RESEARCH & DEVELOPMENT

# Developing Guidelines and Documentation of Engineering Studies for Establishing NC Speed Limits

**Institute for Transportation Research and Education (ITRE)**
**North Carolina State University**
**Daniel J. Findley, Ph.D., P.E.**
**Shannon Warchol**
**Thomas Chase**

**Highway Safety Research Center (HSRC)**
**University of North Carolina-Chapel Hill**
**Libby Thomas**

**NCDOT Project 2017-10**
**FHWA/NC/2017-10**
**April 2018**

## Technical Report Documentation Page

| | | |
|---|---|---|
| 1. Report No.<br>**NCDOT/NC/2017-10** | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>**Developing Guidelines and Documentation of Engineering Studies for Establishing NC Speed Limits** | | 5. Report Date<br>April 20, 2018 |
| | | 6. Performing Organization Code |
| 7. Author(s)<br>**Daniel J. Findley, Ph.D., P.E., Shannon Warchol, Thomas Chase, Libby Thomas** | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>**Institute for Transportation Research and Education**<br>**North Carolina State University**<br>**Centennial Campus Box 8601**<br>**Raleigh, NC** | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address<br>**North Carolina Department of Transportation**<br>**Research and Analysis Group**<br>**104 Fayetteville Street**<br>**Raleigh, North Carolina 27601** | | 13. Type of Report and Period Covered<br>**Final Report**<br>**August 2016 to December 2017** |
| | | 14. Sponsoring Agency Code<br>**NCDOT/NC/2017-10** |
| Supplementary Notes: | | |

16. Abstract

The objectives of the project were 1) to provide more precise guidelines to the NCDOT on how its engineers should conduct speed limit studies for various roadway settings and 2) to recommend ways by which the NCDOT can document those studies. Appropriate speed limits in turn should result in better driver compliance, easier enforcement, and fewer crashes. Conducting the right studies and being able to produce full documentation when requested should reduce liability risks as well. To be fully implemented, the research products should be integrated into the TEPPL and be circulated to the Divisions and other units that perform studies for speed limits.

| | | | |
|---|---|---|---|
| 17. Key Words<br>**Speed Limit, Study, Data, Guideline** | 18. Distribution Statement | | |
| 19. Security Classif. (of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>130 | 22. Price |

**Form DOT F 1700.7** (8-72) **Reproduction of completed page authorized**

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# ACKNOWLEDGEMENTS

The research team wishes to thank the many individuals of the North Carolina Department of Transportation who contributed to the project. The research team greatly appreciates the tremendous support and efforts received from Tony Wyatt and Jimmy Hamrick. Special appreciation is also given to Kevin Lacy, State Traffic Engineer, for his valuable support of the study.

# EXECUTIVE SUMMARY

The 2009 MUTCD[1] contains a standard on the application of a speed limit sign, stating "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 MUTCD does not provide a precise definition of an "engineering study." Further, the 2009 MUTCD[2] provides guidance that "when a speed limit within a speed zone is posted, it should be within 5 mph of the 85th-percentile speed of free-flowing traffic." FHWA subsequently offered information through a guidance memorandum clarifying that setting speed limits does not require using the 85th percentile methodology[3].

The consequences of performing a substandard engineering study, or not being able to produce documentation on the study, can be severe for transportation agencies. Liability concerns are of particular interest, which can involve concerns about whether the study that sought to set a speed limit had been performed adequately and the availability of supporting documentation. Consistently performing engineering studies to set speed limits and thoroughly documenting the results of those studies should result in better driver compliance, easier enforcement, and fewer crashes. The objectives of this project were 1) to provide more precise guidelines to the NCDOT on how its engineers should conduct speed limit studies for various roadway settings and 2) to recommend ways by which the NCDOT can document those studies.

This research project led to the development a number of related products. NCDOT can use the developed research products to provide consistency to the studies that engineers conduct to support recommended speed limits. The substantive portions of this report are included as appendices:

- Speed Limit Review Documentation Forms (Appendix A)
- Data Collection Terms (Appendix B)
- Summary of Speed-Related Research (Appendix C)
- Background and Example Forms for Roadway Speed Limit Review (Appendix D)
- State Speed Study Practices (Appendix E)

A speed limit study can be fully documented with the form provided in this research study (Appendix A). Further appendices provide supporting information and guidance for completing the form and determining an appropriate speed limit. To realize the benefits of a consistent and comprehensive system for studying speeds, a storage system must be used. Each study should be stored at the Division or Region office in a format and system that is efficient and manageable.

[1] MUTCD. Manual on Uniform Traffic Control Devices for Streets and Highway. 2009 Edition with Revision 1 and Revision 2 from May 2012. USDOT. Federal Highway Administration. Section 2B.13. Speed Limit Sign (R2-1). Paragraph 01. Page 56.
[2] MUTCD. Manual on Uniform Traffic Control Devices for Streets and Highway. 2009 Edition with Revision 1 and Revision 2 from May 2012. USDOT. Federal Highway Administration. Section 2B.13. Speed Limit Sign (R2-1). Paragraph 12. Page 58.
[3] FHWA. Bicycle and Pedestrian Funding, Design, and Environmental Review: Addressing Common Misconceptions. August 20, 2015. Item 9.

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# INTRODUCTION

The 2009 MUTCD in Section 2B.13 contains the following standard on application of the R2-1 speed limit sign:

> *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.*

The MUTCD does not provide a precise definition of an "engineering study," which is most likely beneficial because of the wide range of circumstances in which speed zones are applied. FHWA recently issued a guidance memorandum clarifying common engineering misconceptions, among them that speed limits must be set using the 85th percentile methodology. The memorandum states (FHWA 2015):

> *Speed limits must be set using the 85th percentile methodology: This is false. The MUTCD Section 2B.13 contains the following mandatory (Standard) statement: "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." According to the 2012 FHWA Document Methods and Practices for Setting Speed Limits, there are basic ways of setting speed limits. Use of the 85th percentile methodology is just one part of what FHWA calls the Engineering Approach. This is described as "A two-step process where a base speed limit is set according to the 85th percentile speed, the design speed for the road, or other criterion. This base speed limit is adjusted according to traffic and infrastructure conditions such as pedestrian use, median presence, etc." The 2012 document goes on to say that the engineering approach requires the use of judgment. This is different than simply setting a speed limit based on the measured 85th percentile.*

The objective of this project was to provide more precise guidelines to the NCDOT to allow for the more consistent application of engineering studies to set speed limits and methods to thoroughly document the results of those studies. Appropriate speed limits in turn should result in better driver compliance, easier enforcement, and fewer crashes. Conducting the right studies and being able to produce full documentation when requested should reduce liability risks as well.

Speed is one of the nine safety focus areas in North Carolina's Strategic Highway Safety Plan (SHSP, 2014). The Plan vision states:

> *Through our partnerships, we foster safety awareness and provide safe access throughout North Carolina for all users and modes of travel such that* ***everyone*** *arrives safely at their destination.*

This vision is in keeping with a Vision Zero or Toward Zero Deaths approach. If the State is to reach such a vision, effective procedures for setting speed limits and managing speeds to appropriate levels are crucial for success. The first strategy mentioned in the SHSP to help meet speed management objectives is:

> *Set speed limits that are appropriate to the roadway type, area type, and current conditions.*

Setting appropriate limits is an important step in the process of achieving the desired safety benefits. Selecting appropriate designs and other measure to help manage speeds and establishing enforcement to support limits also contribute to the process. Although questions remain about the relationships between designs, speed limits, operating speeds, and safety, it is clear that speed limits and operating speeds have safety consequences.

# LITERATURE REVIEW

As mentioned in the introduction, the MUTCD requires an engineering study be performed to establish a speed zone or change from statutory limits; however, the requirements of such a study are not defined. As also mentioned, the FHWA recently clarified that speed limits are *not* required to be set based on 85$^{th}$ percentile or other operating speeds. TRB Special Report 254, published in 1998, reviewed practices and safety evidence for setting and enforcing speed limits on all types of roads. This report noted that the practice of setting speed limits at the 85$^{th}$ percentile or some other measure of prevailing traffic speeds relies on the assumption that most drivers are capable of judging the speed at which they can safely travel. However, as noted by the report, this assumption raises the question of why bother setting speed limits at all. The report suggests, and more recent research has documented, that drivers impose significant risks on others by their speed selection. Some drivers, such as inexperienced drivers or those unfamiliar with their surroundings or vehicles, may not be able to correctly judge risks and a safe speed to travel; and many drivers may underestimate the risks of speed on crash probability and severity at least under certain conditions such as adverse weather, unusual or sub-optimal roadway alignment, nighttime, and congestion. These issues suggest a clear need for establishing speed limits, but the best means of doing so to achieve safety and mobility objectives remain elusive. Recent research has identified many situations for which the use of 85$^{th}$ percentile as the primary factor in setting speed limits leads to unsafe situations. This literature includes situations such as congested freeway conditions, effects of design and design exceptions, curve geometries and spacing, and other situations that might be considered in setting limits.

In the study of Speed and Safety in North Carolina, conducted for NCDOT between 2010 and 2013, NCDOT and other practitioners documented problems with inconsistencies between speed limits, road designs, and operating speeds on some roads across the State (Thomas et al., 2013). Of course, not all of these inconsistencies can be addressed through speed zoning, and there is still a need for more information on how various factors influence operating speeds and safety. Another issue is how to determine when a speed limit review is needed. Currently, practitioners often conduct such a review in the wake of a serious crash. Recommendations from the *Speed and Safety in North Carolina* report also suggested more proactive and systematic mechanisms for when a speed limit review or study should be conducted. Potential triggers for speed limit review include crash-based screening approaches (but not focusing on a single crash or fatality, although a review may be warranted in some such cases), extensive changes in land use, traffic volume, or significant change in the function of the road for other reasons (such as a new or altered route that takes over some functions of the road in question).

The same report and Jurisdiction Speed Management Action Plan Development Package recently developed for FHWA also suggested that speed limits should not be considered in isolation but rather in the context of safety goals and in consultation with safety partners such as enforcement, since limits that are not enforced lack credibility. The results of a speed limit review also can result in various outcomes: no action, raise the limit, or lower the limit. In addition to these decisions, changes to the road and/or to enforcement should be considered simultaneously if the goal of zero deaths is to be achieved. In Vision Zero countries, an injury minimization approach has been used which takes into account the land uses and purposes of the road or street as well as the conflicts and crash types that are possible in the context of the road design. The aim is to minimize the chances of severe injury or fatality, when crashes occur.

NCHRP 367 developed an expert system tool (US Limits 2) to provide recommendations on speed limits (for most road types, but with exclusions such as school zones) based on the factors identified as important by the expert panelists. *Speed Management*, a guide developed by the World Health Organization, with input from U.S. experts, advises that in a Safe System approach (or Injury Minimization approach as outlined by *Methods and Practices for Setting Speed Limits)* speed limits will be set in recognition of the potential for serious injuries and fatalities. On many types of rural roads for example, such an approach will lead to speed limits that are unlikely to exceed 60 to 70 km/h (around 45 mph) (Global Road Safety Partnership).

The National Transportation Safety Board offered several recommendations to the Federal Highway Adminstration related to this research effort in *Reducing Speeding-Related Crashes Involving Passenger Vehicles*, including:

- Revise Section 2B.13 of the Manual on Uniform Traffic Control Devices so that the factors currently listed as optional for all engineering studies are required
- Require that an expert system such as USLIMITS2 be used as a validation tool
- Remove the guidance that speed limits in speed zones should be within 5 mph of the 85th percentile speed

Information about other states' practices regarding speed studies is included in Appendix E: State Speed Study Practices.

## Guidance on Factors to Consider

Changing the speed limit does not automatically impact operating speeds on a roadway, though there is generally a weak relationship between speed limit changes and operating speeds (FHWA 1997). The order of magnitude may vary, and may be influenced by the amount of enforcement and other road design cues, but generally, raising or lowering limits seems to yield a less than proportional increase or decrease in average operating speeds (Goodwin et al., 2015; Islam, El-Basyouny, & Ibrahim, 2013; Kloeden & Woolley 2017; Vadeby & Forsman, 2014; NCHRP Web-Only Document 90). Other factors may have a larger effect than only a change in speed limit; some of these factors are summarized in the following table (roundabouts and traffic calming measures are not included in this summary, but do have notable impacts on speeds). Further details of these factors are included in Appendix C.

| Factor | An Increase in ___ | Generally Supports | Notes |
|---|---|---|---|
| Road Classification & Area Type, Purpose of Road | Density, Urban | Lower Speeds | Review NCDOT Complete Streets Document |
| Driveways / Intersections / Offset | Access Density | Lower Speeds | 40+ per mi for significant impacts |
| Multimodal Facilities | Ped, Bike Volume | Lower Speeds | |
| Crashes | Severe Injury Speed Related Crashes | Lower Speeds | |
| Surface Treatment | -- | -- | Consider speed limit change only temporarily until resurfacing |
| Shoulders | Shoulder Width | Higher Speeds | Benefits stop at 6ft/side |
| Alignment/Curves | Grade/Tight Curves | Lower Speeds | Ball Bank for Advisory speeds |
| Operating Speed Study | $50^{th}/85^{th}$ or other observed speeds | Higher Speeds | USLIMITS2 Flow Charts by Facility Type |

# RESEARCH PRODUCTS AND RECOMMENDATIONS

This research project led to the development of a number of related products. The NCDOT State Traffic Engineer, Regional Traffic Engineers, Division Traffic Engineers, as well as multiple internal and external review rounds reviewed these products. NCDOT can use the developed research products to provide consistency to the studies that engineers conduct to support recommended speed limits. The substantive portions of this report are included as appendices (which can be used independently as needed):

- Speed Limit Review Documentation Forms (Appendix A)
- Data Collection Terms (Appendix B)
- Summary of Speed-Related Research (Appendix C)
- Background and Example Forms for Roadway Speed Limit Review (Appendix D)
- State Speed Study Practices (Appendix E)
- Smartphone Ball Bank Study Evaluation (Appendix F)

For the purpose of more accessible tools for Ball Bank studies, the research team recommends that a standard smartphone or other device be selected for development of a Ball Bank Test application for NCDOT staff to utilize to reduce cost and time to identify curves needing advisory speeds.

A speed limit study can be fully documented with the form provided in this research study (Appendix A). Further appendices provide supporting information and guidance for completing the form and determining an appropriate speed limit. To realize the benefits of a consistent and comprehensive system for studying speeds, a storage system must be used. Each study should be stored at the Division or Region office in a format and system that is efficient and manageable. Potential options for labeling each study include a code with:

1) the Division, Secondary Road (SR) number, Study number (i.e. 01-1156-01),
2) the Division, Study number (i.e. 01-0001),
3) SAP (financial enterprise application) Work Order Number, or
4) another label that will provide a unique identifier and will be easily located.

In some instances, a validation method could be useful to provide another perspective to the speed limit study conducted by the NCDOT engineer. In these cases, USLIMITS2 can be used a validation tool. USLIMITS2 is an expert system produced by FHWA and developed by a panel of experts (traffic engineers, enforcement personnel, decision makers, and researchers) which provides recommended speed limits. The tool is available at FHWA's website (https://safety.fhwa.dot.gov/uslimits/).

As stated previously, the 85$^{th}$ percentile speed has served as a key determinant for speed limits; however, its use as the primary or only basis for setting speed limits is not required and in instances may not be prudent.

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# APPENDIX A: SPEED LIMIT REVIEW DOCUMENTATION FORMS

**NCDOT Speed Limit Review Documentation Forms**

The Roadway Speed Limit Review Packet includes three documents:

1. Data Collection OFFICE Worksheet (1 page)
2. Data Collection FIELD Worksheet (2 pages)
3. Speed Limit Assessment Worksheet (2 pages)

The speed limit study should be conducted using the following steps. The completion of each item is at the discretion of the engineer.

1. Determine the segmentation of the study road
   An initial review of aerial imagery, the crash report, and the roadway cross section should be conducted to determine if the roadway should be split into two or more segments. Reasons for segmenting the roadway may include:
   - Considerable change in driveway density
   - Considerable change in crash pattern
   - Considerable change in roadway cross-section outside of an intersection influence area
   - Considerable change in land use

2. Using an aerial image tool (i.e. online mapping tool), complete the Data Collection OFFICE Worksheet. For a definition of terms, see the **User Guide for Roadway Speed Limit Review Forms** PDF. In addition to a glossary of terms, the document bookmarks important pages of select reference documents.

3. Complete the Data Collection FIELD Worksheet. For a definition of terms, see the **User Guide for Roadway Speed Limit Review Forms** PDF. In addition to a glossary of terms, the document provides bookmarks for important pages of select reference documents.

4. Complete the Speed Limit Assessment Worksheet
   The purpose of the assessment worksheet is to document the considerations made by the engineer when determining the speed limit. For each element, place an X in the appropriate column to reflect if the data collected for that element supports reducing, increasing, or maintaining the current speed limit. The **Quick Guide on Factors to Consider for Speed Studies** PDF provides a summary of research-based evidence regarding the relationship between each element and speed. If the no data were collected for the element, place an X in the "not evaluated" column.

   In the final column, an X should be placed in any row for which the engineer judges an element to be critical in the determination of the speed limit. This column assists in recording the relative differences in importance of the elements given the context of the area in which the study segment is located. The final recommended speed limit and ordinance number (if necessary) should be noted at the bottom.

5. Store the completed documentation in an organized manner, either electronic or hard copy, for easy retrieval in case of request or reference for future updates to the study.

Reset All Pages

## NCDOT Speed Limit Review - Data Collection OFFICE Worksheet

**Date:** ____________ **Reference #:** ________ **Completed By:** ________

**County:** ____________ **Municipality:** ____________ **NCDOT Route ID:** ________

**Study Road:** ____________ **Length:** _____ miles **Study Motivation:** ________

**Study Segment Begins** ________ ________ ________ of ____________
*(distance)* *(units)* *(direction)* *(reference road)*

**Study Segment Ends** ________ ________ ________ of ____________
*(distance)* *(units)* *(direction)* *(reference road)*

**Current Speed Limit:** _____ mph ☐ Statutory ☐ Ordinance # ________ **Terrain:** Select One

**Speed Limit Upstream of Starting Point:** _____ mph ☐ Statutory ☐ Ordinance # ________

**Speed Limit Downstream of Ending Point:** _____ mph ☐ Statutory ☐ Ordinance # ________

### Past Speed Studies

Date: ________ Result: ____________________

Date: ________ Result: ____________________

### Road Classification & Area Type

**Functional Class:** Select One **NCDOT Complete Street Area Type:** Select One

**AADT:** ________ vehicles per day

### Driveway/Intersection/Offset

**Number of Driveways by Type:** _____ Business _____ Residential _____ Other: ________

**Driveway Density:**
☐ Consistent throughout segment
☐ Considerable variation throughout segment

**Number of Intersections by Type:** _____ Signalized _____ Unsignalized

**Typical Building Offset to Roadway:**
☐ Consistent _____ feet (approximate)
☐ Varies from _____ to _____ feet (approximate)

### Multimodal Facilities

| | Y | N | |
|---|---|---|---|
| Are schools present along the segment? | ☐ | ☐ | Note: ________ |
| Are parks or recreation areas present along the segment? | ☐ | ☐ | Note: ________ |
| Are pedestrian facilities present along the segment? | ☐ | ☐ | Note: ________ |
| Are transit facilities designated along the segment? | ☐ | ☐ | Note: ________ |
| Are bicycle facilities designated along the segment? | ☐ | ☐ | Note: ________ |
| Is on-street parking designated? | ☐ | ☐ | Note: ________ |

### Crashes

Date: MM / DD / YY to MM / DD / YY TEAAS Mile Post: _____ to _____

Fatal: _____ A: _____ B: _____ C: _____ PDO: _____

Total Rate: _____ per 100 million VMT State-wide rate for road type: _____ per 100 million VMT

**NCDOT Speed Limit Review - Data Collection FIELD Worksheet**

**Date:** ____________ **Reference #:** ________ **Completed By:** ____________

**County:** ____________________ **Current Speed Limit:** ____ mph

**Study Road:** ______________ from ______________ to ______________

**Surface Treatment**

Typical Pavement Width: ____ feet

| | | | | |
|---|---|---|---|---|
| Pavement Type: | ☐ Asphalt | ☐ Concrete | ☐ Dirt/Gravel | ☐ Other: ________ |
| Pavement Condition: | ☐ Good/Fair | ☐ Poor | ☐ None | |
| Marking Condition: | ☐ Good/Fair | ☐ Poor | ☐ None | |
| Median Type: | ☐ None | ☐ Traversable | ☐ Non-Traversable | Width: ____ feet |

Total # of Thru Lanes: ______ Typical Lane Width: ______ feet

TWLTL Present? ☐ Yes ☐ No

**Shoulders**

Typical Shoulder Width: ____ feet paved ☐ Varies from ____ to ____ feet

____ feet unpaved ☐ Varies from ____ to ____ feet

| | | | |
|---|---|---|---|
| Shoulder Condition: | ☐ Good/Fair | ☐ Poor | |
| Recoverable Shoulder: | ☐ Yes | ☐ No | Comment: ____________ |
| Curb: | ☐ Vertical | ☐ Sloped | ☐ None |

Typical Distance to Roadside Hazards: ____ feet ☐ Varies from ____ to ____ feet

Roadsize Hazard Rating: ____

**Driving Investigation**

Conduct a driving investigation of the segment and note any areas with potentially inadequate sight distance, vertical alignment, or horizontal alignment. Include comments on locations where travel speed is constrained. Attach ball-bank study sheet if needed.

Notes: ________________________________________

________________________________________

*Check as appropriate*

| | | | | |
|---|---|---|---|---|
| Pedestrian Activity Observed/Expected: | ☐ **None** | ☐ **Low** | ☐ **Medium** | ☐ **High** |
| Bicycle Activity Observed/Expected: | ☐ **None** | ☐ **Low** | ☐ **Medium** | ☐ **High** |
| Truck Activity Observed/Expected: | ☐ **None** | ☐ **Low** | ☐ **Medium** | ☐ **High** |

**Operating Speed Study**

Result of current operating speed study (this may include the results from US Limits 2): ________

________________________________________

**Purpose of Road**

Explain the main purpose of the road. See user guide for examples. ____________

________________________________________

________________________________________

**NCDOT Speed Limit Review - Data Collection FIELD Worksheet (cont.)**

**Notes**

Use this sheet to record any additional notes about the study segment or the data collection effort. Note any warning or regulatory signs missing or in visible need of replacement or repair. An image or drawing of the site may be provided at the bottom.

**Plan-view Sketch of Road Segment** *Include major intersecting roads and label each intersection control type*

**Photographs**

Description of any photographs attached (complete as necessary)

Notes: ____________________

**Attachments** *Check as appropriate and list additional attachments*

- ☐ Strip Analysis/Crash Data
- ☐ Features Report
- ☐ Neighborhood Petition
- ☐ Photographs
- ☐ Speed Data
- ☐ Ball Bank Study Form
- ☐ ____________
- ☐ ____________
- ☐ ____________

**NCDOT Speed Limit Review - Speed Limit Assessment Worksheet**

**Date:** ____________________ **Reference #:** __________ **Completed By:** ____________________

**County:** ______________________________ **Current Speed Limit:** _____ mph

**Study Road:** ________________________ from ____________________ to ____________________

This worksheet helps to record the elements considered by the engineer when determining a speed limit. For each element, place an X in the appropriate column depending on whether the element supports increasing the speed limit, decreasing the speed limit, or maintaining the current speed limit.

In the far column, check the box if the element is critical in determining the speed limit for this road.

| Element | Not Evaluated/ Not Applicable | Supports Reducing Speed Limit | Supports No Change in Speed Limit | Supports Increasing Speed Limit | Check If Element is Critical |
|---|---|---|---|---|---|
| Road Classification & Area Type | | | | | ☐ |
| Driveways / Intersections / Offset | | | | | ☐ |
| Multimodal Facilities | | | | | ☐ |
| Crashes | | | | | ☐ |
| Surface Treatment | | | | | ☐ |
| Shoulders | | | | | ☐ |
| Driving Investigation | | | | | ☐ |
| Operating Speed Study | | | | | ☐ |
| Purpose of Road | | | | | ☐ |
| Neighborhood Petition | | | | | ☐ |
| Statutory Speed Limit | | | | | ☐ |
| Other: | | | | | ☐ |
| Other: | | | | | ☐ |
| Other: | | | | | ☐ |

**Recommended Speed Limit:** ____________ **mph**

☐ Ordinance # ____________

☐ Ordinance # ____________

☐ Ordinance # ____________

**NCDOT Speed Limit Review - Speed Limit Determination Worksheet (cont.)**

**Comments and Discussion**

Include any additional factors which influenced the recommended speed limit. This could include observed traffic conflicts, conditions not readily apparent to the driver (e.g. hidden driveways, schools, shopping centers, seasonal generators, or generators which create unique traffic conditions), or known tourist facility. It may also include consistency with other nearby similar roads.

# APPENDIX B: DATA COLLECTION TERMS

| TERM | DEFINITION |
|---|---|
| ***AADT*** | Most recent Average Annual Daily Traffic volume for the roadway |
| ***Attachments*** | |
| ***Strip Analysis/ Crash Data*** | Check box if strip analysis was conducted and included as an appendix to the data collection form |
| ***Features Report*** | Check box if a features report was conducted and included as an appendix to the data collection form |
| ***Neighborhood Petition*** | Check box if neighborhood petition was submitted and included as an appendix to the data collection form |
| ***Photographs*** | Check box if site photographs were taken and included as an appendix to the data collection form |
| ***Speed Data*** | Check box if a speed study was conducted and raw data included as an appendix to the data collection form |
| ***Ball Bank Study Form*** | Check box if ball bank study was conducted and study form included as an appendix to the data collection form |
| ***Bicycle Activity Observed/Expected*** | Note the level of bicycle activity observed relative to similar roadways in the area. For expected activity, consider any traffic generator which may have high bicycle peaking by time of day (e.g. designated bike route, university campus area, etc.) |
| ***Completed By*** | Name of person completing the worksheet |
| ***County*** | County in which roadway segment is located |
| ***Crashes*** | Using data from Strip Analysis or other crash data source, note the total number (Fatal, A, B, C, and Property Damage Only) crashes as well as the crash rate per 100 million vehicle miles traveled. Additional crash details, such as crash type, may provide useful information. Include the date range and TEAAS mile post range. The most recent state-wide total crash rate for the road type can be found on NCDOT's crash data resource page. |
| ***Curb*** | Note if a curb is vertical, sloped, or not present |
| ***Current Speed Limit*** | Current posted or statutory speed limit of the study segment. Designate if it is set by statute or ordinance. If ordinance, provide the number. |
| ***Date*** | Date the worksheet is being completed |
| ***Driveway Density*** | Indicate if the density of driveways is consistent or variable over the segment |
| ***Driving Investigation*** | Drive the segment and note any areas with potentially inadequate sight distance, vertical alignment, or horizontal alignment issues. |
| ***Functional Classification*** | Use Route ID or FHWA Highway Functional Classification Concepts, Criteria, and Procedures document to determine the functional roadway classification. Possibilities include: Interstate, Freeway/Expressway, Principal Arterial, Minor Arterial, Major Collector, Minor Collector, Local |
| ***Length*** | Length of roadway for which speed limit is being studied |
| ***Marking Condition*** | Check one or more boxes as appropriate indicating the condition of the pavement marking |
| ***Median Type*** | Check one or more boxes as appropriate |

| | |
|---|---|
| ***Median Width*** | Measured from edge of median to edge of median in a representative area away from an intersection. |
| ***Multimodal Facilities*** | |
| ***Are schools present along the segment*** | In the note, detail what level(s) of schools (e.g. middle, high, community) |
| ***Are parks or recreation areas present along the segment*** | In the note, detail type of facility (e.g. playground, garden, sports complex) |
| ***Are pedestrian facilities present along the segment*** | In the note, detail type of facility (e.g. sidewalk, bike lane, shared use path, crosswalk) |
| ***Are transit facilities designated along the segment*** | In note, detail type of facility (e.g. light rail tracks, bus stop) |
| ***Are bicycle facilities designated along the segment*** | In note, detail type of facility (e.g. shared use path, cycle track, sharrows). Make note if it is a designated bike route. |
| ***Is on-street parking designated*** | In note, detail type of parking (e.g. short term, long term, loading zone) ; additionally, areas with loading zones and/or drop-off/pick-up zones may need to be noted |
| ***Municipality*** | Municipality in which roadway segment is located; If the roadway is not within municipality limits, leave blank. This can be used for coordinating with local agencies. |
| ***Operating Speed Study*** | Detail results of operating speed study including percentile and/or distribution characteristics |
| ***NCDOT Complete Street Area Type*** | Use the NCDOT Complete Streets Planning and Design Guidelines to determine the area type found in the chapter on Understanding Context and Designing for All Users. Possibilities include: CBD, Urban Center, Urban Residential, Suburban Center, Suburban Corridor, Suburban Residential, Rural Developed, Rural Village, Countryside. |
| ***NCDOT Route ID*** | Full 10 digit route code for the study road as defined by NCDOT |
| ***Number of Driveways by Type*** | Count of all business and residential driveways within the study segment on both sides of the road |
| ***Number of Intersections by Type*** | Count of all intersections within the study segment on both sides of the road. Intersections which restrict movement (e.g. right in – right out) should be included. |
| ***Pavement Condition*** | Check one or more boxes as appropriate. This should be used to determine if pavement condition is impacting operating speeds. Pavement conditions that reduce speeds below what the typical operator would travel on adequate pavement conditions are of particular interest (e.g. overall roughness or excessive cracking/potholes). |
| ***Pavement Type*** | Check one or more boxes as appropriate |
| ***Past Speed Studies*** | Provide the date and result of past speed studies. |

| | |
|---|---|
| ***Pedestrian Activity Observed/Expected*** | Note the level of pedestrian activity observed relative to similar roadways in the area. For expected activity, consider any traffic generator which may have high pedestrian demand peaking by time of day (e.g. retail shopping area, school). See NCDOT Pedestrian Crossing Guidance for "low" threshold. |
| ***Photographs*** | Describe any photographs taken on site and attach the same to the report |
| ***Plan-view Sketch of Road Segment*** | Include any major landmarks as well as major intersecting roads. Include curves as necessary |
| ***Purpose(s) of Road*** | Explain the purpose(s) of the road (e.g. connection between interstate and town center, primary alternative to major highway, service to neighborhood subdivision, shopping district, etc) |
| ***Recoverable Shoulder*** | Note if the shoulder is recoverable |
| ***Reference #*** | For internal use only. Potential uses include:<br>• Division code – SR number – Study number (i.e. 01-1156-01)<br>• Division code – Study number (i.e. 01-0001)<br>SAP Work Order Number |
| **Roadside Hazard Rating** | Rate from 1 to 7. Definitions are provided in the US Limits 2 User Guide. |
| ***Shoulder Condition*** | Check one or more boxes as appropriate |
| ***Speed Limit Downstream of Starting Point*** | Speed limit of roadway being studied downstream of the start of the study segment. Designate if it is set by statute or ordinance. If ordinance, provide the number. |
| ***Speed Limit Upstream of Starting Point*** | Speed limit of roadway being studied upstream of the start of the study segment. Designate if it is set by statute or ordinance. If ordinance, provide the number. |
| ***Study Motivation*** | State the factor which initiated the study (e.g. citizen request, statutory review, crash history) |
| ***Study Road*** | Road for which the speed limit is being studied |
| ***Study Segment Begins*** | Starting point of the study segment, recorded as a distance and direction from a road intersecting the study roadway |
| ***Study Segment Ends*** | Ending point of the study segment, recorded as a distance and direction from a road intersecting the study roadway |
| **Terrain** | Record the terrain from the options of Flat/Level, Rolling, or Mountainous. Definitions are provided in the US Limits 2 User Guide. |
| ***Traffic Composition*** | Check one or both boxes depending on the surrounding area and likelihood for either local/commuter drivers familiar with the area and/or drivers unfamiliar with the area |
| ***Total Number of Thru Lanes*** | As counted at a representative area away from an intersection |
| ***Truck Activity Observed/Expected*** | Note the level of truck activity observed relative to similar roadways in the area. For expected activity, consider any traffic generator which may have high truck traffic peaking by time of day (e.g. designated truck route, overnight deliveries) and consider the truck percentage from traffic volume study, if available |
| ***TWLTL Present*** | Note if two way left turn lane is present along the segment |

| | |
|---|---|
| ***Typical Building Offset to Roadway*** | Typical average distance between the roadway and the face of buildings along the roadway |
| ***Typical Distance to Roadside Hazards*** | At a representative area away from an intersection, measure the lateral distance from the edge of pavement to the nearest hazard |
| ***Typical Lane Width*** | Measured along a representative continuous through lane from edge of lane line to edge of lane line |
| ***Typical Pavement Width*** | Measured from edge of pavement to edge of pavement |
| ***Typical Shoulder Width*** | At a representative area away from an intersection, measure the paved and unpaved shoulder width.  Provide additional measurement if width varies significantly over the segment. |

# APPENDIX C: SUMMARY OF SPEED-RELATED RESEARCH

This document outlines the factors identified in the speed limit review documentation form and any literature findings on how the factor may be used selecting a speed limit. These are not standards or policy on how to select a speed limit. Some of the following tables indicating speed adjustments are not recommendations for a change in posted speed but rather are to estimate a change in free flow speed compared to a standard roadway.

The following table from the FHWA Speed Management Toolkit provides an estimate of the injury crash effects (Crash Modification Factors, CMFs) for countermeasures that reduce average travel speed.

| CMFs - Injury Crashes | | | | | | |
|---|---|---|---|---|---|---|
| *Change in avg. speed (mph)* | *Baseline Average Speed 30 mph* | *Baseline Average Speed 40 mph* | *Baseline Average Speed 50 mph* | *Baseline Average Speed 60 mph* | *Baseline Average Speed 70 mph* | *Baseline Average Speed 80 mph* |
| **-5** | 0.57 | 0.66 | 0.71 | 0.75 | 0.78 | 0.81 |
| **-4** | 0.64 | 0.72 | 0.77 | 0.8 | 0.83 | 0.85 |
| **-3** | 0.73 | 0.79 | 0.83 | 0.85 | 0.87 | 0.88 |
| **-2** | 0.81 | 0.86 | 0.88 | 0.9 | 0.91 | 0.92 |
| **-1** | 0.9 | 0.93 | 0.94 | 0.95 | 0.96 | 0.96 |
| **0** | 1 | 1 | 1 | 1 | 1 | 1 |
| **1** | 1.1 | 1.07 | 1.06 | 1.05 | 1.04 | 1.04 |
| **2** | 1.2 | 1.15 | 1.12 | 1.1 | 1.09 | 1.08 |
| **3** | 1.31 | 1.22 | 1.18 | 1.15 | 1.13 | 1.12 |
| **4** | 1.43 | 1.3 | 1.24 | 1.2 | 1.18 | 1.16 |
| **5** | 1.54 | 1.38 | 1.3 | 1.26 | 1.22 | 1.2 |

The following table from the FHWA Speed Management Toolkit provides an estimate of the fatal crash effects (Crash Modification Factors, CMFs) for countermeasures that reduce average travel speed.

| CMFs - Fatal Crashes | | | | | | |
|---|---|---|---|---|---|---|
| Change in avg. speed (mph) | Baseline Average Speed 30 mph | Baseline Average Speed 40 mph | Baseline Average Speed 50 mph | Baseline Average Speed 60 mph | Baseline Average Speed 70 mph | Baseline Average Speed 80 mph |
| -5 | 0.22 | 0.36 | 0.48 | 0.58 | 0.67 | 0.75 |
| -4 | 0.36 | 0.48 | 0.58 | 0.66 | 0.73 | 0.8 |
| -3 | 0.51 | 0.61 | 0.68 | 0.74 | 0.8 | 0.85 |
| -2 | 0.66 | 0.73 | 0.79 | 0.83 | 0.86 | 0.9 |
| -1 | 0.83 | 0.86 | 0.89 | 0.91 | 0.93 | 0.95 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1.18 | 1.14 | 1.11 | 1.09 | 1.07 | 1.05 |
| 2 | 1.38 | 1.28 | 1.22 | 1.18 | 1.14 | 1.1 |
| 3 | 1.59 | 1.43 | 1.34 | 1.27 | 1.21 | 1.16 |
| 4 | 1.81 | 1.59 | 1.46 | 1.36 | 1.28 | 1.21 |
| 5 | 2.04 | 1.75 | 1.58 | 1.46 | 1.36 | 1.27 |

## Road Classification and Area Type

In North Carolina, the statutory speed for rural areas is 55 MPH and in incorporated municipalities is 35 MPH. Additionally, the *NCDOT Complete Streets Planning and Design Guidelines* identifies additional area types as well as provides basic guidance based on the characteristics of these area types and typical roadway designs and target speed limits. In general roadways in denser area types supports a lower posted speed.

## Driveways

Increased presence of driveways is correlated to lower speeds as they operate as unsignalized intersections. In the HCM 6$^{th}$ Edition, access points are considered active if it has an entering flow rate of 10 veh/h or more. In US Limits, sections with at least 60 access points per mile use the 50$^{th}$ percentile observed speed instead of 85$^{th}$ percentile. HCM Urban Streets Speed Adjustment for Access Points (Exhibit 18-11) shows how drivers' desired speed is impacted by access density on arterials:

| Access Density $D_a$ (points/mi) | Adjustment for Access Points $f_A$ by Lanes $N_{th}$ (mi/h)[c] | | |
|---|---|---|---|
| | 1 Lane | 2 Lanes | 3 Lanes |
| 0 | 0.0 | 0.0 | 0.0 |
| 2 | -0.2 | -0.1 | -0.1 |
| 4 | -0.3 | -0.2 | -0.1 |
| 10 | -0.8 | -0.4 | -0.3 |
| 20 | -1.6 | -0.8 | -0.5 |
| 40 | -3.1 | -1.6 | -1.0 |
| 60 | -4.7 | -2.3 | -1.6 |

HCM Two Lane and Multilane Highway Speed Adjustment for Access Points (Exhibit 15-8/12-24) shows how drivers' desired speed is impacted by access points on two lane and multilane highways:

| Access Points per Mile (Both Sides) | Reduction in FFS (mi/h) |
|---|---|
| 0 | 0.0 |
| 10 | 2.5 |
| 20 | 5.0 |
| 30 | 7.5 |
| 40 | 10.0 |

Note: Interpolation to the nearest 0.1 is recommended.

## Traffic Composition

Research in this area is not conclusive, but unfamiliar drivers have no learned experience on the safe speed for roadway segments including new or reconstructed segments. Basing the speed solely on 85th percentile of commuters or local drivers may not account for issues that would affect drivers who are unfamiliar with the route or conditions by different periods. A combination of lower posted speed and signage considerations may be appropriate on routes with a large volume of unfamiliar drivers.

## Multimodal Facilities

Research indicates that the presence of pedestrians, bicyclists and transit has safety and operational impacts. The impacts are mitigated by good design of multimodal facilities such as sidewalks buffered from the roadway, shared use paths, bicycle lanes, and separated bus lanes or stops and adequate controlled crossing opportunities. In general, the presence of significant volumes of pedestrians, bicyclists and transit supports a lower posted speed. Research indicates a strong correlation between increasing impact speed and increasing injury and fatality risk when pedestrians and bicyclists are struck by vehicles (Kröyer, Jonson & Várhelyi 2014; Rösen & Sander 2009; Tefft 2011).

As an example of significant pedestrian volume thresholds, the NCDOT Project Report 2014-15 "North Carolina Pedestrian Crossing Guidance" recommends the following thresholds for when marked crosswalks are not necessary:

*Because existing pedestrian volume data is limited, the evaluator must use engineering judgment to choose the appropriate low volume threshold from the following considerations:*

- *The crossing area has less than 25 pedestrians per pedestrian peak hour OR less than 100 pedestrians per day.*
- *At mid-block locations only: crossing area has less than 25 pedestrians per pedestrian peak hour for at least four hours. (NCDOT, 2008)*

- *The crossing area is not near high pedestrian trip generators.*
- *The crossing area does not connect complementary land uses.*

The Complete Streets area type can also be used to estimate pedestrian and bicycle demand. Low presence of pedestrians and bicyclists, especially in urban and suburban areas may also reflect safety concerns, including traffic speed, that inhibit people from walking and biking.

## Crashes

A significant crash history, especially with a higher proportion of fatal and injury crashes compared to other similar roads, or with speed as a contributing factor supports a lower posted speed.

## Neighborhood Petition

A neighborhood petition alone does not support a change in posted speed but may be used to identify issues for the engineer to further investigate. For example, if a majority of drivers are compliant with the speed limit, absolute speed may still be a concern to neighbors. More information could be sought about the specific concerns. Considering the area type and uses of the road or street, traffic calming or other design and operational treatments may be needed along with changes in speed limits. If drivers are not currently compliant, then enhanced enforcement or designs that help to enforce appropriate speeds may also be needed.

## Pavement Condition

While safe travel speeds are lower when pavement is in poor condition, it is important to consider that resurfacing will affect the safe speed. Posted speed limits that were lowered primarily due to pavement condition should be reevaluated once resurfacing is complete.

## Lanes

Research shows that in general lanes narrower than 12 ft in width support lower speeds. Below are the adjustments to free flow speed used in the Highway Capacity Manual. It is important to note that lanes wider than 12 ft do not support higher speeds.
HCM Two-lane Highway Free Flow Speed Adjustment for Lane and Shoulder Width shows how drivers' desired speed is impacted by lane and shoulder widths:

**Exhibit 15-7**
Adjustment Factor for Lane and Shoulder Width ($f_{LS}$)

| Lane Width (ft) | Shoulder Width (ft) | | | |
|---|---|---|---|---|
| | ≥0 <2 | ≥2 <4 | ≥4 <6 | ≥6 |
| ≥9 <10 | 6.4 | 4.8 | 3.5 | 2.2 |
| ≥10 <11 | 5.3 | 3.7 | 2.4 | 1.1 |
| ≥ 11 <12 | 4.7 | 3.0 | 1.7 | 0.4 |
| ≥12 | 4.2 | 2.6 | 1.3 | 0.0 |

| Average Lane Width (ft) | Reduction in FFS, $f_{LW}$ (mi/h) |
|---|---|
| ≥12 | 0.0 |
| ≥11–12 | 1.9 |
| ≥10–11 | 6.6 |

**Exhibit 12-20**
Adjustment to FFS for Average Lane Width for Basic Freeway and Multilane Highway Segments

## Shoulders

In general, hard shoulders narrower than 6 ft support a lower posted speed. The two-lane highway HCM method is shown in the lane section, and the freeway and multilane highway adjustment for shoulders on driver's desired speed is shown below.

| Right-Side Lateral Clearance (ft) | Lanes in One Direction 2 | 3 | 4 | ≥5 |
|---|---|---|---|---|
| ≥6 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.6 | 0.4 | 0.2 | 0.1 |
| 4 | 1.2 | 0.8 | 0.4 | 0.2 |
| 3 | 1.8 | 1.2 | 0.6 | 0.3 |
| 2 | 2.4 | 1.6 | 0.8 | 0.4 |
| 1 | 3.0 | 2.0 | 1.0 | 0.5 |
| 0 | 3.6 | 2.4 | 1.2 | 0.6 |

Note: Interpolate for non-integer values of right-side lateral clearance.

**Exhibit 12-21**
Adjustment to FFS for Right-Side Lateral Clearance, $f_{RLC}$ (mi/h) for Basic Freeway Segments

**Exhibit 12-22**
Adjustment to FFS for Lateral Clearances for Multilane Highways

| Four-Lane Highways TLC (ft) | Four-Lane Highways Reduction in FFS (mi/h) | Six-Lane Highways TLC (ft) | Six-Lane Highways Reduction in FFS (mi/h) |
|---|---|---|---|
| 12 | 0.0 | 12 | 0.0 |
| 10 | 0.4 | 10 | 0.4 |
| 8 | 0.9 | 8 | 0.9 |
| 6 | 1.3 | 6 | 1.3 |
| 4 | 1.8 | 4 | 1.7 |
| 2 | 3.6 | 2 | 2.8 |
| 0 | 5.4 | 0 | 3.9 |

Note: Interpolation to the nearest 0.1 is recommended.

*TLC is sum of left and right clearance, where each side can account for up to 6 ft. Additionally, Multilane highways with an undivided median have a reduction in FFS of 1.6 mi/h.

## Horizontal Curves

In general, tighter (lower radius) horizontal curves support lower operating speeds. Design speeds are also impacted by the superelevation of the curve. Ball bank studies can be used to select an appropriate speed limit. Refer to *A Policy on Geometric Design of Highways and Streets* (Green Book) for design practices, and the FHWA guidance on establishing advisory speeds (Procedures for Setting Advisory Speeds on Curves, June 2011, https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa1122/ch3.cfm).

## Vertical Curves

In general, steeper sag and crest vertical curves support lower speeds to provide sufficient sight distance. Refer to *A Policy on Geometric Design of Highways and Streets* (Green Book) for design practices.

## Sight Distance

Issues in providing appropriate stopping sight distance including curvature and sight obstructions in the median and at access points support lower posted speeds. Refer to *A Policy on Geometric Design of Highways and Streets* (Green Book) for design practices.

## 85th Percentile Speed

Without compelling evidence from critical roadway and traffic elements, the 85th percentile speed is typically used as the standard practice to identify posted speed. However, there is no evidence that the 85th percentile speed is safer than other limits; this practice stems largely from the belief that most drivers are rational, and that enforcement would be impracticable if sizable numbers of drivers are non-compliant with the limit. Although measurement of free-flow speeds is required in an engineering study per the MUTCD, there is no requirement in the MUTCD or elsewhere to post speed limits based on the 85th percentile speed. FHWA's USLIMITS2 (https://safety.fhwa.dot.gov/uslimits/) provides guidance on other speed percentiles to utilize depending on geometric, crash history, and safety conditions. Other important references include FHWA’s *Methods and Practices for Setting Speed Limits: An Informational Report* and *Speed Management Toolkit*.

# APPENDIX D: BACKGROUND AND EXAMPLE FORMS FOR ROADWAY SPEED LIMIT REVIEW

# Example Strip Analysis

North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

## Study Criteria Summary

**County:** CHATHAM **City:** All and Rural
**Date:** 6/1/2011 **to** 5/31/2016 **Study:** 06292016001SR1972
**Location:** SR 1972 (Pea Ridge Road) from SR 1008 (Beaver Creek Road) to SR 1910 (Merry Oaks Church Road).

## Report Details

| Acc | | | | | Total | Injuries | | | | Condition | | | Road | | Trfc Ctl | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Crash ID | Milepost | Date | Accident Type | Damage | F | A | B | C | R | L | W | Ch | Ci | Dv | Op |
| 1 | 103350242 | 0.000 | 01/09/2012 07:00 | SIDESWIPE, OPPOSITE DIRECTION | $ 250 | 0 | 0 | 0 | 0 | 2 | 5 | 3 | 1 | 0 | 13 | 1 |
| Unit 1 : 2 | Alchl/Drgs: 0 | Speed: 55 MPH | Dir: E | Veh Mnvr/Ped Actn: 4 | Obj Strk: | | | | | | | | | | | |
| Unit 2 : 32 | Alchl/Drgs: 7 | Speed: 55 MPH | Dir: W | Veh Mnvr/Ped Actn: 4 | Obj Strk: | | | | | | | | | | | |
| 2 | 104374752 | 0.000 | 05/11/2015 10:59 | FIXED OBJECT | $ 12000 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 13 | 1 |
| Unit 1 : 4 | Alchl/Drgs: 0 | Speed: 55 MPH | Dir: SW | Veh Mnvr/Ped Actn: 4 | Obj Strk: 33 | | | | | | | | | | | |
| 3 | 104451393 | 0.000 | 08/04/2015 04:20 | FIXED OBJECT | $ 5500 | 0 | 0 | 0 | 0 | 1 | 5 | 1 | 1 | 0 | 1 | 1 |
| Unit 1 : 4 | Alchl/Drgs: 1 | Speed: 55 MPH | Dir: E | Veh Mnvr/Ped Actn: 7 | Obj Strk: 42 | | | | | | | | | | | |
| 4 | 103448178 | 0.105 | 05/11/2012 10:35 | FIXED OBJECT | $ 4000 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 | 0 | 13 | 1 |
| Unit 1 : 1 | Alchl/Drgs: 0 | Speed: 65 MPH | Dir: S | Veh Mnvr/Ped Actn: 4 | Obj Strk: 33 | | | | | | | | | | | |
| 5 | 103546765 | 1.000 | 09/06/2012 04:41 | FIXED OBJECT | $ 20000 | 0 | 0 | 0 | 0 | 1 | 5 | 1 | 1 | 0 | 13 | 1 |
| Unit 1 : 1 | Alchl/Drgs: 7 | Speed: 60 MPH | Dir: N | Veh Mnvr/Ped Actn: 4 | Obj Strk: 33 | | | | | | | | | | | |
| 6 | 104434063 | 1.155 | 07/12/2015 08:13 | FIXED OBJECT | $ 2500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | |
| Unit 1 : 1 | Alchl/Drgs: 0 | Speed: 45 MPH | Dir: S | Veh Mnvr/Ped Actn: 4 | Obj Strk: 33 | | | | | | | | | | | |
| 7 | 103467698 | 1.655 | 05/23/2012 13:00 | FIXED OBJECT | $ 4000 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 13 | 1 |
| Unit 1 : 1 | Alchl/Drgs: 7 | Speed: 15 MPH | Dir: N | Veh Mnvr/Ped Actn: 9 | Obj Strk: 64 | | | | | | | | | | | |
| 8 | 103967049 | 1.967 | 01/30/2014 09:09 | FIXED OBJECT | $ 2000 | 0 | 0 | 0 | 2 | 4 | 1 | 1 | 1 | 0 | 13 | 1 |
| Unit 1 : 2 | Alchl/Drgs: 0 | Speed: 45 MPH | Dir: N | Veh Mnvr/Ped Actn: 4 | Obj Strk: 33 | | | | | | | | | | | |
| 9 | 103855110 | 2.117 | 09/23/2013 06:34 | ANIMAL | $ 1500 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 7 | 0 | 13 | 1 |
| Unit 1 : 1 | Alchl/Drgs: 0 | Speed: 55 MPH | Dir: E | Veh Mnvr/Ped Actn: 4 | Obj Strk: 17 | | | | | | | | | | | |

**06/29/2016**



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## North Carolina Department of Transportation
## Traffic Engineering Accident Analysis System
### Strip Analysis Report

| Acc No | Crash ID | Milepost | Date | Accident Type | Total Damage | Injuries F | Injuries A | Injuries B | Injuries C | Condition R | Condition L | Condition W | Road Ch | Road Ci | Trfc Ctl Dv | Trfc Ctl Op |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 103649831 | 2.942 | 01/12/2013 18:27 | ANIMAL | $ 5000 | 0 | 0 | 0 | 0 | 1 | 5 | 5 | | 0 | | |
| Unit 1 : 2 | | Alchl/Drgs: 0 | | Speed: 0 MPH Dir: N | | Veh Mnvr/Ped Actn: 4 | | | | | | | Obj Strk: 17 | | | |
| 23 | 104318786 | 3.041 | 02/22/2015 16:23 | FIXED OBJECT | $ 1000 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 5 | 0 | 13 | 1 |
| Unit 1 : 2 | | Alchl/Drgs: 0 | | Speed: 45 MPH Dir: N | | Veh Mnvr/Ped Actn: 4 | | | | | | | Obj Strk: 38 | | | |
| 24 | 104718683 | 3.042 | 04/25/2016 23:28 | OVERTURN/ROLLOVER | $ 2000 | 0 | 0 | 0 | 0 | 1 | 5 | 1 | 5 | 0 | 13 | 1 |
| Unit 1 : 2 | | Alchl/Drgs: 7 | | Speed: 25 MPH Dir: N | | Veh Mnvr/Ped Actn: 7 | | | | | | | Obj Strk: | | | |

**Legend for Report Details:**

Acc No - Accident Number
Injuries: F - Fatal, A - Class A, B - Class B, C - Class C
Condition: R - Road Surface, L - Ambient Light, W - Weather
Rd Ch - Road Character
Rd Ci - Roadway Contributing Circumstances
Trfc Ctl - Traffic Control: Dv - Device, Op - Operating
Alchl/Drgs - Alcohol Drugs Suspected
Veh Mnvr/Ped Actn - Vehicle Maneuver/Pedestrian Action
Obj Strk - Object Struck

North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

## Summary Statistics

### High Level Crash Summary

| Crash Type | Number of Crashes | Percent of Total |
|---|---|---|
| Total Crashes | 24 | 100.00 |
| Fatal Crashes | 0 | 0.00 |
| Non-Fatal Injury Crashes | 3 | 12.50 |
| Total Injury Crashes | 3 | 12.50 |
| Property Damage Only Crashes | 21 | 87.50 |
| Night Crashes | 12 | 50.00 |
| Wet Crashes | 4 | 16.67 |
| Alcohol/Drugs Involvement Crashes | 1 | 4.17 |

### Crash Severity Summary

| Crash Type | Number of Crashes | Percent of Total |
|---|---|---|
| Total Crashes | 24 | 100.00 |
| Fatal Crashes | 0 | 0.00 |
| Class A Crashes | 0 | 0.00 |
| Class B Crashes | 1 | 4.17 |
| Class C Crashes | 2 | 8.33 |
| Property Damage Only Crashes | 21 | 87.50 |

### Vehicle Exposure Statistics

Annual ADT = 2000

Total Length = 3.042 (Miles) 4.896 (Kilometers)

Total Vehicle Exposure = 11.12 (MVMT) 17.89 (MVKMT)

| Crash Rate | Crashes Per 100 Million Vehicle Miles | Crashes Per 100 Million Vehicle Kilometers |
|---|---|---|
| Total Crash Rate | 215.92 | 134.16 |
| Fatal Crash Rate | 0.00 | 0.00 |
| Non Fatal Crash Rate | 26.99 | 16.77 |
| Night Crash Rate | 107.96 | 67.08 |
| Wet Crash Rate | 35.99 | 22.36 |
| EPDO Rate | 415.64 | 258.26 |

06/29/2016 All data presented in this report comes explicitly from the Traffic Engineering Accident Analysis System based upon various input criteria provided by the report's creator. The onus is strictly upon the user of this report to exercise due diligence in interpreting and further representing this data. -4-

North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

## Miscellaneous Statistics

| | |
|---|---|
| Severity Index = | 1.92 |
| EPDO Crash Index = | 46.20 |
| Estimated Property Damage Total = $ | 91000.00 |

## Accident Type Summary

| Accident Type | Number of Crashes | Percent of Total |
|---|---|---|
| ANIMAL | 11 | 45.83 |
| FIXED OBJECT | 11 | 45.83 |
| OVERTURN/ROLLOVER | 1 | 4.17 |
| SIDESWIPE, OPPOSITE DIRECTION | 1 | 4.17 |

## Injury Summary

| Injury Type | Number of Injuries | Percent of Total |
|---|---|---|
| Fatal Injuries | 0 | 0.00 |
| Class A Injuries | 0 | 0.00 |
| Class B Injuries | 1 | 16.67 |
| Class C Injuries | 5 | 83.33 |
| Total Non-Fatal Injuries | 6 | 100.00 |
| Total Injuries | 6 | 100.00 |

06/29/2016

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North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

**Monthly Summary**

| Month | Number of Crashes | Percent of Total |
|---|---|---|
| Jan | 6 | 25.00 |
| Feb | 2 | 8.33 |
| Mar | 1 | 4.17 |
| Apr | 1 | 4.17 |
| May | 3 | 12.50 |
| Jun | 0 | 0.00 |
| Jul | 1 | 4.17 |
| Aug | 1 | 4.17 |
| Sep | 2 | 8.33 |
| Oct | 1 | 4.17 |
| Nov | 2 | 8.33 |
| Dec | 4 | 16.67 |

**Daily Summary**

| Day | Number of Crashes | Percent of Total |
|---|---|---|
| Mon | 6 | 25.00 |
| Tue | 2 | 8.33 |
| Wed | 1 | 4.17 |
| Thu | 5 | 20.83 |
| Fri | 6 | 25.00 |
| Sat | 1 | 4.17 |
| Sun | 3 | 12.50 |

06/29/2016

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North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

**Hourly Summary**

| Hour | Number of Crashes | Percent of Total |
|---|---|---|
| 0000-0059 | 0 | 0.00 |
| 0100-0159 | 1 | 4.17 |
| 0200-0259 | 0 | 0.00 |
| 0300-0359 | 0 | 0.00 |
| 0400-0459 | 2 | 8.33 |
| 0500-0559 | 0 | 0.00 |
| 0600-0659 | 2 | 8.33 |
| 0700-0759 | 4 | 16.67 |
| 0800-0859 | 1 | 4.17 |
| 0900-0959 | 1 | 4.17 |
| 1000-1059 | 4 | 16.67 |
| 1100-1159 | 0 | 0.00 |
| 1200-1259 | 0 | 0.00 |
| 1300-1359 | 1 | 4.17 |
| 1400-1459 | 0 | 0.00 |
| 1500-1559 | 0 | 0.00 |
| 1600-1659 | 1 | 4.17 |
| 1700-1759 | 0 | 0.00 |
| 1800-1859 | 2 | 8.33 |
| 1900-1959 | 4 | 16.67 |
| 2000-2059 | 0 | 0.00 |
| 2100-2159 | 0 | 0.00 |
| 2200-2259 | 0 | 0.00 |
| 2300-2359 | 1 | 4.17 |

North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

### Light and Road Conditions Summary

| Condition | Dry | Wet | Other | Total |
|---|---|---|---|---|
| Day | 6 | 3 | 1 | 10 |
| Dark | 10 | 1 | 1 | 12 |
| Other | 2 | 0 | 0 | 2 |
| Total | 18 | 4 | 2 | 24 |

### Object Struck Summary

| Object Type | Times Struck | Percent of Total |
|---|---|---|
| ANIMAL | 11 | 50.00 |
| DITCH | 2 | 9.09 |
| GUARDRAIL FACE ON SHOULDER | 1 | 4.55 |
| OFFICIAL HIGHWAY SIGN BREAKAWAY | 1 | 4.55 |
| OTHER FIXED OBJECT | 1 | 4.55 |
| TREE | 6 | 27.27 |

### Vehicle Type Summary

| Vehicle Type | Number Involved | Percent of Total |
|---|---|---|
| PASSENGER CAR | 12 | 48.00 |
| PICKUP | 8 | 32.00 |
| SPORT UTILITY | 2 | 8.00 |
| UNKNOWN | 1 | 4.00 |
| VAN | 2 | 8.00 |

North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

## Yearly Totals Summary

### Accident Totals

| Year | Total Accidents | Fatal Accidents | Injury Accidents | Property Damage Only Accidents |
|---|---|---|---|---|
| 2011 | 0 | 0 | 0 | 0 |
| 2012 | 7 | 0 | 0 | 7 |
| 2013 | 5 | 0 | 0 | 5 |
| 2014 | 3 | 0 | 1 | 2 |
| 2015 | 6 | 0 | 1 | 5 |
| 2016 | 3 | 0 | 1 | 2 |
| Total | 24 | 0 | 3 | 21 |

### Injury Totals

| Year | Fatal Injuries | Class A, B, or C Injuries |
|---|---|---|
| 2011 | 0 | 0 |
| 2012 | 0 | 0 |
| 2013 | 0 | 0 |
| 2014 | 0 | 2 |
| 2015 | 0 | 2 |
| 2016 | 0 | 2 |
| Total | 0 | 6 |

### Miscellaneous Totals

| Year | Property Damage | EPDO Index |
|---|---|---|
| 2011 | $ 0 | 0.00 |
| 2012 | $ 34950 | 7.00 |
| 2013 | $ 14000 | 5.00 |
| 2014 | $ 5500 | 10.40 |
| 2015 | $ 26000 | 13.40 |
| 2016 | $ 10550 | 10.40 |
| Total | $ 91000 | 46.20 |

### Type of Accident Totals

| Year | Left Turn | Right Turn | Rear End | Run Off Road & Fixed Object | Angle | Side Swipe | Other |
|---|---|---|---|---|---|---|---|
| 2011 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 0 | 0 | 0 | 3 | 0 | 1 | 3 |

06/29/2016

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North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

| Year | Left Turn | Right Turn | Rear End | Run Off Road & Fixed Object | Angle | Side Swipe | Other |
|---|---|---|---|---|---|---|---|
| 2013 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 2014 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| 2015 | 0 | 0 | 0 | 4 | 0 | 0 | 2 |
| 2016 | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| Total | 0 | 0 | 0 | 11 | 0 | 1 | 12 |

North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Strip Analysis Report

## Study Criteria

| Study Name | Log No. | PH No. | TIP No. | K/A Cf. | B/C Cf. | ADT | ADT Route |
|---|---|---|---|---|---|---|---|
| 06292016001SR1972 | | | | 76.8 | 8.4 | 2000 | |

| Request Date | Courier Service | Phone No. | Ext. | Fax No. |
|---|---|---|---|---|
| 6/27/2016 | | | | |

| County | | | Municipality | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name | Code | Div. | Name | Code | Y-Line Ft. | Begin Date | End Date | Years |
| CHATHAM | 19 | 8 | All and Rural | | 150 | 6/1/2011 | 5/31/2016 | 5.00 |

| Location Text | Requestor |
|---|---|
| SR 1972 (Pea Ridge Road) from SR 1008 (Beaver Creek Road) to SR 1910 (Merry Oaks Church Road). | Ms. Anita Becker (919)642-0441 |

Fiche Roads

| Name | Code |
|---|---|
| | 40001972 |

Strip Road

| Name | Code | Begin MP | End MP | Miles | Kilometers |
|---|---|---|---|---|---|
| | 40001972 | 0.000 | 3.042 | 3.042 | 4.896 |

## Example Features Report

North Carolina Department of Transportation
Traffic Engineering Accident Analysis System
Features Report

| County | Inventoried Route ID | Begin Milepost | End Milepost |
|---|---|---|---|
| CHATHAM | 40001972 | 0.0 | 6.453 |

| MP No | Feature ID | Feature Name/Type | Special Type | | Distance to Next | Direction to Next | Loop | Beyond Route Limits |
|---|---|---|---|---|---|---|---|---|
| 0.000 | 40001008 | SR 1008 | At grade intersection, | 3 legs | 1.155 | South and East | | |
| 1.155 | 40001907 | SR 1907 | At grade intersection, | 3 legs | 1.112 | South and East | | |
| 2.267 | 40001974 | SR 1974 | At grade intersection, | 3 legs | 0.363 | South and East | | |
| 2.630 | 40001988 | SR 1988 | At grade intersection, | 3 legs | 0.412 | South and East | | |
| 3.042 | 40001910 | SR 1910 | At grade intersection, | 3 legs | 2.090 | South and East | | |
| 5.132 | 20400001 | US 1 SB COUPLET | At grade intersection, | 3 legs | 0.010 | North and East | | |
| 5.142 | 20000001 | US 1 | At grade intersection, | 3 legs | 0.000 | South and East | | |
| 5.142 | 180063 | Structure | Bridge | | 0.106 | | | |
| 5.248 | 40001964 | SR 1964 | At grade intersection, | 3 legs | 1.205 | South and East | | |
| 6.453 | 40001011 | SR 1011 | At grade intersection, | 3 legs | 0.000 | South and East | | |

06/28/2016 Page 1 of 1

# Example Speed Study Raw Data

## SPOT SPEEDS-FIELD-RADAR

County: B D N (O) P S   City/Town/Area: Jacksonville
On Road: SR 1211 - Firetower Road
Looking W  From: 0.5 mile W of SR 1212 - Pony Farm Road
Target area:

Day/Date: Wed. 8/17/16
Weather: Sunny 87°
Speed Limit 55 mph
By: M. Bass, Jr.

mph | Time: Start: 11:48 a.m; End: [redacted] 12:25 p.m

Dir--> N NE (E) SE S SW W NW-bound | N NE E SE S SW (W) NW-bound

| N | 85th%ile | mph | Total | Cumul. | % |
|---|---|---|---|---|---|
| | | <25 | | | |
| 20 | 17.0 | 25 | | | |
| 21 | 17.9 | 26 | | | |
| 22 | 18.7 | 27 | | | |
| 23 | 19.6 | 28 | | | |
| 24 | 20.4 | 29 | | | |
| 25 | 21.3 | 30 | | | |
| 26 | 22.1 | 31 | | | |
| 27 | 23.0 | 32 | | | |
| 28 | 23.8 | 33 | | | |
| 29 | 24.7 | 34 | | | |
| 30 | 25.5 | 35 | | | |
| 31 | 26.4 | 36 | | | |
| 32 | 27.2 | 37 | | | |
| 33 | 28.1 | 38 | | | |
| 34 | 28.9 | 39 | | | |
| 35 | 29.8 | 40 | 1 | 1 | |
| 36 | 30.6 | 41 | | | |
| 37 | 31.5 | 42 | | | |
| 38 | 32.3 | 43 | | | |
| 39 | 33.2 | 44 | | | |
| 40 | 34.0 | 45 | | | |
| 41 | 34.9 | 46 | | | |
| 42 | 35.7 | 47 | 2 | 3 | |
| 43 | 36.6 | 48 | 6 | 9 | |
| 44 | 37.4 | 49 | 4 | 13 | |
| 45 | 38.3 | 50 | 2 | 15 | |
| 46 | 39.1 | 51 | 2 | 17 | |
| 47 | 40.0 | 52 | 1 | 18 | |
| 48 | 40.8 | 53 | 5 | 23 | |
| 49 | 41.7 | 54 | 1 | 24 | |
| 50 | 42.5 | 55 | 7 | 31 | |
| 51 | 43.4 | 56 | 2 | 33 | |
| 52 | 44.2 | 57 | 2 | 35 | |
| 53 | 45.1 | 58 | 3 | 38 | |
| 54 | 45.9 | 59 | 6 | 44 | |
| 55 | 46.8 | 60 | 1 | 45 | |
| 85th%→ 56 | 47.6 | (61) | 3 | 48 | |
| 57 | 48.5 | 62 | 1 | 49 | |
| 58 | 49.3 | 63 | 5 | 54 | |
| 59 | 50.2 | 64 | | | |
| 60 | 51.0 | 65 | | | |
| 61 | 51.9 | 66 | 1 | 55 | |
| 62 | 52.7 | 67 | 1 | 56 | |
| 63 | 53.6 | 68 | | | |
| 64 | 54.4 | 69 | 1 | 57 | |
| 65 | 55.3 | 70 | 1 | 58 | |
| 66 | 56.1 | 71 | | | |
| 67 | 57.0 | 72 | | | |
| 68 | 57.8 | 73 | | | |
| 69 | 58.7 | 74 | | | |
| 70 | 59.5 | 75 | | | |
| 71 | 60.4 | >75 | | | |

| N | 85th%ile | Widths |
|---|---|---|
| 72 | 61.2 | |
| 73 | 62.1 | |
| 74 | 62.9 | |
| 75 | 63.8 | |
| 76 | 64.6 | |
| 77 | 65.5 | |
| 78 | 66.3 | |
| 79 | 67.2 | |
| 80 | 68.0 | |
| 81 | 68.9 | |
| 82 | 69.7 | |
| 83 | 70.6 | |
| 84 | 71.4 | |
| 85 | 72.3 | |
| 86 | 73.1 | |
| 87 | 74.0 | |
| 88 | 74.8 | |
| 89 | 75.7 | |
| 90 | 76.5 | |
| 91 | 77.4 | |
| 92 | 78.2 | |
| 93 | 79.1 | |
| 94 | 79.9 | |
| 95 | 80.8 | |
| 96 | 81.6 | |
| 97 | 82.5 | |
| 98 | 83.3 | |
| 99 | 84.2 | |
| 100 | 85.0 | |
| 101 | 85.9 | |
| 102 | 86.7 | |
| 103 | 87.6 | |
| 104 | 88.4 | |
| 105 | 89.3 | |
| 106 | 90.1 | |
| 107 | 91.0 | |
| 108 | 91.8 | |
| 109 | 92.7 | |
| 110 | 93.5 | |
| 111 | 94.4 | |
| 112 | 95.2 | |
| 113 | 96.1 | |
| 114 | 96.9 | |
| 115 | 97.8 | |
| 116 | 98.6 | |
| 117 | 99.5 | |
| 118 | 100.3 | |
| 119 | 101.2 | |
| 120 | 102.0 | |
| 121 | 102.9 | |
| 122 | 103.7 | |
| 123 | 104.6 | |
| 124 | 105.4 | |
| 125 | 106.3 | |
| 126 | 107.1 | |
| 127 | 108.0 | |

To find the 85th %ile speed for "N" observations from 20 to 127, see left or right columns.

form SSFR-1 25-75 Revised: 10/10/08

# Ball Bank Study Form

**Ball Bank Indicator Worksheet** **Draft Version 2**

The Ball Bank Indicator Worksheet can be used when determining the advisory speed (of 35 mph or greater ) for horizontal curves.

1. Enter the relevant information about the roadway segment at the top of the form.

2. Sketch a plan view of the roadway segment being tested with each curve labeled numerically.

3. For each horizontal curve, record the current posted advisory speed limit. If an advisory speed limit is not posted, record "NP" for "not posted".

4. Driving each curve at the posted advisory speed limit, record if the ball bank indicator (BBI) has a reading less than or greater than 12.0.

   For curves without an advisory speed limit, drive at a comfortable speed. Record that value next to the "NP". Record if the BBI has a reading less than or greater than 12.0. Repeat 3 times.

   Repeat 3 times.

5. For curves which have a majority of indicator readings less than 12.0, repeat Step 4 driving 5 mph faster than the posted advisory speed limit. Write this speed and the BBI reading in the next test block. Repeat 3 times. If the majority of the new readings are greater than 12.0, the test is complete for the curve.

   For curves which have a majority of indicator readings greater than 12.0, repeat Step 4 driving 5 mph slower than the posted advisory speed limit. Write this speed and the BBI reading in the next test block. Repeat 3 times. If the majority of the new readings are less than 12.0, the test is complete for that curve.

6. For any curves which are not complete, repeat Step 5 increasing or decreasing the speed by an additional 5 mph as ncessary.

Note: MUTCD 2009 indicates that the advisory speed corresponding to a 12 -degree ball bank indicator reading for speeds of 35 mph and higher. For speeds of 25 to 30 mph, 14 degrees should be used. For speeds of 20 mph or less, 16 degress should be used

ITRE

**Ball Bank Indicator Worksheet** **Draft Version 2**

**Date:** M M / D D / Y Y **Reference #:** ________ **Completed By:** ____________

**County:** ______________________ **Current Speed Limit:** _____ mph

**Study Road:** ________________ from ______________ to ______________

**Plan-view sketch of road segment with major intersecting roads**

*Number each horizontal curve (HC1, HC2, HC3, etc)*
*Also note any areas with questionable sight distance*



**Presence of Advisory Speed Signs & Ballbank Indicator Readings**

*For each curve, note the posted advisory speed limit or that such sign is not present (NP)*

*For each curve, note if the BBI* has a reading less than or greater than 12.0

| Horizontal Curve | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Advisory Speed Limit (or Comf. Speed)** | | | | | | | | | | | | |
| **First Drive @ AS** | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ |
| **Second Drive @ AS** | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ |
| **Third Drive @ AS** | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ |
| **Complete?** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

| Horizontal Curve | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **New Driving Speed** | | | | | | | | | | | | |
| **First Drive at Speed Above** | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ |
| **Second Drive @ AS** | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ |
| **Third Drive @ AS** | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ | ↑ ↓ |
| **Complete?** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

# SECTION 3. CRITERIA

## 3.1 Definitions and Characteristics

The previous section provided a general overview of the functional classification categories of Arterial, Collector and Local. For Federal functional classification purposes, this section breaks these categories down further to stratify the range of mobility and access functions that roadways serve. Additionally, the physical layout and the official designation of some roadways dictate the classification of certain roadways.

*Access control is a key factor in the realm of functional classification. All Interstates are "limited access" or "controlled access" roadways. The use of the word "access" in this context refers to the ability to access the roadway and not the abutting land use—these roadways provide no "access" to abutting land uses. Access to these roadways is controlled or limited to maximize mobility by eliminating conflicts with driveways and at-grade intersections that would otherwise hinder travel speed. Access to these roadways is limited to a set of controlled locations at entrance and exit ramps. Travelers use a much lower functionally classified roadway to reach their destination.*

### 3.1.1 Interstates

Interstates are the highest classification of Arterials and were designed and constructed with mobility and long-distance travel in mind. (**Figure 3-1**) Since their inception in the 1950's, the Interstate System has provided a superior network of limited access, divided highways offering high levels of mobility while linking the major urban areas of the United States.

*Figure 3-1: Example of Interstate*

Source: CDM Smith

Determining the functional classification designation of many roadways can be somewhat subjective, but with the Interstate category of Arterials, there is no ambiguity. Roadways in this functional classification category are officially designated as Interstates by the Secretary of Transportation, and all routes that comprise the Dwight D. Eisenhower National System of Interstate and Defense Highways belong to the Interstate functional classification category and are considered Principal Arterials.

### 3.1.2 Other Freeways & Expressways

Roadways in this functional classification category look very similar to Interstates. While there can be regional differences in the use of the terms 'freeway' and 'expressway', for the purpose of functional classification the roads in this classification have directional travel lanes are usually separated by some type of physical barrier, and their access and egress points are limited to on- and off-ramp locations or a very limited number of at-grade intersections. Like Interstates, these roadways are designed and constructed to maximize their mobility function, and abutting land uses are not directly served by them.

### 3.1.3 Other Principal Arterials

*Figure 3-2: Example of Other Principal Arterial*

*Source: CDM Smith*

These roadways serve major centers of metropolitan areas, provide a high degree of mobility and can also provide mobility through rural areas. Unlike their access-controlled counterparts, abutting land uses can be served directly. Forms of access for Other Principal Arterial roadways include driveways to specific parcels and at-grade intersections with other roadways. (**Figure 3-2**) For the most part, roadways that fall into the top three functional classification categories (Interstate, Other Freeways & Expressways and Other Principal Arterials) provide similar service in both urban and rural areas. The primary difference is that there are usually multiple Arterial routes serving a particular urban area, radiating out from the urban center to serve the surrounding region. In contrast, an expanse of a rural area of equal size would be served by a single Arterial.

**Table 3-1** presents a few key differences between the character of service that urban and rural Arterials provide.

*Table 3-1: Characteristics of Urban and Rural Arterials*

| Urban | Rural |
|---|---|
| • Serve major activity centers, highest traffic volume corridors and longest trip demands<br>• Carry high proportion of total urban travel on minimum of mileage<br>• Interconnect and provide continuity for major rural corridors to accommodate trips entering and leaving urban area and movements through the urban area<br>• Serve demand for intra-area travel between the central business district and outlying residential areas | • Serve corridor movements having trip length and travel density characteristics indicative of substantial statewide or interstate travel<br>• Connect all or nearly all Urbanized Areas and a large majority of Urban Clusters with 25,000 and over population<br>• Provide an integrated network of continuous routes without stub connections (dead ends) |

### 3.1.4 Minor Arterials

*Figure 3-3: Example of Urban Minor Arterial*

*Source: Unsourced photo*

Minor Arterials provide service for trips of moderate length, serve geographic areas that are smaller than their higher Arterial counterparts and offer connectivity to the higher Arterial system. In an urban context, they interconnect and augment the higher Arterial system, provide intra-community continuity and may carry local bus routes. (**Figure 3-3**)



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Federal Highway Administration

In rural settings, Minor Arterials should be identified and spaced at intervals consistent with population density, so that all developed areas are within a reasonable distance of a higher level Arterial. Additionally, Minor Arterials in rural areas are typically designed to provide relatively high overall travel speeds, with minimum interference to through movement. The spacing of Minor Arterial streets may typically vary from 1/8- to 1/2-mile in the central business district (CBD) and 2 to 3 miles in the suburban fringes. Normally, the spacing should not exceed 1 mile in fully developed areas (see **Table 3-2**).

*Table 3-2: Characteristics of Urban and Rural Minor Arterials*

| Urban | Rural |
|---|---|
| • Interconnect and augment the higher-level Arterials<br>• Serve trips of moderate length at a somewhat lower level of travel mobility than Principal Arterials<br>• Distribute traffic to smaller geographic areas than those served by higher-level Arterials<br>• Provide more land access than Principal Arterials without penetrating identifiable neighborhoods<br>• Provide urban connections for Rural Collectors | • Link cities and larger towns (and other major destinations such as resorts capable of attracting travel over long distances) and form an integrated network providing interstate and inter-county service<br>• Be spaced at intervals, consistent with population density, so that all developed areas within the State are within a reasonable distance of an Arterial roadway<br>• Provide service to corridors with trip lengths and travel density greater than those served by Rural Collectors and Local Roads and with relatively high travel speeds and minimum interference to through movement |

### 3.1.5 Major and Minor Collectors

Collectors serve a critical role in the roadway network by gathering traffic from Local Roads and funneling them to the Arterial network. Within the context of functional classification, Collectors are broken down into two categories: Major Collectors and Minor Collectors. Until recently, this division was considered only in the rural environment. Currently, all Collectors, regardless of whether they are within a rural area or an urban area, may be sub-stratified into *major* and *minor* categories. The determination of whether a given Collector is a Major or a Minor Collector is frequently one of the biggest challenges in functionally classifying a roadway network.

In the rural environment, Collectors generally serve primarily intra-county travel (rather than statewide) and constitute those routes on which (independent of traffic volume) predominant travel distances are shorter than on Arterial routes. Consequently, more moderate speeds may be posted.

The distinctions between Major Collectors and Minor Collectors are often subtle. Generally, Major Collector routes are longer in length; have lower connecting driveway densities; have higher speed limits; are spaced at greater intervals; have higher annual average traffic volumes; and may have more travel lanes than their

Minor Collector counterparts. Careful consideration should be given to these factors when assigning a Major or Minor Collector designation. In rural areas, AADT and spacing may be the most significant designation factors. Since Major Collectors offer more mobility and Minor Collectors offer more access, it is beneficial to reexamine these two fundamental concepts of functional classification. Overall, the total mileage of Major Collectors is typically lower than the total mileage of Minor Collectors, while the total Collector mileage is typically one-third of the Local roadway network (see **Table 3-3**).

*Table 3-3: Characteristics of Major and Minor Collectors (Urban and Rural)*

| **MAJOR COLLECTORS** | |
|---|---|
| **Urban** | **Rural** |
| • Serve both land access and traffic circulation in higher density residential, and commercial/industrial areas<br>• Penetrate residential neighborhoods, often for significant distances<br>• Distribute and channel trips between Local Roads and Arterials, usually over a distance of greater than three-quarters of a mile<br>• Operating characteristics include higher speeds and more signalized intersections | • Provide service to any county seat not on an Arterial route, to the larger towns not directly served by the higher systems and to other traffic generators of equivalent intra-county importance such as consolidated schools, shipping points, county parks and important mining and agricultural areas<br>• Link these places with nearby larger towns and cities or with Arterial routes<br>• Serve the most important intra-county travel corridors |
| **MINOR COLLECTORS** | |
| **Urban** | **Rural** |
| • Serve both land access and traffic circulation in lower density residential and commercial/industrial areas<br>• Penetrate residential neighborhoods, often only for a short distance<br>• Distribute and channel trips between Local Roads and Arterials, usually over a distance of less than three-quarters of a mile<br>• Operating characteristics include lower speeds and fewer signalized intersections | • Be spaced at intervals, consistent with population density, to collect traffic from Local Roads and bring all developed areas within reasonable distance of a Collector<br>• Provide service to smaller communities not served by a higher class facility<br>• Link locally important traffic generators with their rural hinterlands |

### 3.1.6 Local Roads

Locally classified roads account for the largest percentage of all roadways in terms of mileage. They are not intended for use in long distance travel, except at the origin or destination end of the trip, due to their provision of direct access to abutting land. Bus routes generally do not run on Local Roads. They are often designed to discourage through traffic. As public roads, they should be accessible for public use throughout the year.

Local Roads are often classified by default. In other words, once all Arterial and Collector roadways have been identified, all remaining roadways are classified as Local Roads (see **Table 3-4**).

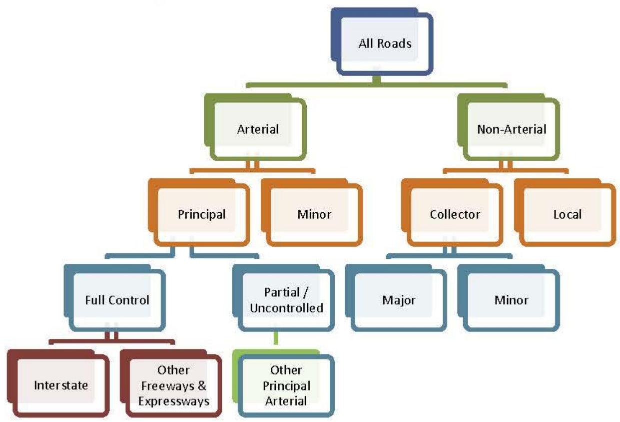
*Table 3-4: Characteristics of Urban and Rural Local Roads*

| Urban | Rural |
|---|---|
| • Provide direct access to adjacent land<br>• Provide access to higher systems<br>• Carry no through traffic movement<br>• Constitute the mileage not classified as part of the Arterial and Collector systems | • Serve primarily to provide access to adjacent land<br>• Provide service to travel over short distances as compared to higher classification categories<br>• Constitute the mileage not classified as part of the Arterial and Collector systems |

## 3.2 Putting it all Together

The functional classification system groups roadways into a logical series of decisions based upon the character of travel service they provide. **Figure 3-4** presents this process, starting from assigning the function of an Arterial by its level of access (limited or full) or Non-Arterial (full access).

*Figure 3-4: Federal Functional Classification Decision Tree*




*Source: FHWA and CDM Smith*

While this document emphasizes the importance of function and service over the urban/rural distinction when classifying roads, the classification process is still influenced by the intensity and distribution of land development patterns. Classification of roadways in urban areas is typically guided by the local comprehensive planning and design process, or the fundamental principles of roadway functional classification. In comparison, rural development patterns are often more diverse, if not less orderly, thereby making the functional classification determination of some rural roadways more challenging (see **Figure 3-5** and **Figure 3-6**).

# NCDOT Complete Streets Planning and Design Guidelines – Area Definitions

Figure 6: Street Type Matrix

| Urban / Suburban | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Street Type | Main Street | | | Avenue | | | Boulevard | Parkway |
| Target Speed (MPH) | 20-25 | 20-25 | 20-25 | 25-35 | 25-35 | 25-35 | 25-40 | > 35 |
| Traffic Volume | H / M | M | M / L | H | M | L | H | H |
| Access Density | H | H | H | M | H / M | H | L/M | L |
| Functional Classification | Arterial | Collector | Local | Arterial | Collector | Local | Arterial | Arterial |

| Rural | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Street Type | Main Street | | | Avenue | | | Boulevard | Parkway | Rural Road | | |
| Target Speed (MPH) | 20-25 | 20-25 | 20-25 | 25-35 | 25-35 | 25-35 | 30-40 | > 35 | 45-55 | 35-55 | 25-55 |
| Traffic Volume | M | L | L | M | L | L | M | H / M | M | L | L |
| Access Density | M | M | M | L/M | M | M | L/M | L | L | L | L |
| Functional Classification | Arterial | Collector | Local | Arterial | Collector | Local | Arterial | Arterial | Arterial | Collector | Local |

**Suggested Ranges:**

| | | | | |
|---|---|---|---|---|
| **Traffic Volume** | L - Low<br>M - Moderate<br>H - High | Less than 8,000 vpd<br>6,000-24,000 vpd<br>Greater than 20,000 vpd | | |
| **Access Density (Traffic Signal Spacing and Access Point Spacing)** | L - Low | Up to 1 signal per mile | OR | Greater than 1000 ft. average spacing between access points (less than 5 access points per mile on each side of the street) |
| | M - Moderate | 1 - 3 signals per mile | OR | 400 -1000 ft. average spacing between access points (5-15 access points per mile on each side of street) |
| | H - High | More than 3 signals per mile | OR | Less than 400 ft. average spacing between access points (more than 15 access points per mile on each side of street) |

Note: Access points include street intersections and commercial access points (excluding single family residential). Access points should be counted on both sides of the street when determining the number of access points.

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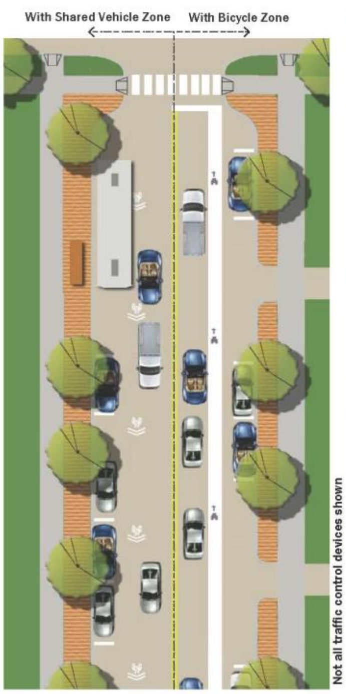
# URBAN/SUBURBAN MAIN STREET

## PLAN VIEW




## KEY ELEMENTS

- May function as an arterial, collector or local street. May function as a collector serving as a primary thoroughfare for traffic circulation in a limited area. May function as a local street for an outlying business district.
- Designed to carry vehicles at low speeds.
- A destination street for a city or town, serving as a center of civic, social and commercial activity.
- Serves substantial pedestrian traffic as well as transit and bicycles.
- Characterized by wide sidewalks, crosswalks and pedestrian amenities, due to emphasis on pedestrian travel.
- Bicycle lanes are allowed but typically not necessary on these streets due to lower speeds and volumes and the desire to keep pedestrian crossing distances to a minimum.

## STREET CROSS-SECTION ZONES

*Sidewalk Zone*: The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably. Pedestrians are the priority on a main street.

*Green Zone:* Consists of the area between the sidewalk zone and curb. Includes street trees and other landscaping, as well as interspersed street furnishings and pedestrian-scale lighting in a hardscaped amenity zone.

*Parking/Transit Zone*: Accommodates on-street parking and transit stops. Width and layout may vary.

*Bicycle Zone*: A zone for bicyclists separate from vehicular traffic.

*Motor Vehicle / Shared Vehicle Zone:* The primary travel way for vehicles. A shared vehicle zone has mixed traffic (cars, trucks, buses and bicycles).

*Development Zone:* Development should be pedestrian-oriented with narrow setbacks and an active street environment.

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# RURAL VILLAGE MAIN STREET

## PLAN VIEW


## KEY ELEMENTS

- May function as an arterial, collector or local street. Could function as an arterial in rural communities. May function as a collector serving as a primary thoroughfare for traffic circulation in a limited area. May function as a local street for an outlying business district.
- Designed to carry vehicles at low speeds.
- Bicycle lanes are allowed but typically not necessary on these streets, due to lower speeds and volumes and the desire to keep pedestrian crossing distances to a minimum.
- A destination for a rural village serving as a center of civic, social and commercial activity.
- Serves substantial pedestrian traffic as well as transit and bicycles.
- Includes wide sidewalks, crosswalks and pedestrian facilities due to the emphasis on pedestrian travel.

## STREET CROSS-SECTION ZONES

*Sidewalk Zone*: The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably. Pedestrians are priority on a main street.

*Green Zone:* This zone consists of the area between the sidewalk zone and curb. It includes street trees and other landscaping, as well as interspersed street furnishings and pedestrian-scale lighting in a hardscaped amenity zone.

*Parking/Transit Zone*: Accommodates on-street parking and transit stops. Parking zone widths and layout may vary.

*Bicycle Zone:* A zone for bicyclists separate from vehicular traffic.

*Motor Vehicle /Shared Vehicle Zone:* The primary travel way for vehicles. A shared vehicle zone has mixed traffic (cars, trucks, buses, and bicycles).

*Development Zone:* Development should be pedestrian-oriented with narrow setbacks and an active street environment.

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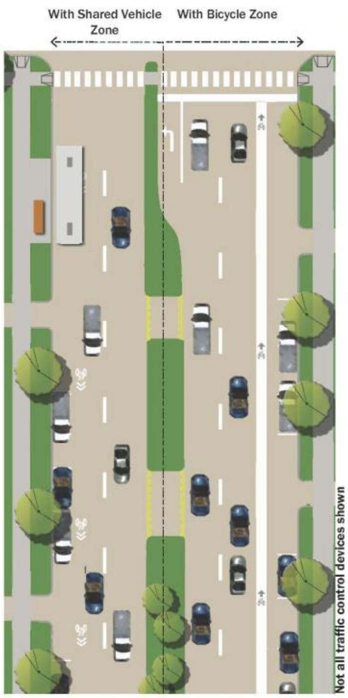
# URBAN / SUBURBAN AVENUE

## PLAN VIEW




## KEY ELEMENTS

- May function as an arterial or collector, but generally at low to moderate speeds.
- An urban street serving a range of traffic levels within and between various area types.
- Characterized by wide sidewalks (scaled to the surrounding land uses) and on-street bicycle facilities.
- May have on-street parking.
- Transit stops, shelters and other amenities are located along the street, preferably within the right of way.

## STREET CROSS-SECTION ZONES

*Sidewalk Zone*: The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably.

*Green Zone:* The landscaped or hardscaped area along the edge of a street. On avenues, this zone should include grass, landscaping, and shade trees in planting strips or, in some cases, hardscaped amenity zones. Pedestrian or decorative lighting may be provided when appropriate for adjacent land uses.

*Parking/Transit Zone*: On-street parking is optional and should be considered in relation to providing convenient access to adjacent land uses. Parking zone width and layout may vary.

*Bicycle Zone:* Accommodation for bicyclists in a zone separate from the motor vehicle zone.

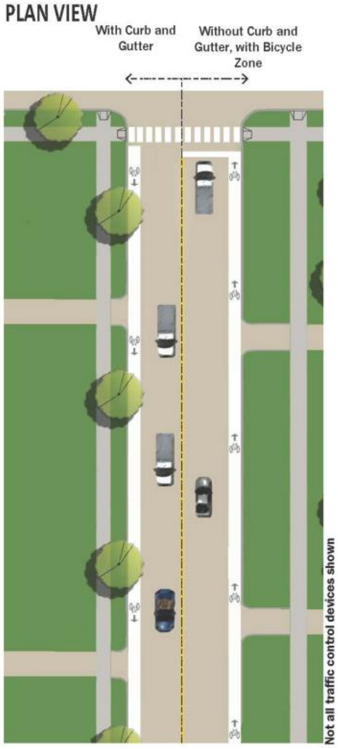
*Motor Vehicle/Shared Vehicle Zone:* The primary travel way for vehicles. A shared vehicle zone has mixed traffic (cars, trucks, buses and bicycles).

*Access Zone:* A landscaped zone or turning zone located between the travel lanes as a center median or turn lane. Avenues typically do not include a continuous median.

*Development Zone:* Development should be oriented toward the street with good functional and visual connection to the street.

# RURAL AVENUE

## PLAN VIEW




## KEY ELEMENTS

- May function as an arterial, collector or local, route, but generally at low to moderate speeds and volumes.
- A rural street serving a range of traffic levels within and between various area types.
- Characterized by wide sidewalks (scaled to the surrounding land uses) and on-street bicycle facilities.
- May have on-street parking.
- Transit stops, shelters and other amenities are located along the roadway, preferably within the right of way.

## STREET CROSS - SECTION ZONES

*Sidewalk Zone*: The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably.

*Green Zone:* The landscaped or hardscaped area along the edge of a street. On avenues this zone should include grass, landscaping, trees in planting strips or, in some cases, hardscaped amenity zones. Pedestrian or decorative lighting may be provided when appropriate for adjacent land uses.

*Bicycle Zone*: Accommodation for bicyclists in a zone separate from the motor vehicle zone.

*Motor Vehicle Zone:* The primary travel way for motor vehicles. In a rural avenue without curb and gutter, the green zone would be relied on for drainage conveyance.

*Development Zone:* Development should be oriented towards the street with good functional and visual connection to the street.

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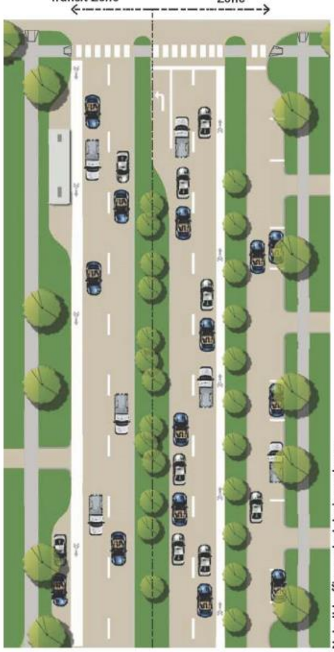
# URBAN / SUBURBAN BOULEVARD

## PLAN VIEW




## KEY ELEMENTS

- Most often functions as an arterial designed to carry vehicles at moderate speeds.
- Thoroughfare characterized by multiple lanes and including a street median.
- Wide sidewalks and on-street bicycle lanes are necessary to accommodate pedestrians and bicyclists due to higher speeds and higher traffic volumes for motor vehicles.
- Transit stops and shelters may be located within the right of way, requiring connections to sidewalks.
- On-street parking is not required. It is allowed where appropriate, but rare due to the nature of the street. If provided, parking should typically be placed on a separate, parallel frontage street separated with a side median.

## STREET CROSS-SECTION ZONES

*Sidewalk Zone:* The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably.

*Green Zone:* This zone serves to separate the sidewalk from the vehicles. This zone contains landscaping and trees or, in some circumstances, hardscape treatments.

*Parking/Transit Zone:* Accommodates on-street parking and transit pull-outs. Parking on the street is rare, but may be separated from the motor vehicle zone by side medians. Width and layout may vary depending on the type of parking provided.

*Bicycle Zone:* A zone for bicyclists separate from vehicular traffic.

*Motor Vehicle Zone:* The primary travel way for motor vehicles.

*Median Zone:* A landscaped zone located between the travel lanes as a center median or as side medians that separate one-way parallel lanes. Median zones should consider provision for turn bays at intersections. May include hardscaping at pedestrian crossings.

*Development Zone:* Building setbacks vary but are typically deeper than on avenues. Building frontage may not always be directed to the street but physical connections to the street from building entrances are important.

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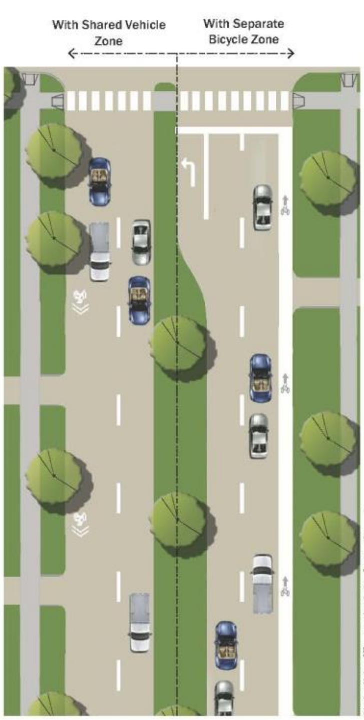
## RURAL BOULEVARD

### PLAN VIEW




### KEY ELEMENTS

- Most often functions as an arterial designed to carry vehicles at moderate speeds.
- Thoroughfare characterized by multiple lanes and including a street median.
- Wide sidewalks and on-street bicycle lanes are necessary to accommodate pedestrians and bicyclists due to higher speeds and higher traffic volumes for motor vehicles.
- Building setbacks will typically be deeper than on avenues.
- Transit stops and shelters may be located within the right of way, requiring connections to sidewalks.
- On-street parking is not required. It is allowed where appropriate, but rare due to the nature of the street and adjacent land uses.

### STREET CROSS - SECTION ZONES

*Sidewalk Zone:* The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably.

*Green Zone:* This zone serves to separate the sidewalk from the vehicles. This zone contains landscaping and trees or, in some circumstances, hardscape treatments. The green zone may be wider if providing an intermittent parking / transit zone.

*Bicycle Zone:* Accommodation for bicyclists either in a separate zone or within the shared vehicle zone.

*Motor Vehicle/Shared Vehicle Zone:* The primary travel way for vehicles. A shared vehicle zone has mixed traffic (cars, trucks, buses and bicycles).

*Median Zone:* A landscaped zone located between the travel lanes as a center median. Median zones should consider provision of turn bays at intersections. The median zone may include hardscaping at pedestrian crossings.

*Development Zone:* Building setbacks vary, but are typically deeper than avenues. Building frontage may not always be directed to the street, but physical connections to the street from building entrances are important.

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## URBAN/SUBURBAN PARKWAY

### PLAN VIEW


### KEY ELEMENTS

- Most often functions as an arterial designed with control of access to carry vehicles at moderate to high speeds.
- Urban or suburban thoroughfare often characterized by landscaping or natural vegetation along roadsides and medians.
- Land uses are set back from the street and are typically not oriented toward the parkway.
- Pedestrian and bicycle traffic usually provided for on separate multi-use paths ideally located adjacent to the facility.
- Convenient access to off-street transit stations, stops and park-and-ride lots.
- Trailer and semitrailer truck traffic is frequently present.


### STREET CROSS - SECTION ZONES

*Multi-Use Path Zone:* A zone for pedestrians and bicyclists in a multi-use path separate from the motor vehicle zone. Please see *Multi-Use Path Zone typology* for more details.

*Green Zone:* Consists of a planting strip with trees to separate the multi-use path zone from the motor vehicle zone. On parkways, typically includes a clear zone.

*Motor Vehicle Zone:* The primary travel way for motor vehicles.

*Median Zone:* A landscaped zone located between the travel lanes as a center median.

*Development Zone:* Deep setbacks due to the typically auto-oriented nature of the street. Access to this zone is limited and controlled.

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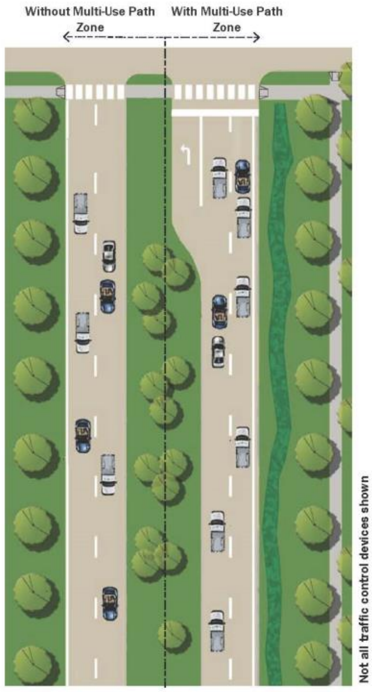
# RURAL PARKWAY

## PLAN VIEW




## KEY ELEMENTS

- Most often functions as an arterial designed with control of access to carry vehicles at moderate to high speeds.
- Rural thoroughfare often characterized by landscaping or natural vegetation along roadsides and medians.
- Land uses are set back from the street and are typically not oriented toward the parkway.
- Pedestrian and bicycle traffic usually provided on separate multi-use paths ideally located adjacent to the facility.
- Convenient access to on-street transit facilities and off-street stations and park and ride lots.
- Large truck traffic may be present.

## STREET CROSS - SECTION ZONES

*Green Zone:* Consists of a planting strip with trees to separate the multi-use path zone from the motor vehicle zone. A portion of the green zone is the roadway shoulder. Parkways typically include a clear zone.

*Motor Vehicle Zone:* The primary travel way for through vehicles. A rural parkway would typically not have curb and gutter, and therefore the green zone would be relied on for drainage conveyance.

*Median Zone:* A landscaped zone located between the travel lanes in the center of the street. A wide median would be needed for drainage conveyance.

*Multi-Use Path Zone*: A zone for pedestrians and bicyclists in a multi-use path separate from the motor vehicle zone. Please see *Multi-Use Path Zone Typology* for more details.

*Development Zone:* Deep setbacks due to the typically auto-oriented nature of the street. Access to this zone is limited and controlled.

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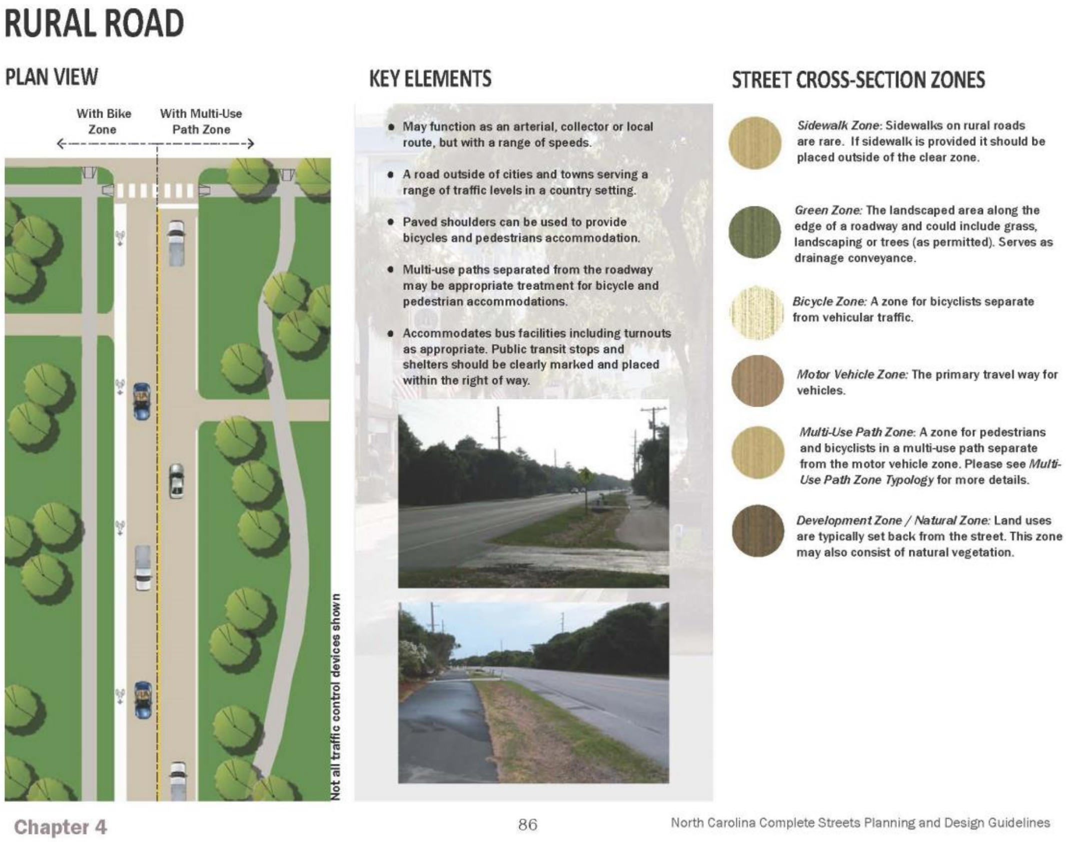
# RURAL ROAD

## PLAN VIEW



## KEY ELEMENTS

- May function as an arterial, collector or local route, but with a range of speeds.
- A road outside of cities and towns serving a range of traffic levels in a country setting.
- Paved shoulders can be used to provide bicycles and pedestrians accommodation.
- Multi-use paths separated from the roadway may be appropriate treatment for bicycle and pedestrian accommodations.
- Accommodates bus facilities including turnouts as appropriate. Public transit stops and shelters should be clearly marked and placed within the right of way.

## STREET CROSS-SECTION ZONES

*Sidewalk Zone:* Sidewalks on rural roads are rare. If sidewalk is provided it should be placed outside of the clear zone.

*Green Zone:* The landscaped area along the edge of a roadway and could include grass, landscaping or trees (as permitted). Serves as drainage conveyance.

*Bicycle Zone:* A zone for bicyclists separate from vehicular traffic.

*Motor Vehicle Zone:* The primary travel way for vehicles.

*Multi-Use Path Zone:* A zone for pedestrians and bicyclists in a multi-use path separate from the motor vehicle zone. Please see *Multi-Use Path Zone Typology* for more details.

*Development Zone / Natural Zone:* Land uses are typically set back from the street. This zone may also consist of natural vegetation.

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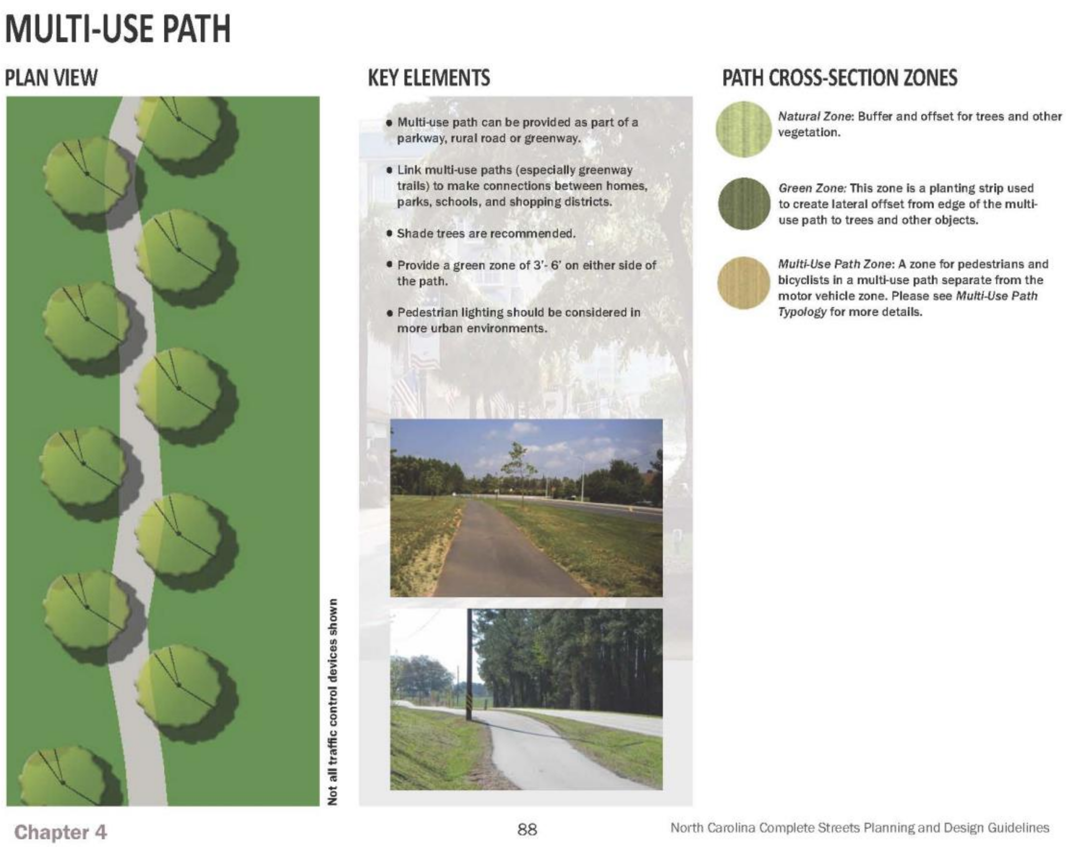

## MULTI-USE PATH

### PLAN VIEW

Not all traffic control devices shown

### KEY ELEMENTS

- Multi-use path can be provided as part of a parkway, rural road or greenway.
- Link multi-use paths (especially greenway trails) to make connections between homes, parks, schools, and shopping districts.
- Shade trees are recommended.
- Provide a green zone of 3'- 6' on either side of the path.
- Pedestrian lighting should be considered in more urban environments.

### PATH CROSS-SECTION ZONES

*Natural Zone*: Buffer and offset for trees and other vegetation.

*Green Zone:* This zone is a planting strip used to create lateral offset from edge of the multi-use path to trees and other objects.

*Multi-Use Path Zone*: A zone for pedestrians and bicyclists in a multi-use path separate from the motor vehicle zone. Please see *Multi-Use Path Typology* for more details.

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# LOCAL / SUBDIVISION STREET: RESIDENTIAL

## PLAN VIEW


## KEY ELEMENTS

- Carries traffic at a low speed.
- Street within a neighborhood or residential development providing direct access to land use.
- Provides additional linkages and connections within and to the overall street network.
- On-street parking typically occurs at different levels depending on land use characteristics. Parking demand will affect street width.
- Pedestrian activity is expected, encouraged, and to be accommodated.
- Local streets provide important connections in the bicycle network.
- Bike lanes are typically not necessary due to low speed and volumes, but are allowed. In some cases, local streets can serve as parallel bicycle or transit route to heavier traveled streets.

## STREET CROSS-SECTION ZONES

*Development Zone:* Density and setbacks will vary, but all should be oriented to the street to support pedestrian access and activity along the street.

*Sidewalk Zone:* The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably.

*Green Zone:* Consists of a planting strip (or, in very urban areas, a hardscaped area), with street trees between the sidewalk zone and the edge of street.

*Shared Vehicle and Parking Zone:* The primary travel way that includes mixed traffic (cars, trucks, buses and bicycles) and on-street parking. Local streets will be two lanes with varying provisions for parking.

* The discussion of local streets begins on page 59.

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# LOCAL / SUBDIVISION: OFFICE, COMMERCIAL AND INDUSTRIAL

## PLAN VIEW


## KEY ELEMENTS

- Carries traffic at a low speed.
- Street providing local access to adjacent office, commercial, or industrial development.
- Provides additional linkages and connections within and to the overall street network.
- On street parking typically occurs although at different levels depending on land use characteristics. Parking demand will affect street width. In industrial areas, this can include parking for larger vehicles.
- Pedestrian activity is expected, encouraged, and to be accommodated on these streets.
- Bike lanes typically not required due to low parking volumes.

## STREET CROSS-SECTION ZONES

*Development Zone:* Development types and setbacks will vary, but all should be oriented to the street to support pedestrian access and activity. The most pedestrian oriented development types will have small setbacks, entrances directly onto the sidewalk zone, and will front streets that include on-street parking.

*Sidewalk Zone*: The pedestrian walk area is of sufficient width to allow pedestrians to walk safely and comfortably.

*Green Zone:* Consists of a planting strip (or, in very urban areas, a hardscaped area), with street trees between the sidewalk zone and the edge of street.

*Shared Vehicle and Parking Zone:* The primary travel way that includes mixed traffic (cars, trucks, buses and bicycles) and on-street parking. Local streets will be two lanes with varying provisions for parking.

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pedestrian volume is checked. It is also recommended to consider pedestrian signal head installations where:

- The estimated pedestrian volume is above a specified "low volume" threshold discussed below,
- To be consistent with adjacent intersections (e.g. in a downtown area), or
- Where they may otherwise enhance pedestrian safety.

#### *1.3.2.1 Check for 2009 MUTCD 4E.03 Conditions*

At a signalized crossing location, the evaluator must review the crossing to determine if it meets any of the conditions listed in 4E.03 of the MUTCD:

*01 Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions:*

*A. If a traffic control signal is justified by an engineering study and meets either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see Chapter 4C);*

*B. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped;*

*C. At an established school crossing at any signalized location; or*

*D. Where engineering judgment determines that multi-phase signal indications (as with split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications.* (Federal Highway Administration, 2009)

If the crossing meets any of items A through D, then the standard **requires** that pedestrian signal heads be installed. Installed pedestrian signal heads should conform to MUTCD's guidance on signal timing to provide sufficient pedestrian clearance times for crossing. See Section 4E.06 of the 2009 MUTCD for further details.

*Figure 6 Protective-permissive left turn signals may be confusing to pedestrians attempting to rely on the vehicular traffic signals to know when it is their turn to cross, and therefore engineering judgement must determine whether Section 1.3.2.1 D of the 2009 MUTCD applies.*

#### *1.3.2.2 Check Estimated Pedestrian Volume*

In most cases, existing pedestrian volume data will be sparse. Therefore, two primary options are available to gather such data: 1) conduct an observational study or 2) estimate volume using proxy measures.

If the evaluator elects to conduct a study, the following is recommended to gather pedestrian counts:

- Seven continuous days of counts are preferred, when possible. Where resources are not available to collect a week's worth of data, a minimum of one weekend and one weekday should be collected. The days of the week selected should target when the highest pedestrian activity is expected.[7]

- Restricting data collection to during daylight hours only is acceptable unless the land use context around the site suggests that nighttime pedestrian activity should be expected.
- Counts at the potential crossing location under study should include pedestrians that cross within 150 feet of either side of the crossing.
- Coordinate effort with the Division of Bicycle and Pedestrian Transportation for feedback on additional or unique site-specific considerations prior to conducting the study, and to obtain guidance on data collection protocols for pedestrian studies.

When observational data does not exist and will not be collected, proxy measures can be estimated based on land use context and are sufficient to estimate pedestrian volume at a crossing. Crossings that are near pedestrian trip generators or destinations, or those that may connect complementary land uses should be considered for enhancement. Where proxy measures are used, they should be well documented in the evaluator's assessment.

Because existing pedestrian volume data is limited, the evaluator must use engineering judgement to choose the appropriate low volume threshold from the following considerations:

- The crossing area has less than 25 pedestrians per pedestrian peak hour OR less than 100 pedestrians per day.
- At mid-block locations only: crossing area has less than 25 pedestrians per pedestrian peak hour for at least four hours. (NCDOT, 2008)
- The crossing area is not near high pedestrian trip generators.
- The crossing area does not connect complementary land uses.

Lower volume thresholds may be considered for crossings with a significant presence of a special population, such as children or the elderly. Where the estimated pedestrian volume is considered low, no action is required.

[7]Bicycle and pedestrian volumes are lower and more variable due to weather (e.g., temperature and precipitation) and other factors than motor vehicle traffic. Therefore, it is more difficult to calculate AADT from shorter durations than seven days. (Nordback, Marshall, Janson, & Stolz, 2013) The *Traffic Monitoring Guide* suggests a 7 day duration, noting that "depending on several other factors…the preferred duration of automatic counts could be as long as 14 days." If manual observers are used to collect the counts due to resource limitations, a 12-hour count is preferred. (Federal Highway Administration, 2013)

## US LIMITS 2 Flow Charts

# Decision Rules for the Expert System

This document contains flow charts describing the decision rules for the expert system for recommending speed limits in speed zones that was developed as a part of NCHRP Project 3-67.

### Terms:

**Closest 85th**

This is the 5 mph increment that is closest to the 85th percentile speed (e.g., if the 85th percentile speed is 63 mph, the Closest_85th will be 65 mph)

**Rounded-down 85th**

This is the 5 mph increment obtained by rounding down the 85th percentile to the nearest 5 mph increment (e.g., if the 85th percentile speed is 63 mph, the Rounded-down_85th will be 60 mph)

**Closest 50th**

This is the 5 mph increment that is closest to the 50th percentile speed (e.g., if the 50th percentile speed is 58 mph, the Closest_50th will be 60 mph)

**SL_1**

Speed limit calculated using safety surrogates

**SL_2**

Speed limit calculated using crash data from the crash module

**SL**

Recommended speed limit

**L.A.F.**

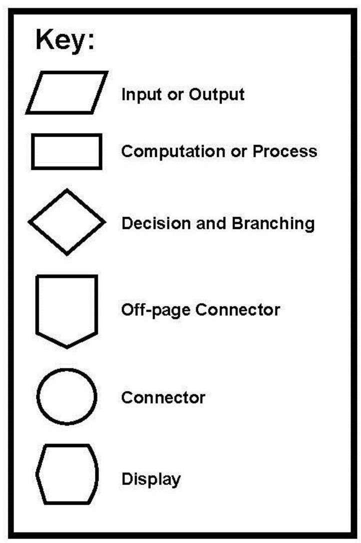
Limited Access Freeway

**R.S.I.U.A.**

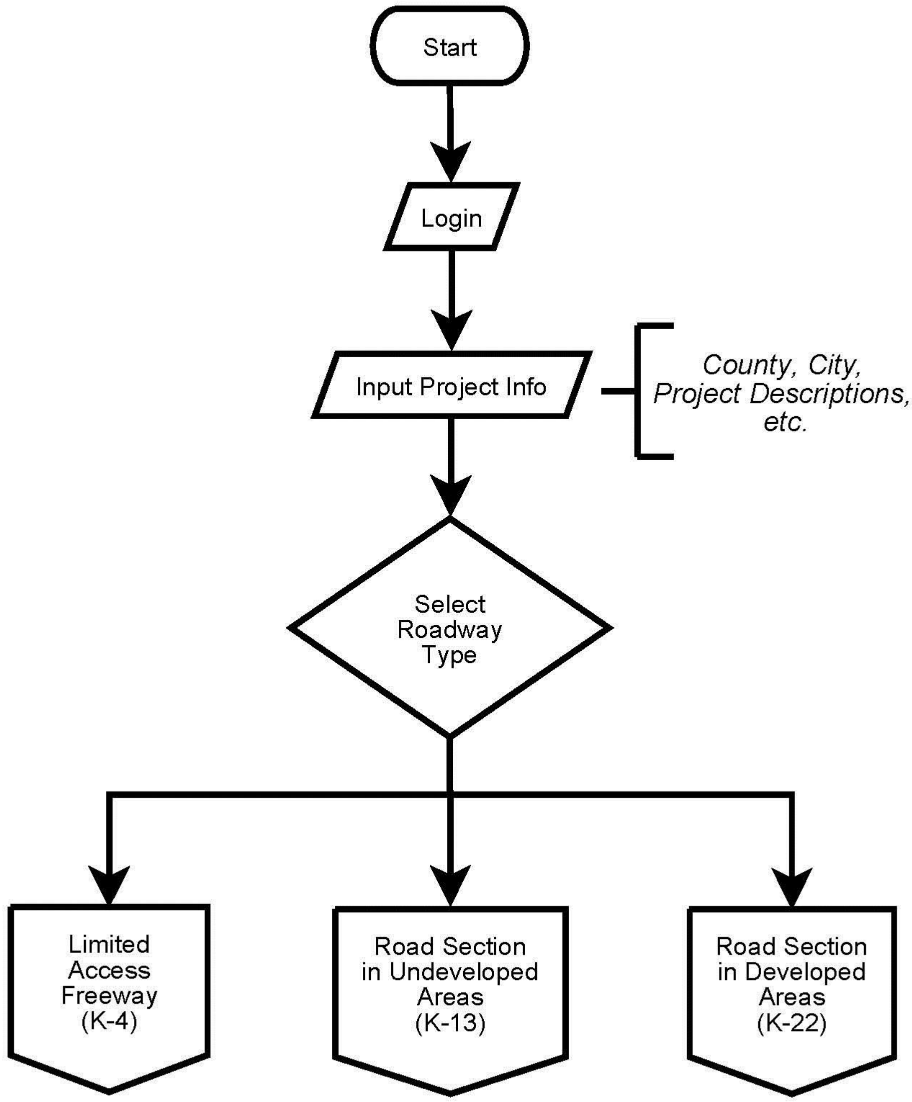
Road Sections in Undeveloped Areas

**R.S.I.D.A.**

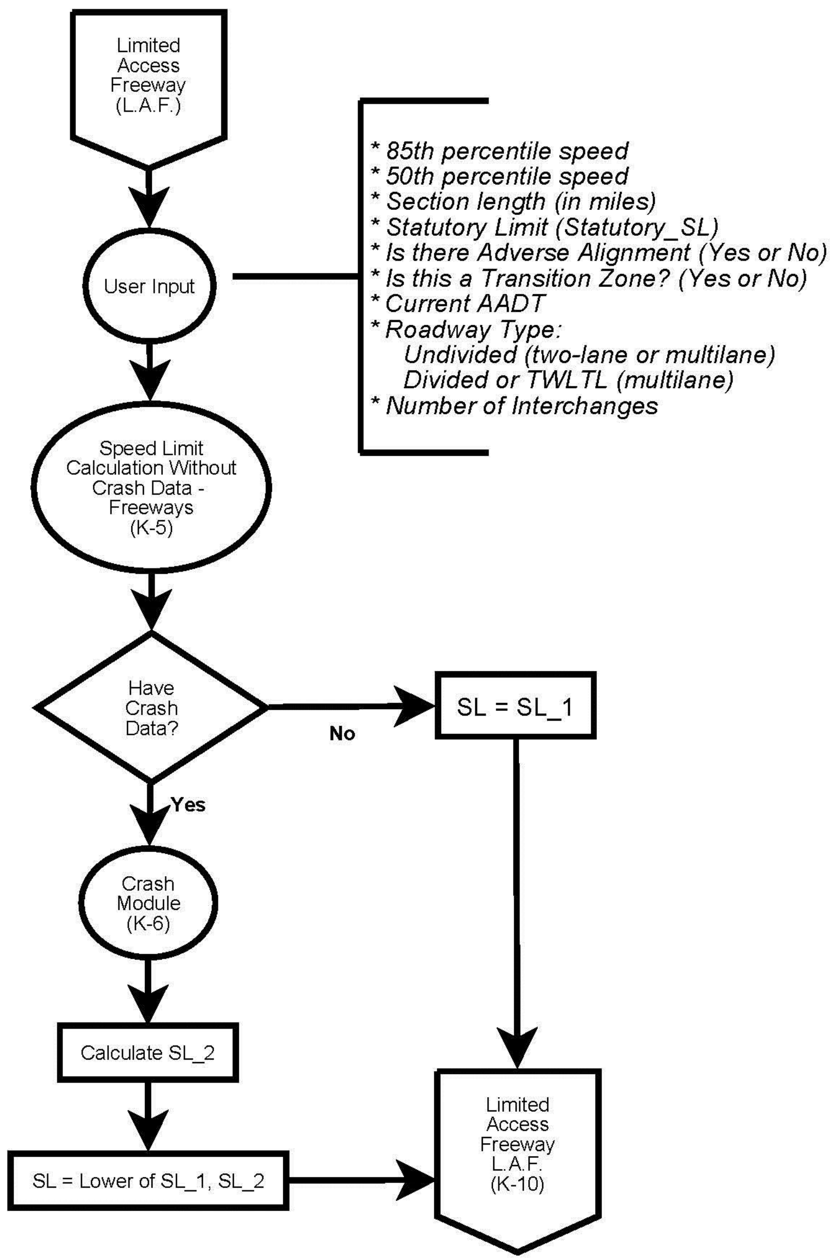
Road Sections in Developed Areas




K-2

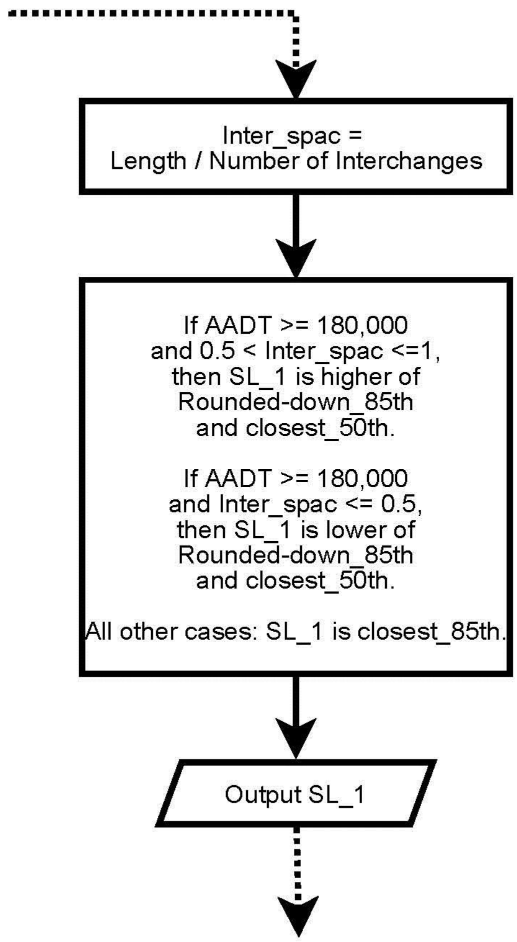

Start
Login
Input Project Info
County, City, Project Descriptions, etc.
Select Roadway Type
Limited Access Freeway (K-4)
Road Section in Undeveloped Areas (K-13)
Road Section in Developed Areas (K-22)

K-3

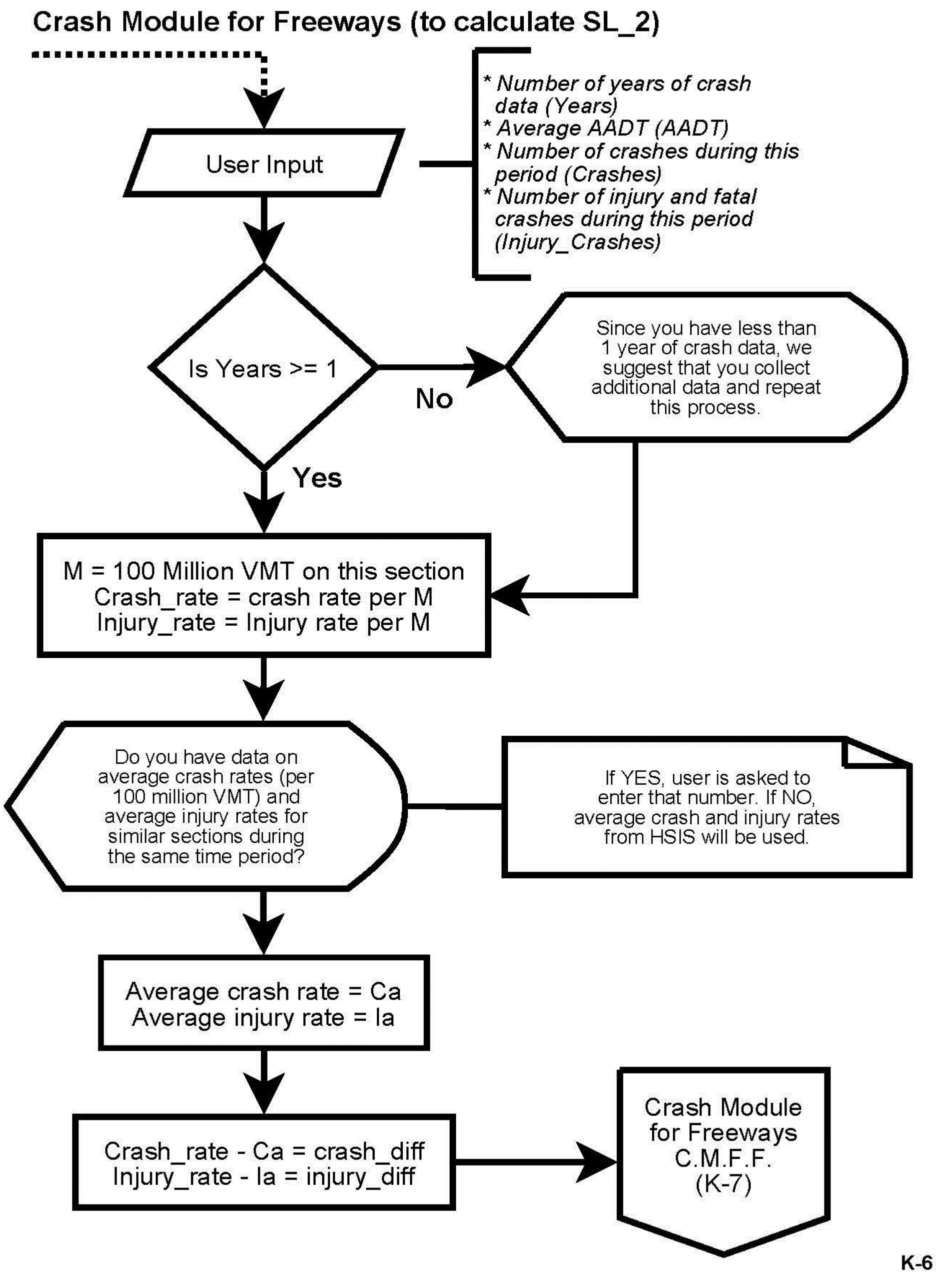

Limited
Access
Freeway
(L.A.F.)
User Input
* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Is this a Transition Zone? (Yes or No)
* Current AADT
* Roadway Type:
Undivided (two-lane or multilane)
Divided or TWLTL (multilane)
* Number of Interchanges
Speed Limit
Calculation Without
Crash Data -
Freeways
(K-5)
Have
Crash
Data?
No
SL = SL_1
Yes
Crash
Module
(K-6)
Calculate SL_2
SL = Lower of SL_1, SL_2
Limited
Access
Freeway
L.A.F.
(K-10)

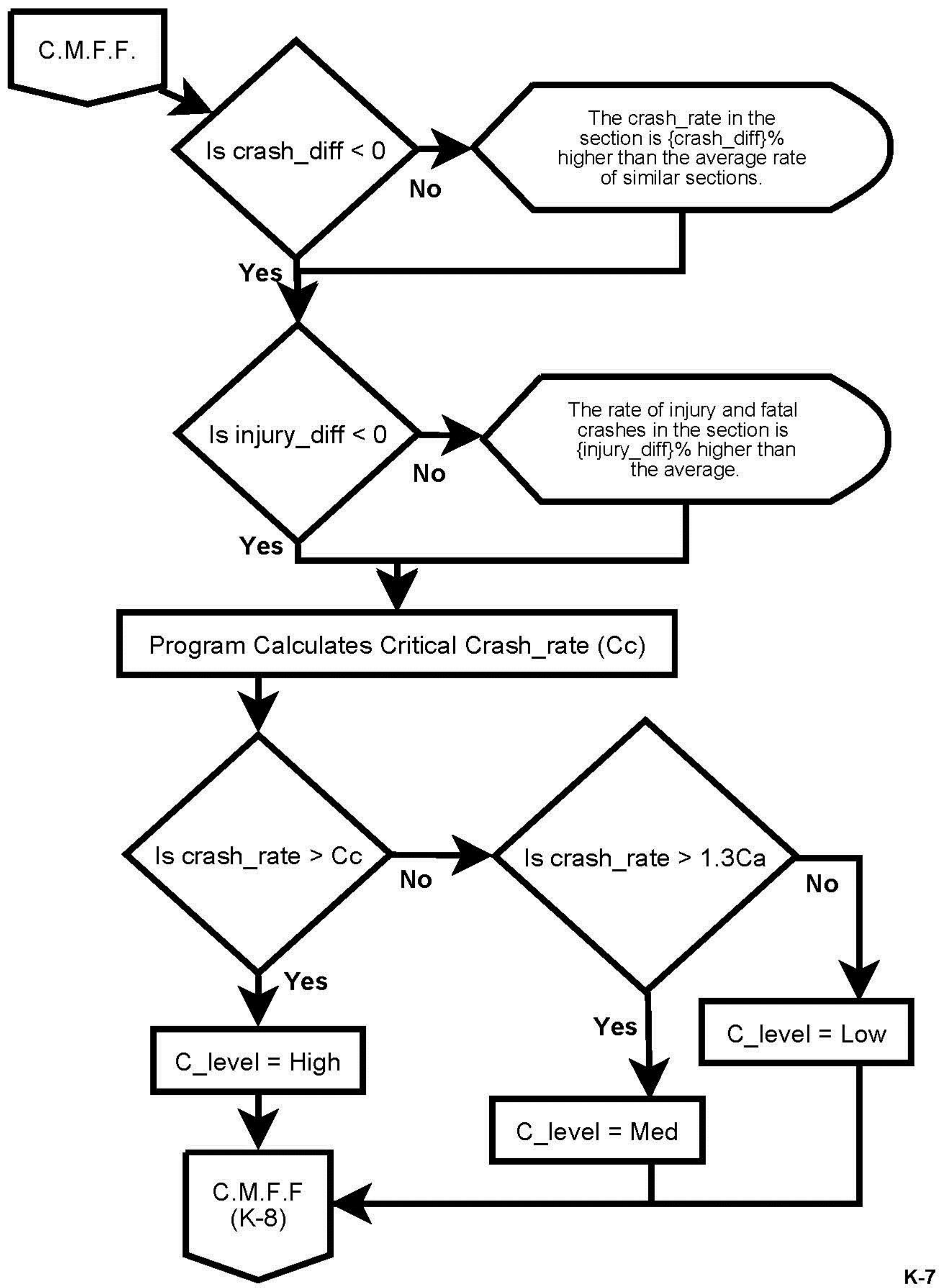
K-4

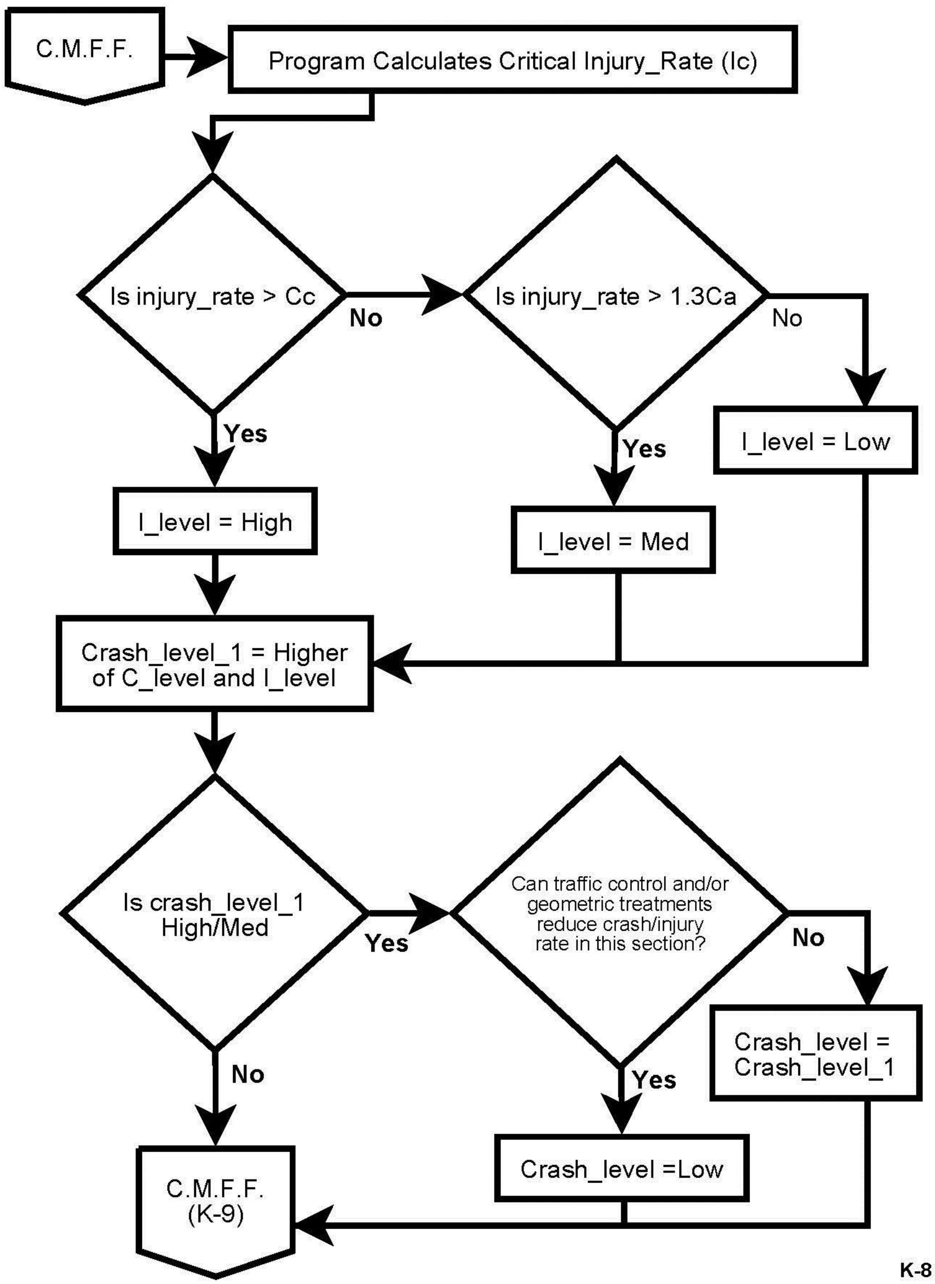
**Speed Limit Calculation Without Crash Data (to calculate SL_1)**
**(Limited Access Freeway)**

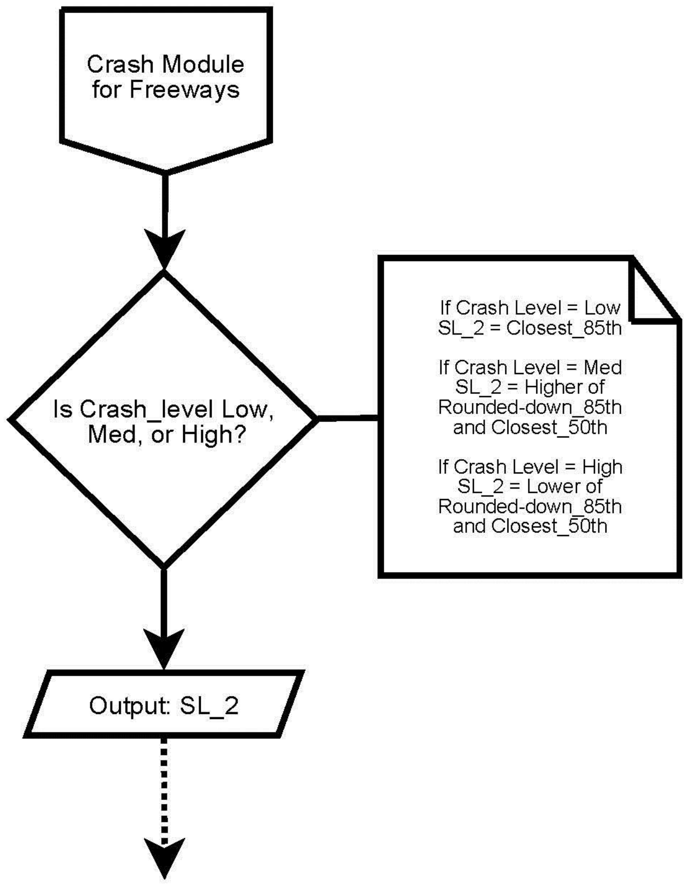



K-5

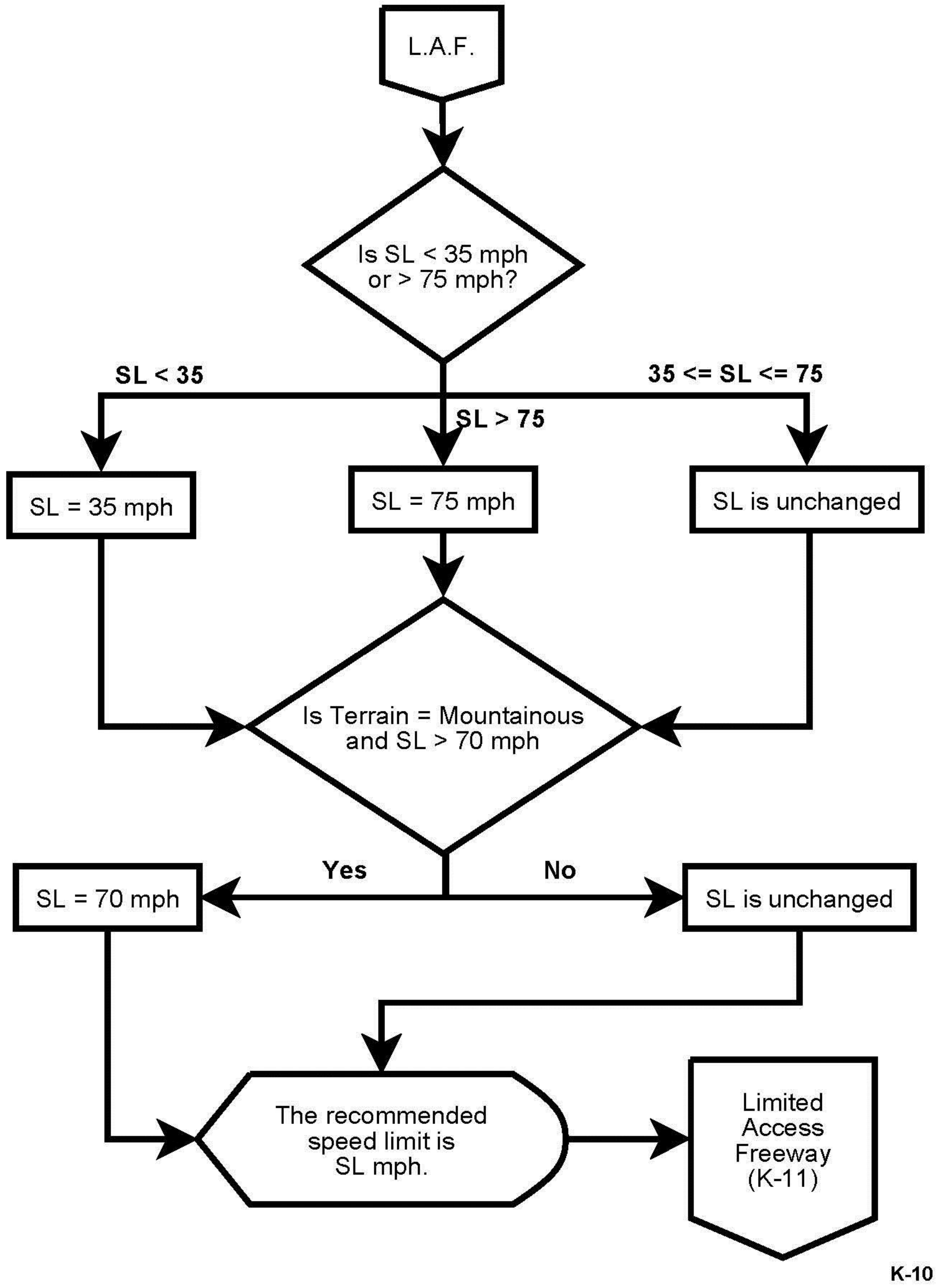

Crash Module for Freeways (to calculate SL_2)
User Input
* Number of years of crash data (Years)
* Average AADT (AADT)
* Number of crashes during this period (Crashes)
* Number of injury and fatal crashes during this period (Injury_Crashes)
Is Years >= 1
No
Since you have less than 1 year of crash data, we suggest that you collect additional data and repeat this process.
Yes
M = 100 Million VMT on this section
Crash_rate = crash rate per M
Injury_rate = Injury rate per M
Do you have data on average crash rates (per 100 million VMT) and average injury rates for similar sections during the same time period?
If YES, user is asked to enter that number. If NO, average crash and injury rates from HSIS will be used.
Average crash rate = Ca
Average injury rate = Ia
Crash_rate - Ca = crash_diff
Injury_rate - Ia = injury_diff
Crash Module for Freeways C.M.F.F. (K-7)
K-6

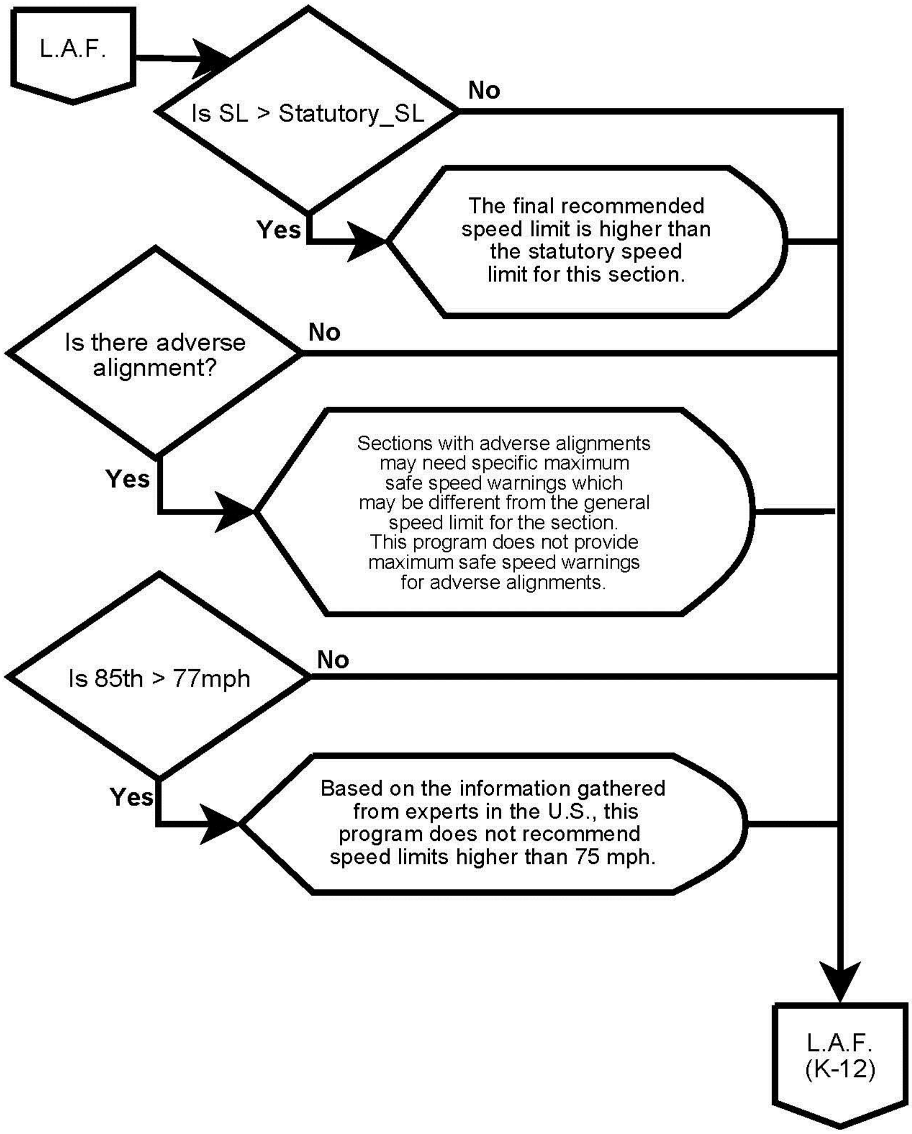

C.M.F.F.
Is crash_diff < 0
No
The crash_rate in the section is {crash_diff}% higher than the average rate of similar sections.
Yes
Is injury_diff < 0
No
The rate of injury and fatal crashes in the section is {injury_diff}% higher than the average.
Yes
Program Calculates Critical Crash_rate (Cc)
Is crash_rate > Cc
No
Is crash_rate > 1.3Ca
No
Yes
C_level = High
Yes
C_level = Low
C_level = Med
C.M.F.F
(K-8)
K-7


C.M.F.F.
Program Calculates Critical Injury_Rate (Ic)
Is injury_rate > Cc
No
Is injury_rate > 1.3Ca
No
Yes
Yes
I_level = Low
I_level = High
I_level = Med
Crash_level_1 = Higher of C_level and I_level
Is crash_level_1 High/Med
Yes
Can traffic control and/or geometric treatments reduce crash/injury rate in this section?
No
Crash_level = Crash_level_1
No
Yes
C.M.F.F. (K-9)
Crash_level =Low
K-8

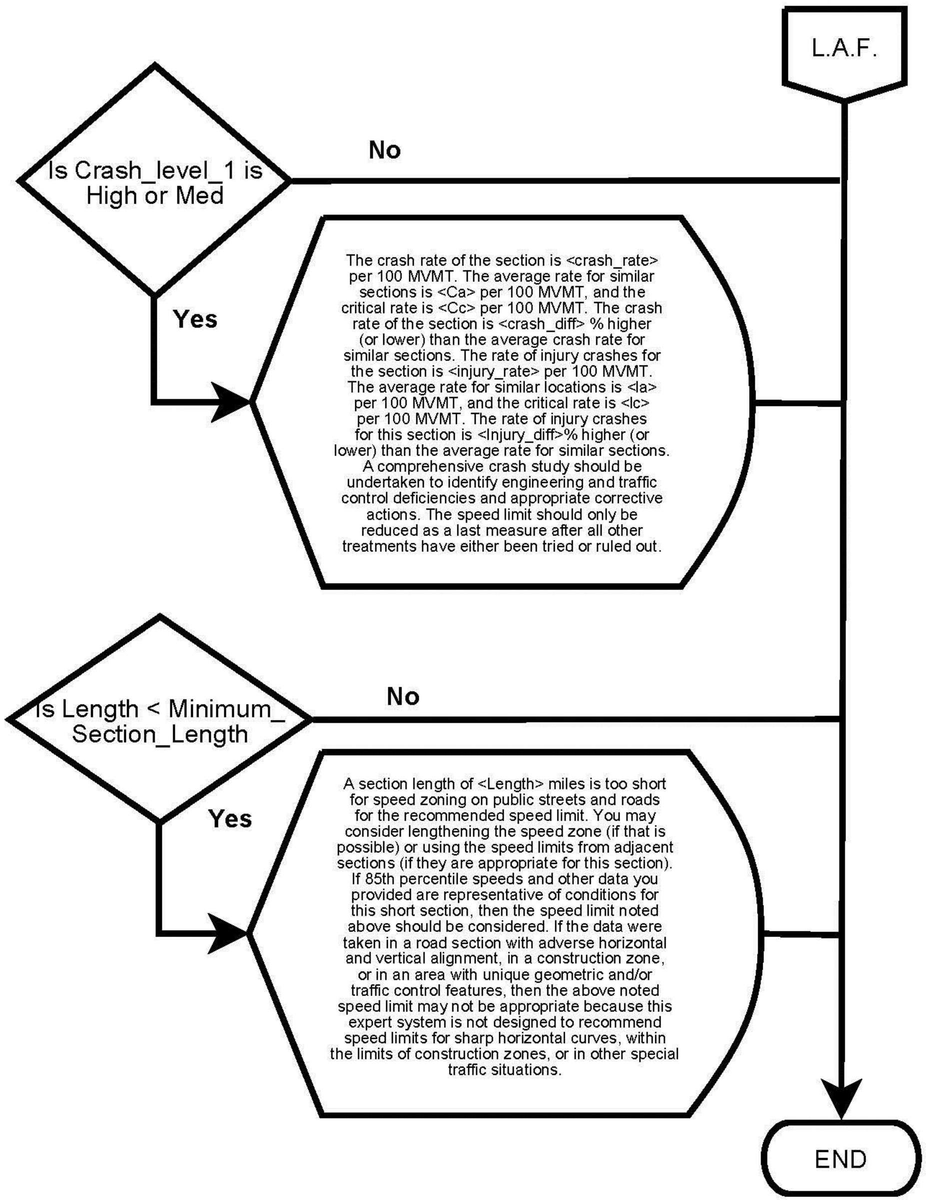

Crash Module for Freeways
Is Crash_level Low, Med, or High?
If Crash Level = Low SL_2 = Closest_85th
If Crash Level = Med SL_2 = Higher of Rounded-down_85th and Closest_50th
If Crash Level = High SL_2 = Lower of Rounded-down_85th and Closest_50th
Output: SL_2

K-9

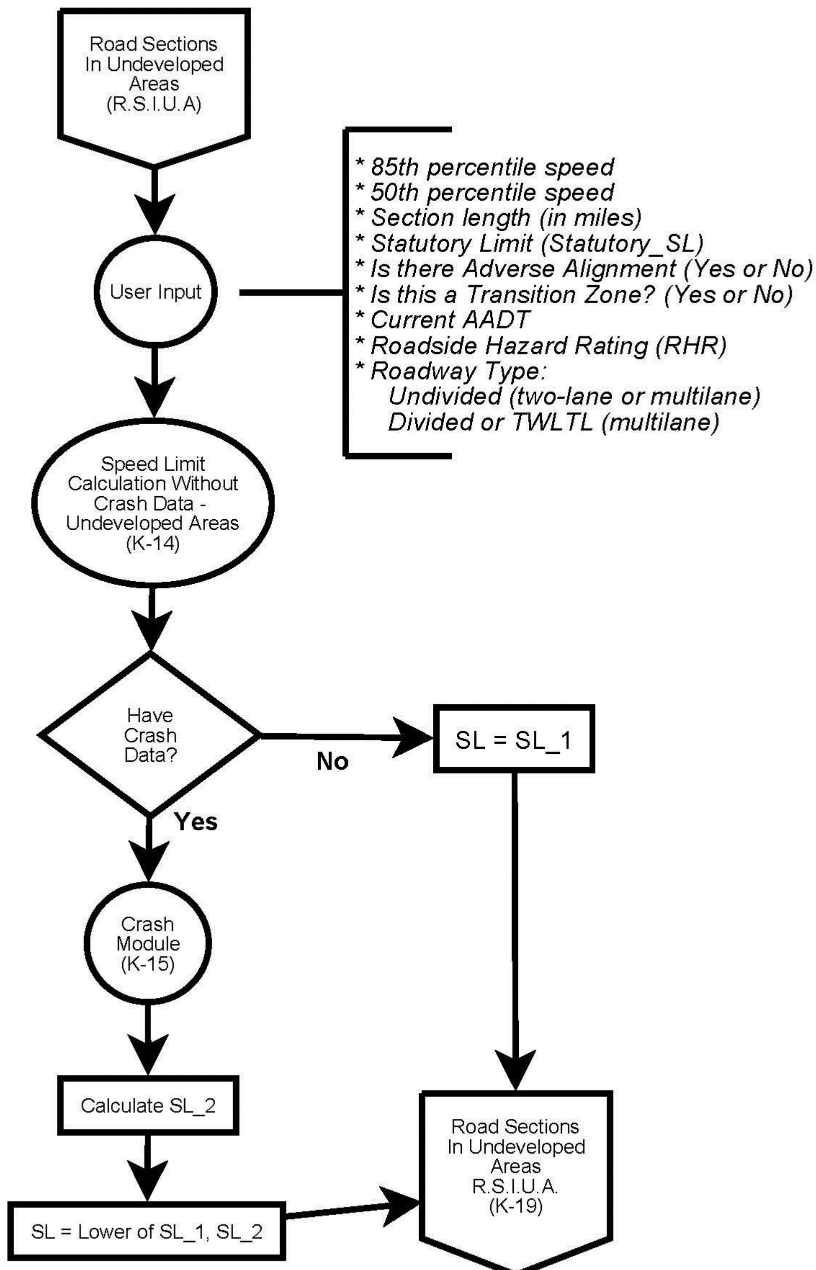

L.A.F.
Is SL < 35 mph or > 75 mph?
SL < 35
SL > 75
35 <= SL <= 75
SL = 35 mph
SL = 75 mph
SL is unchanged
Is Terrain = Mountainous and SL > 70 mph
Yes
No
SL = 70 mph
SL is unchanged
The recommended speed limit is SL mph.
Limited Access Freeway (K-11)
K-10


L.A.F.
Is SL > Statutory_SL
No
Yes
The final recommended speed limit is higher than the statutory speed limit for this section.
Is there adverse alignment?
No
Yes
Sections with adverse alignments may need specific maximum safe speed warnings which may be different from the general speed limit for the section. This program does not provide maximum safe speed warnings for adverse alignments.
Is 85th > 77mph
No
Yes
Based on the information gathered from experts in the U.S., this program does not recommend speed limits higher than 75 mph.
L.A.F. (K-12)

K-11


L.A.F.
Is Crash_level_1 is High or Med
No
Yes
The crash rate of the section is <crash_rate> per 100 MVMT. The average rate for similar sections is <Ca> per 100 MVMT, and the critical rate is <Cc> per 100 MVMT. The crash rate of the section is <crash_diff> % higher (or lower) than the average crash rate for similar sections. The rate of injury crashes for the section is <injury_rate> per 100 MVMT. The average rate for similar locations is <Ia> per 100 MVMT, and the critical rate is <Ic> per 100 MVMT. The rate of injury crashes for this section is <Injury_diff>% higher (or lower) than the average rate for similar sections. A comprehensive crash study should be undertaken to identify engineering and traffic control deficiencies and appropriate corrective actions. The speed limit should only be reduced as a last measure after all other treatments have either been tried or ruled out.
Is Length < Minimum_ Section_Length
No
Yes
A section length of <Length> miles is too short for speed zoning on public streets and roads for the recommended speed limit. You may consider lengthening the speed zone (if that is possible) or using the speed limits from adjacent sections (if they are appropriate for this section). If 85th percentile speeds and other data you provided are representative of conditions for this short section, then the speed limit noted above should be considered. If the data were taken in a road section with adverse horizontal and vertical alignment, in a construction zone, or in an area with unique geometric and/or traffic control features, then the above noted speed limit may not be appropriate because this expert system is not designed to recommend speed limits for sharp horizontal curves, within the limits of construction zones, or in other special traffic situations.
END

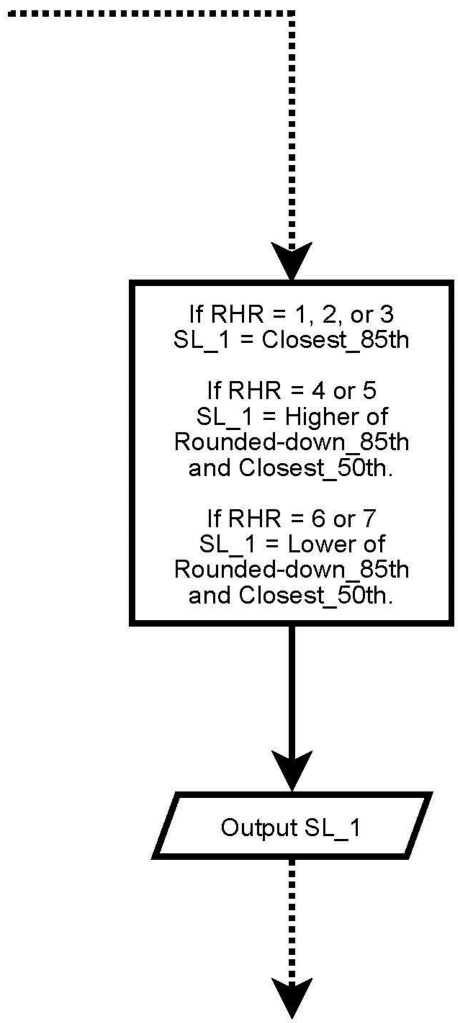
K-12



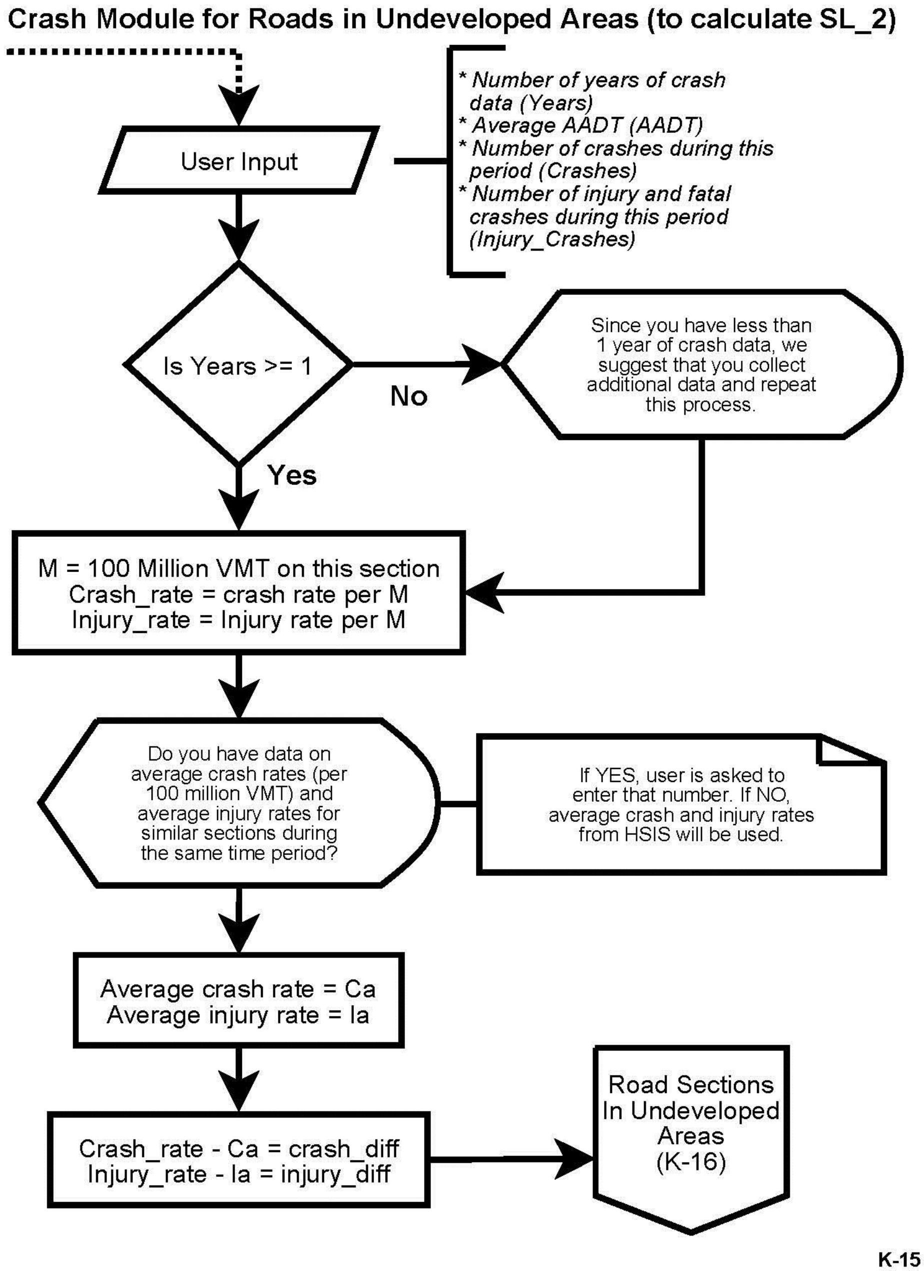
Road Sections In Undeveloped Areas (R.S.I.U.A)
User Input
* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Is this a Transition Zone? (Yes or No)
* Current AADT
* Roadside Hazard Rating (RHR)
* Roadway Type:
Undivided (two-lane or multilane)
Divided or TWLTL (multilane)
Speed Limit Calculation Without Crash Data - Undeveloped Areas (K-14)
Have Crash Data?
No
SL = SL_1
Yes
Crash Module (K-15)
Calculate SL_2
SL = Lower of SL_1, SL_2
Road Sections In Undeveloped Areas R.S.I.U.A. (K-19)


K-13

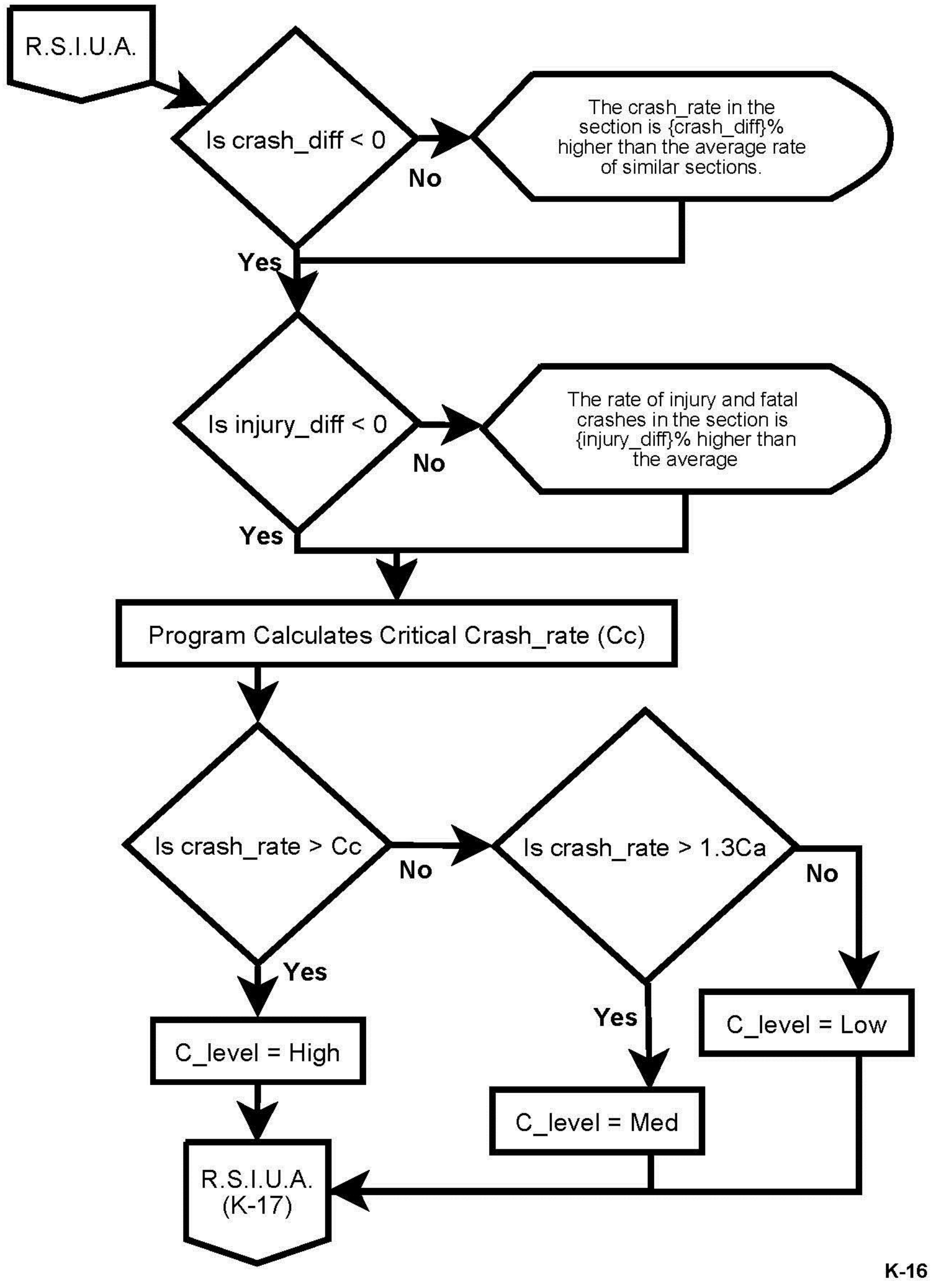
**Speed Limit Calculation Without Crash Data (to calculate SL_1)**
**(Roadway Section In Undeveloped Areas)**

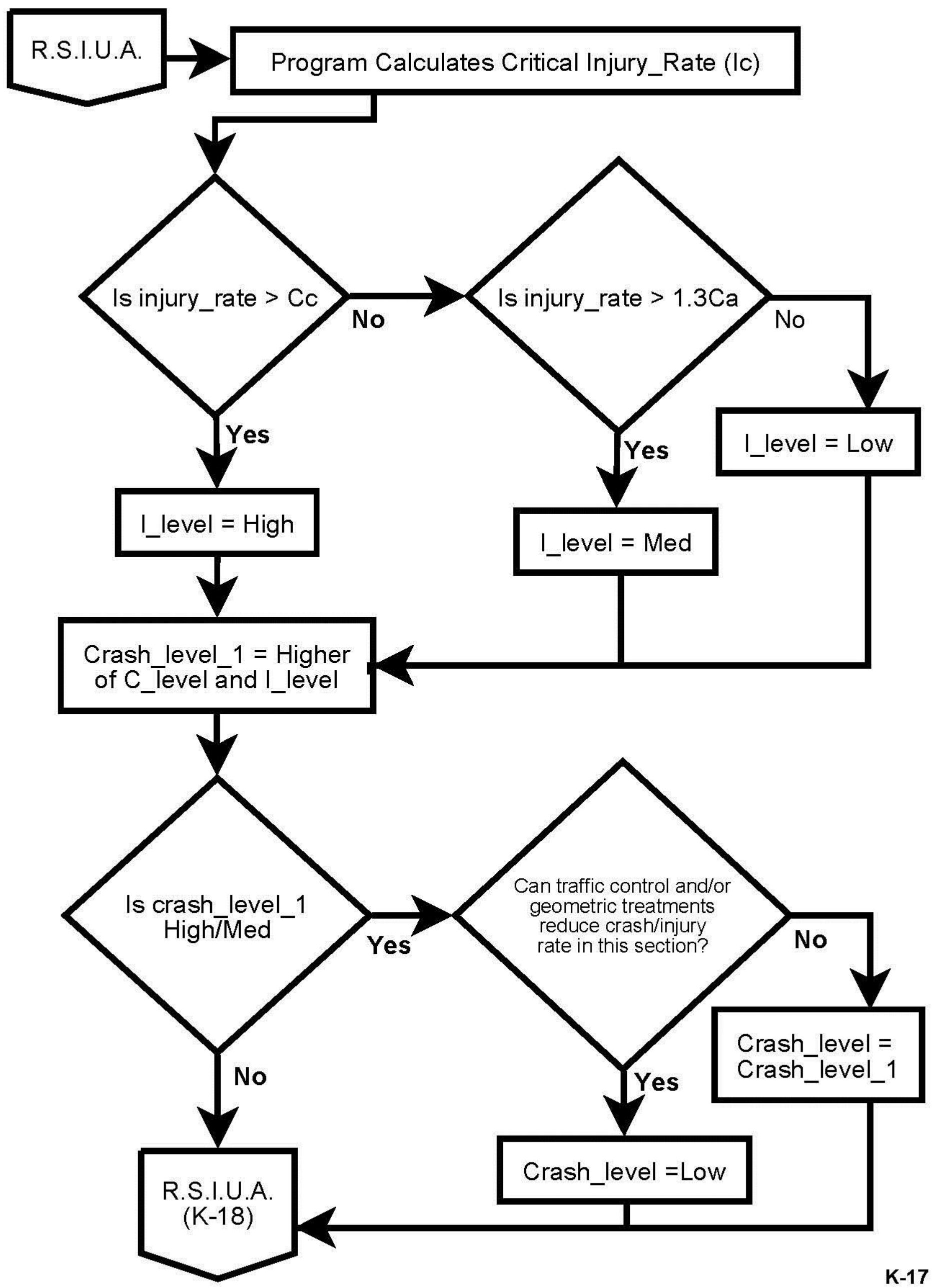


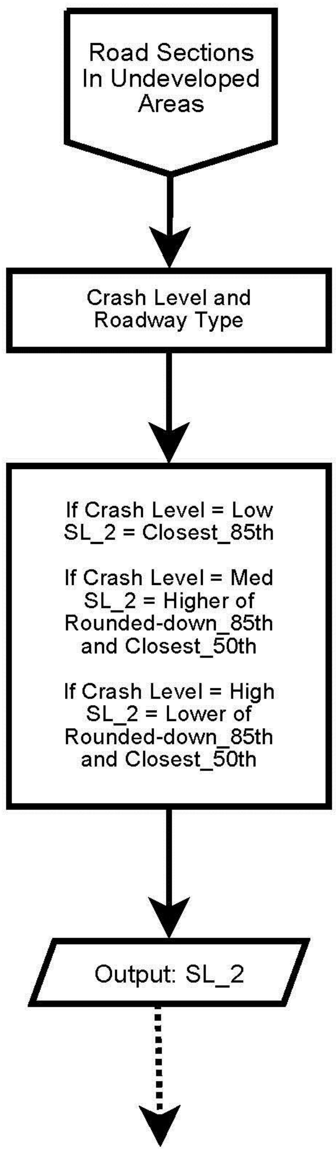

K-14



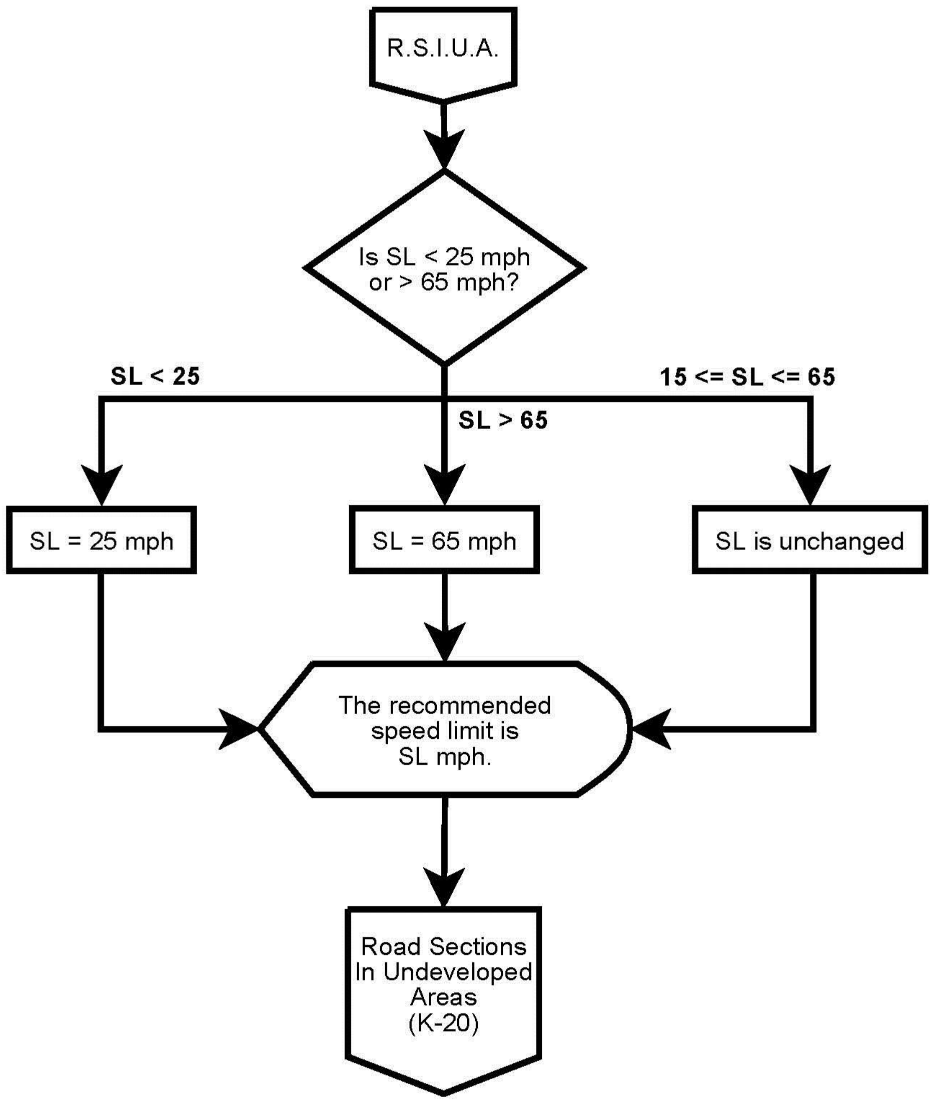
Crash Module for Roads in Undeveloped Areas (to calculate SL_2)
User Input
* Number of years of crash data (Years)
* Average AADT (AADT)
* Number of crashes during this period (Crashes)
* Number of injury and fatal crashes during this period (Injury_Crashes)
Is Years >= 1
No
Since you have less than 1 year of crash data, we suggest that you collect additional data and repeat this process.
Yes
M = 100 Million VMT on this section
Crash_rate = crash rate per M
Injury_rate = Injury rate per M
Do you have data on average crash rates (per 100 million VMT) and average injury rates for similar sections during the same time period?
If YES, user is asked to enter that number. If NO, average crash and injury rates from HSIS will be used.
Average crash rate = Ca
Average injury rate = Ia
Crash_rate - Ca = crash_diff
Injury_rate - Ia = injury_diff
Road Sections In Undeveloped Areas (K-16)
K-15


R.S.I.U.A.
Is crash_diff < 0
No
The crash_rate in the section is {crash_diff}% higher than the average rate of similar sections.
Yes
Is injury_diff < 0
No
The rate of injury and fatal crashes in the section is {injury_diff}% higher than the average
Yes
Program Calculates Critical Crash_rate (Cc)
Is crash_rate > Cc
No
Is crash_rate > 1.3Ca
No
Yes
C_level = High
Yes
C_level = Low
C_level = Med
R.S.I.U.A. (K-17)
K-16

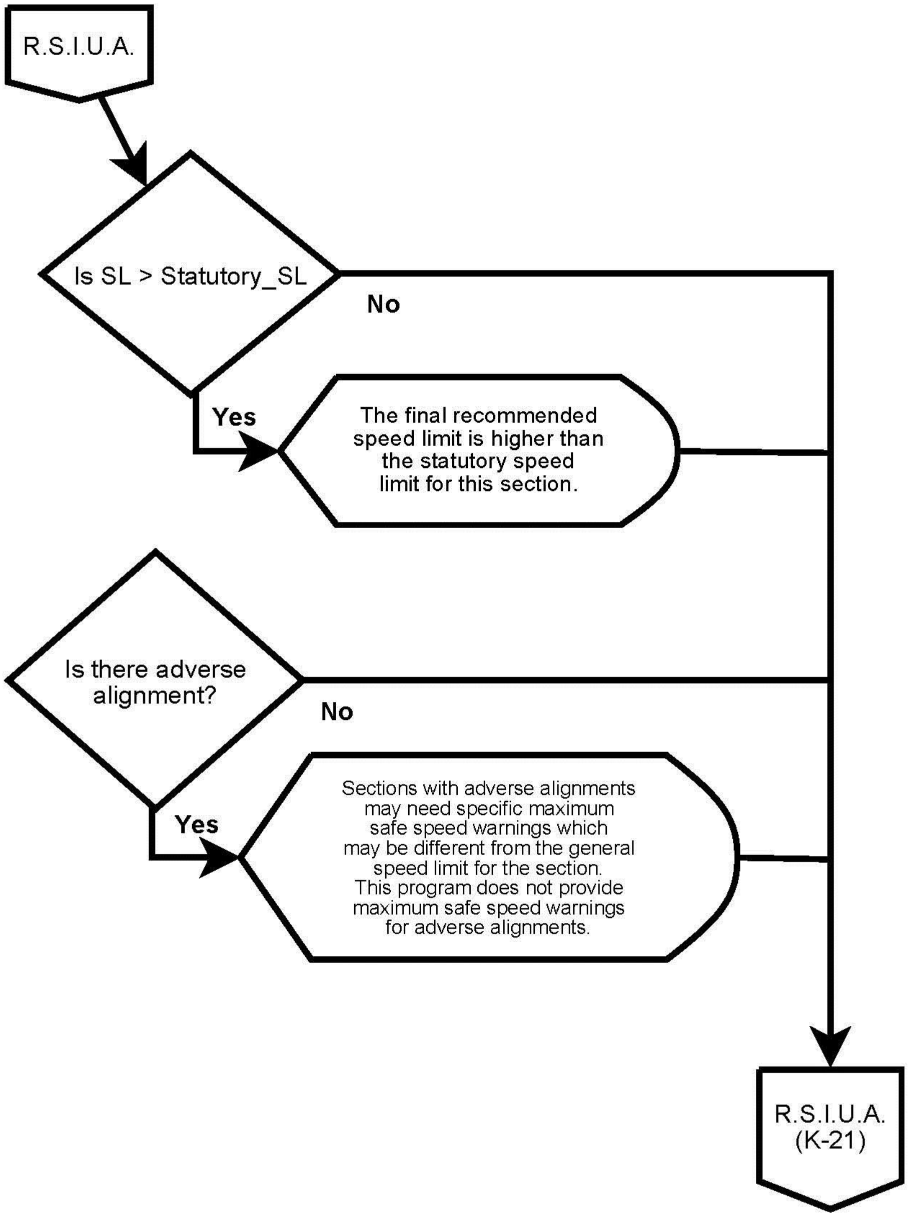

R.S.I.U.A.
Program Calculates Critical Injury_Rate (Ic)
Is injury_rate > Cc
No
Is injury_rate > 1.3Ca
No
Yes
Yes
I_level = Low
I_level = High
I_level = Med
Crash_level_1 = Higher of C_level and I_level
Is crash_level_1 High/Med
Yes
Can traffic control and/or geometric treatments reduce crash/injury rate in this section?
No
Crash_level = Crash_level_1
No
Yes
Crash_level =Low
R.S.I.U.A. (K-18)
K-17


Road Sections In Undeveloped Areas
Crash Level and Roadway Type
If Crash Level = Low SL_2 = Closest_85th
If Crash Level = Med SL_2 = Higher of Rounded-down_85th and Closest_50th
If Crash Level = High SL_2 = Lower of Rounded-down_85th and Closest_50th
Output: SL_2

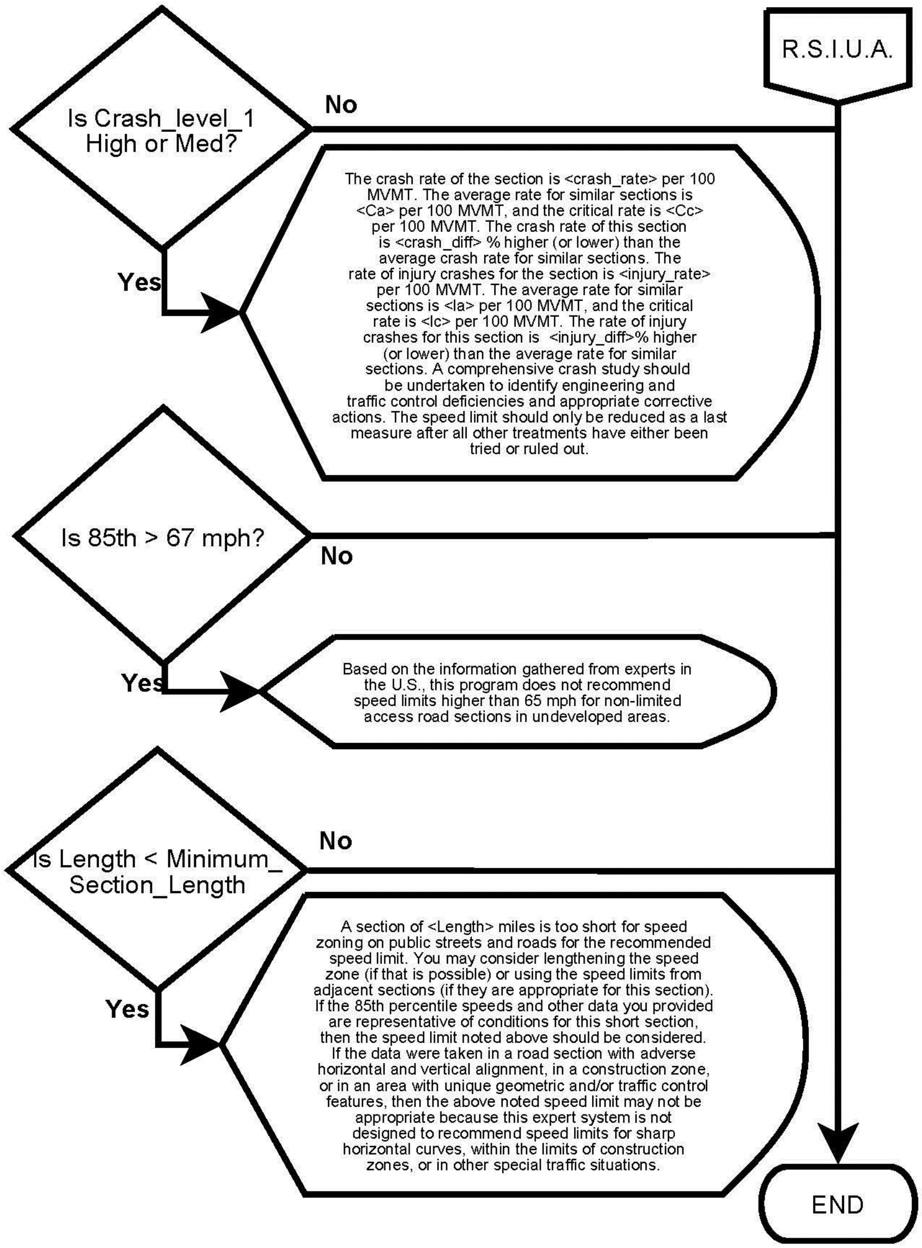
K-18


R.S.I.U.A.
Is SL < 25 mph or > 65 mph?
SL < 25
SL > 65
15 <= SL <= 65
SL = 25 mph
SL = 65 mph
SL is unchanged
The recommended speed limit is SL mph.
Road Sections In Undeveloped Areas (K-20)

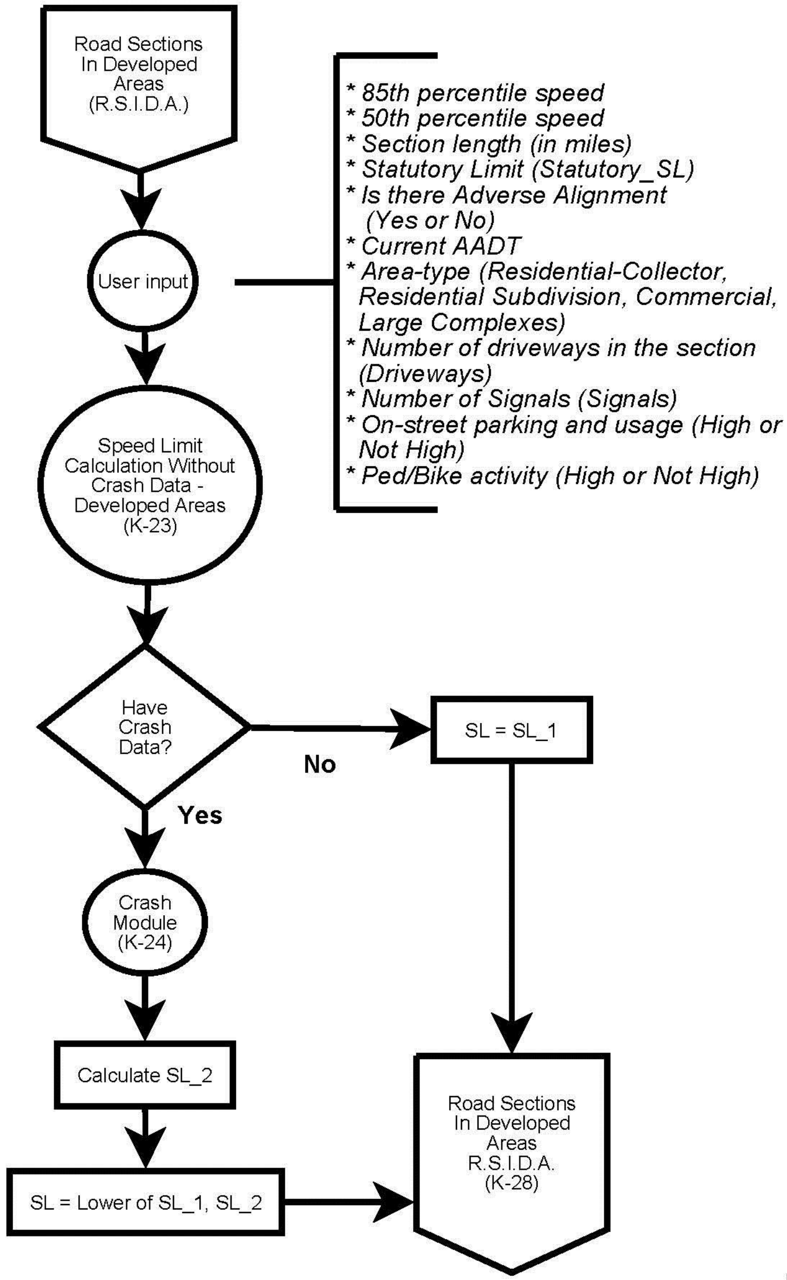
K-19


R.S.I.U.A.
Is SL > Statutory_SL
No
Yes
The final recommended speed limit is higher than the statutory speed limit for this section.
Is there adverse alignment?
No
Yes
Sections with adverse alignments may need specific maximum safe speed warnings which may be different from the general speed limit for the section. This program does not provide maximum safe speed warnings for adverse alignments.
R.S.I.U.A. (K-21)

K-20

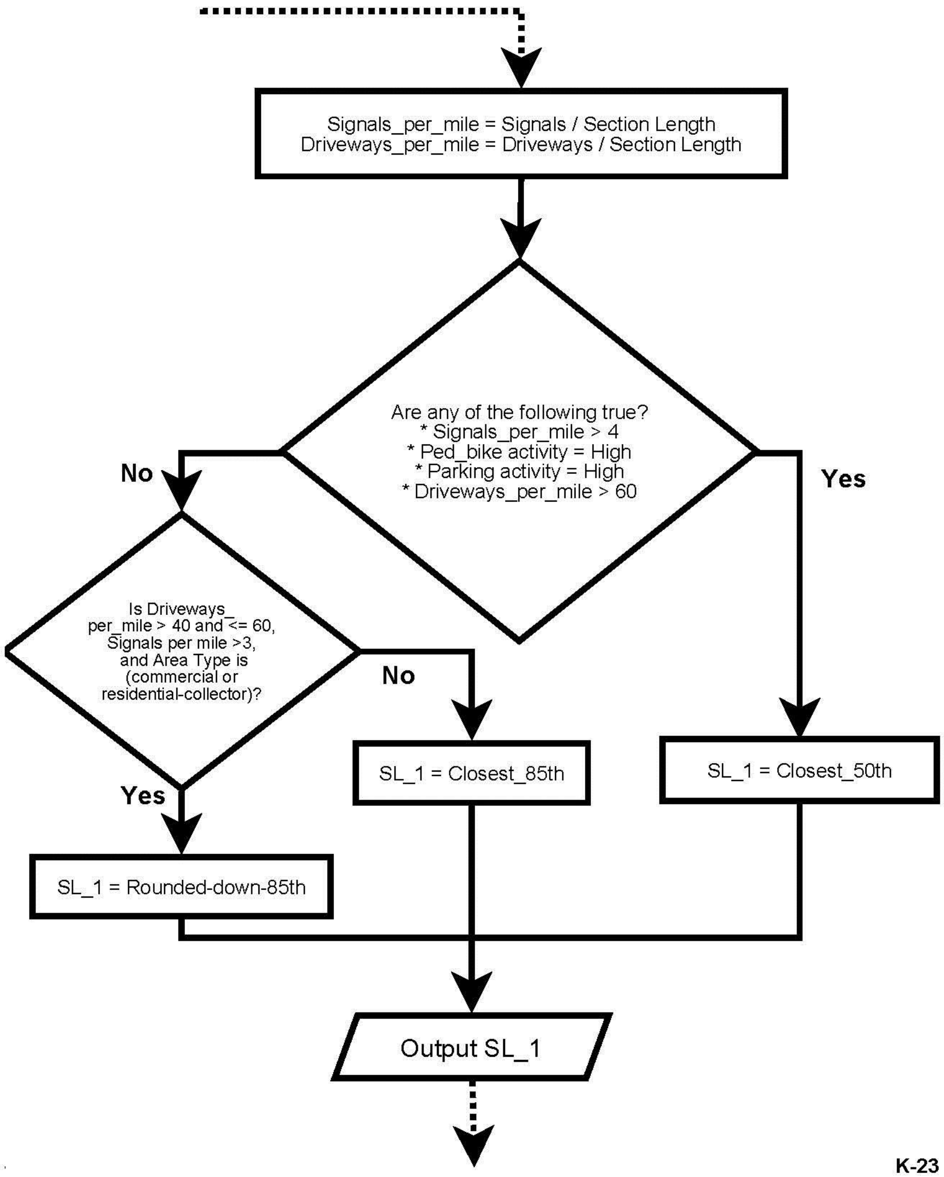

R.S.I.U.A.
Is Crash_level_1 High or Med?
No
Yes
The crash rate of the section is <crash_rate> per 100 MVMT. The average rate for similar sections is <Ca> per 100 MVMT, and the critical rate is <Cc> per 100 MVMT. The crash rate of this section is <crash_diff> % higher (or lower) than the average crash rate for similar sections. The rate of injury crashes for the section is <injury_rate> per 100 MVMT. The average rate for similar sections is <Ia> per 100 MVMT, and the critical rate is <Ic> per 100 MVMT. The rate of injury crashes for this section is <injury_diff>% higher (or lower) than the average rate for similar sections. A comprehensive crash study should be undertaken to identify engineering and traffic control deficiencies and appropriate corrective actions. The speed limit should only be reduced as a last measure after all other treatments have either been tried or ruled out.
Is 85th > 67 mph?
No
Yes
Based on the information gathered from experts in the U.S., this program does not recommend speed limits higher than 65 mph for non-limited access road sections in undeveloped areas.
Is Length < Minimum_ Section_Length
No
Yes
A section of <Length> miles is too short for speed zoning on public streets and roads for the recommended speed limit. You may consider lengthening the speed zone (if that is possible) or using the speed limits from adjacent sections (if they are appropriate for this section). If the 85th percentile speeds and other data you provided are representative of conditions for this short section, then the speed limit noted above should be considered. If the data were taken in a road section with adverse horizontal and vertical alignment, in a construction zone, or in an area with unique geometric and/or traffic control features, then the above noted speed limit may not be appropriate because this expert system is not designed to recommend speed limits for sharp horizontal curves, within the limits of construction zones, or in other special traffic situations.
END

K-21


Road Sections In Developed Areas (R.S.I.D.A.)
User input
* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Current AADT
* Area-type (Residential-Collector, Residential Subdivision, Commercial, Large Complexes)
* Number of driveways in the section (Driveways)
* Number of Signals (Signals)
* On-street parking and usage (High or Not High)
* Ped/Bike activity (High or Not High)
Speed Limit Calculation Without Crash Data - Developed Areas (K-23)
Have Crash Data?
No
SL = SL_1
Yes
Crash Module (K-24)
Calculate SL_2
SL = Lower of SL_1, SL_2
Road Sections In Developed Areas R.S.I.D.A. (K-28)

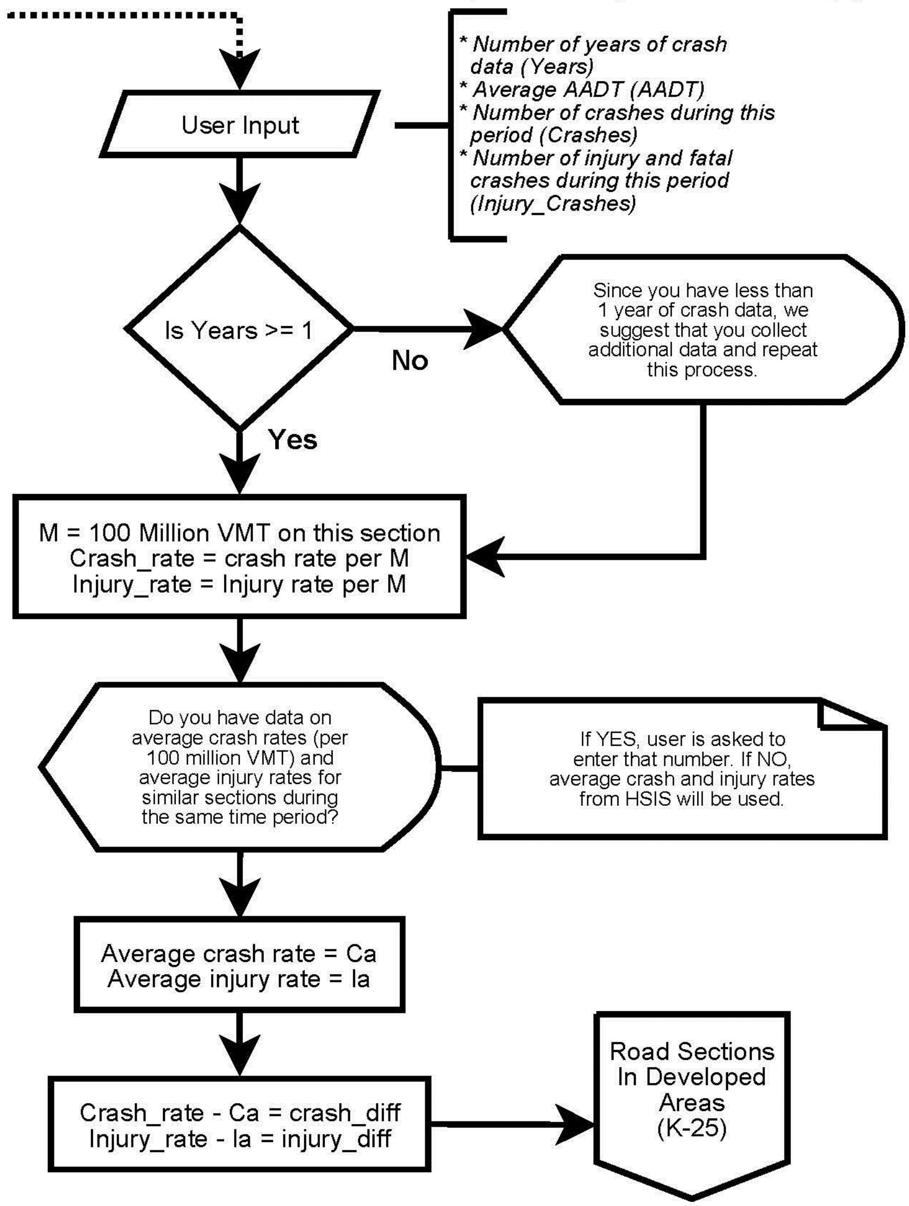
K-22

**Speed Limit Calculation Without Crash Data (to calculate SL-1) (Roadway Section In Developed Areas)**

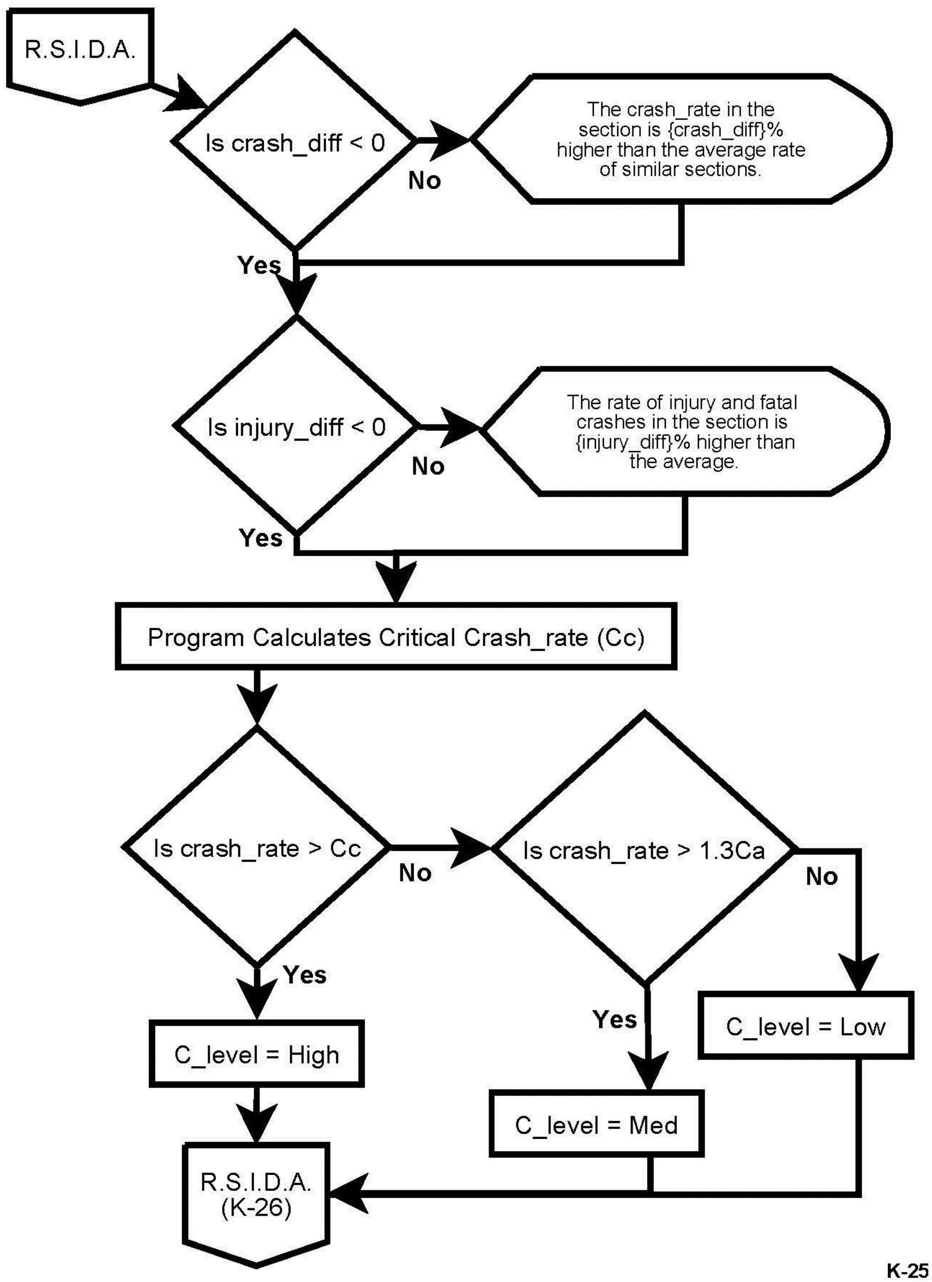


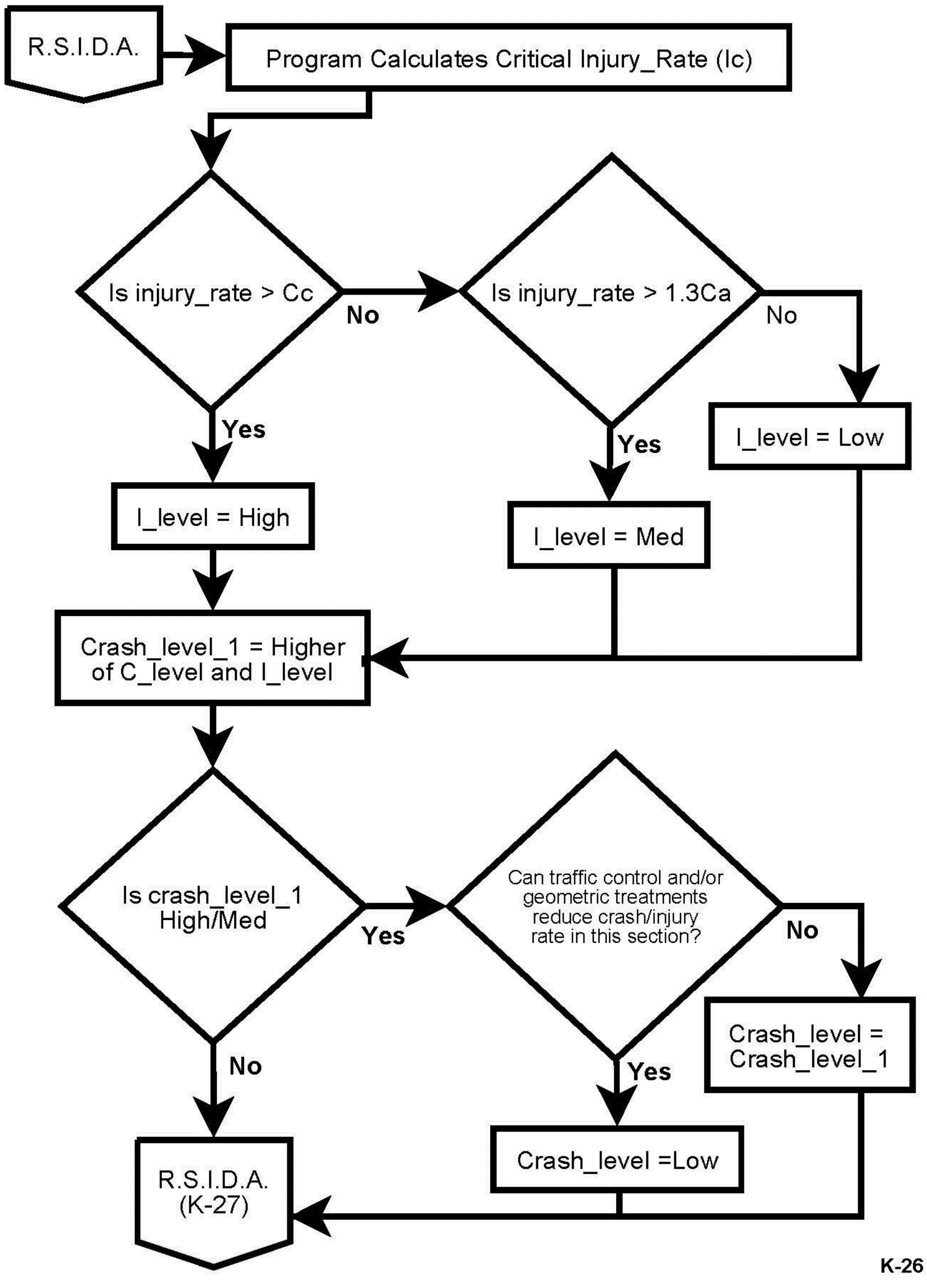

K-23

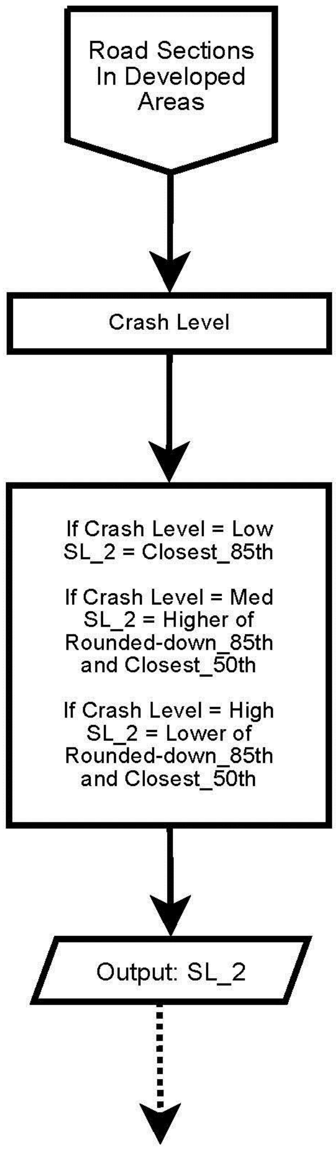
Crash Module for Roads in Developed Areas (to calculate SL_2)



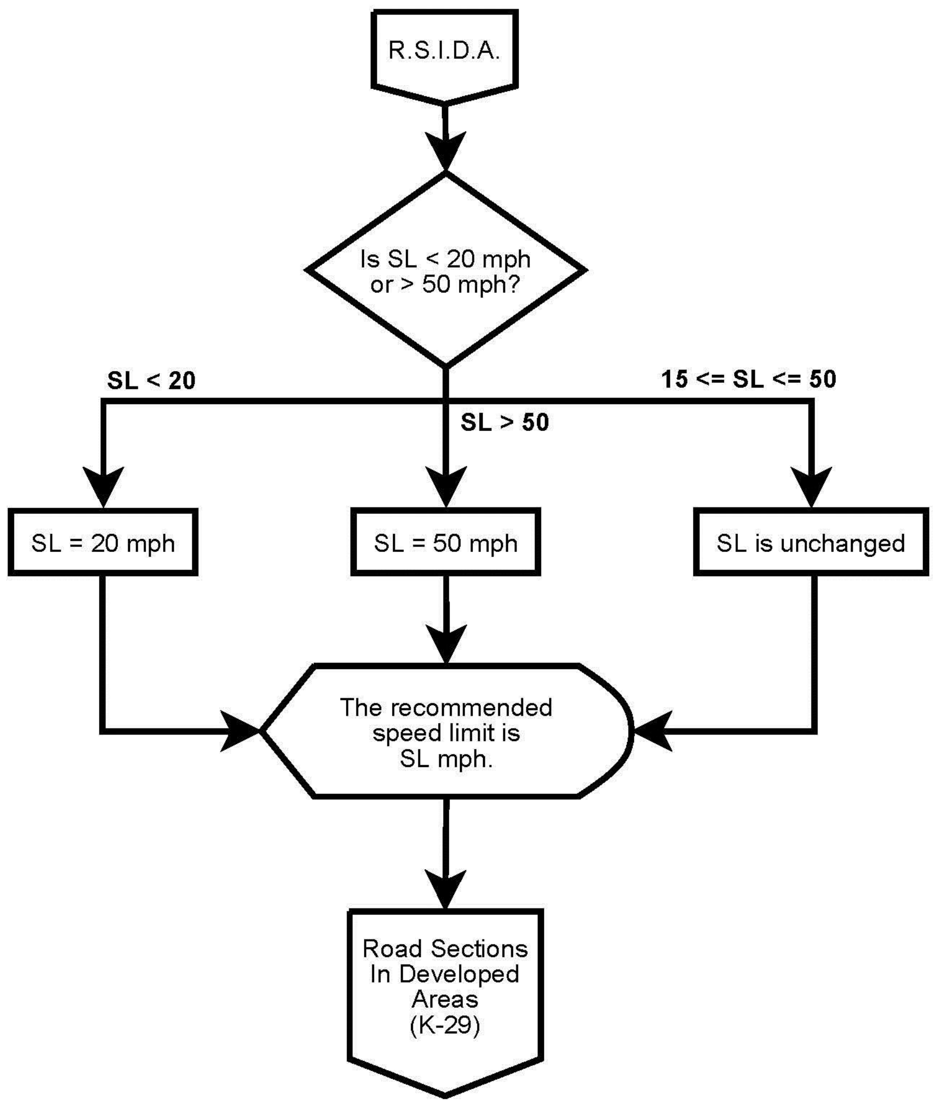

K-24


R.S.I.D.A.
Is crash_diff < 0
No
The crash_rate in the section is {crash_diff}% higher than the average rate of similar sections.
Yes
Is injury_diff < 0
No
The rate of injury and fatal crashes in the section is {injury_diff}% higher than the average.
Yes
Program Calculates Critical Crash_rate (Cc)
Is crash_rate > Cc
No
Is crash_rate > 1.3Ca
No
Yes
Yes
C_level = High
C_level = Med
C_level = Low
R.S.I.D.A. (K-26)
K-25

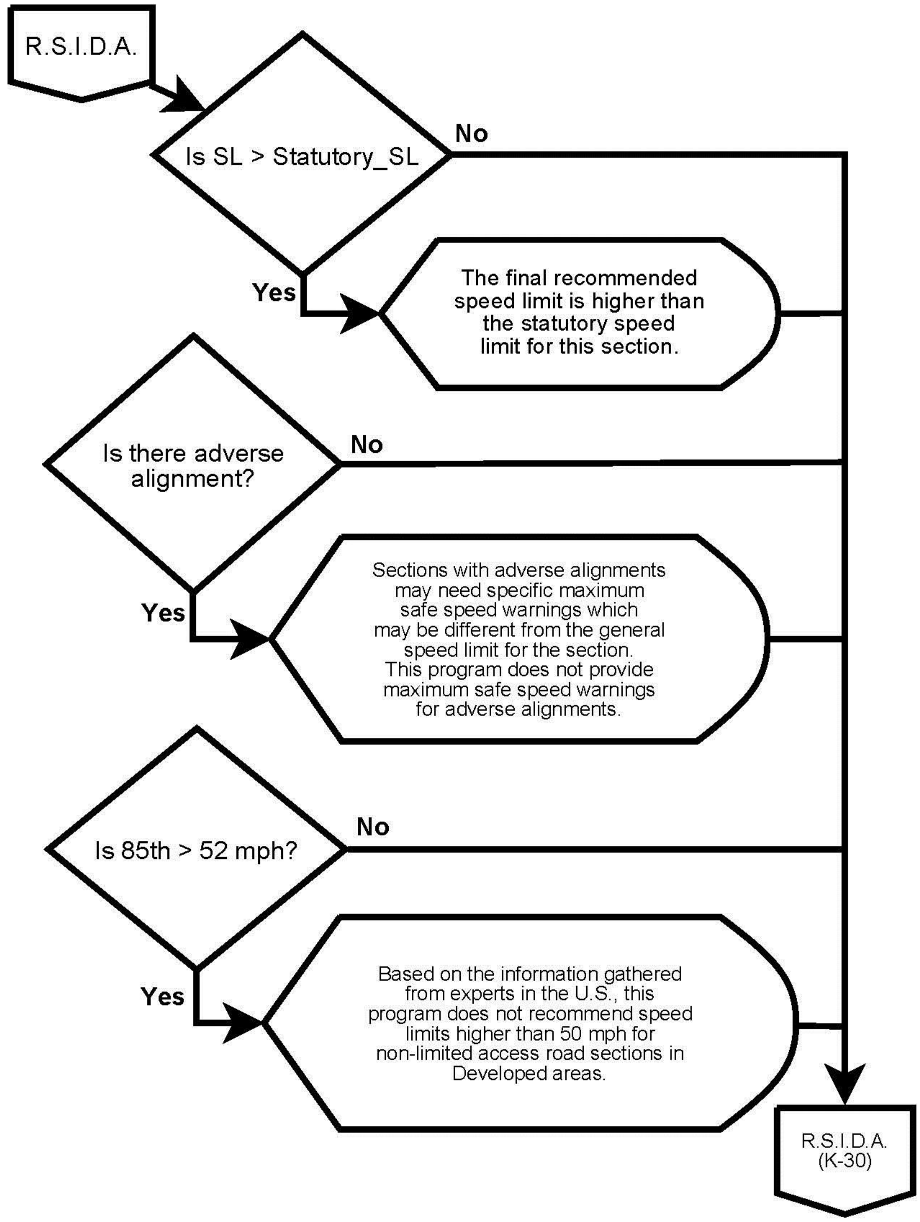

R.S.I.D.A.
Program Calculates Critical Injury_Rate (Ic)
Is injury_rate > Cc
No
Is injury_rate > 1.3Ca
No
Yes
Yes
I_level = Low
I_level = High
I_level = Med
Crash_level_1 = Higher of C_level and I_level
Is crash_level_1 High/Med
Yes
Can traffic control and/or geometric treatments reduce crash/injury rate in this section?
No
Crash_level = Crash_level_1
No
Yes
Crash_level =Low
R.S.I.D.A. (K-27)
K-26


Road Sections
In Developed
Areas
Crash Level
If Crash Level = Low
SL_2 = Closest_85th
If Crash Level = Med
SL_2 = Higher of
Rounded-down_85th
and Closest_50th
If Crash Level = High
SL_2 = Lower of
Rounded-down_85th
and Closest_50th
Output: SL_2

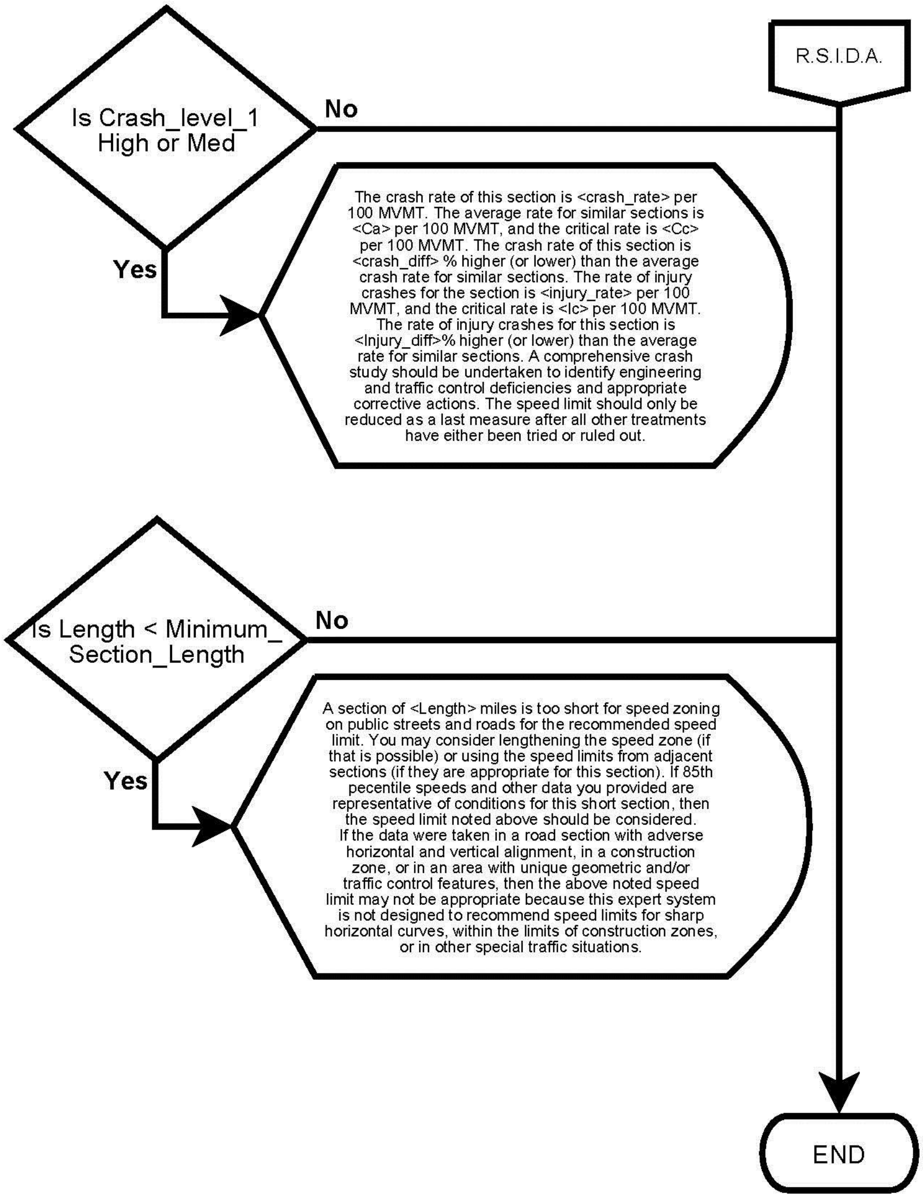
K-27


R.S.I.D.A.
Is SL < 20 mph
or > 50 mph?
SL < 20
15 <= SL <= 50
SL > 50
SL = 20 mph
SL = 50 mph
SL is unchanged
The recommended
speed limit is
SL mph.
Road Sections
In Developed
Areas
(K-29)

K-28


R.S.I.D.A.
Is SL > Statutory_SL
No
Yes
The final recommended speed limit is higher than the statutory speed limit for this section.
Is there adverse alignment?
No
Yes
Sections with adverse alignments may need specific maximum safe speed warnings which may be different from the general speed limit for the section. This program does not provide maximum safe speed warnings for adverse alignments.
Is 85th > 52 mph?
No
Yes
Based on the information gathered from experts in the U.S., this program does not recommend speed limits higher than 50 mph for non-limited access road sections in Developed areas.
R.S.I.D.A. (K-30)

K-29




K-30

**US LIMITS 2 User Guide – Terrain**

alignment typically require posting advisory speed warnings which are lower than the general speed limit for the section. This program does not suggest numerical values that can be used to determine the advisory speed warnings for adverse alignment. If adverse alignment is present, the system gives the following warning as part of the recommended speed limit:

> Sections with adverse alignments may need specific advisory speed warnings which may be different from the general speed limit for the section. See Procedures for Setting Advisory Speeds on Curves for more guidance, Publication No. FHWA-SA-11-22, June 2011.

Transition Zone

For projects on limited access freeways, users are asked to indicate if this section is transitioning to a non-limited access road. For projects with road sections in undeveloped areas, users are asked if the section is transitioning to a road section in a developed area. The answers are mainly used to determine if the operating speed is too low for a particular roadway type – lower operating speeds are typically used in transition zones.

Section Length

This refers to the length of the study section in miles.

Statutory Limit

This refers to the statutory limit for this type of facility in that jurisdiction. Statutory speed limits are limits established by legislative authority and are generally applicable throughout a political jurisdiction. Users should consult the vehicle codes in their state or jurisdiction to determine the statutory limit for the type of facility under study. Many of the laws are available on-line at the state or the local jurisdiction web site. If the recommended speed limit is higher than the statutory limit, the system provides a warning message.

Terrain (only for Limited Access Freeways)

Terrain is classified as Level/Flat, Rolling, or Mountainous which is defined in the following paragraphs.

*Level/flat:*
Level/flat terrain is that condition where highway sight distances, as governed by both horizontal and vertical restrictions, are generally long. Maximum freeway grades are typically less than 3 percent in flat terrain.

*Rolling:*
Rolling terrain is that condition where the natural slopes consistently rise above and fall below the road grade and where occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment. Maximum freeway grades are typically less than 4 percent in rolling terrain.

*Mountainous:*

Mountainous terrain is that condition where longitudinal and transverse changes in the elevation of the ground with respect to the road are abrupt. Maximum freeway grades are typically less than 6 percent in mountainous terrain, but may exceed 7 percent in some areas. In this program, the maximum speed limit for mountainous sections on limited access freeways is 70 mph.

Annual Average Daily Traffic (AADT)

The daily flow of motor traffic is averaged out over the year to give the Average Annual Daily AADT, a useful and simple measurement of how many vehicles use the facility during an average day.

Number of Interchanges (only for Limited Access Freeways)

The number of interchanges within the section is used to calculate the average interchange spacing which is equal to the length of the section divided by the number of interchanges. If the number of interchanges in a section is equal to zero, then the interchange spacing is set equal to the length of the section.

Crash Statistics and Analysis

In order for the system to conduct an analysis of the crash data, the following inputs are requested:

Length of the study period in years and months (we recommend at least 3 years of crash data; if less than 1 year of data are input, the program suggests that additional data should be collected and the process repeated)
Total number of crashes in the section
Total number of injury and fatal crashes in the section
The average AADT for the study period

This information is used to calculate the rate of total crashes and rate of injury and fatal crashes per 100 million vehicle miles. The user is then asked to input the average rate of total crashes and average rate of injury and fatal crashes (again per 100 million vehicles miles) for similar road sections in their jurisdiction. To determine the average crash/injury rate for similar sections, users should select a group of sections that have the same or similar geometry, i.e., number of lanes, median type, etc., and similar traffic volumes and area type.

If the user does not provide average rates, default values from the Highway Safety Information System (HSIS) are used. HSIS is a multi-state database that contains crash, roadway inventory, and traffic volume data for 8 States in the nation. In most of these states, the information in this database is limited to state-maintained facilities. Crash rates and injury rates were calculated using the latest 3 years of data that were available: California (2000-2002), Illinois (2001-2003), Maine (2002-2004), Minnesota (2002-2004), North Carolina (2001-2003),

| | | | |
|---|---|---|---|
| | 5,000 - 6,249 | 131.43 | 47.79 |
| | 6,250 - 7,499 | 125.97 | 46.04 |
| | 7,500 - 8,749 | 132.13 | 48.69 |
| | 8,750 - 9,999 | 129.02 | 48.05 |
| | 10,000+ | 123.98 | 47.37 |
| **Rural multilane divided non freeways (Undeveloped areas)** | 0 - 4,999 | 147.75 | 48.26 |
| | 5,000 - 9,999 | 101.22 | 31.32 |
| | 10,000 - 14,999 | 88.30 | 28.92 |
| | 15,000 - 19,999 | 89.28 | 31.52 |
| | 20,000 - 24,999 | 92.54 | 31.57 |
| | 25,000+ | 93.75 | 32.59 |
| **Rural multilane undivided non freeways (Undeveloped areas)** | 0 - 4,999 | 166.79 | 53.86 |
| | 5,000+ | 149.17 | 49.88 |

Using the average rate provided by the user or from HSIS, the system calculates a critical rate using the following formula (see Zegeer and Deen (1977), "Identification of Hazardous Locations on City Streets", *Traffic Quarterly*, Vol. 31(4), pp. 549-570.)

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

Where:

$R_C$ = critical rate for a given road type
$R_a$ = average rate for a given road type
$K$ = constant associated with the confidence level (1.645 for 95% confidence)
$M$ = 100 million vehicle miles

It is important that the user/practitioner undertake a comprehensive crash study to determine probable causes and appropriate countermeasures that could be implemented to reduce the frequency and severity of crashes. If the crash and/or injury rate is higher than the corresponding critical value (crash or injury level is considered High in this case) or at least 30% higher than the corresponding average rate (crash or injury level is considered Medium in this case), the system will ask the user if the crash or injury rate can be reduced by implementing traffic and/or geometric measures. Depending on the answer to this question, the system provides a recommended speed limit.

Roadside Rating (only for Road Sections in Undeveloped Areas)

The roadside hazard rating is a measure of roadside conditions including: shoulder width and type, side-slope, clear zone distance, and presence/absence of fixed objects on the roadside.

L-22

The scale ranges from 1 to 7, with 1 representing the lowest hazard (best conditions), and 7 representing the highest hazard (worst conditions). These scales are based on the following work that was conducted in the late 1980's for the Federal Highway Administration: Zegeer, C.V., Hummer, J., Reinfurt, D., Herf, L., and Hunter, W., *Safety Effects of Cross-Section Design for Two-Lane Roads*, Volume I-Final Report, FHWA-RD-87/008, October 1987.

Following is a description of ratings 1 through 7. Photographs illustrating these ratings are provided following the description.

*Rating = 1*

- Wide clear zones free from obstacles greater than or equal to 9 m (30 ft) from the pavement edgeline.
- Sideslope flatter than 1:4.
- Recoverable in a run-off-road situation.

*Rating = 2*

- Clear zone free from obstacles between 6 and 7.5 m (20 and 25 ft) from pavement edgeline.
- Sideslope about 1:4.
- Recoverable in a run-off-road situation.

*Rating = 3*

- Clear zone free from obstacles about 3 m (10 ft) from pavement edgeline.
- Sideslope about 1:3 or 1:4.
- Rough roadside surface.
- Marginally recoverable in a run-off-road situation.

*Rating = 4*

- Clear zone free from obstacles between 1.5 and 3 m (5 to 10 ft) from pavement edgeline.
- Sideslope about 1:3 or 1:4.
- May have guardrail (1.5 to 2 m [5 to 6.5 ft] from pavement edgeline).
- May have exposed trees, poles, or other objects (about 3 m or 10 ft from pavement edgeline).
- Marginally forgiving in a run-off-road situation, but increased chance of a reportable roadside collision.

*Rating = 5*

- Clear zone free from obstacles between 1.5 and 3 m (5 to 10 ft) from pavement edgeline.
- Sideslope about 1:3.
- May have guardrail (0 to 1.5 m [0 to 5 ft] from pavement edgeline).

- May have rigid obstacles or embankment within 2 to 3 m (6.5 to 10 ft) of pavement edgeline.
- Virtually non-recoverable in a run-off-road situation.

*Rating = 6*

- Clear zone free from obstacles less than or equal to 1.5 m (5 ft).
- Sideslope about 1:2.
- No guardrail.
- Exposed rigid obstacles within 0 to 2 m (0 to 6.5 ft) of the pavement edgeline.
- Non-recoverable in a run-off-road situation.

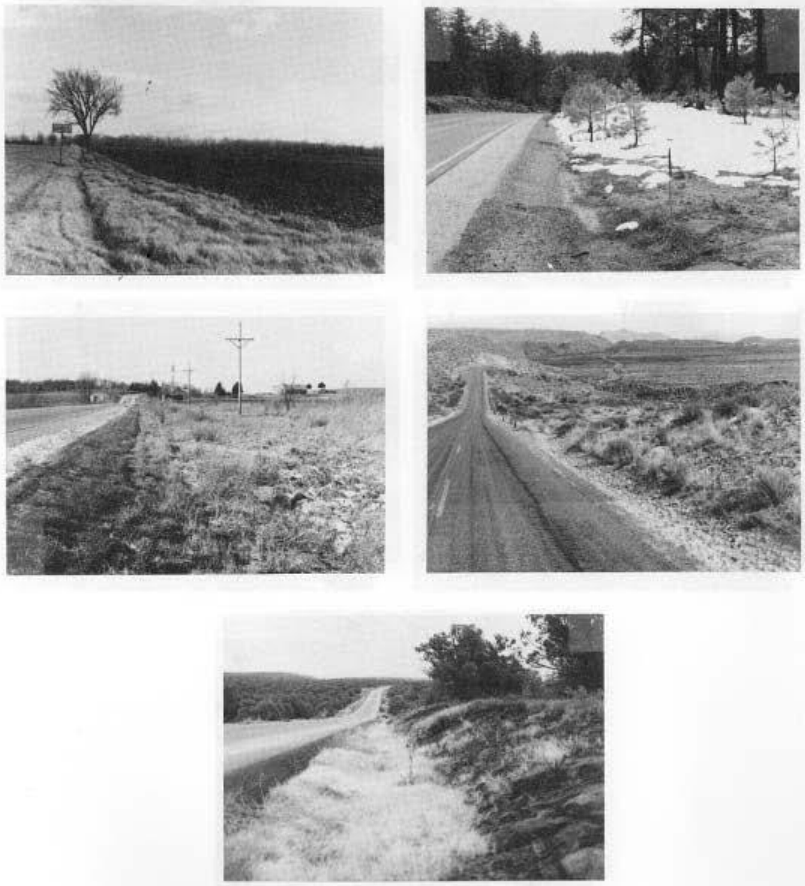
*Rating = 7*

- Clear zone free from obstacles less than or equal to 1.5 m (5 ft).
- Sideslope 1:2 or steeper.
- Cliff or vertical rock cut.
- No guardrail.
- Non-recoverable in a run-off-road situation with a high likelihood of severe injuries from roadside collision.

Rural roadside hazard rating of 1.

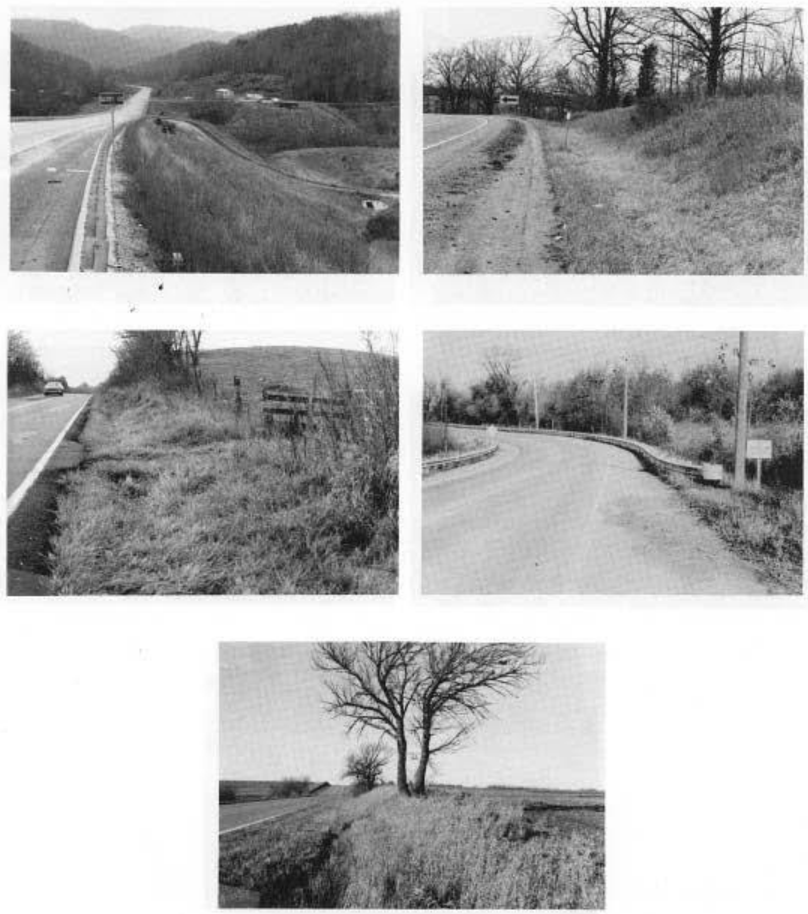
Rural roadside hazard rating of 2.

L-26



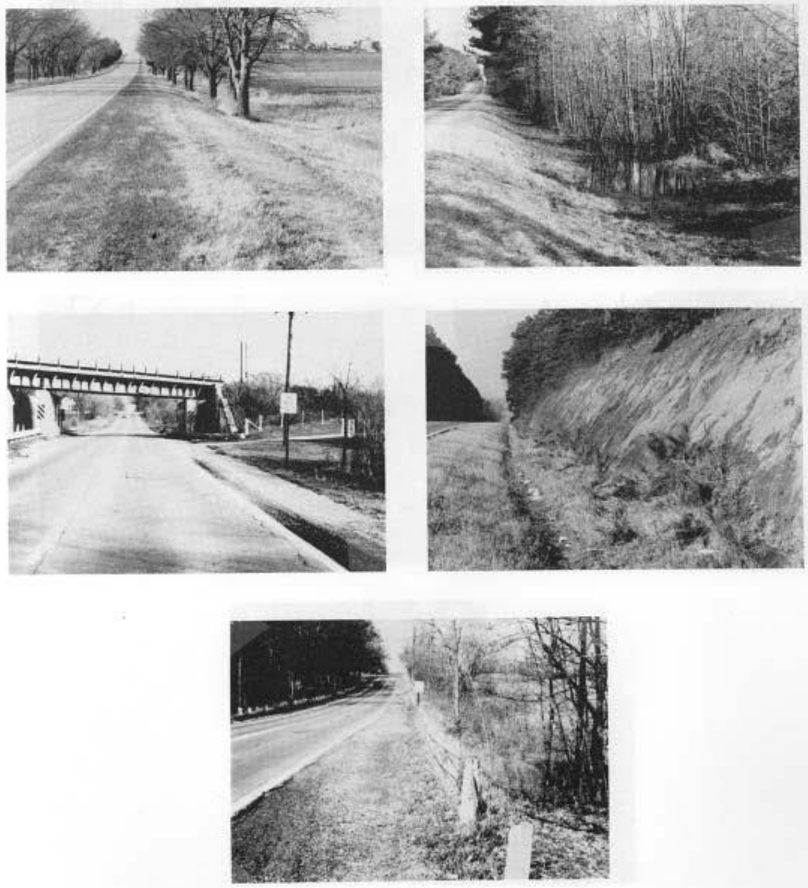
Rural roadside hazard rating of 3.

L-27



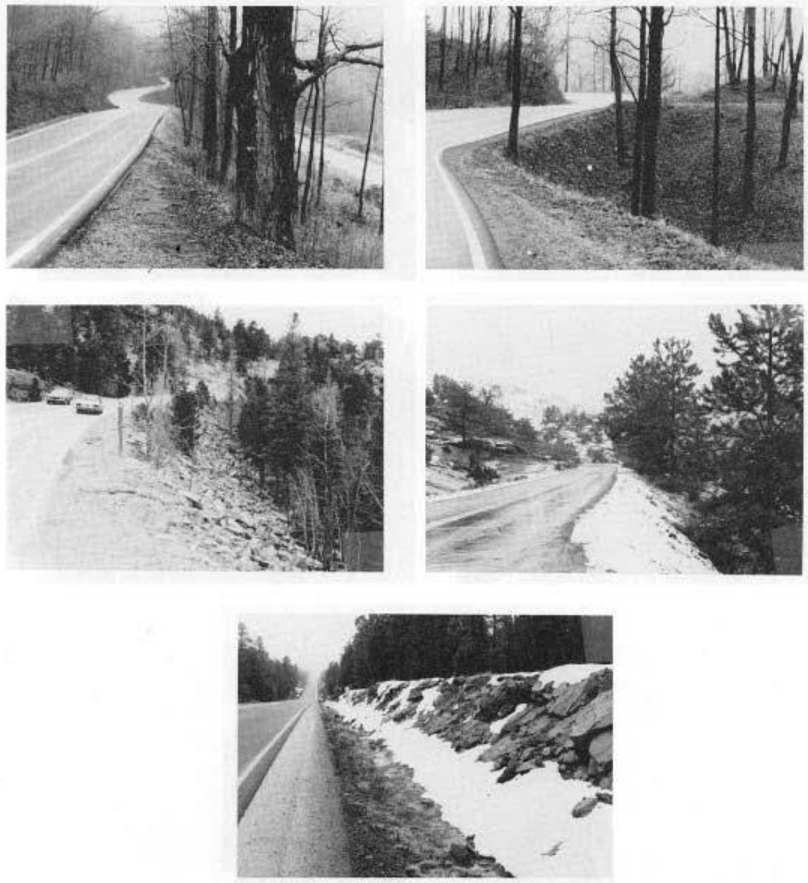
Rural roadside hazard rating of 4.

L-28



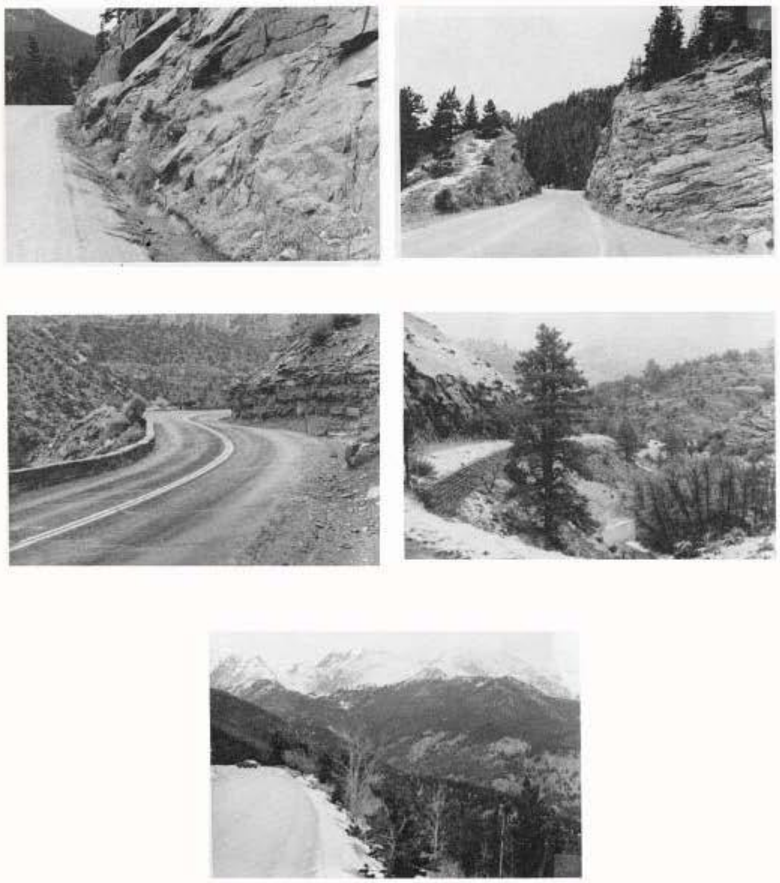
Rural roadside hazard rating of 5.

L-29



Rural roadside hazard rating of 6.

L-30



Rural roadside hazard rating of 7.

L-31

# APPENDIX E: STATE SPEED STUDY PRACTICES

## Data Collection Guidance

### *Existing Conditions*

As indicated in the Montana DOT Traffic Manual (2007) and Wisconsin DOT Speed Guidelines (2009), prior to determining the appropriate stations, equipment, etc. the engineer needs to obtain and review:

- Construction plans and specs
- Crash history (previous 3-5 years)
- Major traffic control devices (signals)
- All existing files pertaining to the site
- Geometric info
- Roadway Alignment
- Recent photos and aerial photos
- Functional class of roadway
- Presence of passing zones (Vermont AOT 2012)

### *Station Selection*

In order to make a station selection at which the study will occur the following characteristics should be considered:

- A speed study should collect a sufficient number of stations to define the boundaries of the special need and identify significant changes in the speed profile (Montana DOT 2007).
- In urban areas, measurements should be taken at 1600 foot intervals at locations where there is minimal disturbance from adjacent streets or start up traffic from stop signs or signals (Montana DOT 2007).
- Where traffic signals are present, stations should be located between signals or 0.2 miles from a signal (Alabama DOT 2015).
- In rural areas measurements are made at points were traffic, roadway, and/or environmental characteristics change (Montana DOT 2007).

### *Time of Day/Week/Year*

- Studies should be made in off peak hours during ideal conditions (Montana DOT 2007, Wisconsin DOT 2009, and Massachusetts DOT 2012).
- Studies should be performed on a typical weekday (a Tuesday, Wednesday, or Thursday), when motorists are likely to be moving at uninterrupted speeds (Wisconsin DOT 2009, Texas DOT 2015).

- Speed data should not be gathered during holidays as this can affect typical free- flowing speed (Alabama DOT 2015).
- One hour shall be the minimum amount of time to perform a speed study (Wisconsin DOT 2009).

***Operational Characteristics***

- Operational and environmental characteristics that influence speeds and should be considered may include (Montana DOT 2007 and Alabama DOT 2015):
    - Roadside Development
    - Roadway Geometry
    - Parking Activity
    - Pedestrian Activity
    - Directional Speeds
    - Vehicular Classification
    - Railroad Crossings
    - Intersections
    - Work Zones

***Safety***

- During any data collection, safety should be the top priority while the observer or technician is performing the task. The observer or technician shall not be placed in a situation where their safety or that of motorists are in question (Wisconsin DOT 2009).

***Sample Size***

- A minimum sample size for a speed study should not be less than 100 vehicles per lane per direction. This provides an accurate representation of vehicle speeds within the study area (Wisconsin DOT 2009).

## Speed Study Warrants

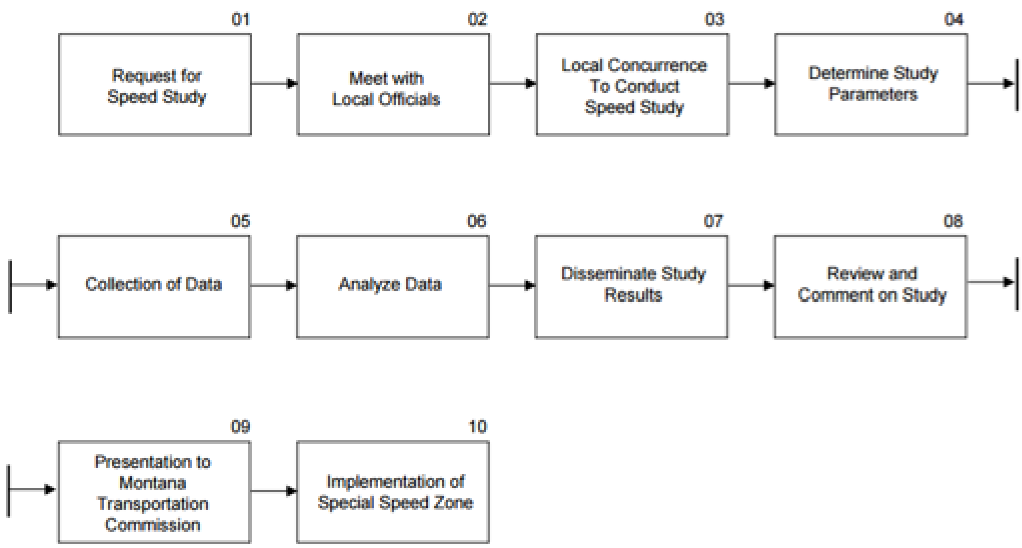
A speed study should be performed to determine traffic speeds on a new or reconstructed section of highway (Texas DOT 2015). Speed studies can be initiated by the request of transportation agencies, local governments, or a group of citizens.

### *Speed Study Request*

- For example, in Ohio, local governments can request for a change in speed limits for road or streets within the municipality (Delaware County, Ohio 2016).
- For county and township roads, the County Commissioners have authority to request a change in the speed limit and may direct the County Engineer to conduct the engineering and traffic study for the road in question (Delaware County, Ohio 2016).
- Counties in Illinois have the authority to establish altered speed limits on all county highways, township roads, and district roads (Kendall County, Illinois 2002).
- In Vermont, a petition signed by a significant number of residents can result in a speed study (Vermont AOT 2012).

### *Flowchart: Speed Study Procedures*

A general guideline of possible steps to consider when performing a speed study can be found below (Montana DOT 2007):



## Posted Speed Limit

In selecting a safe speed limit, the 85th percentile method is most commonly used by transportation agencies throughout the country. Variations to the 85th percentile speed can be made, however the following guidelines from various state DOT agencies limit the range of the maximum posted speed.

- The safe speed range should be determined and should not be less than 7 mph below the 85th percentile speed or greater than the 95th percentile speed (Massachusetts DOT 2012).
- In determining maximum posted speed, the value should be as close as possible to the 85th percentile. When minimum speeds are used, they should be within 5 miles per hour of the 17th percentile (Texas DOT 2015).
- The proposed speed limit should be set within 5 mph of the observed 85th percentile speed of free-flowing traffic. It is widely accepted that speed limits set at unrealistic levels above or below the 85th percentile speed have little impact on a driver's choice of speed. In addition, the lowest risk of being involved in a crash occurs at approximately the 85th percentile speed (Wisconsin DOT 2009).
- The 85th percentile speed is usually at or near 2 mph of the upper limit of pace (Montana DOT 2007).

Other considerations and resources when determining a safe speed range include:

- Speed limit should be coordinated with the upper limit of the 10 mph pace (Montana DOT 2007).
- Variations in speed limit should follow a 10 mph change rate (Montana DOT 2007).
- USLIMITS2 is a computer web-based expert tool to assist in setting reasonable, safe and consistent speed limits. It provides an objective perspective and supplemental support for speed limits determined by an engineering study. It is applicable to all roadway types – ranging from rural two-lane roadway segments and residential streets to urban freeway segments. The USLIMITS2 analysis would be considered supplemental to the primary speed limit assessment (Alabama DOT 2015).
- A reasonable and safe speed will give a driver time to react and stop or slow down sufficiently to avoid potential conflicts while driving at a comfortable speed. You can test for the proper speed by driving the road section at constant speeds, increasing the speed by 5 mph on each pass (Vermont AOT 2012).

## Speed Study Parameter: 85th Percentile Speed

***Measurement Methods***

The most commonly used measurement methods to determine the 85th percentile speed include:

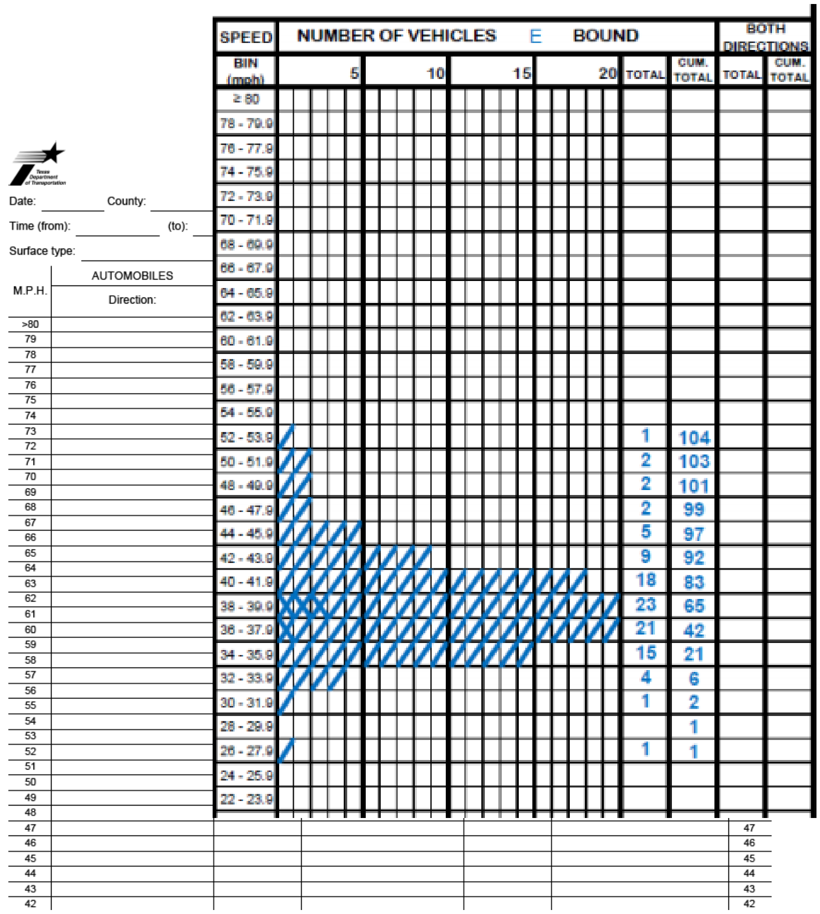
- Radar speed meters, which use radar principles (Texas DOT 2015).
- Manually-operated, handheld devices such as a stopwatch, radar gun, and laser guns (Wisconsin DOT 2009).
- Other possible equipment to collect data include pneumatic tubes, Hi-Star Counters, and mounted radar (Alabama DOT 2015).
- Speed calculations at curves can be made using a ball bank indicator based on the following table. This provides engineers with possible test speeds for a curve but should not be used as the recommended speed limit for a roadway (Massachusetts DOT 2012).

| Speed | Ball Bank Reading |
|---|---|
| 20 mph | 16 degrees |
| 25 mph | 14 degrees |
| 30 mph | 14 degrees |
| 35 and up | 12 degrees |

- Out-of-road devices that are installed overhead or on the side of the road such as radar recorders are also possible measurement methods. These devices must be adjusted so that only speeds where long gaps exist between vehicles are collected (Alabama DOT 2015).

***Calculation***

- The Texas DOT (2015) recommends that the 85th percentile be calculated by finding the 85th percent speed of the total vehicles measured. The "Radar Motor Vehicle Speed Field Talley Sheet" should be used to record tally marks beside the observed speed for each vehicle. This form can be seen in the figure on the right:

  | SPEED BIN (mph) | TOTAL | CUM. TOTAL | BOTH DIRECTIONS TOTAL | BOTH DIRECTIONS CUM. TOTAL |
  |---|---|---|---|---|
  | ≥ 80 | | | | |
  | 78 - 79.9 | | | | |
  | 76 - 77.9 | | | | |
  | 74 - 75.9 | | | | |
  | 72 - 73.9 | | | | |
  | 70 - 71.9 | | | | |
  | 68 - 69.9 | | | | |
  | 66 - 67.9 | | | | |
  | 64 - 65.9 | | | | |
  | 62 - 63.9 | | | | |
  | 60 - 61.9 | | | | |
  | 58 - 59.9 | | | | |
  | 56 - 57.9 | | | | |
  | 54 - 55.9 | | | | |
  | 52 - 53.9 | 1 | 104 | | |
  | 50 - 51.9 | 2 | 103 | | |
  | 48 - 49.9 | 2 | 101 | | |
  | 46 - 47.9 | 2 | 99 | | |
  | 44 - 45.9 | 5 | 97 | | |
  | 42 - 43.9 | 9 | 92 | | |
  | 40 - 41.9 | 18 | 83 | | |
  | 38 - 39.9 | 23 | 65 | | |
  | 36 - 37.9 | 21 | 42 | | |
  | 34 - 35.9 | 15 | 21 | | |
  | 32 - 33.9 | 4 | 6 | | |
  | 30 - 31.9 | 1 | 2 | | |
  | 28 - 29.9 | | 1 | | |
  | 26 - 27.9 | 1 | 1 | | |
  | 24 - 25.9 | | | | |
  | 22 - 23.9 | | | | |

  EXAMPLE: If 125 cars are counted in the southbound direction, 85 percent would be 106. Thus, the 106th highest speed would be the 85th percentile speed (Texas DOT 2015).

  - In no case should the 85th percentile speed be interpolated between two speeds (Texas DOT 2015).
  - The 85th percentile should be calculated immediately after data collection in the field (Texas DOT 2015).

- The Florida DOT (2010) does allow for interpolation in the calculation of the 85th percentile speed. An example can be found below:

  EXAMPLE: Given a sample size of 104 vehicles and the data sheet below:

  85th percentile point is 104 x 0.85 = 88.4 vehicles

  The 85th percentile point falls between (40-41.9) mph and (42-43.9) mph corresponding to 83 and 92 of the cumulative total number of cars at those speeds.

  Interpolating between the values we find:

$$\frac{88.4 - 92}{92 - 83} = \frac{x - 43}{43 - 41}$$

  85th percentile speed = x = 42.20 mph

Other methods of calculating the 85th percentile method include graphing speeds vs. number of cars and determining the 85th percentile through data observation of the graphical results (Alabama DOT 2015).

## Other Speed Study Parameters

Many factors can affect the safe operating speed of vehicles. It is not always practical to study each factor individually. Instead, factors should be compared in combination and evaluated as a whole. The following sections will examine different parameters that should be considered when determining a safe speed for a roadway.

## Speed Study Parameter: Land Use

When performing a speed limit study, it is important to examine the surrounding land use of a road and how it may affect travel speeds.

### *Classifications*

The location of a roadway within a rural or urban setting can influence a drivers experience and the expectations of a safe speed of travel. Urban settings vary from (Wisconsin DOT 2009):

- Dense urban core
- Urban fringe
- Suburban area
- Small/isolated urban lane development (less than ¼ to ½ mile long)

Some important questions that a designer should ask about the land use around a road include is it:

- A densely residential area?
- A commercial area with many driveways entering the highway?
- A school zone?
- A trailer park?
- Or rural farmland?

Designers should considering the type and the density of development to aid in the determination of a safe and reasonable speed (Vermont AOT 2012). They should also record the parking practices and pedestrian activity in the area. Record whether parking is on the roadway or off street. Is parking controlled by signs or markings or meters? (Vermont AOT 2012).

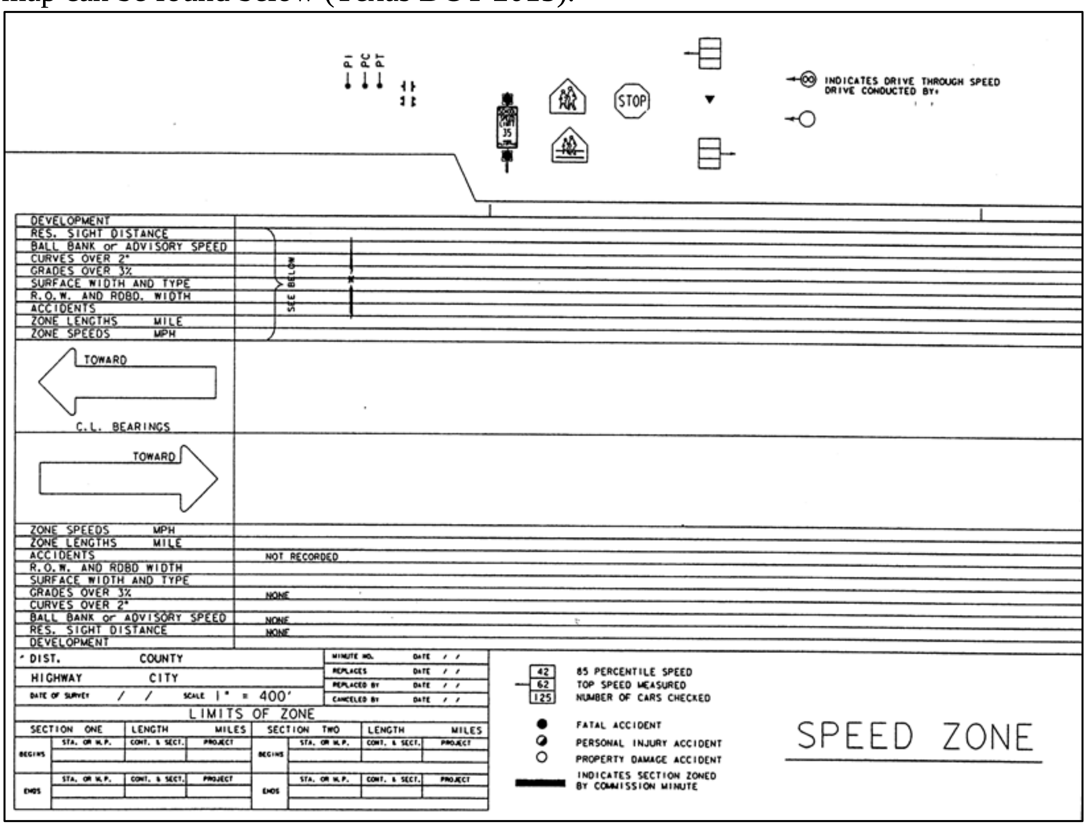
Changes to adjacent land use can change the road's purpose, requiring an updated speed limit study and designation. A change in commercial, recreational, or residential development can bring more drives, pedestrians, and cyclists to a road. Intersections, driveways and side streets may also increase resulting in the need to adjust the speed limit to correspond to changes in the corridor (Alabama DOT 2015).

## Speed Study Parameter: Crash Rates

### *Crash Rate Study*

An overview of crash rate data should always be reviewed when performing a speed study (Texas DOT 2015).

- Crash data should be obtained from state databases. For example, the state of Alabama uses the Alabama Department of Transportation Critical Analysis and Reporting Environment Database. Data should include the most recent three-year period at a minimum, with a five-year period being preferred (Alabama DOT 2015, Texas DOT 2015).
- Data should also include the crash location, light/weather/pavement conditions, type of crash and contributing factors such as speed (Wisconsin DOT 2009).
    - Other contributing factors include the driver's physical condition (age, chemical impairment, sleeping, and seat belt use) and time of day (Wisconsin DOT 2009).
- Strip maps can be used to indicate the locations of all accidents reported. Distinctive marks to represent fatal, personal injury, and property damage accidents should be used (Massachusetts DOT 2012). A strip map should be used when recommended speed zones will be 5 miles per hour or more below the 85th percentile speed. An example of a strip map can be found below (Texas DOT 2015).




***Interpretation***

- The conclusion of a speed study shall report a crash rate for the runway segment being studied compared to the statewide average.
- If it is found that the crash rates on a specific section of road are greater than the statewide average crash rate for similar types of roadways, the speed limit may be reduced by up to 12 miles per hour below the 85th percentile speed (Texas DOT 2015).

- The crash rate study should produce results that agree with the recommended safe speed that is proposed by the designer (Wisconsin DOT 2009).
- High accident results may indicate a need to moderate the speed limit. However, it is important to consider the other contributing factors previously mentioned before making a determination (Vermont AOT 2012).

## Speed Study Parameter: Legislative Action

### *Maximum Allowable Speed Limits*

State legislators have the ultimate authority over the speed limit on all state roads. It is common for states to set a maximum allowable speed limit for a given roadway type and its surroundings through legislative action. A few examples of fixed limits on the maximum allowable speed are seen in the table below:

Wisconsin DOT 2009: Speed Limits and Authority to Change

| Fixed Limit | Roadway Type | Local Government Authority |
|---|---|---|
| 65 mph | Freeway / Expressway | DOT only |
| 55 mph | County / State Highways | DOT only |
| 55 mph | Town Roads | Lower by 10 mph or less |
| 45 mph | Rustic Roads | Lower by 15 mph or less |
| 35 mph | Town road with 150’ driveway spacing | Lower by 10 mph or less |
| 35 mph | Outlying district within a city or village limits | Raise to 55 mph or less, Lower by 10 mph or less |
| 25 mph | Inside corporate limits of a city | Raise to 55 mph or less, Lower by 10 mph or less |
| 15 mph | School zone / crossing, parks, or public transit stops | Raise to that of the adjacent roadway, lower by 10 mph or less |

In cases where no speed limit is posted, statutory limits automatically govern. The tables below from the Code of the State of Alabama (Section 32) and Montana Code Annotated (2015) give examples of statutory limits.

Alabama DOT 2015: Statutory Limits

| Fixed Limit | Roadway Type |
|---|---|
| 70 mph | Interstate Highways (4 or more lanes) |
| 65 mph | State Highways with 4 or more lanes |
| 55 mph | State Highways (all other) |
| 45 mph | County paced road in unincorporated area |
| 35 mph | Unpaved road |
| 30 mph | Urban District |

Montana Code Annotated (2015): Statutory Limits

| Fixed Limit | Roadway Type |
|---|---|
| 80 mph | Interstate Highways outside an urbanized area of 50,000 in population |
| 70 mph | Public Highway during the daytime |

| | |
|---|---|
| 65 mph | Public Highway during the nighttime |
| 65 mph | Interstate Highways within an urbanized area of 50,000 in population |
| 25 mph | Urban District |

* ”Daytime” means from one-half hour before sunrise to one-half after sunset. “Nighttime” is any other time.

If legislative or congressional action results in the immediate increase in statewide maximum legal speed limits, then reasonable and prudent speed zones may be established by trial runs and engineering judgment in lieu of other speed check procedures (Texas DOT 2015).

***Blanket Lowering***

In some cases, states have the authority to set a blanket lowering of maximum speed limits. This can be justified:

- During state or national emergencies or disasters, such as war or energy crisis, where an authoritative study indicates that a reduction of speeds will result in a significant reduction in the consumption of fuel and energy and will promote fuel and energy conservation (Texas DOT 2015).
- To avoid non-compliance with direct requests from the federal government to lower the statewide maximum speed limit to a speed equal or below the national speed limit (Texas DOT 2015).

## Speed Study Parameter: Roadway Factors

***Geometrics***

The design speed of a roadway is the speed limit for which geometric features of the roadway were designed to accommodate. It is common for the posted speed limit to be 5 mph less than the design speed. If the design speed is unknown, it can often be estimated by roadway geometrics (Wisconsin DOT 2009).

It is common that roadway geometrics will have an impact on vehicle speeds. This includes the presents or absence of (Alabama DOT 2015):

- Medians
- Horizontal curves
- Vertical curves
- Superelevation
- Traffic Signals
- Sidewalks
- On- Street Parking
- Driveways

These elements are a static influence on a driver's perception of a potential conflict. This results in effects on traffic flow and its relative speed profile (Montana DOT 2007). It is important to consider roadway geometrics when performing a speed study. Any changes to roadway geometrics can affect operating speeds and the speed limit should always be reexamined whenever such geometrics changes are made.

***Horizontal and Vertical Alignment***

Horizontal alignment, combined with vertical alignment, serves as the primary controlling element associated with the design of all types of public streets and highways (Massachusetts DOT 2006). As a result, the horizontal and vertical alignment along with the design speed, should be reviewed and examined before making a determination on a safe speed limit.

***Surface***

On some road surfaces, such as gravel roads, most people will drive at speeds that are slower than the safe speed that a speed study recommends. Because of this, some agencies such as the Vermont AOT do not recommend setting speed limits on class 3 gravel roads (Vermont AOT 2012).

# APPENDIX F: SMARTPHONE BALL BANK STUDY EVALUATION

The research team performed testing to compare the Rieker Inclinometer output to various smartphone accelerometer output. The testing procedure is detailed on the next page, and the testing was done with the Rieker unit and smartphones mounted to the same vehicle, which drove from NCSU campus through the US-1/I-440 and I-40 interchange loop ramps shown in Figure 1 at various speeds. Each loop ramp has a posted advisory speed of 25 MPH.

Detailed charts are included after the testing procedure. Overall, the Nexus 6 smartphone performs with similar accuracy to the Rieker Inclinometer when aggregated. Further testing can identify differences in quality between devices used in order to recommend certain smartphones for future application. The research team recommends that a standard smartphone or other device be selected for development of a Ball Bank Test application for Division staff to utilize to reduce cost and time to identify curves needing advisory speeds.


**Figure 1 Curve Test Route – Loop Ramps Labeled**

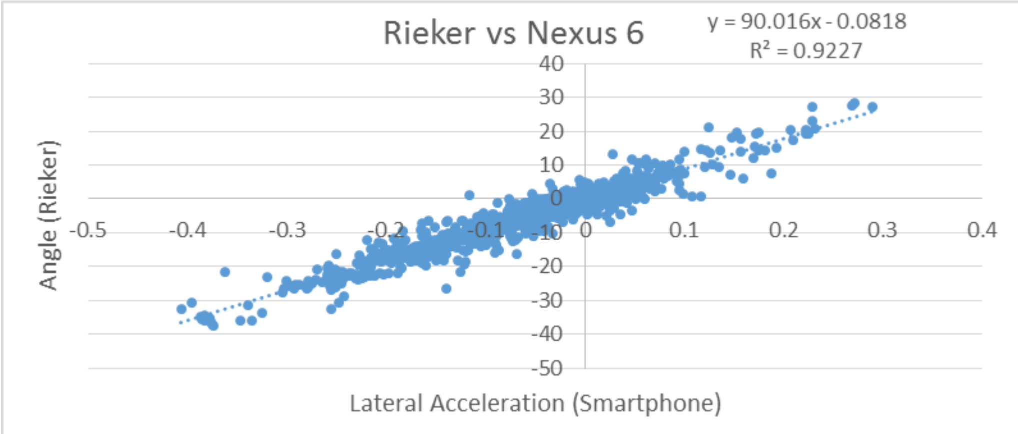



**Figure 2 Comparison and Regression for Rieker Inclinometer and Nexus 6 Smartphone (Aggregation to 1 second)**

### Testing Procedure

Units Tested: Rieker RDS7-BB-09, Nexus 5 Smartphone, Nexus 6 Smartphone
Additional Apps/Equipment: Rieker COM to USB cable, Laptop, RealTerm software, Torque Pro app, Level app, Smartphone Mount, Bluetooth OBD Reader
Mounting:

- Rieker unit is attached to dash using double sided Velcro tape
- Smartphones are mounted to windshield or dash as shown below

**Figure 3 Unit Mounting and Testing**

Calibration:

- Once units are all mounted, drive to a level location to calibrate the devices
- Rieker User manual details the calibration procedure
- Smartphone mounts are adjusted using a level app until smartphone shows it is level

Data Collection Settings:

- RealTerm is set to record Matlab time stamp along with the Rieker angle in real time (usually 0.25-0.3 seconds interval)
- Torque pro is configured to record OBD/GPS Speed, GPS Location, X/Y/Z Acceleration at 0.1 second intervals

Driving:

- In order to get the most curves with advisory speeds tested, the loop ramps from a clover interchange were driven multiple times at different speeds
- All of the trip from campus to the test site and back was used for analysis, so turns at intersections are also included in the full dataset
- One test run was performed using the FHWA Curve Advisory Speed Methods (https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa1122/ch3.cfm) with manual readings of the smartphone and Rieker data

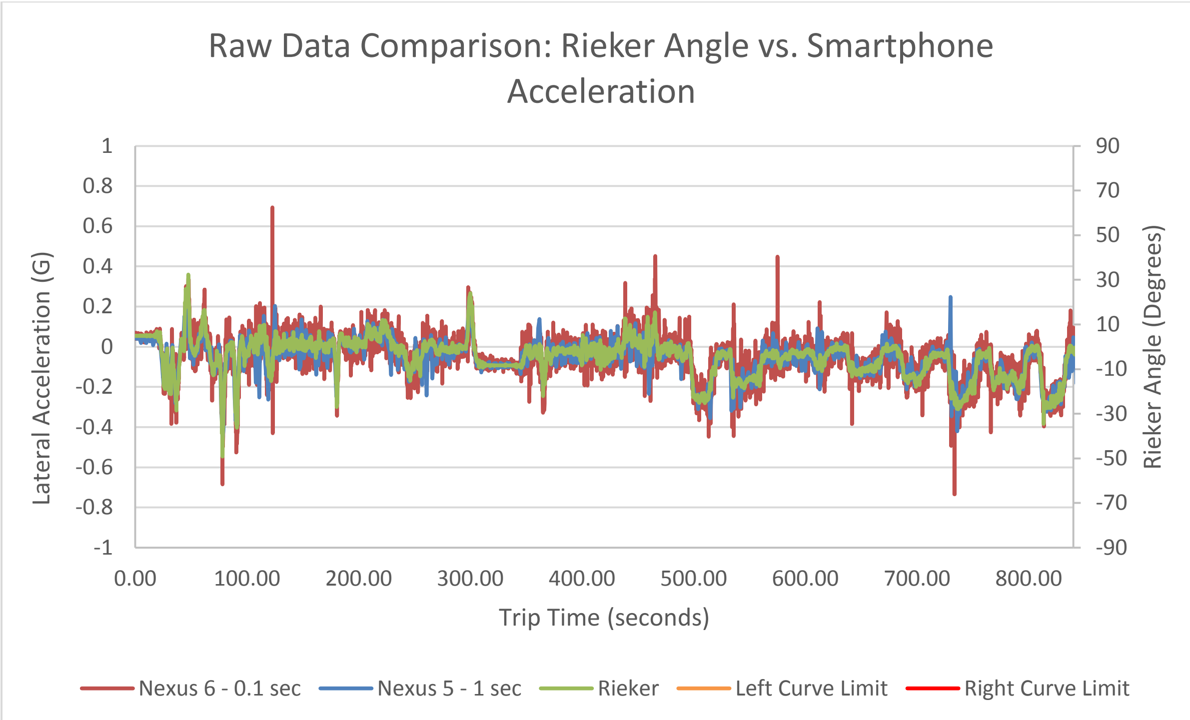



**Figure 4 Raw Data Comparison: Rieker Angle vs. Smartphone Acceleration**

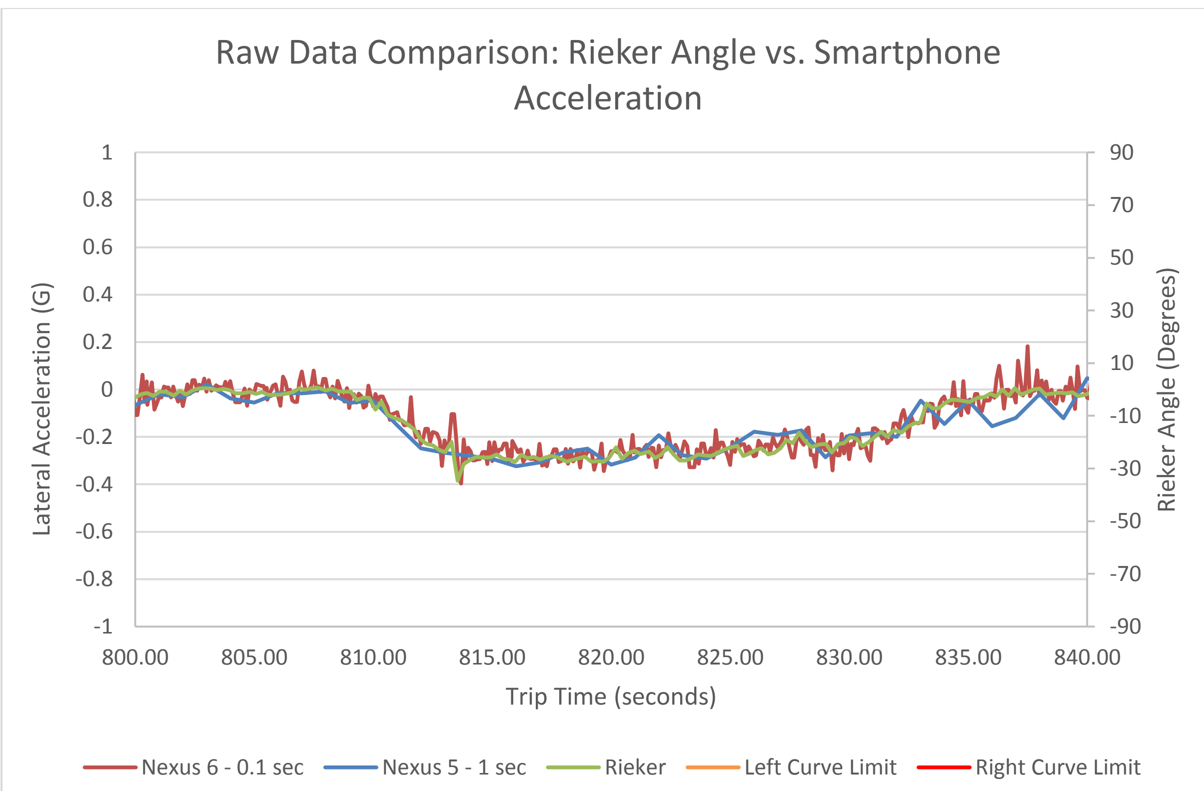



**Figure 5 Raw Data Comparison: Rieker Angle vs. Smartphone Acceleration (Detail)**

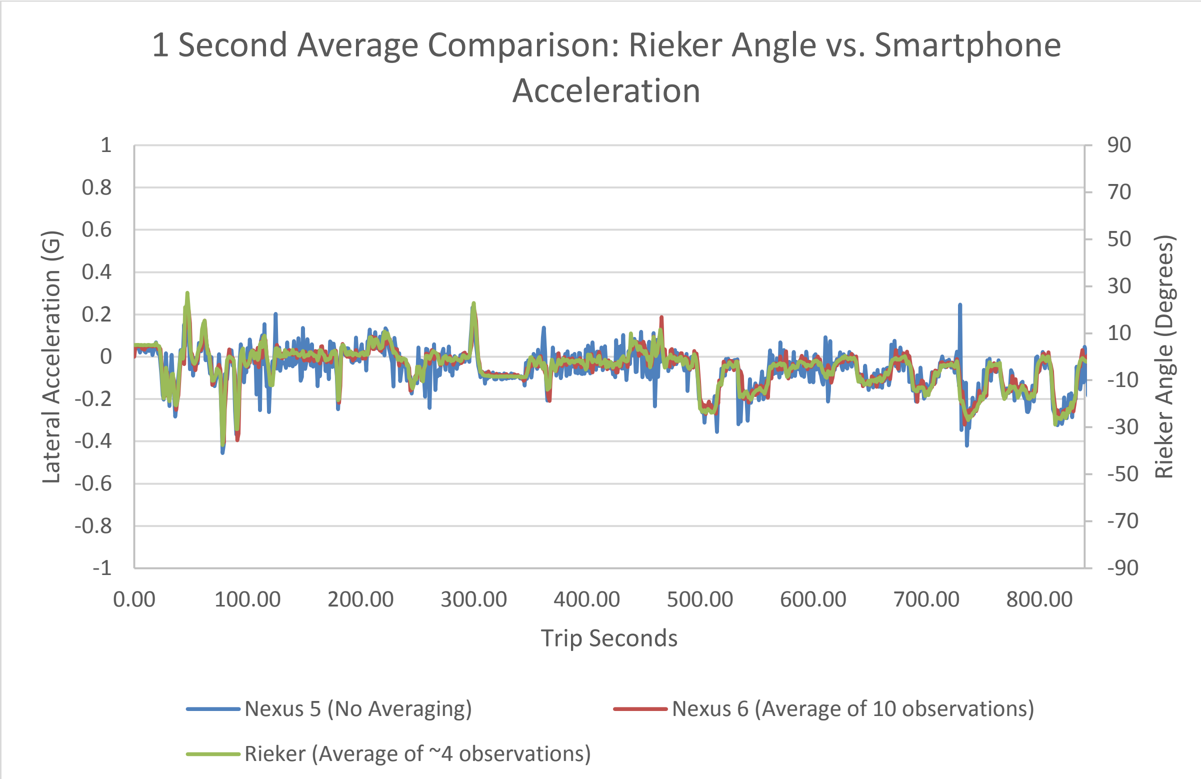



**Figure 6 1 Second Average Comparison: Rieker Angle vs. Smartphone Acceleration**

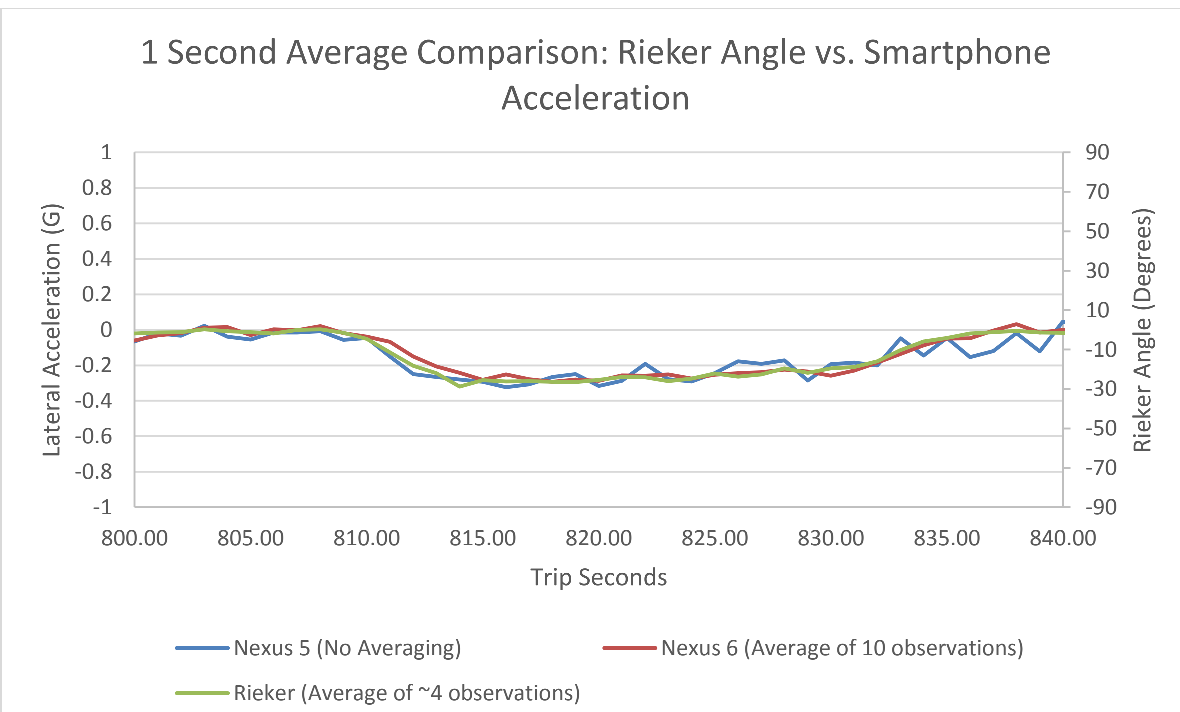



**Figure 7 1 Second Average Comparison: Rieker Angle vs. Smartphone Acceleration (Detail)**

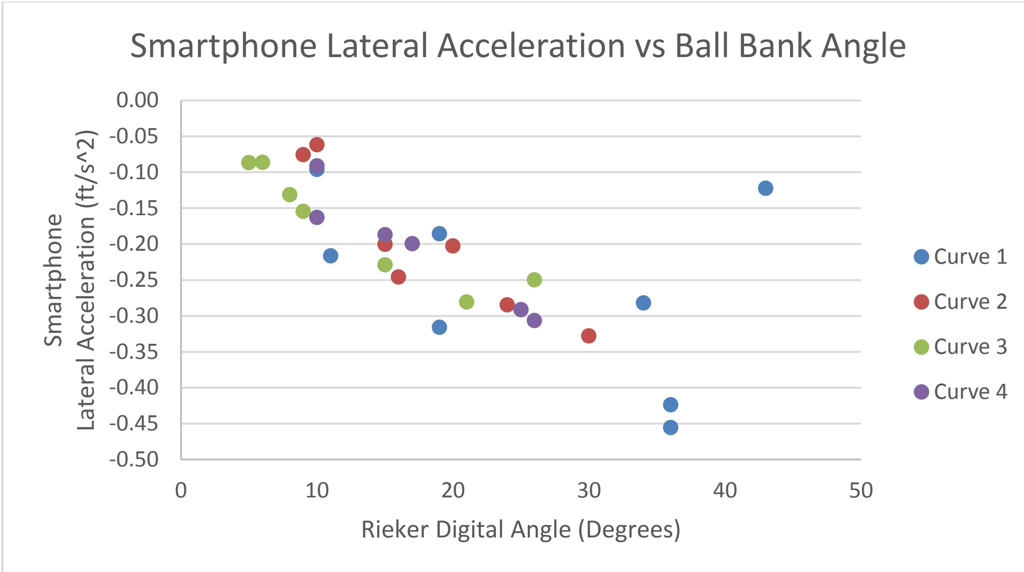



**Figure 8 Manual Curve Testing Comparison***

*In this final figure, it is important to note that the speeds were increased in successive runs (between 20 and 35 MPH). For a given curve (color), the speed increases as the angle increases and acceleration is more negative