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Considering Roadway Context in Setting Posted Speed Limits

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Abstract

The National Cooperative Highway Research Program (NCHRP) Project 17-76 investigated factors that influence operating speed and safety through a review of the literature and an analysis of the relationships for speed, safety, and roadway characteristics on urban/suburban streets. That knowledge, along with a review of existing speed limit setting practices, was used to develop a Speed Limit Setting Procedure (SLS-Procedure) as well as a user manual to explain the SLS-Procedure. In addition, the SLS-Procedure was automated via a spreadsheet-based Speed Limit Setting Tool (SLS-Tool). These products will permit engineers to make informed decisions about the setting of speed limits. The SLS-Procedure is fact based and transparent, relying on a set of decision rules that consider both driver speed choice and safety associated with the roadway. The SLS-Procedure was designed to be applicable across 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 uses the operating speed distribution as a starting point for the suggested speed limit, with the resulting suggested value based on consideration of roadway type, context, safety performance, and other characteristics.

Speed limits are posted to inform drivers of the highest speed that is considered reasonable and prudent for ideal traffic, road, and weather conditions, while providing a basis for the enforcement of unreasonably high travel speeds. For a given section of roadway, speed limits are typically set based on consideration of several factors. Until very recently, most, if not all, of the speed limit setting procedures used in the U.S. relied on the 85th percentile speed as the primary basis (*1*). The *Manual on Uniform Traffic Control Devices* (MUTCD) provides information on the setting of non-statutory speed limits, which indicates that the selection of the speed limit value is based on an engineering study (*2*). The speed limit is to be within 5 mph of the measured 85th percentile speed for the roadway segment.

Speed management has long been a concern of transportation agencies. In rural areas, the 85th percentile speed is often influenced by the most restrictive geometric element, usually a horizontal or vertical curve. However, 85th percentile speeds in urban areas are often more variable and influenced by traffic characteristics along with the contextual features of the roadway and surrounding area. Because of this, the MUTCD allows for several factors to be considered for adjusting the 85th percentile speed, such as road characteristics, roadside development, parking practices, pedestrian activity, and crashes (*2*). In light of this, several state speed limit setting procedures include other factors, such as bicyclist activity or alignment, in addition to the factors listed in the MUTCD. And although various tools exist that help guide the speed limit setting process, few, if any, give a comprehensive consideration to the road context or to the context of the surrounding area.

To address the desire to update the procedures used in setting posted speed limits, a recent National Cooperative Highway Research Program (NCHRP) Project (Project 17-76) was established to investigate the factors that influence operating speed and safety. This knowledge would be subsequently applied toward development of a Speed Limit Setting Procedure (SLS-Procedure) to help inform decisions related to the setting of speed limits. The SLS-Procedure was automated with the Speed Limit Setting Tool (SLS-Tool), which is

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spreadsheet-based and included with the *User Guide for Posted Speed Limit Setting Procedure and Tool* publication (*3*). The overall goal of the NCHRP Project 17-76 research was to develop guidance so users can make informed decisions in relation to the setting of speed limits.

The publication of NCHRP Research Report 855 *An Expanded Functional Classification System for Highways and Streets* during the early stages of NCHRP 17-76 outlined contexts beyond urban and rural and facilitated accommodation of modes other than personal vehicles (*4*). The timing of this report, along with the increased activity by states and cities in exploring alternative methods for setting posted speed limits (see following sections) provided the opportunity for the NCHRP 17-76 research team to better integrate consideration of context into a refined speed limit setting procedure.

Calls for Change

While the rural highway speed limit debate had been ongoing for years, the speed limit debate in urban areas increased in 2017 with two publications. First, in March 2017, the National Association of City Transportation Officials (NACTO) released a policy statement aimed at improving multi-modal urban transportation (*5*). One of the action items in that statement would "permit local control of city speed limits." They recommend "state rules or laws that set speed limits at the 85th percentile speed should be repealed." Then in July 2017, the National Transportation Safety Board (NTSB) published a report on speeding: *Reducing Speeding-Related Crashes Involving Passenger Vehicles* (*6*). That document contained several recommendations for reducing speed-related crashes including two recommendations directed to the Federal Highway Administration (FHWA) for changes to the MUTCD (*6*). NTSB recommended: (*a*) that the MUTCD factors that were listed as optional for all engineering studies be required, (*b*) that it be required that an expert system such as USLIMITS2 be used as a validation tool, (*c*) to remove the guidance that speed limits in speed zones should be within 5 mph of the 85th percentile speed, and (*d*) to incorporate the safe system approach for urban roads to strengthen protection for vulnerable road users.

Shortly thereafter, a National Committee on Uniform Traffic Control Devices (NCUTCD) task force was formed to consider the NTSB recommendations. The task force conducted a survey on speed limits with the findings documented in two 2019 papers (*7*, *8*). One of the questions from the NCUTCD task force survey was "How would you set speed limits if given the choice?" The provided responses included rounding to the nearest 5 mph of the 85th percentile, or rounding up or down, and so forth. Half of the survey participants selected "other" and typed a response, with the word "context" being used more than any other word.

Also, at that time, in California, a Zero Traffic Fatalities Task Force was formed to "develop a structured, coordinated process for early engagement of all parties to develop policies to reduce traffic fatalities to zero" (*9*). In addition, the task force also examined alternatives to the 85th percentile method for determining speed limits in California. The California Zero Traffic Fatalities Task Force made several recommendations, including having a policy that would allow increased deviation (more than 5 mph) from the 85th percentile speed for high injury networks and areas adjacent to land uses and types of roadways that have high concentrations of vulnerable road users (*10*). Similar activities to change procedures for setting speed limits in cities and counties also began in Oregon and elsewhere in the U.S.

Speed Limits in U.S. Cities

Several U.S. cities have recently campaigned to be able to set lower citywide default speed limits. NACTO and Vision Zero are contributing to the speed limit discussion and using speed-related pedestrian/bike crash survivability to justify uniformly low posted speeds. NACTO is currently working on a publication that will provide guidance on the "setting of safe speed limits on urban streets" (*11*). Examples of U.S. cities that are setting a 25 mph citywide speed limit include Boston, Massachusetts; New York City, New York; Seattle, Washington; and Austin, Texas (*12–15*). Portland, Oregon, has the authority to set residential streets at 20 mph. On October 24, 2016, Oregon provided the City of Portland approval to begin the use of its proposed experimental alternative speed zone investigation method. The alternative method is to be used on streets that are under the jurisdiction of the City of Portland (*16*). Portland notes on its website that speeds "must account for people traveling in different ways: walking, driving, using mobility devices, biking, skateboarding, etc." and that "it is important to consider people traveling outside of motor vehicles because they are not protected from the impact of crashes" (*17*). Portland provides the following four methods that the city can use to request speed limit changes:

- Alternative method. For use on non-arterial streets with speed limits above 25 mph. It uses a streamlined request process that places greater emphasis on vulnerable users and the risk of a future crash relative to the traditional method;
- Traditional method. It is required on arterial streets except on sections eligible for business

district statutory speed limits. It uses multiple factors to determine speed limits, including 85th percentile speeds, crash history, roadside culture, traffic volumes, roadway alignment, width, and surface;
- Statutory method. For streets with a speed limit specified by law;
- Special clauses. It allows for 5 mph below statutory speed limits on certain streets such as low-traffic neighborhood greenways and certain residential streets.

Slow zones are corridors or regions with a lower speed limit than surrounding areas. An example of a slow zone program is the Neighborhood Slow Zones program implemented by New York City (*13*). The Neighborhood Slow Zones program aims to lower the incidence and severity of crashes and to enhance quality of life by reducing cut-through traffic and traffic noise in residential neighborhoods. Within the slow zone area, speed limits are reduced from 25 mph to 20 mph, and roadway geometric treatments—such as speed bumps or other traffic-calming treatments—are added with the intention of changing driver behavior. Gateway signs and markings are used at intersections to alert drivers to the reduced speed limit.

Neighborhood Slow Zones are typically established in small, self-contained areas that consist primarily of local streets where the streets within the zones can be self-enforcing because of the roadway characteristics. They are implemented in areas with low traffic volumes and minimal through traffic, where reducing the speed limit will not cause traffic congestion. New York City has reported that areas where neighborhood slow zones have been implemented experienced "a 10%–15% decrease in speeds, 14% reduction in crashes with injuries" (*13*).

The California Zero Traffic Fatalities Task Force made several recommendations, including developing a different approach to setting speed limits that provides a roadway-based context-sensitive approach that prioritize the safety of all road users (*9*).

Objective

The objective of this paper is to present the speed limit setting procedure that explicitly considers roadway context in developing suggested posted speed limits. Unique decision rules were developed for four combinations of roadway types and contexts based on the categories established in NCHRP Report 855, including: limited-access, undeveloped, developed, and full-access facilities (*4*). This paper documents the research used to justify and develop the new speed limit setting procedure and the accompanying tool that can be used to automate the procedure.

Review of Literature and Existing Techniques for Selecting Posted Speed Limits

The review of the literature identified several studies that have explored the relationships among operating speed, safety, and roadway characteristics, see Fitzpatrick et al. for details (*1*). To summarize, the consensus is that higher operating speeds (in many cases as represented by the posted speed limit) are associated with more severe crashes, as supported by basic physics. A 2006 NCHRP study estimated that increasing speed limits on rural highways from 55 mph to 65 mph would increase total crash occurrence by 3.3%, and the conditional probability of a fatality (assuming a crash had occurred) would increase by 24% (*18*). However, such safety impacts would be expected if and only if operating speeds (mean, 85th percentile, or variance) are subsequently impacted by the change in posted speed limit.

To that end, few recent studies are available that examine the relationship between the magnitude of operating speed and the *frequency* of crashes, likely primarily because of the difficulties in obtaining actual operating speed data for significant time durations, segment lengths, or number of sites. This is particularly true for urban areas, where the operating speeds are highly variable based on traffic volumes, non-motorized activity, on-street parking, driveway density, signal spacing, transit activity, and other factors. A 2017 study on rural two-lane highways in Israel and a 2016 study on two-lane urban roads in the city of Edmonton, Canada, are notable exceptions (*19, 20*). These two studies found that as the average operating speed increases, the number of crashes also increases.

The review of USLIMITS2, Portland, New Zealand, and Canada's procedures showed that several of the variables identified in the literature review are also being considered in their procedures (*16, 21, 22*). In some cases, the consideration is specific; for example, in USLIMITS2, a precise value for signal or access density (e.g., four signals per mile) would change the recommendation. In other cases, the value for the variable is based on engineering judgment (e.g., is parking activity high or not).

The roadways, traffic control devices, and traffic variables that were found to affect speed or crashes were identified and used to develop a list of variables that should be considered in an updated speed limit setting procedure.

Speed Limit Setting (SLS) Procedure

Guiding Principles

The research team began the process of developing a new or refined SLS-Procedure by identifying guiding principles that included the following:

- Ensure the procedure explicitly considers the context of the road and surrounding area;
- Develop a single procedure (tool) that can be used for all roadway types and roadway contexts by incorporating unique decision rules for the diverse characteristics of each speed limit setting group;
- Use a data-driven approach with research-based decision rules;
- Ensure the procedure produces 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 process;
- Consider agency data and human resource constraints;
- Allow for future modifications to accommodate new knowledge;
- Create efficiencies in the decision process, where possible.

Selecting the Base Format for SLS-Procedure

The NCUTCD Task Force findings along with other recent calls for changes (see Introduction section) have demonstrated that the consideration of road context is increasing in importance (*7*). Within the design community, there is also greater emphasis on designing roadways to fit the context of the site. The philosophy of complete streets, context-sensitive design, and context-sensitive solutions are examples of where the consideration of the roadway context is factored into the decision-making process. These ideals were also reinforced by the recent publication of a series of related NCHRP research reports that developed an expanded functional classification system, explored a performance-based design process, or advanced guidance on integrating safety and cost-effectiveness in design (*4, 23–25*).

Given the increased emphasis on the context within the profession, the research team decided that the SLS-Procedure should also be sensitive to context. The Expanded Functional Classification System available in NCHRP Report 855 (see Figure 1 for an illustration) was used to develop Speed Limit Setting Groups (SLSGs) that reflect logical collections with respect to setting speed limits (*4*). For example, freeways, which have very specific geometric design criteria, are present within several roadway types and roadway context combinations and they were grouped into a Limited-Access SLSG. Additional material on roadway context and roadway type is available in the user guide developed as part of NCHRP 17-76 (*3*). Table 1 shows the four SLSGs formed from the various combinations of roadway contexts and types:

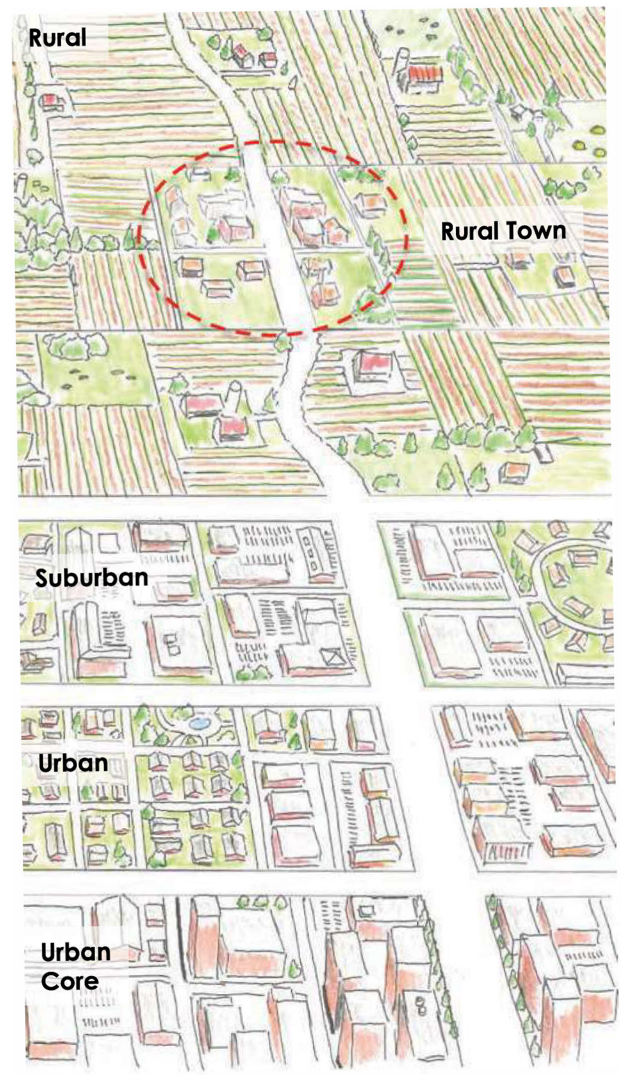

Figure 1. National Cooperative Highway Research Program (NCHRP) Report 855 illustration of five roadway contexts (*4*). Source: Transportation Research Board. 2018. *An Expanded Functional Classification System for Highways and Streets*. HTTPS://DOI.ORG/10.17226/24775. Figure 2, p. 3.

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

With consideration of the issues identified along with research into the relationships among roadway characteristics, including posted speed limit, operating speed, and safety, the NCHRP Project 17-76 team developed a

Table 1. Suggested Speed Limit Setting Groups (*1*)

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

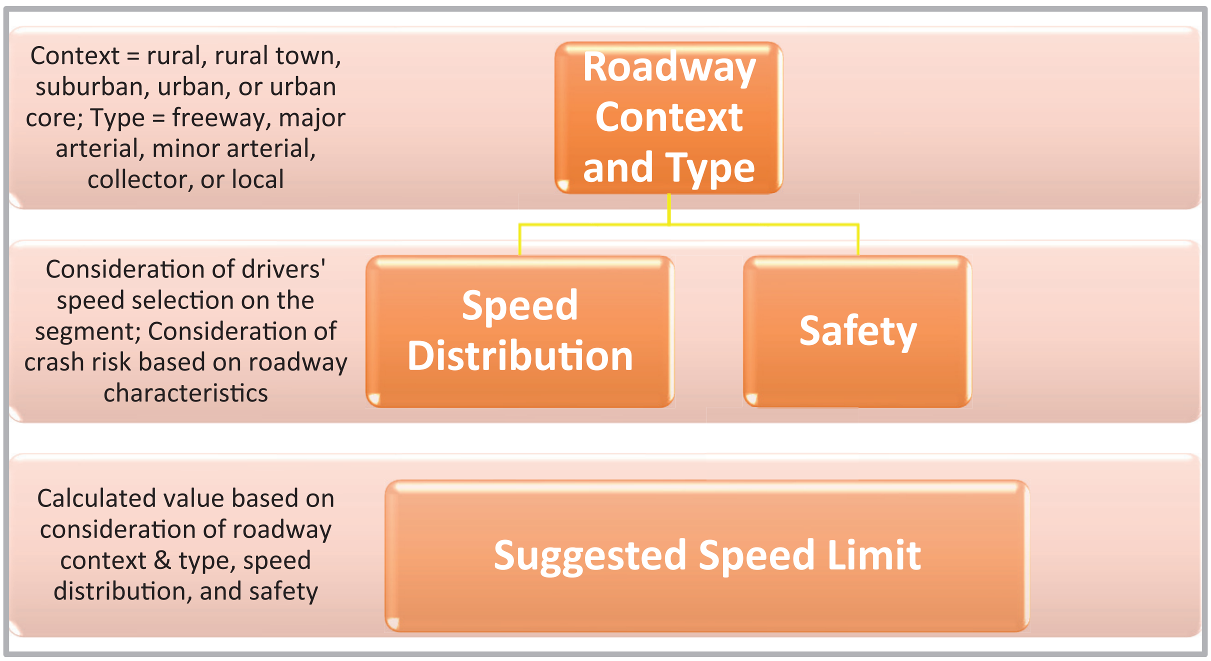

Figure 2. Overview of Speed Limit Setting Procedure (SLS-Procedure) to calculate the suggested speed limit (*1*).

procedure to calculate a suggested speed limit (SSL). The SLS-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 SSL that is then adjusted with consideration of the crash potential for the segment. Figure 2 illustrates the steps for the procedure.

Starting Value from Speed Distribution Curve

Currently, the predominant method for setting speed limits is with the use of the 85th percentile speed. It is frequently viewed as being representative of a "safe speed" that will minimize crashes, and the 1964 Solomon study is frequently quoted as being the source to justify the use of the 85th percentile speed (*26*). A recent 2020 publication noted that the "85th percentile rule actually emerged decades earlier amidst the nascent traffic engineering profession's preoccupation with 'traffic service' to increase vehicular throughput; and with respect to safety, the rule was explicitly intended as a starting point in speed limit setting, and not the last word" (*27*).

The use of the 85th percentile speed has been supported with the following ideas:

- 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 drivers (i.e., 85%);
- Represents reasonable and prudent drivers since the fastest 15% of drivers are excluded;
- Is enforceable in that it is fair to ticket the small percentage (15%) of drivers that are exceeding the posted speed limit;

- Accepted as a common practice or compromise with the understanding that it accommodates a large group of drivers, promoting their mobility, while allowing or recognizing that 15% of drivers will go faster;

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;
- Measurement of vehicular speeds are often only at one or more spot locations, which may not represent the conditions along the entire corridor to which the resulting posted speed limit would apply;
- Setting the posted speed limit based on existing driver behavior rather than the roadway context may not adequately consider vulnerable roadway users such as pedestrians and bicyclists;
- Data collection for speed limit studies typically only occurs during ideal free-flow conditions, often only considering passenger vehicles, which may not be representative of typical conditions on the roadway;
- 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. In this case, 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, so it may not be appropriate for urban roads.

For the Limited-Access and Undeveloped SLSGs with their higher operating speed and greater emphasis on mobility, retaining a connection to measured operating speed, specifically the 85th percentile speed, was deemed appropriate. After much debate among the research team, and with the NCHRP panel and other subject matter experts, the research team also decided to retain the connection with measured operating speed for the Developed SLSG—with the knowledge that the measured operating speed percentile (e.g., 85th percentile or 50th percentile) along with whether to use the closest speed or rounded down to nearest 5 mph increment would be influenced by consideration of safety through the use of decision rules.

Extensive debate was then engaged in relation to how to set the decision rules for the Full-Access SLSG, which included local streets and the urban core. The research team initially considered having set speed limits (e.g., 25 mph) for a set of conditions (e.g., specific combinations of roadway characteristics such as the number of lanes, average lane width, median presence, and sidewalk presence). After additional extensive discussion among the team, panel, and subject matter experts, the final decision by the research team was to also have the Full-Access SLSG use measured operating speed; however, the measured operating speed would only consider the 50th percentile rather than the 85th percentile to provide greater consideration for the anticipated other users of the street within those settings.

In summary, for the SLS-Procedure, the research team recommended considering the measured operating speed as the starting point for selecting a posted speed limit. The specific percentile of the speed measurement distribution would be selected based on the roadway type and context and could be further adjusted based on roadway conditions and crash experience on the segment. The NCHRP Project 17-76 SLS-Procedure was developed based on this key decision.

Decision Rule Development

Within each of the SLSGs, a unique set of decision rules was developed. For example, the research team considered the following sources in creating the decision rules for Limited-Access roadways:

- Rules used in USLIMITS2 (*21*);
- Information included in the updated *User Guide for USLIMITS2* (*28*);
- Findings from the literature, particularly the final report from NCHRP Project 17-45 and NCHRP Report 783 (*29, 30*);
- Guidance from the *Green Book* and the *Highway Safety Manual* (*31, 32*);
- Research team expert opinions;
- Feedback from experts, including the project panel.

In general, the relationship of a variable with crashes was used to suggest whether the suggested posted speed limit should reflect:

Table 2. Input Variables for Speed Data (*1*)

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 speed limit setting group (SLSG); - = variables not used in SLSG.

- 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).

When the roadway conditions are optimal, the suggested speed limit should reflect the 85th percentile speed, for example when the crash rate is low rather than medium or high. When roadway conditions are not favorable to all users or when crashes are a significant concern, then the suggested speed limit should reflect the 50th percentile speed. An RD85 speed limit is suggested when conditions are between those extremes.

When crash data are available, the procedure compares crash rate—both all and injury—for the section with critical crash rate and average crash rate and uses the worst-case scenario:

- High: section crash rate > critical crash rate;
- Medium: section crash rate > 1.3 average crash rate;
- Low: neither of the above is true.

The length of segment, number of crashes, and annual average daily traffic (AADT) are used to calculate the section crash rate for total crashes and for injury and fatal crashes per 100 million vehicle miles (MVM). If the user does not provide average rates, default values from the Highway Safety Information System (HSIS) are used. 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 of values included in the procedure that are based on default values from HSIS;

K = constant associated with the confidence level (1.645 for a one-sided interval, 95% confidence);

M = exposure (100 MVM).

Additional details on the sources used to create the decision rules for the Undeveloped, Developed, and Full-Access speed limit setting groups are available in Fitzpatrick et al. (*1*). That information is not provided here because of space limitations; however, a list of the variables selected for each speed limit setting group can provide the reader with an appreciation of what is being used within the 17-76 SLS-Procedure. The variables needed within the 17-76 SLS-Procedure for speed data are listed in Table 2. Table 3 shows the roadway segment input variables, and crash data variables are in Table 4.

In NCHRP Project 17-76, the research team was able to collect crash, geometric, and traffic data for suburban and urban roads in Austin, Texas, and Washtenaw County (Ann Arbor), Michigan, to fill the known research gap for city streets. Also available for Austin were binned operating speed data (generally for 24 h periods) obtained from the city along with 7-day speed data collected at an additional 50 locations. The developed databases for Austin, Texas, and Washtenaw, Michigan, were used to investigate the relationships among crashes, roadway characteristics, and posted speed limits. The findings from those evaluations supported including the following variables within the Developed and Full Access SLSGs 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.

- The data available from Austin also provided the opportunity to examine the operating speed and crashes relationship. The team found that crashes on city streets were lowest when the operating speed was within 5 mph of the average operating speed, see Figure 3 for a summary graphic illustrating that finding (*1*). 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.

SLS-Tool

The SLS-Procedure was automated into an SLS-Tool using a spreadsheet as the base format. Along with the

Table 3. Roadway Segment Input Variables (*1*)

Roadway segment variable	Limited access	Undeveloped	Developed	Full access
AADT (two-way total), annual average daily traffic (vpd)	✓	✓	-	-
Adverse alignment present (yes or no)	✓	✓	✓	✓
Angle parking present (no, yes for at least 40% of the segment, or yes for less than 40% of the segment)	-	-	✓	✓
Bicyclist activity (high or not high)	-	-	✓	✓
Design speed (mph)	✓	-	-	-
Directional design-hour truck volume (trk/h)	✓	-	-	-
Grade (%)	✓	-	-	-
Inside (left) shoulder width (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) shoulder width (ft)	✓	-	-	-
Parallel parking permitted (yes or no)	-	-	✓	-
Pedestrian activity (high, some, or negligible)	-	-	✓	✓
Segment length (mile)	✓	✓	✓	✓
Shoulder width (ft)	-	✓	-	-
Sidewalk buffer (present or not present)	-	-	✓	✓
Sidewalk presence/width (none, narrow, adequate, or wide)	-	-	✓	✓

Note: ✓ = variables used in speed limit setting group (SLSG); - = variables not used in SLSG; AADT = annual average daily traffic; TWLTL = two-way left-turn lanes; vpd = vehicles per day.

SLS-Tool is a stand-alone document, the *User Guide for Posted Speed Limit Setting Procedure and Tool* (*3*). This guide provides information in relation to the variables used in the spreadsheet tool along with general information about the setting of speed limits. A goal for the tool was to include inputs and outputs on the same screen to more easily demonstrate the relationship between each roadway characteristic and the suggested speed limit.

In the SLS-Tool, users input data for a roadway segment to obtain the suggested speed limit. The NCHRP 17-76 SLS-Tool includes three worksheets:

- Welcome. This worksheet provides an overview of the SLS-Tool;
- Analysis. This worksheet is used to enter input data and obtain analysis results. Key cells on this worksheet have been color-coded to indicate the type of data entered or displayed (see top right corner of the Analysis worksheet for legend). An example Analysis worksheet is provided in Figure 4;
- Support Tables. This worksheet contains several tables that are used in the Analysis calculations. The values can be changed but only if based on agency policy or new knowledge (i.e., new research, extensive local data, etc.).

An example of the analysis worksheet is shown in Figure 4. The top section is for site description data while the bottom sections are for entering the speed data, site characteristics, and crash data. The section labeled "Analysis Results" provides the suggested speed limit determined from the SLS-Procedure as documented by the SLS-Tool. Additional examples are available in the user guide along with instructions on how to use the tool.

Conclusions

The process of selecting a posted speed limit value for a roadway segment can be influenced by many factors, including engineering concerns, roadway characteristics,

Table 4. Input Variables When Crash Data are Available (*1*)

Crash data variable	Limited access	Undeveloped	Developed	Full access
Number of years of crash data	✓	✓	✓	✓
AADT (two-way total) for crash data period (vpd)	✓	✓	✓	✓
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	✓	✓	✓	✓
Median type	-	✓	✓	✓

Note: ✓ = variables used in speed limit setting group (SLSG); - = variables not used in SLSG; AADT = annual average daily traffic; HSIS = Highway Safety Information System; KABCO = injury scale for crashes (where K = fatal, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = no injury/property damage only); KABC = injury scale for crashes (where K = fatal, A = incapacitating injury, B = non-incapacitating injury, and C = possible injury); MVM = million vehicle miles; vpd = vehicles per day.

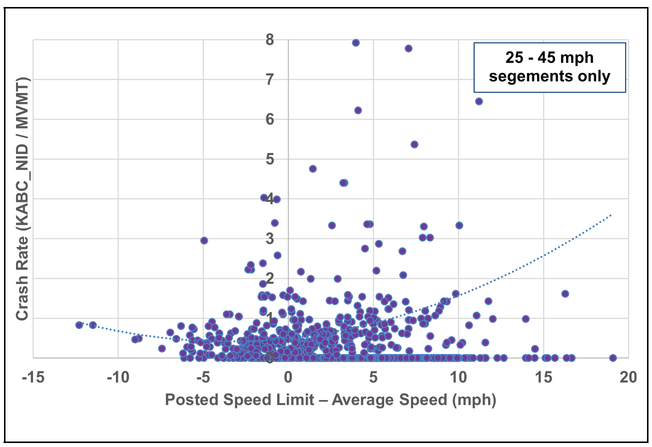

Figure 3. Comparison of crash rate with the difference between posted speed limit and average speed (*1*).
Note: KABC_NID = KABC crashes (where K = fatal, A = incapacitating injury, B = non-incapacitating injury, and C = possible injury) that occurred at not intersections (NI) or driveways (D) and MVMT = million vehicle miles traveled.

human factors such as the way drivers react to the roadway environment in relation to the speed they select, and policies including established agency policies or protocols that implement state or city laws, along with political pressures.

The operating speed (engineering) approach is the most common method used in the U.S. It relies on the 85th percentile speed with adjustments used to account for existing roadway geometry or crash experience. Many states/local agencies have their own laws/criteria for setting speed limits (many are very detailed). Professionals who perform posted speed limit studies rarely use *only* the 85th percentile speed (i.e., they use several other factors).

Using techniques other than the 85th percentile speed to select the posted speed limit is gaining in popularity in other countries. Several cities—such as Portland, Oregon; Boston, Massachusetts; New York City, New York; Seattle, Washington; Austin, Texas; and others—are also experimenting with alternative speed limit setting approaches for city streets.

NCHRP Project 17-76 collected insights into how the roadway environment influences operating speed and safety (crashes) through the review of the literature and the collection and analysis of data from two states. Using those insights along with an understanding of different methods being used and currently being considered for the setting of posted speed limits, the research team developed the SLS-Procedure, automated that procedure with the SLS-Tool, and then explained the procedure with a user guide (*3*).

The SLS-Procedure uses fact-based decision rules that consider both driver speed choice and safety associated with the roadway. The SLS-Procedure was designed to be applicable to all roadway types and contexts by having a set of unique decision rules for different combinations of roadway types and contexts. The combinations included Limited Access, Undeveloped, Developed, and Full Access facilities. With the SLS-Tool having data entry and results on the same screen along with warning and advisory messages on that same screen, it is a transparent product that should help the user understand what factors influenced the suggested speed limit calculations.

Recommendations

The overall goal of the NCHRP Project 17-76 research was to develop guidance so users can make informed decisions in relation to the setting of speed limits.

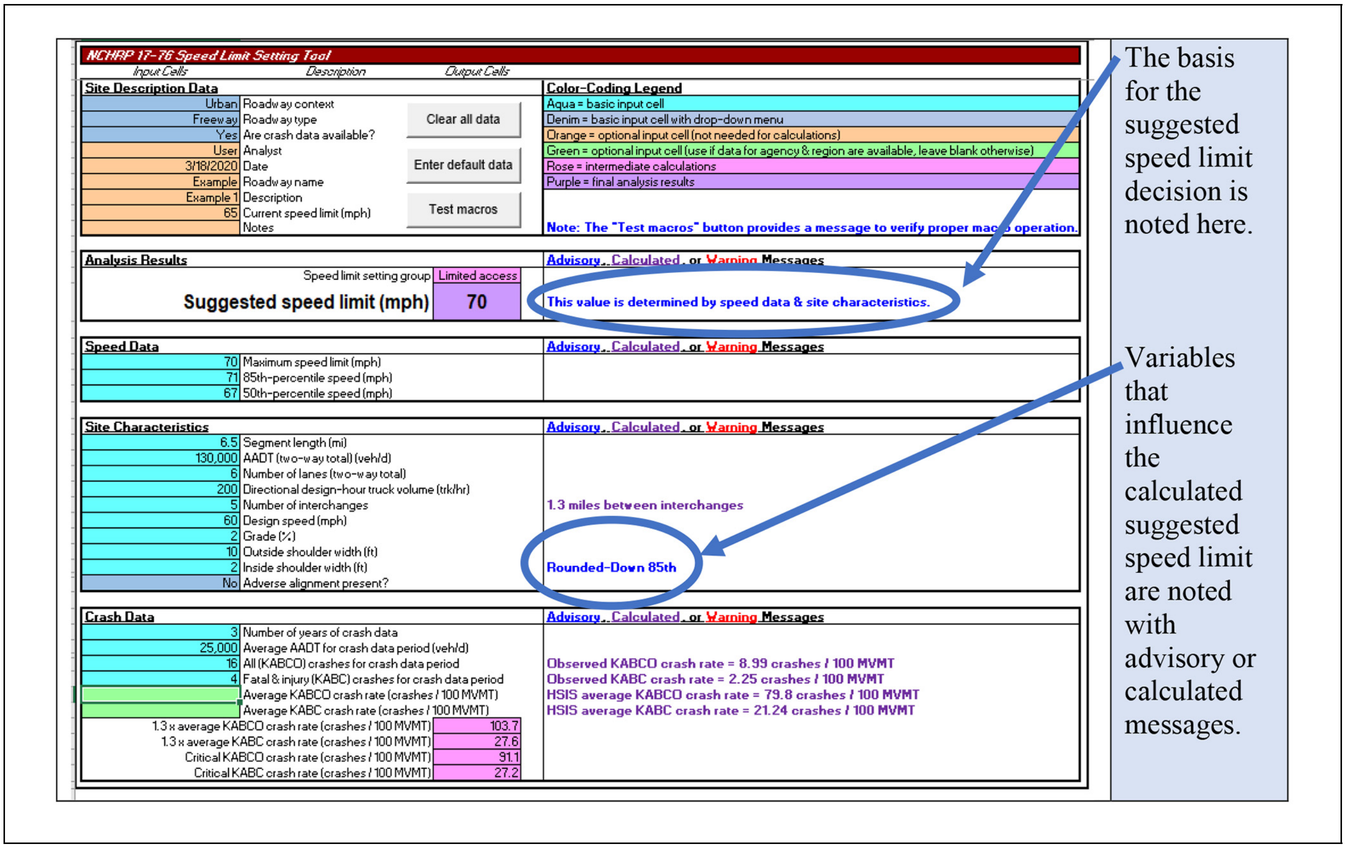

Figure 4. Example of Speed Limit Setting Tool (SLS-Tool) (*1*).

Employing the SLS-Procedure with the user guide and the SLS-Tool can help an agency make those informed decisions and communicate to a region's leadership and citizens how speed limits are set (*3*).

For the SLS-Procedure/SLS-Tool to gain acceptance, it must be introduced to the profession, included in key reference documents or on key websites, and discussed by users. Thus, the research team recommended the following ways to encourage use of the tool:

- Identify ways to encourage use of the tool, such as the following:
- Identify key groups to receive presentations about the SLS-Procedure/SLS-Tool;
- Include the availability of the SLS-Tool and user guide on key websites such as the FHWA speed management website (https://safety.fhwa.dot.gov/speedmgt/);
- Identify implementation funds that can help to move this research into practice;
- Make presentations on the research findings and on the availability of the SLS-Procedure, SLS-Tool, and user guide;
- Develop and conduct training on the SLS-Procedure, SLS-Tool, and user guide.

Suggested Research

While NCHRP Project 17-76 was a comprehensive study on setting speed limits, the research team identified several suggestions for additional research including the following:

- Perform additional research on the relationships among operating speed, roadway characteristics, posted speed limit, and crashes for city streets to confirm the findings in Austin, Texas, especially with respect to the relationships with 50th or 85th percentile speeds. (Speed data are being collected by more groups, which can assist with making this type of research more affordable; however, the speed data need to be accompanied by the number of vehicles present when the speed reading was made. Preferably, the speed data would represent a time period of about 1 h or less. Speed readings that represent a typical day or more remove too much of the variability in the speed behavior);
- Conduct similar research for roads with other speed ranges, such as freeways (generally 55 mph and greater), rural highways (subdivided into two speed groups of higher speeds and lower speeds

and perhaps subdivided by number of lanes), and local/residential streets;

- Investigate how the presence of a marked bike lane should influence the SLS-Procedure. (While it is logical to consider the need to have lower speed limits when a high number of bicyclists are present, and the SLS-Tool considers that condition, additional research is needed on how to consider bicyclist infrastructure and establish related criteria. For example, is the critical element just the presence of the bike lane, or is it the separation distance between the bike lane and the vehicle lane, or is a minimum bicycle volume also needed?)
- Establish criteria for pedestrian volume and bicyclist volume. (Currently, the SLS-Procedure uses qualitative criteria for pedestrian volume [negligible, some, or high] and bicyclist volume [high or not high]. Research is needed to identify appropriate and acceptable values for these levels. These values need to be sensitive to the roadway type and context. In addition, these values may vary by region; for example, transit-heavy areas like New York City may have different values for high levels of pedestrian activities compared with other large cities that do not have such an extensive transit network.)
- Explore and evaluate alternative speed limit setting approaches for city streets. (Several cities are experimenting with alternative approaches. NACTO is in the process of developing a speed limit setting process for lower-speed streets.)
- Determine other tools that can be used to manage speed along with the setting of defendable speed limits. (These tools could include speed feedback signs or increased enforcement, among others. The effectiveness of these tools should be identified, and the results communicated to practitioners. While this effort is ongoing by many researchers, perhaps a central clearinghouse could improve the technology transfer.)
- Determine how to integrate target speeds into the decision process (potentially as part of a uniform, best-practice statutory speed framework).
- Determine whether select variables should have greater weight. (Should the user be able to adjust those weights for a given evaluation?)
- Explore whether safety performance functions rather than average crash rates should be integrated into the SLS-Procedure.
- Consider adding a check with respect to pace similar to what is contained in the Florida Department of Transportation (DOT) manual (*33*). (The Florida DOT process is to post the speed limit at or near the upper limit of the 10 mph pace when the observed 85th percentile speed falls above the upper limit of the 10 mph pace. The manual notes that an observed 85th percentile speed that exceeds the 10 mph pace could result from a small percentage of vehicles exceeding the posted speed limit to a greater degree than the average driver traveling within the 10 mph pace.)

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Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: K. Fitzparick, S. Das, T. Gates, K. Dixon, E. Sug Park; data collection: K. Fitzpatrick, S. Das, T. Gates; analysis and interpretation of results: K. Fitzparick, S. Das, T. Gates, K. Dixon, E. Sug Park; manuscript preparation: K. Fitzparick, S. Das, T. Gates, E. Sug Park. All authors reviewed the results and approved the final version of the manuscript.

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