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Guide on Using Alternative Data Sources for a Texas Speed Zone Study

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16. Abstract

Within Texas, the Texas Department of Transportation *Procedures for Establishing Speed Zones* (TxSZ) and the *Texas Manual on Uniform Traffic Control Devices* (TxMUTCD) are used for setting speed limits other than statutory speed limits. The TxSZ details how to conduct an engineering study that is needed when investigating the appropriate speed limit for a speed zone. The objective of this guide is to provide methods and examples on how to use alternative sources of data when evaluating speed limits. It does not replace the material in the TxSZ or the TxMUTCD. Rather, it provides suggestions on how INRIX speed data can be used in an engineering study required in a speed zone study and demonstrates other supplemental methods and guidance when conducting a speed zone study. It provides step-by-step instructions on how to obtain the INRIX speed data, convert it into representative free-flow speed measures, and use it in both the TxSZ method and the Speed Limit Setting Tool.

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DISCLAIMER

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CHAPTER 1: INTRODUCTION

Within Texas, the Texas Department of Transportation (TxDOT) *Procedures for Establishing Speed Zones* (TxSZ) (*1*) and the *Texas Manual on Uniform Traffic Control Devices* (TxMUTCD) (*2*) are used for setting speed limits other than statutory speed limits.

As defined in the TxMUTCD, an engineering study is "the comprehensive analysis and evaluation of available pertinent information, and the application of appropriate principles, provisions, and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. An engineering study shall be performed by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. An engineering study shall be documented" (*2*, pages 63–64). The TxSZ provides details on how to conduct an engineering study that is needed when investigating the appropriate speed limit for a speed zone.

The TxMUTCD also states that "speed zones (other than statutory speed limits) shall only be established on the basis of an engineering study that has been performed in accordance with traffic engineering practices. The engineering study shall include an analysis of the current speed distribution of free-flowing vehicles" (*2*, page 57, Section 2B.13, paragraph 1).

OBJECTIVE

The objective of this document, *Guide on Using Alternative Data Sources for a Texas Speed Zone Study*, is to provide methods and examples on how to use alternative sources of data while evaluating speed limits. It does not replace the material in the TxSZ or the TxMUTCD. Rather, it provides suggestions on different approaches that can supplement the engineering study required in a speed zone study. In particular, this document describes an approach for using probe speed data to determine the speed measures that could be considered in a speed zone study. The approach uses speed data that is available to TxDOT staff from their computer rather than having to collect the data in the field. It can serve as an initial check on the magnitude of a potential speed limit change for a corridor.

ORGANIZATION OF THIS GUIDE

This guide consists of six chapters. In addition to this introductory chapter, the guide contains the following material:

- Chapter 2 provides an overview of the four-stage speed zone study method and descriptions of key reference documents.
- Chapter 3 presents stage 1 (identify study areas for speed zone study).
- Chapter 4 presents stage 2 (gather data needed).

- Chapter 5 describes stage 3 (calculate speed measures), including how to obtain the needed probe speed data measures that could be used in a speed zone study.
- Chapter 6 describes stage 4 (investigate or identify suggested speed limits).
- Chapter 7 provides two case studies. The first case study considers a site on a rural highway near a small town. The second case study considers a site on a freeway.

CHAPTER 2: SPEED ZONE STUDY AND REFERENCE MATERIALS

STAGES FOR SPEED ZONE STUDY DISCUSSED IN THIS GUIDE

Several methods are available for conducting a speed zone study, and several key reference documents are available to aid in performing such a study. These methods and documents are discussed in this chapter. The material in this guide provides a broad overview on how to conduct a speed zone study but focuses on how alternative data sources could be integrated into a Texas speed zone study.

Figure 1 lists the speed zone study stages discussed in this document. These stages are discussed in the following chapters:

- Stage 1 is discussed in Chapter 3 of this document.
- Stage 2 is discussed in Chapter 4 of this document.
- Stage 3 is discussed in Chapter 5 of this document.
- Stage 4 is discussed in Chapter 6 of this document.

Case studies applying all four stages are provided in Chapter 7 of this document.

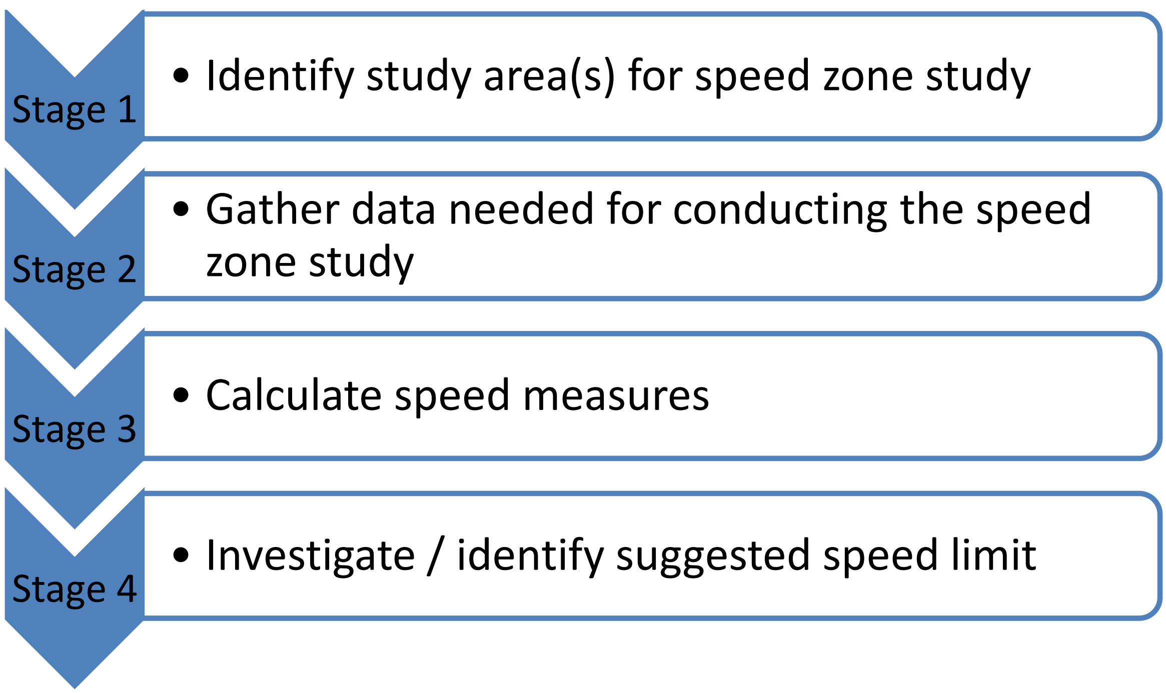


Figure 1. Speed Zone Study Stages.

KEY REFERENCE DOCUMENTS

Several reference documents are available to aid in the conduct of a speed study for a speed zone. This section provides brief overviews of the key reference documents.

TxDOT Procedures for Establishing Speed Zones

The stated purpose of the TxSZ is to provide the information and procedures necessary for establishing speed zones and advisory speeds on the state highway system. It contains the following five chapters:

1. Introduction.
2. Regulatory and Advisory Speeds.
3. Speed Zone Studies.
4. Speed Zone Approval.
5. Application of Advisory Speeds.

It also includes an appendix that provides links to forms used in a speed zone study.

Texas Manual on Uniform Traffic Control Devices

The TxMUTCD guides the setting of non-statutory speed limits. The speed limit value is selected via an engineering study. The current version of the TxMUTCD was published in 2014 and reflects material from the 2009 edition of the national *Manual on Uniform Traffic Control Devices* (MUTCD) (*3*). The TxMUTCD is currently being revised, and the next edition may reflect updates that are now present in the most current version of the MUTCD (*4*), which was published in 2023.

Per the TxMUTCD (*2*), the speed limit is to be within 5 mph of the measured 85th percentile speed for a roadway segment. The following factors can be considered for adjusting the 85th percentile speed:

- Road characteristics, shoulder condition, grade, alignment, and sight distance.
- Pace.
- Roadside development and environment.
- Parking practices and pedestrian activity.
- Reported crash experience for at least a 12-month period.

Manual on Uniform Traffic Control Devices

The 2023 MUTCD (*4*) includes the following revised list of factors:

- Roadway environment (such as roadside development, number and frequency of driveways and access points, and land use), functional classification, public transit volume and location or frequency of stops, parking practices, and pedestrian and bicycle facilities and activity.

- Roadway characteristics (such as lane widths, shoulder condition, grade, alignment, median type, and sight distance).
- Geographic context (such as an urban district, rural town center, non-urbanized rural area, or suburban area), and multimodal trip generation.
- Reported crash experience for at least a 12-month period.
- Speed distribution of free-flowing vehicles including the pace, median (50th percentile), and 85th percentile speeds.
- A review of past speed studies to identify any trends in operating speeds.

National Cooperative Highway Research Program 17-76 Speed Limit Setting Tool

In the National Cooperative Highway Research Program (NCHRP) Research Project 17-76, researchers built a framework and an accompanying spreadsheet-based Speed Limit Setting Tool (SLS-Tool) to assist practitioners in setting regulatory speed limits. The framework is documented in the NCHRP Report 966 (*5*). The details of the research are available in a web-only document (*6*). The framework involves classifying a roadway segment based on its roadway type and context and then incorporating data to describe the speed distribution, roadway characteristics, and crash rates for similar roadways. Table 1 shows the four SLS groups as they are defined based on the matrix of roadway type and context categories.

Table 1. SLS Groups Used in the NCHRP 17-76 Framework (*5*).

Roadway Type	**Roadway Context**				
	Rural	**Rural Town**	**Suburban**	**Urban**	**Urban Core**
Freeway	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

The NCHRP 17-76 framework uses decision rules that account for key site characteristics that are relevant to the speed limit setting group and its expected users. For example, the decision rules for the limited access group focus on characteristics that affect drivers, such as interchange spacing and shoulder widths, while the decision rules for the developed and full-access groups account for characteristics that affect pedestrians and bicyclists, such as bike lane presence and sidewalk presence and width. Many of the decision rules are based in the USLIMITS2 program (*7*), while others were added by the NCHRP 17-76 researchers.

The NCHRP 17-76 framework incorporates crash data as an optional input to improve the speed limit setting practice. Practitioners can provide the traffic volume and count of total and fatal-and-injury crashes for a past period and compare the computed rates with crash rates for similar facilities. Fatal-and-injury crashes include K (fatal), A (incapacitating injury), B (nonincapacitating injury), and C (possible injury) crashes from the KABCO scale. Total crashes include all fatal-and-injury crashes plus O (property damage only) crashes from the KABCO scale.

Modified SLS Tool for Texas

An expert system is software that was programmed using the knowledge of experts. The NCHRP 17-76 SLS Tool is considered to be an expert system. It can be used to supplement practitioner decision-making when recommending speed limits. The NCHRP 17-76 SLS Tool was updated to reflect Texas crash data and is available either with spreadsheet macros (SLS Tool-Texas-macro) or without spreadsheet macros (SLS Tool-Texas-nomacro).

The NCHRP 17-76 SLS Tool is available from the NCHRP website (see section labeled *resources at a glance* and *tool no macro* or *tool macro*), which can be accessed at https://nap.nationalacademies.org/catalog/26216/posted-speed-limit-setting-procedure-and-tool-user-guide. The Texas-based tools will be accessible at https://library.ctr.utexas.edu/Presto/home/home.aspx once posted (anticipated late fall 2024) using the search engine and key word of *5-7049-01*.

OTHER SOURCES PROVIDING ADVICE ON CONDUCTING SPEED STUDIES

Several other sources provide advice on how to conduct a speed zone study. For example, the *Manual of Transportation Engineering Studies* (*8*) provides technical details of various common data collection methods. It also addresses other important considerations when planning a speed study, including the following:

- Study preparation and coordination.
- Safe deployment and recovery of equipment and personnel.
- Positioning equipment to minimize measurement error (e.g., minimizing the angle of incidence for radar and LiDAR devices).
- Calibrating equipment.
- Documentation.

CHAPTER 3: STAGE 1–IDENTIFY STUDY AREA(S) FOR THE SPEED ZONE STUDY

An initial effort in performing a speed zone study is to identify the corridor limits for the study area. The speed zone limits, along with other details, are documented on a strip map. Table 2 provides a list of items that are to be included on a strip map per the TxSZ (*1*). Additional details regarding the strip map are included in the TxSZ.

Table 2. Information to Show on a Strip Map per the TxSZ (*1*).

Information Item	Notes
Name and highway number of the route to be zoned	• Show all names and/or highway numbers if the route has more than one name and/or highway number • Indicate sections to be zoned by Transportation Commission minute order with a wide center line on the strip map
Limits of the speed zone	• Show all names and highway numbers if the crossroads and cross streets have more than one name and carry one or more highway designations • Show numbered highway routes by wider lines than those used for county roads and city streets
Adjoining speed zone(s) of connecting map(s)	
Limits of any incorporated city or town	• Show reference marker and mile point and control and section numbers for these points
Names and approximate limits of the developed area of unincorporated towns	• Indicate by *beginning of developed area* and *end of developed area* under the Development heading, not as *city limits*
Urban districts	• Indicate any urban district clearly under the Development heading; u*rban district* is defined in the Texas Uniform Act Regulating Traffic on Highways as "the territory contiguous to and including any highway or street which is built up with structures devoted to business, industry or dwelling houses, situated at intervals of less than 100 feet for a distance of 0.25 mile or more on either side"
Schools and school crossings	• Show only those schools abutting the highway • Show location of schools • Show all school crosswalks
Traffic signals	• Show location of existing devices to aid in proper spacing and placement of speed zone signs
Important traffic generators	• Show all factories, shopping centers/malls, and any other establishments that attract large volumes of traffic
Ball bank readings	• Show each direction of travel for all curves having a safe speed of 10 mph or more below the statewide maximum speed limit
Railroad crossings	• Indicate the number of tracks and type of grade crossing protection (crossbucks, cantilevers, crossbucks with signals, gates) • Show the name of the railroad at each crossing
Bridges	• Indicate if the roadway on the bridge is narrower than the roadway on either side of it

SPEED ZONE LENGTH

The length of any section of zone set for a particular speed should be as long as possible and still be consistent with the roadway characteristics including the 85^{th} percentile speeds. These zone lengths should be shown on the strip map in miles to three decimal places. For graduated zones on the approach to the city or town at locations where speeds fluctuate, the speed zone should generally be 0.200 miles or more. School zones are the exception to this rule and may be as short as reasonable in urban areas, depending on approach speeds. School zones in urban areas where speeds are 30 mph or less may have school zones as short as 200–300 feet.

TRANSITIONS

The change in speed between two adjacent zones should not normally be greater than 15 mph because the change in speed would be too abrupt for driver observance. If adjacent 85^{th} percentile speeds show an abrupt change of more than 15 mph, a transition zone of approximately 0.200 miles or more in length should be used.

CHAPTER 4: STAGE 2–GATHER DATA NEEDED FOR CONDUCTING THE SPEED ZONE STUDY

Several documents provide lists of site characteristics to consider when conducting a speed zone study including the TxSZ, TxMUTCD, MUTCD, NCHRP Report 966, and USLIMITS2. Some of these documents list the site characteristics (sometimes called *factors*) without specifying how the value for that element should influence the recommended speed limit. For example, the TxMUTCD says that "reported crash experience for at least a 12-month period" is a factor that may be considered; however, it does not provide details on what number or type of crashes should trigger a reduction in the suggested speed limit. The TxSZ does provide additional details regarding the consideration of crashes (e.g., exceeding statewide crash averages); however, the document largely relies on the application of engineering judgment without providing details on how other factors are to be judged. Other documents (e.g., NCHRP Report 966) provide a prescriptive approach for considering the factors when identifying the suggested speed limit.

This chapter discusses factors that could be considered during an engineering study for a speed zone (non-statutory speed limit). The source of the factor guidance (the TxSZ or another source) is noted. This chapter also provides additional details on collecting and analyzing data that can be used when evaluating these factors. Other than speed data, which will be discussed in Stage 3, the factors are grouped into the following categories:

- Geographic context or roadway environment.
- Roadway characteristics.
- Crashes.

Note that each study area is unique, and not every data element described in this section will be applicable to a given study area. Practitioners must use their judgment and familiarity with the study area to determine which data elements are relevant to a given engineering study. Some data elements are to be included in the strip map (see Chapter 3). The engineering study project file should document any data not included in the map.

If an expert system is being applied during the study, it will also be necessary to collect additional data used by that system. Expert systems, such as the NCHRP 17-76 SLS Tool and USLIMITS2 (*9*), are tools that are nationally available to supplement practitioner decision-making when recommending speed limits. Data elements used by the NCHRP 17-76 SLS Tool (or SLS Tool-Texas) expert system are noted in the tables in this document.

GEOGRAPHIC CONTEXT OR ROADWAY ENVIRONMENT

Geographic context or roadway environment factors or data elements are currently not a significant consideration within the TxSZ method. Current national activities along with recent key reference documents such as the 2023 MUTCD and NCHRP Report 966 indicate, however, a growing recognition that context should be considered in the setting of speed limits.

Table 3 summarizes the geographic context or roadway environment data elements being considered within the TxSZ, NCHRP 17-76 SLS Tool, 2023 MUTCD, or TxMUTCD.

Table 4 lists commonly considered roadway environment data elements along with potential sources. Roadway environment factors consider the conditions around the roadway that could influence the safety of the corridor. Within the TxSZ, the potential for pedestrian and bicycle traffic is considered via the rural residential or developed areas factor.

Collecting geographic context or roadway environment data will generally require a mix of data collection techniques. The type of geographic context information used in the NCHRP 17-76 SLS Tool may be determined from the practitioner’s knowledge of the study area or from NCHRP Report 1022, *Context Classification Application: A Guide*, which provides guidance on identifying geographic context, including characteristics and transportation expectations for each context (*10*).

Demographic context is a factor that has been proposed by others; however, it is not currently considered within the TxDOT procedure. If a practitioner wants to consider demographics, the following data sources and tools can be explored:

- United States Census Bureau data (*11*). For example, a practitioner can search for age information from the American Community Survey on the Census site to determine the percentage of the population in an area that was 60 years old and older (*12*).
- Climate and Economic Justice Screening Tool (*13*). A mapping tool that summarizes information on the local area and population.
- United States Department of Transportation Equitable Transportation Community Explorer. A tool that provides data on transportation-disadvantaged populations in a defined study area (*14*).

Table 3. Geographic Context or Roadway Environment Data Elements by Method and Potential Sources.

Framework	Data Element/Factor	Source on Where/How to Obtain
TxSZ	• Specific data elements or factors for the geographic level are not provided; however, general guidance regarding rural and urban conditions with respect to identifying the location of speed check stations is provided	• TxSZ (pages 3-6 and 3-7)
TxSZ	For rural residential or developed areas: • TxSZ notes that rural residential or developed area factors can be associated with higher potential for pedestrian and bicycle traffic (page 3-20) • TxSZ (pages 1-9 and 2-2)	• RU_F_SYSTEM (concatenation of rural-urban code and functional system) variable in the TxDOT Roadway Highway Inventory Network Offload (RHINO) database can identify if the corridor is within a rural or urban area and provide the functional classification; however, this variable may not be sensitive enough to identify if the area is associated with higher potential for pedestrian and bicycle traffic • Local knowledge, field visits, or corridor reviews using aerial photos may be needed to determine conditions
NCHRP 17-76 SLS Tool	• Context = rural, rural town, suburban, urban, or urban core • Type = freeway, major arterial, minor arterial, collector, or local	• Agency designations • Practitioner judgment, based on applicable American Association of State Highway and Transportation Officials, state, or local guidance. • NCHRP Report 1022
NCHRP 17-76 SLS Tool	• Mountainous terrain	• Determined by grade and design speed
2023 MUTCD	• Geographic context (e.g., urban district, rural town center, non-urbanized rural area, or suburban area) and multimodal trip generation • Roadway environment (e.g., roadside development, number and frequency of driveways and access points, and land use), functional classification, public transit volume and location or frequency of stops, parking practices, and pedestrian and bicycle facilities and activity	• RU_F_SYSTEM (concatenation of rural-urban code and functional system) variable in the RHINO database can identify if the corridor is within a rural or urban area and provide the functional classification • Aerial and street-level photographs
TxMUTCD	• Roadside development and environment	• Aerial and street-level photographs

Table 4. Examples of Roadway Environment Data Elements and Potential Sources.

Framework	Data Element/Factor	Source on Where/How to Obtain
Literature: Multimodal trip generators	• Schools • Grocery stores, markets • Medical offices, clinics, hospitals, rehabilitation facilities • Senior centers, community centers, libraries, churches • Parks, playgrounds, recreation centers, trailheads • Restaurants, shopping • Multifamily housing, mixed-use development • Hotels	• Field visit • Online tools
Literature: Demographics	• Elderly population • Youth population • Disabled population • At or below poverty-level households • Zero-car households	• American Community Survey • Climate and Economic Justice Screening Tool • Equitable Transportation Community Explorer
Literature: Transit	• Transit facilities and service characteristics	• Field visit or online tools to determine bus lane and bus stop locations and whether pullouts are provided • Peak period bus frequency from transit agency website
Literature: Vulnerable road user (VRU) facilities	• Pedestrian and bicycle facilities (e.g., sidewalk, bidirectional buffered bicycle lane, side path)	• Field visit or online imagery to determine presence, type, and buffer from roadway • Project as-built plans
Literature: Activity levels	• Activity levels • Non-motorized road users (e.g., pedestrian, bicycle, horse) • Farm vehicles, golf carts, scooters, etc. • Wildlife crossings	• Field visit • User counts • Wearable fitness tracking data vendors • Crash data specific to wildlife- or livestock-involved crashes
Literature: Average daily traffic	• Traffic volume (annual average daily traffic [AADT]) • Truck percentage	• Current or recent count data from agency databases • Connected vehicle data vendors
Literature: On-street parking	• On-street parking and other curbside activity	• Field visit or online tools to determine where on-street parking/loading/drop-off is allowed, how it is provided (parallel vs. angle), times of day allowed, and allowed durations

ROADWAY CHARACTERISTICS

Roadway characteristics, also called *geometric design features*, are frequently considered within a speed zone study. By considering these features, the proposed speed limit reflects the roadway's design.

Texas Roadway Characteristic Data Elements

Many roadway characteristics are available from the TxDOT RHINO database; however, the values may need to be checked by reviewing roadway plans, reviewing aerial and street-level photographs, or conducting a field visit. Table 5 summarizes the roadway characteristic data elements being considered within the TxSZ, 2023 MUTCD, or TxMUTCD.

Table 5. Roadway Characteristic Data Elements and Potential Sources.

Framework	Data Element/Factor	Source on Where to Obtain
TxSZ	For high driveway density: • TxSZ notes that the higher the number of driveways, the higher the potential for encountering entering and turning vehicles (page 3-20) • TxSZ (pages 1-9 and 2-2)	• Count number of driveways using online imagery • Count number of driveways during a field visit
TxSZ	• Narrow pavement	• Engineering judgement • RB_WID, SUR_W, and NUM_LANES variables in the RHINO database give roadway and surface widths and number of lanes
TxSZ	• Horizontal or vertical curves	• Aerial photographs • ArcGIS Online: Curves for TxDOT on System Centerline Highways and Frontage Roads website (*15*)
TxSZ	• Lack of shoulders	• S_TYPE_I and S_TYPE_O variables in the RHINO database give inside and outside shoulder type (0 indicates no shoulder)
TxSZ	• Hidden driveways and other roadside development	• Field visit
2023 MUTCD	• Roadway characteristics (e.g., lane widths, shoulder condition, grade, alignment, median type, and sight distance)	• SUR_W and NUM_LANES variables in the RHINO database can be used to compute lane width • MED_TYPE, S_TYPE_I, and S_TYPE_O variables in the RHINO database give median and inside and outside shoulder type
TxMUTCD	• Road characteristics, shoulder condition, grade, alignment, and sight distance • Parking practices and pedestrian activity	• S_TYPE_I and S_TYPE_O variables in the RHINO database give inside and outside shoulder type • Aerial and street-level photographs can inform about parking practices

The TxSZ identifies various roadway conditions to consider in speed zone studies (e.g., *high* driveway density or *narrow* pavement) but does not specify quantitative thresholds to define these conditions. The analyst conducting a speed zone study must define these conditions and account for their occurrence on the roadway of interest. To account for this lack of guidance, the next section provides an example set of thresholds for the four SLS groups that are used in the NCHRP 17-76 analysis framework.

NCHRP 17-76 SLS Tool Roadway Characteristic Data Elements

The following roadway characteristic data elements are considered in the NCHRP 17-76 SLS Tool (along with the SLS Tool-Texas):

- Access data elements (see Table 6).
- VRU-related data elements (see Table 7).
- Number of lanes and other cross section data elements (see Table 8).
- Width-based cross section data elements (see Table 9).
- On-street parking data elements (see Table 10).
- Terrain data elements (see Table 11).

Table 6. Access-Related Roadway Characteristic Data Elements and Rounding Criteria Used in the NCHRP 17-76 SLS Tool.

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Access density[a]	Developed	{Not applicable, see criteria in other cells}	> 60 driveways/ unsignalized intersections per mile	> 40 and ≤ 60 driveways/ unsignalized intersections per mile	≤ 40 driveways/ unsignalized intersections per mile
Access density[a]	Full access	> 60 driveways/ unsignalized intersections per mile	≤ 60 driveways/ unsignalized intersections per mile	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}
Access density[a]	Undeveloped	{Not applicable, see criteria in other cells}	> 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)
Inter_spac[b]	Limited access	{Not applicable, see criteria in other cells}	≤ 0.5 mi and AADT ≥ 180,000 veh/d	> 0.5 and ≤ 1 mi and AADT ≥ 180,000 veh/d	All other cases

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Signal density[c]	Developed	{Not applicable, see criteria in other cells}	> 4 signals/mile	> 3 signals/mile	≤ 3signals/mile
Signal density[c]	Full access	> 8 signals/mile	≤ 8 signals/mile	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}

[a]Access density = number of nonresidential driveways and intersections per mile.
[b]Inter_spac = average interchange spacing in miles calculated from the number of interchanges. Variable considers AADT (two-way total) in veh/d.
[c]Signal density = number of signalized intersections per mile.

Table 7. VRU-related Roadway Characteristic Data Elements and Rounding Criteria Used in the NCHRP 17-76 SLS Tool.

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Bicyclist activity (in lane)[a]	Developed	{Not applicable, see criteria in other cells}	High	{Not applicable, see criteria in other cells}	Not high
Bicyclist activity (in lane)[a]	Full access	High	Not high	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}
Bicyclist activity (separate lane)[b]	Developed	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}	High	Not high
Bicyclist activity (separate lane)[b]	Full access	High	Not high	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}
Sidewalk[c]	Developed	{Not applicable, see criteria in other cells}	See NCHRP Report 966, Table 8	See NCHRP Report 966, Table 8	See NCHRP Report 966, Table 8
Sidewalk[c]	Full access	See NCHRP Report 966, Table 10	See NCHRP Report 966, Table 10	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}

[a]In-lane bicyclist activity level within motor vehicle lane, shoulder, or non-separated bike lane (high or not high).
[b]Separate lane bicyclist activity level within separated bike lane (high or not high).
[c]Sidewalk characteristics, presence/width (none, narrow, adequate, or wide), and buffer (present or not present) and pedestrian activity (high, some, or negligible).

Table 8. Number of Lanes Cross Section Data Elements and Rounding Criteria Used in the NCHRP 17-76 SLS Tool.

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Number of lanes, median type, AADT combination	Undeveloped	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}	≥ 4 lanes with no median (undivided) and AADT > 2000 veh/d	≥ 4 lanes with divided median 2 lanes with any median type ≥ 4 lanes with no median (undivided) and AADT ≤ 2000 veh/d Any number of lanes/median type combination when AADT ≤ 2000
Number of lanes, median type (undivided, two-way left-turn lane [TWLTL], or divided)	Developed	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}	≥ 4 lanes with undivided median	≥ 4 lanes with divided or TWLTL median < 4 lanes with any median type

Table 9. Width-Based Cross Section Data Elements and Rounding Criteria Used in the NCHRP 17-76 SLS Tool.

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Lane width	Undeveloped	{Not applicable, see criteria in other cells}	≤ 9 ft and AADT > 2000 veh/d	> 9 and < 11 ft and AADT > 2000 veh/d	≥ 11 ft and AADT > 2000 veh/d Any lane width when AADT ≤ 2000 veh/d
Shoulder width	Undeveloped	{Not applicable, see criteria in other cells}	< 2 ft and AADT > 2000 veh/d	≥ 2 and < 6 ft and AADT > 2000 veh/d	≥ 6 ft and AADT > 2000 veh/d Any shoulder width when AADT ≤ 2000 veh/d

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Shoulder width (inside considering number of lanes and directional design-hour truck volumes)	Limited access	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}	< 12 ft and > 250 trk/hr < 10 ft and ≥ 6 lanes and ≤ 250 trk/hr < 4 ft and < 6 lanes and ≤ 250 trk/hr	All other cases
Shoulder width (outside)	Limited access	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}	< 8 ft	≥ 8 ft

Table 10. On-Street Parking Data Elements and Rounding Criteria Used in the NCHRP 17-76 SLS Tool.

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Mountainous terrain determined by percent grade and design speed	Limited access	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}	Grade > 4% and design speed ≥ 60 mph Grade > 5% and design speed ≤ 55 mph	All other cases
On-street parking activity	Developed	{Not applicable, see criteria in other cells}	High	{Not applicable, see criteria in other cells}	Not high
On-street parking activity	Full access	High	Not high	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}
On-street parking type	Developed	{Not applicable, see criteria in other cells}	Angle parking present in ≥ 40% of section	Parallel parking permitted Angle parking present in < 40% of section	None
On-street parking type	Full access	Angle parking present for 40 percent or more of section	No parking present Angle parking present in < 40% of section	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}

Table 11. Terrain Data Elements and Rounding Criteria Used in the NCHRP 17-76 SLS Tool.

Data Element	SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Mountainous terrain determined by percent grade and design speed	Limited access	{Not applicable, see criteria in other cells}	{Not applicable, see criteria in other cells}	Grade > 4% and design speed ≥ 60 mph Grade > 5% and design speed ≤ 55 mph	All other cases

CRASHES

The TxSZ includes crash history as a factor to consider. The number of crashes is needed along with the study segment length to calculate the crash rate for the proposed speed zone. The statewide average for similar roadways is also needed. Table 12 lists the crash data elements along with potential sources for the data.

Table 12. Examples of Crash Data Elements and Potential Sources.

Framework	Data Element/Factor
TxSZ	Crash history along the location (*1*, page 2-2)
NCHRP 17-76 SLS Tool or SLS Tool-Texas	Number of crashes by severity level (KABCO)
TxMUTCD	Reported crash experience for at least a 12-month period
2023 MUTCD	Reported crash experience for at least a 12-month period

Crash Experience

In 2015, TxDOT issued a notice in response to a rule change by the Texas Transportation Commission (*1*, pages 2-89, 3-18, and 3-19). When the crash rate is greater than the statewide average for similar roads, the 85th percentile speed can be lowered. When establishing a speed within an existing zone on the state highway system, the speed limit may be reduced by up to 12 mph below the 85th percentile speed if the crash rate in the section of the roadway is greater than the statewide average crash rate for similar roadways.

The TxSZ (*1*, page 3-16) states the following:

> When districts submit strip maps or prints to the Traffic Operations Division (TRF) for review, TRF will obtain the crash rate for the roadway section in question as well as the statewide average crash rate for the appropriate type of roadway section and add these data to the strip map. Crash rates will be considered before lowering the zone. These data will be an important consideration in determining whether the lower zoning is justified.

Details on how the statewide average crash rates are determined are not provided in the TxSZ. The Texas Statewide Crash Rate Calculations section below provides background information on the statewide average crash rates recently calculated as part of a TxDOT research project (using 2019 crash data).

Number of Months

The TxSZ does not indicate the minimum number of months of crashes that are to be obtained for the speed study. The TxMUTCD states that a minimum of 12 months of crash data is to be considered. Given typical year-to-year variability in crashes—particularly crashes involving people walking or bicycling—using 3 to 5 years of crash data is advisable.

Additional Data Needed when Using the NCHRP 17-76 SLS Tool

When using the NCHRP 17-76 SLS Tool expert system, the following information is needed in addition to the number of crashes:

- Crash severity for each crash (KABCO scale).
- Length of the road section under study.
- Whether the roadway is one-way or two-way.

Table 13 provides the recommended rounding criteria when using the NCHRP 17-76 SLS Tool.

Table 13. Rounding Criteria for the Crash Data Element (KABCO or KABC Crashes) in the NCHRP 17-76 SLS Tool.

SLS Group	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Limited access	NA	High	Medium	Low
Developed	NA	High	Medium	Low
Full access	High or medium	Low	NA	NA
Undeveloped	NA	High	Medium	Low

NA = not applicable.

Texas Statewide Crash Rate Calculations

The NCHRP 17-76 spreadsheet tool contains crash rates that were computed using Highway Safety Information System (HSIS) data from the states of California, Minnesota, North Carolina, Ohio, and Washington as originally published in 2012 (*7*) and updated in 2017 (*16*). The crash rates currently in the NCHRP 17-76 spreadsheet tool are computed for roadway configurations that correspond to the SLS groups shown in Table 14. This grouping of roadway configuration categories within the SLS groups was used in USLIMITS2 and carried forward into the NCHRP 17-76 framework with some adjustments, such as the addition of the full access group.

Table 14. NCHRP 17-76 SLS Groups and Corresponding Roadway Configurations.

SLS Group	Roadway Configuration
Limited access	Urban freeway
	Rural freeway
Undeveloped	Rural two-lane highway
	Rural multilane divided highway
	Rural multilane undivided highway
Developed or Full access	Urban two-lane street
	Urban multilane divided street
	Urban multilane undivided street
	Urban one-way street

To facilitate use of the NCHRP 17-76 framework in Texas, the research team computed crash rates using TxDOT-maintained databases, including the state's Texas Reference Marker (TRM) road log database and the state's Crash Records Information System (CRIS) crash database. The research team obtained data for 2019—the last full year for which data were available before traffic volume and crash trends were affected by the COVID-19 pandemic-related shutdowns. The research team used TRM data to compute exposures (in hundred million vehicle-miles, or HMVM) and CRIS data to compute crash counts (KABCO and KABC) for each roadway configuration category.

Exposure

To compute exposures for the various roadway configuration categories, the research team queried the TRM database and assigned the categories to the roadway segments as follows:

- The record type variable was used to include only on-system mainline segments that have the linear distance from origin variable for merging with the CRIS database.
- The roadbed identifier variable was used to include only centerline records.
- The functional classification, highway design, number of lanes, and maximum speed limit variables were used to categorize the segments as shown in Table 15.
- The segments were binned into traffic volume ranges for each category based on the distribution of total exposure across bins.

Table 16 shows the distribution of the TRM segments across the roadway configuration categories. The three middle columns of the table show the number of traffic volume bins in each category for the originally-published USLIMITS2 crash rate query (*7*), the updated USLIMITS2 crash rate query (*16*), and the new crash query conducted by the research team, respectively. The research team computed the total exposure for the included segments in the Texas query as almost 200 billion vehicle-miles in the year 2019. For comparison, the total exposure for all roadways in the 2019 TRM database was slightly over 400 billion vehicle-miles.

Table 15. Texas TRM Variables Used to Classify a Segment Within a Roadway Configuration.

Roadway Configuration	TRM Variable Values			
	Functional Classification (RU_F_SYSTE)	Highway Design (HWY_DES1)*	Number of Lanes (NUM_LANES)	Maximum Speed Limit (SPD_MAX) (mph)
Urban freeway	U1 or U2	5	≥ 4	≥ 50
Rural freeway	R1 or R2	5	≥ 4	≥ 50
Rural two-lane highway	R3, R4, R5, R6, or R7	2	2	≥ 30
Rural multilane divided highway	R3, R4, R5, R6, or R7	3 or 4	≥ 2	≥ 30
Rural multilane undivided highway	R3, R4, R5, R6, or R7	2	≥ 4	≥ 30
Urban two-lane street	U3, U4, U5, U6, or U7	2	2	≥ 25
Urban multilane divided street	U3, U4, U5, U6, or U7	3 or 4	≥ 2	≥ 25
Urban multilane undivided street	U3, U4, U5, U6, or U7	2	≥ 4	≥ 25
Urban one-way street	U3, U4, U5, U6, or U7	0 or 1	Any value	≥ 20 and ≤ 45

* The HWY_DES1 variable is defined as follows: 0 = one-way pair (couplet); 1 = one-way; 2 = two-way, undivided; 3 = two-way, divided–boulevard; 4 = two-way, divided–expressway (partial access control); 5 = two-way, divided–freeway (full access control).

Table 16. Roadway Configuration Bins and Exposure.

Roadway Configuration	Number of Traffic Volume Bins			Total Segment Length (mi)	Total Exposure (HMVM)
	USLIMITS2 (Original)	USLIMITS2 (Updated)	Texas		
Urban freeway	7	7	6	2,449	752
Rural freeway	3	3	3	2,042	203
Rural two-lane highway	9	9	8	51,342	288
Rural multilane divided highway	6	6	6	3,168	129
Rural multilane undivided highway	2	3	4	1,855	54
Urban two-lane street	7	7	6	3,643	95
Urban multilane divided street	8	6	7	1,863	163
Urban multilane undivided street	5	4	7	2,718	169
Urban one-way street	0	7	1	43	3
Total	47	52	48	84,995	1,859

The research team defined the traffic volume bins by using the volume ranges from the USLIMITS2 queries and the consolidating bins as needed to obtain a consistent distribution of exposure across the bins for each roadway configuration category. For most categories, the number of bins for the Texas query was similar to the number of bins for the USLIMITS2 queries. The notable exception was urban one-way streets. These roadways were not included in the original USLIMITS2 query but were added to the updated USLIMITS2 query. The research team found very few on-system urban one-way street segments in the TRM database, yielding a total exposure of only 3 HMVM. It is likely that most one-way streets are city-maintained (e.g., streets in urban core grids) so they would not be included in the queried TRM records.

Crash Count for Calculating Average Statewide Crash Rates

The research team merged the CRIS database with the categorized roadway segments from the TRM query to identify the crashes that occurred on those segments. The research team identified 226,306 crashes on the categorized segments and 98,234 segments that experienced no crashes in the merged data. Table 17 shows the distribution of the crashes across the roadway configuration categories.

Table 17. Crash Distribution across Roadway Configuration Categories.

Roadway Configuration	Crash Count by Severity		
	KABCO	KABC	Unknown Severity
Urban freeway	69,714	23,317	1,202
Rural freeway	9,176	2,470	91
Rural two-lane highway	27,318	10,228	594
Rural multilane divided highway	7,588	2,688	93
Rural multilane undivided highway	4,888	1,698	87
Urban two-lane street	17,867	6,110	384
Urban multilane divided street	37,272	13,160	393
Urban multilane undivided street	50,407	17,825	461
Urban one-way street	2,076	672	35
Total	226,306	78,168	3,340

The last column of Table 17 shows that there were 3,340 crashes that were coded as unknown severity in the CRIS database. These crashes would be counted among the KABCO crashes, and some of them should be counted among the KABC crashes. The research team estimated the number of crashes that were fatal or injury (incorporating crashes of unknown severity) as follows:

$$N_{KABC,rev} = N_{KABC} + N_U \frac{N_{KABC}}{N} \quad \text{Equation (1)}$$

where:

$N_{KABC,rev}$ = revised number of fatal-and-injury crashes.
N_{KABC} = number of fatal-and-injury crashes from CRIS query.
N_U = number of crashes with unknown severity from CRIS query.
N = total number of crashes from CRIS query.

The $N_{KABC,rev}$ values were used to compute the KABC rates tabulated in the next section.

Crash Rates

Table 18 provides the default Texas crash rates computed for all roadway configuration categories and traffic volume range bins. The one exception was urban one-way streets, which had unreasonably high rates for KABCO and KABC crashes. These rates are shown in strikeout text. This finding was likely due to the limited sample for this roadway configuration on the state-maintained highway system. Hence, the research team recommends using the updated USLIMITS2 crash rates for urban one-way streets, provided in Table 19.

Table 18. Default Texas Crash Rates for NCHRP 17-76 Framework Application.

Roadway Configuration	AADT Range (veh/d)	Crash Rate (crashes/HMVM)	
		KABCO	KABC
Urban freeway	0–49,999	75.47	24.03
	50,000–74,999	73.27	24.08
	75,000–99,999	85.68	27.53
	100,000–149,999	89.26	31.50
	150,000–199,999	107.41	37.79
	≥ 200,000	118.40	40.11
Rural freeway	0–24,999	38.77	12.18
	25,000–49,999	46.09	12.25
	≥ 50,000	51.66	12.60
Rural two-lane highway	0–1,249	118.07	45.85
	1,250–2,499	96.76	36.22
	2,500–3,749	84.97	33.73
	3,750–4,999	83.37	31.69
	5,000–6,249	81.91	31.49
	6,250–7,499	85.17	33.08
	7,500–9,999	96.29	35.51
	≥ 10,000	98.56	36.53
Rural multilane divided highway	0–7,499	61.74	22.85
	7,500–9,999	59.12	21.48
	10,000–14,999	53.35	19.31
	15,000–19,999	58.59	20.61
	20,000–24,999	59.14	20.45
	≥ 25,000	66.41	23.55

Roadway Configuration	AADT Range (veh/d)	Crash Rate (crashes/HMVM)	
		KABCO	KABC
Rural multilane undivided highway	0–6,249	89.18	35.57
	6,250–9,999	86.99	31.58
	10,000–14,999	85.49	31.50
	≥ 15,000	100.70	29.66
Urban two-lane street	0–4,999	193.43	70.04
	5,000–7,499	181.94	63.57
	7,500–9,999	184.63	68.03
	10,000–14,999	191.34	67.53
	15,000–19,999	206.51	67.02
	≥ 20,000	173.33	56.93
Urban multilane divided street	0–14,999	212.73	78.26
	15,000–19,999	213.88	78.79
	20,000–24,999	215.64	81.17
	25,000–29,999	267.42	99.05
	30,000–39,999	223.84	74.80
	40,000–49,999	250.80	86.63
	≥ 50,000	215.31	74.73
Urban multilane undivided street	0–9,999	276.61	96.83
	10,000–14,999	293.87	103.89
	15,000–19,999	302.69	108.82
	20,000–24,999	321.01	118.03
	25,000–29,999	316.16	115.74
	30,000–39,999	288.52	105.30
	≥ 40,000	282.43	88.57
~~Urban one-way street~~	~~≥ 0~~	~~745.52~~	~~245.39~~

Strikeout = unreasonably high rates for KABCO and KABC crashes. Recommend using crash rates in Table 19.

Table 19. Default Crash Rates for Urban One-Way Streets (*16*).

Roadway Configuration	AADT Range (veh/d)	Crash Rate (crashes/HMVM)	
		KABCO	KABC
Urban one-way street	0–4,999	245.12	60.21
	5,000–9,999	139.27	37.29
	10,000–14,999	72.18	22.79
	15,000–19,999	58.31	18.19
	20,000–24,999	57.36	17.72
	25,000–29,999	63.87	20.07
	≥ 30,000	54.63	15.03

The following figures show comparisons of the computed crash rates for each roadway configuration category:

- Figure 2. Comparison of Urban Freeway Crash Rates.
- Figure 3. Comparison of Rural Freeway Crash Rates.
- Figure 4. Comparison of Rural Two-Lane Highway Crash Rates.
- Figure 5. Comparison of Rural Multilane Divided Highway Crash Rates.
- Figure 6. Comparison of Rural Multilane Undivided Highway Crash Rates.
- Figure 7. Comparison of Urban Two-Lane Street Crash Rates.
- Figure 8. Comparison of Urban Multilane Divided Street Crash Rates.
- Figure 9. Comparison of Urban Multilane Undivided Street Crash Rates.

In each of these graphs, solid lines denote the KABCO crash rates and dashed lines denote the KABC crash rates. The original and revised USLIMITS2 crash rates are labeled *USL2 (1998–2004)* and *USL2 (2009–13)* to indicate the earliest and latest years included in the respective data queries. Note that these queries included multiple years, but not necessarily the same years, in the various states' datasets.

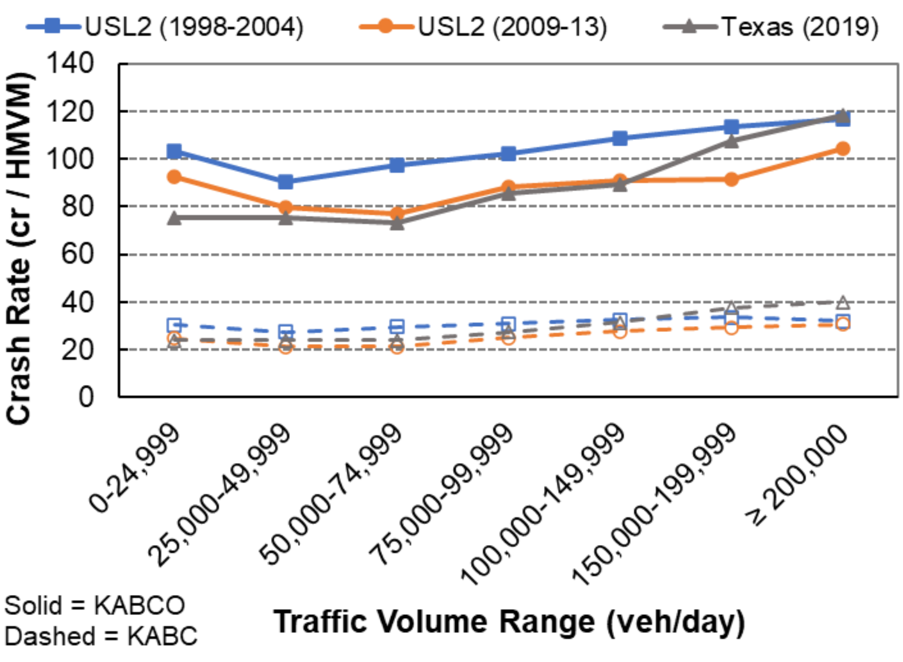


Figure 2. Comparison of Urban Freeway Crash Rates.

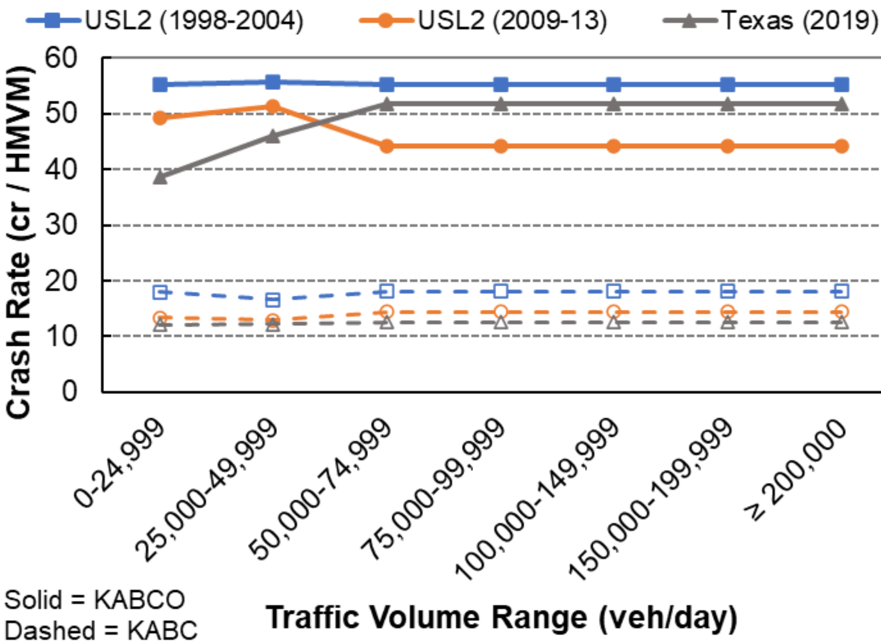


Figure 3. Comparison of Rural Freeway Crash Rates.

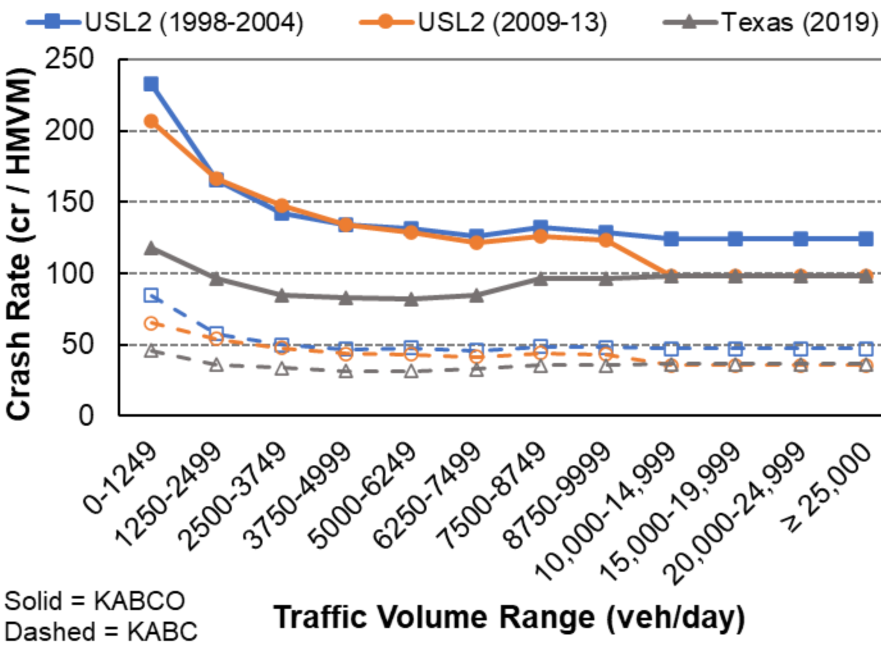


Figure 4. Comparison of Rural Two-Lane Highway Crash Rates.

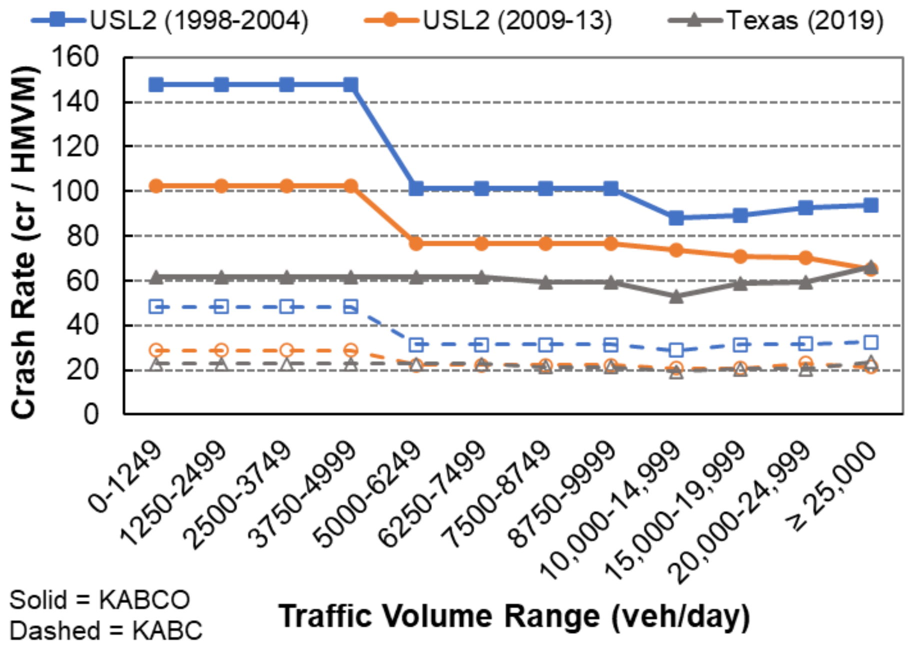


Figure 5. Comparison of Rural Multilane Divided Highway Crash Rates.

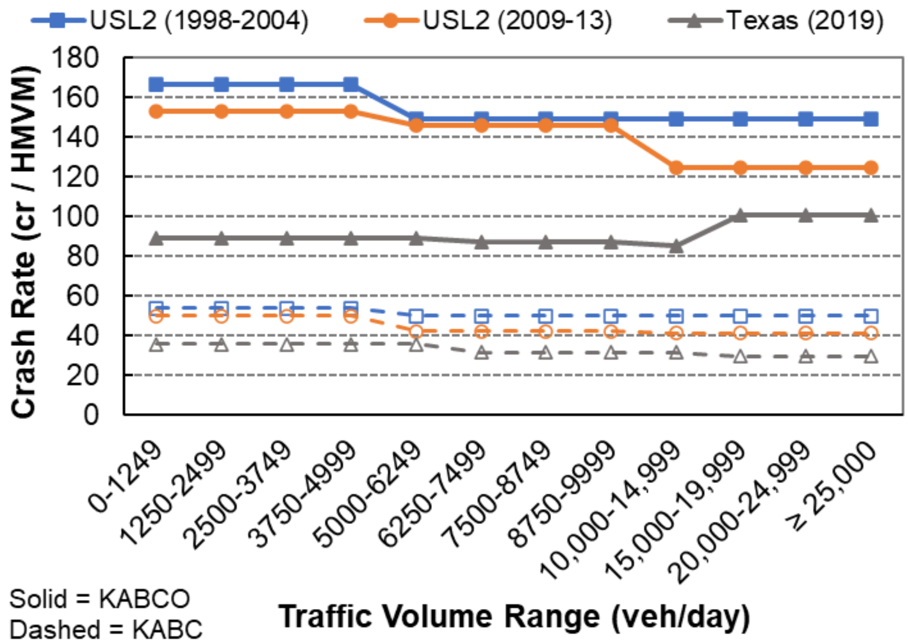


Figure 6. Comparison of Rural Multilane Undivided Highway Crash Rates.

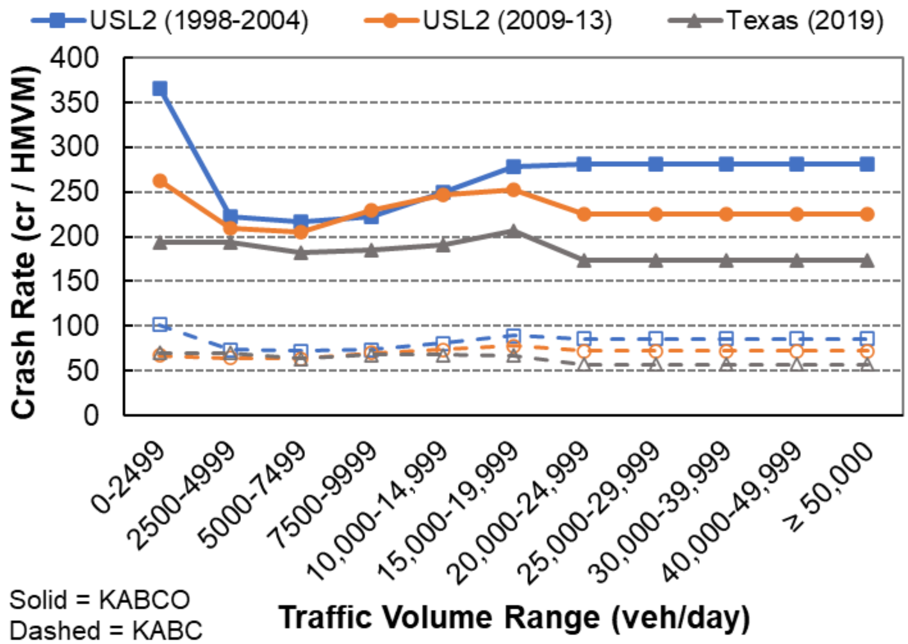


Figure 7. Comparison of Urban Two-Lane Street Crash Rates.

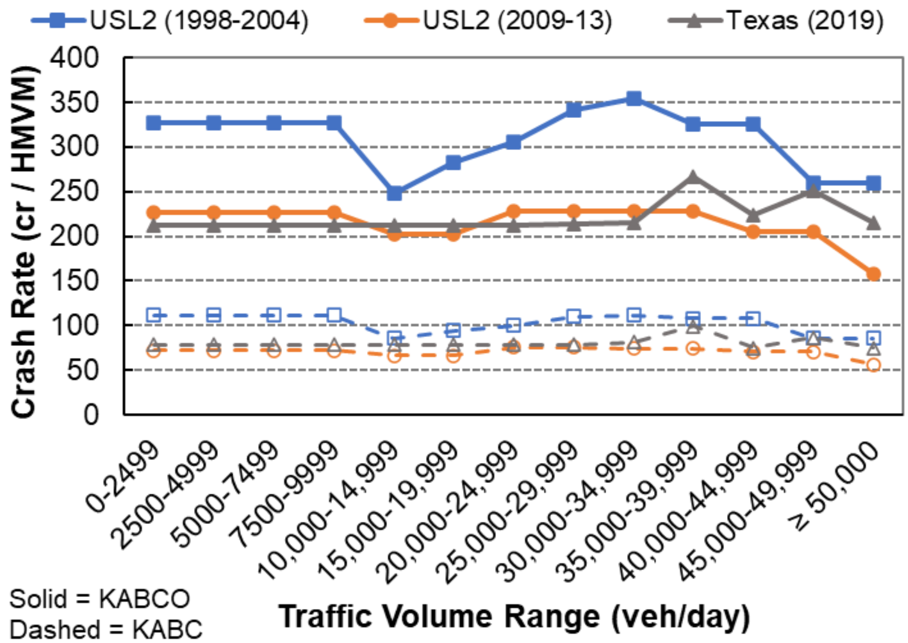


Figure 8. Comparison of Urban Multilane Divided Street Crash Rates.

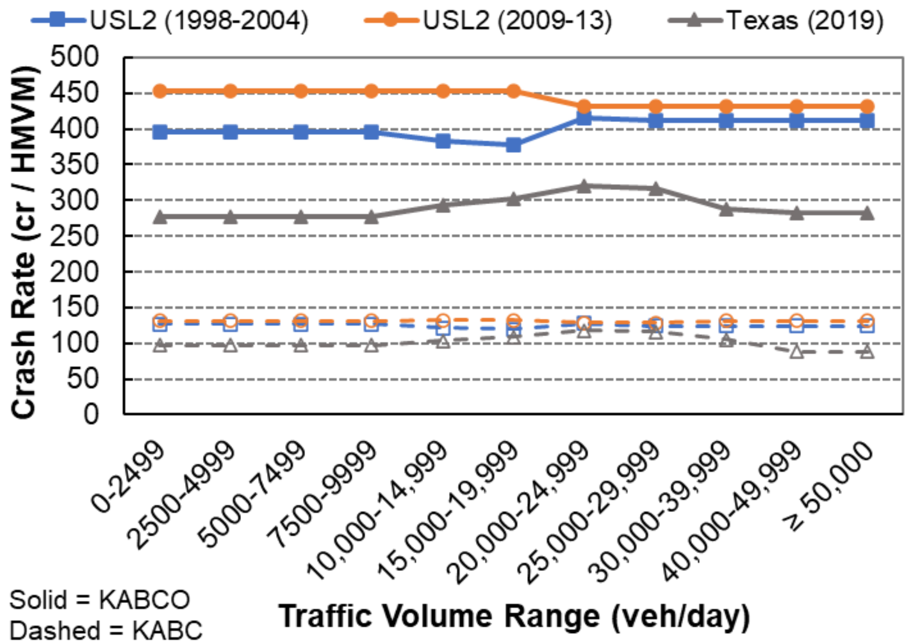


Figure 9. Comparison of Urban Multilane Undivided Street Crash Rates.

Recommended Texas Statewide Average Crash Rates

The research team recommends that TxDOT practitioners consider the NCHRP 17-76 spreadsheet tool as a resource for weighing the needs of various road users when setting regulatory speed limits. Practitioners who have access to crash data should use that data along with the recommended crash rates from Table 18 and Table 19. The research team developed a version of the NCHRP 17-76 spreadsheet tool (SLS Tool-Texas) that includes the recommended crash rates entered into its support tables.

CHAPTER 5: STAGE 3–CALCULATE SPEED MEASURES (VEHICLE SPEED DISTRIBUTION)

Table 20 lists the speed measures discussed in key reference documents for speed zone studies. This chapter describes data collection methods used to obtain the speed data needed to calculate the speed measures considered in a speed study. The speed measures are obtained from the distribution of vehicle speeds measured for a site. Depending on the equipment used for data collection, either the speeds of individually selected vehicles, the speeds of all vehicles, or the speeds of a sample of vehicles may be measured.

Table 20. Speed Measures.

Framework	Measure
TxSZ	• 85th percentile speed
NCHRP 17-76 SLS Tool or SLS Tool-Texas	• 85th percentile speed • 50th percentile speed
2023 MUTCD	• Speed distribution of free-flowing vehicles including the pace, median (50th percentile), and 85th percentile speeds • A review of past speed studies to identify any trends in operating speeds
TxMUTCD	• Current speed distribution of free-flowing vehicles (*2*, Section 2B.13, paragraph 1) • Should be within 5 mph of the 85th percentile speed of free-flowing traffic (*2*, Section 2B.13, paragraph 13) • Pace (*2*, Section 2B.13, paragraph 18)

DATA COLLECTION METHODS

A variety of methods are available to measure speeds. These methods can generally be grouped based on the installation location of the collection equipment and whether a spot speed or a segment speed is recorded.

On-Site Speed Study (Spot Speeds)

On-site devices measuring spot speeds—that can also measure traffic volume, measure vehicle classification, and in some cases measure or account for traffic flow gaps—include the following:

- **Handheld devices.** Devices that can be used in most places are those that are handheld, manually operated, and portable. Examples include radar and LiDAR guns. Advantages for these devices are that the equipment is easily portable, and the user controls the vehicles sampled. These devices also have several disadvantages. Cosine error limits horizontal/vertical deployment scopes and sights may not be user-friendly. Laser beams are more sensitive to environmental variances than radar. Maintenance and calibration are required. These devices can be detected by drivers, which may change driver behavior. Finally, using handheld devices results in a relatively small dataset.

- **On-road (or in-road) devices.** On-road devices are installed into or on top of the roadway surface and include, for example, pneumatic road tubes and loop detectors. These devices are visible to the traveling public, which may change driver behavior. Their use is discouraged when snowplows may be present. Because the device is installed on the road surface, traffic control may be needed for installation. After installed, minimal labor is required to tabulate data. Other traffic-related data may be collected at the same time as the speed data are collected.
- **Off-road devices.** Examples of devices installed overhead or to the side of the roadway surface can include radar recorders and in some cases toll-tag readers. While relatively less labor is needed to tabulate data, installation of the device may be more intensive than the installation of other devices, especially when installed temporarily. This type of device can collect a lot of speed and other traffic-related data over long periods of time. Other benefits are that it can be placed to avoid the impact of snowplows, and it is less visible to the traveling public than road tubes.

Probe Speed Study (Segment Speeds)

Devices that can measure segment speeds include the following:

- **Floating car or trial-run speed measurement.** The speed is determined based on the engineer's judgment of the driver to the roadway. This approach is only to be used in Texas if 125 cars cannot be checked during a two- or four-hour speed check. It provides speed values for low-volume roadways or as a *second opinion*. Disadvantages include that the driver's selected operating speed may not be representative of the general public's travel speed, and the method provides a very small dataset.
- **Toll tag readers.** Readers installed to record toll tags or recognize license plates could also be used to measure speed. An advantage of this type of device is that the equipment has already been installed for other purposes and it can collect large datasets over long period of time. A disadvantage is that the segment represented by these readers may not reflect the speed study area. Addressing privacy concerns may limit use of this method.
- **Probe vehicles.** Several methods are used to record travel times for probe vehicles that are operating within the traffic stream. The methods are used by a number of vendors who sell post-processed data. This method can collect data for long periods of time and has resulted in data being readily available for many roadways. Vendors have created multiple ways of displaying key measures from the data on dashboards. Significant disadvantages for this type of data are that the speed values may not reflect free-flow conditions or the study area of interest. Only a subset of all vehicles is measured, with observations typically representing the averages for those vehicles measured. Additional labor may be required if measures not currently supported by the vendor are needed.

The TxSZ (*1*, page 3-7) notes that new technologies may be used in determining vehicular speeds for use in calculating 85th percentile speed if the measured speeds are accurate to within 2 mph and the gap between vehicles is 3 seconds or greater. Counter-classifiers, which are capable of classifying vehicles, determining vehicular speeds, and differentiating the gap between vehicles, provide one example of new technologies.

DATA COLLECTION PROCEDURES

Locations

When positing themselves to collect data, the data collector should pick a location that will not unduly influence the behavior of the drivers. Vehicles used in the data collection effort should not resemble a law enforcement or other official vehicle (i.e., with lights on top) to minimize effects on driver behavior. The data collection units are to be located at a sufficient distance from interchanges, intersections, and other access points such that accelerating or decelerating vehicles do not influence the speed profile. Section 2B.13 in the TxMUTCD (*2*) (and Section 2B.21.12 in the 2023 MUTCD [*4*]) recommends that speed studies for signalized intersection approaches should be taken outside the influence area of the traffic control signal, which is generally considered to be approximately ½ mile. This distance was selected to avoid obtaining skewed results for the 85th percentile speed (or speed distribution). The 2023 MUTCD also states that if the signal spacing is less than 1 mile, the speed study should be at the approximate middle of the segment (*4*). Table 21 shows recommendations from the TxSZ for speed data collection.

Table 21. Speed Data Collection Site Guidance for Texas from the TxSZ (*1*).

Context	Data Collection Site Location Guidance
Urban	• Sites should generally be located at intervals of 0.25 miles, or less, if necessary, to ensure an accurate picture of the speed patterns • Sites should be located midway between signals or 0.2 miles from any signal, whichever is less, to ensure an accurate representation of speed patterns • Sites should be located midway between interchanges on freeway and expressway mainlines • Sites should consider locality; the uniformity of physical and traffic conditions may be determined by trial runs through the area if volumes are too low or if a recheck of speeds is all that is needed • Speeds should be checked midway between interchanges on the main lanes of expressways and freeways
Rural	• Sites may be at intervals greater than 0.25 mile, as long as the general speed pattern is followed and may only be necessary at each end and the middle point if the characteristics of the roadway are consistent throughout the entire section • Sites may be determined by test runs through the area if the characteristics of the roadway are consistent throughout the entire section and a speed check in that section indicates that 125 vehicles cannot be checked within 2 hours if radar is used or after 4 hours if a traffic counter that classifies vehicles by type is used

Time of Day

When using manual data collection techniques, the practitioner supervising the engineering study must determine an appropriate day-of-week and time-of-day to conduct the study. The *Manual of Transportation Engineering Studies* (*8*) recommends that when using automatic data collection equipment, speed data should be collected at sites for one or more 24-hour periods on typical days.

Sample Size

Table 22 lists the sample sizes and sample periods provided in the TxSZ. The TxSZ specifies that the vehicles to be measured are cars. Most states use 100 or more vehicles in each direction for each station as a minimum sample size (*6*). Using automated data collection equipment to collect speed data generally avoids sample size issues and provides a more robust dataset if the collection method filters non-free-flowing vehicles. A random sample of vehicle speeds is needed to produce statistically valid speed estimates. The *Manual of Transportation Engineering Studies* (*8*) provides discussion, equations, and tables that practitioners can also use to determine sample size.

On roads with very low volumes, it may take some time to obtain a suitable sample size. In Texas, a floating car may alternatively be used for data collection if it takes longer than 2 hours for radar or 4 hours for a traffic counter to obtain a sample of 125 vehicles.

Table 22. Sample Sizes and Data Collection Periods for Texas from the TxSZ (*1*).

Sample Size	Exception
A minimum of 125 cars in each direction, at each station	Discontinue after 2 hours if radar is used or after 4 hours if a traffic counter that classifies vehicles by type is used—even if 125 cars have not been sampled

Free-Flow Vehicles

The traditional method for determining the 85^{th} percentile speed used in a speed zone study is to only include vehicles that are considered to be free flowing. The 85^{th} percentile speed is to be the speed used by "the large majority of drivers who are reasonable and prudent, do not want to have a crash, and desire to reach their destination in the shortest possible time" (*1*).

Free-flow speed represents the speed that a motorist would travel if no congestion or adverse conditions (such as bad weather or limited visibility) existed. The process for identifying free-flow vehicles depends on the method of data collection selected for the study. These methods can be distinguished as manual observations (i.e., from a handheld speed measurement device) and automated observations that can be collected either with or without time stamps, depending on the equipment available.

Manual Observations

When speed data are collected manually, the data collector's judgement is used to select passenger cars that are free flowing.

Automated Observations with Time Stamps

If speed data are collected automatically and each observation has an associated time stamp at a sufficient resolution (i.e., with sub-second accuracy), the practitioner can filter the data to identify those vehicles that meet the definition of a free-flow vehicle. For example, if the definition of a free-flow vehicle is a vehicle at least 3 seconds behind the preceding vehicle in its lane, all observations in a given lane with a time stamp less than 3 seconds after the preceding observation would be filtered. In Texas, the TxSZ indicates that 3 seconds is acceptable (*1*).

Automated Observations without Time Stamps

When speed data are collected automatically but do not include individual time stamps, an approach that has been suggested as a method to reduce the dataset to reflect free-flow conditions is to identify a low-volume period where most vehicles can be assumed to be free-flowing. Note that this approach is theoretical, has not been tested with research, and relies on the judgment of the practitioner. The recommendation is for the practitioner to use speed observations during 15-minute periods where traffic volumes meet select criteria.

The *Highway Capacity Manual* (*17*) identifies the following volume ranges as being representative of free-flow conditions:

- Freeways and uninterrupted-flow multilane highways with volumes less than 1,000 passenger cars per hour per lane.
- Uninterrupted flow two-lane highways with volumes less than 100 vehicles per hour per lane.
- Interrupted-flow streets with volumes less than 250 vehicles per hour per lane.

Probe Data

The probe data available from vendors represent a selection of the vehicles present along the corridor; therefore, whether a specific speed measure reflects free-flow conditions is not known. This research project explored how to account for this lack of information when estimating the operating speed using probe data (see Use of Probe Data to Identify Operating Speed Measures later in this chapter).

CALCULATION OF OPERATING SPEED MEASURES FROM ON-SITE SPEED DATA

When collecting data using a manual method, the practitioner can use Form 1882, Radar Motor Vehicle Speed Field Tally Sheet in the TxSZ (*1*, Figure 3-2) to record tally marks, which are then considered when identifying the 85th percentile speed. If another method is used, the speed observations can be imported into a spreadsheet or statistical analysis software package to produce the 85th and 50th percentile speeds (and any other desired percentile), along with the mean speed. The pace can be determined from a histogram of the speed distribution. It can also be determined by first counting the number of observations in each 1-mph speed bin and then summing the counts over each combination of 10 consecutive bins (e.g., 26–35 mph, 27–36 mph, 28–37 mph). The 10 consecutive bins with the highest total counts represent the pace.

USE OF PROBE DATA TO IDENTIFY OPERATING SPEED MEASURES

Research-Based Methods to Consider Probe Data in Speed Zone Studies

Speed zone studies are performed to justify a change in posted speed limit and normally involve on-site speed data collection using either radar guns or traffic counters. In Texas, samples must consist of at least 125 *free-floating* vehicles (excluding trucks and buses) in each direction. A maximum of 2 hours for radar guns and 4 hours for traffic counters is allowed for data collection.

Manual data collection for speed zone studies is labor intensive and places data collectors at risk of unsafe exposure by increasing their chances of a traffic crash. The presence of probe data that contains vehicle speeds provides an opportunity to perform speed zone studies without manual speed data collection. Thus, the TxDOT project 0-7156 explored the application of probe data for speed zone studies using INRIX data (*18*).

The study compared on-site speed data and INRIX data from the same location. Because the INRIX data represent segment speeds while the on-site speed gun or traffic counter data represent spot speeds, several statistical models were developed to explain the variability between the INRIX speed data and the on-site speed data. In addition to the 85th percentile speed, the average speed was used to compare the on-site speed data and the INRIX speed data.

Use of INRIX Data to Predict Speeds for Speed Zone Studies

This section describes how the INRIX data can be used to generate spot speeds for consideration in a speed zone study.

Step 1–Obtain INRIX Segment IDs for the Corridors of Interest

The INRIX speed data can be accessed through the Probe Data Analytics Suite in the Regional Integrated Transportation Information System (RITIS) analysis platform using the IDs for the segments of interest. These IDs are unique numbers that represent the identification of each INRIX segment from the entire network of INRIX segments. The analyst must first identify the coordinates of the site of interest and then use geographic information system (GIS) tools to map all sites of interest. Figure 10 shows an example of the mapped INRIX segments and automatic traffic recorder (ATR) locations across the state.

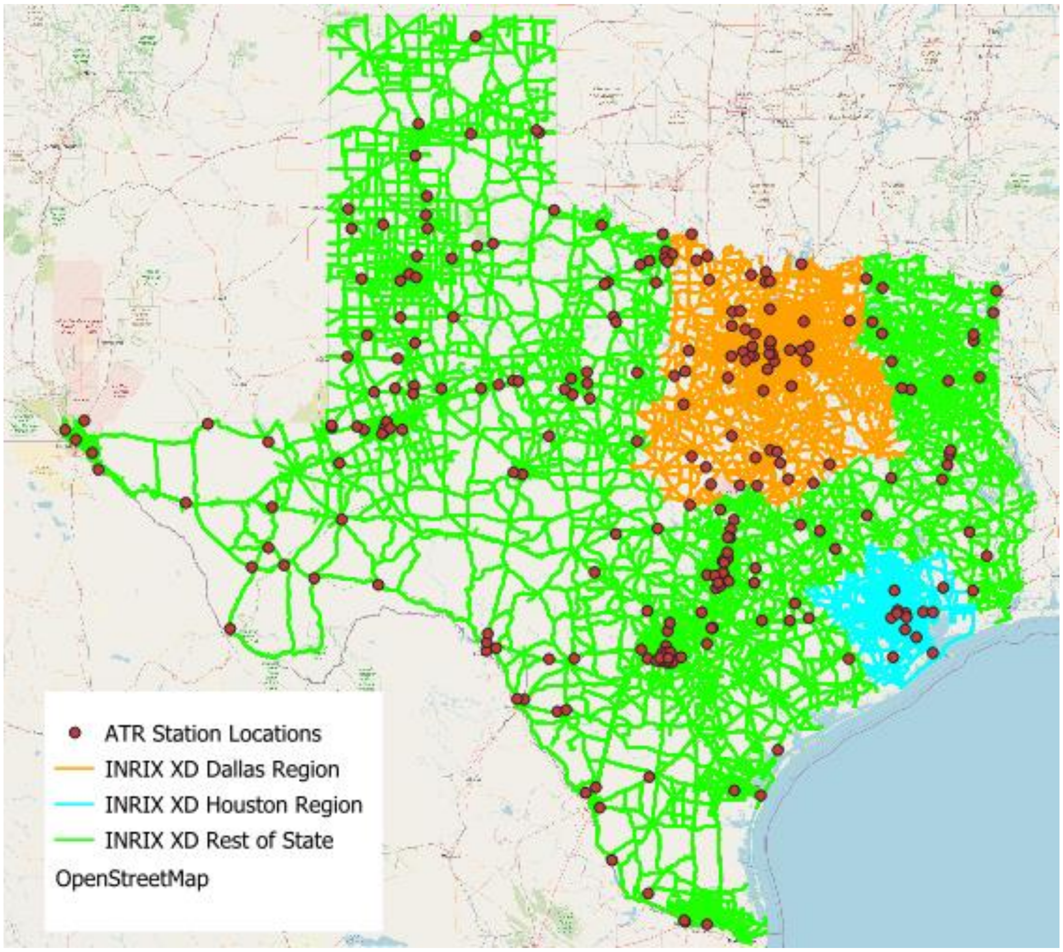


Figure 10. Example of Mapped INRIX Segments and ATR Locations in Texas.

The analyst next creates a 50-ft buffer around the location of interest (Figure 11). Then, using the spatial join feature of the GIS, the analyst overlays and extracts the INRIX segments that correspond to the identified site(s) of interest. The extracted segments can be saved in a comma-separated value (CSV) or text file for further processing.

The INRIX segments have various associated information, such as the segment ID, length, beginning and ending coordinates, number of lanes, etc. However, in this case, only the segment ID is of interest. With the INRIX segment IDs, the analyst can proceed to access the INRIX speed data.

Step 2–Download INRIX Speed Data

To download the speed data, the analyst must access the data source via the Probe Data Analytics Suite, which can be accessed at https://pda.ritis.org/suite/download/. A login page appears upon opening the website (Figure 12). The analyst must enter their email and password to proceed; if the analyst does not have a RITIS account, they can request one at https://www.ritis.org/register/.

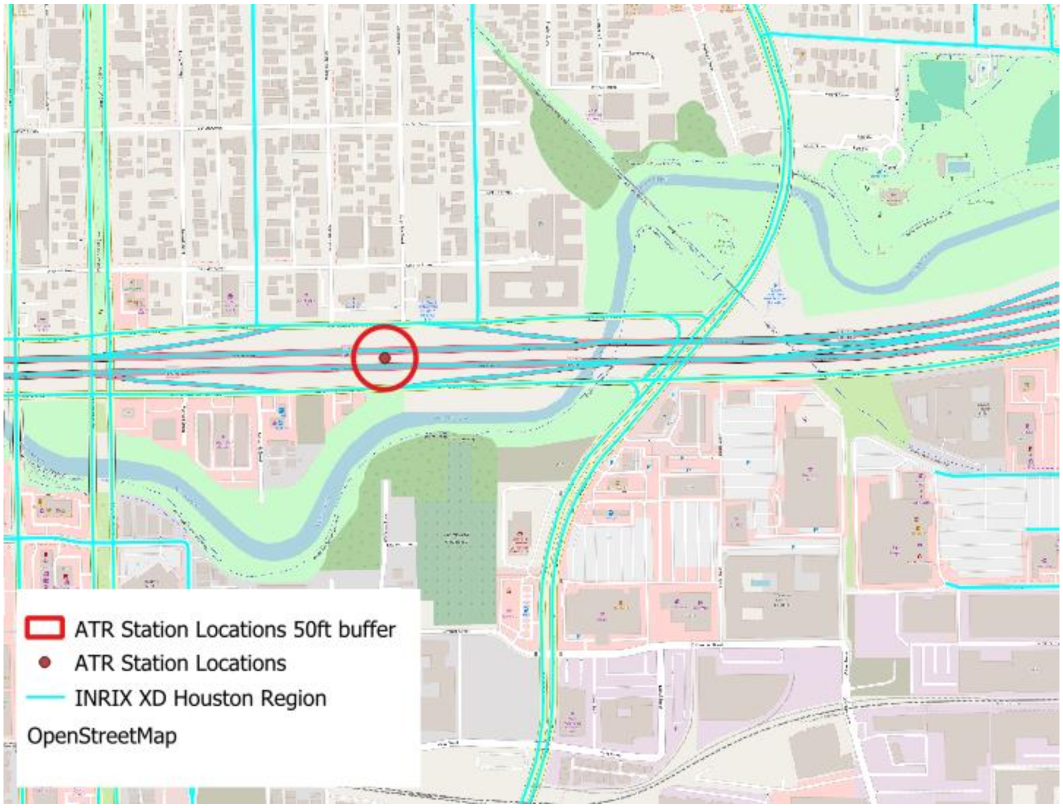


Figure 11. Example 50-ft Buffer Around an ATR Location Overlayed on INRIX Segments.

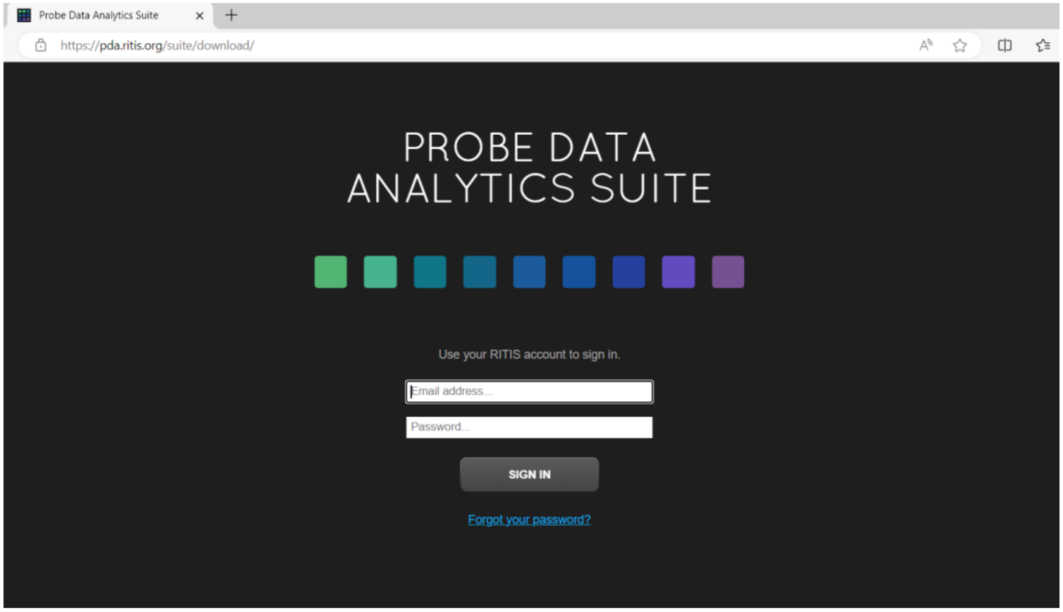


Figure 12. Probe Data Analytics Suite Login Page.

After successfully entering their email and password, the Probe Data Analytics Suite main page appears in a new window (Figure 13). The analyst is then able to specify various criteria for the data to be downloaded. On the left side of Figure 13, the analyst must specify the following:

- Country (select country; default is United States).
- Segment type (select XD).
- Roads (click segment codes, then copy and paste the segment IDs).
- Date ranges (enter start and end dates).
- Day of the week (select days of interest; default is all days).
- Times of day (select times of interest; default is 24 hours).
- Measures such as speed, travel time, reference speed, historical speed, etc. (select measures of interest; default is all measures).
- Units for travel time (do not change; default is seconds).
- Null record handling (select preference; default is to not include null values).
- Averaging (do not change unless aggregated data are sought; default is to not average).

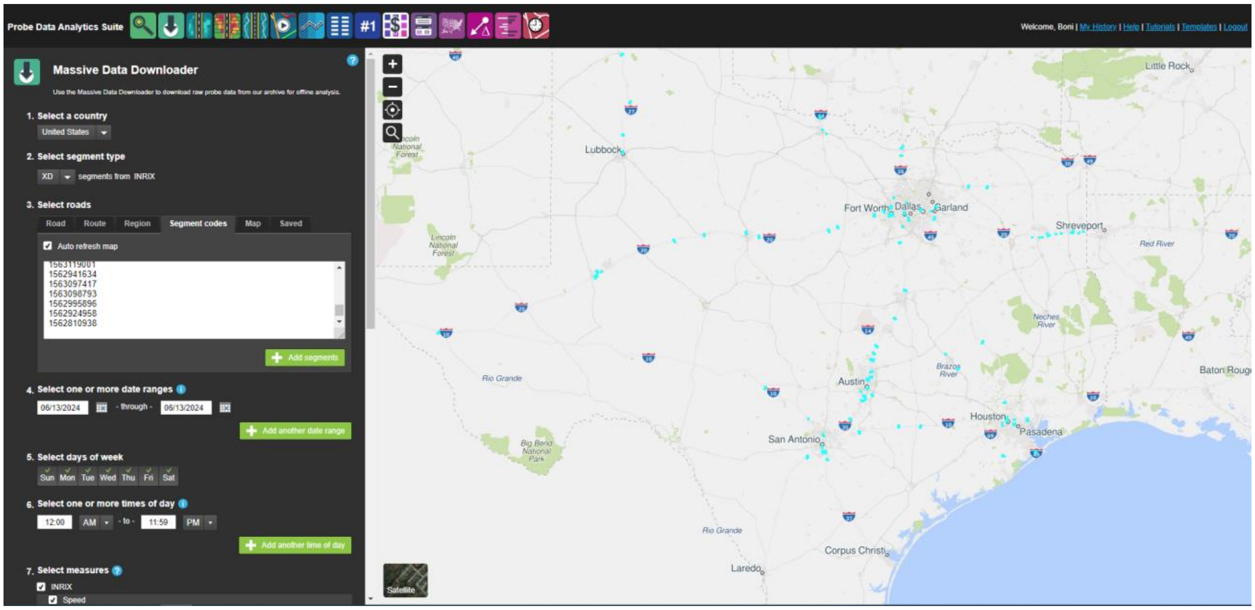


Figure 13. Probe Data Analytics Suite Main Page.

After specifying all the criteria, the analyst must provide a file name and submit the query for the Probe Data Analytics Suite to search the speed data. After submitting the query, the Probe Data Analytics Suite searches the speed data and sends a link to the email the analyst provided when registering the account. To download the data, the analyst must open the email and click the link. The link opens a new tab on a browser, and the download begins. If the download does not begin, the analyst must click on the link shown on the opened browser.

Step 3–Compute the 85th Percentile Speed

To compute the 85th percentile speed, the analyst must unzip the downloaded folder, which contains two CSV files (speed data and XD identification) and one text file. The speed data file normally retains the same name assigned in the Probe Data Analytics Suite when downloading the data.

The analyst uses the *speed* variable in the speed data file to compute the 85th percentile and average speeds for the INRIX data. The average and 85th percentile speeds for each INRIX segment are computed using the average and percentile functions, respectively. Figure 14 shows a screenshot of a spreadsheet with a function/formula to compute the 85th percentile speed.

C105067 | fx | =PERCENTILE(C2:C105066, 0.85)

	A	B	C	D	E	F	G	H
1	xd_id	measurement_tstamp	speed	historical_average_speed	reference_speed	travel_time_seconds	confidence_score	cvalue
105057	1595219599	12/31/2021 23:10	67.6	71	71	21.5	30	100
105058	1595219599	12/31/2021 23:15	68.19	71	71	21.31	30	100
105059	1595219599	12/31/2021 23:20	64.4	71	71	22.57	30	100
105060	1595219599	12/31/2021 23:25	64.8	71	71	22.43	30	100
105061	1595219599	12/31/2021 23:30	65.6	71	71	22.15	30	100
105062	1595219599	12/31/2021 23:35	65.39	71	71	22.22	30	100
105063	1595219599	12/31/2021 23:40	66.2	71	71	21.95	30	100
105064	1595219599	12/31/2021 23:45	66	71	71	22.02	30	100
105065	1595219599	12/31/2021 23:50	64.8	71	71	22.43	30	100
105066	1595219599	12/31/2021 23:55	64	71	71	22.71	30	100
105067		**85th Percentile**	**71.2**					
105068								

Figure 14. Screenshot of Spreadsheet Computation of 85th Percentile Speed from INRIX Data.

For small datasets, the entire process of determining the average and 85th percentile speeds can be performed in a spreadsheet. However, computer code may be needed to simplify the work if the analysis involves a large dataset that a spreadsheet cannot handle.

Step 4–Calculate the Predicted 85th Percentile Speed

Finally, the analyst uses the equations developed in the TxDOT project 0-7156 (*18*) to convert the INRIX yearly 85th percentile speeds to predicted representative spot speeds. These equations are provided in the next section.

Calculation of a Freeway Operating Speed Measure Using the Research Model

The following series of equations was developed in the TxDOT project 0-7156 (*18*) to convert INRIX segment speeds into representative spot speeds for rural and urban freeway corridors.

Rural Freeway Equation to Predict 85th Percentile Speed

The equation to predict the 85th percentile spot speed for a rural freeway corridor using INRIX yearly speed is as follows:

$$Spd85(FreewayRuralPredicted) = 29.1680 + 0.7335\ X\ Spd85(YrDataINRIX) - 1.1163\ X\ RampDen \quad \text{Equation (2)}$$

where:

Spd85(FreewayRuralPredicted) = predicted 85th percentile speed (mph) for a rural freeway corridor.
Spd85(YrDataINRIX) = 85th percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.
RampDen = ramps per mile for the corridor.

Rural Freeway Equation to Predict Average Speed

The equation to predict the average spot speed for a rural freeway corridor using INRIX yearly speed is as follows:

$$SpdAve(FreewayRuralPredicted) = 19.2780 + 0.7719\text{X}\ Spd85(YrDataINRIX) - 1.0883\ \text{X}\ RampDen \quad \text{Equation (3)}$$

where:

SpdAve(FreewayRuralPredicted) = predicted average speed (mph) for a rural freeway corridor.
Spd85(YrDataINRIX) = 85th percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.
RampDen = ramps per mile for the corridor.

Urban Freeway Equation to Predict 85th Percentile Speed

The equation to predict the 85th percentile spot speed for an urban freeway corridor using INRIX yearly speed is as follows:

$$Spd85(FreewayUrbanPredicted) = -48.6515 + 1.8024 \text{ X } Spd85(YrDataINRIX) - 0.4476 \text{ X } RampDen \quad \text{Equation (4)}$$

where:

Spd85(FreewayUrbanPredicted) = predicted 85th percentile speed (mph) for an urban freeway corridor.
Spd85(YrDataINRIX) = 85th percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.
RampDen = ramps per mile for the corridor.

Urban Freeway Equation to Predict Average Speed

The equation to predict the average spot speed for an urban freeway corridor using INRIX yearly speed is as follows:

$$SpdAve(FreewayUrbanPredicted) = -51.9589 + 1.7497 \, X \, Spd85(YrDataINRIX) - 0.5943 \, X \, RampDen \quad \text{Equation (5)}$$

where:

SpdAve(FreewayUrbanPredicted) = predicted average speed (mph) for an urban freeway corridor.
Spd85(YrDataINRIX) = 85th percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.
RampDen = ramps per mile for the corridor.

Suggested Default Values for Freeway Equations to Predict Speed

Default values were developed by the research team (Table 23) by considering the average values of variables present in the databases when developing the regression equations and applying engineering judgement.

Table 23. Suggested Default Values when Such Values are not Available or Difficult to Obtain for Freeway Corridors.

Variable	Urban	Rural
Spd85_AllHrAllDay_INRIX.YrData	70.99	73.60
RampDensity_SiteChar	1.95	0.94

Calculation of a Non-freeway Operating Speed Measure Using the Research Model

The following equations were developed in the TxDOT project 0-7156 (*18*) to convert INRIX segment speeds into a representative spot speed for rural and urban non-freeway corridors.

Rural Non-freeway Equation to Predict 85th Percentile Speed

The equation to predict the 85th percentile spot speed for a rural non-freeway corridor using INRIX yearly speed is as follows:

$$Spd85(NonFreewayRuralPredicted) = 9.6910 + 1.0213 \times Spd85(YrDataINRIX) - 2.4241 \times SigDen - 0.1920 \times DrvUsigPerMileBoth + 0.000101 \times AADT/Lane - 0.3492 \times AvgLaneWidth - 0.6686 \times Curb(1yes) - 0.4915 \times Miles(INRIXseg) - 0.0762 \times KFAC + 1.4641 \times R3 + 1.1702 \times R4 - 0.5285 \times R5 - 0.8189 \times R6 - 1.2869 \times R7$$

Equation (6)

where:

Spd85(NonFreewayRuralPredicted) = predicted 85th percentile speed (mph) for a rural non-freeway corridor.

Spd85(YrDataINRIX) = 85th percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.

SigDen = signals per mile for the corridor.

DrvUsigPerMileBoth = driveways and unsignalized intersections (both directions) per mile for the corridor.

AADT/Lane = average annual daily traffic per lane.

AvgLaneWidth = average lane width for the corridor.

Curb(1yes) = 1 when curb and gutter is present within the corridor, 0 otherwise.

Miles(INRIXSeg) = number of miles for the INRIX segment.

KFAC = peak factor (%).

R3 = 1 when RHINO's RU_F_SYSTEM = R3, Rural Other Principal Arterial, 0 otherwise.

R4 = 1 when RHINO's RU_F_SYSTEM = R4, Rural Minor Arterial, 0 otherwise.

R5 = 1 when RHINO's RU_F_SYSTEM = R5, Rural Major Collector, 0 otherwise.

R6 = 1 when RHINO's RU_F_SYSTEM = R6, Rural Minor Collector, 0 otherwise.

R7 = 1 when RHINO's RU_F_SYSTEM = R7, Rural Local, 0 otherwise.

Rural Non-freeway Equation to Predict Average Speed

The equation to predict the average spot speed for a rural non-freeway corridor using INRIX yearly speed is as follows:

$$\text{SpdAve}(\textit{NonFreeway}\text{RuralPredicted}) = 7.5660 + 0.9737 \times \text{Spd85(YrDataINRIX)} - 2.5349\ \text{SigDen} - 0.2180 \times \text{DrvUsigPerMileBoth} + 0.000069 \times \text{AADT/Lane} - 0.0895 \times \text{AvgLaneWidth} - 0.2830 \times \text{Curb(1yes)} - 0.5580 \times \textit{Miles}(\textit{INRIXseg}) - 0.1053 \times \textit{KFAC} + 1.1465 \times R3 + 0.3639 \times R4 - 1.2149 \times R5 - 0.0000 \times R6 - 0.2956 \times R7 \qquad \text{Equation (7)}$$

where:

SpdAve(NonFreewayRuralPredicted) = predicted average speed (mph) for a rural non-freeway corridor.
Spd85(YrDataINRIX) = 85^{th} percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.
SigDen = signals per mile for the corridor.
DrvUsigPerMileBoth = driveways and unsignalized intersections (both directions) per mile for the corridor.
AADT/Lane = average annual daily traffic per lane.
AvgLaneWidth = average lane width for the corridor.
Curb(1yes) = 1 when curb and gutter is present within the corridor, 0 otherwise.
Miles(INRIXSeg) = number of miles for the INRIX segment.
KFAC = peak factor (%).
R3 = 1 when RHINO's RU_F_SYSTEM = R3, Rural Other Principal Arterial, 0 otherwise.
R4 = 1 when RHINO's RU_F_SYSTEM = R4, Rural Minor Arterial, 0 otherwise.
R5 = 1 when RHINO's RU_F_SYSTEM = R5, Rural Major Collector, 0 otherwise.
R6 = 1 when RHINO's RU_F_SYSTEM = R6, Rural Minor Collector, 0 otherwise.
R7 = 1 when RHINO's RU_F_SYSTEM = R7, Rural Local, 0 otherwise.

Urban Non-freeway Equation to Predict 85th Percentile Speed

The equation to predict the 85th percentile spot speed for an urban non-freeway corridor using INRIX yearly speed is as follows:

$$\text{Spd85}(\mathit{NonFreeway}\text{UrbanPredicted}) = 27.7463 + 0.7738 \times \text{Spd85(YrDataINRIX)} - 0.4612\ \text{SigDen} - 0.0095 \times \text{DrvUsigPerMileBoth} + 0.000271 \times \text{AADT/Lane} - 0.2743 \times \text{AvgLaneWidth} - 0.575 \times \mathit{Miles}(\mathit{INRIXseg}) - 0.3821 \times \mathit{KFAC} - 0.1088 \times \mathit{U}3 + 2.1511 \times \mathit{U}4 + 1.2176 \times \mathit{U}5 - 3.2599 \times \mathit{U}7 \qquad \text{Equation (8)}$$

where:

Spd85(NonFreewayUrbanPredicted) = predicted 85th percentile speed (mph) for an urban non-freeway corridor.
Spd85(YrDataINRIX) = 85th percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.
SigDen = signals per mile for the corridor.
DrvUsigPerMileBoth = driveways and unsignalized intersections (both directions) per mile for the corridor.
AADT/Lane = average annual daily traffic per lane.
AvgLaneWidth = average lane width for the corridor.
Miles(INRIXSeg) = number of miles for the INRIX segment.
KFAC = peak factor (%).
U3 = 1 when RHINO's RU_F_SYSTEM = U3, Urban Other Principal Arterial, 0 otherwise.
U4 = 1 when RHINO's RU_F_SYSTEM = U4, Urban Minor Arterial, 0 otherwise.
U5 = 1 when RHINO's RU_F_SYSTEM = U5, Urban Major Collector, 0 otherwise.
U7 = 1 when RHINO's RU_F_SYSTEM = U7, Urban Local, 0 otherwise

Urban Non-freeway Equation to Predict Average Speed

The equation to predict the average spot speed for an urban non-freeway corridor using INRIX yearly speed is as follows:

$$\text{SpdAve}(\mathit{NonFreeway}\text{UrbanPredicted}) = 28.9242 + 0.7215 \times \text{Spd85(YrDataINRIX)} - 0.4404\ \text{SigDen} - 0.0014 \times \text{DrvUsigPerMileBoth} + 0.000193 \times \text{AADT/Lane} - 0.3979 \times \text{AvgLaneWidth} + 1.0593 \times \mathit{Miles}(\mathit{INRIXseg}) - 0.4798 \times \mathit{KFAC} - 0.8549 \times \mathit{U}3 + 1.7050 \times \mathit{U}4 + 1.9501 \times \mathit{U}5 - 2.8001 \times \mathit{U}7 \qquad \text{Equation (9)}$$

where:

SpdAve(NonFreewayUrbanPredicted) = predicted average speed (mph) for an urban non-freeway corridor.
Spd85(YrDataINRIX) = 85th percentile INRIX speed (mph) using non-zero INRIX XD daytime and nighttime hourly speed data for up to 8,760 hourly speed readings for the segment's year of interest.
SigDen = signals per mile for the corridor.
DrvUsigPerMileBoth = driveways and unsignalized intersections (both directions) per mile for the corridor.
AADT/Lane = average annual daily traffic per lane.
AvgLaneWidth = average lane width for the corridor.
Miles(INRIXSeg) = number of miles for the INRIX segment.
KFAC = peak factor (%).
U3 = 1 when RHINO's RU_F_SYSTEM = U3, Urban Other Principal Arterial, 0 otherwise.
U4 = 1 when RHINO's RU_F_SYSTEM = U4, Urban Minor Arterial, 0 otherwise.
U5 = 1 when RHINO's RU_F_SYSTEM = U5, Urban Major Collector, 0 otherwise.
U7 = 1 when RHINO's RU_F_SYSTEM = U7, Urban Local, 0 otherwise.

Suggested Default Values for Non-freeway Equations to Predict Speed

Default values were developed by the research team with consideration of the average for that variable present in the databases when developing the regression equations along with engineering judgement. Table 24 provides the suggested default values for non-freeway corridors.

Table 24. Suggested Default Values when Such Values are not Available or Difficult to Obtain for Non-freeway Corridors.

Variable	Urban	Rural
SigDen	1.3	0.1
DrvUsigPerMileBoth	17.3	3.9
AADT/Lane	2,600	2,000
AvgLaneWidth	11.5	11.8
KFAC	10.1	10.1
RU_F_SYSTE	U3	R3
Curb-1yes_SiteChar	Not a variable for urban conditions	0

CHAPTER 6: STAGE 4–INVESTIGATE/IDENTIFY SUGGESTED SPEED LIMIT

The fourth stage in the speed zone study process is to analyze the speed zone and identify the suggested speed limit. The key data element for this stage is the 85th percentile speed that was obtained in Stage 3. As previously discussed, the 85th percentile speed can be obtained using either an on-site speed study (measuring spot speeds) or prediction methods based on probe data (measuring segment speeds). Two analysis frameworks are available for identifying the suggested speed limit: (1) the TxSZ and (2) the NCHRP 17-76 SLS Tool (or SLS Tool-Texas). Table 25 summarizes these methods and frameworks.

Table 25. Suggested Speed Limit Methods and Frameworks.

Speed Limit Analysis Framework	Method(s) to Obtain 85th Percentile Speed	Other Required Speed Measurements
TxSZ	• On-site speed study (spot speeds) • Predicted speed from probe data (segment speeds)	None
NCHRP 17-76 SLS Tool (or SLS Tool-Texas)	• On-site speed study (spot speeds) • Predicted speed from probe data (segment speeds)	50th percentile speed

TXSZ ANALYSIS FRAMEWORK

In the TxSZ analysis framework, the 85th percentile speed is the key input. The TxSZ calls for the regulatory speed limit to be posted at the value rounded to the closest 5-mph increment but allows the supervising engineer to depart as much as 5 mph above or below the closest 5-mph increment of the 85th percentile speed based on professional judgment. This framework also allows 85th percentile speeds from adjacent speed check stations to be averaged if they are "approximately the same," excluding 85th percentile speeds from individual stations that differ from the average of adjacent 85th percentile speeds by more than 7 mph (*1*, page 3-18).

The TxSZ analysis framework allows the posting of regulatory speed limits as much as 10 mph below the 85th percentile speed based on various site characteristics or as much as 12 mph based on site characteristics and crash history (*1*). These site characteristics include some cross-sectional widths, curvature, access density, and presence of rural residential or developed areas. Table 26 summarizes the two separate lists of site characteristics considered in the TxSZ.

The first list applies to roadway sections that have a crash rate greater than the statewide average for similar roadway types, and the second list applies to all roadway sections. These two lists overlap substantially. All site characteristics in the first list are also included in the second list and crash history appears in both lists. To incorporate this site characteristic information from Table 26, the analyst would collect the relevant data, determine if any of the specified conditions are met, and select a regulatory speed limit that is as much as 10 mph (or 12 mph, if the crash rate criterion is met) below the 85th percentile speed obtained from the speed zone study.

Table 27 provides a set of example thresholds for some of the site characteristics developed by the research team as part of TxDOT project 0-7156; however, the TxSZ allows the analyst to apply judgment to determine if any of the conditions are met instead of prescribing quantitative thresholds. The research team recommends that the analyst identify thresholds based on typical roadway conditions in the jurisdiction of interest and apply those thresholds consistently across all analyzed speed zones.

Table 26. Site Characteristics used in the TxSZ Analysis Framework (*1*).

Site Characteristic	List One: Crash Rate Above Average (lower by up to 12 mph)	List Two: Additional Roadway Factors (lower by up to 10 mph [typical] or 12 mph [high crash rate])	Notes (from List Two variable descriptions)
Narrow roadway pavement	X	X	Pavement widths ≤ 20 ft
Horizontal and vertical curves	X	X	Possible limited sight distance
Hidden driveways and other developments		X	Possible limited sight distance
High driveway density	X	X	Higher numbers of driveways have higher potential for encountering entering and turning vehicles
Lack of striped, improved shoulders	X	X	Constricted lateral movement
Crash history	X	X	
Rural residential or developed areas		X	Higher potential for pedestrian and bicycle traffic

Table 27. Example Thresholds for TxSZ Site Characteristics Developed by the Research Team for Use in Comparisons.

Site Characteristic/Factor	Example Threshold Value
Narrow roadway pavement	Average lane width < 11 ft
Horizontal curves	More than 20% of the speed zone length consists of horizontal curves with ≤ 1,500-ft radii (freeways) or ≤ 750-ft radii (urban and suburban arterials)
High driveway density	Driveway density > 25 driveways per mile (urban and suburban arterials) or > 15 driveways per mile (rural highways)
Lack of striped, improved shoulders	Average paved shoulder width < 6 ft (freeways), < 2 ft (urban and suburban arterials), < 8 ft (rural two-lane or four-lane undivided highways), or < 4 ft (rural four-lane divided highways)
Crash history	Crash rate > statewide average for similar facilities (stated in the TxSZ)

NCHRP 17-76 SLS TOOL (OR SLS TOOL-TEXAS) ANALYSIS FRAMEWORK

The NCHRP 17-76 analysis framework is based on decision rules that account for both traffic speeds and the needs of other road users based on site characteristics and the SLS groups that were defined in Table 1. The following site characteristics are considered in the NCHRP 17-76 analysis framework:

- Access data elements (see Table 6).
- VRU-related data elements (see Table 7).
- Number of lanes and other cross section data elements (see Table 8).
- Width-based cross section data elements (see Table 9).
- On-street parking data elements (see Table 10).
- Terrain data elements (see Table 11).

These tables provide the thresholds used for setting the regulatory speed limit based on the various site characteristics. Many of these site characteristics are also included in the TxSZ analysis framework, but they are considered more explicitly and in greater detail in the NCHRP 17-76 analysis framework.

The NCHRP 17-76 analysis framework is implemented using one of two versions of the NCHRP 17-76 SLS Tool spreadsheet. One version contains a single analysis worksheet for all SLS groups and uses macros to display only the data input rows that are needed for the SLS group for the roadway segment of interest. The other version contains four analysis worksheets, one for each SLS group. Figure 15 shows a screenshot of the NCHRP 17-76 SLS Tool instruction worksheet.

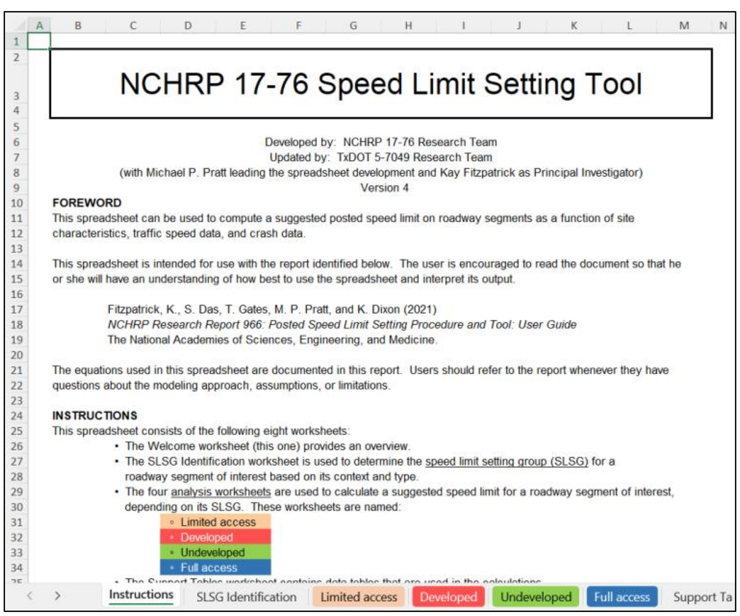


Figure 15. Screenshot of NCHRP 17-76 SLS Tool Instructions Worksheet.

Figure 16 shows the analysis worksheet for the undeveloped SLS group. The worksheet provides boxes for the various categories of key inputs—site description data, speed data, site characteristics, and crash data. The required speed data include the 85th percentile and average speeds obtained from the speed zone study and the maximum (or statutory) speed limit. The analyst enters data to describe the speed zone of interest, and the spreadsheet automates the calculations needed to apply the NCHRP 17-76 decision rules and provide a suggested regulatory speed limit. In cases where the suggested speed limit deviates from the closest 85th percentile value, the spreadsheet provides messages to indicate which variable value(s) caused the deviation.

The same procedure described above is used to apply the NCHRP 17-76 analysis framework using 85th percentile and average speed estimates that were calculated from INRIX data.

NCHRP 17-76 Speed Limit Setting Tool

Input Cells	*Description*	*Output Cells*		
Site Description Data				**Color-Coding Legend**
	Are crash data available?		O	Aqua = basic input cell
	User name			Denim = basic input cell with drop-down menu
	Date			Orange = optional input cell (not needed for calculations)
	Roadway name			Green = optional input cell (use if data for agency & region are available, leave blank otherwise)
	Description			Rose = intermediate calculations
	Current speed limit (mph)			Purple = final analysis results
	Notes			Gray = unneeded input cell based on other input data (e.g., Crash Data section is gray when B5 = no)

Analysis Results				**Advisory, Calculated, or Warning Messages**
	Speed limit setting group	Undeveloped		
	Suggested speed limit (mph)			Enter values for all variables marked with O.

Speed Data				**Advisory, Calculated, or Warning Messages**
	Maximum speed limit (mph)		O	
	85th-percentile speed (mph)		O	
	50th-percentile speed (mph)		O	

Site Characteristics				**Advisory, Calculated, or Warning Messages**
	Segment length (mi)		O	
	AADT (two-way total) (veh/d)		O	
	Number of lanes (two-way total)		O	
	Median type			
	Number of access points (total of both directions)		O	
	Lane width (ft)		O	
	Shoulder width (ft)		O	
	Adverse alignment present?			

Crash Data				**Advisory, Calculated, or Warning Messages**
	Number of years of crash data		O	
	Average AADT for crash data period (veh/d)		O	
	All (KABCO) crashes for crash data period		O	
	Fatal & injury (KABC) crashes for crash data period		O	
	Average KABCO crash rate (crashes / 100 MVMT)			
	Average KABC crash rate (crashes / 100 MVMT)			
	1.3 x average KABCO crash rate (crashes / 100 MVMT)			
	1.3 x average KABC crash rate (crashes / 100 MVMT)			
	Critical KABCO crash rate (crashes / 100 MVMT)			
	Critical KABC crash rate (crashes / 100 MVMT)			

Figure 16. Screenshot of NCHRP 17-76 SLS Tool Analysis Worksheet for Undeveloped SLS Group.

CHAPTER 7: SPEED LIMIT CASE STUDIES

This chapter describes two case studies that demonstrate the four stages of a speed zone study. More importantly, these case studies illustrate the use of probe data in a speed zone study and distinguish the suggested speed limits obtained using either the TxSZ method (along with assumptions on when a lower speed limit should be considered) or the SLS Tool-Texas.

CASE STUDY 1: RURAL ARTERIAL NEAR SMALL TOWN

Stage 1–Identify Study Area

Figure 17 provides an aerial view of FM 407 just west of Justin, Texas, which was selected for Case Study 1. Speed data were collected at site-02 denoted in this figure. The road has 2 lanes and is in the rural area west of the city. The current speed limit for this roadway section is 55 mph. The length of the speed zone is 2.37 miles.

Figure 17. Case Study 1: Aerial View of FM 407 near Justin, Texas.

Stage 2–Gather Data Needed

Table 28 lists the site data that were collected for the speed zone study. Table 29 lists the site characteristic data needed to predict the operating speed using INRIX data.

Table 28. Case Study 1: Site Data for the Speed Zone Study.

Speed Zone Study Framework	Data Element	Value Site-02 Segment
TxSZ	Horizontal curves (percent of segment with ≤ 750-ft radii)	0
TxSZ	Lane width (ft)	11
TxSZ	Shoulder width (ft)	0
TxSZ and SLS Tool-Texas	AADT for crash data period	5,289
TxSZ and SLS Tool-Texas	Fatal and injury crashes for crash data period (2019–2022, 4 years) per study segment length	0
TxSZ and SLS Tool-Texas	Fatal and injury crashes for crash data period (2019–2022, 4 years) per mile	0
TxSZ and SLS Tool-Texas	Number of years of crash data	4
TxSZ and SLS Tool-Texas	Total crashes for crash data period (2019–2022, 4 years) per study segment length	2 × 2.78 = 5.56, rounded to 6
TxSZ and SLS Tool-Texas	Total for crash data period (2019–2022, 4 years) per mile	2
TxSZ and SLS Tool-Texas	Number of access points per mile	2
SLS Tool-Texas	Presence of adverse alignment	No
SLS Tool-Texas	Median type	None
SLS Tool-Texas	Number of lanes	2
SLS Tool-Texas	Speed study segment length	2.78

Table 29. Case Study 1: Site Data to Convert INRIX Speeds into Predicted 85th Percentile Speeds.

Data Element	Variable Name	Value for Site-02 Segment
Lane width (ft)	AvgLaneWidth	11
K_Fac (RHINO)	KFAC	9.5
Number of traffic signals	SigDen	0
Number of access points per mile	DrvUsigPerMileBoth	2
Curb or shoulder	Curb(1yes)	0 (No curb, shoulder)
AADT	AADT	5,289
Number of lanes	Lane	2
Length of INRIX segment under study (mi)	Miles(INRIXseg)	0.62150199

Stage 3–Obtain Speed Measure

On-Site Speed Measures

A speed zone study was conducted within this segment on March 31, 2023. Table 30 provides the resulting speed measures.

Table 30. Case Study 1: On-Site Speed Data.

Data Category	Data Element	Value for Site-02 Segment (mph)
Speed data	Statutory maximum speed limit	70
Speed data, eastbound toward town	85th percentile speed	63.0
Speed data, eastbound toward town	50th percentile speed	57.2
Speed data, westbound away from town	85th percentile speed	60.0
Speed data, westbound away from town	50th percentile speed	55.5

Speed Measures Using Probe Data

Step 1–Obtain the INRIX Segment IDs for the Corridor

The first step in computing a predicted speed using INRIX data was to obtain the INRIX segment IDs for the area being studied. This study corridor covers a long distance; INRIX segment IDs were required along its entire length. The researcher team identified the study corridor's starting and ending points and the speed data collection points using Google Maps. Then, the research team obtained the coordinates of the start and end points of the study corridor and saved them in a CSV file. Next, the research team plotted the start and end points of the study corridor and the data collection points on the GIS/QGIS map, then overlayed the INRIX segment shapefile (Figure 18).

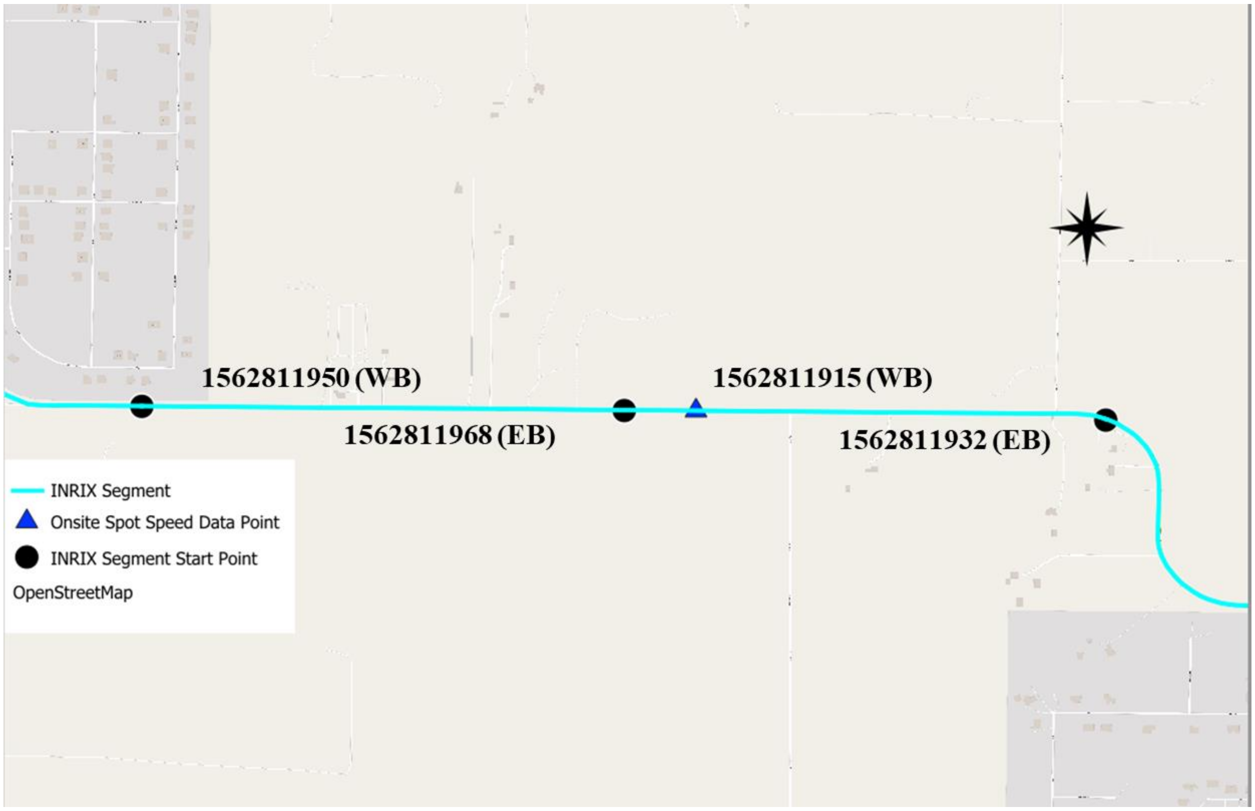


Figure 18. Case Study 1: Speed Zone Study Data Collection Points and INRIX Segment Start/End Points.

After locating the INRIX segments within the study corridor, the research team used the *identify* feature to select all segments within the corridor. For this case study example, this process resulted in the selection of two INRIX segments (Figure 19). To obtain the INRIX segment IDs, the research team clicked on the small triangle to the left of the RoadName items in the right-hand window. The associated segment turned red to indicate that it has been selected. For example, the INRIX segment IDs corresponding to the segments to the right of Site-02 were 1562811915 for westbound and 1562811932 for eastbound, and the INRIX segment IDs corresponding to the segments to the left of Site-02 were 1562811950 for westbound and 1562811968 for eastbound. The research team copied and saved these IDs in the Excel spreadsheet for further processing.

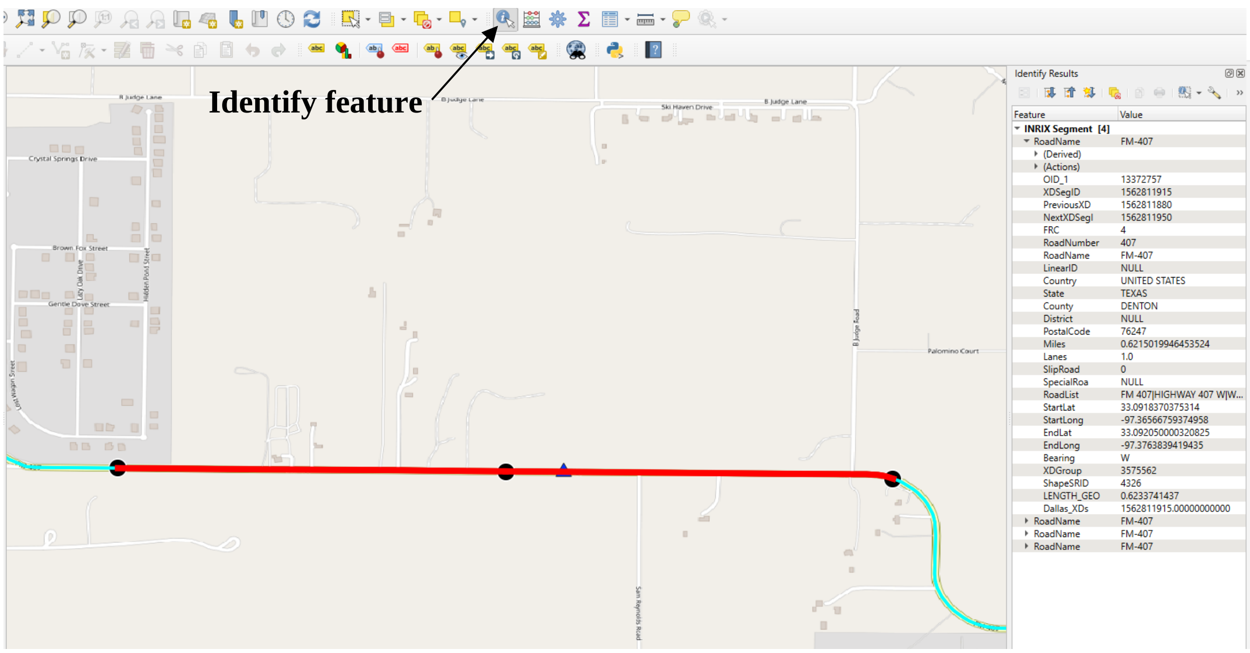


Figure 19. Case Study 1: Location of INRIX Segments.

Step 2–Download the INRIX Speed Data

The second step in computing a predicted speed using INRIX data was to download the speed data associated with the INRIX segment ID. This step involved logging in to the Probe Data Analytics Suite and specifying the segment ID and time. For this case study, the 2021 data were of interest. In the Probe Data Analytics Suite, the research team selected *XD* under 2. Select segment type, then selected *segment codes* under 3. Select roads, and then typed or copy-pasted INRIX segment ID 1562811932 into the *segment codes* field. The segment was then selected and highlighted (Figure 20). Next, the research team clicked *add segments* to add the segments to the system. The added segment(s) appeared below the white window under 3. Select roads. The research team then specified the dates of the data collection (i.e., January 1 to December 31, 2023; the speed zone study at this location was performed in 2023) under 4. Select one or more date ranges. The research team left sections 7 through 9 of the Probe Data Analytics Suite at their default settings. In 10. Select averaging, the research team specified 5 minutes as the averaging time; the research team could have also chosen the default setting of *don't average*. Under 11. Provide title, the research team provided a file name (e.g., 1562811932_EB). Next, the research team clicked *submit* and waited for the system to download the data. To obtain INRIX speed data for 1562811915, the research team first removed all segments loaded in 3. Select roads by clicking the *remove all* button, then reloaded the new segments by typing or copy-pasting 1562811915 in the white window under 3. Select roads then clicking *add segments*. The research team repeated Step 2–Download the INRIX Speed Data for all remaining segments.

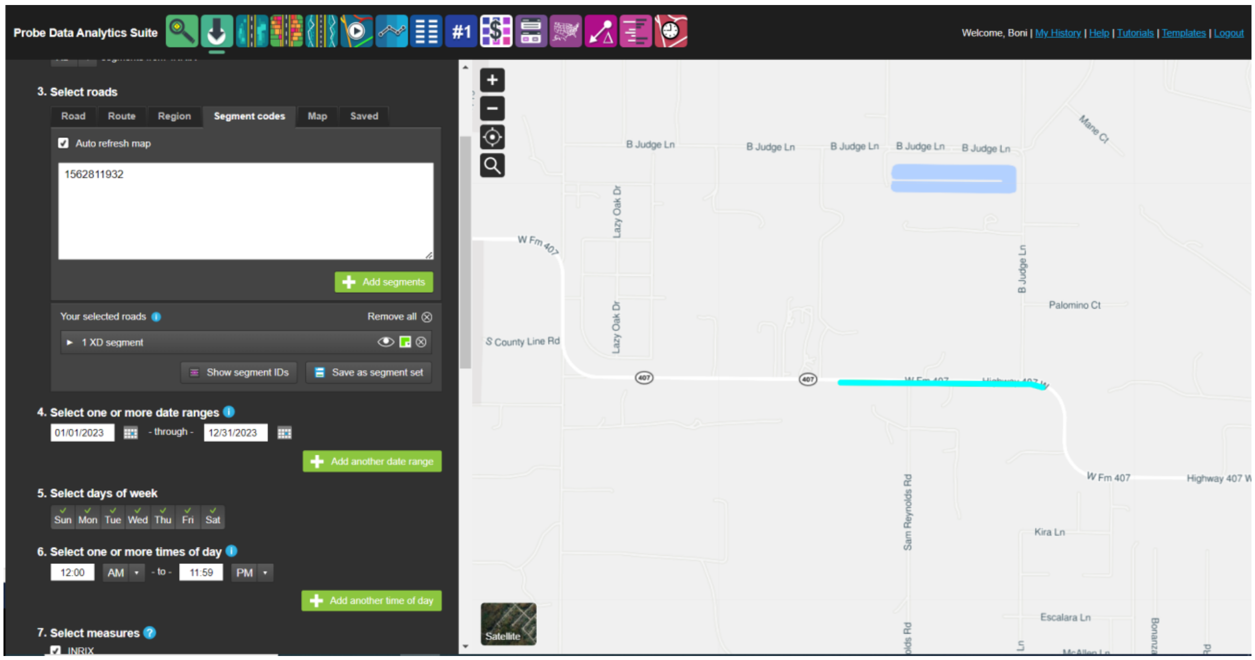
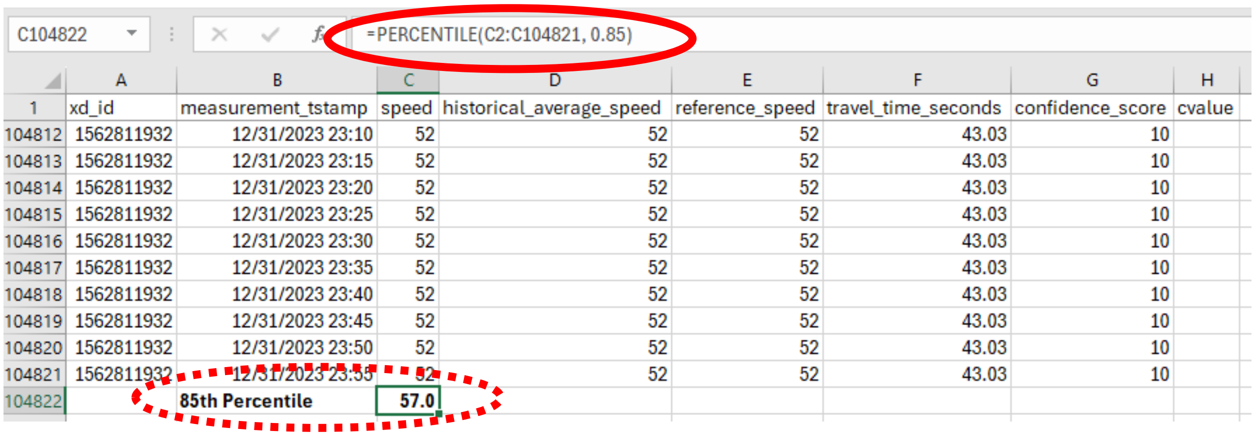


Figure 20. Case Study 1: Code for INRIX Segment ID 1562811932.

Step 3–Computation of the INRIX 85th Percentile Speed

After downloading the data, the next step was to compute the 85th percentile speed using the Excel *percentile* function. Figure 21 shows the spreadsheet computation of 85th percentile speed for the eastbound segment ID 1562811932 from yearly INRIX speed data. The solid oval highlights the equation used to calculate the 85th percentile speed and dashed oval highlights the resulting speed measure. To compute the 85th percentile, the research team clicked on an empty cell, then typed an equal sign followed by the word *percentile* and brackets. Within the bracket, the research team specified the range of data, which was the entire column with the speed data for a given INRIX segment, and specified the desired percentile (0.85). In this case study, the speed data were in column C, from row 2 to 104,815 for segment ID 1562811932 and from row 2 to 104,818 for segment ID 1562811915. The corresponding equations were = PERCENTILE (C2: 104815, 0.85) for segment ID 1562811932 and = PERCENTILE (C2: 104818, 0.85) for segment ID 1562811915.



C104822 =PERCENTILE(C2:C104821, 0.85)

	A	B	C	D	E	F	G	H
1	xd_id	measurement_tstamp	speed	historical_average_speed	reference_speed	travel_time_seconds	confidence_score	cvalue
104812	1562811932	12/31/2023 23:10	52	52	52	43.03	10	
104813	1562811932	12/31/2023 23:15	52	52	52	43.03	10	
104814	1562811932	12/31/2023 23:20	52	52	52	43.03	10	
104815	1562811932	12/31/2023 23:25	52	52	52	43.03	10	
104816	1562811932	12/31/2023 23:30	52	52	52	43.03	10	
104817	1562811932	12/31/2023 23:35	52	52	52	43.03	10	
104818	1562811932	12/31/2023 23:40	52	52	52	43.03	10	
104819	1562811932	12/31/2023 23:45	52	52	52	43.03	10	
104820	1562811932	12/31/2023 23:50	52	52	52	43.03	10	
104821	1562811932	12/31/2023 23:55	52	52	52	43.03	10	
104822		85th Percentile	57.0					

Figure 21. Case Study 1: Spreadsheet Computation of 85th Percentile Speed for the Eastbound Segment ID 1562811932 from Yearly INRIX Speed Data.

In this case study, the Spd85_AllHrAllDay_INRIX-YrData for this segment was 57.0 mph for segment ID 1562811932 and 55.4 for segment ID 1562811915. The research team repeated this procedure for the remaining segments. Table 31 shows the final computations of Spd85_AllHrAllDay_INRIX-YrData for each of the four INRIX segments in the case study.

Table 31. Case Study 1: 85th Percentile Speeds per Segment from Yearly INRIX Speed Data.

Bearing	Segment ID	TxDOT Data Point	Segment Length	Spd85_AllHrAllDay_ INRIX-YrData
Eastbound	1562811968	Left of Site_02	0.6215017	58.7
Eastbound	1562811932	Site_02	0.6215020	57.0
Westbound	1562811915	Site_02	0.6215020	55.4
Westbound	1562811950	Left of Site_02	0.6215017	57.2

Step 4–Calculate Predicted Speeds

To calculate the predicted speeds, the research team used Equation (6) and Equation (7) presented in Chapter 4 under Rural Non-freeway Equation to Predict 85th Percentile Speed and Rural Non-freeway Equation to Predict Average Speed, respectively. The rural non-freeway 85th percentile speed equation incorporating the site characteristics for INRIX segment 1562811932 was formulated as follows:

$$Spd85(NonFreewayRuralPredicted) = 9.6910 + 1.0213 \times [Spd85(YrDataINRIX) = 57.0] - 2.4241 \times [SigDen = 0] - 0.1920 \times [DrvUsigPerMileBoth = 2] + 0.000101 \times \left[\frac{AADT}{Lane} = \frac{5289}{2}\right] - 0.3492 \times [AvgLaneWidth = 11] - 0.6686 \times [Curb(1yes) = 0] - 0.4915 \times [Miles(INRIXseg) = 0.6215020] - 0.0762 \times [KFAC = 9.5] + 1.4641 \times [R3 = 0] + 1.1702 \times [R4 = 0] - 0.5285 \times [R5 = 1] - 0.8189 \times [R6 = 0] - 1.2869 \times [R7 = 0] \quad \text{Equation (10)}$$

After substituting the values for each site characteristic for INRIX segment 1562811932, the following equation resulted:

$$\begin{aligned} &Spd85(NonFreewayRuralPredicted) \\ &\quad = 9.6910 + 1.0213 \times 57.0 - 2.4241 \times 0 - 0.1920 \times 2 \\ &\quad + 0.000101 \times \frac{5289}{2} - 0.3492 \times 11.0 - 0.6686 \times 0 \\ &\quad - 0.4915 \times 0.6215020 - 0.0762 \times 9.5 + 1.4641 \times 0 \\ &\quad + 1.1702 \times 0 - 0.5285 \times 1 - 0.8189 \times 0 \\ &\quad - 1.2869 \times 0 = 62.05 \end{aligned} \qquad \text{Equation (11)}$$

The research team performed these computations for the predicted 85th percentile and average speeds for each of the four INRIX segments. Table 32 lists the Pred-Spd85th and Pred-SpdAve values for the four INRIX segments.

Table 32. Case Study 1: Pred-Spd85 and Pred-SpdAve per INRIX Segment.

Bearing	Segment ID	TxDOT Data Point	Spd85_AllHrAllDay _INRIX-YrData (mph)	Pred-Spd85 (mph)	Pred-SpdAve (mph)
Eastbound	1562811968	Left of Site_02	58.7	64.09	60.88
Eastbound	1562811932	Site_02	57.0	62.05	59.18
Westbound	1562811915	Site_02	55.4	60.77	57.71
Westbound	1562811950	Left of Site_02	57.2	62.58	59.44

Stage 4–Investigate/Identify Suggested Speed Limit

TxSZ Method

For the TxSZ method, the site characteristic data are listed in Table 28, the on-site speed measures are listed in Table 30, and the predicted speed measures are listed in Table 32. The threshold values shown in Table 27 were considered when deciding whether the suggested speed limit should round the 85th percentile speed to the nearest 5-mph increment or should reduce the 85th percentile speed by up to 10 mph due to a concern with one of the site characteristic factors or up to 12 mph due to a concern with crashes. For the two speed study sites being considered in Case Study 1, the 11-ft lane width did not trigger a suggested speed reduction. Having only 2 access points per mile also did not trigger a suggested speed reduction. None of the segments had horizontal curves with radii < 750 ft; therefore, this factor also did not trigger a suggested speed reduction. However, the lack of shoulders did trigger a suggested speed limit reduction. The TxDOT RHINO database indicated a 0-ft shoulder width for these segments. A review of the site using Google Earth Street View showed a nominal shoulder width.

Because of the lack of shoulder, the suggestion for this Case Study 1 was to reduce the suggested speed limit by 10 mph. Note that the TxSZ does not provide specific guidance on whether the factor should trigger a reduction of 5 or 10 mph. For this case study, the research team decided to generate the upper suggested speed limit (SSL_SZMupper) and the lower suggested speed limit (SSL_SZMlower), which would reflect either a 10- or 12-mph reduction depending upon whether crashes were a concern. Table 33 lists the suggested speed limit per INRIX segment using either the on-site speed data or the predicted speed measures. When using the on-site speed data, the suggested speed limit after reducing due to the lack of shoulders is 55 mph for the eastbound and 50 mph for the westbound direction. The suggested speed limits using the predicted speed resulted in either 50 or 55 mph depending on the INRIX segment.

Table 33. Case Study 1: Suggested Speed Limit per INRIX Segment Using the TxSZ Method.

Bearing	INRIX Segment ID	Spd85_On-Site-R	SSL_SZMlower_Spd85_Onsite	SSL_SZMupper_Spd85_Onsite	Spd85_AllHrAllDay_INRIX-YrData	Pred-Spd85	SSL_SZMlower_Pred-Spd85	SSL_SZMupper_Pred-Spd85
Eastbound	1562811968	63.00	55	65	58.7	64.09	55	65
Eastbound	1562811932	63.00	55	65	57.0	62.05	50	60
Westbound	1562811915	60.00	50	60	55.4	60.77	50	60
Westbound	1562811880	60.00	50	60	57.2	62.58	55	65

SLS Tool-Texas

The SLS Tool-Texas was also used to determine the suggested speed limit for site-02 (Table 34) and each of the four INRIX segments (Table 35). Using the SLS Tool-Texas, the suggested speed limit for the eastbound direction was 55 mph when using on-site speed data (see final column, SSL_SLS Tool-Texas_Spd85_Onsite, in Table 34) and 60 mph when using predicted speed measures (see final column, SSL_SLS Tool-Texas_Spd85_Onsite, in Table 35). Figure 22 shows a screenshot of the SLS Tool-Texas page when using the on-site speed data while Figure 23 shows a screenshot of the SLS Tool-Texas page when using the predicted speed.

Table 34. Case Study 1: Suggested Speed Limits for Site-02 Using the SLS Tool-Texas.

Bearing	Study Site	Spd85_Onsite-R	SpdAve_Onsite-R	SSL_SLS Tool-Texas_Spd85_Onsite
Eastbound	Site-02	63.00	57.21	55
Westbound	Site-02	60.00	55.50	55

Table 35. Case Study 1: Suggested Speed Limit per INRIX Segment Using the SLS Tool-Texas.

Bearing	Segment ID	Spd85_AllHrAllDay_INRIX-YrData	Pred-Spd85	Pred-SpdAve	SSL_SLS Tool-Texas_Pred-Spd85
Eastbound	1562811968	58.66	64.09	60.88	60
Eastbound	1562811932	57.00	62.05	59.18	60
Westbound	1562811915	55.40	60.77	57.71	60
Westbound	1562811880	57.18	62.58	59.44	60

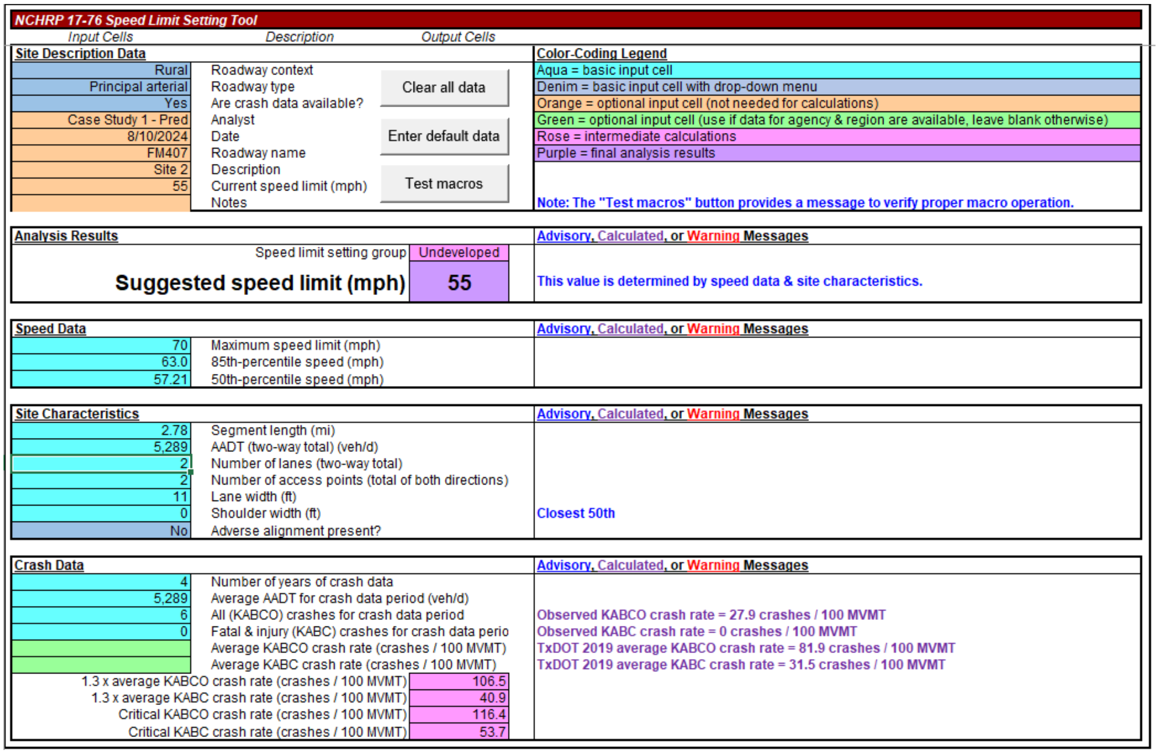


Figure 22. Case Study 1: SLS Tool-Texas Using On-Site Speed Data.

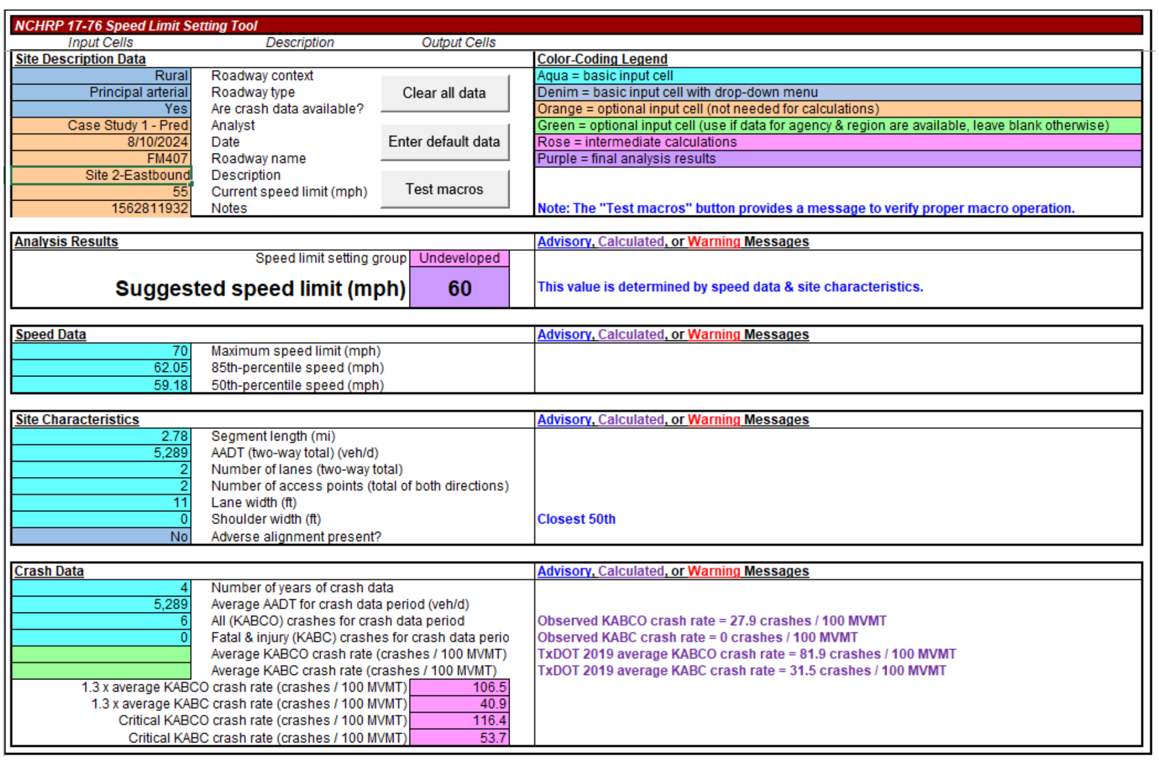


Figure 23. Case Study 1: SLS Tool-Texas Using Predicted Speed Data for INRIX Segment 1562811932.

CASE STUDY 2: FREEWAY IN WEST TEXAS

Stage 1–Identify Study Area

For the freeway corridor case study, an existing speed zone study was not available. Therefore, for Case Study 2, the research team used speed data from an ATR station located on TX-191 E in Odessa, Texas. The speed zone segment length was assumed to be 0.5 miles on either side of the ATR station for a total length of 1 mile. The freeway in this section has 2 lanes in each direction divided by a wide grass median. Per the TxDOT RHINO database, this section is in an urban environment. Figure 24 provides an aerial view of TX-191 E in Odessa, Texas.

Figure 24. Case Study 2: Aerial View of TX-191 E in Odessa, Texas.

Stage 2–Gather Data Needed

Table 36 lists the site data collected for the speed zone study. The current speed limit for this segment is 75 mph.

Table 36. Case Study 2: Site Data for the Speed Zone Study and to Convert INRIX Speeds into Predicted 85th Percentile Speeds.

Data Element	Value (Both Directions)
Speed zone length used for case study (mi)	1.00
Number of lanes per direction	2
Median type	Grass
Number of interchanges per mile	0.5
Design speed (mph)	75
Trk_AADT_P_Rhino (%)	7.2
Directional design-hour truck volume (trk/hr)	2247
Lane width (ft)	12.0
Outside shoulder width (ft)	10.0
Inside shoulder width (ft)	6.0
Presence of adverse alignment	No
Number of years of crash data	4 (2019–2022)
AADT for crash data period	31,205 (2020)
Length of segment under study (mi)	1.0
Total crashes for crash data period	5
Fatal and injury crashes for crash data period	2

Stage 3–Obtain Speed Measure

On-Site Speed Measures

The research team obtained speed data from ATRs for every hour of the day for the 2nd Wednesday of each month from 2019. The data were extensively filtered to identify the 85th percentile and average speeds that represented free-flow conditions; details are provided in (*18*). One of the steps was to remove a site period when on-site volumes were greater than 1,000 vehicles per lane per hour. The *Highway Capacity Manual* (HCM) identifies volumes less than 1,000 passenger cars per hour per lane as being representative of free-flow conditions for freeways and uninterrupted-flow multilane highways (*17*, Chapter 12, pages 12–27).

The speed data measures provided in Table 37 represented 63 hours of data for the eastbound vehicles and 58 hours of data for westbound vehicles. The standard deviation for those hours of data was about 1.0 mph, indicating that if 1 hour of data were used rather than the average of multiple hours of data, the speed measure would only change by about 1 mph.

Table 37. Case Study 2: On-Site Speed Data.

Data Category	Data Element	Value (mph)
Speed data	Statutory maximum speed limit	75
Speed data, eastbound (or northbound) toward Midland	85th percentile speed	80.5
Speed data, eastbound (or northbound) toward Midland	50th percentile speed	74.7
Speed data, westbound (or southbound) toward Odessa	85th percentile speed	82.5
Speed data, westbound (or southbound) toward Odessa	50th percentile speed	75.7

Note: Speed data represent the following conditions: daytime, on-site volume < 1,000 vehicles per lane per hour; temperature > 32°; and precipitation is < 0 inches.

Speed Measures Using Probe Data

This example illustrates the steps followed to obtain the 85th percentile speed for the Spd85(YrDataINRIX) variable.

Step 1–Obtain the INRIX Segment ID of the Corridor

The first step in computing the speed value was obtaining the corridor's INRIX segment IDs. For this case study, we considered the speed zone study of interest to be along TX-191 E in Odessa, Texas, between Mission Boulevard and San Antonio Street (Figure 25). Table 38 lists the latitude and longitude coordinates for the ATR station.

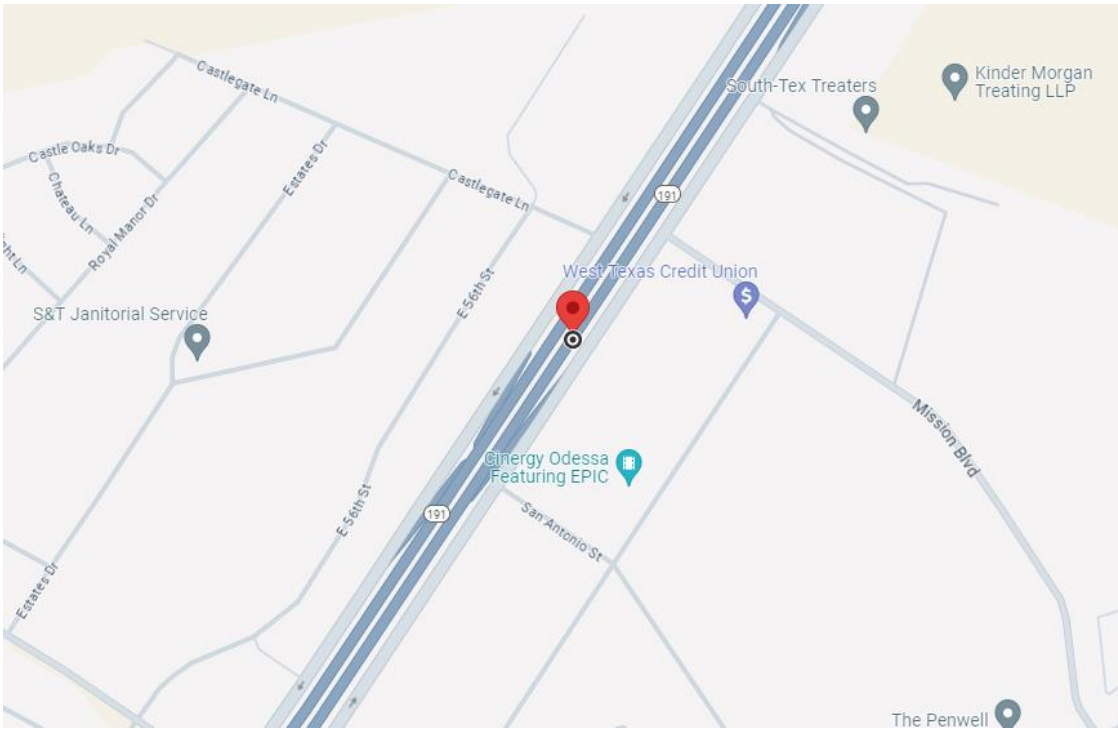


Figure 25. Case Study 2: ATR Location.

Table 38. Case Study 2: Latitude and Longitude for ATR and INRIX Segments.

Variable	Eastbound Segment	Westbound Segment
StreetName_Loc	TX-191 E	TX-191 W
XDSegID_INRIX(Seg)	1595219599	441594005
Bearing_INRIX(Seg)	Eastbound	Westbound
Latitude_ATR	31.92718	31.92718
Longitude_ATR	–102.286	–102.286
StartLat_INRIX(Seg)	31.92418	31.92914
StartLong_INRIX(Seg)	–102.288	–102.285
EndLat_INRIX(Seg)	31.92905	31.92523
EndLong_INRIX(Seg)	–102.284	–102.288

To identify the INRIX segment IDs associated with the case study site, the research team followed This section describes how the INRIX data can be used to generate spot speeds for consideration in a speed zone study.

Step 1–Obtain INRIX Segment IDs for the Corridors of Interest, which included plotting the point on the GIS/QGIS map, creating a buffer, and extracting the segment of interest. Alternatively, because the study area includes only one segment, the research team may have opted to plot it in the GIS/QGIS map, overlay the INRIX segment shapefile, click on the identify feature and the INRIX segment that corresponds to the point of interest, and either copy the segment ID from the window that appears at the right-hand side of the screen (see Figure 26) or save the selected INRIX segment to a CSV file. In this case study, the INRIX segment IDs were 1595219599 and 441594005 for the eastbound and westbound directions, respectively.

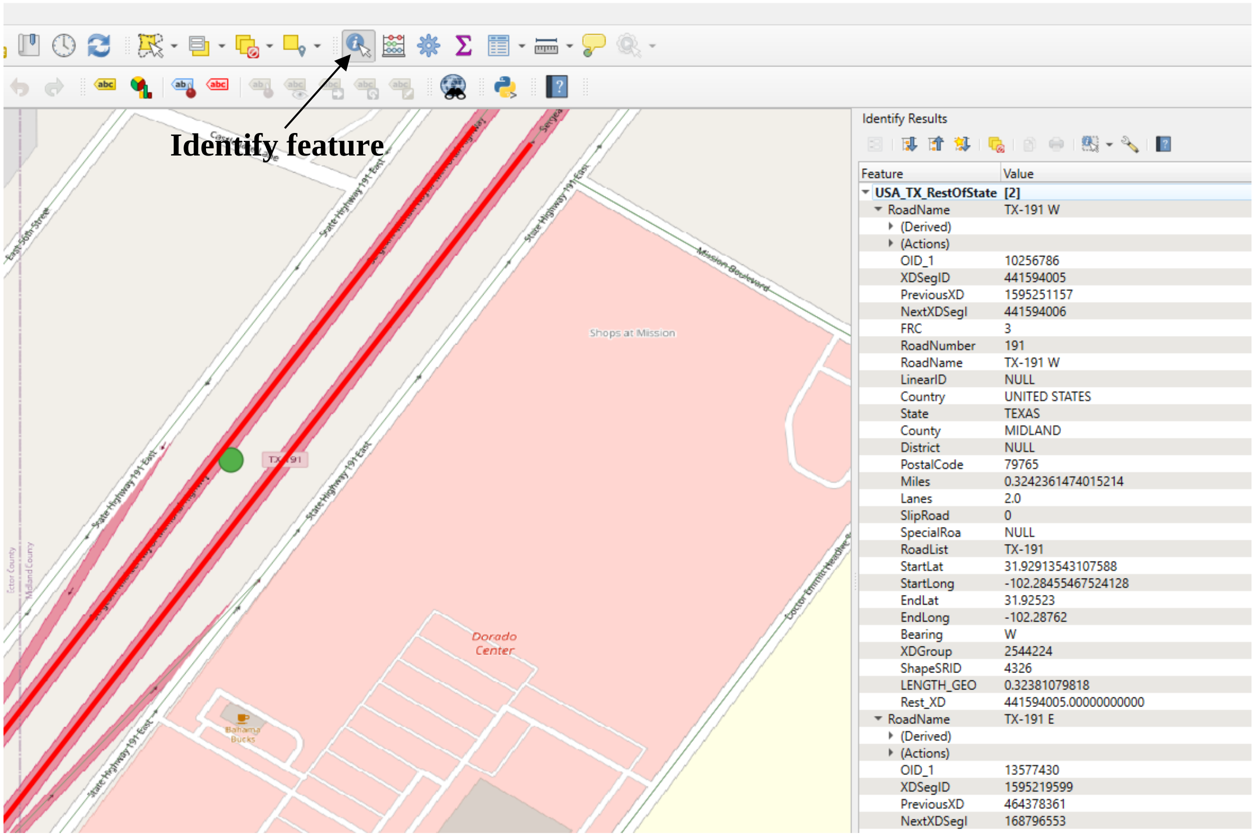


Figure 26. Case Study 2: Location of INRIX Segments.

Step 2–Download the INRIX Speed Data

The second step was to download the speed data associated with the INRIX segment IDs. This step involved logging in to the Probe Data Analytics Suite and specifying the segment ID and time. For this case study, the 2021 data were of interest. In the Probe Data Analytics Suite, the research team selected *XD* under 2. Select segment type, then *segment codes* under 3. Select roads, and then either typed or copy-pasted the INRIX segment ID 1595219599 in the field for *segment codes*. Next, the research team clicked *add segments* under 3. Select roads. The segment was selected and highlighted (Figure 27). Next, the research team specified the dates of data collection (i.e., January 1 to December 31, 2021) under 4. Select one or more date ranges. Sections 7 through 9 of the Probe Data Analytics Suite were left at their default settings. In 10. Select averaging, the research team specified 5 minutes as the averaging time; the research team may have also chosen to use the default setting of *don't average*. Under 11. Provide title, the research team provided a file name (e.g., Odessa_TX191_EB). The research team then clicked *submit* and waited for the system to download the data for the eastbound direction. To download data for the westbound direction, the research team first removed the segment ID 1595219599 from 3. Select roads by clicking *remove all*, then reassigned segment ID 441594005 using the same procedure followed for the eastbound direction.

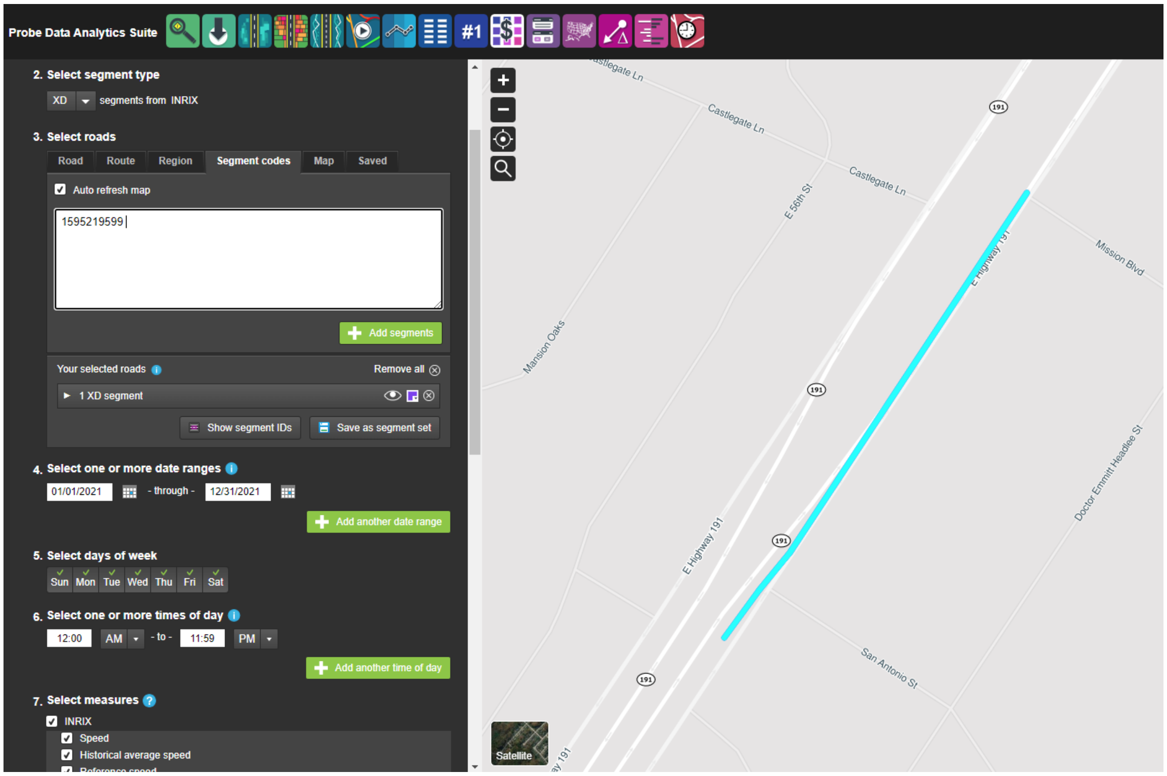
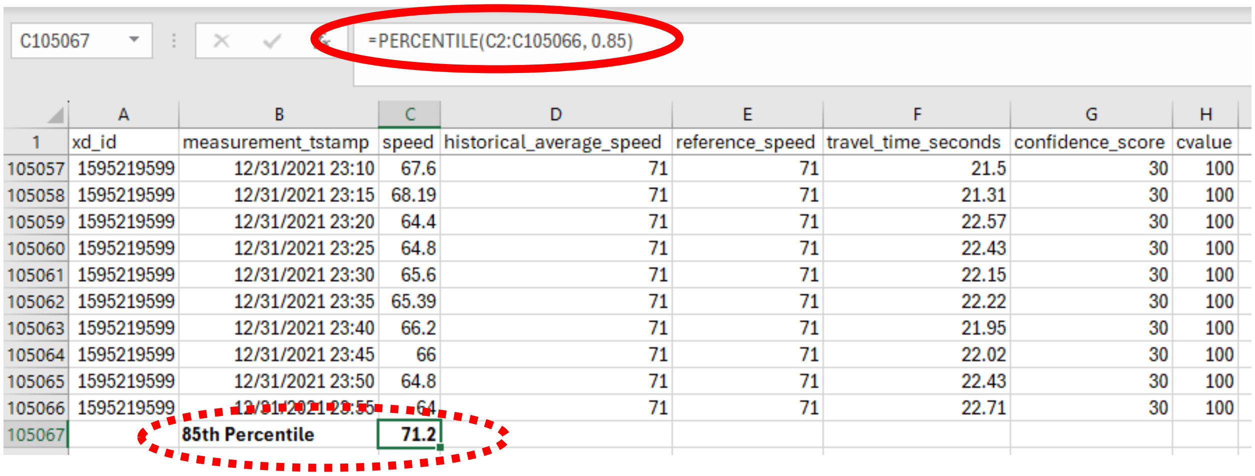


Figure 27. Case Study 2: Code for INRIX Segment ID 1595219599.

Step 3–Computation of the INRIX 85th Percentile Speed

After downloading the data, the next step was to compute the 85th percentile speed using the Excel *percentile* function. To compute the 85th percentile, the research team clicked on an empty cell, then typed an equal sign followed by the word *percentile* and brackets. Within the bracket, the research team specified the range of data, which was the entire column with the speed data for a given INRIX segment, and specified the desired percentile (0.85). For the eastbound direction, the speed data are in column C, from row 2 to 105,066 (Figure 28). The equation for the 85th percentile speed in the eastbound direction was =PERCENTILE(C2:C105066, 0.85).



C105067 =PERCENTILE(C2:C105066, 0.85)

	A	B	C	D	E	F	G	H
1	xd_id	measurement_tstamp	speed	historical_average_speed	reference_speed	travel_time_seconds	confidence_score	cvalue
105057	1595219599	12/31/2021 23:10	67.6	71	71	21.5	30	100
105058	1595219599	12/31/2021 23:15	68.19	71	71	21.31	30	100
105059	1595219599	12/31/2021 23:20	64.4	71	71	22.57	30	100
105060	1595219599	12/31/2021 23:25	64.8	71	71	22.43	30	100
105061	1595219599	12/31/2021 23:30	65.6	71	71	22.15	30	100
105062	1595219599	12/31/2021 23:35	65.39	71	71	22.22	30	100
105063	1595219599	12/31/2021 23:40	66.2	71	71	21.95	30	100
105064	1595219599	12/31/2021 23:45	66	71	71	22.02	30	100
105065	1595219599	12/31/2021 23:50	64.8	71	71	22.43	30	100
105066	1595219599	12/31/2021 23:55	64	71	71	22.71	30	100
105067		85th Percentile	71.2					

Figure 28. Case Study 2: Spreadsheet Computation of 85th Percentile Speed for the Eastbound Segment ID 1595219599 from Yearly INRIX Speed Data.

In this case study, the 85th percentile speed was 71.2 mph for the eastbound INRIX segment and 73.4 mph for the westbound INRIX segment. However, depending on how the analyst sets up the parameters when downloading the data, the 85th percentile speed may vary slightly. For example, when the research team did not specify the time interval in which the speed data was to be averaged (see 10. Select averaging in Figure 29) before downloading, the resulting 85th percentile speed for the eastbound direction was 71.0 mph. Averaging the speed in a given time interval resulted in fewer observations but slightly different 85th percentile speed values. Thus, the averaging approach may be appropriate when an analyst has many study locations.

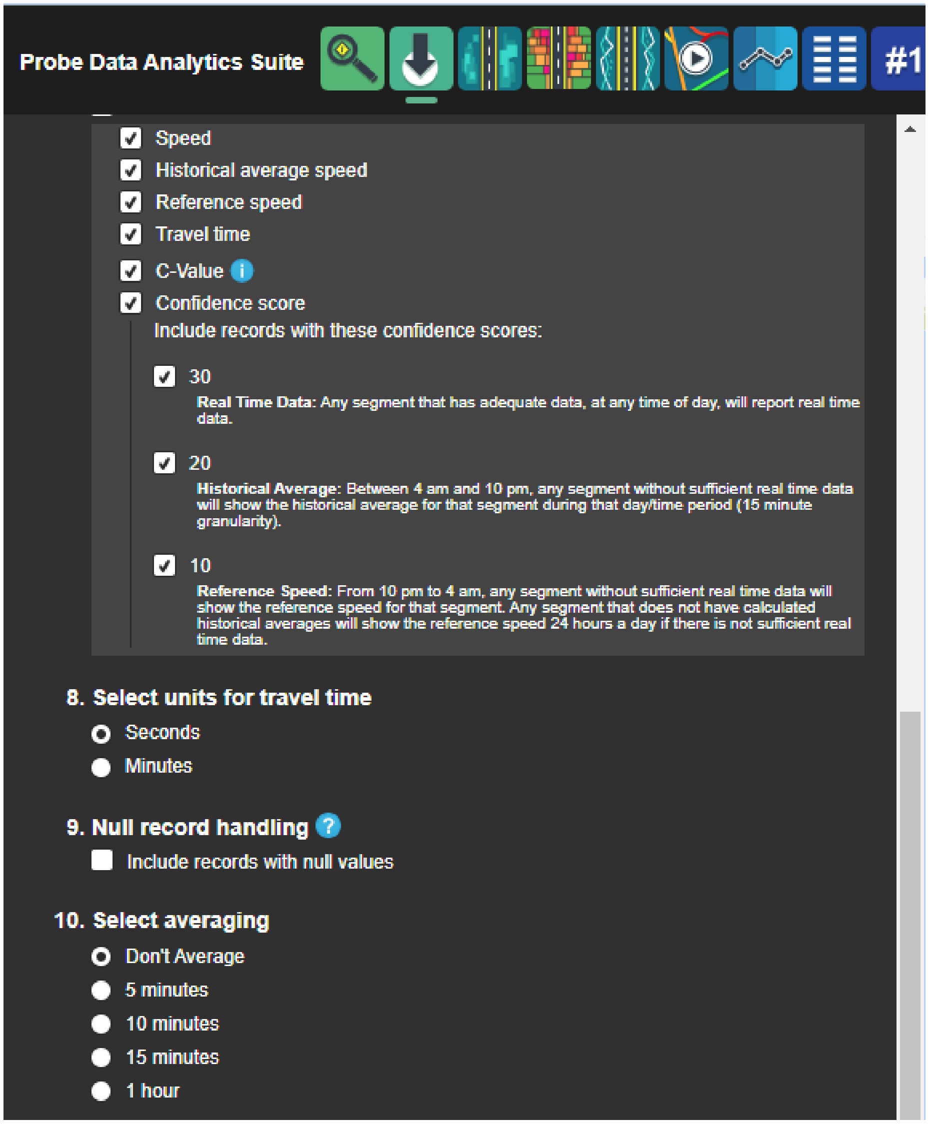


Figure 29. Case Study 2: Screenshot of Select Averaging Options.

Step 4–Calculate Predicted Speeds

To calculate the predicted speed, the research team used Equation (4) and Equation (5) presented in Chapter 4 under Urban Freeway Equation to Predict 85th Percentile Speed and Urban Freeway Equation to Predict Average Speed, respectively. The urban freeway 85th percentile speed equation incorporating the site characteristics for INRIX segment 1595219599 was formulated as follows:

$$Spd85(FreewayUrbanPredicted) = -48.6515 + 1.8024 \text{ X } [Spd85(YrDataINRIX) = 71.2] - 0.4476 \text{ X } [RampDen = 1.5\,] \quad \text{Equation (12)}$$

The predicted 85th percentile speed for the eastbound direction (INRIX segment 1595219599) was 79.01 mph. Table 39 provides the predicted speed values for both the eastbound and westbound directions.

Table 39. Case Study 2: Pred-Spd85 and Pred-SpedAve per INRIX Segment.

Bearing	Segment ID	Spd85_AllHrAllDay_INRIX-YrData (mph)	Pred-Spd85 (mph)	Pred-SpdAve (mph)
Eastbound	1595219599	71.20	79.01	71.73
Westbound	441594005	73.40	82.97	75.58

Stage 4–Investigate/Identify Suggested Speed Limit

TxSZ Method

For the TxSZ method, the site characteristic data are listed in Table 36, the on-site speed measures are listed in Table 37, and the predicted speed measures are listed in Table 39. The threshold values shown in Table 27 were considered when deciding whether the suggested speed limit should round the 85th percentile speed to the nearest 5-mph increment or should be reduced by up to 10 mph or 12 mph due to a concern with one of the site characteristic factors.

For Case Study 2, the 12-ft lane and available shoulder widths did not trigger a suggested speed reduction. Also, none of the segments had horizontal curves with radii < 750 ft. Finally, the crashes did not exceed the TxDOT 2019 statewide averages for this type of facility.

Table 40 summarizes the suggested speed limits for each of the INRIX segments using either the on-site speed data or the predicted speed measures. Because none of the site characteristics triggered a recommended reduction in the suggested speed limit, the upper and lower bounds for this value were similar. In all cases, the suggested speed limit was 75 mph, reflecting the maximum speed limit for this type of facility.

Table 40. Case Study 2: Suggested Speed Limit per INRIX Segment Using the TxSZ Method.

Bearing	INRIX Segment ID	Spd85_Onsite-R	SSL_SZM lower_Spd85_Onsite	SSL_SZM upper_Spd85_Onsite	Spd85_AllHrAllDay_INRIX-YrData	Pred-Spd85	SSL_SZM lower_Pred-Spd85	SSL_SZM upper_Pred-Spd85
Eastbound	1595219599	80.5	75	75	71.20	79.01	75	75
Westbound	441594005	82.5	75	75	73.40	82.97	75	75

SLS Tool-Texas

The SLS Tool-Texas was also used to determine suggested speed limits for each of the INRIX segments (Table 41). Using the SLS Tool-Texas, the suggested speed limit for both directions was 75 mph when using on-site speed data (see column SSL_SLS Tool-Texas_Spd85_Onsite) and predicted speed measures (see column SSL_SLS Tool-Texas_Pred-Spd85). Figure 30 shows a screenshot of the SLS Tool-Texas page when using the eastbound on-site ATR speed data.

Table 41. Case Study 2: Suggested Speed Limit per INRIX Segment Using the SLS Tool-Texas.

Bearing	Spd85_Onsite-R	SpdAve_Onsite-R	SSL_SLS Tool-Texas_Spd85_Onsite	Segment ID	Spd85_AllHrAllDay_INRIX-YrData	Pred-Spd85	Pred-SpdAve	SSL_SLS Tool-Texas_Pred-Spd85
Eastbound	80.5	74.7	75	1595219599	71.20	79.01	71.73	75
Westbound	82.5	75.7	75	441594005	73.40	82.97	75.58	75

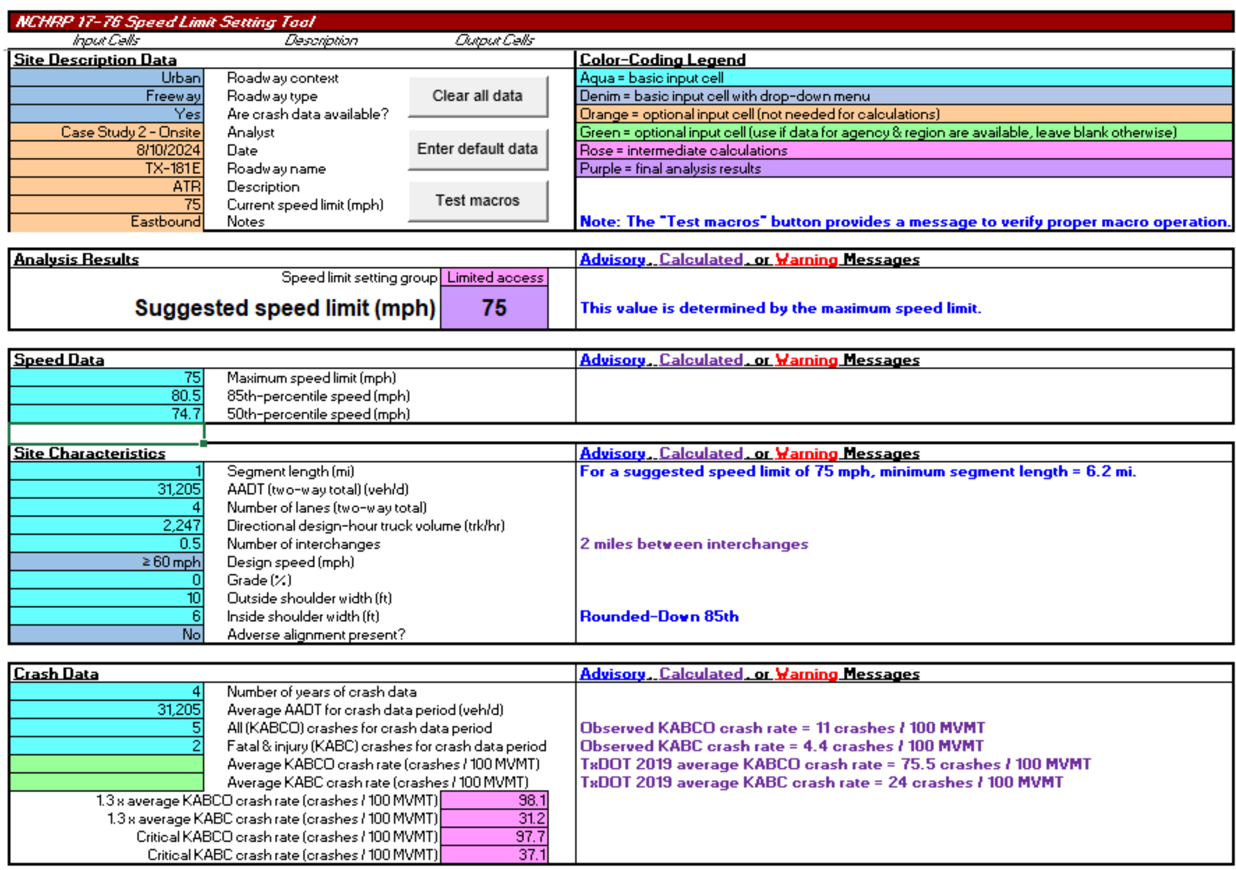


Figure 30. Case Study 2: SLS Tool-Texas Using Eastbound On-Site ATR Speed Data.

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