6 to 8 mph reduction in 85th percentile speed at this site. At the second site, a 1 to 4 mph reduction in mean speed and a 3 to 5 mph reduction in 85th percentile speed were found. The third site experienced a 3 mph reduction in mean speed and a 3 mph reduction in 85th percentile speed. These reductions were sustained over a six-year period.

School Zones

School zones are a common location for DSFS. Most studies on DSFS in school zones have found a decrease in various speed metrics after installation of the countermeasure, as noted in the following summaries.

Jeihani et al. (2012) evaluated the effectiveness of a DSFS on a residential road with a 25 mph school zone. The DSFS was a 15- by 18-inch dynamic sign that displayed the approaching vehicle’s speed with a static YOUR SPEED sign. The authors evaluated speeds before and after installation and found a 0.2 mph reduction in mean speed and no change in 85th percentile speed. The report does not provide specific results regarding speeds during sign activation.

Ullman and Rose (2005) evaluated DSFS at several school zone locations. The display showed YOUR SPEED as a static message along with the vehicle’s speed. One application was along a two-lane rural/suburban highway with a school zone speed limit of 35 mph (and a 55 mph posted speed limit). The DSFS was installed in conjunction with a beacon that flashed when the school zone speed limit was active. The evaluation revealed a 9.2 mph decrease in mean speed and a 10 mph decrease in 85th percentile speed immediately after installation. At four months after installation, mean speeds were 8.8 mph lower and 85th percentile speeds were 8 mph lower than before installation. Results are presented for when the school zone speed limit was active.

Ash (2006) evaluated DSFS at four school zones in Utah. The devices displayed the static text YOUR SPEED and the driver’s speed in mph. The first site, SR 89 in Logan, is a four-lane roadway with a 35 mph posted speed limit and a 20 mph school zone speed limit. Mean speeds decreased by 3 mph and 85th percentile speeds decreased by 3 mph. The number of vehicles exceeding the 20 mph speed limit also decreased by 39%. The second location, on State Street, has an approach speed of 35 mph with six lanes and a school zone speed limit of 20 mph. For this location, the mean speed increased slightly for northbound traffic but decreased 2 mph for southbound traffic. The 85th percentile speed was unchanged for northbound traffic but decreased 2 mph for southbound traffic. The third site, SR-146, is a two-lane highway with an approach speed of 35 mph and a school zone speed limit of 20 mph. At this site, the mean and 85th percentile speeds decreased by around 1 mph for northbound traffic. The fourth site, US 6, is a two-lane road with a 35 mph approach speed and 20 mph school zone speed limit. A slight increase in the mean and 85th percentile speeds (of about 2 mph) was found for the eastbound direction while a minor decrease in the mean and 85th percentile speeds (of less than 0.5 mph) was found for the westbound direction.

O'Brien et al. (2012) evaluated DSFS in school zones. The authors used a YOUR SPEED static sign with the driver's speed below in conjunction with a school zone speed limit sign and a flashing beacon. The study revealed a 2.9 to 4.5 mph reduction in mean speed over a 12-month period after installation, with a decrease of 0.7 to 7.0 mph in the 85th percentile speed. Additionally, the percentage of vehicles traveling over the posted speed limit decreased by 9% to 25%. In all cases, the speed reductions were sustained over the 12-month period.

Hallmark and Hawkins (2009) evaluated a DSFS near a school zone in the rural community of Slater, Iowa. The sign had the capability of displaying two rows of alphanumeric characters (Figure 12) so the sign message could be customized.

Hallmark et al./CTRE

Figure 12. DSFS system in Slater, Iowa

The sign was placed and evaluated at the north community entrance (County Road/CR R-38) to the town. CR R-38 is a rural two-lane paved roadway with earth shoulders and a posted speed limit of 25 mph.

The sign was set to display the following depending on the approaching driver's speed:

- No display if the approaching vehicle was traveling over 75 mph
- A flashing SLOW DOWN 25 message if the approaching vehicle was traveling over 40 mph but under 75 mph
- A YOUR SPEED message and the vehicle's speed if the approaching vehicle was traveling between 26 and 29 mph

Data were collected before installation of the sign and at three months after installation, as shown in Table 14.

Table 14. Results for alphanumeric feedback sign at the north community entrance in Slater, Iowa

Measure	Before	1 Month	Change
Sample	4,566	4,121	NA
Mean speed	31.3	25.9	-5.4
85th percentile speed	37	30	-7
Fraction of vehicles traveling ≥ 5 mph over posted speed limit	0.64	0.16	-75.6%
Fraction of vehicles traveling ≥ 10 mph over posted speed limit	0.29	0.03	-90.8%
Fraction of vehicles traveling ≥ 15 mph over posted speed limit	0.07	0.01	-92.8%

Source: Hallmark et al. 2013b

As the table shows, decreases of 5 mph in the mean speed and 7 mph in the 85th percentile speed were found. The table also shows significant reductions in the percentage of vehicles traveling over the posted speed limit.

Williamson et al. (2016) assessed the impact of a DSFS along a road segment entering a university campus (Southern Illinois University, Edwardsville campus). A radar speed trailer was placed at the location on the road where drivers first encounter pedestrians within the university campus. Drivers at this location had been traveling on roadways with 55 to 65 mph speed limits prior to approaching the 25 mph zone. The display showed the posted speed limit as well as the driver's speed. The report did not provide speed metrics, but one of the conclusions was that the DSFS had different impacts depending on the time of day. The greatest decrease in speeds occurred during the p.m. peak period. Immediately after installation, there was an 85.6% reduction in the percentage of drivers exceeding the speed limit, with a reduction to 80.0% one year later.

Transition Zones

DSFS have been used in the transition zones between high-speed and low-speed roadways. In most studies of DSFS in transition zones, the signs were placed in rural communities. As noted below, studies have generally found that speeds decreased after installation of the DSFS and that the reductions were sustained over time.

Several studies were conducted within the transition zone into a small rural town in Iowa. The DSFS installed was a simple speed feedback display (Figure 13).

Hallmark et al./CTRE

Figure 13. DSFS in Rowley, Iowa

The sign displayed a static YOUR SPEED message and the approaching driver's speed in mph. One sign was installed at the east community entrance of Rowley, Iowa, along County Road D-47 (which runs 55 mph outside of the community and 25 mph within the community). The traffic volume was 610 vpd at the east entrance. The results of one speed study at this location are shown in Table 15.

Table 15. Results for simple speed feedback sign at Rowley, Iowa, east community entrance

Measure	Before	1 Month	Change	12 Month	Change
Mean speed	36.7	29.1	-7.6	30.8	-5.9
85th percentile speed	44	35	-9	38	-6
Fraction of vehicles traveling ≥ 5 mph over posted speed limit	0.84	0.46	-45.2%	0.56	-33.3%
Fraction of vehicles traveling ≥ 10 mph over posted speed limit	0.64	0.17	-73.4%	0.30	-53.1%
Fraction of vehicles traveling ≥ 15 mph over posted speed limit	0.38	0.08	-78.9%	0.11	-71.1%

Source: Hallmark et al. 2013b

As the table shows, mean speeds decreased by 7.6 mph at 1 month and 5.9 mph at 12 months after installation, and 85th percentile speeds decreased by 9 and 6 mph at 1 and 12 months, respectively. There was also a significant decrease in the percentage of vehicles traveling over the posted speed limit (Hallmark et al. 2013b).

Two DSFS were placed in transition zones into Union, Iowa. One of these was at the north community entrance along S-62, which has a traffic volume of 1,680 vpd and a speed limit of 55 mph outside of town and 30 mph at the north community entrance (Figure 14).

Hallmark et al./CTRE

Figure 14. DSFS system in Union, Iowa

The second DSFS in Union, Iowa, was placed at the west community entrance along CR D-65, which has a traffic volume of 830 vpd and a speed limit of 55 mph outside of the community and 25 mph at the west community entrance. The results for these locations are provided in Table 16.

Table 16. Results for two simple speed feedback signs at Union, Iowa, community entrances

Measure	North			West		
	Before	1 Month	Change	Before	1 Month	Change
Mean speed	33.9	29.3	-4.6	44	38.7	-5.3
85th percentile speed	40	35	-5	52	49	-3
Fraction of vehicles traveling ≥ 5 mph over posted speed limit	0.45	0.17	-62.4%	0.94	0.82	-12.0%
Fraction of vehicles traveling ≥ 10 mph over posted speed limit	0.19	0.05	-73.4%	0.86	0.65	-24.7%
Fraction of vehicles traveling ≥ 15 mph over posted speed limit	0.06	0.01	-76.4%	0.73	0.45	-38.2%

Source: Hallmark et al. 2013b

As the table shows, average speeds decreased by about 5 mph for both signs and 85th percentile speeds decreased by 3 to 5 mph (Hallmark and Hawkins 2009).

Another type of DSFS was evaluated at two rural community entrance locations in Iowa. These DSFS included LED lights embedded around the outside of the sign, as shown in Figure 6. The LED lights would be dark until a vehicle was detected traveling 5 mph or more over the posted speed limit. The LED lights were then activated (Hallmark et al. 2013).

The first DSFS was placed at the east community entrance to St. Charles, Iowa, along IA 251 (West Main Street), which has a traffic volume of 2,240 vpd. IA 251 is posted at 55 mph outside the community entrance and 25 mph within the community. The second DSFS was placed at the west community entrance to Rowley, Iowa, along CR D-47, which has a traffic volume of 980 vpd. CR D-47 is also posted at 55 mph outside the community entrance and 25 mph within the community.

The results for the sign in St. Charles are shown in Table 17.

Table 17. Results for radar-activated LED-enhanced speed limit sign at St. Charles, Iowa, east community entrance

Measure	Before	1 Month	Change	12 Month	Change
Mean speed	29.0	38.6	-0.4	28.4	-0.6
85th percentile speed	35	35	0	34	-1
Fraction of vehicles traveling ≥ 5 mph over posted speed limit	0.46	0.42	-8.7%	0.41	-10.9%
Fraction of vehicles traveling ≥ 10 mph over posted speed limit	0.18	0.16	-11.1%	0.14	-22.2%
Fraction of vehicles traveling ≥ 15 mph over posted speed limit	0.04	0.05	25.0%*	0.03	-25.0%

*not statistically significant at 95% confidence level
Source: Hallmark et al. 2013b

As the table shows, only a minor decrease in speeds occurred at the St. Charles site, with a 0.4 mph decrease in the mean speed at 1 month and a 0.6 mph increase at 12 months after installation. No change in the 85th percentile speed was observed at 1 month after installation, and a decrease of 1 mph was observed at 12 months after installation.

The fraction of vehicles traveling 5 mph or more over the posted speed limit decreased by around 8% and 11% for both the 1- and 12-month after periods, respectively. The fraction of vehicles traveling 10 mph or more over the posted speed limit decreased by 11% and 22% at 1 and 12 months, respectively. Finally, the fraction of vehicles traveling 15 mph or more over the posted speed limit (25%) increased at 1 month, although the change was not statistically significant. At 12 months, the fraction traveling 15 mph or more over the posted speed limit decreased by 25%.

The results for the second LED-enhanced sign, located in Rowley, are shown in Table 18.

Table 18. Results for radar-activated LED-enhanced speed limit sign at Rowley, Iowa, west community entrance

Measure	Before	1 Month	Change	12 Month	Change
Mean speed	37.8	31.9	-5.9	32.4	-5.4
85th percentile speed	49	42	-7	43	-6
Fraction of vehicles traveling ≥ 5 mph over posted speed limit	0.75	0.56	-25.3%	0.61	-18.7%
Fraction of vehicles traveling ≥ 10 mph over posted speed limit	0.67	0.40	-40.3%	0.42	-37.3%
Fraction of vehicles traveling ≥ 15 mph over posted speed limit	0.51	0.24	-52.9%	0.25	-51.0%

Source: Hallmark et al. 2013b

Decreases of almost 6 mph in the mean speed and 7 mph in the 85th percentile speed occurred 1 month after installation of the sign. The decreases in the fraction of vehicles traveling 5, 10, or 15 mph or more over the posted speed limit were 25%, 40%, and nearly 53%, respectively.

The results at 12 months after installation were similar to those at 1 month after, with decreases of about 5 to 6 mph in the mean and 85th percentile speeds. The fraction of vehicles traveling 5, 10, or 15 mph over the posted speed limit also decreased by about 18%, 37%, and 51%, respectively.

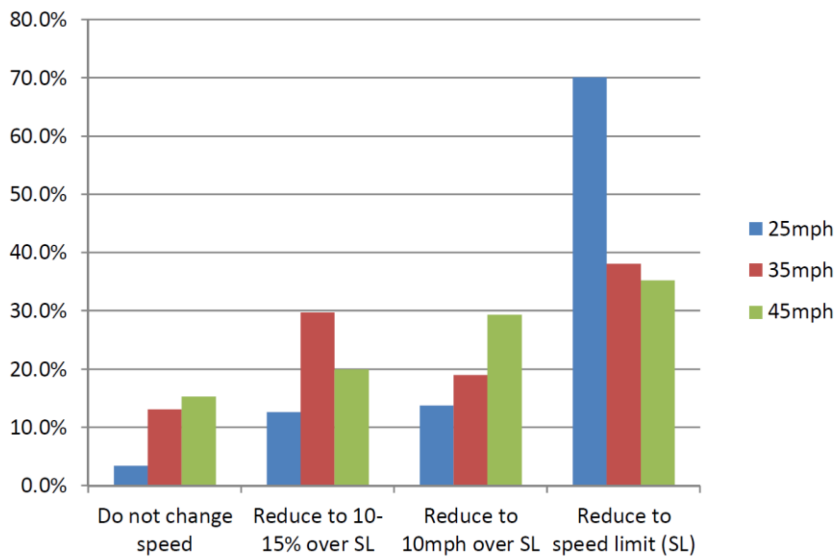
Cruzado and Donnell (2009) evaluated DSFS at 12 transition zones along rural two-lane highways entering rural communities in Pennsylvania. Speed decreases ranged from 0.7 to 8.4 mph, with an average speed reduction of 5.9 mph.

Sandberg et al. (2008) evaluated DSFS in speed transition zones from rural county roads into urbanized areas at four different locations in Minnesota. The average decrease in mean speed was 5.4 mph at 2 months after installation and 6.6 mph at 12 months after installation. The average reduction in the 85th percentile speed was 5 mph at both 2 and 12 months after installation.

4.2 Driver Attitudes toward DSFS

Jeihani et al. (2012) conducted a survey of driver attitudes and reactions to DSFS in Baltimore, Maryland. The study was distributed to students in the Morgan State University Department of Transportation and Urban Infrastructure Studies. Students were asked to complete the survey or distribute it to a friend or family member. Of the 88 responses, 95% indicted that the respondent was familiar with DSFS, and 77% indicated that the respondent encountered a DSFS at least a few times per month.

Respondents were asked how much they reduced their speed when they encountered a DSFS on a 25, 35, or 45 mph roadway. As shown in Figure 15, 70.1% indicated that they would reduce their speed when encountering a DSFS on a 25 mph roadway, while only 35% to 38% would reduce their speed on a 35 or 45 mph roadway.



Jeihani et al. 2012, Morgan State University National Transportation Center

Figure 15. Driver response to DSFS by speed limit

The majority of respondents (63%) indicated that they reduced their speed after passing a DSFS because they believed they may receive a speeding ticket, and 37% slowed down after passing a DSFS because they did not realize they were speeding and the DSFS reminded them of their speed. While the survey results suggested that DSFS did appear to positively impact driver behavior, almost half of the respondents (48%) said that they would increase their speed if their speed was lower than the speed limit. About 55% of drivers believed that DSFS increase safety, and 25% believe that they improve both safety and traffic flow.

Addison County, Vermont (2013), conducted a survey on DSFS in school zones. Drivers were asked to rank five different factors that influenced their speed in a school zone: presence of children, presence of law enforcement, presence of a crossing guard, presence of a DSFS, and flashing beacons on school zone speed limit signs. The presence of children had the highest impact, followed by flashing beacons on school zone speed limit signs and then presence of law enforcement. Presence of a crossing guard was ranked fourth and presence of a DSFS was ranked last. This low ranking for DSFS may be due to the fact that drivers regularly encounter the first four factors but encounter DSFS less frequently. Drivers were also asked how helpful DSFS were in informing them of their speed. Over 85% of drivers ranked them as very helpful, helpful, or sometimes helpful; over 72% of drivers responded that they are effective in warning of a danger ahead; and 84% indicated that they were effective in making drivers slow down.

4.3 Summary of Guidelines for Use of DSFS

Although DSFS have been generally shown to be effective, agencies prefer select application of these devices for several reasons. Although their cost is relatively low, i.e., $2,500 or more, this amount is still a significant outlay of resources for a small agency.

Additionally, these signs require regular maintenance, including calibration and monitoring to ensure that they are positioned properly. Some agencies are also concerned that, without guidelines for using these devices, requests by citizens for their application will escalate. Another concern is that overuse of the devices may cause drivers to pay less attention to them.

A number of groups have developed guidelines for use of DSFS. In general, most of the guidance suggests that their use be limited to locations where there is a demonstrated speed issue. Some guidance suggests that DSFS may be more effective on roadways with speed limits under 35 mph. However, some guidance suggests that their use on higher speed roadways is preferred. Guidance from various agencies is summarized in Table 19.

Table 19. Summary of factors considered by agencies when placing DSFS

Metric	Considerations for Use
85th percentile speed	• Greater than 5 mph over the posted speed limit • Greater than the posted speed limit plus 5 mph (3 mph in a school zone)
Mean	• Greater than 5 mph over the posted speed limit
Average daily traffic	• Greater than 500 vpd
Crashes	• Correctable speed-related problem exists within a recent period
Pedestrians	• Within 500 yards of a major pedestrian generator • Primarily a residential or heavily traveled pedestrian area • Pedestrian-based crash problem exists
Posted speed limit	• Greater than 25 mph • Less than or equal to 35 mph • Less than or equal to 40 mph • High-speed signalized intersection approaches where speed limit is greater than 45 mph
Other traffic control	• More effective with other indicators, such as school zone speed limit beacon, signal change warning, etc. • More effective with regulatory than advisory speed limit • The DSFS supports a driver information system that provides a clear and real need to reduce speeds • Less effective at locations with an overabundance of driver information
Other Roadway Characteristics	• More effective if sight distance less than decision sight distance • More effective on two-way two-lane or one-way one-lane roads, where lead vehicles that slow impact the following vehicles • Discouraged in non-residential areas • Not appropriate on freeways or major arterials except in work zones
Transition zones	• High to low speed • Change in speed greater than 10 mph
Work zone	• Work zone speed limit greater than 35 mph • Mean speed greater than 10 mph over posted speed limit • 85th percentile speed greater than 10 mph over posted speed limit • When speed-related crashes have occurred
School zone or park	• Within 0.5 miles of school zone or park • Posted speed limit at school zone or park greater than 15 mph • 85th percentile speed greater than 5 mph over posted speed limit OR mean speed greater than 5 mph over posted speed limit OR ADT greater than 500 vpd OR supplement to advisory or conditional speed limit is already in place

More detailed descriptions of various guidelines are provided in the following sections.

Iowa

The *Iowa Design Manual* includes guidance specific to speed feedback trailers (Iowa DOT 2019). The manual suggests that DSFS are more likely to be effective in the following cases:

- In areas with higher speeds
- If the perception of regular enforcement (and the threat of citation) exists
- If the sight distance is less than the decision sight distance
- In locations with one lane per direction
- If used with other indicators of a need to reduce speed
- If the DSFS trailer supports a regulatory speed limit
- If the overall information system at the location does not overwhelm the speed display sign
- When not overused
- When rotated among sites
- During the initial stages of deployment

The guidance suggests that the changeable message portion should display the driver's speed in mph and be supplemented by the permanent or work zone speed limit. A black-on-white YOUR SPEED sign is displayed above the changeable message portion.

Speed feedback trailers should be programed with the following guidelines:

- The changeable message portion should be blank when no vehicles are present.
- The threshold speed settings should be set at 30 mph over the speed limit.
- When the driver's speed is over the threshold, the changeable message portion should be blank.
- Only speed values may be used; other text, icons, strobe lights, or flashing lights should not be used.
- The changeable message portion should only operate when the regulatory speed limit is in effect, workers are present, or roadway conditions warrant reduced speeds for traffic safety.
- Countdown functions should not be used.

Trailers should be placed at the point of speed reduction, immediately adjacent to workers or work activity, or in advance of areas requiring speed reduction. When only a single lane is present, the trailer can be placed on either side of traffic. When two or more lanes are present and one adjacent lane is closed, the trailer should be placed in the closed adjacent lane. Trailers should not be placed more than one mile in advance of work activity or locations warranting reduced speeds. An effective distance of 1,000 feet should be assumed. Trailers should not be placed on curves.

Other Guidelines

Veneziano et al. (2012) summarized California's guidance on the use of DSFS, which includes the following:

- DSFS that display vehicle speeds should use the legend YOUR SPEED.
- Numeric displays should be white, yellow, yellow-green, or amber colored on a black background.
- When activated, the display should be steady.
- DSFS should not be alternatively operated as variable speed limit signs.
- As far as practical, the numerals for displaying speeds should be similar in font and size to the numerals on the corresponding speed limit sign.
- DSFS may be mounted on either a separate support or the same support as the speed limit sign.
- DSFS are appropriate for use with advisory speed signs and with temporary signs in temporary traffic control zones.

Veneziano et al. (2012) also developed general guidance on the use of DSFS, as shown in Table 20. Location-specific guidance is provided in Table 21.

Table 20. General guidance for use of DSFS

Metric	Guidance
85th percentile speed	May be considered if 85th is greater than 5 mph over the posted speed limit
Mean	May be considered when mean speed is greater than 5 mph
Average daily traffic	May be considered when ADT is greater than 500 vpd
Crashes	May be considered when a correctable speed-related problem exists within a recent period
Pedestrians	May be used when a pedestrian-based crash problem exists
Posted speed limit	May be considered in conjunction with other guidance when posted speed limit is over 25 mph

Source: Veneziano et al. 2012

Table 21. Location-specific guidance for use of DSFS

Location	Guidance
School zones and parks	Within 0.5 miles of school zone or park
	Posted speed limit at school or park is over 15 mph
	85th percentile speed is more than 5 mph over posted speed limit OR Mean speed is more than 5 mph over posted speed limit OR ADT is greater than 500 vpd OR A supplement to the advisory or conditional speed limit is already in place
Street conditions	High- to low-speed transition zone
	Curve warning advisory sign is present
	High-speed signalized intersection approaches where speed limit is greater than 45 mph
Work zones	Work zone speed limit is greater than 35 mph
	Observed mean speed is more than 10 mph over posted speed limit
	85th percentile speed is greater than 10 mph
	When speed-related crashes have occurred

Source: Veneziano et al. 2012

A pooled fund study that developed guidance for the installation and use of devices for transportation operations and maintenance included guidance on the use of DSFS (ENTERPRISE 2015). The recommendations are summarized as follows, though the basis for the recommendations was not stated:

- The 85th percentile speed is greater than the posted speed limit plus 5 mph (3 mph in a school zone).
- The transition zone has a change in speed of 10 mph or more.
- The DSFS is located within 500 yards of a major pedestrian generator.
- The DSFS is located in a primarily residential or heavily traveled pedestrian area.
- The posted speed limit less than or equal to 35 mph.

Addison County, Vermont (2013), conducted several studies on DSFS. The studies suggest that DSFS are more effective on lower speed roadways (with speed limits of 40 mph or less) in locations such as school zones or neighborhood collectors, while they may be less effective on higher speed roadways. However, the studies did not evaluate DSFS on multiple types of roadways.

Rose and Ullman (2003) evaluated DSDS on several types of roadways and developed the effectiveness guidelines provided in Table 22.

Table 22. Effectiveness of DSFS

Characteristics	Impact on DSFS
Perceived enforcement	• More effective with perception of regular enforcement
Sight distance	• More effective if sight distance is less than decision sight distance
Number of travel lanes	• More effective on two-way, two-lane or one-way, one-lane roadways, where lead vehicles that slow impact the following vehicles
Other traffic control	• More effective with other indicators, such as school zone speed limit beacons or signal change warnings • More effective with regulatory than advisory speed limit • More effective where the DSFS supports a driver information system that provides a clear and real need to reduce speeds • Less effective at locations with an overabundance of driver information

Source: Rose and Ullman 2003

The Delaware DOT allows DSFS on roads with a speed limit of 25 mph or less (Li et al. 2017). The agency discourages DSFS on non-residential roads. In particular, the agency states that DSFS are not appropriate on freeways and major arterials, except in work zones.

4.4 Permanent Versus Temporary Installation

Countermeasures whose primary purpose is to get a driver's attention may lose effectiveness over time as drivers become habituated to the device. It has been suggested that this applies to DSFS.

A psychologist examined the phenomenon of habituation to speed feedback signs (Burkley 2019). The author notes that unlike static traffic signs, DSFS provide an individualized message, which psychologists call a feedback loop. A feedback loop consists of an action, feedback, and then a reaction. In this case, the sign provides information to a driver about his/her action (i.e., "You are speeding"), the driver sees his/her speed (or other message), and then the driver reacts (slows down), which creates a positive response in the brain (see Figure 16).

Burkley 2019, ©2019 Speed Patrol

Figure 16. Psychology of radar signs

The author suggests that feedback loops are highly effective in modifying behavior because the human brain is hardwired to respond to them. Burkley (2019) also suggests that DSFS provide drivers with a personalized message about their behavior in relation to the posted speed limit. In particular, the author notes that drivers consistently overestimate their driving skills and underestimate how much they speed.

Burkley (2019) also notes that the human brain becomes desensitized when exposed to repetitive stimulus, a concept called habituation. For instance, when drivers see the same static traffic control devices over and over, their brains stop registering the presence of the devices. In contrast, when the device is dynamic and constantly changing and drivers see a different message (a different speed) each time they encounter the device, the device is more likely to be noticed. As a result, drivers may be less likely to become habituated to DSFS than static countermeasures.

Burkley also postulates that DSFS can reduce distraction, since DSFS draw a driver's attention back to the roadway.

5. RECOMMENDATIONS FOR USE OF DSFS

As a speed management countermeasure, DSFS can be effective in both short- and long-term installations. However, DSFS messages have a limited reach downstream from the location of the sign.

The following recommendations are sourced from other agencies' practices and the research team's expertise in both speed management and evaluation of DSFS for various projects. These recommendations exclude the special considerations required for work zones.

5.1 Demonstrated Speeding Problem

When a location is being considered for application of a DSFS, the first consideration should be the adequacy of the existing posted or advisory speed limits and sign placement.

DSFS are most likely to be effective when a demonstrated speeding problem exists, as evidenced by any of the following conditions:

- The 85th percentile speed is 5 mph or more over the posted limit.
- There is a documented history of speed-related crashes in the area.

5.2 Roadway Type

Based on sign visibility, DSFS work best on one- or two-lane roadways. When a DSFS is placed at a location with more than one lane in the travel direction, use caution to ensure that the DSFS is appropriately targeted to the corresponding lane of traffic.

5.3 Other Traffic Control

Specific recommendations for the use of DSFS with other traffic control include the following:

- DSFS are more likely to be effective when used with regulatory rather than advisory speed limits.
- Posted speed limit signs should be used in conjunction with a DSFS to remind drivers of the target speed.
- The decision to place a DSFS should be made in consideration of the other traffic control present in an area. Sign clutter or over-use of traffic control may lessen the impact of a DSFS.

5.4 School Zones

In school zones, additional consideration may be given to what constitutes a demonstrated speeding problem. The criteria may include either of the following:

- The 85th percentile speed is 3 mph or more over the posted speed limit.
- There is a documented history of speed-related crashes.

5.5 Roadway Context

The characteristics of the surrounding roadway should be considered, including the following:

- Sight distance
- Horizontal/vertical curvature
- Whether right of way or shoulder/side characteristics impact the ability to place signs as recommended by the manufacturer

5.6 Other

Several other general recommendations include the following:

- Before installing an electronic radar-based sign, consider a progressive approach to applying countermeasures, starting with lower cost alternatives. For instance, place crosswalks at locations where drivers need to slow down for pedestrians or install community entrance signs to alert drivers that they are entering a rural community.
- One of the first considerations in a given scenario should be to assess the suitability of the current speed limit.
- Since DSFS are only effective for a limited distance, they should be placed at locations where speed reductions are desired.

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