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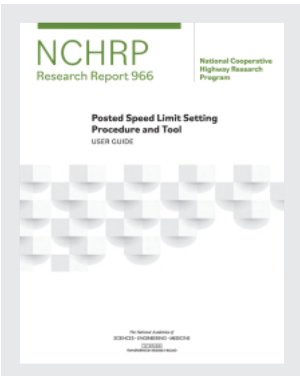

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP RESEARCH REPORT 966

Posted Speed Limit Setting Procedure and Tool

USER GUIDE

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2021

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed, and implementable research is the most effective way to solve many problems facing state departments of transportation (DOTs) administrators and engineers. Often, highway problems are of local or regional interest and can best be studied by state DOTs individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation results in increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

Recognizing this need, the leadership of the American Association of State Highway and Transportation Officials (AASHTO) in 1962 initiated an objective national highway research program using modern scientific techniques—the National Cooperative Highway Research Program (NCHRP). NCHRP is supported on a continuing basis by funds from participating member states of AASHTO and receives the full cooperation and support of the Federal Highway Administration (FHWA), United States Department of Transportation, under Agreement No. 693JJ31950003.

The Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine was requested by AASHTO to administer the research program because of TRB's recognized objectivity and understanding of modern research practices. TRB is uniquely suited for this purpose for many reasons: TRB maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; TRB possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; TRB's relationship to the National Academies is an insurance of objectivity; and TRB maintains a full-time staff of specialists in highway transportation matters to bring the findings of research directly to those in a position to use them.

The program is developed on the basis of research needs identified by chief administrators and other staff of the highway and transportation departments, by committees of AASHTO, and by the FHWA. Topics of the highest merit are selected by the AASHTO Special Committee on Research and Innovation (R&I), and each year R&I's recommendations are proposed to the AASHTO Board of Directors and the National Academies. Research projects to address these topics are defined by NCHRP, and qualified research agencies are selected from submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Academies and TRB.

The needs for highway research are many, and NCHRP can make significant contributions to solving highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement, rather than to substitute for or duplicate, other highway research programs.

NCHRP RESEARCH REPORT 966

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The work was performed under the general supervision of Dr. Fitzpatrick. The research reported here was supported by several staff members at TTI and MSU. The authors wish to acknowledge the many experts who contributed to this research by participating in discussions on posted speed limits and providing comments during presentations and early drafts. The authors appreciate the time and effort of these individuals.

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FOREWORD

By David Jared
Staff Officer
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NCHRP Research Report 966 provides a procedure for setting speed limits and a practitioner-ready user manual explaining the speed limit setting procedure (SLS-Procedure). Additionally, it provides an automated version of the SLS-Procedure via a spreadsheet-based Speed Limit Setting Tool (SLS-Tool). The guidebook will be of interest to engineers responsible for making informed decisions about the setting of speed limits.

Several factors are considered within engineering studies when determining the posted speed limit for a speed zone. Currently, the predominant method for setting speed limits uses the 85th percentile speed. This method is viewed as being a fair way to set speed limits based on the driving behavior of most drivers (85 percent), representing reasonable and prudent drivers since the fastest 15 percent of drivers are excluded. The 85th percentile speed is also believed to represent a safe speed that would minimize crashes.

The SLS-Procedure is based on decision rules that consider both driver speed choice and safety associated with the roadway. The SLS-Procedure was designed to be applicable for different roadway types and contexts by having a set of unique decision rules for four combinations of roadway types and contexts: Limited-Access, Undeveloped, Developed, and Full-Access facilities. The SLS-Procedure provides a fact-based, transparent set of decision rules to determine the suggested speed limit for a specific roadway segment.

Under NCHRP Project 17-76, "Guidance for the Setting of Speed Limits," Texas A&M Transportation Institute was asked to investigate factors that influence operating speed and safety through a review of the literature and an analysis of the relationships of speed, safety, and roadway characteristics on urban/suburban streets. That knowledge and a review of existing speed limit setting practices were used to develop the SLS-Procedure and accompanying SLS-Tool. Note that the SLS-Tool is provided in two formats, one with macros and one without. The without macros version is made available for users who are not able to use macro codes on their computers. The research team also conducted several workshops and presentations during the development of the SLS-Procedure, and these presentations provided opportunities to obtain feedback on its potential format.

The SLS-Procedure and SLS-Tool are accompanied by *NCHRP Web-Only Document 291: Development of a Posted Speed Limit Setting Procedure and Tool*, which details the research activities and methods. The SLS-Tool and *NCHRP Web-Only Document 291* are available on the TRB website (TRB.org) by searching for "NCHRP Research Report 966."

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SUMMARY

Posted Speed Limit Setting Procedure and Tool: User Guide

Several factors are considered within engineering studies when determining the posted speed limit for a speed zone. National Cooperative Highway Research Program (NCHRP) Project 17-76 investigated the factors that influence operating speed and safety and used that knowledge to develop the Speed Limit Setting Procedure (SLS-Procedure) so engineers can make informed decisions about the setting of speed limits. The SLS-Procedure was automated with the Speed Limit Setting Tool (SLS-Tool). The SLS-Tool is spreadsheet based and is included with this report for download.

Currently, the predominant method for setting speed limits uses the 85th percentile speed. It is viewed as a fair way to set speed limits based on the driving behavior of most drivers (85 percent), who represent reasonable and prudent drivers since the fastest 15 percent of drivers are excluded. The 85th percentile speed is also believed to represent a safe speed that would minimize crashes. Criticisms of the 85th percentile speed method include a concern that drivers may not see or be aware of all the conditions present within the corridor, and such an approach may not adequately consider vulnerable roadway users such as pedestrians and bicyclists. Other concerns are that drivers are not always reasonable and prudent, or they only consider what is reasonable and prudent for themselves and not for all users of the system; and the use of measured operating speeds to set speed limits could cause increase speed over time (i.e., speed creep). Drivers frequently select speeds a certain increment above the posted speed limit, anticipating that they will not receive a ticket if they are not above that assumed enforcement speed tolerance. Also, most of the early research justifying the use of the 85th percentile speed was conducted on rural roads; therefore, the 85th percentile speed may not be appropriate for urban roads.

The research team considered the breadth of approaches available for the setting of speed limits and the need to develop a methodology that could be used for any roadway type. The research team selected a decision-rule–based procedure for the SLS-Procedure. Given the increased emphasis on designing for the context of the roadway, the research team decided that the SLS-Procedure should be sensitive to context and use the expanded functional classification scheme available in *NCHRP Research Report 855* (*33*). The roadway types and roadway contexts available within the expanded functional classification scheme were collapsed into four Speed Limit Setting Groups (SLSGs): Limited-Access, Undeveloped, Developed, and Full-Access. Unique decision rules were developed for each SLSG.

For the SLS-Procedure, the research team proposed consideration of the measured operating speed as the starting point for selecting a posted speed limit but that the measured operating speed be adjusted based on roadway conditions and consideration of the crash experience on the segment.

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The guiding principles developed by the research team for the SLS-Procedure included the following:

- Use a data-driven approach with research-based decision rules.
- Produce consistent results for a given set of conditions.
- Incorporate contemporary policies, guidelines, and practices.
- Consider drivers' speed choice and roadway safety.
- Provide transparency in the decision-making process.
- Consider all roadway types and roadway contexts.
- Vary the decision rules to account for the diverse characteristics of each SLSG.
- Consider agency data and human resource constraints.
- Include inputs and outputs on the same screen to demonstrate the relationship between each roadway characteristic and selection of the suggested speed limit.
- Allow for future modifications to accommodate new knowledge.
- Create efficiencies in the decision process, where possible.

The SLS-Procedure starts with identifying the roadway segment context and type, which determine the appropriate SLSG. For that SLSG, the roadway characteristics and crash potential for the segment are used to identify the speed distribution that should be considered and whether the closest 5-mph increment value or a rounded-down 5-mph increment value should be used.

For this project, the research team focused a portion of the Phase II efforts on collecting data for suburban and urban roads to fill the known research gap for city streets. The developed databases for Austin, Texas, and Washtenaw County/Greater Ann Arbor, Michigan, were used to investigate the relationships among crashes, roadway characteristics, and posted speed limits. The team found that crashes on city streets were lowest when the average vehicle operating speed was within 5 mph of the posted speed limit. Therefore, the research team recommended that the 50th percentile speed be a consideration within the SLS-Procedure, especially for the SLSGs of Developed and Full-Access. The evaluation of the Austin, Texas, and Washtenaw County/Greater Ann Arbor, Michigan, data supported including the following variables within the decision rules: signal density, access density, and undivided median on four-lane (or more) streets. Findings from the literature were also used to develop the decision rules.

Presenting a workshop was a requirement of the research. Members of the research team conducted several workshops and presentations during the development of the SLS-Procedure, and these presentations provided opportunities to obtain feedback on the potential format of the procedure. The presentations with the panel were especially influential in setting the direction for the SLS-Procedure and SLS-Tool.

This project concluded with the development of two products:

- *NCHRP Research Report 966: Posted Speed Limit Setting Procedure and Tool: User Guide* (this document).
- *Web-Only Document 291: Development of a Posted Speed Limit Setting Procedure and Tool* is available for download from the TRB website (TRB.org) by searching for "NCHRP Research Report 966."

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SECTION 1

Introduction

Background

The speed limit is the maximum speed legally permitted for a given roadway segment. Several types of speed limits exist, including statutory speed limit, posted speed limit, school zone speed limit, work zone speed limit, variable speed limit, and advisory speed limit. (Figure 1 illustrates these different types of speed limits).

A posted speed limit could be the same as the statutory speed set by the state legislature or could be an adjustment to the statutory speed limit determined using an engineering speed study. States establish statutory speed limits for specific types of roads—such as freeways, rural highways, or urban streets—which are applicable even if the speed limit sign is not posted.

Objective

The National Cooperative Highway Research Program (NCHRP) Project 17-76 research team was tasked with identifying factors that influence a driver's operating speed and then developing a Speed Limit Setting Procedure (SLS-Procedure) and automating the SLS-Procedure with a Speed Limit Setting Tool (SLS-Tool). The SLS-Procedure and SLS-Tool are used to calculate the suggested speed limit for a segment. The goal of the SLS-Procedure and SLS-Tool is to produce an objective suggested speed limit value. Traffic engineers can use the SLS-Procedure and the suggested speed limit generated by the SLS-Tool to communicate with the public or government officials to explain the general procedures behind setting speed limits.

The products developed through NCHRP Project 17-76 focused on posted speed limits and not on other types of speed limits (see Figure 1 for examples). The SLS-Tool is designed to cover the most frequently encountered road designs and settings, though there may be circumstances not covered by the SLS-Tool that will require additional engineering judgment in the selection of the appropriate posted speed limit.

Two products were generated as part of this project:

- *NCHRP Research Report 966: Posted Speed Limit Setting Procedure and Tool: User Guide* (this document).
- *NCHRP Web-Only Document 291: Development of a Posted Speed Limit Setting Procedure and Tool* (*2*).

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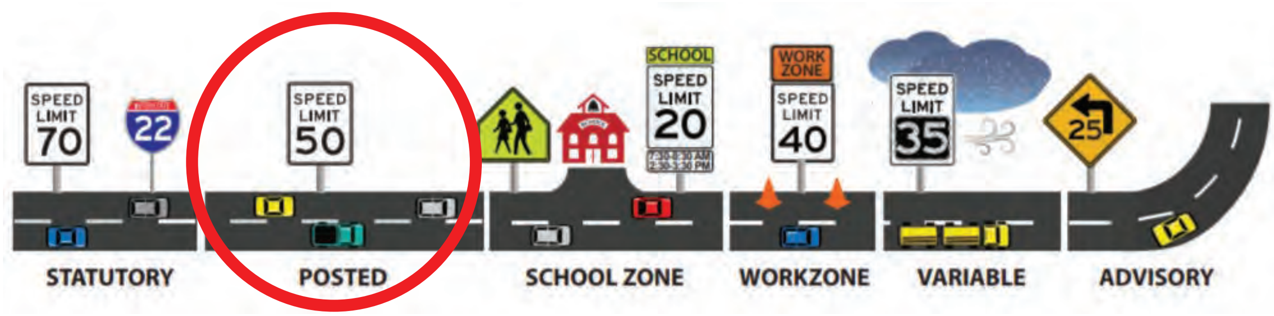

Source: Federal Highway Administration, *Speed Limit Basics*, page 1 (*1*).

Figure 1. Examples of speed limits.

Organization of User Guide

This document is the user guide for the SLS-Procedure and SLS-Tool. It contains the following sections:

- **Section 1: Introduction:** provides an overview of the document including the project objectives and the organization of the guide.
- **Section 2: Speed Limit Relationships and Practices:** introduces several basic relationships with regard to speed limits.
- **Section 3: Procedure to Calculate the Suggested Speed Limit:** presents the procedure to develop a suggested speed limit for a corridor.
- **Section 4: Decision-Making Steps Within the Suggested Speed Limit Procedure:** documents the four decision-making steps, which include selecting roadway segment context and type, identifying the appropriate speed distribution, adjusting for safety considerations, and finally calculating the suggested speed limit.
- **Section 5: Variables for Decision-Making Procedure:** discusses each variable used within the decision-making procedure (i.e., the SLS-Procedure).
- **Section 6: Speed Limit Setting Tool:** provides an overview of the SLS-Tool, including data entry requirements, messages that may be generated, and default values if data are not available for one of the variables.
- **Section 7: SLS-Tool Case Study Examples:** presents a case study for each of the four Speed Limit Setting Groups (SLSGs).
- **Section 8: Other Considerations When Setting Posted Speed Limits:** discusses several issues associated with the setting of posted speed limits.
- **Section 9: Related Reference Materials:** lists other reference materials on posted speed limits including links when available.
- **Acronyms and Abbreviations:** lists the acronyms and abbreviations used within this user guide.
- **References:** provides details on the material referenced in this user guide.

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SECTION 2

Speed Limit Relationships and Practices

Speed and Crashes

Approximately one-quarter of all traffic fatalities are related to speeding (Figure 2), either traveling in excess of the posted speed limit or driving too fast for the conditions. Although the downward trend is encouraging, speeding continues to be a primary contributor in traffic fatalities.

Ongoing Debate on How to Set a Posted Speed Limit

Several sources are available to aid in evaluating and identifying the appropriate posted speed limits. Many states and cities have their own laws and criteria for setting of speed limits, with some being more detailed than others. The *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) (*4*) provides details on the use of speed limit signs as a traffic control device (TCD), providing details on color, size, retroreflectivity, etc. The MUTCD also provides general advice on variables to consider when selecting the speed limit on a roadway segment; however, specific methods and decision steps are not included. The MUTCD broadly serves as a reference regarding the setting of speed limits; other references and guidelines to provide more detailed criteria for selecting the posted speed limit. This user guide provides such a procedure to calculate suggested speed limits.

Many different approaches are available and used to set a posted speed limit. Within the United States, the operating speed approach based on the 85th percentile speed is typically used. In the operating speed approach, the selection of the speed limit value uses the measured 85th percentile speed for the roadway segment, and in some cases, adjustment factors that consider a number of conditions are also applied.

The driver often plays a key role in the speed limit setting process since the speeds considered when establishing speed limits are typically measured when traffic is flowing freely. During free-flow conditions, drivers select speeds that they believe optimize the tradeoffs between travel time and risk. Basing the speed limit on the 85th percentile indicates a belief that drivers are pretty good at assessing these tradeoffs, and that their judgment is trustworthy in establishing a level where exceeding that speed may be cited by law enforcement. While that may be true, additional conditions could exist that *do not* influence the 85th percentile speed but *do* contribute to crashes. A posted speed limit that is lower than the 85th percentile speed could help to minimize the consequences of those conditions. In addition, the desire to provide roadway corridors that encourage active (non-motorized) transportation should consider the safety and mobility needs of pedestrians and bicyclists when setting posted speed limits. Given these competing preferences, the debate about the best approach to setting speed limits is ongoing.

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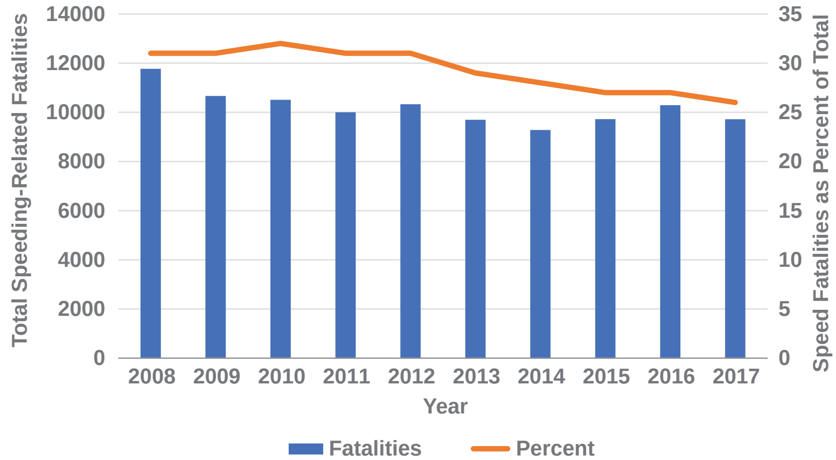

Source: Data from Insurance Institute for Highway Safety, "Fatality Facts 2017: Yearly Snapshot" (*3*).

Figure 2. Motor vehicle crash deaths involving speeding as a contributing factor, 2008–2017.

This user guide discusses a procedure that can be used to identify a *suggested* posted speed limit for a street or highway segment. The procedure is based on the speed distribution for a segment of current drivers with adjustments for the consideration of safety.

The Consequences of Speed

The release of the recent National Transportation Safety Board (NTSB) report *Reducing Speeding-Related Crashes Involving Passenger Vehicles* (*5*) provides insight into the ongoing challenges related to speeding and examines the causes and trends in speeding-related passenger vehicle crashes along with countermeasures that can prevent these crashes. Such issues include driver speed behavior and the setting of speed limits, data-driven approaches for speeding countermeasures and enforcement, and the use of automated speed enforcement as a deterrent. The report reflects the understanding that addressing speeding involves a continuum of design approaches, countermeasures, and policies all aimed at supporting a community safety plan.

It is well known that speed has an influence on crash severity, particularly in pedestrian crashes, and evidence shows that speed may also influence the number of crashes. The severity increases are not linear with respect to speed and tend to increase more substantially at higher speeds. It is unclear whether knowledge of that on the part of drivers would influence their speed choice. Some transportation professionals and safety experts believe that the 85th percentile should not be the sole factor in determining the speed limit, particularly in urbanized areas. For example, it may be prudent to post speed limits that are lower than the 85th percentile on roadways with pedestrians and/or bicyclist activity. However, if the decision is not based on objective data or accompanied by needed enforcement, education, or infrastructure changes, then slower travel speeds may not be achieved. Drivers often make their personal speed assessment based on their own needs and perceptions and do not necessarily consider other road users.

Challenges with the Relationship Between Posted Speed and Operating Speed

Establishing speed limits is often a complicated task. If speed limits are set with safety as the only consideration, the result will be low speed limits, which is not practical for mobility. The speed limit is generally a policy decision made by elected or appointed officials, typically

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after considering the recommendations of their agency's traffic engineers but not always, and sometimes without limiting their considerations to 85th percentile speeds. Like most efforts in traffic engineering, setting speed limits involves balancing competing desires and perceptions. One key issue facing the profession is what measurable factors should be considered in making these recommendations and their respective weights pertaining to speed limit. In addition, the process should incorporate the consideration of safety.

Consideration of which roadway and roadside characteristics to include in the decision-making process is central to the discussion related to speed. As illustrated with data for urban streets in Figure 3, the existing *average* operating speed is closer to the posted speed limit than the 85th percentile speed. This supports the observation that the setting of posted speed limits is influenced by more than the 85th percentile speed. Possible factors affecting speed (and safety) include, but are not limited to:

- Crash history including severity consequences.
- Available roadside elements.
- Horizontal curvature characteristics including radius, superelevation, and friction.
- Roadway lighting.
- Adjacent pedestrian and bicycle activity.
- Roadway facility type and context.
- Number of signals.
- Number of access points.
- Type of median.
- Presence of sidewalk.
- Presence of bicyclist facilities.

The linear trendlines in Figure 3 demonstrate a relationship between the posted speed limit and the operating speed. The average and 85th percentile operating speeds are higher when the posted speed limits are higher, or are lower when the posted speed limits are lower. While several roadway characteristics also influence operating speed, the research conducted in this project found that the posted speed limit influences operating speed (*2*), indicating that the number on the sign does matter. Several other studies have also found the posted speed limit

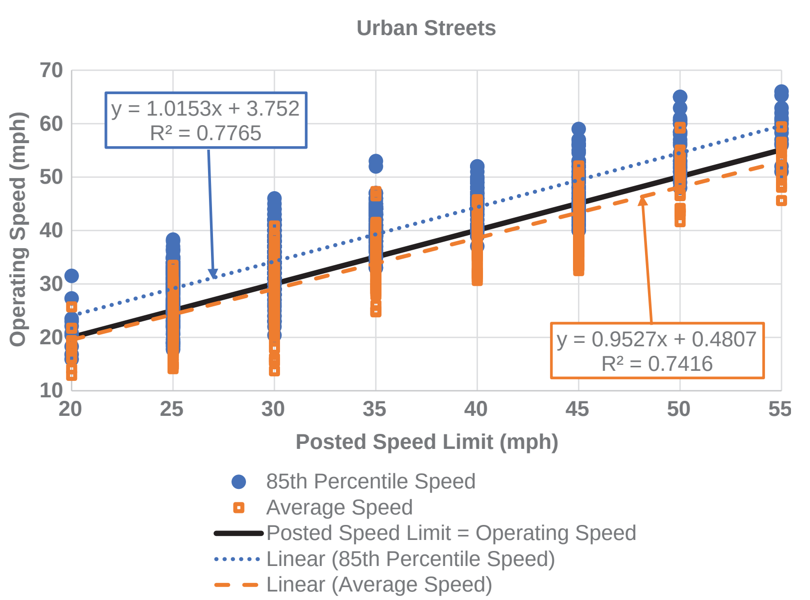

Figure 3. Comparison of operating speeds versus posted speed limits on urban streets.

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has a significant effect on free-flow speed on urban streets (*6, 7, 8, 9, 10, 11, 12*), rural two-lane highways (*13, 14, 15, 16*), and rural multilane highways (*17, 18*).

In addition to the safety impacts of speed limits, another area of substantive debate is how much speed limits influence the actual speed selection behavior of drivers. Research has generally shown that speed limit changes result in changes in the observed mean and 85th percentile speeds but are less pronounced than the actual speed limit changes. This has been true for cases where speed limits were decreased (*19, 20*) or increased (*21, 22, 23, 24, 25*).

In one of the most extensive studies in this area, Parker (*26*) conducted a large-scale study from 1985 to 1992 to determine the impact that raising or lowering posted speed limits on non-Limited-Access highways had on driver behavior. At the time of the study, the maximum speed limit on such roadways was 55 mph. Over the duration of the study, states and local authorities raised and lowered posted speed limits on short segments of roadways, typically less than 2 miles in length. Data on driver behavior and crashes were collected from 22 states. These included 100 sites along non-Limited-Access highways where the speed limits were either raised or lowered and 83 control sites where speed limits were not changed. The range of speed limit changes consisted of lowering the speed limit by 5, 10, 15, or 20 mph, or increasing the speed limit by 5, 10, or 15 mph, with only one change made at each site. Interestingly, the difference in operating speed after these changes was less than 1.5 mph on average (*26*).

Kockelman (*13*) found that speed limit increases tend to increase average vehicle speeds. On average, speed increases were generally less than half the amount of the actual speed limit increase. Dixon et al. (*27*) reviewed speed data for 12 rural multilane sites in Georgia to evaluate the effects of repealing the 55-mph national speed limit. The authors found that operating speeds were higher after the increase in the posted speed limit. The evidence cited in the NTSB report (*5*) also indicates that speed limits do have some effect on operating speed, primarily in increasing them and perhaps in reducing them to a lesser extent.

The magnitude of the change in operating speed when there is an increase (or decrease) in posted speed is typically only a fraction of the amount of the actual speed limit change (*13, 28, 29, 30*). For undivided high-speed rural roadways, mean speeds are generally 3 to 5 mph higher for every 10-mph increase in speed limit above 55 mph, with smaller increases at higher speed limits (*13, 28, 29*). In summary, while the research findings indicate a change in the posted speed limit sign can affect operating speeds, it is not as influential as the magnitude of the speed limit value change.

If traffic engineers could actually achieve desired operating speeds merely by setting and posting speed limits, their work would be done. Simply setting speed limits without other corrective measures is rarely likely to achieve target speeds, which is the operating speed intended for drivers to go on a given roadway facility. Granted, setting appropriate speed limits is an essential step in achieving target speeds, so it is critical to improve the methods for recommending them. The overwhelming reality is that there will never be enough law enforcement resources to enforce speed limits, no matter how they are determined. Furthermore, it will require a fundamental change in public opinion before automated enforcement (spot or segment) is adopted on a broad basis.

Achieving Target Speeds Through Roadway Configuration and Traffic Control

The central issue to achieving target speeds involves the configuration and operation of roadways so that target speeds, compatible with context and all roadway users, are chosen by—and not forced upon—vehicle operators. However, much of the roadway context, especially the

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urban one, has already been established, so a large part of the effort of achieving target speeds involves retrofitting the existing environment. Since only lane width, reallocating the cross section, elements on the roadside such as bus stops or trees, and vertical and horizontal deflections to alter the physical alignment are available, a clear understanding of what combination of those, and in what configurations, achieves target speeds (or at least what greatly influences operating speeds) is needed. Several previous research efforts (*31*) and anticipated research efforts (*32*) offer insights, but a formula for achieving a target speed is currently not available.

Transportation professionals can install the simplest and most straightforward, proven method to achieve target speeds on major streets in urban areas by implementing traffic signal progression. If drivers realize they will have a stop-free, steady, but appropriate speed to travel, then they may be more likely to actually drive the posted speed. For low-speed urban roads and streets that are unsignalized, transportation professionals will have to achieve target speeds through appropriate combinations of physical design features, many of which are now being included in context-sensitive, complete streets.

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SECTION 3

Procedure to Calculate the Suggested Speed Limit

Overview

With consideration of the issues discussed, along with research into the relationships among roadway characteristics including posted speed limit, operating speed, and safety, the research team developed a procedure to calculate a suggested speed limit. The procedure starts with identifying the roadway segment context and type. Next, the speed distribution of drivers on that segment is used to identify a potential suggested speed limit that is adjusted with consideration of the crash potential for the segment. Figure 4 illustrates the steps for the procedure. Additional details are provided in the sections that follow. The suggested speed limit procedure applies to posted speed limits. Procedures for setting school zone, work zone, variable, or advisory speeds are not discussed in this document.

Speed Limit Setting Tool

The SLS-Tool was developed to facilitate calculating the suggested speed limit. The tool uses spreadsheets to automate the procedure. A copy of the SLS-Tool is available on the TRB website (TRB.org) by searching for "NCHRP Research Report 966."

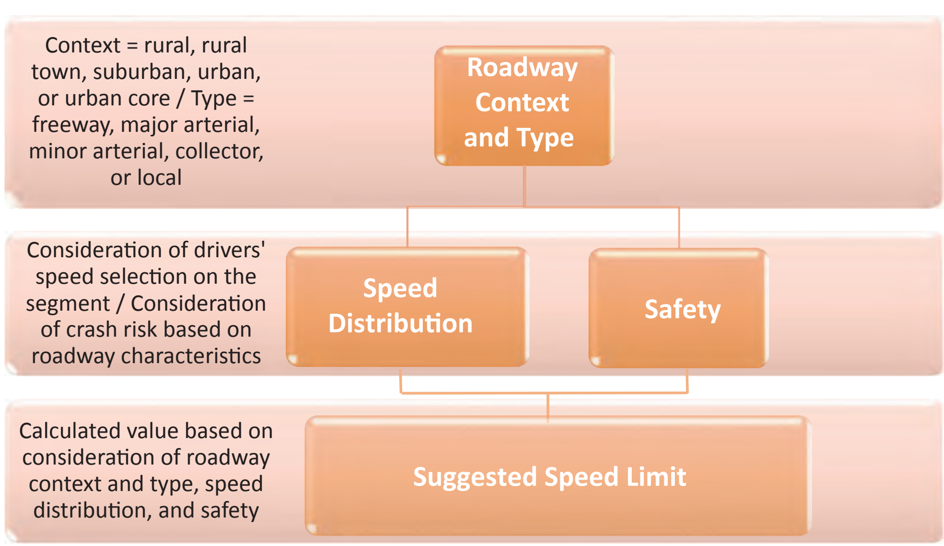

Figure 4. Overview of procedure to calculate suggested speed limit.

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SECTION 4

Decision-Making Steps Within the Suggested Speed Limit Procedure

Roadway Segment Context and Type

The initial step in decision-making is identifying the roadway segment content and type. The Expanded Functional Classification System (Expanded FCS) aides in that determination. The Expanded Functional Classification System was developed to replace the existing functional classification scheme in order to facilitate optimal geometric design solutions with consideration of context, road functions, and user needs. The scheme was introduced in *NCHRP Research Report 855* (*33*) and is intended to build upon existing efforts from state departments of transportation that have initiated and implemented a new classification system to address contextual multimodal deficiencies of the existing classification system.

As stated in *NCHRP Research Report 855* (*33*), "the major objective of the Expanded FCS is to provide enhanced information to designers to better inform the design decision process. . . . This enhanced information is provided by increasing the resolution of roadway's design context to enable understanding of the role the roadway plays within the community; identifying the role of the roadway within the local, city, and regional transportation network; and identifying the multiple roadway user groups and their priority within the design corridor."

The goal of the Expanded FCS is to provide practitioners with a practical tool for determining appropriate design criteria and elements to help better understand the impacts of the tradeoffs necessary to balance user needs and safety and to address other community issues. The Expanded FCS and associated design matrix can be used to identify preliminary requirements for proper consideration of roadway context and user needs.

As presented in *NCHRP Research Report 855*, the Expanded FCS considers roadway context, roadway type, roadway users, and overlays. The SLS-Procedure uses the basic roadway context/roadway type matrix. *NCHRP Research Report 855* provides additional information on the Expanded FCS.

Roadway Context

The Expanded FCS includes five distinct contexts. These were determined to represent unique land use that requires different geometric design practices in terms of desired operating speeds, mobility/access demands, and user groups. *NCHRP Research Report 855* (*33*) describes the context categories as follows and provides the illustration shown in Figure 5:

- **Rural:** areas with lowest density, few houses or structures (widely dispersed or no residential, commercial, and industrial uses), and usually large setbacks.
- **Rural Town:** areas with low density but diverse land uses with commercial main street character, potential for on-street parking and sidewalks, and small setbacks.

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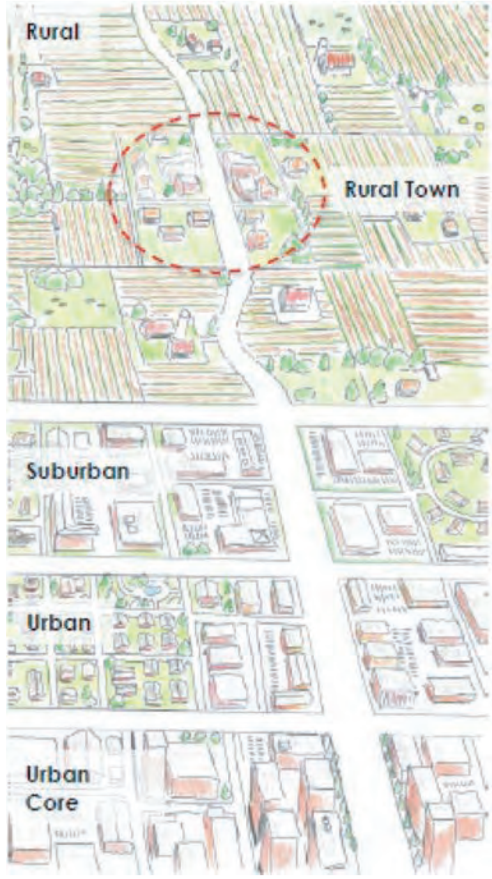

Figure 5. **NCHRP Research Report 855** ***illustration of five roadway contexts. [Source: Transportation Research Board. 2018.*** **NCHRP Research Report 855: An Expanded Functional Classification System for Highways and Streets.** ***HTTPS://DOI.ORG/10.17226/24775. Reproduced with permission from the National Academy of Sciences. Figure 2, page 3. (*****33*****)]***

- **Suburban:** areas with medium density, mixed land uses within and among structures (including mixed-use town centers, commercial corridors, and residential areas), and varied setbacks.
- **Urban:** areas with high density, mixed land uses and prominent destinations, potential for some on-street parking and sidewalks, and mixed setbacks.
- **Urban Core:** areas with highest density and mixed land uses within and among predominately high-rise structures, and small setbacks.

Table 1 summarizes the primary factors associated with each roadway context.

Roadway Type

The roadway types used in the Expanded FCS are based on their network function and the connectivity they provide among various centers of activity. The roadway types are as follows:

- **Interstates/Freeways/Expressways:** corridors of national importance connecting large centers of activity over long distances.

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Table 1. Characteristics of roadway contexts.

Context	Density	Land Use	Setback
Rural	Lowest (few houses or other structures)	Agricultural, natural resource preservation, and outdoor recreation uses with some isolated residential and commercial uses	Usually large setbacks
Rural Town	Low to medium (single-family houses and other single-purpose structures)	Primarily commercial uses along a main street (some adjacent single-family residential uses)	On-street parking and sidewalks with predominately small setbacks
Suburban	Low to medium (single- and multifamily structures and multistory commercial)	Mixed residential neighborhood and commercial clusters (including town centers, commercial corridors, big-box commercial, and light industrial uses)	Varied setbacks with some sidewalks and mostly off-street parking
Urban	High (multistory, low-rise structures with designated off-street parking)	Mixed residential and commercial uses, with some intuitional and industrial uses, and prominent destinations	On-street parking and sidewalks with mixed setbacks
Urban Core	Highest (multistory and high-rise structures)	Mixed commercial, residential, and institutional uses within and among predominately high-rise structures	Small setbacks with sidewalks and pedestrian plazas

Source: Transportation Research Board. 2018. *NCHRP Research Report 855: An Expanded Functional Classification System for Highways and Streets*. HTTPS://DOI.ORG/10.17226/24775. Reproduced with permission from the National Academy of Sciences, Table 1, page 10 (*33*).

- **Principal Arterials:** corridors of regional importance connecting large centers of activity.
- **Minor Arterials:** corridors of regional or local importance connecting centers of activity.
- **Collectors:** roadways of lower local importance providing connections between arterials and local roads.
- **Locals:** roads with no regional or local importance for local circulation and access only.

Matrix

Table 2 shows the roadway context/roadway type matrix along with the target speed for each context/type combination. Target operating speed is the desirable speed for motorists to travel along a roadway within the particular context/roadway type combination. *NCHRP Research Report 855* grouped the target operating speed into three categories (*33*):

- Low (25 mph and below).
- Medium (30 to 45 mph).
- High (50 mph and above).

NCHRP Research Report 855 provides the following justification for the target speed values:

The speed used in the Expanded FCS is the target operating speed of the roadway. The rationale for selecting operating speed in the Expanded FCS is the need to recognize the influence of driver desire and expectations. Moreover, the goal is to develop a facility where the operating speed is close to the design speed, resulting in an environment with smaller speed differences among drivers. Smaller speed differentials could improve safety, since they will eliminate discrepancies between design speed and operating speeds, creating a more uniform speed profile among drivers. These speeds need to be considered with both existing and future volumes and contexts.

The limits for each category are based on established practices and extensive research. The speed of 25 mph was considered the limit for the low-speed environments based on current trends of several urban areas to facilitate a speed limit of 25 mph. Indeed, 20 mph is considered the survivability speed for pedestrians and bicyclists in the event of a collision with a vehicle. Such collisions typically result in injuries, and non-drivers have a high chance of surviving when speeds remain at or below 20 mph. As such, speeds of 20 mph or less should be considered in areas of higher pedestrian activity in the urban and urban core environments. Target speeds for urban and rural towns have been designated as

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Table 2. Suggested target speed by roadway context and type.

Context and Type	Rural	Rural Town	Suburban	Urban	Urban Core
Limited-Access Freeway	High 50 mph and above	High 50 mph and above	High 50 mph and above	High 50 mph and above	High 50 mph and above
Principal Arterial	High 50 mph and above	Low to Medium 45 mph and below	Medium to High 30 mph and above	Low to Medium 45 mph and below	Low 25 mph and below
Minor Arterial	High 50 mph and above	Low to Medium 45 mph and below	Medium 30 to 45 mph	Low to Medium 45 mph and below	Low 25 mph and below
Collector	Medium 30 to 45 mph	Low 25 mph and below	Medium 30 to 45 mph	Low 25 mph and below	Low 25 mph and below
Local	Medium 30 to 45 mph	Low 25 mph and below	Low 25 mph and below	Low 25 mph and below	Low 25 mph and below

Source: Adapted from Transportation Research Board. 2018. *NCHRP Research Report 855: An Expanded Functional Classification System for Highways and Streets*. HTTPS://DOI.ORG/10.17226/24775. Reproduced with permission from the National Academy of Sciences, Figure 19 (*33*).

low/medium because of the competing issues within these contexts and the varied pedestrian and roadside environment. The designer should examine the available speed range to select the operating speed most appropriate for all users given the facilities and context. The upper limit for high speeds is based on the American Association of State Highway and Transportation Officials' (AASHTO's) *A Policy on Geometric Design of Highways and Streets* (commonly known as the *Green Book*) (*42*) definition of high-speed roads, which are those with speeds of 50 mph and above. (*33*, page 26)

Speed Limit Setting Groups

The roadway context and type should be considered when identifying a posted speed limit for a facility. While the expanded functional classification matrix has 25 unique combinations of roadway types and roadway contexts (Table 2), there are combinations where a similar decision process would be employed. For example, the setting of posted speed limits for Limited-Access freeways may be the same for suburban or urban freeways. Table 3 shows the SLSGs by roadway context/roadway type and includes the following:

- Limited-Access.
- Undeveloped.
- Developed.
- Full-Access.

Table 3. Suggested SLSGs.

Context and Type	Rural	Rural Town	Suburban	Urban	Urban Core
Freeways	Limited-Access	Limited-Access	Limited-Access	Limited-Access	Limited-Access
Principal Arterial	Undeveloped	Developed	Developed	Developed	Full-Access
Minor Arterial	Undeveloped	Developed	Developed	Developed	Full-Access
Collector	Undeveloped	Full-Access	Developed	Full-Access	Full-Access
Local	Undeveloped	Full-Access	Full-Access	Full-Access	Full-Access

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Speed Distribution

The distribution of individual vehicle speeds within the traffic stream is dependent on several factors. Speeds tend to be relatively uniform (i.e., narrowly distributed) during periods of heavy congestion and more broadly distributed during free-flow conditions. Typically, for speed limit setting purposes, the speed distribution should only include free-flowing vehicles. The distribution of individual vehicle speeds may be characterized by variables that include the average, 50th percentile, 85th percentile, standard deviation, and pace of the measured speeds, each of which is defined in Table 4. Figure 6 illustrates key speed terms within a speed distribution plot.

For speed setting purposes within the SLS-Tool, the primary variables of interest related to speed are the 50th percentile and the 85th percentile speed. While not used within the SLS-Tool, minimizing the standard deviation or maximizing the pace (largest percent of vehicles within a 10-mph range) is associated with fewer crashes; therefore, other tools such as enforcement or changes in roadway design could be considered.

Consideration of Geometric Variables, Human Factors, and Safety

Geometry, human factors, and safety are all considerations that are utilized within a set of decision rules for each SLSG to determine the suggested speed limit. The possible suggested speed limit options are as follows, listed in order from highest to lowest speed within the distribution:

- The 85th percentile speed rounded to the closest 5-mph increment (C85).
- The 85th percentile speed rounded down to the nearest 5-mph increment (RD85).
- The 50th percentile speed rounded to the closest 5-mph increment (C50).
- The 50th percentile speed rounded down to the nearest 5-mph increment (RD50).

Table 4. Speed definitions.

Term	Definition
50th percentile (median)	The speed at or below which 50 percent of the total observed values fall in a sample of measured spot speeds.
85th percentile	The speed at or below which 85 percent of the total observed values fall in a sample of measured spot speeds.
Average travel speed	The average speed of the traffic stream over a specified section of highway.
Free-flow speed	The average speed of vehicles on a given segment, measured under low-volume conditions, when drivers are free to drive at their desired speed and are not constrained by the presence of other vehicles or downstream TCDs (e.g., traffic signals, roundabouts, or stop signs).
Operating speed	The operating speed of a road is the speed at which motor vehicles generally operate on that road. In a general sense, the term *operating speed* refers to the speed at which drivers are observed operating their vehicles. The 85th percentile of a sample of observed speeds has been typically used as a descriptive statistic for establishing the operating speed associated with a particular road segment; however, other percentiles have also been used.
Pace	The 10-mph range that contains the greatest percentage of observations, expressed as a percentage of the number of speed measurements within the 10-mph range divided by the total number of speed measurements.
Posted speed	Numeric speed limit value displayed on regulatory speed limit signs.
Space-mean speed	Harmonic mean of several spot speed measurements (or calculated using the average travel times of vehicles measured over a given length of roadway).
Speed	Rate of movement of a vehicle in mph.
Spot speed	Instantaneous measure of speed at a specific location on a roadway.
Standard deviation	Spread of individual speeds around the mean, calculated as the square root of the sum of squares of the deviations of the individual spot speeds from the mean divided by the number of measurements less one.
Statutory speed limit	Statutory speed limits are established by state legislatures and are enforceable by law. Such limits typically vary by highway type (e.g., interstate) or by location (e.g., urban district).
Target speed	The highest speed at which vehicles should ideally operate on a roadway.
Time-mean speed	Arithmetic mean or average of several spot speed measurements (or the average of speeds of vehicles passing a given point along a roadway over a certain time period).

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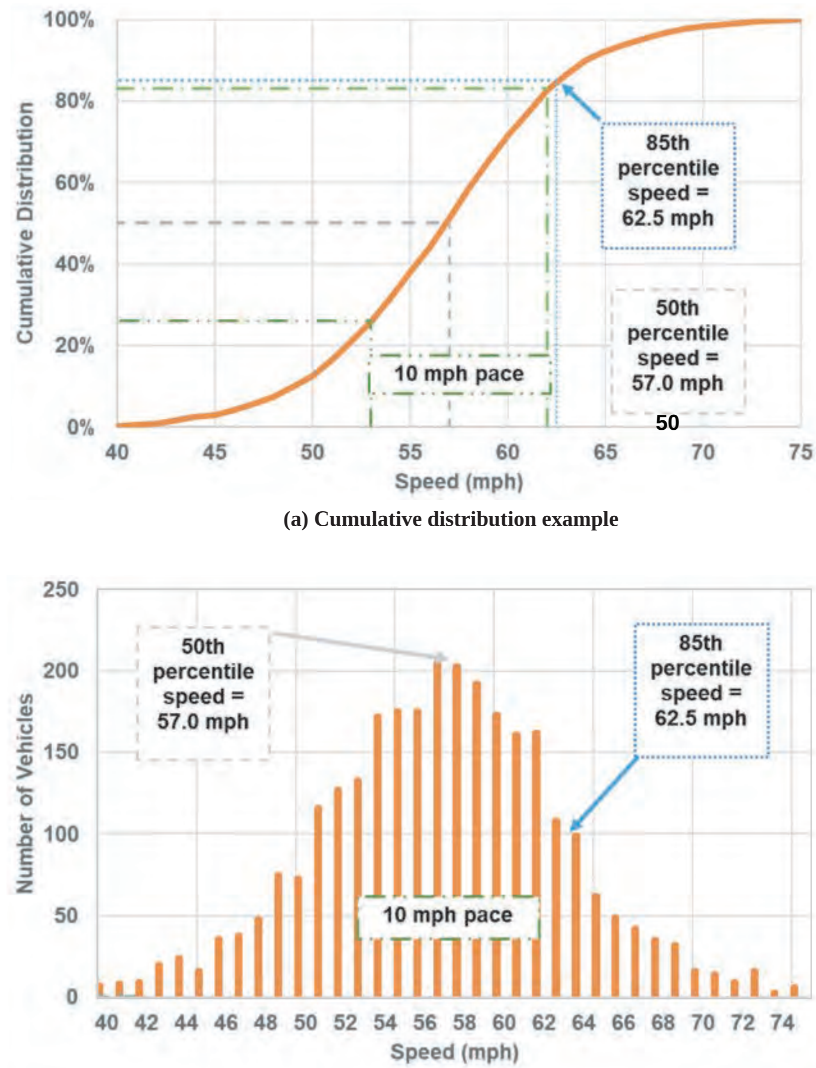

(a) Cumulative distribution example

(b) Histogram example

Figure 6. Example illustrations of speed distribution curves.

When the roadway conditions are optimal, the suggested speed limit would reflect the 5-mph increment closest to the 85th percentile speed except for segments within the Full-Access SLSG, where it would reflect the 5-mph increment closest to the 50th percentile speed in recognition of the anticipated users within those facilities. When roadway conditions are not favorable to all users or when crashes are a significant concern, then the suggested speed limit would reflect the 5-mph increment closest to the 50th percentile speed for Limited-Access, Developed, or Undeveloped SLSGs or the 5-mph increment rounded down from the 50th percentile speed for the Full-Access SLSG. An RD85 speed limit is suggested when conditions are between those extremes for Limited-Access, Developed, or Undeveloped SLSGs.

In rare cases, the RD85 will be less than the C50 due to rounding. As an example, if the 50th percentile speed was 58 mph and the 85th percentile speed was 59 mph, then the C50 would equal 60 mph, and the RD85 would equal 55 mph. This situation only occurs when the 85th and 50th percentile speeds are within 1 mph of each other. The results may appear

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unusual but are accurate given the provided speed data, and hence should be interpreted with caution.

Decision Rules for Each Speed Limit Setting Group

The following sections presents the decision rules for selecting the 5-mph increment that reflects C50, RD85, or C85 by SLSGs.

Crashes are considered by comparing the crash rate [crashes/100 million vehicle miles (MVM)] for the segment with the crash rate for similar road sections in the jurisdiction or, if not available, with crash rates from the Highway Safety Information System (HSIS). KABCO is a crash severity scale where:

- K = fatal.
- A = incapacitating injury.
- B = non-incapacitating injury.
- C = possible injury.
- O = no injury, property damage only.

KABCO includes crashes for all severity levels and KABC includes crashes with fatal or injury severity levels.

Speed Limit Setting Group: Limited-Access

Table 5 provides an overview of the variables along with the variable value that would trigger using C85, RD85, or C50.

Speed Limit Setting Group: Undeveloped

Table 6 provides an overview of the variables along with the variable value that would trigger using either C85, RD85, or C50.

Table 5. Overview of decision rules for Limited-Access SLSG.

Variable	Closest 50th (C50)	Rounded Down 85th (RD85)	Closest 85th (C85)
Average interchange spacing (Inter_spac) expressed as length/number of interchanges in miles (mi) and annual average daily traffic (AADT) (two-way total) in vehicles per day (veh/d)	Inter_spac ≤ 0.5 mi and AADT ≥ 180,000 veh/d	0.5 mi < Inter_spac ≤ 1 mi and AADT ≥ 180,000 veh/d	All other cases
Mountainous terrain as determined by grade in percent and design speed in mph	{Not applicable, see criteria in other cells}	• Design speed ≥ 60 mph and grade > 4% • Design speed ≤ 55 mph and grade > 5%	All other cases
Outside shoulder width (SW) in feet	{Not applicable, see criteria in other cells}	SW < 8 ft	SW ≥ 8 ft
Inside shoulder width (ISW) in feet, number of lanes (N), and directional design-hour truck volume in trucks per hour (trk/hr)	{Not applicable, see criteria in other cells}	• Truck_vol > 250 trk/hr and ISW < 12 ft • Truck_vol ≤ 250 trk/hr, N ≥ 6, and ISW < 10 • Truck_vol ≤ 250 trk/hr, N < 6, and ISW < 4	All other cases
KABCO or KABC crash rate	High	Medium	Low

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Table 6. Overview of decision rules for Undeveloped area SLSG.

Variable	Closest 50th (C50)	Rounded-Down 85th (RD85)	Closest 85th (C85)
Access points (non-residential driveways and intersections per mile)	• > 40 access points per mile (divided) • > 30 access points per mile (undivided)	• > 20 and ≤ 40 access points per mile (divided) • > 15 and ≤ 30 access points per mile (undivided)	• ≤ 20 access points per mile (divided) • ≤ 15 access points per mile (undivided)
Number of lanes, median type, AADT combination	{Not applicable, see criteria in other cells}	Four or more lanes with no median (undivided) and AADT > 2000 veh/d	• Four or more lanes with divided median • Two lanes with any median type • Four or more lanes with no median (undivided) and AADT ≤ 2000 veh/d • Any number of lanes/median type combination when AADT ≤ 2000
Lane width (LW)	LW ≤ 9 ft and AADT > 2000 veh/d	9 ft < LW < 11 ft and AADT > 2000 veh/d	• LW ≥ 11 ft and AADT > 2000 veh/d • Any lane width when AADT ≤ 2000
SW	SW < 2 ft and AADT > 2000 veh/d	2 ft ≤ SW < 6 ft and AADT > 2000 veh/d	• SW ≥ 6 ft and AADT > 2000 veh/d • Any SW when AADT ≤ 2000
KABCO or KABC crash rate	High	Medium	Low

Speed Limit Setting Group: Developed

Table 7 provides an overview of the variables along with the variable value that would trigger using C85, RD85, or C50. Table 8 provides the decision matrix for sidewalk presence/width, sidewalk buffer, and pedestrian activity combinations for Developed SLSG.

Speed Limit Setting Group: Full-Access

Table 9 provides an overview of the variables along with the variable value that would trigger using C50 or RD50. Table 10 provides the decision matrix for sidewalk presence/width, sidewalk buffer, and pedestrian activity combinations for Full-Access SLSG.

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Table 7. Overview of decision rules for Developed area SLSG.

Variable	Closest 50th (C50)	Rounded-Down 85th (RD85)	Closest 85th (C85)
Signal density	> 4 signals/mile	> 3 signals/mile	≤ 3 signals/mile
Access density	> 60 driveways/ unsignalized intersections per mile	> 40 and ≤ 60 driveways/ unsignalized intersections per mile	≤ 40 driveways/ unsignalized intersections per mile
Number of lanes/ median type [undivided, two-way left-turn lane (TWLTL), or divided]	{Not applicable, see criteria in other cells}	Four or more lanes with undivided median	• Four or more lanes with divided or TWLTL median • Fewer than four lanes with any median type
Bicyclist activity in motor vehicle lane, shoulder, or non-separated bike lane	High	{Not applicable, see criteria in other cells}	Not high
Bicyclist activity in separated bike lane	{Not applicable, see criteria in other cells}	High	Not high
Sidewalk presence/width (none, narrow, adequate, or wide), sidewalk buffer (present or not present), and pedestrian activity (high, some, or negligible)	See Table 8	See Table 8	See Table 8
On-street parking activity	High	{Not applicable, see criteria in other cells}	Not high
On-street parking type	Angle parking present for 40 percent or more of section	• Parallel parking permitted • Angle parking present for less than 40 percent of section	None
KABCO or KABC crash rate	High	Medium	Low

Table 8. Decision matrix for sidewalk presence/width, sidewalk buffer, and pedestrian activity combinations for Developed SLSG.

Pedestrian Activity	Sidewalk Presence/Width	Sidewalk Buffer	Speed Percentage
High	Adequate	Not present	RD85
High	Adequate	Present	C85
High	Narrow	Not present	C50
High	Narrow	Present	RD85
High	None	Not applicable	C50
High	Wide	Not present	C85
High	Wide	Present	C85
Some	Adequate	Not present	RD85
Some	Adequate	Present	C85
Some	Narrow	Not present	C50
Some	Narrow	Present	RD85
Some	None	Not applicable	C50
Some	Wide	Not present	C85
Some	Wide	Present	C85
Negligible	Adequate	Not present	C85
Negligible	Adequate	Present	C85
Negligible	Narrow	Not present	C85
Negligible	Narrow	Present	C85
Negligible	None	Not applicable	RD85
Negligible	Wide	Not present	C85
Negligible	Wide	Present	C85
See text for additional discussion on sidewalk presence/width and sidewalk buffer characteristics.			

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Table 9. Overview of decision rules for Full-Access SLSG.

Variable	Rounded-Down 50th (RD50)	Closest 50th (C50)
Signal density	> 8 signals/mile	≤ 8 signals/mile
Access density	> 60 driveways/unsignalized intersections per mile	≤ 60 driveways/unsignalized intersections per mile
Bicyclist activity – in motor vehicle lane, shoulder, or non-separated bike lane	High	Not high
Bicyclist activity – in separated bike lane	High	Not high
Sidewalk presence/width (none, narrow, adequate, or wide), sidewalk buffer (present or not present), and pedestrian activity (high, some, or negligible)	See Table 10	See Table 10
On-street parking activity	High	Not high
On-street parking type	Angle parking present for 40 percent or more of section	• No parking present • Angle parking present for less than 40 percent of section
KABCO or KABC crash rate	High or Medium	Low

Table 10. Decision matrix for sidewalk presence/width, sidewalk buffer, and pedestrian activity combinations for Full-Access Speed Limit Setting Group.

Pedestrian Activity	Sidewalk Presence/Width	Sidewalk Buffer	Speed Percentage
High	Adequate	Not present	RD50
High	Adequate	Present	C50
High	Narrow	Not present	RD50
High	Narrow	Present	RD50
High	None	Not applicable	RD50
High	Wide	Not present	C50
High	Wide	Present	C50
Some	Adequate	Not present	RD50
Some	Adequate	Present	C50
Some	Narrow	Not present	RD50
Some	Narrow	Present	RD50
Some	None	Not applicable	RD50
Some	Wide	Not present	C50
Some	Wide	Present	C50
Negligible	Adequate	Not present	C50
Negligible	Adequate	Present	C50
Negligible	Narrow	Not present	C50
Negligible	Narrow	Present	C50
Negligible	None	Not applicable	C50
Negligible	Wide	Not present	C50
Negligible	Wide	Present	C50
See text for additional discussion on sidewalk presence/width and sidewalk buffer characteristics.			

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SECTION 5

Variables for Decision-Making Procedure

Roadway Context

NCHRP Research Report 855 (*33*) provides the following two questions for determining a roadway segment's context category:

- For the most part, does it meet the category's primary factors?
- Does the landscape adjacent to the roadway look similar to the photographs/graphic examples in Figure 7?

Roadway Type

The Expanded FCS roadway types follow basic transportation system functions and are defined based on their network function and connectivity. *NCHRP Research Report 855* (*33*) provides the following key characteristics for each roadway type:

1. **Interstates/Freeways/Expressways:** corridors of national importance providing long-distance travel.
   - Limited-Access.
   - Through traffic movements.
   - Primary freight routes.
   - Possible transit network support.
   - No pedestrian or bicycle traffic.
   - Guided by Federal Highway Administration (FHWA) design standards.
2. **Principal Arterials:** corridors of regional importance connecting large centers of activity.
   - Through-traffic movements.
   - Long-distance traffic movements.
   - Long-haul public transit buses.
   - Primary freight routes.
3. **Minor Arterials:** corridors of local importance connecting centers of activity.
   - Connections between local areas and network principal arterials.
   - Connections for through traffic between arterial roads.
   - Access to public transit and through movements.
   - Pedestrian and bicycle movements.
4. **Collectors:** roadways providing connections between arterials and local roads.
   - Traffic with trips ending in a specific area.
   - Access to commercial and residential centers.
   - Access to public transportation.
   - Pedestrian and bicycle movements.
5. **Local:** all other roads.
   - Direct property access—residential and commercial.
   - Pedestrian and bicycle movements.

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Illustration	Description
Rural 	Ranges from no development (natural environment) to some light development (structures), with sparse residential and other structures mostly associated with farms. The land is primarily used for outdoor recreation, agriculture, farms, and/or resource extraction. In a rural setting, there are no or very few pedestrians, bicyclists are most likely of recreational nature, and transit is limited or nonexistent.
Rural Town 	Characterized by low density (low-rise—one or two story—structures) but a concentrated development of diverse uses—residential and commercial. Rural towns are generally incorporated but have limited government services. Rural towns usually have a roadway section that has a main street character (or even a town square) with on-street parking and sidewalks and in some cases bicycle lanes.
Suburban 	Diverse range of commercial and residential uses that have a medium density. The buildings tend to be multistory with off-street parking. Sidewalks are usually present, and bicycle lanes may exist. The range of uses encompasses health services, light industrial (and sometimes heavy industrial) uses, quick-stop shops, gas stations, restaurants, and schools and libraries. Typically, suburban areas rely heavily on passenger vehicles, but some transit may be present.
Urban 	High density, consisting principally of multistory and low- to medium-rise structures for residential and commercial use. Areas usually exist for light and sometimes heavy industrial use. Many structures accommodate mixed uses: commercial, residential, and parking. Streets have minimal on-street parking. Wide sidewalks and plazas accommodate more intense pedestrian traffic, while bicycle lanes and transit corridors are frequently present.
Urban Core 	Highest level of density with its mixed residential and commercial uses accommodated in high-rise structures. While there may be some on-street parking, it is usually very limited and time restricted. Most parking is in multilevel structures attached or integrated with other structures. The area is accessible to automobiles, commercial delivery vehicles, and public transit. Sidewalks and pedestrian plazas are present along with multilevel pedestrian bridges connecting commercial and parking structures. Bicycle facilities and transit corridors are typically common.

Source: Transportation Research Board. 2018. *NCHRP Research Report: An Expanded Functional Classification System for Highways and Streets*. HTTPS://DOI.ORG/10.17226/24775. Reproduced with permission from the National Academy of Sciences, pages 10–16 (*33*).

Figure 7. Roadway context illustrations and descriptions.

Roadway Segment Input Variables for Speed Limit Setting Groups

Several variables are needed for use in the SLS-Procedure. The needed variables vary by the SLSG. The speed data variables are provided in Table 11. The table also indicates when the variable is needed based on the SLSG, for example, the 85th percentile speed is not needed for the Full-Access SLSG. Table 12 summarizes the variables and indicates when the variable is needed based on the SLSG. Table 13 shows the variables needed when crash data are available.

Table 11. Input variables for speed data.

Speed Data Variable	Limited-Access	Undeveloped	Developed	Full-Access
50th percentile speed (mph)	✓	✓	✓	✓
85th percentile speed (mph)	✓	✓	✓	-
Maximum speed limit (mph)	✓	✓	✓	✓

Note: ✓ = variables used in SLSG, - = variables not used in SLSG.

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Table 12. Roadway segment input variables.

Roadway Segment Variable	Limited-Access	Undeveloped	Developed	Full-Access
AADT (two-way total), annual average daily traffic (veh/d)	✓	✓	-	-
Adverse alignment present (yes or no)	✓	✓	✓	✓
Angle parking present (no, yes for at least 40 percent of the segment, or yes for less than 40 percent of the segment)	-	-	✓	✓
Bicyclist activity (high or not high)	-	-	✓	✓
Design speed (mph), used with grade to identify mountainous terrain	✓	-	-	-
Directional design-hour truck volume (trk/hr)	✓	-	-	-
Grade (%), used with design speed to identify mountainous terrain	✓	-	-	-
Inside (left) SW (ft)	✓	-	-	-
Lane width (ft)	-	✓	-	-
Median type, developed or Full-Access (undivided, TWLTL, or divided)	-	-	✓	✓
Median type, undeveloped (undivided or divided)	-	✓	-	-
Number of access points (total of both directions)	-	✓	✓	✓
Number of interchanges	✓	-	-	-
Number of lanes (two-way total)	✓	✓	✓	✓
Number of traffic signals	-	-	✓	✓
On-street parking activity (high or not high)	-	-	✓	✓
Outside (right) SW (ft)	✓	-	-	-
Parallel parking permitted (yes or no)	-	-	✓	-
Pedestrian activity (high, some, or negligible)	-	-	✓	✓
Segment length (mi)	✓	✓	✓	✓
SW (ft)	-	✓	-	-
Sidewalk buffer (present or not present)	-	-	✓	✓
Sidewalk presence/width (none, narrow, adequate, or wide)	-	-	✓	✓

Note: ✓ = variables used in SLSG, - = variables not used in SLSG.

Table 13. Input variables when crash data are available.

Crash Data Variable	Limited-Access	Undeveloped	Developed	Full-Access
Number of years of crash data	✓	✓	✓	✓
Average AADT (two-way total) for crash data period (veh/d)	✓	✓	✓	✓
All (KABCO) crashes for crash data period	✓	✓	✓	✓
Fatal and injury (KABC) crashes for crash data period	✓	✓	✓	✓
Average KABCO crash rate (crashes/100 MVM) and average KABC crash rate (crashes/100 MVM)? If not provided, the KABCO and KABC crash rates from HSIS is used	✓	✓	✓	✓
Is the segment a one-way street?	-	-	✓	✓
Number of lanes (pulled from the Site Characteristics section)	✓	✓	✓	✓
Median type (pulled from the Site Characteristics section)	-	✓	✓	✓

Note: ✓ = variables used in SLSG, - = variables not used in SLSG.

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Speed Data Input Variables for Speed Limit Setting Groups

Speed Data Variable: 50th Percentile Speed (All SLSGs)

The user provides the 50th percentile speed.

Speed Data Variable: 85th Percentile Speed (All SLSGs)

The user provides the 85th percentile speed.

Speed Data Variable: Maximum Speed Limit (All SLSGs)

The user enters the maximum speed limit for the roadway segment in mph.

Roadway Segment Data Input Variables for Speed Limit Setting Groups

Roadway Segment Variable: AADT (Limited-Access, Undeveloped SLSGs)

The user provides the AADT (two-way total) on the Limited-Access or Undeveloped segment.

Roadway Segment Variable: Adverse Alignment Presence (All SLSGs)

The user answers the question "Is an adverse alignment present?" as either yes or no. If yes, the SLS-Tool provides a warning to consider location-specific advisory speed warnings. This variable does not contribute to the calculation of the suggested speed limit.

Roadway Segment Variable: Angle Parking Present (Developed and Full-Access SLSGs)

Because the on-street parking characteristics may vary within a segment, the user provides the on-street parking characteristics that are predominant within the segment. The user indicates if angle parking is present (no, yes for at least 40 percent of the segment, or yes for less than 40 percent of the segment).

Roadway Segment Variable: Bicyclist Activity (Developed and Full-Access SLSGs)

The user indicates if the bicyclist activity is high or not high and whether there is a separated bike line present. Suggested examples of high bicyclist activity are:

- Residential development with four or more housing units per acre interspersed with multi-family dwellings.
- Bicycle treatments including marked bike lanes, bike boxes, etc.
- Multiple transit stops within the segment.

Roadway Segment Variable: Design Speed (Limited-Access SLSG)

The user selects either ≥ 60 mph or ≤ 55 mph for the design speed of the freeway segment. This value along with the grade is used to identify mountainous terrain.

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Roadway Segment Variable: Directional Design-Hour Truck Volume (Limited-Access SLSG)

The user enters the directional design-hour truck volume for the freeway segment in the units of trucks per hour.

Roadway Segment Variable: Grade (Limited-Access SLSG)

The user enters the grade for the freeway segment.

Roadway Segment Variable: ISW (Limited-Access SLSG)

The user enters the inside (left) SW for the freeway segment.

Roadway Segment Variable: Lane Width (Undeveloped SLSG)

The user enters the typical LW (ft) for the segment. Examination of the LW crash modification factor (CMF) for undeveloped facilities in the *Highway Safety Manual* (HSM) (*43*) shows that a 12-ft lane width is assigned a CMF of 1.00 (see Table 10.8, Table 11.11, and Table 11.16 in the HSM). The CMF value computes as 1.05 for 11-ft lane width and 1.30 for 10-ft lane width for two-lane roadways. For multilane undivided roadways, these values are 1.04 and 1.23 for 11-ft and 10-ft roadways, respectively. Stapleton et al. (*34*) found that rural two-lane roadway lane widths greater than 12 ft had fewer fatal and injury crashes (KABC) crashes. The guidance for lane width is synthesized as follows:

- If the LW is less than 10 ft, the posted speed limit should be set at the lower of the closest increment to the 50th percentile (C50) or rounded down to the closest increment to the 85th percentile (RD85).
- If the LW is less than 11 ft, the posted speed limit should be set at the higher of the closest increment to the 50th percentile (C50) or rounded down to the closest increment to the 85th percentile (RD85).
- If the LW is equal to or greater than 11 ft, the posted speed limit should be set at the closest increment to the 85th percentile.

Roadway Segment Variable: Median Type (Undeveloped, Developed, and Full-Access SLSGs)

With respect to Developed and Full-Access SLSGs, the safety analyses conducted as part of NCHRP Project 17-76, published as *Web-Only Document 291* (*2*) (Appendix D on Austin, Texas, and Appendix E on Washtenaw County/Greater Ann Arbor, Michigan) found fewer crashes for a raised (divided) median compared to no median. A review of the literature found studies that documented reduction in crashes when a TWLTL was added to a four-lane undivided roadway (*35, 36*).

The research team suggested that the presence of a divided (raised or depressed) median or a TWLTL on a road with four or more lanes be considered the baseline condition, and for undivided four-lane roads to be associated with suggested posted speed limits that reflect the rounding down of the 85th percentile speed.

Because the type of median may vary within a section, the user is asked for the type of median treatment that is predominant within the section.

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How median type is used for the Undeveloped SLSG is discussed in the "Number of Lanes/ Median Type Combination" section that follows.

Roadway Segment Variable: Number of Access Points (Undeveloped, Developed, and Full-Access SLSGs)

The user provides the number of non-single-family residential driveways and unsignalized intersections within the segment, and the SLS-Tool calculates the access density (access point per mile). The variable is called *access density* to avoid the question of whether driveways per mile should include unsignalized intersections, which it should.

For the Developed and Full-Access SLSGs, the findings from the NCHRP Project 17-76 research supports the breakpoints used in USLIMITS2 (*37*). All types of non-single-family home driveways, such as multifamily residential, commercial, etc., along with unsignalized intersections, should be counted. The guidance for access points is provided in Table 7 for the Developed SLSG and Table 9 for the Full-Access SLSG, and can be synthesized as follows:

- If the number of access points is less than 40 per mile on Developed or Full-Access streets, the suggested posted speed limit should be the 5-mph increment closest to the 85th percentile speed.
- If the number of access points is greater than 40 per mile or less than or equal to 60 per mile, then the suggested posted speed limit should use RD85.
- If the number of access points is more than 60 per mile, then the suggested posted speed limit should be the 5-mph increment closest to the 50th percentile speed.

Previous studies for undeveloped facilities have shown that roadway safety decreases as the number of access points increases (*34, 38*). Access density for undeveloped conditions should also include any signalized intersection within the corridor. Table 6 provides guidance for access points.

Roadway Segment Variable: Number of Interchanges (Limited-Access SLSG)

The user enters the number of interchanges within the segment. This information is used with the segment length and AADT (two-way total) in veh/d. The program computes interchange spacing as length per interchange and calls for lower suggested speed limits for the specified levels of interchange spacing if the AADT equals or exceeds 180,000 veh/d.

Roadway Segment Variable: Number of Lanes (All SLSGs)

The user enters the number of lanes for both directions of travel.

Roadway Segment Variable: Number of Traffic Signals (Developed and Full-Access SLSGs)

The user provides the number of signals within the segment and the program calculates the number of signals/segment length. Previous research used breakpoints at three and four signals per mile and these values were supported by the findings from the analyses conducted in this research [see *NCHRP Web-Only Document 291* (*2*)]. A revised breakpoint was needed for use in the Full-Access SLSG, and the value of eight signals per mile was selected based on feedback from the research project panel.

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Roadway Segment Variable: On-Street Parking Activity (Developed and Full-Access SLSGs)

Because the on-street parking characteristics may vary within a segment, the user provides the on-street parking characteristics that are predominant within the segment. The user indicates if on-street parking activity is high or not high. A high level of on-street parking can be characterized as having parking on both sides of the road with parking time limits.

Roadway Segment Variable: Outside (Right) SW (Limited-Access SLSG)

For Limited-Access facilities, the *Green Book* (*42*) (Chapter 8) calls for outside SWs of at least 12 ft if the truck volume exceeds 250 trk/hr, and at least 10 ft otherwise. Examination of the outside SW CMF for Limited-Access facilities in the HSM (*43*) shows that the outside SW can be reduced slightly without a significant increase in crash frequency. The CMF value computes as 1.21 for an outside SW of 7 ft and 1.14 for an outside SW of 8 ft. In other words, when the outside SW (rounded down to the nearest foot) is less than 8 ft, crash frequency is expected to increase by about 21 percent. Therefore, based on safety considerations, the research team suggested setting the posted speed limit based on the rounded-down 85th percentile if the outside SW is less than 8 ft, or the closest 85th percentile otherwise.

Roadway Segment Variable: Parallel Parking Permitted (Developed SLSGs)

Because the on-street parking characteristics may vary within a segment, the user provides the on-street parking characteristics that are predominant within the segment. The user indicates if parallel parking is permitted (yes or no). Permitted parallel parking on a street within the Developed SLSG results in using RD85.

Roadway Segment Variable: Pedestrian Activity (Developed and Full-Access SLSGs)

The user indicates if the pedestrian activity is high, some, or negligible. Suggested examples of high pedestrian activity are:

- Residential development with four or more housing units per acre interspersed with multi-family dwellings.
- Hotels located within one half mile of other attractions such as retail stores, recreation areas, or senior centers.
- Paved sidewalks, marked crosswalks, and pedestrian signals.
- Multiple transit stops within the segment.

Roadway Segment Variable: Segment Length (All SLSGs)

The user enters the length of the segment in miles.

Roadway Segment Variable: SW (Undeveloped SLSG)

The user enters the typical SW for the segment in feet. Studies have consistently found that wider paved shoulders on undeveloped roadways result in fewer crashes (*39, 40*). Examination of the SW CMF for undeveloped facilities in the HSM (*43*) shows that a 6-ft SW is assigned a CMF of 1.00 (see Table 10.9, Table 11.12, and Table 11.16 in the HSM). The CMF value

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computes as 1.15 for 4-ft and 1.30 for 2-ft lane widths for two-lane roadways. For multilane undivided roadways, these values are 1.15 and 1.30 for 4-ft and 2-ft SWs, respectively. For multilane divided roadways, an 8-ft right SW is assigned a CMF of 1.00 (see Table 11-17 in the HSM). Table 6 provides the guidance for SW within the SLS-Tool.

Roadway Segment Variable: Sidewalk Buffer (Developed and Full-Access SLSGs)

The user indicates if a sidewalk separation (or buffer) is present or not present. A sidewalk separation (or buffer) reflects the space between the road (the face of the curb when a curb and gutter are present, or the edge of the travel lane when a shoulder is present) and the sidewalk. A buffer could include a nature strip, a bike lane, or on-street parking.

Because the type of sidewalk buffer may vary within a section, the user provides the type of sidewalk buffer treatment that is predominant within the section.

Roadway Segment Variable: Sidewalk Presence/Width (Developed and Full-Access SLSGs)

The *FHWA University Level Course on Bicycle and Pedestrian Transportation* (*41*) (page 13-1) states that "sidewalks require a minimum width of 5.0 feet if set back from the curb or 6.0 feet if at the curb face. Any width less than this does not meet the minimum requirements for people with disabilities."

Because the sidewalk characteristics may vary within a segment, the user provides the sidewalk characteristics that are predominant within the segment. The user indicates the predominant width of the sidewalk within the following four categories for the segment:

- **None:** no sidewalk is present on either side of the street.
- **Narrow:** a narrow sidewalk is present (the sidewalk is less than 5 ft if set back from the curb or 6 ft if at the curb face).
- **Adequate:** An adequate sidewalk is present (the sidewalk is between 8 ft and 5 ft if set back from the curb, or between 8 ft and 6 ft if at the curb face).
- **Wide:** A wide sidewalk is present (the sidewalk is 8 ft or greater).

Combination of Roadway Segment Variables

Roadway Segment Combination of Variables: Grade and Design Speed (Limited-Access SLSG)

Consideration for mountainous terrain based on *Green Book* guidance for maximum grade and design speed of Limited-Access facilities (*42*) (Table 8-1) generated the following guidance:

- If the design speed is 60 mph or greater and the maximum grade exceeds 4 percent, set the posted speed limit as the higher of the closest 50th percentile or the rounded-down 85th percentile.
- If the design speed is 55 mph or less and the maximum grade exceeds 5 percent, set the posted speed limit as the higher of the closest 50th percentile or the rounded-down 85th percentile.
- In all other cases, set the posted speed limit as the closest 85th percentile.

The first two conditions are based on the breakpoints between maximum grades for rolling and mountainous terrain specified by the *Green Book*.

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Roadway Segment Combination of Variables: ISW, Number of Lanes, and Hourly Truck Volume (Limited-Access SLSG)

For Limited-Access facilities, the *Green Book* (*42*) (Chapter 8) calls for the following minimum ISW:

- Directional design-hour truck volume ≤ 250 trk/hr and number of lanes (two-way total) < 6 then ISW ≥ 4 ft.
- Directional design-hour truck volume ≤ 250 trk/hr and number of lanes ≥ 6 then ISW ≥ 10 ft.
- Directional design-hour truck volume > 250 trk/hr then ISW ≥ 12 ft.

Examination of the ISW CMF for Limited-Access facilities in the HSM (*43*) shows that the ISW has a minor effect on crash frequency. The CMF value computes as 1.07 for the ISW of 2 ft. Therefore, the research team suggested setting the posted speed limit based on the *Green Book* criteria. If the criteria are met, the posted speed limit is based on the closest 85th percentile. If the criteria are not met, set the posted speed limit based on the rounded-down 85th percentile.

Roadway Segment Combination of Variables: Number of Lanes, Median Type, AADT Combination (Undeveloped SLSG)

With respect to the Undeveloped SLSG, a review of the HSM showed that the crash prediction for undivided four-lane roadways is greater than that for divided four-lane roadways. Four-lane undivided roads with AADT value (two-way total) of 2,000 has about 35 percent more crashes as four-lane divided roads with the same AADT value. The percentage is smaller for roads with AADT values less than 2,000 and larger for AADT values greater than 2,000. Therefore, the research team suggested the rounded-down 85th percentile speed be used when the road has four lanes, is undivided, and has an AADT value of 2,000 or more. Other cases, such as two-lane roads or AADT values less than 2,000, would use the closest 85th percentile speed.

The guidance for the number of lanes/median type combination is synthesized as follows:

- If the undeveloped roadway has an AADT value more than 2,000 is four or more lanes, and is undivided, the posted speed limit should be set using the rounded-down 85th percentile speed (RD85).
- For other cases, such as when the roadway is divided, the closest 85th percentile speed is used. Roads with raised, depressed, or grass medians would be considered divided.

Roadway Segment Variable: Sidewalk Presences/Width, Sidewalk Buffer, and Pedestrian Activity (Developed and Full-Access SLSGs)

When there is a reasonable expectation of pedestrians on or very near a roadway, selection of a lower operating speed can be justified. Sidewalk conditions (width and buffer) and the level of pedestrian activity are used in combination to select the speed percentile; those values are provided in Table 8 for the Developed SLSG and Table 10 for the Full-Access SLSG.

Crash Data Input Variables for Speed Limit Setting Groups

Table 13 shows the variables needed when crash data are available.

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Table 14. Average KABCO rate per 100 MVM for Limited-Access SLSG.

AADT Category—Minimum	AADT Category—Maximum	Urban Limited-Access Facilities (Inter_spac > 1 mi)	Rural Limited-Access Facilities (Inter_spac > 1 mi)
0	24,999	92.83	49.20
25,000	49,999	79.80	51.23
50,000	74,999	76.96	44.16
75,000	99,999	88.34	44.16
100,000	149,999	91.16	44.16
150,000	199,999	91.60	44.16
200,000	No Limit	104.51	44.16

Note: Crash rates and injury rates were calculated using the latest 3 years of data that were available: California (2009–2011), Minnesota (2010–2012), North Carolina (2011–2013), Ohio (2010–2012), and Washington State (2010–2012).

Source: Adapted from *User Guide for USLIMITS2* (*44*), Table 1.

Crash Variables

The following variables are needed to be able to conduct an analysis of the crash data:

- Length of the study period in years and months (least 3 years of crash data is recommended; if less than 1 year of data is input, the program suggests that additional data be collected and the process repeated).
- Total number of all crashes (KABCO) in the segment.
- Total number of fatal and injury crashes (KABC) in the segment.
- AADT (two-way total) for the study period.
- Average rate of all (KABCO) crashes and average rate of fatal and injury (KABC) crashes [100 million vehicle miles (MVM)] for similar road segments in their jurisdiction. To determine the average crash/injury rate for similar segments, users should select a group of segments that have the same or similar geometry (i.e., the number of lanes, median type, etc.) and similar traffic volumes and area type.
- For Developed and Full-Access SLSGs, the user also indicates if the road is a one-way street.

Average Crash Rate

The length of study, number of crashes, and AADT are used to calculate the segment crash rate for all (KABCO) crashes and for fatal and injury (KABC) crashes per 100 MVM. If the user does not provide average rates, default values from the HSIS are used (*44*). Table 14 and Table 15 provide the values for the Limited-Access SLSG, Table 16 and Table 17 provide the values for the Undeveloped SLSG, and Table 18 and Table 19 provide the values for the Developed and Full-Access SLSGs.

Table 15. Average KABC crash rate per 100 MVM for Limited-Access SLSG.

AADT Category—Minimum	AADT Category—Maximum	Urban Limited-Access Facilities (Inter_spac > 1 mi)	Rural Limited-Access Facilities (Inter_spac > 1 mi)
0	24,999	24.74	13.39
25,000	49,999	21.24	12.92
50,000	74,999	21.37	14.41
75,000	99,999	25.15	14.41
100,000	149,999	27.69	14.41
150,000	199,999	29.25	14.41
200,000	No Limit	30.75	14.41

Note: Crash rates and injury rates were calculated using the latest 3 years of data that were available: California (2009–2011), Minnesota (2010–2012), North Carolina (2011–2013), Ohio (2010–2012), and Washington State (2010–2012).

Source: Adapted from *User Guide for USLIMITS2* (*44*), Table 1.

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Table 16. Average KABCO rate per 100 MVM for Undeveloped SLSG.

AADT Category—Minimum	AADT Category—Maximum	Two-Lane Roads	Multilane Divided	Multilane Undivided
0	1,249	206.56	102.55	153.35
1,250	2,499	166.00	102.55	153.35
2,500	3,749	147.23	102.55	153.35
3,750	4,999	133.96	102.55	153.35
5,000	6,249	128.57	76.77	145.63
6,250	7,499	121.91	76.77	145.63
7,500	8,749	125.70	76.77	145.63
8,750	9,999	123.35	76.77	145.63
10,000	14,999	98.16	73.90	124.54
15,000	19,999	98.16	70.83	124.54
20,000	24,999	98.16	70.59	124.54
25,000	No limit	98.16	65.56	124.54

Note: Crash rates and injury rates were calculated using the latest 3 years of data that were available: California (2009–2011), Minnesota (2010–2012), North Carolina (2011–2013), Ohio (2010–2012), and Washington State (2010–2012).

Source: Adapted from *User Guide for USLIMITS2* (*44*), Table 1.

Table 17. Average KABC crash rate per 100 MVM for Undeveloped SLSG.

AADT Category—Minimum	AADT Category—Maximum	Two-Lane Roads	Multilane Divided	Multilane Undivided
0	1,249	65.21	28.93	50.00
1,250	2,499	54.01	28.93	50.00
2,500	3,749	47.73	28.93	50.00
3,750	4,999	43.89	28.93	50.00
5,000	6,249	43.29	22.14	42.08
6,250	7,499	41.46	22.14	42.08
7,500	8,749	44.14	22.14	42.08
8,750	9,999	43.46	22.14	42.08
10,000	14,999	35.60	20.77	41.14
15,000	19,999	35.60	20.79	41.14
20,000	24,999	35.60	23.11	41.14
25,000	No limit	35.60	21.28	41.14

Note: Crash rates and injury rates were calculated using the latest 3 years of data that were available: California (2009–2011), Minnesota (2010–2012), North Carolina (2011–2013), Ohio (2010–2012), and Washington State (2010–2012).

Source: Adapted from *User Guide for USLIMITS2* (*44*), Table 1.

Table 18. Average KABCO crash rate per 100 MVM for Developed and Full-Access SLSGs.

AADT Category—Minimum	AADT Category—Maximum	Two-Lane Roads	Multilane Divided	Multilane Undivided	One-Way Streets
0	2,499	263.17	226.43	452.14	245.12
2,500	4,999	209.14	226.43	452.14	245.12
5,000	7,499	205.37	226.43	452.14	139.27
7,500	9,999	229.55	226.43	452.14	139.27
10,000	14,999	246.62	202.46	452.26	72.18
15,000	19,999	253.25	202.46	452.26	58.31
20,000	24,999	225.17	228.69	431.09	57.36
25,000	29,999	225.17	228.69	431.09	63.87
30,000	39,999	225.17	228.37	431.25	54.63
40,000	49,999	225.17	205.73	431.25	54.63
50,000	No limit	225.17	158.17	431.25	54.63

Note: Crash rates and injury rates were calculated using the latest 3 years of data that were available: California (2009–2011), Minnesota (2010–2012), North Carolina (2011–2013), Ohio (2010–2012), and Washington State (2010–2012).

Source: Adapted from *User Guide for USLIMITS2* (*44*), Table 1.

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Table 19. Average KABC crash rate per 100 MVM for Developed and Full-Access SLSGs.

AADT Category—Minimum	AADT Category—Maximum	Two-Lane Roads	Multilane Divided	Multilane Undivided	One-Way Streets
0	2,499	67.32	72.02	131.02	60.21
2,500	4,999	64.31	72.02	131.02	60.21
5,000	7,499	63.75	72.02	131.02	37.29
7,500	9,999	70.26	72.02	131.02	37.29
10,000	14,999	73.14	66.16	131.98	22.79
15,000	19,999	78.14	66.16	131.98	18.19
20,000	24,999	71.82	75.37	129.00	17.72
25,000	29,999	71.82	75.37	129.00	20.07
30,000	39,999	71.82	74.01	131.10	15.03
40,000	49,999	71.82	70.84	131.10	15.03
50,000	No limit	71.82	56.32	131.10	15.03

Note: Crash rates and injury rates were calculated using the latest 3 years of data that were available: California (2009–2011), Minnesota (2010–2012), North Carolina (2011–2013), Ohio (2010–2012), and Washington State (2010–2012).

Source: Adapted from *User Guide for USLIMITS2* (*44*), Table 1.

Critical Crash Rate

The critical crash rate is calculated from:

$$R_c = R_a + K\sqrt{\frac{R_a}{M}} + \frac{1}{2M}$$

Where:

R_c = Critical crash rate for a given road type.
R_a = Average crash rate for a given road type, provided by the user or obtained from Tables 14 through 19.
K = Constant associated with the confidence level (1.645 for 95 percent confidence).
M = Exposure (100 MVM).

Crash Rate Scenarios

When crash data are available, the program compares the crash rate—both all (KABCO) and fatal and injury (KABC)—for the segment to the critical crash rate and average crash rate, and uses the worst-case scenario. The crash rate is put into one of three categories:

- **High:** Segment crash_rate > critical crash rate.
- **Medium:** Segment crash_rate > 1.3 average crash rate.
- **Low:** neither of the above is true.

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SECTION 6

Speed Limit Setting Tool

Overview of SLS-Tool Requirements

The SLS-Tool is designed to help practitioners assess and establish consistent speed limits for segments of streets and highways. The tool combines customary engineering studies with context-sensitive considerations to identify appropriate speed limits. The engineering studies typically include evaluating criteria such as 85th percentile speed, traffic volume, number of access points, bicyclist activity, pedestrian activity, crash history, and others. The SLS-Tool is designed to produce an unbiased and objective suggested speed limit value based on the 50th and 85th percentile speed, roadway characteristics, and safety.

The SLS-Tool is an Excel®-based spreadsheet program that provides an objective suggested speed limit that traffic engineers can use to communicate with the public or government officials to explain the methodology behind setting speed limits. The tool provides the rationale for setting the speed limit based on key site characteristics, including the statutory speed limit, the distribution of traffic speed, site characteristics, and crash data.

Two versions of the SLS-Tool are available:

- N17-76 SLS-Tool (macro).
- N17-76 SLS-Tool (no macro).

The N17-76 SLS-Tool (macro) uses macro code to display the required data input cells for the specified roadway context and type. This worksheet contains a single analysis worksheet that is used for all SLSGs. The macro code displays only the required data entry rows for the roadway context and type specified by the user. The macro code also includes control buttons that allow the user to clear the data from the Analysis worksheet or populate the data entry cells with a set of default values. When the user opens the tool, Excel® may display a security message indicating that macro code has been disabled. The user must click the “Enable Content” button that appears in a yellow ribbon on the top of the screen. It may also be necessary to check the macro security settings as follows:

1. Select “File” in the upper ribbon.
2. Select “Options.”
3. Select “Trust Center.”
4. Click the “Trust Center Settings” button.
5. Select “Macro Settings.”
6. If the option of “Disable all macros without notification” is selected, select a different option and click the “OK” button.

The other version of the SLS-Tool—N17-76 SLS-Tool (no macro)—does not use macro code. This version is available for users who are not able to use macro codes on their computers. The no-macro version contains one analysis worksheet for each SLSG (Limited-Access, Developed,

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Undeveloped, and Full-Access), and the user must select the appropriate worksheet for each analyzed segment. This version does not provide control buttons to clear data or populate the data entry cells with default values.

Data Entry

The main data entry area is located in columns A–F of the worksheet. The data entry area is organized with boxes for the following data categories:

- **Site Description Data:** Enter basic roadway characteristics such as the roadway context and type, indicate whether crash data are available for the analysis, and enter optional information such as the user's name, analysis date, and roadway segment location.
- **Analysis Results:** The SLS-Tool provides the roadway group (Limited-Access, Developed, Undeveloped, or Full-Access) based on the specified roadway context and type, and displays the suggested speed limit.
- **Speed Data:** Enter the maximum (statutory) speed limit and the needed speed distribution values. The 50th percentile speed is needed for all roadway groups, and the 85th percentile speed is needed for all roadway groups except Full-Access.
- **Site Characteristics:** Enter data to specify the segment length, AADT (two-way total), number of lanes, and other attributes describing the segment's design and traffic control characteristics.
- **Crash Data:** If crash data are available, enter data to specify the time period, traffic volume, and crash counts.

Most of the cells in the SLS-Tool are locked to prevent the user from altering equations and obtaining inaccurate results. Data entry cells are unlocked, and many of the cells have drop-down menus that contain the valid entry options for the cell. For example, the roadway context cell is limited to the categories listed in Figure 7 (Rural, Rural Town, Suburban, Urban, and Urban Core).

The data entry cells are color coded to help the user understand the type of data needed. The following colors are used:

- **Aqua:** basic input cell.
- **Denim:** basic input cell with drop-down menu.
- **Orange:** optional input cell (not needed for calculations). These cells include the user's name, analysis date, roadway name and description, current speed limit, and notes. The user may enter this information for documentation purposes if desired.
- **Green:** optional input cell. These cells contain values that are used for calculations but should be left blank if values are not available. Specifically, the user may enter average crash rates for segments like the one being analyzed, but the SLS-Tool can also estimate average crash rates if the user lacks data to provide average crash rates.
- **Rose:** intermediate calculations.
- **Purple:** final analysis results (specifically, the suggested speed limit).
- **Yellow:** calibration coefficient or policy value. The user should change these cells only based on actual data (e.g., crash rates for specified roadway types) or documented policies (e.g., statutory minimum and maximum speed limits).

Select values used in the analysis calculations are in the "Support Tables" worksheet. That worksheet includes the assumed values for minimum segment lengths by speed limits, upper and lower speed limits by roadway group, SLSGs by roadway type and roadway context, and HSIS crash rates.

Intermediate calculation cells are located to the right of the data entry area. Users will not need to use these cells.

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A legend is provided on the top portion of the main data entry area to summarize the color-coding patterns. A button labeled "Clear all data" is also provided to allow the user to clear input data and restart the analysis with a blank worksheet. When this button is clicked, a message box appears and asks, "Clear all input data?" Click yes to clear the data or no to cancel the operation. After clicking yes, a second message box appears and asks, "Enter default values into data entry cells?" Click yes to populate the data entry cells with default values or no to leave the cells blank.

Advisory, Calculated, or Warning Messages

The SLS-Tool checks for several conditions and issues messages as needed. Table 20 lists the conditions along with the advisory, calculated, or warning messages. These messages are color coded to indicate the message types as follows:

- **Advisory message:** blue font, used to call attention to issues that are not errors but could be improved.
- **Calculated message:** purple font, used to describe calculation results.
- **Warning message:** red font, used to call attention to erroneous input data.

Table 20. SLS-Tool advisory, calculated, or warning messages.

Condition	Message
Missing required data	Enter values for all variables marked with O. (An O will appear to the right of empty input cells.)
Missing roadway context or roadway type	Specify roadway context and roadway type in cells B5 and B6.
Completed calculations	This value is determined by <*x*>. (The quantity *x* is specified as the maximum speed limit, speed data, site characteristics, and/or crash data, depending on which variables governed the setting of the speed limit.)
Completed calculations but with maximum speed limit out of range (too high)	The calculated value exceeds the upper value for this speed limit setting group; therefore, the suggested speed limit reflects the assumed upper value.
Completed calculations but with maximum speed limit out of range (too low)	The calculated value is below the lower value for this speed limit setting group; therefore, the suggested speed limit reflects the assumed lower value.
Maximum speed limit out of range (too high)	The assumed upper value for this speed limit setting group is <max> mph.
Maximum speed limit out of range (too low)	The assumed lower value for this speed limit setting group is <min> mph.
50th percentile speed is greater than 85th percentile speed	The 85th percentile must be greater than the 50th percentile.
85th percentile speed is only 1 mph greater than 50th percentile speed (suggesting a very tight speed distribution)	The 85th percentile is only 1 mph greater than 50th percentile. Interpret results with caution.
Segment length < Minimum_Segment_Length	For a suggested speed limit of *x* mph, minimum segment length = *y* mi.
Adverse alignment present	Consider location-specific advisory speed warnings.
Less than 1 year of crash data	Calculations based on 1 year of crash data or less and should be interpreted with caution.
Less than 3 years of crash data	Consider collecting at least 3 years of crash data.
Average crash rates are greater than computed critical crash rates	Critical rates should be higher than average rates.
The entered number of KABC crashes is greater than the entered number of KABCO crashes	The number of KABC crashes must be less than or equal to the number of KABCO crashes.
Crash rates are calculated from input data	Observed/average KABCO/KABC crash rate = *x* crashes/100 MVM. (For average crash rates, the message will also specify "from User" if the user provided the rate or "from HSIS" if the user did not provide the rate.)
Input data value justifies lowering the speed limit below the closest 85th percentile value	Rounded-down 85th, closest 50th, or rounded-down 50th percentile value.

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Table 21. Upper and lower speed limit checks by Speed Limit Setting Group.

SLSG	Upper Speed Limit Check[a]	Lower Speed Limit Check
Limited-Access	Depends on the state. The SLS-Tool has 85 mph as the upper limit because it is the highest currently allowed in the United States.	50
Undeveloped	Depends on the state. The SLS-Tool has 70mph.	25
Developed	55	25
Full-Access	30	15

[a]Use the maximum speed provided by the user if the user-provided speed is lower than the value in this table.

Several messages refer to the upper and lower speed limit values for the relevant roadway group. Table 21 provides these upper and lower values. The values can be altered in the yellow table in the “Calibration Tables” worksheet if needed. For example, if the segment of interest is an undeveloped facility in a jurisdiction that has a maximum speed limit of 75 mph for these types of facilities, then the user can enter 75 mph into the appropriate cell in the yellow table.

How to Handle Situations When Data Are Not Available for One of the Variables

Some of the variables are fundamental quantities that must be provided for all analysis cases. These variables include roadway context and roadway type. For all other variables, default values can be used if actual data are not available. Table 22 shows these values for speed- and geometric-related variables, and Table 23 shows values for crash-related variables.

Table 22. Input data default values for speed and geometric-related variables.

Variable	Roadway Group	Default Value
50th percentile speed	All	Maximum speed limit – 5 mph
85th percentile speed	Limited-Access, Developed, or Undeveloped	Maximum speed limit – 2 mph
AADT (two-way total)	Developed	30,000 veh/d
AADT (two-way total)	Full-Access	10,000 veh/d
AADT (two-way total)	Limited-Access (roadway context = rural)	25,000 veh/d
AADT (two-way total)	Limited-Access (roadway context = urban)	60,000 veh/d
AADT (two-way total)	Undeveloped	15,000 veh/d
Angle parking present	Developed or Full-Access	No
Bicyclist activity	Developed or Full-Access	Not high
Design speed	Limited-Access	≥ 60 mph
Directional design-hour truck volume	Limited-Access	200 trucks/hr
Grade	Limited-Access	0%
ISW	Limited-Access	6 ft
Lane width	Undeveloped	12 ft
Maximum speed limit	All	See Table 21
Median type	Developed or Full-Access	Divided
Median type	Undeveloped	Divided
Number of access points	Developed	40 access points
Number of access points	Full-Access	60 access points
Number of access points	Undeveloped	15 access points
Number of interchanges	Limited-Access	7 (1 interchange/mi × 7 mi)
Number of lanes	Developed, Undeveloped, or Full-Access	4 lanes
Number of lanes	Limited-Access	6 lanes

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Table 22. (Continued)

Variable	Roadway Group	Default Value
Number of traffic signals	Developed	3 signals
Number of traffic signals	Full-Access	8 signals
On-street parking activity	Developed or Full-Access	Not high
Outside SW	Limited-Access	10 ft
Parallel parking permitted?	Developed	No
Pedestrian activity	Developed or Full-Access	Negligible
Segment length	Developed or Full-Access	1 mi
Segment length	Limited-Access or Undeveloped	7 mi
SW	Undeveloped	10 ft
Sidewalk buffer	Developed or Full-Access	Present
Sidewalk presence/width	Developed or Full-Access	Adequate

Table 23. Input data default values for crash-related variables.

Variable	Roadway Group	Default Value
Crash data availability	All	Yes
Number of years of crash data	All	3 years
Is the segment a one-way street?	Developed or Full-Access	No
Average AADT (two-way total) for crash data period	All	Same as AADT for site characteristics data
All (KABCO) crashes for crash data period	All	Number needed to yield a crash rate equal to 1/3 that of the HSIS-based average rate
Fatal and injury (KABC) crashes for crash data period	All	Number needed to yield a crash rate equal to 1/3 that of the HSIS-based average rate

The default values are chosen to reflect ideal conditions. That is, a site with conditions equal to the default values will have its speed limit set based on the closest 85th percentile speed. The user must enter any data values that deviate from ideal conditions, which may result in setting the speed limit based on a lower speed.

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SECTION 7

SLS-Tool Case Study Examples

Example 1: Limited-Access

Example 1 is a freeway in a large city. Crash data are not available. The following information is available for the site:

- Segment length = 6.5 mi.
- AADT (two-way total) = 130,000 veh/d.
- Directional design-hour volume = 200 trucks/hr.
- Number of lanes (total in both directions) = 6.
- Number of interchanges = 5.
- Design speed ≥ 60 mph.
- Grade = 2 percent.
- Outside SW = 10 ft.
- ISW = 2 ft.
- Maximum speed limit = 70 mph.
- Current posted speed limit = 65 mph.
- 85th percentile = 71 mph.
- 50th percentile = 67 mph.
- No adverse alignment present.

With these input variables, the suggested speed limit is computed as 70 mph. The speed limit criterion is identified as the rounded-down 85th percentile because of the narrow 2-ft ISW. Figure 8 shows the calculations.

Example 2: Undeveloped

Example 2 is for a rural, two-lane highway with the following characteristics:

- Segment length = 7.2 mi.
- AADT (two-way total) = 2250 veh/d.
- Number of lanes = 2.
- Median type = none.
- Number of access points (non-residential driveways and unsignalized intersections) = 14.
- Lane width = 12 ft.
- SW = 4 ft.
- Current posted speed limit = 65 mph.
- 85th percentile = 72 mph.
- 50th percentile = 68 mph.
- Adverse alignment is present.

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NCHRP 17-76 Speed Limit Setting Tool

Input Cells	Description	Output Cells

Site Description Data		Color-Coding Legend
Urban	Roadway context	Aqua = basic input cell
Freeway	Roadway type	Denim = basic input cell with drop-down menu
Yes	Are crash data available?	Orange = optional input cell (not needed for calculations)
User	Analyst	Green = optional input cell (use if data for agency & region are available, leave blank otherwise)
3/18/2020	Date	Rose = intermediate calculations
Example	Roadway name	Purple = final analysis results
Example 1	Description	
65	Current speed limit (mph)	
	Notes	Note: The "Test macros" button provides a message to verify proper macro operation.

Clear all data

Enter default data

Test macros

Analysis Results		Advisory, Calculated, or Warning Messages
Speed limit setting group	Limited access	
Suggested speed limit (mph)	70	This value is determined by speed data & site characteristics.

Speed Data		Advisory, Calculated, or Warning Messages
70	Maximum speed limit (mph)	
71	85th-percentile speed (mph)	
67	50th-percentile speed (mph)	

Site Characteristics		Advisory, Calculated, or Warning Messages
6.5	Segment length (mi)	
130,000	AADT (two-way total) (veh/d)	
6	Number of lanes (two-way total)	
200	Directional design-hour truck volume (trk/hr)	
5	Number of interchanges	1.3 miles between interchanges
≥ 60 mph	Design speed (mph)	
2	Grade (%)	
10	Outside shoulder width (ft)	
2	Inside shoulder width (ft)	Rounded-Down 85th
No	Adverse alignment present?	

Crash Data		Advisory, Calculated, or Warning Messages
3	Number of years of crash data	
25,000	Average AADT for crash data period (veh/d)	
16	All (KABCO) crashes for crash data period	Observed KABCO crash rate = 8.99 crashes / 100 MVMT
4	Fatal & injury (KABC) crashes for crash data period	Observed KABC crash rate = 2.25 crashes / 100 MVMT
	Average KABCO crash rate (crashes / 100 MVMT)	HSIS average KABCO crash rate = 79.8 crashes / 100 MVMT
	Average KABC crash rate (crashes / 100 MVMT)	HSIS average KABC crash rate = 21.24 crashes / 100 MVMT
1.3 x average KABCO crash rate (crashes / 100 MVMT)	103.7	
1.3 x average KABC crash rate (crashes / 100 MVMT)	27.6	
Critical KABCO crash rate (crashes / 100 MVMT)	91.1	
Critical KABC crash rate (crashes / 100 MVMT)	27.2	

Figure 8. Spreadsheet analysis of Example 1: Limited-Access Segment.

Crash data are available and include the following:

- Number of years of crash data = 5 years.
- Average AADT (two-way total) for crash data period = 2200 veh/d.
- Number of all (KABCO) crashes for crash data period = 30 crashes.
- Number of fatal and injury (KABC) crashes for crash data period = 20 crashes.

With these input variables, the suggested speed limit is computed as 70 mph. The speed limit criterion is identified as the rounded-down 85th percentile because of the narrow 4-ft SW. Figure 9 shows the calculations.

Example 3: Developed

Example 3 is for a principal arterial in a suburban area with the following characteristics:

- Current posted speed limit = 40 mph.
- Maximum speed limit = 50 mph.
- 85th percentile = 43 mph.
- 50th percentile = 38 mph.
- Segment length = 2 mi.

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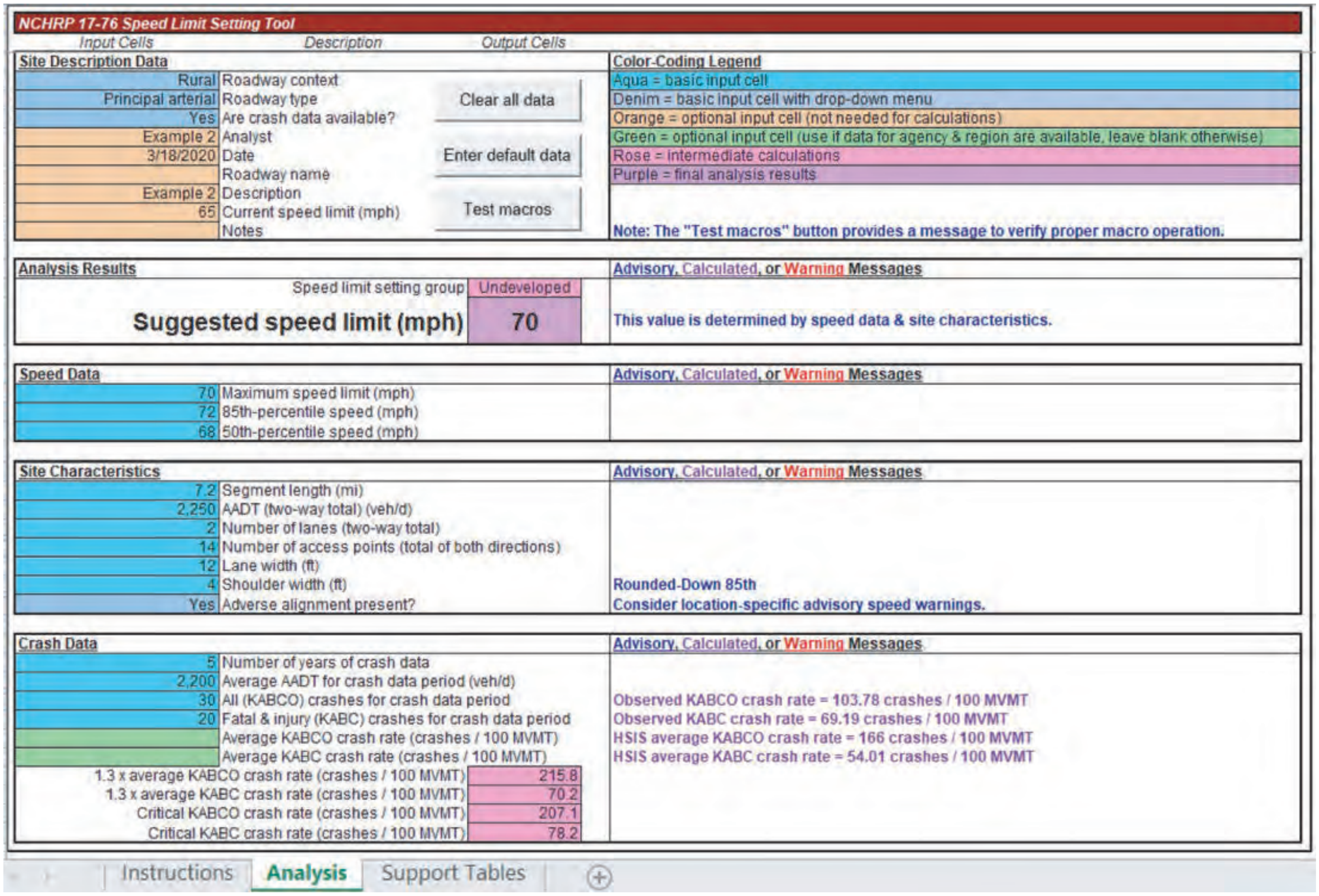

Figure 9. Spreadsheet analysis of Example 2: Undeveloped Segment.

- Number of lanes = 4.
- Median type = TWLTL.
- Number of traffic signals = 3.
- Number of access points (non-residential driveways and unsignalized intersections) = 15.
- Bicyclist activity = not high.
- Sidewalk presence/width = none.
- Sidewalk buffer = not applicable since sidewalk is not present.
- Pedestrian activity = some.
- On-street parking activity = not high.
- Parallel parking permitted = yes.
- Angle parking present = no.
- Adverse alignment present = no.

Crash data are available and include the following:

- Number of years of crash data = 2 years.
- Average AADT (two-way total) for crash data period = 20,000 veh/d.
- The segment has two-way traffic.
- Number of all (KABCO) crashes for crash data period = 25 crashes.
- Number of fatal and injury (KABC) crashes for crash data period = 10 crashes.

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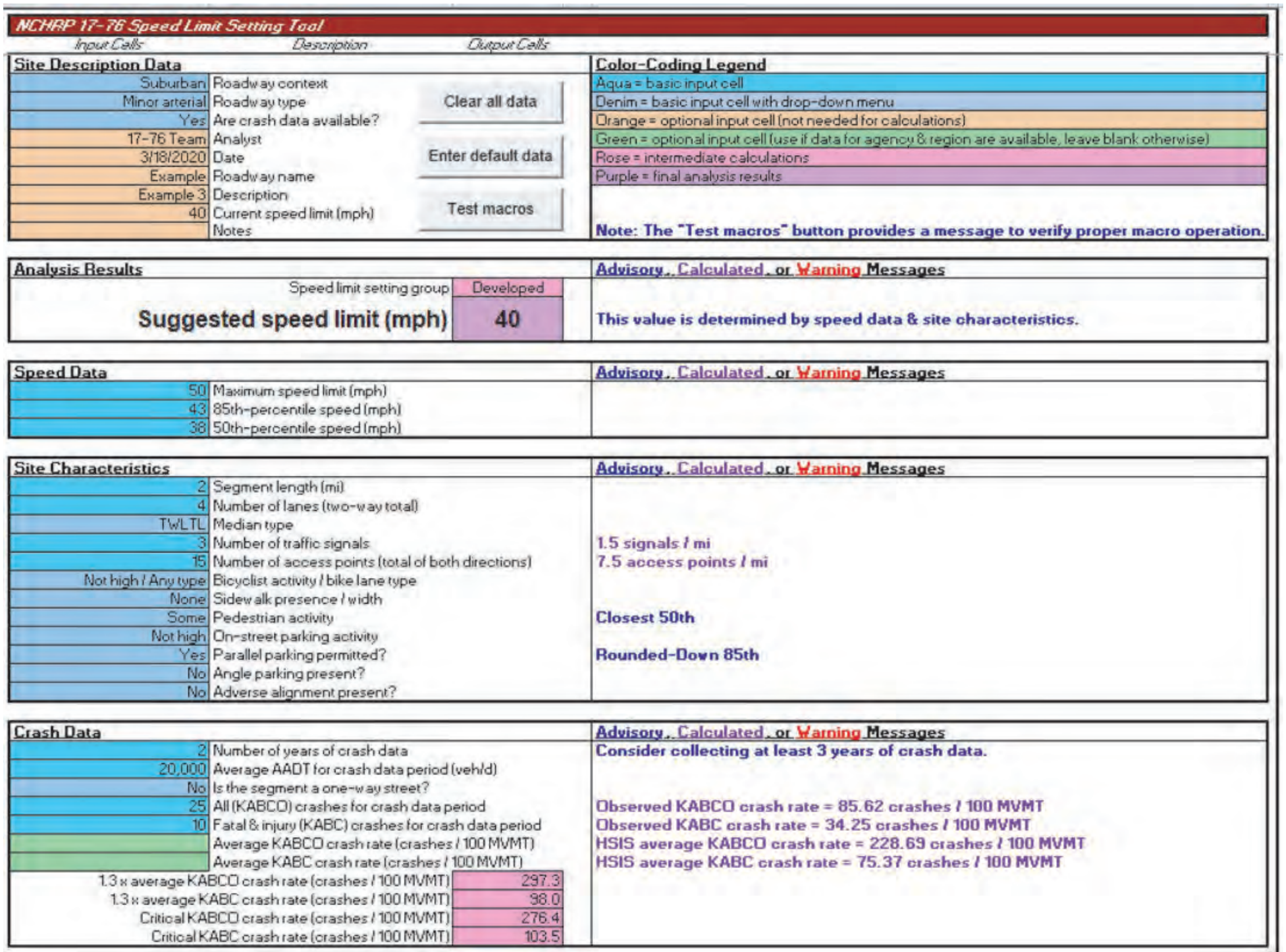

Figure 10. Spreadsheet analysis of Example 3: Developed Segment.

With these input variables, the suggested speed limit is computed as 40 mph. Figure 10 shows the calculations. The speed limit criterion is identified as the closest 50th percentile because no sidewalks are present. If sidewalks of adequate width were added, sidewalks with narrow width and a buffer were added, or pedestrian activity was negligible, the speed limit criterion would be the rounded-down 85th percentile. Because the years of crash data is less than desired (only 2 years rather than 3 years), the SLS-Tool provides an advisory message of "Consider collecting at least 3 years of crash data."

Example 4: Full-Access

Example 4 is for a collector street in the urban core of a city. The following characteristics are available:

- Current posted speed limit = 30 mph.
- Maximum speed limit = 30 mph.
- 50th percentile = 32 mph.

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- Segment length = 1 mi.
- Number of lanes = 2.
- Median type = undivided.
- Number of traffic signals = 3.
- Number of access points, total of both directions (non-residential driveways and unsignalized intersections) = 10.
- Bicyclist activity = not high.
- Sidewalk presence/width = wide.
- Sidewalk buffer = present.
- Pedestrian activity = high.
- On-street parking activity = high.
- Angle parking present = no.
- Adverse alignment present = no.

Crash data are available and include the following:

- Number of years of crash data = 5 years.
- Average AADT (two-way total) for crash data period = 10,000 veh/d.
- The segment has two-way traffic.
- Number of all (KABCO) crashes for crash data period = 50 crashes.
- Number of fatal and injury (KABC) crashes for crash data period = 25 crashes.

With these input variables, the suggested speed limit is computed as 30 mph. The speed limit criterion is identified as the rounded-down 50th percentile because of the high number of KABC crashes on the segment. The observed KABC crash rate of 114.16 crashes/100 MVM exceeds the critical KABC crash rate of 105.5 crashes/100 MVM. The high level on-street parking activity also results in the suggested speed limit being the rounded-down 50th percentile value. Figure 11 shows the calculations.

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NCHRP 17-76 Speed Limit Setting Tool				
Input Cells	*Description*	*Output Cells*		
Site Description Data			**Color-Coding Legend**	
Urban core	Roadway context		Aqua = basic input cell	
Collector	Roadway type	Clear all data	Denim = basic input cell with drop-down menu	
yes	Are crash data available?		Orange = optional input cell (not needed for calculations)	
User	Analyst		Green = optional input cell (use if data for agency & region are available, leave blank otherwise)	
3/18/2020	Date	Enter default data	Rose = intermediate calculations	
Example	Roadway name		Purple = final analysis results	
Example 4	Description			
30	Current speed limit (mph)	Test macros		
	Notes		Note: The "Test macros" button provides a message to verify proper macro operation.	

Analysis Results			**Advisory, Calculated, or Warning Messages**
	Speed limit setting group	Full access	
	Suggested speed limit (mph)	**30**	This value is determined by speed data, site characteristics, & crash data.

Speed Data		**Advisory, Calculated, or Warning Messages**
30	Maximum speed limit (mph)	
33	50th-percentile speed (mph)	

Site Characteristics		**Advisory, Calculated, or Warning Messages**
1.2	Segment length (mi)	
2	Number of lanes (two-way total)	
Undivided	Median type	
3	Number of traffic signals	2.5 signals / mi
10	Number of access points (total of both directions)	8.33 access points / mi
Not high / Any type	Bicyclist activity / bike lane type	
Wide	Sidewalk presence / width	
Present	Sidewalk buffer	
High	Pedestrian activity	
High	On-street parking activity	Rounded-Down 50th
No	Angle parking present?	
No	Adverse alignment present?	

Crash Data			**Advisory, Calculated, or Warning Messages**
5	Number of years of crash data		
10,000	Average AADT for crash data period (veh/d)		
No	Is the segment a one-way street?		
50	All (KABCO) crashes for crash data period		Observed KABCO crash rate = 228.31 crashes / 100 MVMT
25	Fatal & injury (KABC) crashes for crash data period		Observed KABC crash rate = 114.16 crashes / 100 MVMT
	Average KABCO crash rate (crashes / 100 MVMT)		HSIS average KABCO crash rate = 246.62 crashes / 100 MVMT
	Average KABC crash rate (crashes / 100 MVMT)		HSIS average KABC crash rate = 73.14 crashes / 100 MVMT
	1.3 x average KABCO crash rate (crashes / 100 MVMT)	320.6	
	1.3 x average KABC crash rate (crashes / 100 MVMT)	95.1	
	Critical KABCO crash rate (crashes / 100 MVMT)	304.1	
	Critical KABC crash rate (crashes / 100 MVMT)	105.5	Rounded-Down 50th

Figure 11. Spreadsheet analysis of Example 4: Full-Access Segment.

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SECTION 8

Other Considerations When Setting Posted Speed Limits

Why 85th or 50th Percentile Speed?

Currently, the predominant method for setting speed limits is with the use of the 85th percentile speed. It was viewed as being representative of a safe speed that would minimize crashes, and the 1964 Solomon study (*45*) is frequently quoted as being the source to justify the use of the 85th percentile speed. The use of the 85th percentile speed has been supported because it:

- Represents a safe speed that minimizes crashes.
- Promotes uniform traffic flow along a corridor.
- Is a fair way to set the speed limit based on the driving behavior of most of the drivers (i.e., 85 percent).
- Represents reasonable and prudent drivers since the fastest 15 percent of drivers are excluded.
- Is enforceable in that it is fair to ticket the small percentage (15 percent) of drivers that exceed the posted speed limit.

Criticisms of the 85th percentile speed method have included the following:

- Setting the posted speed limit based on existing driver behavior may create unsafe road conditions because drivers may not see or be aware of all the conditions present within the corridor.
- Setting the posted speed limit on existing driver behavior rather than the roadway context may not adequately consider vulnerable roadway users such as pedestrians and bicyclists.
- Drivers are not always reasonable and prudent, or they only consider what is reasonable and prudent for themselves and not for all users of the system.
- Using measured operating speeds could cause operating speeds to increase over time (i.e., speed creep). Drivers frequently select speeds a certain increment above the posted speed limit, anticipating that they will not receive a ticket if they are not above that assumed enforcement speed tolerance. If this occurs, the resulting operating speed would be above the posted speed limit. Using the 85th percentile speed approach in this situation would result in recommending a posted speed limit that is higher than the existing posted speed limit. Posting that higher speed limit would set up the cycle that the next spot speed study may again find a higher operating speed because of drivers using the assumed speed enforcement tolerance to select their speed.
- Most of the early research justifying the use of the 85th percentile speed was conducted on rural roads; therefore, it may not be appropriate for urban roads.

The NCHRP Project 17-76 research team focused Phase II on collecting data for suburban and urban roads to investigate the relationships among crashes, roadway characteristics, and posted speed limit to fill the known research gap for city streets. The team found that crashes were lowest when the operating speed was within 5 mph of the average operating speed (see Appendix D of *NCHRP Web-Only Document 291*). Therefore, the research team recommended that the 50th percentile speed also be a consideration within the SLS-Procedure.

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For the SLS-Procedure, the research team suggested the consideration of measured operating speed as the starting point for selecting a posted speed limit, but that the measured operating speed be adjusted based on roadway conditions and the crash experience on the segment.

Identifying the Segment Limits

Roadway segments are defined based on roadway characteristics and roadway context and type. In general, segments should be homogeneous; that is, the key variables listed in Table 22 should be reasonably uniform throughout the length of the segment. Whenever a significant change in a variable occurs, a new segment should be defined. In particular, a new segment should be defined if the number of lanes, roadway context, or roadway type changes. New segments may also be defined at logical break points based on traffic operations, such as at a major intersection with high turning volumes or a large freeway system interchange. Consider the following rules of thumb in defining break points between segments:

- Roadway context: any change.
- Roadway type: any change.
- AADT or directional design-hour volume: a change of 10 percent or more.
- Number of lanes: any change.
- Median type: any change.
- LW: change of 1 ft or more (length-weighted average for the overall segment).
- Outside or ISW: change of 2 ft or more (length-weighted average for the overall segment).
- Number of interchanges, traffic signals, or access points: the number per mile changes by 50 percent or more.
- Pedestrian or bicyclist activity: any change.
- Sidewalk presence/width: any change.
- Sidewalk buffer presence: any change.
- On-street parking activity, parallel parking presence, or angle parking presence: any change.

Some of these rules of thumb are based on the principles described for the segmentation process in Section 18.5.2 of the HSM but with somewhat higher tolerances permitted for segmentation in speed limit calculation than for safety prediction model application.

Table 24 provides minimum segment lengths based on the speed limit. If segments are defined with shorter lengths than the minimums, the roadway may have too many speed limit changes

Table 24. Minimum segment length for a particular speed limit.

Speed Limit (mph)	Minimum Length (miles)
20	0.30
25	0.30
30	0.30
35	0.35
40	0.40
45	0.45
50	0.50
55	0.55
60	1.20
65	3.00
70	6.20
75	6.20
80	6.20
85	6.20

Source: FHWA, USLIMITS 2, Table 2, page 34 (*44*).

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along its length, and record keeping for the roadway will be more complex. If the roadway has a large number of short segments, it may be necessary to combine adjacent segments that are reasonably similar or apply speed limits from adjacent segments to the segment of interest, if appropriate. However, at locations where a significant change in roadway context occurs, it may be desirable to include short sections where the speed limit transitions from a high value to a low value. For example, if a rural principal arterial approaches a rural town, several short segments may be used to reduce speeds to a value consistent with rural town traffic.

Roadway segments may have individual concerns, such as a sharp horizontal curve, that require lower speeds. These concerns should be addressed with treatments that consider the specific location, such as posting an advisory speed, rather than by lowering the regulatory speed limit for the entire segment.

Gathering Operating Speed

In a general sense, the term *operating speed* relates to the speed at which drivers operate their vehicles along a section of roadway. Typically, for speed limit setting purposes, operating speeds are collected for a representative sample of free-flowing vehicles traveling along a road segment. Free-flowing vehicles are those that are unimpeded by other vehicles or TCDs. Speed data are typically collected at a specific location (or *spot*) to represent the operating speed along an entire homogeneous segment. The speed data should be collected outside the influence area of a traffic control signal, which is generally considered to be approximately 0.5 miles. If the signal spacing is less than 1 mile, the speed study should be at approximately the middle of the segment. Attention should also be given to collect data away from other potential traffic interruptions, including stops signs, driveways, and bus stops. Further, data should only be collected during dry conditions and during off-peak daytime periods.

Various types of equipment may be used to collect spot speed data, including equipment placed on the road surface (e.g., road tubes, piezoelectric sensors, tape switches, etc.) or hand-held from the roadside (e.g., radar or LIDAR). While each of these devices is appropriate for purposes of setting speed limits, it is important to understand how the data are collected such that only free-flowing vehicles are used in the speed study. For road tubes and other on-road equipment, speeds are collected for all vehicles traveling over the roadway during the duration of the study. These data must be filtered to only include free-flowing vehicles that are unimpeded by other vehicles. Similarly, when using radar or LIDAR, the data collection technician must ensure that free-flowing vehicles are selected at random.

Gathering Crash Data

Crash data should be collected from a query of crash records for the jurisdiction of interest. At least 3 years of crash data should be used, but the SLS-Tool can accommodate crash counts for times as short as 1 year. Two crash counts need to be computed for the segment: all crashes (KABCO), and fatal and injury crashes (KABC).

The SLS-Tool compares the crash counts to the computed average and critical crash rates for similar segments. The user may enter average crash rates (computed from similar segments in the state or region) or leave the average crash rate input cells blank. If the cells are left blank, the SLS-Tool computes average crash rates based on HSIS data.

In addition to setting speed limits, the crash data query can also be used to identify sites that could benefit from implementing engineering or enforcement treatments to manage speed.

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Design Speed

The relationship between design speed and posted speed was addressed in a 2015 memorandum from FHWA (*46*). The memo started with quoting Joseph S. Toole's foreword to the 2009 FHWA's *Speed Concepts: Informational Guide* (*47*): "designers of highways use a designated design speed to establish design features; operators set speed limits deemed safe for the particular type of road; but drivers select their speed based on their individual perception of safety. Quite frequently, these speed measures are not compatible and their values relative to each other can vary." The 2009 guide (*47*) introduced the concept of "inferred design speed" and defined that term as "the maximum speed for which all critical design-speed-related criteria are met at a particular location." Stated in another manner, a given set of roadway characteristics can be used to infer the design speed met by that roadway section.

The results of a 2003 NCHRP project examining the relationship between design speed, posted speed, and operating speed concluded that "while a relationship between operating speed and posted speed limit can be defined, a relationship of design speed to either operating speed or posted speed cannot be defined with the same level of confidence" (*6*). The research also found that design speed appears to have minimal impact on operating speeds unless a tight horizontal radius or a vertical curve with a low K-value is present. Large variance in operating speed was found for a given inferred design speed on rural two-lane highways. The research also concluded that when posted speed exceeds design speed, liability concerns may arise even though drivers can safely exceed the design speed.

The FHWA memo (*46*) stated that the selection of a posted speed is an operational decision for which the owner and operator of the facility is responsible and that inferred design speeds less than the posted speed limit do not necessarily present an unsafe operating condition. The memo recommended that "if a state legislature or highway agency establishes a speed limit greater than a roadway's inferred design speed, FHWA recommends that a safety analysis be performed to determine the need for appropriate warning or informational signs such as advisory speeds on curves or other mitigation measures prior to posting the speed limit" (*46*).

Relationships Among Safety, Speed, and Roadway Characteristics, Including Posted Speed Limit

The relationships among safety, speed, and roadway characteristics, including posted speed limit, are complex. The association among these variables can vary widely. Table 25 provides a brief and simple overview of the relationship for different variables with operating speed and crash frequencies by rural and urban facility. A short synthesis on key variables follows. Additional details about these relationships are available in the *NCHRP Web-Only Document 291*, especially in Appendices A and B (*2*).

Traffic Variables

For a motor vehicle crash to occur or to measure how fast a driver is moving, a vehicle must be present. The quantity of traffic and the characteristics of that traffic have an obvious relationship with both speed and safety. Traffic variables include:

- **AADT:** Traffic flow measure AADT is considered the most determinant variable for the occurrence of crashes. Many safety performance functions consider only traffic flow and segment length in the model development. The relationship between traffic volume and crashes

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Table 25. Effect of variables on operating speeds and crash frequencies.

Category	Variables	Rural Operating Speed	Rural Crash Frequency	Urban Operating Speed	Urban Crash Frequency
Traffic	AADT	⇩⇧	⇧	⇧	⇧
	Operating speed	—	⇩⇧	—	⇧
	Congestion	—	—	—	⇧
	Percent truck	⇧	⇧	⇧	⇩
TCD	Posted speed limit	⇧	⇩⇧	⇧	⇩⇧
	Signalized intersection	—	—	—	⇧
	Passing lane/zones	—	⇩	—	—
Roadway Geometry	Horizontal alignment	⇩	⇧	⇩	⇩⇧
	Vertical alignment	⇩	⇧	⇩	⇧
	Presence of median	⇧	⇩⇧	⇧	⇩⇧
	Median width	⇧	⇩⇧	⇧	⇩⇧
	Number of lanes	⇧	⇧	⇧	⇧
	LW	⇧	⇩	⇧	⇩
	SW	⇧	⇩	⇧	⇩
	Bike lanes	—	—	⇧	⇩
	Intersection angle	—	—	—	⇧
	Intersection lighting	—	—	—	⇩
Surroundings	Access density (driveways and intersections)	⇩	⇧	⇩	⇧
	School	—	—	⇩	⇩
	Parking	—	—	⇩	⇧
	Liquor store	—	—	—	⇧
	Sidewalk presence	—	—	—	⇩
	Development (surrounding land and use)	⇩	⇧	⇩	—
Other variables	One-way or two-way	—	—	⇩	—

Note: ⇧ = increase with increase of the attribute, ⇩ = decrease with increase of the attribute, ⇩⇧ = mixed effect, — = relationship not identified or unknown.

can be affected by whether the section is undivided or divided. The effect of this variable on crash frequencies differs based on the facility type. Usually, roadways with higher AADT values are associated with higher operating speeds on both urban and rural roadways. However, Jessen et al. (*15*) found lower operating speeds to be associated with higher AADT roadways. The researchers commented that motorists may view increases in traffic volume as a motivation to slow down.

- **Operating speed:** The operating speed measures are evaluated to assess the consistency of the adopted design values along the designed road alignment. Operating speeds reflect the speed behavior of drivers who are affected by roadway geometry, surroundings, traffic, and other variables. A study using 179 roadway sections in Israel explored the relationship between operating speeds (obtained from global positioning system devices) and crashes on rural two-lane roadways with 50-mph posted speed limit (*48*). The main finding of the study was that in both day and night hours, the number of injury crashes increased with an increase in the segment mean speed, while controlling for traffic exposure and road infrastructure conditions. Wang et al. (*49*) reviewed several previous studies to identify factors, especially traffic and road geometry factors, related to crashes. The authors concluded that some studies found increased speed reduces safety, and other studies found the opposite.
- **Other traffic variables:** Other traffic variables include congestion and the percentage of trucks. Several studies showed that congestion increases risk of traffic crashes. The percentage of trucks has a mixed effect on operating speeds.

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TCD Variables

The type of TCDs present can influence operating speeds and crashes. For example, when traffic signals are timed to optimize progression along a corridor, drivers tend to operate at that speed to avoid having to stop at the next signal. Most signs and markings, however, do not have such a major impact on speeds with the exception of the posted speed limit sign. TCD variables include:

- **Posted speed limit:** Prior studies showed that posted speed limit has a significant effect on operating speed on urban streets. For rural high-speed highways, posted speed limits are typically established with consideration of several factors, including the roadway design speed. Several studies showed that vehicular operating speeds are impacted by the posted speed limit, with vehicular speeds tending to increase as the posted speed limit increases. However, the magnitude of the increase in operating speed is typically only a fraction of the amount of the actual speed limit increase. The research literature generally suggests that the resulting change in operating speeds would likely lead to an increase in the overall crash rate and would also shift the severity distribution toward crashes of greater severity.
- **Other TCD variables:** Other important TCD variables include the presence of intersections and passing lanes. For urban roadways, the presence of an intersection is associated with higher crash frequencies and lower operating speeds. Passing lanes are effective in crash reduction on rural roadways. However, passing lanes are associated with higher intersection-related crash frequencies on rural roadways.

Roadway Geometry Variables

The design of the roadway can influence either operating speed or crashes in select cases. Roadway geometry variables include:

- **Horizontal alignment:** Horizontal curves have been identified as the geometric variable that is the most influential on driver speed behavior and crash risk. The measures used in the studies varied and included the degree of curve, length of curve, deflection angle, and/or superelevation rate. Horizontal alignment is also associated with negatively affecting safety as shown in the HSM (*43*). Prior research has shown that crash frequency increases with the length and/or degree of horizontal curvature (*43*, *50*) although there is a value where the influence is no long present.
- **Vertical alignment:** Studies showed that roadways with vertical alignment experience lower operating speeds once the vertical alignment exceeds a certain value. Prior research has showed that steeper vertical alignments could induce higher crash potentials (*13*). Total crash rates typically increase with the degree of vertical alignments, mainly in the presence of hidden horizontal curves, intersections, or driveways. Safety risks associated with higher speed limits increased on segments with steeper vertical curves.
- **Median:** Median barriers are associated with severe crash rate reduction but have also been found to be associated with more property-damage-only crashes. A Michigan study found that the presence of a TWLTL was associated with a significant increase in total and injury crashes but was also associated with a significant decrease in fatal crashes (*50*).
- **SW:** Wider shoulder widths are associated with higher operating speeds. The HSM suggests that the width of the paved shoulder along non-freeways has a similar effect on crashes as travel lane widths, and that wider widths are associated with fewer crashes (*43*). The increased recovery and vehicle storage space and increased separation from roadside hazards are associated with fewer crashes.

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- **Other roadway geometry variables:** Other roadway geometry variables that may have an effect on speed or crashes include the LW, number of lanes, presence of bike lane, intersection angle, and intersection lighting.

Variables Associated with Roadway Surroundings

The characteristics of the road's surroundings, including the neighboring land use, affect both operating speed and crashes. Variables associated with roadway surroundings include:

- **Access density (driveways and intersections):** Prior studies have demonstrated that as the density of access points (or the number of intersections and/or driveways per mile of highway) increases, the frequency of traffic crashes also increases. This occurs partially due to driving errors caused by intersections and/or driveways that may result in rear-end and/or sideswipe type crashes. Specifically, *NCHRP Report 420* concluded that an increase in crashes occurs due to the higher number of access points (*51*). Roadways with high access densities usually experience lower operating speeds.
- **Other variables associated with surroundings:** Other variables associated with surroundings include the presence of schools, presence of liquor stores, presence of sidewalks, and development.

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SECTION 9

Related Reference Materials

This section introduces other reference materials that can be used when considering how to address speed within a segment. The materials are listed by date order with the most recent publications first.

Speed Management Safety Website

- Source: https://safety.fhwa.dot.gov/speedmgt/.
- Date: last modified April 2019.
- Publisher: Federal Highway Administration.
- Description: This website provides links to several publications and tools along with ongoing research.

Speed Management ePrimer for Rural Transition Zones and Town Centers

- Source: https://safety.fhwa.dot.gov/speedmgt/ref_mats/rural_transition_speed_zones.cfm.
- Date: January 2018.
- Publisher: Federal Highway Administration.
- Description: The *Speed Management ePrimer for Rural Transition Zones and Town Centers* reviews speeding-related safety issues facing rural communities and discusses the basic elements required for data collection, information processing, and countermeasure selection by rural transportation professionals and community decision makers. The ePrimer is presented in six distinct modules developed to allow the reader to move between each to find the desired information, without a cover-to-cover reading.

Traffic Calming ePrimer

- Source: https://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm.
- Date: February 15, 2017.
- Publisher: Federal Highway Administration.
- Description: The ePrimer presents a review of traffic calming practice in eight modules. The ePrimer presents:
  - A definition of traffic calming, its purpose, and its relationship to other transportation initiatives (like complete streets and context-sensitive solutions).
  - Illustrations and photographs of 22 different types of traffic calming measures.
  - Considerations for their appropriate application, including effects and design and installation specifics.

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- Research on the effects of traffic calming measures on mobility and safety for passenger vehicles; emergency response, public transit, and waste collection vehicles; and pedestrians and bicyclists.
- Examples and case studies of both comprehensive traffic calming programs and neighborhood-specific traffic calming plans.
- Case studies that cover effective processes used to plan and define a local traffic calming program or project and assessments of the effects of individual and series of traffic calming measures.

Highway Safety Manual

- Source: available for purchasing from http://www.highwaysafetymanual.org/Pages/default.aspx.
- Date: 2010, with supplement for freeways published in 2014.
- Publisher: AASHTO.
- Description: The HSM is the premier guidance document for incorporating quantitative safety analysis in the highway transportation project planning and development processes.

Speed Management Program Plan

- Source: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/812028-speedmgtprogram.pdf.
- Date: April 2012.
- Publisher: National Highway Traffic Safety Administration, FHWA, and Federal Motor Carrier Safety Administration.
- Description: The most recent version of the *Speed Management Program Plan* was published in 2014 and is an update of the original version published in 2005. The document contains strategies based on research related to managing speed through setting and enforcing speed limits and guidance on reducing speeding-related crashes. The document includes specific goals, objectives, and action items for speed management. The report also includes priority areas that transportation professionals are encouraged to focus on. However, over the past 5 years, the topic has evolved to the extent that specific content for each of these elements needs to be updated. A recent FHWA study is developing an updated version.

Methods and Practices for Setting Speed Limits: An Informational Report

- Source: https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa12004/.
- Date: April 2012.
- Publisher: FHWA (FHWA-SA-12-004) and Institute of Transportation Engineers.
- Description: The report describes primary practices and methods to set speed limits and includes an engineering approach, expert systems, optimization, and injury minimization. Guidance for setting speed limits is provided, and case studies are included. The guidance also discusses speed zones including advisory, school zones, work zones, variable speed limits, and transition zones. This includes guidance for when speed transitions are needed and the setting of transition zone speeds.

Speed Concepts: Informational Guide

- Source: https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa10001/fhwasa10001.pdf
- Date: December 2009.
- Publisher: FHWA (FHWA-SA-10-001).

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- Description: The guide discusses speed concepts and includes:
  - Definitions of speed terms (e.g., 85th percentile speed and design speed).
  - Summary of research on the effects of speed.
  - Characteristics of speed such as speed distributions and speed profiles.
  - Processes to document speeds.
  - Agency roles in addressing speed including establishing speed limits and advisory speeds and enforcing speed limits.
  - Speed management technique and countermeasures.

NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 23: A Guide for Reducing Speeding-Related Crashes

- Source: http://www.trb.org/Publications/Public/Blurbs/A_Guide_for_Reducing_Speeding Related_Crashes_160862.aspx.
- Date: 2009.
- Publisher: Transportation Research Board.
- Description: The guide summarizes the collection and evaluation of speed and crash data. The guide covers strategies to set reasonable and prudent speed limits that account for roadway design, traffic, and environment. The guide also covers increasing drivers' awareness of the risks of driving at unsafe speeds.

MUTCD for Streets and Highways

- Source: https://mutcd.fhwa.dot.gov/.
- Date: last modified December 2009.
- Publisher: FHWA.
- Description: The MUTCD is the national standard for signing on all highways. Sections 2B.13–16 address regulatory speed limits, Section 2C addresses advisory speed signs, Section 7B addresses school zone speed limit signs, and Section 6C addresses work zone speed limits.

USLIMITS2

- Source: https://safety.fhwa.dot.gov/uslimits.
- *User Guide for USLIMITS2*: https://safety.fhwa.dot.gov/uslimits/documents/appendix-l-user-guide.pdf.
- Date: March 2008 for initial development, December 2017 for updated user guide.
- Publisher: U.S. Department of Transportation, FHWA.
- Description: USLIMITS2 is a web-based tool that was designed to assist practitioners in setting consistent and safe speed limits. It is used to set speed limits for specific segments of roads and can be used on all types of roads (local roads to freeways).

Speed Enforcement Program Guidelines

- Source: https://www.safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa09028/resources/Speed Enforcement Program Guidelines.pdf%23page=1.
- Date: March 2008.

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- Publisher: U.S. Department of Transportation, National Highway Traffic Safety Administration.
- Description: The objective of the guidelines is to provide law enforcement personnel and decision-makers with tools to establish and maintain an effective speed management program. The guidelines include:
  - Identification of the problem.
  - Legislative, regulation, and policy.
  - Program management, including public outreach.
  - Enforcement countermeasures.
  - Program evaluation.

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Acronyms and Abbreviations

AADT	Average annual daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average daily traffic
C50	The 5-mph increment that is closest to the 50th percentile speed
C85	The 5-mph increment that is closest to the 85th percentile speed
CMF	Crash modification factor
Expanded FCS	Expanded Functional Classification System
FHWA	Federal Highway Administration
HSIS	Highway Safety Information System
HSM	*Highway Safety Manual*
ISW	Inside shoulder width
K	Constant associated with the confidence level (1.645 for 95 percent confidence)
KABC	Fatal and injury crash severity levels
KABCO	All crash severity levels
LW	Lane width
M	Exposure (100 million vehicle miles)
mph	Miles per hour
MUTCD	*Manual on Uniform Traffic Control Devices*
MVM	Million vehicle miles
N	Number of lanes
NCHRP	National Cooperative Highway Research Program
NTSB	National Transportation Safety Board
R_a	Average crash rate for a given road type, provided by the user or obtained from HSIS tables
R_c	Critical crash rate for a given road type
RD50	The 5-mph increment obtained by rounding down the 50th percentile to the nearest 5-mph increment
RD85	The 5-mph increment obtained by rounding down the 85th percentile to the nearest 5-mph increment
SLS-Procedure	Speed Limit Setting Procedure
SLS-Tool	Speed Limit Setting Tool
SLSG	Speed Limit Setting Group
SW	Shoulder width
TCD	Traffic control device
TWLTL	Two-way left-turn lane

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

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