Project No. 3-67 **COPY NO. ____**

EXPERT SYSTEM FOR RECOMMENDING SPEED LIMITS IN SPEED ZONES

FINAL REPORT

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

Raghavan Srinivasan
University of North Carolina Highway Safety Research Center
Chapel Hill, NC 27599-3430

Martin Parker
Wade Trim Associates, Inc.
Taylor, MI 48180

David Harkey
University of North Carolina Highway Safety Research Center
Chapel Hill, NC 27599-3430

Dwayne Tharpe
University of North Carolina Highway Safety Research Center
Chapel Hill, NC 27599-3430

Roy Sumner
FreeAhead, Inc., Virginia

November 2006

ACKNOWLEDGMENT OF SPONSORSHIP

This work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the **National Cooperative Highway Research Program**, which is administered by the Transportation Research Board of the National Academies.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 3-67 by the University of North Carolina Highway Safety Research Center, Wade Trim Associates, Inc., and PB Farradyne, Inc. The University of North Carolina Highway Safety Research Center was the contractor for this study. The work undertaken at Wade Trim Associates, Inc. and PB Farradyne, Inc. were under subcontracts with the University of North Carolina Highway Safety Research Center.

Raghavan Srinivasan, Senior Transportation Research Engineer, University of North Carolina Highway Safety Research Center, was the Principal Investigator. The other authors of the report are Martin Parker, Senior Associate, Wade Trim Associates, Inc., David Harkey, Director, University of North Carolina Highway Safety Research Center, Dwayne Tharpe, Senior Programmer at the University of North Carolina Highway Safety Research Center, and Roy Sumner, former Vice President at PB Farraydne, now President of FreeAhead, Inc.

The research team would like to thank the members of the expert panel for donating their time and effort to participate in the panel meetings. The research team would also like to thank several practitioners from all over the country that volunteered their time to respond to case studies and participated in testing the prototype expert system.

ABSTRACT

The idea of controlling vehicle speed evolved from the assumption that reducing speed also reduces crashes. Speed limits are selected to balance travel efficiency versus safety. It can be argued that a rational speed limit is one that is safe, that most people consider appropriate, that will protect the public, and that can be enforced. Previous work has shown that better methods are needed to identify appropriate speed limits especially on urban roads having higher traffic volumes, a mix of road users, and more roadside activity. The objective of this project was to develop a knowledge-based expert system for recommending speed limits in speed zones that are considered to be credible and enforceable.

The expert system (hereafter referred to as USLIMITS2) was developed based on results from previous research, responses from practitioners to hypothetical case studies as part of two web-based surveys, input from experts from three panel meetings, and lessons learned from the current USLIMITS program developed by the Australian Road Research Board for FHWA. The expert system developed as a result of this research is accessed through the Internet and has been designed to address the establishment of speed limits in speed zones on all types of roadways, from rural two-lane segments to urban freeway segments. The types of speed limits not addressed by the system include statutory limits such as maximum limits set by State legislatures for Interstates and other roadways, temporary or part-time speed limits such as limits posted in work zones and school zones, and variable speed limits that are raised or lowered based on traffic, weather, and other conditions.

Based on input from the user, the expert system employs a decision algorithm to advise the user of the speed limit for the specific road section of interest. Appropriate warnings are also provided in a summary report that may suggest that additional information and/or action is necessary to address areas of concern. The system is meant to assist the user in making the speed limit decision for a road segment, but will not make the decision for him or her.

This report documents the research effort that was used to develop the expert system. For those primarily interested in applying the expert system to assist in setting speed limits on roads and streets in their area, a User Guide is provided in Appendix L, and flow charts illustrating the decision rules are provided in Appendix K.

EXECUTIVE SUMMARY

Speed limits are selected to balance travel efficiency versus safety. The optimal balance depends on the type of road and the environment in which it exists. Roads in areas such as residential subdivisions provide access, while collector roads distribute local traffic between neighborhoods and arterial street systems. On local roads, low operating speeds are desired to accommodate pedestrians and bicyclists and to provide access to residences and businesses. On arterial streets where the function of the road is to carry traffic and provide access to businesses, the goal of speed management is to maintain mobility and capacity while increasing safety. On limited access roads built to the highest standards, there is greater emphasis on reducing travel times without comprising safety.

It may be argued that a rational speed limit is one that is safe, that most people consider appropriate, that will protect the public, and that can be enforced. Artificially low speed limits can lead to poor compliance as well as large variations in speed within the traffic stream. Increased speed variance can also create more conflicts and passing maneuvers that can lead to more crashes.

The objective of this project was to develop a knowledge-based expert system for recommending speed limits in speed zones that are considered to be credible and enforceable. The expert system is accessible through the Internet and has been designed to address the establishment of speed zones on all types of roadways, from rural two-lane segments to urban freeway segments. The types of speed limits not addressed by the system include statutory limits such as maximum limits set by State legislatures for Interstates and other roadways, temporary or part-time speed limits such as limits posted in work zones and school zones, and variable speed limits that change as a function of traffic, weather, and other conditions.

A brief overview of the technical approach that was followed in this study is given below along with the conclusions:

Review of Previous Work. A review of the literature was conducted to identify relevant work in this area. The review focused on the several topics including the impact of speed limit changes, relationship between site characteristics and operating speeds, motorist compliance with existing speed limits, and factors and methods used to set speed limits.

Survey of USLIMITS Users. USLIMITS is an expert system developed for FHWA by the Australian Road Research Board based on several years of experience in developing expert systems for many provinces in Australia and New Zealand. The objective of the survey was to get feedback on several aspects of the program including: the ease of use, problems encountered, and the potential utility of the USLIMITS program. The intent of the survey was to determine the weaknesses of the current USLIMITS program (if any) and use that information to develop USLIMITS2.

Identification of Expert Panel. The knowledge base and decision making processes used in expert systems were drawn from experts with a background and experience in the area of interest. Members of the expert panel chosen to provide input for the expert system were selected from a comprehensive list of persons engaged in setting, enforcing, or adjudicating speed limits in speed zones.

User Needs and System Requirements. Based on input provided by the expert panel, user needs were developed and subsequently used to develop the system requirements.

Development of the Decision Rules. The decision rules for the expert system were developed using the information obtained from several face to face meetings and surveys of the expert panel, the NCHRP panel, and lessons learned from the use of the current USLIMITS program.

Conclusions. The following conclusions are based on the results of this research:

- Most previous studies suggest that the increase in posted speed limits on interstate roads in 1987 and 1995 resulted in more fatalities. Very little work has been conducted to study the effect of changes in speed limits on crash frequency and severity in non-limited access speed zones in this country.

- The survey of USLIMITS users revealed that most respondents felt that the speed limit recommended by USLIMITS was reasonable. Some felt that the USLIMITS program should provide more information regarding the decision rules and the factors used/not used in developing the final recommendation.

- In order to provide easy access to many practitioners, the expert system needs to be a web-based application.

- When developing an expert system, care should be taken to ensure that the system does not require extensive data collection that is beyond the scope of data now collected and maintained by an agency. The system's interface should be intuitive and provide explanation of each step and the consequences of each decision made by the user.

- There is consensus that operating speed is a critical factor in determining an appropriate speed limit for a speed zone. Other factors identified as being critical included interchange spacing (in limited access freeways), roadside development, presence of pedestrian and bicycle activities, presence/absence of medians, roadside hazards, and crash and injury statistics.

- On road sections in rural areas where crash risk is typically not very high, many experts recommend posting the speed limit at the 5 mph multiple closest to the 85^{th} percentile speed (the 85^{th} percentile speed is the speed at or below which 85 percent of motorists drive on a given road). In urban areas with high pedestrian and bicycle activity, many experts recommend selecting the 5 mph multiple closest to the 50^{th} percentile speed (the 50^{th} percentile speed is the speed at or below which 50 percent of motorists drive on a given road) as the speed limit.

- Most experts agree that on road sections with high crash rates, a detailed crash analysis needs to be conducted to identify the contributing factors for all crashes. Countermeasures for reducing crashes should be selected based on identified causal factors; which can include measures other than the posted speed limit.

- To create widespread use of the product and truly have an effect on how speed limits are set, there is a need to promote the expert system and train potential users.

CHAPTER 1

BACKGROUND AND INTRODUCTION

The idea of controlling speed evolved from the assumption that reducing speed also reduces crashes, and indeed, speed is related to crash occurrence in three ways (*1*, *2*). First, speed influences the amount of time needed to respond to vehicles, pedestrians, or other objects in the roadway and to either stop or avoid the problem. Second, the difference in speed between vehicles on the roadway, or between vehicles and roadside objects such as parked cars or obstructions directly influences the probability of crashes. Third, greater speed influences the severity of injuries and property damage when crashes do occur.

Speed limits are selected to balance travel efficiency versus safety. The optimal balance depends on the type of road. Roads in areas such as residential subdivisions provide access, while collector roads distribute local traffic between neighborhoods and arterial street systems. On these roads, low operating speeds are desired to accommodate pedestrians and bicyclists and provide local access. On arterial streets where the primary function of the road is to carry traffic, the goal of speed management is to maintain mobility and capacity while increasing safety (*1*, *2*). On limited access roads built to the highest standards, there may be greater emphasis on reducing travel times without comprising safety.

It can be argued that a rational speed limit is one that is safe, that most people consider appropriate, that will protect the public, and that can be enforced. Even if a majority of motorists feel that they can make reasonable judgments about their driving speeds, posted speed limits are still essential, because:

1) Excessive speed selected by a particular driver who may have a higher tolerance for risk imposes significant risks on other drivers,
2) Some motorists are unable to correctly judge the capabilities of their vehicles, and/or unable to anticipate roadway geometry and roadside conditions sufficiently to determine appropriate driving speeds, and
3) Some motorists tend to underestimate or misjudge the effects of speed on crash probability and severity (*3*).

Artificially low speed limits can lead to poor compliance as well as large variations in speed within the traffic stream. Increased speed variance creates more conflicts and passing maneuvers, which can lead to more crashes (*4*, *5*). Some have argued that as a general proposition, speed limits should be set at levels that are self-enforcing so that law enforcement officials can concentrate their efforts on the worst offenders. “When speed limits are set artificially low and enforcement action cannot be directed at all the violators, the enforcement officer has too much discretion in selecting the motorists to be penalized” (*6*).

NEED FOR EXPERT SYSTEMS

The Manual of Uniform Traffic Control Devices (MUTCD 2003 Edition) notes that "when a speed limit is to be posted, it should be within 10 km/h or 5 mph of the 85th percentile speed of free-flowing traffic". However, the MUTCD also indicates that the following factors may be considered in addition to the 85th percentile speed when establishing speed limits, but does not provide specifics on how to account for these variables:

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

Due to lack of specific guidance and procedures from the MUTCD and other documents, engineers often rely on their experience and judgment in considering other factors apart from the operating speed while deciding on the appropriate speed limit in a speed zone. This sometimes leads to inconsistencies in how speed limits are set in different jurisdictions and can be confusing to the driver. An expert system is one approach that can be used to identify the appropriate speed limit for a speed zone. TRB Special Report 254 (*3*) argues that "the expert system approach deserved consideration because it provides a systematic and consistent method of examining and weighing factors other than vehicle operating speeds in determining an appropriate speed limit".

Expert systems aim to mimic an expert's thought process in solving complex problems. The original expert system (VLIMITS) developed by the Australian Road Research Board (ARRB) for Victoria, was a DOS-based program (*7*). Development of VLIMITS began with field measurements at over 60 locations. The data collected from the field were reviewed by a panel of experts who used this information to come up with decision rules for appropriate speed limits for different types of roads and traffic conditions. This information was reduced to a computer program. In this program, users were prompted to respond to a series of questions, and the system responds with a recommended speed limit. VLIMITS was updated in 1992 (*3*). Since then, programs have been developed for all Australian state roads authorities and for New Zealand. These include NLIMITS (for New South Wales), SALIMITS (for South Australia), WALIMITS (for Western Australia), QLIMITS (for Queensland), TLIMITS (for Tasmania), and NZLIMITS (for New Zealand). Collectively, these are called XLIMITS. It is important to note that the logic in these systems is hard coded, and the system does not learn with previous experience, as some expert systems do.

The most recent version of XLIMITS takes the user through a five-step process before recommending a speed limit (*3*). The first step deals with the type of area, rural, urban, urban fringe, or rural fringe. The next step deals with roadway and roadside characteristics such as number of lanes, access control, type of road, and median width. Using the information entered in these two steps, the system develops a first approximation for the speed limit. In the next two steps this speed limit may be modified based on other factors such as schools, accidents, alignment, and the 85th percentile speed. The final outcome is the recommended speed limit with warnings about specific factors that need to be studied further.

USLIMITS is the next generation in this series and was specifically developed by ARRB for application in the U.S. This application was developed for the Federal Highway Administration based on the logic used in the XLIMITS programs, but with changes made to suit the conditions in this country. One change was to force the recommended speed limits to be within the 50 to 85th percentile range. The logic and decision rules used in developing USLIMITS are not available to the user. Hence, it is not clear which variables affect the final recommendation and to what extent. Based on the research team's experience in using this system with several case studies, the area type, roadway characteristics, abutting development, and the operating speed do seem to affect the recommended speed limit. However, other factors such as accident counts, adjacent limits, and presence/absence of adverse alignment do not seem to affect the recommended speed limit, but the information on these factors are considered while providing warnings along with the recommended speed limit at the end of the program. USLIMITS can be accessed through the Internet (www.uslimits.com), but a username and password are required.

This project has developed a second generation expert system based on knowledge gained from experts in the United States (hereafter called USLIMITS2). Similar to USLIMITS, this program is accessed through the Internet (www2.uslimits.org). Unlike, USLIMITS, the user can create their own username and password, and the decision rules used to develop the system are documented in the form of flow charts, which are available to the user along with a User Guide.

STUDY OBJECTIVE AND SCOPE

The objective of this project was to develop a knowledge-based expert system for recommending speed limits in speed zones that are considered to be credible and enforceable. Credibility must be achieved in the eyes of multiple audiences including, but not limited to:

- Practitioners using the system and applying the results.
- Elected officials and public policy makers that must respond to the community.
- Drivers who are directly impacted by the limits established and whose behavior is a direct reflection of the effectiveness of the system.
- Judges and magistrates who must often address the "reasonableness" rule within their courts.
- Enforcement officials who need a more objective means of separating the egregious violators from the rest of the driving population.

The system has been designed to address the establishment of speed zones on all types of roadways, from rural two-lane segments to urban freeway segments. The types of speed limits not addressed by the system include statutory limits such as maximum limits set by State legislatures for Interstates and other roadways, temporary or part-time speed limits such as work zones and school zones, and variable speed limits that may change as a function of traffic, weather, and other conditions.

OVERVIEW OF THE APPROACH

Following is a brief overview of the approach (i.e., the steps) that was followed in this study:

Review of Previous Work

A review of the literature was conducted to identify relevant work in this area. The review focused on the following topics

- Impact of speed limit changes
- Relationship between site characteristics and operating speeds
- Motorist compliance with existing speed limits
- Factors and methods used to set speed limits
- Agencies/personnel involved in making speed limit decisions

Chapter 2 provides a brief summary of the literature review. The complete review is provided in Appendix A.

Survey of USLIMITS Users

A survey was sent in December 2003 to 55 individuals who had an account for using the current USLIMITS program. The objective of the survey was to get feedback on several aspects of the program including: the ease of use, problems encountered, and the potential utility of the USLIMITS program. The intent of the survey was to determine the weaknesses of the current USLIMITS program (if any) and use that information to develop USLIMITS2. A brief overview of the results from this survey is presented in Chapter 3. Appendix B has the detailed summary of the results.

Identification of Expert Panel

The knowledge base and decision making processes used in expert systems are drawn from experts with a background and significant experience in the area of interest. Members of the expert panel chosen to provide input for the expert speed limit system were selected from a comprehensive list of persons engaged in setting, enforcing, or adjudicating speed limits in speed zones, and persons with significant research experience in this area. Chapter 4 discusses the approach that was used in selecting the expert panel, and the list of members who attended the expert panel meetings.

User Needs and System Requirements

Chapter 5 outlines the user needs and system requirements of the expert system developed by the research team. The user needs were discussed at the expert panel meeting in June 2004, and subsequently used to define the system requirements.

Development of the Decision Rules

The decision rules for the expert system were developed using the information obtained from several face to face meetings and surveys of the expert panel, the NCHRP panel, and previous research. Chapter 6 gives a detailed discussion of the approach followed in the developing the decision rules for the expert system, and also presents an overview of the decision rules. Flow charts illustrating the decision rules are presented in Appendix K. A user guide is presented in Appendix L. The decision rules and the user guide are also available to the user from the expert system (www2.uslimits.org).

Long-Term Management Strategy

Chapter 7 discusses the issues related to the management of the product once the development contract ends, including site administration, upgrade cycle, and marketing.

Conclusions and Future Research

Chapter 8 provides a summary of the conclusions from this study and directions for future research.

CHAPTER 2

REVIEW OF PREVIOUS WORK

This chapter provides a brief summary of the literature review. The complete review is provided in Appendix A. The review is summarized in the following categories:

- Impact of speed limit changes
- Relationship between site characteristics and operating speeds
- Motorist compliance with existing speed limits
- Factors and methods used to set speed limits
- Agencies/personnel involved in making speed limit decisions

IMPACT OF SPEED LIMIT CHANGES

Effect on Average Speeds and Speed Dispersion

Several studies have tried to assess the effect of changes in speed limits on average speeds and speed dispersion. In many studies, speed dispersion is expressed as the difference between the 85^{th} percentile speed and the average speed, which is approximately equal to the standard deviation (i.e., square root of the variance).

Effect of System-Wide Changes in Speed Limits

Most of the work in the United States has focused on studying the effect of system-wide changes in speed limits in Interstate highways. In 1974, the maximum speed limit was reduced to 55 mph; in 1987, maximum speed limits on rural interstates were increased to 65 mph; in 1995, the authority to set speed limits was given back to the individual States. The 1974 legislation was effective for some time in reducing average speeds due to the oil crises and because drivers understood that lower speeds were associated with less fuel consumption. When gas became more easily available, speeds started creeping up. Following the increase in the speed limits in 1987 from 55 to 65 mph on rural Interstate highways, average speeds increased between 1 and 5 mph. However, there is very little consensus on the relationship between changes in speed limits and speed dispersion.

Effect of Changes in Speed Limits in Speed Zones

In contrast to the large number of studies in the United States that have tried to examine the effect of changes in system-wide speed limits in Interstate highways, very few studies have looked at the effect of changes in speed limits in speed zones. Parker (*8*), in a landmark study, collected speed and crash data from 100 experimental sites where speed limits were increased or decreased and 83 comparison sites where speed limit was not altered. Overall, the study found very little evidence of a relationship between posted speed limits and speed distributions.

Effect on Safety

Speed is directly related to the severity of crash injury. It can also be argued that lower speeds lead to safer driving, based on at least 3 reasons. At lower speeds the vehicle travels a shorter distance during the fixed period of time that it takes for the driver to perceive and react to a problem. Second, the distance required to stop the vehicle decreases with a decrease in speed. Third, lower speeds reduce the chances of a vehicle running off the road while negotiating a horizontal curve.

Effect of System-Wide Changes in Speed Limits

Again, most studies have focused on the effect of *system-wide* changes in speed limits on safety. In general, most studies have concluded that the decrease in Interstate speed limits in 1974 was associated with a significant reduction in fatal crashes, and the increase in speed limits in 1987 and 1995 were associated with an increase in fatal crashes. Charles Lave from the University of California at Irvine has challenged these results indicating that the methodologies used in these studies are flawed and did not consider changes in enforcement and shifts in traffic from less safe non-Interstate roads to safe Interstate roads following the increase in speed limits in 1987. Recently, NCHRP (through Project 17-23) sponsored a study to look at the safety impacts of changes in speed limits on high-speed roads (*9*). This study concluded that an increase in speed limit from 55 to 65 mph can lead to a 28% increase in fatal crashes; and, an increase in speed limit from 65 to 75 mph can lead to a 13% increase in fatal crashes.

Effect of Changes in Speed Limits in Speed Zones

Regarding the effect of changes in speed limits on non-limited access speed zones, studies conducted by Parker (*10*) and Parker (*8*) are notable. Both studies used before-after designs with a comparison group to study this issue. A group of roadway sections had their speed limit increased or decreased (treatment group) while for another group of roadway sections, the speed limit was not altered (comparison group). Both the studies concluded that changes in speed limit had very little effect on the frequency and severity of crashes.

More recently, Elvik and Vaa (*11*) conducted a meta-analysis of the results from 52 studies between 1966 and 1995 that had studied the effect of changes in speed limits. It is not clear how many of these studies had looked at system-wide changes in speed limits and how many looked at changes in speed limits in speed zones. The meta-analysis showed that overall, reduction in the speed limit was associated with a reduction in fatal and injury crashes; fatal crashes were reduced more than injury crashes. For example, a 10 km/h (6 mph) reduction in the speed limit was associated with approximately a 10% reduction in injury crashes and a 20% reduction in fatal crashes; whereas, a 20 km/h (12 mph) reduction in the speed limit was associated with approximately a 20% reduction in injury crashes, and a 40% reduction in fatal crashes.

Effect of Changes in Average Speeds

Elvik (*12*) tried to determine if there is a relationship between average speeds and crashes. Specifically, he tried to assess if the Nilsson power model (*13*) is a reasonable model for the relationship between crashes and average speeds. The power model states that a given change in the mean speed of traffic is associated with a relative change in the number of crashes or number of injuries/fatalities by means of a power function. Elvik (*12*) conducted a meta-analysis based on a detailed review of 97 studies that provided 460 estimates of the relationship between changes in the average speed and changes in the number of crashes/injuries/fatalities, and concluded that in general, the power model was a reasonable model. However, Elvik (*12*) also acknowledged that some of its implications are counter-intuitive. For example, the Power model predicts that the effect on fatalities of reducing speed from 80 to 40 km/h is the same as the effect of reducing speed from 10 to 5 km/h. This seems unlikely to be the case. Further work using the same data set is ongoing in NCHRP Project 17-25 to determine if alternative model forms can better explain the relationship between the relative change in crashes and the relative change in mean speed.

RELATIONSHIP BETWEEN SITE CHARACTERISTICS AND OPERATING SPEED

The research team reviewed studies that have tried to study the relationship between site characteristics and operating speed. This review was helpful in identifying the possible factors that may need to be considered in identifying the appropriate speed limit in speed zones. Fitzpatrick et al. (*14*), as part of recently completed NCHRP Project 15-18, conducted a detailed review of the literature on this topic. The review looked at different types of roadways including rural two-lane highways, low-speed urban streets, urban and suburban arterials. Most of the studies used regression type models to relate average speeds with different site characteristics. Some studies included speed limit as one of the independent variables apart from other site characteristics, while others did not include the speed limits. Collectively, the following variables were found to be significant for different types of roads:

Rural two-lane highways: In horizontal curves, degree of curve, length of curve, deflection angle, radius, and grade had some relationship with operating speed. In tangent sections, region of the country, grade, length of the tangent section, and characteristics of preceding and succeeding curves were found to be statistically significant.

Low-speed urban streets: Average curvature, percent of zone with residential land use, percent of zone with parking allowed, roadside hazard rating, and lane width were related to operating speed.

Urban and suburban arterials: Deflection angle (in horizontal curves), access density, presence and type of median, lane width (in straight segments), and roadside characteristics were found to be related to operating speed.

MOTORIST COMPLIANCE WITH SPEED LIMITS IN SPEED ZONES

Many studies have reported that the posted speed limit is usually significantly lower than the measured 85th percentile value. For example, Parker (*8*) found that, in general, posted speed limits were set at the 45th percentile value on non-limited access roads. ITE (*15*) found that for roadways with posted speed limits of 45 mph and below, most of the measured speeds are higher than the posted speed limit. When the posted speed limit is 55 mph or more, about half of the measured speeds are above the posted speed limit. Collectively, these studies indicate that there is very little motorist compliance with existing speed limits.

FACTORS AND METHODS USED FOR SETTING SPEED LIMITS

Setting System-Wide Speed Limits

Statutory limits are one-way of setting system-wide speed limits. These limits are established by legislation at the national, state, or municipal level. The National Maximum Speed Limit (NMSL) of 55 mph that was established in 1974 during the oil crisis is one example. Typically statutory limits apply to a category of highways. Other statutory limits apply to vehicle categories. Differential limits for cars vs. trucks on Interstates in many States are examples of such. Usually, with statutory limits, the trade-off between safety, travel time, and other objectives is determined politically, and hence the limits can sometimes not be appropriate for a section of road.

Another approach to setting system-wide speed limits is setting optimum speed limits. Initially proposed in the 1960's (*16*), this approach is based on the argument that the speeds selected by drivers do not take into account risks imposed on other drivers and society. In order to apply this approach, there is a need to estimate the relationship between speed limits and parameters such as travel time, vehicle operating costs, crashes, comfort, and convenience. Although this approach has conceptual appeal, there is no universal consensus on the relationship between speed limit and the other parameters, making it difficult to implement in practice.

Setting Speed Limits in Speed Zones

The most common approach to setting speed limits is based on an engineering study, which requires collecting data on operating speeds, crash frequency and severity, and other site characteristics such as roadway geometry, traffic characteristics, and roadside characteristics. The MUTCD recommends that the speed limit *should* be set at the 85th percentile speed, but adds that other factors including crash statistics, roadway cross section, pace speed, roadside development, and parking and pedestrian activities, *may* be considered.

ITE (*15*) conducted a survey to determine the factors that are being used to set speed limits in speed zones. The 85th percentile speed, roadway geometry, and accident experience, were always or usually considered by over 90% of the responding agencies. The survey revealed that roadway geometry, accident experience, and politics were the three most common reasons why a number other than the 85th percentile speed was used when setting the speed limit. Some survey responses stated that the "85th percentile does not work and a better method is needed".

It is clear that better methods are needed to identify appropriate speed limits, especially in urban roads having higher traffic volumes, a mix of road users, and more roadside activity. Practitioners have to use their experience and judgment in considering these factors. A knowledge-based expert system provides a valuable opportunity for improving the decision making process.

Expert systems for recommending speed limits have been used in Australia for more than a decade starting the late 1980's (*7*). USLIMITS, an expert system for recommending speed limits for speed zones in the USA, was developed based on the experience in developing and using the expert systems in Australia, but with changes made to suit the conditions in this country. The USLIMITS system asks the user to enter data for the following factors before recommending a speed limit:

- roadway and roadside characteristics,
- abutting development,
- nature of road user activity,
- operating speeds,
- traffic volume, and
- speed limits in adjacent sections
- presence of adverse alignment
- crash statistics
- special situations

Information about some of these factors is used by the system to provide warnings at the end of the program. USLIMITS can be accessed through the Internet, but a username and password are required, which can be obtained from the Federal Highway Administration.

AGENCIES/PERSONNEL INVOLVED IN SPEED LIMIT DECISIONS IN SPEED ZONES

Most state and local agencies base their decision to raise or lower a speed limit in a speed zone on the results of an engineering and traffic investigation. Agencies and persons frequently involved in speed limit decisions are included, but not limited to, the following groups:

- Practitioners conducting the speed studies and interpreting the results.
- Elected officials and public policy makers that respond to community affairs.
- Drivers whose behavior is a direct reflection the effectiveness of the system.
- Citizens living or working in the area who are directly impacted by the traffic flow.
- Judges and magistrates who must address the 'reasonableness' of the limit in their court decisions.
- Enforcement officials who need an objective means of separating the egregious violators from the rest of the driving population.

CONCLUSIONS

The following conclusions can be made based on this review:

- Consistent speed limits are essential even if a majority of motorists feel that they can make reasonable judgments about their driving speeds

Conclusions regarding changes to system-wide speed limits

- Increase in speed limits on interstate roads in 1987 and 1995 seem to be followed by an increase in average speeds, although the increase in average speeds was typically less than the increase in the speed limit. Effect of the increase in speed limits on speed dispersion is not very clear.

- Most researchers argue that the increase in speed limits on interstate roads in 1987 and 1995 resulted in more fatalities.

Conclusions regarding changes to speed limits in speed zones

- Very little work has been conducted to study the effect of changes in speed limits on average speeds on non-limited access speed zones.

- Very little work has been conducted to study the effect of changes in speed limits on crash frequency and severity in non-limited access speed zones. Parker (*10*) and Parker (*8*) in their work on non-limited access roads did not find any significant associations between speed limits and crash frequency/severity.

- Many studies have tried to find relationships between site characteristics and operating speed. Depending on the type of road under consideration and whether tangent sections or horizontal curves are being considered, several factors including degree of curve, deflection angle, radius, grade, lane width, presence/absence of parking, roadside hazard rating, access density, presence and type of median, pedestrian activity, and roadside characteristics, seem to be associated with operating speeds.

- In general, there is limited motorist compliance to existing speed limits.

- It is clear that posted speed limits in speed zones should be credible and enforceable. It is also clear that better methods are needed to identify appropriate speed limits especially in urban roads having higher traffic volumes, a mix of road users, and more roadside activity. Practitioners have to use their experience and judgment in considering these factors. A knowledge-based expert system provides a better opportunity of improving the decision making process.

CHAPTER 3

SURVEY OF USLIMITS USERS

A survey was sent in December 2003 to 55 individuals who had an account for using USLIMITS. The objective of the survey was to get feedback on several aspects of the program including: the ease of use, problems encountered, and the potential utility of the USLIMITS program. Fifteen individuals responded to the survey. Three had used the product for establishing speed limits, 11 had explored the application (not actually used it to set speed limits), and 1 had not used USLIMITS.

A brief summary of the results is provided here. Further details about the survey and the response are available in Appendix B. The questions asked in the survey were as follows:

1. Have you or your agency explored or applied the USLIMITS program for the purpose of setting speed limits?
2. Enter the number of speed zoning projects in each roadway type for which you have applied USLIMITS.
3. Apart from using USLIMITS, describe how you currently set speed limits, e.g., do you have established or written guidelines (this question applies to only those agencies that have authority to set speed limits).
4. Please rate the overall Ease of Use of the USLIMITS program. Indicate how the ease of use can be improved.
5. Please comment on the clarity and completeness of the input screens, on-line help, and the Users Manual.
6. The data collection form in the USLIMITS program asks the user to input information on several variables/factors. Based on your knowledge and experience, please indicate whether you feel each of these factors are of "primary importance", "secondary importance", or "not important" (the variables are described in the USLIMITS user manual). In addition, also list additional factors that need to be considered, and indicate whether they are of primary or secondary importance.
7. Please describe problems and annoyances encountered in using USLIMITS. If you have a specific recommended solution to a problem, please provide that as well.
8. Was USLIMITS useful in assisting with your speed zoning decision? Explain.
9. Would you say that speed limits recommended by USLIMITS are reasonable based on your knowledge and experience? If No, please explain. For example, are the recommended speed limits higher or lower than what you would have recommended for certain types of roads, areas, or conditions?
10. Please comment on the content, completeness, and flexibility of the USLIMITS output report.
11. Does the USLIMITS output report provide all the relevant information that you need? What changes would you suggest?

Eleven respondents felt that USLIMITS was easy to use; two felt that it was not easy to use (question 4). Eleven respondents felt that the speed limit recommended by USLIMITS was reasonable; two felt that the speed limit recommended by USLIMITS was not reasonable (question 9).

Twelve individuals responded to question 6, which asked the user to rate the importance of factors currently used by USLIMITS to develop its recommended speed limit. Road length, road function, number of accesses, number of lanes, whether the section is a freeway (or not a freeway), traffic volume, operating speeds, presence/absence of adverse alignment, presence/absence of signals or unprotected pedestrian crossings, special activities, and crash rate, were selected as of 'primary importance' by more than half the respondents (i.e., at least 7 of the respondents): operating speeds and adverse alignment were identified by 11 respondents, road function was identified by 10 respondents, and crash rate was identified by 9 respondents to be of primary importance.

Some respondents provided detailed comments on different features of USLIMITS. Here is a summary of the some of the problems that the users faced, their recommendations for improvement, and actions taken by the research team to avoid these problems in the second generation expert system:

- The program should provide more information about the logic that it uses and the factors that are used/not used in developing the final recommendation. One respondent pointed out that the system is not sensitive to a lot of variables that are required to be input.
    - It is possible that the lack of information about the decision rules used in USLIMITS reduces the confidence in the potential users. The decision rules used to develop the second generation expert system (USLIMITS2) is documented and available to the user.

- Some respondents felt that it would be easier to have a single long form to enter most of the data rather than waiting for different screens to load. The program should allow easier navigation among the input windows.
    - The USLIMITS program has several windows with one window allocated for each factor. USLIMITS2 allows users to enter most of the site characteristics (except crash data) in one screen, and hence reduces the time it takes to go through the program.

- Definitions should be provided for some of the variables such as access, access types, street classifications, shoulder, and density of surrounding development.
    - In USLIMITS2, by clicking on the More Info link, the user can obtain further information about each variable. Users also have access to the User Guide that provides more information about each variable.

- A couple of respondents felt that the tool is probably geared only towards high speed facilities and not very useful for lower speed urban situations.
    - Since the decision rules used to develop USLIMITS is not available to the user, it is hard to know if this is true or not. In USLIMTS2, decision rules have been developed to deal with different types of roads including high speed facilities and lower speed urban situations.

- Improve the output to make it easier to read. The output should also include information about the input data that was entered by the user.
    - In USLIMITS2, users can download the output in a MS Word file, and this file provides information on the input data entered by the user.

CHAPTER 4

IDENTIFICATION OF THE EXPERT PANEL

The knowledge base and decision making processes used in expert systems are drawn from experts with background and experience in the area of interest. The success or failure of an expert system is dependent upon the selection of an appropriate group of experts with knowledge, experience, and interest in the subject area. Members of the expert panel chosen to provide input for the expert system were selected from a comprehensive list of persons engaged in setting, enforcing, or adjudicating speed limits in speed zones, and individuals with significant research experience in this area. The process used to identify the panel members is outlined in this section.

SELECTION OF EXPERT PANEL MEMBERS

The expert panel for this study was involved in all areas of product development, starting with the planning stage, continuing with development of the decision rules, and concluding with the evaluation of the prototype expert system. The expert panel provided expertise in how speed limits are set and enforced; identified the level of skill, needs, and requirements of the user community; determined the variables to be considered; provided data on how problems and issues are addressed in practice; and advised on how the system must function to be accepted by users.

In order to fulfill the general data and other needs of the project, the research team identified a comprehensive list of individuals involved in the speed limit setting process. The list was further refined to identify candidates who would attend the expert panel meetings in Washington, DC. This group is hereafter referred to as the Expert Panel. All other candidates (hereafter referred to as the expanded panel) were retained on a second list and were contacted by email, telephone, mail, etc. to provide input on specific topics.

Development of the Comprehensive List of Potential Candidates

The initial selection of candidates to provide input for this project was based on identifying individuals whose responsibility included, but was not limited to, the following speed management-related areas:

- Highway engineer.
- Traffic operations administrator.
- Traffic engineers who analyze speed and other data and recommend a posted speed limit. (Engineers from a cross-section of States were solicited. The group also included engineers from local jurisdictions, i.e., cities, counties, etc.)
- Traffic operations/safety systems computer analyst.
- Public policy and political issues specialist and elected officials.
- Traffic enforcement administrator.
- Traffic patrol officer.

- Judicial administrative representative.
- Researchers with significant experience in speed studies.

After identifying the areas of specific expertise, the next step in the selection process was to select individuals for each of the categories mentioned above. To initiate this process, the research team examined a wide variety of membership lists including, but not limited to, the following organizations and events:

- State Department of Transportation members as well as practitioners with cities, counties, and other local highway agencies.
- Presenters and attendees at the Speed Management Workshops that were held in Washington, DC on January 9, 2000; Dallas, Texas on March 6, 2000; Jacksonville, Florida on June 12, 2002; and at the Institute of Transportation Engineers (ITE) annual meeting in Philadelphia, Pennsylvania on August 4, 2002 http://safety.fhwa.dot.gov/fourthlevel/flspeedwkshp.htm, [Accessed 11/8/2002].
- Members of the AASHTO Traffic Engineering Subcommittee.
- ITE Traffic Engineering Council and Safety County Committee members.
- Member of ITE Committees 4M-25, Speed Zoning Guidelines, and TENC 97-12, Survey of Speed Zoning Practices.
- Participants in the TRB Committee that developed TRB Special Report 254, Managing Speed – Review of Current Practice for Setting and Enforcing Speed Limits.
- Members of the FHWA Scanning Program Study Tour for Speed Management and Enforcement Technology (http://ntl.bts.gov/DOCS/speed06.html), [Accessed 11/6/2002]
- Participants in the ongoing Cooperative Agreements on Speed Setting and Enforcement Projects in Connecticut, Mississippi, etc.
- Members of the U.S. DOT Speed Management Team, which includes sponsors from FHWA, NHTSA, and FMCSA.
- Members of NCHRP Project 3-67 Panel who would be willing to provide their knowledge and expertise.
- Persons who had obtained a username and password to examine the beta version of USLIMITS.

Contact information for persons identified through the above sources was placed in a spreadsheet for further analysis. Over 100 individuals were initially placed on the master list.

Selection of Potential Candidates

As previously noted, the Expert Panel consisted of individuals who were willing to attend panel meetings in Washington, DC. In selecting the Expert Panel, the following general criteria were used:

- Individuals were identified with the following expertise:

    - Enforcement
    - Judicial
    - Traffic Engineering

- Other including research, public policy, elected officials, etc.

- In accordance with the travel budget allocated for this activity, a maximum of eight candidates were selected from outside the greater Washington, DC area. Other candidates were selected within Washington, DC area.

- For each expertise and within the travel constraints listed above, candidates were selected from different geographic regions as well as from states, cities, and other jurisdictions ranging from rural to large urban centers.

Based on the selection criteria, individuals from the master list were chosen as candidates to be on one of the two panels. Prior to contacting the persons on the Expert Panel list to determine their availability, the meeting group list and the contract group list was sent to the NCHRP 3-67 Panel for review and comment. In written comments received from the Panel, eight additions and one deletion were suggested for the Expert Panel proposed to meet in Washington, DC. In addition, eight additions and one deletion were suggested for the Expanded Panel.

Following input from the NCHRP Panel, the revised list of candidates for the Expert Panel was further refined. The selection process consisted of sending or directly contacting the person and asking the questions shown in Table 1. Based on the responses to the questions, each person was placed on either the Expert Panel list or the Expanded Panel list. Some of the individuals were not available for travel, and three candidates did not respond to the inquiry. Of the persons who were available to meet, the list was further refined to only include eight persons from outside the greater Washington, DC. The criterion used in this refinement was primarily based on the experience and involvement of the candidate in setting speed limits in speed zones.

The list of Expert Panel members who were invited to the June 10 and 11, 2004 meeting in Washington, DC is shown in Table 2. The list of members who attended at the December 2005 expert panel meeting is shown in Table 3.

The persons who were either not selected or were not available to attend the Washington, DC meeting were placed in the Expanded Panel except for those who noted that they could not participate (see Appendix C for the Expanded Panel). It should be noted that persons attending the meeting were also periodically contacted and asked to provide specific expertise needed to complete the knowledge base and/or logic for the expert speed limit system.

Through two meetings in Washington, DC (one held on June 10-11, 2004 and the other in December 2005) and through the use of regular mail, e-mail, and telephone, the expert and expanded panels provided information and feedback in the following project areas:

- Expert System Planning – What should the system do? Who are the end users? Who should administer and maintain the site?
- Speed Management Knowledge – Knowledge of user needs, user requirements, variables and factors considered, problems encountered in setting and enforcing speed limits and solutions, etc.

- Expert System Development – Breakpoints for critical variables and factors, decision rules, and logic flow.
- System Validating and Evaluation – Reviewed and critiqued the beta version, provided recommendations for system modifications, etc.

Table 1: Questions for Potential Expert Panel Candidates

NCHRP 03-67
Expert System for Recommending Speed Limits in Speed Zones

1. Are you directly involved in setting speed limits for roads and streets in your jurisdiction?

2. Please describe your experience with speed limits, including years of experience?

3. Have you heard of USLIMITS, an advisory program used to set speed limits?

4. Do you have an interest in our project?

5. Would you be interested in traveling to Washington, DC to serve on an expert panel?

6. Are you available for travel to Washington, DC on June 10 and 11 and again next year (date to be determined)? Reimbursement is available for travel costs only.

7. Would you be interested in being a member of our expert advisory group which does not require travel to Washington, D.C.?

Table 2. Attendees at the Expert Panel Meeting in Washington, DC (June 10-11, 2004)

<u>Out of Town Attendees</u>

Bruce Ward, Traffic Engineer, Town of Gilbert, AZ
Cpl. Michael Caldwell, Traffic Bureau, Taylor Police Department
Michael J. Cynecki, Traffic Engineering Supervisor, City of Phoenix
George W. Black, Jr., Senior Civil Engineer/National Resource Specialist, National Transportation Safety Board
Michael K. Curtit, Technical Support Engineer, Missouri Department of Transportation
Robert S. Ciolek, Magistrate, City of Taylor, MI
Harold T. Thompson, National Safety Council
William Taylor, Michigan State University, NCHRP 3-67 Panel Member

<u>Washington, DC Area Attendees</u>

Lt. Dennis R. O'Neill, Police Officer, Fairfax County Police Department
Davey Warren, FHWA Office of Safety Programs, NCHRP 3-67 Panel Member
Mena Lockwood, Virginia DOT
David Snyder, Falls Church, VA City Council
Ron Lipps, Traffic Engineer, Maryland State Highway Administration

Table 3 Attendees at the Expert Panel Meeting in Washington, DC (December 2005)

Name	**Affiliation**
Joseph Durkee	Arlington County, VA
Michael Caldwell	Taylor Police Dept, Michigan
Dennis O'Neill	Fairfax County Police
Martin Bretherton	Gwinnett County, Georgia
Bruce Ward	City of Gilbert, Arizona
Larry Caldwell	Virginia DOT
Ron Lipps	Maryland DOT
Bill Finger	City of Charlotte, NC
William Taylor	Michigan State University, NCHRP 3-67 Panel Member
Davey Warren	FHWA, NCHRP 3-67 Panel Member
David Synder	American Insurance Association; City Council Member – Falls Church, VA

CHAPTER 5

USER NEEDS, SYSTEM REQUIREMENTS, AND HARDWARE/SOFTWARE REQUIREMENTS

USER NEEDS AND SYSTEM REQUIREMENTS

The identification of user needs and system requirements for the expert speed limit system was accomplished via a two-step process. First, the research team developed a preliminary set of user needs and system requirements based on extensive experience and contacts with agencies and persons involved in setting and enforcing speed limits at the state and local level throughout the United States. In the second step, this preliminary set of needs and requirements was refined by the Expert Panel at the meeting in June 2004, and the NCHRP Panel during the Interim Meeting in August 2004. The refined needs and requirements were used in developing the hardware, software, and interface requirements which were used as the basic building blocks for developing the expert system. In addition, the fundamental user needs were used to evaluate the effectiveness of the completed system, e.g. is the system user-friendly, do users accept the system, is the system maintainable, etc.

User Needs

Based on years of experience working with state and local highway and law enforcement officials and public officials involved in speed management, the following user characteristics were identified:

- Most State and larger urban jurisdictions have computer networks connected to the Internet. Most of the users have been trained and are experienced Internet users. Web applications are accepted practice for interactive problem solving, and the results are widely accepted by administrators, politicians, and the public.

- Some small jurisdictions may or may not have Internet access. As computer prices and Internet access has become commonplace across the county, most localities will have Internet connections in the near future. In addition, affordable high-speed Internet access is becoming available in many areas.

- The basic requirements of an engineering and traffic study, which is conducted to set speed limits in speed zones, typically consists of a large number of geometric, vehicle characteristics and volumes, land use, non-motorized user information, crash statistics, and operating speed data. In some cases, much of this data is often not used effectively because of the absence of guidelines in how the information should be considered in speed limit decisions.

- Engineers and other practitioners that may use this system are typically very busy and do not have time to learn new systems or continually refer to manuals on how to use a software product. Hence, the expert system should require no formal classroom training. Not only should the interface be intuitive, it should provide explanation at each step of what is happening and the consequences of each decision made by the user.

- While context sensitive self-help features are one means of addressing user needs, some users are not satisfied until they have their questions addressed by a site monitor. Responses to questions from users must be provided in a reasonable amount of time and should be specific enough to address the user's concerns.

- Practitioners are frequently faced with political influences that encroach on speed limit decisions.

System Requirements

Based on the experiences of the research team, the results of the literature review, and the user needs described above, the following general system requirements were identified:

- The system should be a web-based application; however, as mentioned earlier, some users in small communities and rural areas may not have access to the Internet.

- When developing the expert system, the type of variables and amount of data collected or that can be collected by the agency must be taken into consideration. Care should be taken to insure that the system does not require extensive data collection that is beyond the scope of data now collected and maintained by the agency. In other words, the system needs to be data-driven but not data-intensive.

- The user interface and method of interacting with the user should be compatible with the expectations of the user and the physical realities of the road or street being examined. For example, the user should not be asked to input the number of driveways on limited-access highways.

- The system data needs and decision-making process should be self-explanatory. Convenient electronic assistance should be provided.

- Training requirements for a new user should be minimal with sufficient help provided to assist with the terms or processes used.

Expert Panel Feedback

The preliminary set of user needs and requirements were summarized and presented at the Expert Panel meeting held in Washington, DC on June 10-11, 2004. Panel members were asked to comment on, remove, add to, or modify the preliminary list of user needs. The panel agreed with the needs and requirements identified, but emphasized the following two issues:

Access of the Expert System through Internet versus CD

Some members of the expert panel indicated that some jurisdictions still do not have access to the Internet and others have filters that prevent them from accessing certain sites. Hence, a CD product would be useful. Other members argued that jurisdictions that do not have access to Internet are unlikely to use a tool such as an expert system to set speed limits. Since developing a CD version of the product in addition to the Internet version incurs additional costs, this issue was discussed further with the NCHRP Panel at the Interim Meeting. The NCHRP Panel felt that the development of the CD product was not worth the additional cost.

Information about the Decision Rules

In order for the decision maker to use the tool effectively, information about the factors considered by the system and the decision rules should be available to the user.

APPLICATION DESIGN AND HARDWARE/SOFTWARE REQUIREMENTS

Application Platform

There are a variety of tools that could be used in the development of the expert system. The tools can be divided into two categories: programming languages and expert system shells. Programming languages that have been used by project team members for expert advisor systems range from Microsoft Excel for the selection of appropriate signal timing plans to Allaire's ColdFusion for a web-based system that allows one to select the most appropriate countermeasures for pedestrian safety.

Expert system shells (e.g., EXSYS, CLIPS, Nexpert-Object, VP Expert) are specifically designed so that their modular development allows for additions and changes as the defined knowledge base grows. One has to be careful in selecting an appropriate expert shell that can not only provide the programming robustness required to meet the functional specifications, but also be applicable in a web-based environment. In addition, the cost of the development tool is a consideration.

For this project, the research team used a traditional programming backed by a database rather than the use of an expert system shell. The research team felt that while there are shells on the market that allow for non-programmers to create and maintain the necessary code, these options limit the overall functionality of the system. The final product is envisioned to be a robust and versatile web application that is best created and maintained with an equally robust and versatile programming language. Furthermore, by storing the variables and valid values in a database, and structuring the code accordingly, future updates or modifications will only require the modification of the database, and not the code. Maintaining a database is much easier, less costly, and safer that editing code.

Product Medium

The primary product developed in this effort is a web-based application. Subsequently, the discussion that follows pertains to the hardware and software requirements for such.

End-User Hardware, Software, and Interface Requirements

With a web-based product, the user is only required to have a computer with web-browsing software connected to the internet. Any web browser version developed in 2003 or later would be sufficient. Examples include Netscape (Version 6.0 or later), MS Explorer (Version 5.5 or later), and Firefox (Version 0.8 or later). The final results are output to the user's computer screen. Users will not need any special skills to access and use the system.

Server Hardware, Software, and Interface Requirements

The system host configuration includes a web server, an application server, and a database server. The host machine should be server-grade, with sufficient memory and disk space to accommodate the selected server software. The server, operating system, web server, and application server are an integrated package. The minimum requirements for the application installed in a UNIX server are as follows:

- Processor: UltraSPARC IIIi
- Memory: 2048 MB
- Disk Subsystem: SCSI or RAID

The minimum requirements for a WINDOWS server are:

- Processor: Pentium IV 2.8 GHz
- Memory: 1024 MB
- Disk Subsystem: SCSI or SATA

Product Development Software

In creating numerous web applications over the years, the research team has found ColdFusion MX and Oracle to be the best overall programming language and database structure for building powerful applications, and hence used to develop the expert system. While other options did exist (such as ASP and PHP) when the decision was made to use ColdFusion, ASP and PHP had limitations that the research team felt would be detrimental to this application.

ColdFusion is a server-side solution for creating interactive, database-driven Web sites. It works in conjunction with a Web server to deliver dynamic, rather than static, Web pages. In other words, the web page content varies according to user input. Web pages are built including special tags, which must be hosted on an application server that supports ColdFusion. When a

Web browser requests one of those pages, the application server first interprets the special tags, replaces those tags with the results of whatever calculations or database queries are specified, and then sends the completed page to the Web server, which then sends it to the browser.

ColdFusion uses a tag-based language—normal HTML tags are mingled with those of ColdFusion Markup Language (CFML). CFML includes tags for querying databases and outputting text, and interacting with other Web services such as email. Instead of ending the filenames with .htm or .html, the .cfm extension is used.

CHAPTER 6

DEVELOPMENT OF THE DECISION RULES

The decision rules were developed using information obtained from several meetings/conference calls with the expert panel and the NCHRP Panel, and surveys of practitioners around the country. The following list outlines the meetings, surveys, and other steps that were undertaken:

- Expert Panel Meeting (June 2004)
- Interim Meeting with the NCHRP 3-67 Panel (August 2004)
- Survey of NCHRP Panel and Expert Panel (Fall and Winter 2004)
- Web-Based Pilot Tests (Spring and Summer 2005)
- Final Round of Web-Based Case Studies (Fall 2005)
- Expert Panel Meeting (December 2005)
- Development of Draft Decision Rules (January 2006)
- Develop of Expert System Prototype (March and April 2006)
- Conference Call to Discuss Draft Decision Rules and the Prototype (May 2006)
- Final Decision Rules and Expert System for Panel Review (August 2006)

Further details about each of these steps are discussed below.

EXPERT PANEL MEETING IN JUNE 2004

This section provides an overview of the activities at the expert panel meeting in June 2004 that were used to identify critical factors and gives insight to how the information may be considered in the decision making process when determining a recommended speed limit in a speed zone. The critical factors and elementary decision logic were identified via a review of the literature and through case studies presented during the meeting.

One of the first steps in developing an expert speed limit system is to identify critical factors that need to be included. *Critical factors* are factors and variables that are considered by experts to be essential to formulating a speed limit recommendation. Without a critical factor or default value supplied by the system, it is not possible to make a speed limit decision.

Prior to the June 2004 meeting, the members of the expert panel were sent the following materials for review:

- Tentative Agenda for the two-day meeting
- Draft version of the Literature Review (Appendix A has the updated version)
- Results of the Survey of USLIMITS Users (Appendix B)
- Preliminary List of Variables and Factors (Appendix D)

In addition, prior to the meeting, the research team developed a series of case studies, which consisted of photographs and supporting speed, crash, geometric, and other data. Each case study was a section of road or street in southeastern Michigan where speed, crash, and other data were recently collected in order to determine the appropriate speed limit for the speed zone. The Expert Panel was not furnished with the case studies prior to the meeting.

The primary objective of the meeting was to use the knowledge and experience of the group to identify the critical factors and variables needed to make a speed limit decision. In addition, once the major factors were identified, the second major objective was to obtain a preliminary understanding of how the variables were evaluated and used in making the speed limit decision.

At the beginning of the meeting, the research team presented an overview of the project, a brief demonstration of the current USLIMITS program, and described the meeting objectives. The research team then made a presentation on user needs and requirements and obtained feedback from the Expert Panel. Following a break, the reminder of the day and most of the following day was devoted to identifying the critical variables.

The session on critical variables began with a PowerPoint introduction of the preliminary list of variables. The variables were presented for the following roadway types:

- Rural interstate highways
- Urban interstate highways
- Rural high-speed two-lane and multi-lane highways
- Urban and suburban multi-lane and two-lane roads
- Rural lower speed two-lane roads
- Urban residential streets

Some members of the expert panel felt that the distinction between rural and urban was sometimes ambiguous and the distinction between high speed/low speed roads should be made based on factors such as operating speed/design speed. There was a general consensus that the roads could be categorized into freeway, multi-lane, and two-lane, for undeveloped and developed areas.

Case Studies

Up to this point in the meeting the Panel members were provided with the list of variables based on the literature review and the experience of others. While this information may have introduced some bias either for or against a particular variable, the research team did not make the assumption that all of the variables described in the literature were actually used in practice to make speed limit decisions. To identify which variables the Expert Panel felt were critical to the decision making process, a series of case studies were introduced through photographs, and the attendees were asked to tell the research team which variables they felt were critical for the particular road section under study. Thus, the Panel members had to examine the photographs, which were projected on the screen for all members to review, and then decide what information, or variables they needed to determine the speed limit for the section.

To initiate the use of case studies and to set the stage for having the Panel members identify critical variables based on their experiences, the research team made a presentation that is summarized on the next two pages in Figure 1. The purpose of the presentation was to provide a general overview of the process that would be used by the panel to identify critical variables. The presentation consisted of eight slides taken at various road and street locations in southeastern Michigan. A broad cross section of roads was used which included the road types identified during the literature review. As shown on the next two pages, only general titles, such as Rural two-lane, Urban with on-street parking, etc. was used to describe the sections. No other information, such as operating speeds, traffic volumes, etc., was supplied. Throughout the presentation, the Panel was asked to think about what variables they would need to determine the speed limit on the section if the road was in their jurisdiction.

During the two-day meeting, a total of six case studies were presented to the Expert Panel. To illustrate the process used to identify the critical variables, one of the case studies, a rural two-lane road, is presented in this section.

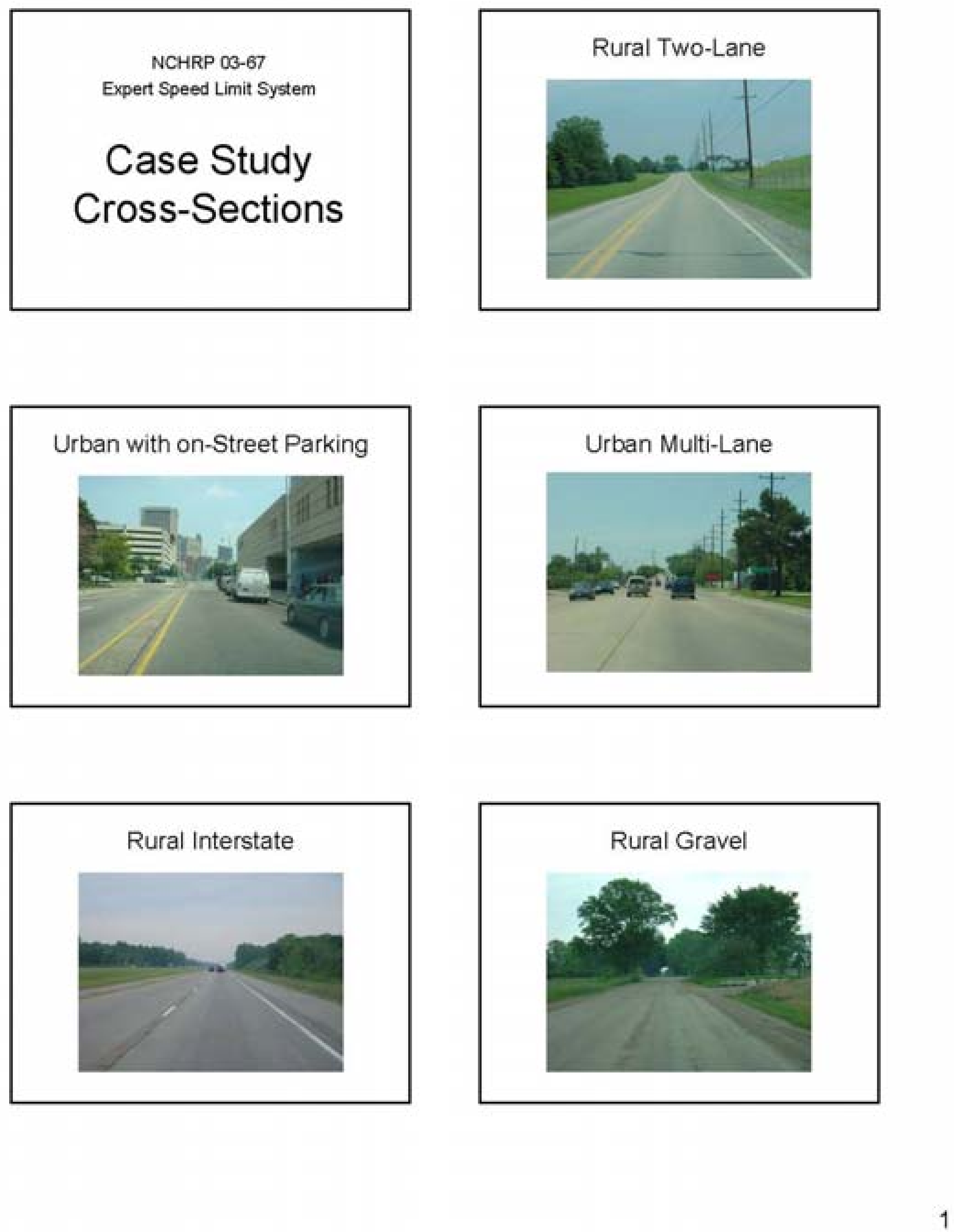


Figure 1. Typical cross-sections for the case studies used in the Expert Panel meeting.

Figure 1 (con't). Typical cross-sections for the case studies used in the Expert Panel meeting.

Case Study Example (Rural Two-Lane Road)

As shown on Figure 2, photographs of representative cross sections of a rural two-lane road in southeastern Michigan were shown to the Panel on the screen. The members were asked to review the photographs and determine the variables they would use to determine the appropriate speed limit for the section. A general or broad list of variables was not permitted, because this is not reflective of general practice, i.e., speed limit decisions are usually based on collecting just the amount and type of information needed to make the decision. The collection of other variables may be desirable; however, it is not routinely done due to personnel and budget limitations.

The following variables were requested by the Panel for this road segment. The information presented below is based on the data that was actually collected at the site prior to the meeting.

- Section length = Two miles.
- Speed data
    - 85^{th} percentile speed ranges from 53 to 55 miles per hour.
    - Average speed ranges from 47 to 49 miles per hour.
    - Pace ranges from 47 to 56 with approximately 72 percent of the vehicles in the pace.
- Posted speed Limit = 40 miles per hour
- Speed limits on the adjacent sections = 55 and 35 mph. The 35 mph section is in a small town.
- ADT = 1,200 vehicles per day.
- Reason for the study = Request to raise the speed limit.
- Crash experience was extremely low (4 crashes in 3 years with 1 injury crash).
- Little pedestrian or bike traffic observed on the section.
- The shoulder width is variable.
- There are no schools in the area.
- The roadside development consists of a few residential farmhouses, i.e., low density.
- There are no public road intersections within the segment.

After identifying the critical variables for each case study similar to the process described above, the Panel was subdivided into break-out groups and asked to categorize each variable by high, medium, or low importance. Each breakout group was presented with photographs of different types of roadway segments and asked to develop the list of factors for which data would be necessary in order to identify the appropriate speed limit for a particular roadway section.

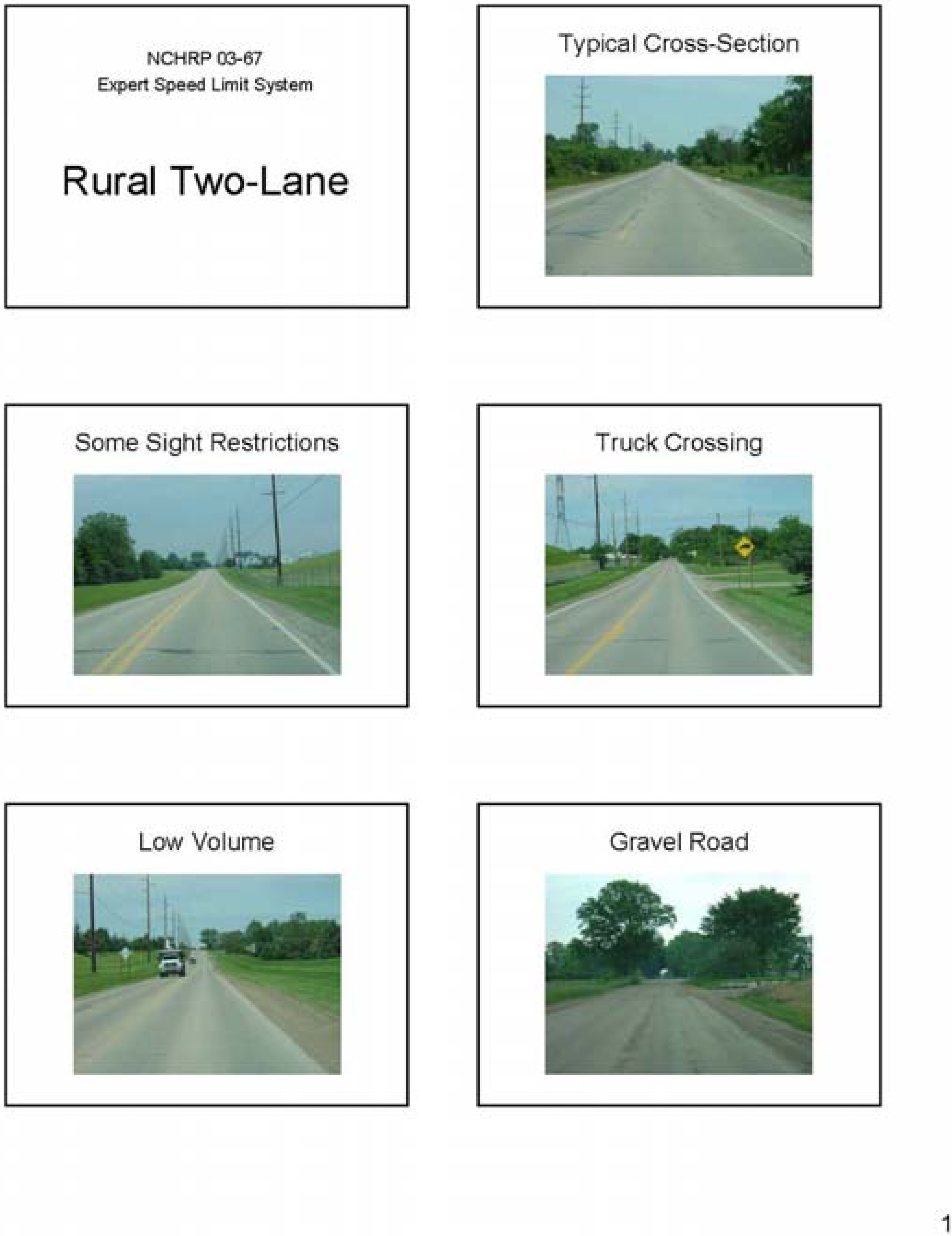


Figure 2. Images used in the Expert Panel meeting for the Rural Two-Lane case study.

In subsequent exercises, the Panel was asked to consider the quantitative information for each section (e.g., operating speeds, crash statistics, etc.) and to recommend a speed limit for the section. This was done to examine the decision logic used by the experts to arrive at the recommended speed limit. Generally, using the data the Panel requested, the majority of the panel members recommended a speed limit within 5 miles per hour of each other for a particular road segment. Most members felt that the operating speed was an important factor in obtaining an initial speed limit, but there were differences on how the other variables should be considered in the decision making process.

Critical Variables

The panel identified the following variables as critical for the three different roadway types (Table 4):

Variable	Freeway	Multi-lane	Two-lane
Operating Speed	X	X	X
Roadway Geometrics (more critical if operating speeds are not available)	X	X	X
Cross-section (includes clear zone)	X	X	X
Crash statistics	X	X	X
Roadside friction		X	X
Major intersection/interchange spacing	X	X	X
Ped/Bike activity		X	X
Road classification		X	X
Proximity to a School Zone		X	X

Table 4: Critical variables for the three different roadway types

Conclusions from the June 2004 Expert Panel Meeting

The processes used to identify the decision rules used to determine the numerical value of the posted speed limit for a section of road included utilizing the experience of the research team and the knowledge and experience of the Expert Panel. The list of critical variables and a preliminary understanding of the logic used to recommend a speed limit in a speed zone was obtained at the Expert Panel meeting. However, it was recognized that to further develop the decision rules, more work was needed including input from the Expanded Panel of experts listed in Appendix C.

The following conclusions were made following the expert panel meeting:

- Operating speed is a critical factor in all types of roads. Based on the speed limit provided by the individual members of the expert panel for the different case studies, it is clear that the speed limit should not exceed the 85^{th} percentile speed. Some members of the expert panel felt that average speed, median speed, and pace, should be considered in addition to the 85^{th} percentile speed, although it was not clear how exactly the supplemental speed measures were being applied to the decision.

- Crash statistics were also considered a critical factor by the members of the expert panel. A three year crash history, as a minimum, was felt necessary by the panel. A road with a poor crash history might need input requiring road features, while a section with a below average crash history would not require this additional information. For some members of the expert panel, information on the 85^{th} percentile speeds and crash statistics was sufficient for them to identify the appropriate speed limit. In addition, some members of the Expert Panel felt that on road sections with a higher-than-average crash rate, the expert system should call for a safety investigation to identify the problem and determine the appropriate course of action, which may or may not include changing the posted speed limit.

- Number of access points, available clear zone, roadside friction, extent of ped/bicycle activity, and road classification were variables considered critical by many members of the expert panel for non-limited-access roads.

- For many members of the expert panel, operating speed and crash statistics were the two most critical factors. In other words, if operating speed and crash statistics are available, the other factors become supplemental. If operating speed and crash statistics are not available, these other factors become surrogates and therefore are more critical. There were exceptions, e.g., some members in the expert panel felt that speed limits in two-lane residential streets should be limited regardless of crash statistics and operating speeds.

- Many members of the expert panel felt that there should be a clear distinction between new/reconstructed roads and existing roads. New roads (either in the design or construction phase) will have no speed or crash data. Reconstructed roads may have been altered to the point that any historical data on speed and crashes no longer represent the existing conditions. This issue was discussed further at the Interim Meeting with the NCHRP Panel.

- Ideally, the variables used in the expert system must be objective and measurable. Ease of measurement should be considered.

- The system must be able to provide default values for factors when data are missing or not available.

- In formulating a decision, it must be determined under what conditions an advisory limit effects a speed limit in a speed zone.

- In most cases, knowledge of the statutory speed limit will be necessary in developing a speed limit recommendation.

INTERIM MEETING WITH THE NCHRP 3-67 PANEL (AUGUST 2004)

The Interim Meeting involved a detailed discussion of several issues including the critical factors identified at the June 2004 Expert Panel and the options for developing the decision rules for the expert system. Here is a summary of these discussions.

Discussion of Critical Factors

As discussed in the beginning of Chapter 6, the expert panel identified critical factors for freeways, multi-lane roads, and two-lane roads that need to be included in the development of the expert system. Following is further discussion of issues and questions with respect to the individual critical factors:

Operating Speed

Although there was general agreement among the expert panel that the 85^{th} percentile speed is an important parameter, and the speed limit should not exceed the 85^{th} percentile value, some panel members wanted to know the median speed, the pace speed, and the percentage of vehicles in the pace, before they made the decision about the appropriate speed limit. However, it was not clear how exactly these parameters were used. Some questions that need to be answered include:

- Can the recommended speed limit be lower than the median speed? If yes, what are the conditions/roadway types where this should be (or should not be) an option?
- How should the pace, and the percentage of vehicles in the pace, influence the recommended speed limit, or provide an upper/lower bound for the recommended speed limit?
- Should the system provide guidelines on where speed data should be collected, e.g., in tangent sections, middle of a horizontal curve, etc.?

Crash Statistics

Part of the concern is that the crashes experienced on a roadway section may be totally unrelated to operating speed or speed limits, and the problem cannot be resolved by simply lowering the speed limit. A roadway section may have a high crash rate because of poor design, irregular pavement surface, insufficient sight distance, and a host of other factors. However, many of the NCHRP panel members felt that a system that would exclude safety would not be well accepted by the users. Most of the NCHRP panel members felt that the system should require the user to obtain and input crash data. How safety should be incorporated in the expert system should be determined based on expert knowledge.

Roadway Geometry

In this context, roadway geometry includes the frequency/severity of horizontal and vertical curves, and adverse alignment. Previous research has shown that there is a relationship between roadway geometry and operating speeds (see Appendix A under the section entitled "Relationship between site characteristics and operating speed"). Hence, if reliable operating speeds are available and roadway geometry is uniform over the segment, roadway geometry is less critical. However, if information on operating speed is not available and the section includes adverse alignment, then geometry can become more critical. With adverse alignment, it is necessary to decide if advisory speeds are sufficient, or if the speed limit for the whole section needs to be reduced.

Cross-section

In some ways, issues regarding cross section parameters are similar to the issues associated with roadway geometry. Relationships between cross section characteristics and operating speeds are available in the literature (see Appendix A under the section entitled "Relationship between site characteristics and operating speed"). Again, if reliable operating speeds are available and section characteristics are uniform over the segment, cross section characteristics are probably not critical. However, if information on operating speed is not available, and the section includes design exceptions (such as narrow lanes), then, cross-section characteristics can become more critical. Examples of questions that need to be addressed here include:

- How should road design exceptions, such as narrow lanes (e.g., 10 foot lanes) affect the speed limit?
- If a median is installed on an undivided multi-lane road, should that lead to a change in the speed limit? Should type of median have an impact on the posted speed limit?
- If a roadway segment has a limited clear zone (e.g., due to trees and utility poles), should that result in a reduction in the speed limit?

Roadside Friction

This refers to number of access points, parking activity, and surrounding land use. This variable is applicable only for multi-lane and two-lane roads. Although there is some evidence in the literature about the relationship between roadside friction and operating speeds and safety, few studies have examined this association. The question here is how to quantify the individual and combined effects of these factors on speed limits. Examples of questions include:

- How should the effect of parking activity quantified?
- Should the number of access points affect the speed limit decision?
- Should the type of adjacent land-use (i.e., residential, commercial, and industrial) influence the speed limit decision?

Number of MajorIntersections/Interchanges

Number of major intersections/interchanges increases the interaction between slow and fast moving traffic, and can have an effect on safety and operating speeds. Again, the question is how to quantify the effect on this variable. Examples of questions include:

- How should the number of intersections in a section used in the speed limit decision?
- Should the volume of turning and cross street traffic be considered in the system? Is it reasonable to expect users to obtain detailed turning and cross street traffic information?

Ped/Bike Activity

Again, this variable is applicable only for multi-lane and two-lane roads. One could argue that some measure of activity, i.e., number of pedestrian and bicycle crossings during a certain period and the presence/absence of unprotected crossings needs to be considered. There is a need to be able to quantify the effect of the different levels of these factors. Examples of questions to be addressed include:

- How should the presence/number of uncontrolled pedestrian crossings affect the speed limit?
- Should the system consider exposure information on the number of pedestrians/bicycles? Is it reasonable to expect the user to have this information?
- Should the system recommend lower speed limits if school-age children are present or because the section is located adjacent to a school zone?

Road Classification

One way to classify multi-lane and two-lane roads is to classify them as *through* and *local*. The goal here would be an attempt to separate those roadways with primarily commuter traffic and those comprised of local residents. Using traffic volume (i.e., AADT), one may be able to roughly distinguish between through and local. For example, through roads would be expected to carry a higher traffic volume than local roads. By itself, road classification may not affect the speed limit. However, in combination with other variables such as roadside friction and ped/bike activity, a reduction in the speed limit may be appropriate. Examples of questions to be addressed include:

- Is there a specific definition for through versus a local street that should be provided to the user of the expert system?
- How should the presence of traffic calming influence the recommended speed limit? Should the system try to differentiate between different types of traffic calming devices?

Roadway Segments Near School Zones

Setting speed limits specifically for school zones is outside the scope of this application. However, some members of the expert panel indicated that roadway segments near school zones where school-age children may be crossing may need to have a speed limit reduction. One way to address this issue is by introducing a level in the Ped/Bike Activity variable that will account for the presence of school-age children.

Residential Subdivision Streets

The NCHRP Panel felt that the expert system should recommend that residential (or subdivision streets) be posted at the statutory speed.

New and Reconstructed Roads

The NCHRP Panel felt that the expert system should recommend that the statutory speed be posted on new roads until such time that reliable data on operating speed, crashes, and other factors can be collected.

Different Approaches for the Development of the Decision Rules for the Expert System

Following the discussion of the critical variables, the research team presented three options that could be used to complete the development of the decisions rules for the expert system and answer the questions raised earlier. Following is a brief discussion of these options.

Option A

In this approach, a comprehensive set of real-world case studies providing all necessary combinations of the relevant levels/values of the critical factors will be assembled. Examples utilizing this approach were presented at the Expert Panel meeting in June 2004. A large number of case studies will be required in order to cover all the relevant levels/values of the critical factors. This will possibly require extensive field data collection in order to obtain the values for these critical factors. After these case studies are compiled, the expanded panel of experts will be asked to provide the recommended speed limit for each case study. By estimating a regression type model with the recommended speed limit as the dependent variable and the levels of the critical factors as the independent variables, it will be possible to determine if a particular critical factor is significantly related to the recommended speed limit. The results of this model will be used to develop the decision rules.

Option B

In Option B, the experience and knowledge of the research team and results of previous work (including the June 2004 expert panel meeting) will be used to develop draft decision rules for the expert system. The draft decision rules will be tested internally by the research team through case studies to ensure that it appears reasonable. In the third step, the draft decision rules will be sent to the expanded panel for their review and comments. The fourth step will incorporate the comments and recommendations from the expanded panel to refine the decision rules.

Option C

Option C, similar to Option A also relies on case studies to develop the decision rules. However, instead of compiling data from a large number of real-world case studies, this approach will rely on hypothetical case studies. Each case study will consist of series of scenarios. In each scenario, the value (or level) of one critical factor will be altered while keeping the values (and levels) of the other critical factors constant. The expanded panel of experts will be asked to provide the recommended speed limit for each scenario. Regression type models will be estimated with the recommended speed limit as the dependent variable and the levels of the critical factors as the independent variables. The results of this model will be used to develop the decision rules.

Following the discussion of the three options at the Interim Meeting, the NCHRP panel felt that Option C will be the best approach for this project. Many members of the panel felt that Option B would not make use of expert knowledge to the required degree, and Option A would be too expensive.

SURVEY OF NCHRP PANEL AND EXPERT PANEL (FALL AND WINTER 2004)

Before developing the case studies (following Option C), the research team felt that it is important to determine the appropriate categories/levels/ranges for the different critical variables. In order to get feedback from the NCHRP panel and the expert panel regarding the categories and levels for the critical variables, a survey was developed and distributed. In this survey, for each roadway type (i.e., limited access freeways, multilane roads, and two lane roads) variables were presented along with the proposed categories, levels, and the range of appropriate values to be considered. The respondents were asked to indicate if they agree/disagree with the proposed categories/levels. If they did not agree, they were asked to suggest an alternative set of categories and levels for that variable and/or alternative ways of considering that variable.

The results of the survey are presented in Appendix E. Eight individuals filled out the survey. In addition, two individuals made some general comments about the survey.

WEB-BASED PILOT TESTS (SPRING AND SUMMER 2005)

During the Interim Meeting in August, the NCHRP panel had suggested that a limited set of case studies and scenarios be developed in order to pilot test the methodology and the format in which the case studies and scenarios can be presented to the experts. The research team developed 14 case studies with 56 scenarios for the Pilot Tests (see Appendix F). Each case study had between 3 and 7 scenarios. Within each case study, one or two factors were modified while keeping other factors constant. The changing factors were highlighted. These case studies were implemented over the web (http://www.pedbikeinfo.org/speedlimits/pilot/). Each potential respondent was asked to select a link. Once they selected this link, they were asked to fill out a brief survey indicating their affiliation and experience in setting speed limits. They were then provided the background and instructions for filling out the survey. For each scenario, respondents were asked to:

- State what speed limit (in mph) they would select for each scenario, or indicate that 'not enough information' is available for making the decision,
- Indicate which critical factors were used for making your decision, and
- Identify other data/factors that they feel are critical and need to be provided to make a speed limit recommendation for that scenario.

For the Pilot Tests, the following assumptions were made:

- Sections are in urban/suburban areas
- Sections are multi-lane
- The crash rate for the sections under consideration is below average, compared to similar sections
- There is no adverse alignment in these sections

Respondents were able to access these case studies through a link to a website. Several members of this expert panel responded to these case studies.

The following factors are included in the case studies for the pilot tests:

- 85^{th} percentile speed
- Median speed
- Roadside hazard rating
- Presence and type of median
- Number of traffic signals in the section
- Total length of section
- Roadside development
- Pedestrian and bicycle activity
- On-street parking

The link to the survey was forwarded to the NCHRP panel, the expert panel, and selected members of the expanded panel. A total of 23 individuals accessed the link to fill out the survey. Out of these, 20 actually completed the survey, while 3 individuals completed only the first two case studies.

The results from the pilot web survey were used to construct a regression model to relate the speed limit with the site characteristics. Here is a brief discussion of the findings. More detailed results are available in Appendix F.

- Operating speed (85^{th} percentile and 50^{th} percentile speed) was the most important factor that was considered by the participants.

- More signals per mile is associated with lower speed limits, although this factor was only marginally significant in the regression analysis (p value was approximately 0.2).
- The regression analysis indicated that compared to Hazard level 7 (the most hazardous roadside condition), hazard levels 1 through 5 were usually assigned higher speed limits by the participants.
- In general, undivided roads were associated with lower speed limits compared to divided roads. The participants did not treat TWLTL and divided roads in a significantly different way.
- In general, participants assigned higher speed limits for low/medium ped/bike conditions compared to the high ped/bike condition.
- Compared to on-street parking on two sides, the participants assigned higher speed limits for roads with no parking. The participants in the survey treated parking on one-side and two-sides in a similar way.

FINAL ROUND OF WEB-BASED CASE STUDIES (FALL 2005)

Using the results of the pilot case studies, the research team developed case studies for five different roadway types. These case studies included more variables compared to the pilot case studies. Links to these case studies were sent to 148 individuals that included traffic engineers, enforcement personnel, and researchers. This included the NCHRP 3-67 and the expert panel. These 148 individuals were divided into five groups corresponding to the five roadway types (freeway, two-lane undeveloped, multilane undeveloped, two-lane developed, multilane developed). State DOT personnel were primarily assigned to the freeway group. City engineers and practitioners were assigned to the developed roadway types. County engineers and practitioners were assigned to either the developed or the undeveloped roadway types. Enforcement personnel and researchers were randomly assigned to one of the roadway types. Here is the link to the case studies that were developed for the five roadway types (the case studies and scenarios used in the final round of web-based case studies are presented in Appendix G):

Freeway
http://www.pedbikeinfo.org/speedlimits/speed2/fway.cfm

Two-lane Undeveloped Roads
http://www.pedbikeinfo.org/speedlimits/speed2/twolan_undv.cfm

Multilane Undeveloped Roads
http://www.pedbikeinfo.org/speedlimits/speed2/multilan_undv.cfm

Two-lane Developed Roads
http://www.pedbikeinfo.org/speedlimits/speed2/twolan_dv.cfm

Multilane Developed Roads
http://www.pedbikeinfo.org/speedlimits/speed2/multilan_dv.cfm

After filling out the case studies for the roadway type that they were assigned to, all respondents were encouraged to fill out the case studies for the other four roadway types.

Here is the number of experts who completed the case studies for the five different roadway types:

Freeway – 8
Two-lane Undeveloped – 8
Multilane Undeveloped – 12
Two-lane Developed – 9
Multilane Developed – 7

In addition, there were some individuals who started responding to the case studies, but did not complete them. One researcher completed the case studies for three roadway types. Four individuals completed the case studies for two roadway types.

In order to determine the effect of individual factors in the recommended speed limit for a facility, the research team analyzed the responses to the web survey in a couple of ways. The first approach was to calculate the average value of the speed limit recommended by the different experts for each scenario. In addition, for each scenario, the minimum speed limit, the maximum speed limit, and standard deviation of the speed limit were recorded for each scenario – this provided some indication of the extent to which the experts agreed or disagreed with each other in providing the recommended speed limit. Since, within each case study, one variable was modified while keeping the other variables a constant, by comparing the average speed limit for a particular scenario with the average speed limit for another scenario within a case study, it was possible to make a preliminary assessment of the effect on that variable (which was modified in that case study) on the speed limit.

A second approach used regression analysis to assess the effect of different factors was linear regression. In this approach, the recommended speed limit was included as a dependent variable, and the site characteristics were included as independent variables. The results of these analyses (discussed in Appendixes H and I) were used to develop preliminary decision rules for the expert system for review at the expert panel meeting in December 2005.

EXPERT PANEL MEETING (DECEMBER 2005)

The objective of the expert panel meeting was to review the results of the web survey and determine how these results could be used to determine the decision rules for the expert system. The first part of the meeting focused on the project objectives, scope, and status. This was followed by a discussion of the results of the web-based survey. In general, many of the panel members did not agree with the coefficients and factors generated by the regression models (discussed in Appendix H), although some agreed with the final speed limit recommended by the regression model for a particular situation. They recommended that the results of the regression models should not be used as the basis for developing the decision rules. Many of the panel members were surprised that the participants to the survey gave importance to adjacent speed limits even for relatively long sections. Some panel members felt that crash statistics (i.e., injury rates and rates of speed-related injury crashes) should have been given much more importance compared to adjacent speed limits.

Following the discussion of the results of the web survey, there was a detailed discussion about how each critical variable should be used in coming up with the recommended speed limit for a situation. The final session of the expert panel meeting on Friday, December 16, 2005, was used for discussing 6 case studies, which included alternate scenarios within each case study. In this session, each expert was asked to select the recommended speed limit for a condition and indicate why they made that decision. The majority of the experts agreed on the same speed limit for most of the scenarios that were presented on December 16, 2005. However, there was disagreement among the experts when one of the following two conditions occurred:

1. Undivided roads in high-speed rural areas with high crash rates. About half the experts who were present at the meeting chose the rounded_down_50^{th}_speed (rounded-down_50^{th} is obtained by rounding down the 50^{th} percentile speed to the nearest 5 mph multiple) as the speed limit under these conditions. However, the others did not want to choose anything lower than the closest_50^{th}_speed (Closest_50^{th} is the 5 mph multiple that is closest to the 50^{th} percentile speed) as the speed limit under these conditions.

2. Urban roads with significant ped-bike activity and high crash rates. Again, half the experts who were present at the meeting chose the rounded_down_50^{th}_speed as the speed limit under these conditions. However, the others chose the closest_50^{th}_speed as the speed limit under these conditions.

Even those members of the expert panel who were willing to recommend the rounded_down_50^{th}_speed as the speed limit, indicated that a detailed crash investigation should be conducted and other traffic and geometric measures should be considered before the speed limit is lowered.

A report summarizing the discussions at the expert panel meeting is presented in Appendix J.

DEVELOPMENT OF DRAFT DECISION RULES AND THE PROTOTYPE

The draft decision rules were developed based on the information obtained from previous research, expert panel meeting in June 2004, web-based pilot survey in Spring 2005, web-based pilot survey in Fall 2005, expert panel meeting in December 2005, and the judgment of the research team. The decision rules for the expert system were developed, documented in the form of flow-charts, and forwarded to the HSRC programmer for development of the prototype of the expert system. The HSRC programmer implemented the decision rules and developed a prototype expert system. This prototype, along with flow-charts describing the expert system were sent the expert panel, the NCHRP panel, and practitioners around the country for beta-testing. The panel members and practitioners were asked to review the decision rules document, the prototype expert system, and comment on various aspects of the system. The intent was to use the responses from the panel members and the practitioners to verify, evaluate, and validate the system. The panel members and practitioners were asked to answer the following questions:

- Is the system user-friendly?
- Do users accept the system? Are there any bugs in the system?
- Will you make use of the recommendations from this system to set speed limits?
- Are the recommendations from the system consistent with your knowledge and experience?
- Based on your opinion, what percentage of recommendations from the system is correct?
- Do you feel the recommendations from the system are more or less accurate for certain types of roads or areas?
- Do you feel that the system takes into account all critical factors? If no, what other factors should be considered?
- Do you feel that the logic used in this system is appropriate? If no, how should it be modified?

Six panel members and practitioners provided written comments on the decision rules and prototype for the expert system. The research team provided a written response to these comments.

CONFERENCE CALL TO DISCUSS DRAFT DECISION RULES AND THE PROTOTYPE

A web conference was held on May 17, 2006, to discuss the decision rules, the prototype, and the written comments provided by the panel members and practitioners to the prototype. Here is a summary of the discussion during the conference call:

- Prior to the meeting, one of the reviewers of the prototype was concerned that the crash and injury rates from HSIS may not be representative of data for city streets. The panel members at the web conference did confirm that average rates do need to be provided as default since some users may not have access to these values in their jurisdictions. The panel members suggested that it may be worthwhile to explore the possibility of comparing crash data complied by the South East Michigan Council of Governments (SEMCOG) and from Charlotte, North Carolina, with the HSIS data to examine the applicability of using the HSIS data as a baseline for city streets. Subsequent to the meeting, the research team contacted the City of Charlotte and also tried to obtain data from SEMCOG. However, the research team was not successful in obtaining crash and injury rates for different roadway types and AADT categories from these agencies.

- There was some concern that the program does not provide definitions for mountainous roads. The research team was asked to look into the information provided by AASHTO concerning terrain and horizontal and vertical curvature that can be used to provide some guidance to the user.

- The panel members indicated that minimum section length needs to be considered in developing the decision rules. One approach is to provide a warning if the section length is shorter than the minimum section length.

- Some panel members were concerned that the information currently provided to distinguish between roads in Developed and Undeveloped areas is not sufficient and more qualifiers need to be added. Some thought that these qualifiers can include population, population density, and level of roadside activity. They also suggested that the access to the definitions and photographs should be improved to eliminate the long user delay in downloading this information.

- There was considerable discussion about whether the rounded-down 50^{th} percentile speed is too low for the recommended speed limit. There was disagreement among the panel members on whether this was too low. However, most of the panel members agreed that the rounded-down 50^{th} percentile was too low when crash data were not available and the speed limit is calculated based on surrogates. Panel members also agreed that if crash rates are high, the program should suggest a detailed crash study to determine the causes and possible solutions.

- The panel members felt that more information needs to be provided to the user about procedures for collecting and analyzing speed data.

- In the prototype expert system, the speed limit for road sections in undeveloped areas had a lower bound of 45 mph. Most panel members felt that when there is adverse alignment in a section, the lower bound of 45 mph for undeveloped roads is not appropriate. Here again, the location where the speed data are collected was identified as an important factor.

- In the prototype expert system, residential subdivision streets were considered a separate roadway type apart from road sections in developed areas. Some panel members suggested that residential subdivision streets could be combined with the developed roadway section. However, there was not a clear consensus on how to treat this roadway type.

- Most panel members agreed that if the recommended speed limit was higher than the statutory limit, then a warning will be useful. There was less agreement about how to deal with the absolute maximum speed limit in a particular State.

DECISION RULES AND EXPERT SYSTEM FOR PANEL REVIEW

Changes were made to the draft decision rules and the prototype expert system based on the comments received from the panel members and the practitioners as part of the beta testing process. Here is a summary of the changes that were made:

- A user guide was developed and provided as a link to the expert system. In the prototype expert system, the more info links provided access to photographs describing different area types. Since some users experienced significant delays while accessing the photographs that were available as part of the more info link in the prototype, the photographs were moved to the user guide.

- A warning was introduced if the length of a section was below the minimum length. Minimum lengths from the current USLIMITS program were used for guidance.

- The help screens were modified to include more information to help the user understand the meaning of the different factors and variables, including guidance for collecting speed data, further information to distinguish between road sections in undeveloped and developed areas, information to distinguish between mountainous, flat, and rolling terrain.

- The flow charts representing the modified decision rules from the expert system are available in Appendix K. The user guide is documented in Appendix L. The expert system can be accessed through the following link: http://www2.uslimits.org

DESCRIPTION OF THE DECISION RULES

Here is a brief overview of the logic flow and the decision rules that are used in the expert system (further details are provided in Appendix K and L). After entering the location of the project, the user is asked to indicate whether the road is a limited access freeway, road section in an undeveloped area, or a road section in a developed area. Here is a definition of the three roadway types. Photographs illustrating the different roadway types are available in the User Guide (see Appendix L).

***Limited Access Freeway* –** This route type includes U.S. and state numbered freeways and expressways and Interstate routes where access to and from the facility is limited to interchanges with grade separations. These high-speed routes typically have posted speed limits ranging from 55 mph in urban areas to 75 mph in some rural areas. Some urban areas may have short segments directly connecting the freeway to surface streets where the posted speed limit is as low as 35 mph. In rural western Texas, an 80 mph limit has recently been posted on selected segments of I-10 and I-20. As of September 2006, this is the highest posted speed limit on a freeway segment in the United States. This expert system will not recommend speed limits higher than 75 mph for limited access freeways.

***Road Section in Undeveloped Area* –** An undeveloped area is generally an area where the human population is low and the roadside primarily consists of the natural environment. Access is not restricted and posted speed limits are typically in the 40 mph to 65 mph range depending upon terrain and road design features. Road sections with lower speed limits usually have narrower pavement widths, little or no shoulders, and horizontal and vertical curvature that limits driver speeds. Road sections with higher speed limits usually have 12-foot lanes, 8-foot or greater shoulders which may be paved, and horizontal and vertical curvature that supports higher speed travel. This expert system will not recommend speed limits higher than 65 mph for road sections in undeveloped areas.

***Road Section in Developed Area* –** A developed or built-up area is an area where the human-built environment has generally replaced most of the natural environment. Access is not restricted and posted speed limits are usually in the 25 mph to 50 mph range depending on the degree of human activity that interacts with vehicular travel, the road design, and degree of traffic control used. Road sections with lower speed limits are found in downtown and residential areas with considerable pedestrian and other non-motorized movements and on-street parking activity. Road sections with higher speed limits have little pedestrian activity, no on-street parking, and traffic control which favors through traffic movement. In this expert system, the maximum speed limit for road sections in developed areas is 50 mph. Roads in developed areas are further subdivided into residential subdivision/neighborhood street, residential collector street, commercial street, and a street serving a large complex such as a large shopping mall:

> ***Residential Subdivision/Neighborhood Street* –** A residential neighborhood street is a public street located within a subdivision or group of homes that serves the motorized and non-motorized activities of residents. Posted speed limits generally range from 25 to 35 mph. Two-way traffic operations are permitted along with on-street parking on both sides of the road, however, the pavement width is usually too narrow to allow unimpeded bidirectional traffic and on-street parking. Accordingly, painted centerlines are not typically used on these facilities. These streets do not carry through traffic. Commercial development is not permitted in the area.
>
> ***Residential Collector Street* –** A residential collector street carries both through traffic from residential neighborhoods and local traffic generated by residents who live along the corridor. Posted speed limits generally range from 25 mph to 45 mph. The pavement widths permit full time operation of bidirectional traffic. On-street parking on one or both sides may or may not be permitted. Painted centerlines are typically found on these facilities. Development along the street is primarily single- and multi-family homes. Typically, there are more than 30 residential driveways per mile. The corridor may contain a small amount of commercial development; usually convenience stores at major intersections.
>
> ***Commercial Street* –** A commercial street is a street that serves both through traffic and local shopping needs. Development along the corridor is primarily commercial with more than 30 business driveways per mile. Posted speed limits generally range from 25 mph to 45 mph. The streets usually tend to be multilane and on-street parking on one or both sides may or may not be permitted.
>
> ***Street Serving Large Complexes* –** Large area business developments typically include shopping malls, office buildings and industrial complexes. Streets that serve large complexes generally are designed to carry large volumes of traffic to and from the complex and typically are designed to manage access to carry through volumes. The streets tend to be multilane facilities and the number of access driveways is usually less than 30 per mile. Posted speed limits range from 35 mph to 50 mph.

After the user selects the roadway type, they are taken to a window where they are asked to enter the site characteristics. For each route type, users are asked to enter the following site characteristics:

Limited Access Freeway

- Operating Speed: 85th percentile speed and 50th percentile speed
- Presence/absence of adverse alignment (if adverse alignment is present, a warning is provided to the user in the end; by itself, this variable does not affect the recommended speed limit)
- Is this section transitioning to a non-limited access highway? (this is used to determine if a particular operating speed that is entered is too low; by itself, this variable does not affect the speed limit)
- Section Length
- Current statutory limit for this type of road (if the recommended speed limit is higher than the statutory limit, a warning is provided to the user in the end; there was some discussion on whether the speed limit recommended by the expert system can exceed the statutory limit. Some members of the expert panel indicated that in some States the posted limit can exceed the statutory limit if it can be justified by an engineering study)
- The terrain (the maximum speed limit in mountainous terrain is 70 mph)
- Annual Average Daily Traffic
- Number of Interchanges within this section
- Crash Statistics (if available)

Road Sections in Undeveloped Areas

- Operating Speed: 85th percentile speed and 50th percentile speed
- Presence/absence of adverse alignment (if adverse alignment is present, a warning is provided to the user in the end; by itself, this variable does not affect the recommended speed limit)
- Is this section transitioning to a road section in a developed area? (this is used to determine if a particular operating speed that is entered is too low; by itself, this variable does not affect the speed limit)
- Current statutory limit for this type of road (if the recommended speed limit is higher than the statutory limit, a warning is provided to the user in the end; there was some discussion on whether the speed limit recommended by the expert system can exceed the statutory limit. Some members of the expert panel indicated that in some States the posted limit can exceed the statutory limit if it can be justified by an engineering study)
- Annual Average Daily Traffic
- Roadside Hazard Rating (based on Zegeer et al., *18*)
- Number of lanes and presence/type of median
- Crash Statistics (if available)

Road Sections in Developed Areas

- Operating Speed: 85th percentile speed and 50th percentile speed

- Current statutory limit for this type of road (if the recommended speed limit is higher than the statutory limit, a warning is provided to the user in the end; there was some discussion on whether the speed limit recommended by the expert system can exceed the statutory limit. Some members of the expert panel indicated that in some States the posted limit can exceed the statutory limit if it can be justified by an engineering study)
- Annual Average Daily Traffic
- Presence/absence of adverse alignment (if adverse alignment is present, a warning is provided to the user in the end; by itself, this variable does not affect the recommended speed limit)
- Area type
- Number of driveways and unsignalized intersections in the section
- Number of traffic signals within the section
- Presence/usage of on-street parking
- Extent of ped/bike activity
- Crash Statistics (if available)

For each project, the program calculates a speed limit based on two approaches:

Approach 1 - Based on operating speeds and other site characteristics (also called safety surrogates).

The surrogates were chosen based on input from the expert panel and evidence (based on previous research) of a relationship between these surrogates and crash statistics. For freeways, safety surrogates include interchange spacing and AADT. Based on the research team's judgment in interpreting the results of the recent work of Bared et al. (*17*), if AADT is higher than 180,000 and the average interchange spacing is between 0.5 and 1 mile, the recommended speed limit from this approach will be the 5 mph multiple obtained by rounding-down the 85th percentile speed; if AADT is higher than 180,000 and the average interchange spacing is less than 0.5 mile, the recommended speed limit is the 5 mph multiple closest to the 50th percentile speed. For other situations in freeways, the recommended speed limit from this approach will be the 5 mph multiple closest to the 85th percentile speed.

For road sections in undeveloped areas, the roadside hazard rating (*18*) was selected as the safety surrogate. For roadside hazard ratings of 1, 2, or 3, the recommended speed limit is the 5 mph multiple closest to the 85th percentile speed. For roadside hazard ratings of 4 or 5, the recommended speed limit is the 5 mph multiple obtained by rounding down the 85th percentile speed. For roadside hazard ratings of 6 or 7, the speed limit is the 5 mph multiple closest to the 50th percentile speed.

For road sections in developed areas, extent of pedestrian/bicycle activity, presence/usage of on-street parking, number of traffic signals, and the number of driveways and unsignalized access points, were selected as surrogates. Based on the results from FHWA's work on the Safety Impacts of Access Management (http://ops.fhwa.dot.gov/access_mgmt/docs/benefits_am_trifold.htm), and the opinions of the expert panel, the following rules are used to calculate the recommended speed limit for road sections in developed areas:

If <u>at least one of the following is true</u>, the speed limit is the 5 mph multiple closest to the 50^{th}:

Signals_per_mile > 4
Ped_bike activity is High (definitions are available in the user manual)
Parking activity is High (definitions are available in the user manual)
Driveways_per_mile > 60

If the following is true, the speed limit is the 5 mph multiple obtained by rounding down the 85^{th}:

Driveways_per_mile > 40 and <=60, and Signals per mile > 3, and Area Type is (commercial or residential-collector)

All other conditions, the speed limit is the 5 mph multiple closest to the 85^{th} percentile speed

Approach 2 - Based on operating speeds and results from the crash module.

In the crash module, the user is asked to enter the total number of crashes and total number of injury crashes. In addition, the user is also asked to enter the average crash rate and the average rate of injury and fatal crashes for similar sections in the same jurisdiction. If data on average rates are not available, the program makes use of average rates calculated with data from 8 States that are part of the Highway Safety Information System (HSIS). Using the average crash rate and the average rate of injury and fatal crashes, the program calculates the critical crash rate and critical injury rate (*70*).

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

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

If the crash or injury rate is higher than the corresponding critical rates or at least 30% higher than the corresponding average rates, the user is asked to indicate if traffic and geometric measures can reduce the crash and/or injury rate in this section. If the user answers Yes to this question, the recommended speed limit from this module will be the 5 mph multiple closest to the 85^{th} percentile speed. If the user answers No or Unknown, the recommended speed limit from this module will be the 5 mph increment obtained by rounding-down the 85th percentile speed (if crash or injury rate is at least 30% higher than the average rate) or closest to the 50th (if the crash or injury rate is higher than the critical rate).

The lower value of the calculated speed limits from Approaches 1 and 2 is reported as the recommended speed limit in the output window. The expert system does not recommend speed limits higher than the 5 mph multiple closest to the 85th percentile speed; it also does not recommend speed limits lower than the 5 mph multiple closest to the 50th percentile speed. The system also provides warnings if the 85th percentile speed entered by the user is unusually low or high for a particular roadway type.

At the output window, the program provides the recommended speed limit, and some additional warnings depending on the site characteristics that were entered by the user. For example, warnings are provided if the following conditions occur:

- If the length of the section is shorter than the minimum section length for the recommended speed limit. The guidelines regarding minimum section length are based on the information available in the current USLIMITS program.

- The final recommended speed limit is higher than the statutory limit for that type of road

- There is adverse alignment in the section

- If the crash rate is higher than the critical crash rate or at least 30% higher than the average crash rate.

- The rate of injury and fatal crashes is higher than the critical injury rate or at least 30% higher than the average injury rate.

- The 85th percentile speed is higher than 52 mph for road sections in developed areas, higher than 67 mph for road sections in undeveloped areas, or higher than 77 mph for limited access freeways.

CHAPTER 7

LONG-TERM MANAGEMENT OF THE EXPERT SYSTEM

For this product to be widely implemented and continue to be upgraded, a long-term strategy must be developed for administering and maintaining it. As previously discussed, this product is a web-based application. The specific issues addressed in developing a long-term management strategy include:

- Capability and responsibility for hosting the application.
- Administrator assignment and responsibilities.
- Maintenance and troubleshooting.
- Upgrade cycle.
- Marketing (including training and outreach).
- Long-term needs (e.g., planning for future data sources or analysis needs).

The proposed strategy below discusses each of these issues and provides specific recommendations for consideration by the panel and those agencies that may be involved in promoting and managing the application.

APPLICATION HOST

This application requires a host. HSRC has offered to host the application for up to one year following the end date of the contract, and provide some administrative support to ensure that the site is running and accessible to users. This effort is undertaken as a short-term solution until a decision is made with respect to where the application should reside. When the application is moved to another host, the users will be informed about these changes through electronic mail.

SITE ADMINISTRATION

Irrespective of where the application is hosted, a site administrator will be required to perform a variety of tasks, including:

- Monitoring the site to ensure that it is running and accessible to users.
- Handling inquiries from users – may include specific technical issues related to the web site as well as questions related to the logic or merits of the application itself.
- Working with the server administrator to address any technical problems of the site.
- Working with a web application programmer to address any bugs in the application.

The research team communicated with individuals in ITE, AASHTO, and FHWA, through phone and email to understand their willingness in hosting the expert system after it is completed. Each agency was provided a one page summary of the project before the phone call that included an overview of NCHRP Project 3-67, hardware and software requirements for hosting the expert system, and responsibilities of the site administrator. The research team spoke with ITE staff Tom Brahms, Executive Director, and Phil Caruso, Deputy Executive Director.

The research team gave an overview of the project, presented the system hardware, software, and interface requirements, and the issues associated with administering the site. ITE staff indicated that they will be interested in hosting the expert system as long as it is a user-friendly product, and ITE will not be flooded with questions from users, and the benefit of hosting the expert system (to its membership) exceed the costs. The research team assured ITE that the product will be user friendly.

Then, the research team spoke with AASHTO staff Ken Kobetsky, Director of Engineering, and David Dubov, Web Business Manager. Both Ken and David indicated that AASHTO was interested in hosting the expert system. In addition to discussing the system hardware and software issues, David Dubov also wondered if the States would like to have the option of refining the decision rules and the logic flow to suit their regulations and conditions.

Following this, research team had email exchanges with Davey Warren (Office of Safety Programs, FHWA), and Carl Shea (IT Policy and Infrastructure Team Leader, FHWA) regarding this issue. FHWA also expressed an interest earlier in hosting the product.

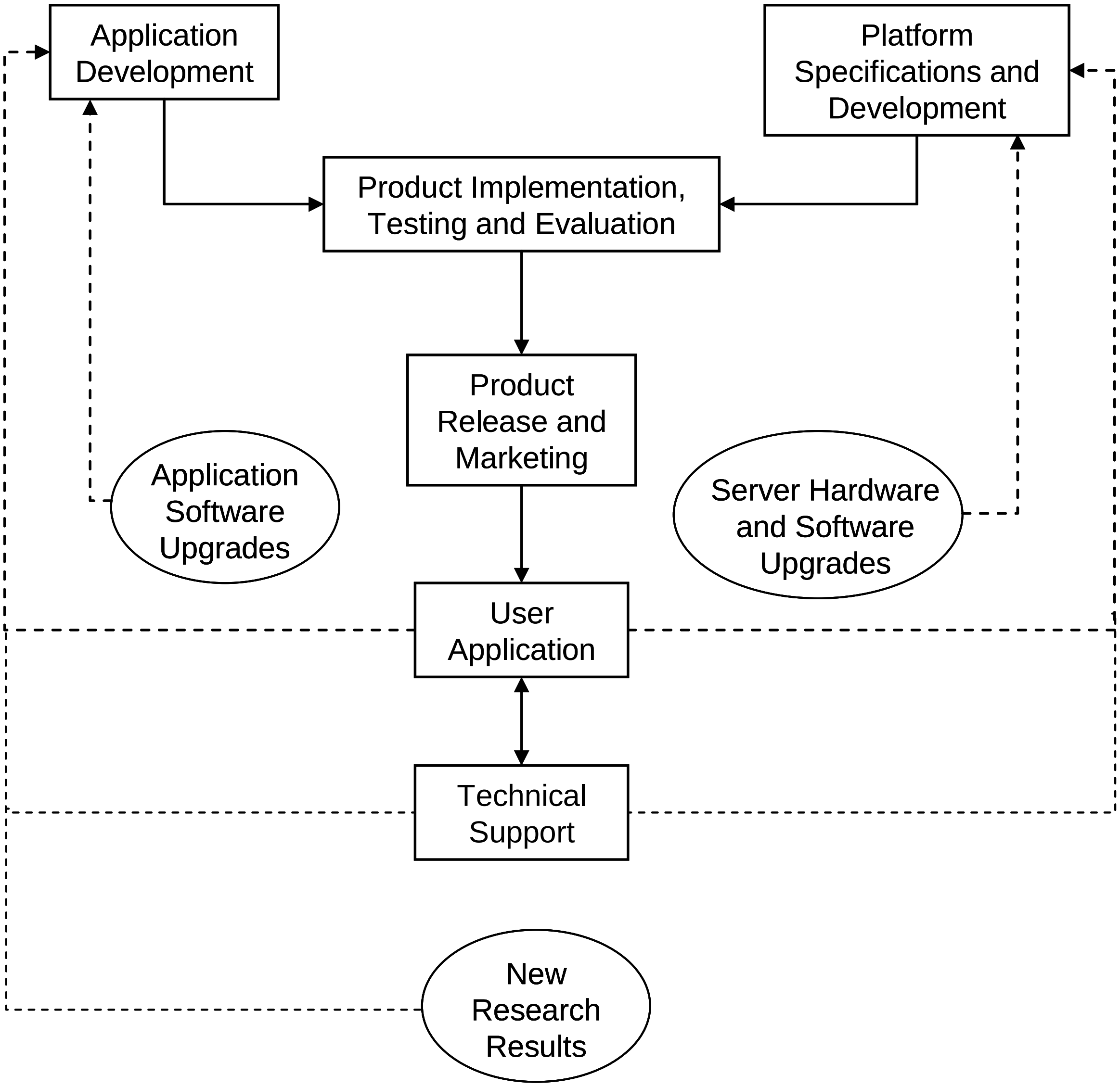
In summary, all the three agencies (ITE, AASHTO, and FHWA) showed an interest in hosting the expert system after it is completed. However, they would all prefer to host it in a Windows system. ITE and AASHTO do not own currently own UNIX workstations, and do not intend to purchase one. HSRC programmers had suggested that a UNIX environment because they consider UNIX to be more secure and robust. In theory, an application developed using Coldfusion in a UNIX environment, should work in a WINDOWS environment without any problems. However, in practice, there may be a need to make some minor changes to the application to ensure that it runs properly in a Windows environment. It is important to note that the prototype expert system that was evaluated by the expert and NCHRP panel in April and early May of 2006 was initially installed in a WINDOWS environment. The expert system has since been moved to an UNIX server, and it is working properly.

UPGRADE CYCLE

Traditionally in the field of transportation engineering, the upgrading of "guidance" products took decades. The Highway Capacity Manual is one example that was in place 20 years (1965 to 1985) before a major upgrade. Other documents such as the AASHTO Green Book and the MUTCD were also upgraded once in several years. In recent years, however, there has been a shift toward more frequent upgrades, which means that the most recent research and best practices are being disseminated to practitioners more quickly. With the Internet now a major source of many guidance documents and application tools, the ability to upgrade products can be more frequent since there is no publication expense. In addition, there is a greater expectation on the part of the user that anything on the web be the latest information available.

Given that the expert system is now and will continue to be a web-based product, it will be important for credibility reasons to keep it up to date. As shown in the life-cycle graphic in Figure 3, the development of this product can be divided into two distinct components – the application itself, which includes the decision-making algorithm, and the platform (server) specifications and development. These two components are interlinked, as the decisions made for each affect the other. Combining these two elements results in the implementation of the final product, that should be tested and evaluated on a continual or periodic basis. The product is then released and marketed, and followed by practitioners using the application. Over time, there will be a need for users to acquire technical support.

The components in this life-cycle graphic that serve as immediate feedback mechanisms to the development components are the users and technical support personnel. Issues identified by either should be documented. Critical issues, i.e., those that prevent one from using the application, need to be addressed immediately by changes in the application and/or platform. Such changes may range from simply providing a clarifying statement on the site related to a variable to fixing a bug in the application to changing a hardware component on the server. Non-critical issues and recommendations need to be archived for consideration of future changes in the product. How often these non-critical changes need to be considered is a key question. It is recommended that they be considered at the same time as incorporating the latest research results and upgrading the hardware/software (discussed below).



Life-cycle graphic for the USLIMITS application.

Figure 3: Life-cycle graphic for the speed limit expert system

Other elements that will impact the decisions to upgrade the product are also shown on the graphic and include new research results, application and database software upgrades, and server hardware and software upgrades. Generally, most application, database and server software packages are upgraded about every 2 years. Similarly, server hardware has been in a cycle of upgrading every 18 to 24 months over the past decade or so. It has been our experience that there is no need to keep pace with each generation of hardware and software. The changes are usually not substantive enough to warrant making such a monetary investment. The recommendation is to skip a generation at a minimum. Given the current development cycle for hardware and software, this would require a review of the advantages and costs about every 3 years.

With respect to new research results, the goal should be to monitor the research for information that could be used to improve the knowledge base in the application and specifically the decision rules in the algorithm. The question then becomes how often to critically review such results for possible changes in the application. Generally, research studies require 2 to 4 years to complete. Therefore, a comprehensive review of the literature every 3 years would seem to be a reasonable cycle. In addition to the review itself, other more substantive techniques should also be considered at the same time. Examples of three such techniques are described below.

Meta-Analysis

A meta-analysis of results such as those conducted by Elvik and Vaa (*11*), where statistical techniques are used to combine the independent estimates from separate studies by weighting each individual estimate according to its variance.

Reanalysis of Data from Prior Studies

Reanalysis of existing data is another way to identify critical variables and factors and their relationship to operating speed, posted speed limits, and crashes. As per the discussion in McCarthy (*19*), many before-after studies on speed limits "generally used univariate classification procedures, regression analysis, or ARIMA time-series models, and multivariate classification models are rarely used". Also, "among simple regression models, there is often a surprising lack of diagnostics and correction for common statistical problems" and very "little work has been done on developing and estimating simultaneous frameworks to capture the interaction" between different factors.

Based on several years of research on speed limits, several data sets are available. Examples of the more recent ones include: Kockelman et al., (*9*), Fitzpatrick et al., (*14*), and Stokes et al., (*20*). Examples of other data sets that may be available include Parker (*8*) and Poe and Mason (*21*).

Development and Analysis of New Data Sets

Limited analysis of new data sets can provide useful insights into the relationship between operating speed, posted speed limit, design speed, crashes, and site characteristics. One option is to consider the use of the Highway Safety Information System (HSIS), which has data on roadway inventories and detailed data on crash statistics from 9 states. These data will have to be combined with data on operating speeds from State DOTs. If such data can be acquired, the advantage in using HSIS is the ability to explicitly study the relationship between operating speed and crashes, posted speed, and other site characteristics.

MARKETING

The development of the expert systems product is the required first step. However, to create widespread use of the product and truly have an effect on how speed limits are set, there is a need to promote the application and to train potential users. FHWA has recently executed a contract to begin this process for the current USLIMITS system. Members of the research team are in the process of developing brochures and other materials to promote that product. Members of the research team also conducted a web-based training course in July 2006 to educate different stakeholders about the capabilities and limitations of the current USLIMITS system. A similar marketing effort is necessary to make potential users aware of the expert system (USLIMITS2) from this project. This type of effort needs to be coordinated by the FHWA/NHTSA Speed Management Team as it cuts across a number of disciplines.

DESIGN IMPLICATIONS OF LONG-TERM NEEDS

This system will function as an expert advisory system that uses pre-defined decision rules. It has not been developed as a "true expert system" that makes use of output measures and constantly revises the algorithm on the basis of inputs and subsequent performance measures. Based on discussions with the NCHRP panel, the expert panel, and other practitioners, it is not clear if the long-term goal is to develop a true expert system. Given that there are still some disagreements among practitioners on what the appropriate speed limits should be under certain situations, any changes to the algorithm should be based on results from evaluations that are methodologically and statistically defensible. One example of such an evaluation is a before-after study that will require collecting several years of crash data before and after a new speed limit is posted, and applying state of the art techniques such as the empirical Bayes approach to account for regression-to-the-mean, trends in crashes, and changes in exposure and other site characteristics over time. We suggest that this be addressed as part of periodic upgrades.

One other possible long-term need that has been raised is the ability to retrieve and archive the input data for the projects created in the system for the purposes of research. At the first panel meeting in August 2004, some of the panel members believed the system should be an open public site that allows anyone to use the system (without an account). The projects created in this case would be downloaded and stored on the individual user's computer and then uploaded again when needed. However, subsequently, it was decided that it is necessary to store the projects in a server that can be retrieved for purposes of research in the future. In USLIMITS2, each user creates an account (with a username and password) and will have access to projects that are created in that account. The site administrator can access the projects created by all the users.

CONCLUSIONS REGARDING THE LONG-TERM MANAGEMENT OF THE EXPERT SYSTEM

- This application requires a host. HSRC will host the application for one year on its site (www2.uslimits.org) following the completion of the project. After this period, an appropriate host needs to be identified. ITE, AASHTO, and FHWA, are possible hosts, and have shown interest in hosting the product.

- Irrespective of where the application is hosted, a site administrator will be required to perform a variety of tasks, including monitoring the site to ensure that it is running and accessible to users, handling inquiries from users, working with the server administrator to address any technical problems of the site, and working with a web application programmer to address any issues with the application.

- Given that the expert system is now and will continue to be a web-based product, it will be important for credibility reasons to keep it up to date. It is important that the results of new research are used to improve the knowledge base and refine the decision rules of the algorithm. A comprehensive review of the literature at least every 3 years is recommended followed by appropriate updates in the algorithm as necessary.

- To create widespread use of the product and truly have an effect on how speed limits are set, there is a need to promote the application and to train potential users.

CHAPTER 8

CONCLUSIONS AND FUTURE RESEARCH

CONCLUSIONS

Here are the major conclusions based on this study

Conclusions based on previous work

- Posted speed limits, consistent for similar road features, are essential even if a majority of motorists feel that they can make reasonable judgments about their driving speeds.

- The increase in speed limits on interstate roads in 1987 and 1995 seem to be followed by an increase in average speeds, although the increase in average speeds was less than the increase in the speed limit. Effect of the increase in speed limits on speed dispersion is not very clear.

- Most researchers seem to suggest that the increase in speed limits on interstate roads in 1987 and 1995 resulted in an increase in fatalities.

- Very little work has been conducted to study the effect of changes in speed limits on crash frequency and severity in non-limited access speed zones. Parker (*10*) and Parker (*8*) did not find any significant associations between speed limits and crash frequency/severity in their studies on limited access facilities.

- There is a need for guidance to practitioners to help them in identifying appropriate speed limits in speed zones.

Conclusions based on survey of USLIMITS users

- The survey of USLIMITS users revealed that most respondents felt that the speed limit recommended by USLIMITS was reasonable. Some felt that the USLIMITS program should provide more information regarding the decision rules and the factors used/not used in developing the final recommendation.

Conclusions based on the analysis of user needs and requirements

- In order to provide easy access to many practitioners, this program needs to be a web-based application.

- The system should not require extensive data collection that is beyond the scope of data now collected and maintained by the agency.

- Practitioners that are likely to use the expert system are typically very busy and do not have time to learn new systems or continually refer to manuals on how to use a software product. Hence, the system's interface should be intuitive and provide explanation of each step and the consequences of each decision made by the user.

Conclusions based on web surveys and expert panel meetings

- The operating speed was identified as a critical factor in determining an appropriate speed limit. Other factors identified as being critical included interchange spacing (in limited access freeways), roadside development, presence of pedestrian and bicycle activities, presence/absence of medians, roadside hazards, and crash and injury statistics.

- The results of the web surveys and expert panel meetings indicated that in general there is good consensus among experts regarding the appropriate speed limit on road sections where crash rates are not high. Typically, in such situations, experts recommended posting the 5 mph multiple closest to the 85^{th} percentile speed.

- Many experts recommended the 5 mph multiple closest to the 50^{th} percentile speed for urban areas with high pedestrian and bicycle activity.

- There was some disagreement among experts regarding the appropriate speed limit when crash rates are high. However, there is universal agreement that a detailed crash analysis needs to be conducted to identify the contributing factors for all crashes. If crash and/or injury rates are high, this program provides a warning to the user and suggests a detailed crash investigation to identify traffic and engineering measures to reduce the crash and injury rates.

- In the web surveys, some experts seem to consider speed limits in adjacent sections as a critical factor even in relatively long sections. However, the expert panel did not agree that speed limits in adjacent sections should be a critical factor. If the length of the section is below the minimum section for the recommended speed limit, the program gives a warning that the section length is too short for the recommended speed limit, and the user 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).

- To create widespread use of the product and truly have an effect on how speed limits are set, there is a need to promote the application and to train potential users. FHWA has a contract to do this for the current USLIMITS system. A similar marketing effort is necessary to make potential users aware of the expert system from NCHRP Project 3-67 (i.e., USLIMITS2). This type of effort needs to be coordinated by the FHWA/NHTSA Speed Management Team as it cuts across a number of disciplines.

FUTURE RESEARCH DIRECTIONS

Reanalysis of existing data sets

It is important to continuously monitor the research for information that could be used to improve the knowledge base in the application and specifically the decision rules in the algorithm. There may also be some value in reanalyzing existing data to identify critical variables and factors and their relationship to operating speed, posted speed limits, and crashes. As per the discussion in McCarthy (*19*), many before-after studies on speed limits "generally used univariate classification procedures, regression analysis, or ARIMA time-series models, and multivariate classification models are rarely used". Also, "among simple regression models, there is often a surprising lack of diagnostics and correction for common statistical problems" and very "little work has been done on developing and estimating simultaneous frameworks to capture the interaction" between different factors. Based on several years of research on speed limits, several data sets are available. Examples of the more recent ones include: Kockelman et al., (*9*), Fitzpatrick et al., (*14*), and Stokes et al., (*20*). Examples of other data sets that may be available include Parker (*8*) and Poe and Mason (*21*). The recent work by Kockelman et al. (*9*) may be good starting point in this regard – this study used simultaneous equations to study the relationship between speed limit, operating speed, and crash statistics.

Development and Analysis of New Data Sets

Limited analysis of new data sets can provide useful insights into the relationship between operating speed, posted speed limit, design speed, crashes, and site characteristics. One option is to consider the use of the Highway Safety Information System (HSIS), which has data on roadway inventories and detailed data on crash statistics from 9 states. These data will have to be combined with data on operating speeds from State DOTs. If such data can be acquired, the advantage in using HSIS is the ability to explicitly study the relationship between operating speed and crashes, posted speed, and other site characteristics.

Obtaining input from a larger sample of experts

In this study, 44 practitioners and researchers responded to the final round of case studies that tried to assess the critical variables and the logic used by experts while determining the appropriate speed limit for a speed zone. Although the results of the web survey was very useful in determining the decision rules, future research should explore the possibility of obtaining input from a larger group of experts and practitioners.

REFERENCES

1. Parham, A.H. and Fitzpatrick, K., *Handbook of Speed Management Techniques*, Research Report 1770-2, Report No. FHWA/TX-99/1770-2, Texas Transportation Institute, College Station, TX, (1998).

2. Parham, A.H. and Fitzpatrick, K., *Investigating Speed Management Techniques*, Project Summary Report 1770-S, Report No FHWA/TX-99/1770-S, Texas Transportation Institute, College Station, TX, (1999).

3. "Managing Speed: Review of Current Practice for Setting and Enforcing Speed Limits", *TRB Special Report* 254, National Research Council, Washington, D.C., (1998).

4. Harkey, D. L. and Mera, R., *Safety Impacts of Different Speed Limits on Cars and Trucks*, FHWA-RD-93-161, The Scientex Corporation, Charlotte, N.C., (May 1994).

5. Garber, N.J. and Gadiraju, R., *Impact of Differential Speed Limits on Highway Speeds and Accidents*, University of Virginia, Charlottesville, (February 1991).

6. *Speed zone guidelines: a proposed recommended practice*, ITE, Washington, D.C., (1993).

7. Jarvis, J.R. and Hoban, C.J., *VLIMITS: An Expert System for Speed Zone Determination in Victoria*, ARRB Report No. 155, (October 1988).

8. Parker, M.R., *Effects of Raising and Lowering Speed Limits on Selected Roadway Sections*, FHWA/RD-92/084, (1997).

9. Kockelman, K. et al., "Safety Impacts and Other Implications of Raised Speed Limits on High-Speed Roads", *NCHRP Web-Only Document* 90 (Project 17-23): Contractor's Final Report, (March 2006).

10. Parker, M.R., *Comparison of Speed Zoning Procedures and their Effectiveness*, Final Report, Contract No. 89-1204, Prepared for Michigan Department of Transportation, (September 1992).

11. Elvik, R. and Vaa, T., *The Handbook of Road Safety Measures*, Elsevier Science, New York, NY, (2004).

12. Elvik, R., "Speed and Road Safety: Synthesis of Evidence from Evaluation Studies", *Transportation Research Record* 1908, (2005), pp. 59-69.

13. Nilsson, G., *Traffic Safety Dimensions and the Power Model to Describe the Effect of Speed on Accidents*, Bulletin 221, Lund Institute of Technology, Department of Technology and Society, Traffic Engineering, Lund, (2004).

14. Fitzpatrick, K., Carlson, P., Brewer, M., Wooldridge, M., and Miaou, S.-P., "Design Speed, Operating Speed, and Posted Speed Practices", *NCHRP Report* 504, TRB, Washington, D.C., (2003).

15. *Survey of Speed Zoning Practices*, ITE, Washington, D.C., (2001).

16. Oppenlander, J.C., "A Theory on Vehicular Speed Regulation", *Bulletin* 341, Highway Research Board, Washington, D.C., (1962).

17. Bared, J.G., Edara, P., and Kim, T., "Safety Impact of Interchange Spacing on Urban Freeways", Presented at the *2006 Annual Meeting of the Transportation Research Board*, Washington, D.C., (January 2006).

18. 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).

19. McCarthy, P., "Effect of Speed Limits on Speed Distributions and Highway Safety: a Survey of the Literature", Appendix C of Managing Speed: review of current practice for setting and enforcing speed limits, *TRB Special Report* 254, Washington, D.C., (1998).

20. Stokes, R.W., Najjar, Y.M., Russell, E.R., Rys, M.J., Roy, J.L., Basheer, I.A., and Ali, H.E., *Speed Zone Guidelines Using Roadway Characteristics and Area Development*, Department of Civil Engineering, Kansas State University, Manhattan, KTRAN/KSU-96-3, (1999).

21. Poe, C.M. and Mason, J.M., "Analyzing Influence of Geometric Design on Operating Speeds Along Low-Speed Urban Streets: Mixed-Model Approach", *Transportation Research Record* 1737, (2000), pp. 18-25.

22. Wilmot, C.G. and Khanal, M., "Effect of Speed Limits on Speed and Safety: a Review", *Transport Reviews*, Vol. 19(4), (1999), pp. 315-329.

23. Garber, N.J. and Gadiraju, R., *Speed Variance and its Influence on Accidents*, University of Virginia, Charlottesville, (July 1988).

24. "55: A Decade of Experience", *TRB Special Report* 204, National Research Council, Washington, D.C., (1984).

25. Olson, P.L., *Effect of the 65 mph Speed Limit on Vehicle Speeds in Michigan*, University of Michigan Transportation Research Institute, UMTRI-88-52, (December 1988).

26. Upchurch, J., "Arizona's Experience with the 65 mph Speed Limit", *Transportation Research Record* 1244, (1989), pp. 1-6.

27. Brown, D.B., Maghsoodloo, S., and McArdle, M.E., “The Safety Impact of the 65 mph Speed Limit: A Case Study Using Alabama Accident Records”, *Journal of Safety Research*, Vol. 21(4), (1990), pp. 125-139.

28. Jernigan, J.D., and Lynn, C.W., “Impact of the 65 mph Speed Limit on Virginia’s Rural Interstate Highways through 1989”, *Transportation Research Record* 1318, (1991), pp. 14-21.

29. *Effects of the 65 mph Speed Limit through 1990: A Report to Congress*, U.S.DOT and NHTSA, (May 1992).

30. Ossianger, E.M. and Cummings, P., “Freeway Speed Limits and Traffic Fatalities in Washington State”, *Accident Analysis and Prevention*, Vol. 34(1), (2002), pp. 13-18.

31. Retting, R.A. and Greene, M.A., “Traffic Speeds Following Repeal of the National Maximum Speed Limit”, *ITE Journal*, (May 1997), pp. 42-46.

32. *The 36 Month Study Report on the 65 mph Speed Limit in New Jersey*, Prepared by the New Jersey Department of Transportation, (August 2001).

33. Streff, F.M. and Schultz, R.H., *The 65 mph Speed Limit in Michigan: A Second Year Analysis of Effects on Crashes and Crash Casualties*, University of Michigan Transportation Research Institute, UMTRI-90-37, (September 1990).

34. McKnight, A.J. and Klein, T.M., “Relationship of 65 Mph Speed Limit to Speeds and Fatal Accidents”, *Transportation Research Record* 1281, (1990), pp. 71-77.

35. Ullman, G.L. and Dudek, C.L., “Effects of Reduced Speed Limits in Rapidly Developing Urban Fringe Areas”, *Transportation Research Record* 1114, (1987), pp. 45-53.

36. Jocksh, H.C., “Velocity Change and Fatality Risk in a Crash”, *Accident Analysis and Prevention*, Vol. 25, (1993), pp. 103-104.

37. Godwin, S.R. and Kulash, D.J., “The 55 mph Speed Limit on US Roads: Issues Involved”, *Transport Reviews*, Vol. 8(3), (1988), pp. 219-235.

38. Renski, H., Khattak, A.J., and Council, F.M., “Effect of Speed Limit Increases on Crash Injury Severity: Analysis of Single-Vehicle Crashes on North Carolina Interstate Highways”, *Transportation Research Record* 1665, (1999), pp. 100-108.

39. Cirillo, J.A., “Interstate System Accident Research – Study II – Interim Report II”, *Public Roads*, Vol. 35(3), (1968).

40. Hauer, E., “Accidents, Overtaking, and Speed Control”, *Accident Analysis and Prevention*, Vol. 3, (1971), pp. 1-13.

41. Lave, C. (1985), “Speeding, Coordination, and the 55 mph Speed Limit”, *The American Economic Review*, Vol. 75, (1985), pp. 1159-1164.

42. Chang, G.-L., Chen, C.-H., and Carter, E.C., “Intervention Analysis for the Impacts of the 65 mph Speed Limit on Rural Interstate Highway Fatalities”, *Journal of Safety Research*, Vol. 24, (1993), pp. 33-53.

43. Balkin, S. and Ord, J.K., “Assessing the Impact of Speed Limit on Fatal Interstate Crashes”, *Journal of Transportation and Statistics*, April, Vol. 4(1), (2001), pp. 1-26.

44. Lave, C. and Elias, P., “Did the 65 mph Speed Limit Save Lives?,” *Accident Analysis and Prevention*, Vol. 26(1), (1994), pp. 49-62.

45. Godwin, S.R., “Effect of the 65 Speed Limit on Highway Safety in the USA”, *Transport Reviews*, Vol. 12(1), (1992), pp. 1-14.

46. *Report to Congress: Effect of Increased Speed Limits in the Post-NMSL Era*, U.S. Department of Transportation and NHTSA, (1998).

47. Farmer, C.M., Retting, R.A., and Lund, A.K., “Changes in Motor Vehicle Occupant Fatalities after Repeal of the National Maximum Speed Limit”, *Accident Analysis and Prevention*, Vol. 31, (1999), pp. 537-543.

48. Vernon, D.D., Cook, L.J., Peterson, K.J., and Dean, J.M., “Effect of Repeal of the National Maximum Speed Limit Law on Occurrence of Crashes, Injury Crashes, and Fatal Crashes on Utah Highways”, *Accident Analysis and Prevention*, Vol. 36, (2004), pp. 223-229.

49. Kloeden, C.N., McLean, A.J., and Glonek, G., *Reanalysis of Travelling Speed and the Risk of Crash Involvement in Adelaide South Australia*, Australian Transport Safety Bureau, Road Safety Research Report CR 207, (April 2002).

50. Hauer, E., *Speed and Crash Risk*, Royal Automobile Club of Victoria, Research Report 04/02, (May 2004).

51. Lamm, R. and Choueiri, E.M., “Recommendations for Evaluating Horizontal Design Consistency Based on Investigations in the State of New York”, *Transportation Research Record* 1122, (1987), pp. 68-78.

52. Krammes, R.A., Brackett, R.Q., Shafer, M.A., Ottesen, J.L., Anderson, I.B., Fink, K.L., Collins, K.M., Pendleton, O.J., and Messer, C.J., *Horizontal Design Alignment Consistency for Rural Two-Lane Highways*, Research Report FHWA-RD-94-034, (1994), Washington, D.C.

53. Islam, M.N. and Seneviratne, P.N., “Evaluation of Design Consistency of Two-Lane Rural Highways”, *ITE Journa*l, Vol. 64(2), (February 1994), pp. 28-31.

54. Fitzpatrick, K., Elefteriadou, L., Harwood, D., Collins, J., McFadden, J., Anderson, I.B., Krammes, R.A., Irizarry, N., Parma, K., Bauer, K., and Passetti, K., *Speed Prediction for Two-Lane Rural Highways*, Report FHWA-RD-98-171, (June 1999).

55. Schurr, K.S., McCoy, P.T., Pesti, G., and Huff, R., "Relationship Between Design, Operating, and Posted Speeds on Horizontal Curves on Rural Two-Lane Highways in Nebraska", *Presented at the 2002 Annual Meeting of the Transportation Research Board*, Washington, D.C., (January 2002).

56. Parma, K., *Evaluation of Alignment Indices in Estimating Tangent Speeds on Rural Two-Lane Highways*, A Master's Thesis, Texas A & M University, College Station, TX, (1997).

57. Polus, A., Fitzpatrick, K., and Fambro, D., "Predicting Operating Speeds on Tangent Sections of Two-Lane Rural Highways", *Transportation Research Record* 1737, (2000), pp. 50-57.

58. Smoker, M.D., Tarris, J.P., and Mason, J.M., "Relationship Between Zonal Variables and Individual Vehicle Speeds on Low-Speed Urban Streets", *1996 Institute of Transportation Engineers Compendium of Technical Papers*, (1996), pp. 341-345.

59. Fitzpatrick, K., Carlson, P., Brewer, M., and Wooldridge, M., "Design Factors that Affect Driver Speed on Suburban Streets", *Transportation Research Record* 1751, (2001), pp. 18-25.

60. Harkey, D.L., Robertson, H.D., and Davis, S.E., "Assessment of Current Speed Zoning Criteria", *Transportation Research Record* 1281, (1990).

61. Elvik, R., "Optimal Speed Limits: Limits of Optimality Models", *Transportation Research Record* 1818, (2002), pp. 32-38.

62. Solomon, D., *Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle*, Bureau of Public Roads, U.S. Department of Commerce, (July 1964).

63. West, L.B., and Dunn, J.W., "Accidents, Speed Deviation, and Speed Limits", *Traffic Engineering*, Vol. 41(10), (1971), pp. 52-55.

64. Taylor, W.C., "Speed Zoning: a Theory and its Proof", *Traffic Engineering*, Vol. 34(12), (1965).

65. Joscelyn, K.B., Jones, R.K., and Elston, P.A., *Maximum Speed Limits – Volume I: A Study for the Selection of Maximum Speed Limits*, Indiana University, Prepared for National Highway Safety Bureau, D.C., (October 1970).

66. Parker, M.R., *Synthesis of Speed Zoning Practices*, FHWA/RD-85/096, (July 1985).

67. Lu, J.J., Park, J., Pernia, J., and Dissanayake, S., *Criteria for Setting Speed Limits in Urban and Suburban Areas in Florida*, Florida Department of Transportation, Final Report, Contract or Grant No. BC353-14, (March 2003).

68. Robertson, H.D., and Warren, D.L., "Highway Speed Limits: a Judicial Perspective", *Presented at the 2001 Annual Meeting of the Institute of Transportation Engineers*, Chicago, Illinois, August 19-22, (2001).

69. Warren, D. and Rousseau, G., "Acceptable Speeds from the Pedestrians's Perspective", *Presented at the 2002 Annual Meeting of the Institute of Transportation Engineers*, Philadelphia, PA, August 4-7, (2002).

70. Zegeer, C.V., and Deen, R.C., "Identification of Hazardous Locations on City Streets", *Traffic Quarterly*, Vol. 31(4), (1977), pp. 549-570.

APPENDIX A:
LITERATURE REVIEW

A review of the literature was conducted to identify relevant work in this area. Wherever appropriate, the review distinguishes between studies that have looked at changes in system-wide speed limits versus studies that have looked at speed zoning. The material is summarized in the following topics:

- Impact of changes in speed limits
- Relationship between site characteristics and operating speeds
- Motorist compliance with existing speed limits
- Factors and methods used to set speed limits
- Agencies/personnel involved in making speed limit decisions

IMPACT OF CHANGES IN SPEED LIMITS

Since driver speed is a function of several factors, it is difficult to identify the effect of just the speed limit on speeds. In the case of limited access roads, several studies have looked at the impact of the introduction of NMSL in 1974, changes that were made to rural interstates in 1987, and the suspension of the National Maximum Speed Limit (NMSL) in 1995. A few studies have also looked at effect of changes in speed limits on non-limited access roads.

Effect on Average Speeds and Speed Dispersion

Driver speed is a function of several factors apart from the posted speed limits, e.g., alignment, lane and shoulder width, design speed, land use, surrounding land use, traffic volumes, percentage of trucks in the traffic stream, weather, time of day, enforcement, visibility, vehicle operating characteristics, and driver factors such as risk taking behavior (*3*, *22*). To find out the effect of changes in speed limit on average speeds, most researchers have relied on a comparison of average speeds before the change in speed limit with average speeds after the change in speed limit.

In many studies, speed dispersion is expressed as the difference between the 85th percentile speed and the average speed, which has been found to be approximately equal to the standard deviation, the square root of the variance. If the dispersion is relatively low, speeds are more uniform. Speed dispersion is also a function of several factors in addition to the posted speed limit. In a study of urban and rural freeways in Virginia, speed variance was found to increase with an increase in the difference between the design speed and the posted speed limit (*23*). In other words, if the posted speed limit is too low for a highway with high design standards, many drivers may not obey the posted speed limit.

Effect of System-Wide Changes in Speed Limits in Interstate Highways

In the early 80's, the Transportation Research Board conducted a study of the impacts of the 1974 NMSL legislation, leading to a special report (*24*). The study found that immediately following the introduction of the NMSL, there was a significant reduction in the average speed limit. Many drivers understood that lower speeds were associated with less fuel consumption. However, as gas became more easily available, speeds started increasing, although based on data until the early 80's average speeds in rural Interstate highways were well below the pre-NMSL values (*22*).

When Congress allowed rural interstate speed limits to be raised in 1987, most states found a 1 - 5 mph increase in the average speed, which is less than increase in the speed limit (e.g., *25*, *26*, *27*, *28*, *29*, *30*). However, the results were not consistent across the states: "of the 13 states that were studied after the 1987 speed limit increase, average speeds increased in 8 states, fell in 4, and did not change in 1, between the first quarter of 1987 and the first quarter of 1988" (*3*). In addition, among 9 States that kept the speed limits at 55 mph, average speeds increased in 5 states and decreased in 4 states, during the same time period. This indicates the importance of considering local factors and other confounding variables in the analysis.

According to the TRB special report 254 published in 1998, "average speeds typically increased 1 to 3 mph" following the abolition of the NMSL in 1995 (*3*). Controlled before-after studies in Riverside, CA, and Houston, TX, have shown increases of 2-5 mph (*31*). Another example is a before-after study conducted by the New Jersey Department of Transportation (NJDOT) of speeds and accidents based on 36 months of data after the speed limit was increased from 55 mph to 65 mph on selected freeway segments (*32*). Following the increase in the speed limit, "average travel speeds increased 1 mph on the various roadway sections in the 65 mph zones, with the exception of the Turnpike and Parkway which increased 3 to 4 mph on various segments". Again, this is reasonably consistent with results from other states, where an increase in the average speed was noted, although this increase was smaller than the increase in speed limit.

Looking at the effect of the 1987 legislation on speed dispersion, the results are mixed. In some cases, there was an increase in speed dispersion, although the magnitude was small, approximately 1 mph. For example, in Washington, the difference between the 85^{th} percentile speed and the mean speed was 5.5 mph before 1987, and 6.6 mph after 1987, an increase of 1.1 mph in the speed dispersion.

Some have argued that in addition to looking at average speed and speed dispersion, one should also look at the number or percentage of vehicles driving at high speeds, e.g., look at the percentage of vehicles that exceed 65 mph, and how this number has changed after the change in the speed limit. Based on the limited evidence that is available, this percentage seems to have increased with an increase in the speed limit. For example, in Michigan, the percentage of vehicles exceeding 65 mph increased from 30% when the speed limit of 55 mph to 42% when the speed limit was increased to 65 mph in 1987 (*33*). Similarly, a multi-state analysis conducted in 1990 by McKnight and Klein (*34*) concluded that, "there was a 48.2% increase in the percentage of drivers who exceeded the 65 mph speed limit in rural interstates in the 65 mph states. In 55 mph highways in 65 mph states, there was a 9% increase in the percentage of drivers who exceeded 65 mph".

Effect on Changing Speed Limits in Speed Zones in Non-Interstate and Non-Limited Access Roads

Parker (*8*) conducted a study to examine the effect of changes in speed limits on non-limited access highways. The sample included 100 experimental (consisting of 172 miles of highway) and 83 comparison (consisting of 132 miles of highway) non-limited access sites from 22 States. In the beginning, Parker proposed an experimental design where the sites will be selected randomly for implementing changes in posted speed limits. However, due to legal and other considerations, the States refused to participate in such an experiment. Hence, the experimental sites were chosen from those where speed limits were scheduled to be changed. The comparison sites were selected to match as closely as possible to the associated experimental sites. The study was conducted from October 1985-September 1992, when the maximum speed limit was 55 mph on non-limited access highways. Posted speed limits were increased in 41 of these sites and decreased in 59 of the sites. The maximum decrease in the speed limit was 20 mph and the maximum increase was 15 mph. In general, the study found very little evidence of a relationship between posted speed limits and speed distributions. Parker (*8*) concluded that "..there is statistically sufficient evidence in this dataset to reject the hypothesis that driver speeds do not change when speed limits are either raised or lowered. However, the difference in average speeds was less than 1.5 mph, and not sufficiently large to be of practical significance, and are primarily due to large sample sizes…" The study did not define the meaning of 'sufficiently large'. The study also found that driver violations of the speed limits increased when posted speed limits were lowered, and violations decreased when speed limits were raised. Parker (*8*) argued that "..this does not reflect a change in driver behavior, but a change in how compliance is measured, i.e., from the posted speed limit.."

Ullman and Dudek (*35*) studied the effect of reducing the speed limit from 55 mph to 45 mph at six urban fringe areas in Texas. Spot speed data were collected before and after the change in the speed limits at the same location in each site. Several statistics including average speed, 85th percentile speed, proportion of speeds exceeding 60 mph, standard deviation of speed, and skewness index of the distribution of speeds, were calculated. One of the sites experienced a 4 to 6 mph reduction in the average and the 85th percentile speeds, and a 6 to 10 percent reduction in the proportion of drivers exceeding 6 mph. However, the other five sites did not experience such changes, and the authors concluded that lower speed zones were not effective in changing average vehicle speeds or the speed distribution.

EFFECT ON SAFETY

Speed is directly related to the severity of crash injury. Probability of severe injury increases sharply with the increase in the impact speed of a vehicle (*36*). Godwin and Kulash (*37*), and others have argued that lower speeds lead to safer driving, because:

- "When traveling at a higher speed, the car moves a greater distance during the fixed period of time that it takes for the driver to react to a perceived problem.

- On highways lacking adequate super-elevation, a driver's ability to steer safely around curves diminishes with speed.

- The distance required to stop a vehicle by braking increases with speed."

In terms of crash rates, single vehicle crashes have been shown to increase with travel speed (e.g., *38*). Some studies have shown an association between crash involvement rates and deviation from average speed (*23*, *39*, *40*, *41*). These studies argue that speed dispersion is a more important factor than average speed with respect to crash involvement.

After a detailed literature review on the relationship between crashes and speed dispersion, McCarthy (*19*) concluded the following:

- "There is a positive relationship between crash severity and speed dispersion, particularly for rural Interstate roads. Also, evidence suggests that minimum speed dispersion occurs when the difference between a road's design speed and the posted speed limit lies between 5 mph and 10 mph.

- The safety effect of speed dispersion appears to be most important for the fastest rather than the slowest drivers."

McCarthy (*19*) also indicated that more research with disaggregate data are required to better understand the relationship between average, speed dispersion, and highway safety. For example, some studies have tried to relate aggregate measures of speed dispersion with crash frequency, and this measure may not necessarily correspond to the speed dispersion at the time of the crash. In addition, many studies do not control for other confounding factors.

Effect of System-Wide Changes in Speed Limits

The fatality rate dropped significantly after the implementation of NMSL in the early 70's. Some have argued that several factors may have played a role in this drop (*24, 37*). The shortage of fuel during the Arab oil embargo reduced the amount of total traffic. It is also possible that accident intensive recreation travel may have decreased. There were also some technological changes: "1974 was the first year that new cars were required to have interlock that did not permit the car to start unless the driver's seat belt was fastened" (*24*).

Despite these issues, most researchers have argued that decline in the number and rate of fatalities in 1974 is larger than can be explained by these factors. For example, Godwin and Kulash (*37*), indicate that, "highway travel declined by 1.5% between 1973 and 1974, and long-term improvements in the rate of fatalities per mile driven averaged around 3%. The sudden drop in the fatality rate in 1974 was around 15% - more than 3 times the combined effect of these two factors. Further the greatest declines in fatality rates occurred on these roads where the speed limit reductions were largest."

Most researchers argue that the increase in speed limit on rural Interstates in 1987 led to an increase in fatalities (e.g., *22, 28*, *30, 33*, *34, 42*). For example, USDOT (*29*) estimated that after the 1987 speed limit increase, the 1990 fatality toll on rural interstates in the 38 states with 65 mph speed limits was “30% greater than might have been expected”, had the speed limit remained the same. Many studies have come to similar conclusions, although the magnitude of change in crashes / fatalities after the 1987 speed limit increase varied in different States probably due to differences in the local conditions and the methodology that was adopted in the particular study. For example, Balkin and Ord (*43*), based on their structural time series analysis of fatal crashes from all 40 states that changed their speed limits in 1987, concluded that only “19 of 40 states experienced significant increases in fatal crashes” following the increase in speed limits on rural interstates.

Unlike other researchers, Lave and Elias (*44*) have argued that the 65 mph speed limit actually saved lives. Their paper argues that, “overall state fatality rates fell by 3.4 to 5.1% for the group of states that adopted the 65 mph speed limit”. Their conclusions are based on the following arguments:

- “Most studies have looked at the number of fatalities, before and after the increase to 65 mph. The numbers usually increased since traffic usually increased – but we should be looking at rates, i.e., fatalities per vehicle miles traveled (VMT)”. It is true that some earlier studies did look only at frequency of fatalities, in some cases because VMT data were not reliable. However, many subsequent studies, e.g., the one conducted by Farmer et al. (*47*) did consider miles traveled.

- “Enforcing the 55 mph speed limit on the Interstate highways required a substantial amount of highway patrol resources: the new 65 mph limit allows highway patrols to shift these resources to other safety activities and other highways – something they wished to do”. Lave and Elias, discuss about anecdotal evidence from Nevada, California, Montana, West Virginia, and Wyoming, indicating that some reallocation did occur. Again, one would expect this to be local issue depending on the needs and resources of the State and local communities.

- The new 65 mph speed limit on rural Interstates in 1987 produced a shift of traffic from rural non-interstate roads to rural Interstates, which are safer. Based on travel data, Lave and Elias indicate that traffic on the rural Interstate highways in the 65 mph states grew 1.73 times faster than the overall growth in those states, supporting their argument of a shift in travel towards the high speed rural Interstates. Godwin (*45*) argues that even if there was a shift in traffic to the higher speed rural Interstates, it was not large enough to justify the reductions in fatalities that Lave and Elias estimated.

Regarding the effect of the 1995 legislation, according to preliminary results published by NHTSA and USDOT in 1998 (*46*), “states that increased speed limits after the 1995 suspension of NMSL experienced approximately 350 more fatalities than would have been expected based on historical trends – about 9% above expectations”. Another study conducted by the Insurance Institute for Highway Safety (IIHS), concluded that on Interstates, fatalities increased by 15% and fatality rates increased by 17% after speed limits were raised (*47*). Balkin and Ord (*43*) found that “10 or 36 States experienced a significant increase in fatal crashes on rural interstates” and “6 of 31 states experienced a significant increase in fatal crashes on urban interstates", following the abolition of NMSL in 1995. Vernon et al. (*48*) found that that the increase in speed limits on urban interstates in Utah following the abolition of NMSL was associated with significant increases in total crash rates. However, the authors add that these results may be confounded by major reconstruction work in the Salt Lake area in 1996 in preparation for the 2002 Winter Olympics (Salt Lake County includes Salt Lake City and contains nearly half of all urban interstate mileage in Utah). This study also found that the increase in rural interstate speed limits from 65 mph to 70-75 mph did not seem to be associated with an increase in the frequency or severity of crashes.

The second part of Vernon et al. (*48*) studied the effect of changes in speed limits system-wide on non-interstate roads. Here, the analysis focused on non-interstate roads where the speed limits were increased from 55 mph to 60-65 mph following the abolition of NMSL. The results showed a significant increase in the fatal crash rate on non-interstate roads where the speed limits were increased (total crashes and injury crashes did not change); however, non-interstate roads where the speed limits stayed at 55 mph did not experience an increase in the fatal crash rate. The authors note that the non-interstate roads where the speed limits were increased had a higher fatal crash rate compared to roads where the speed were not increased, even before the speed limit was increased (i.e., when both roads had their speed limits at 55 mph), indicating that other factors apart from speed limit have a significant impact of fatal crash rates on non-interstate roads.

Recently, Kockelman et al. (*9*) completed a study for NCHRP to study the safety impacts of raised speed limits on high-speed roads. One part of this study involved a cross-sectional comparison of routes with different speed limits from the State of Washington. Based on the results of this study, the authors concluded that an increase in speed limit from 55 to 65 mph is associated with about a 3% increase in total crash counts and a 28% increase in fatal injury counts; and, an increase in speed limit from 65 to 75 mph is associated with a 0.64% increase in total crash counts and a 13% increase in fatal injury counts. However, the authors also caution that their "..crash severity models were based on cross-sectional data", and "may overestimate the speed change impact by a factor of roughly 2 when compared to the results of actual before-after studies on individual roadways".

Effect on Changing Speed Limits in Speed Zones

Ullman and Dudek (*35*) (discussed earlier) also studied the effect of the speed limit reduction (55 mph to 45 mph) that was implemented on non-limited access roads, on crash rates. The analysis was based on 1 year of crash data before the speed limit change and 1 year of data after the speed limit change. The results indicated that the "..overall evaluation generally showed no change in accident rates..", although two of the six sites experienced a reduction in accidents. The authors acknowledged that since the data are limited to just 1 year before and after the change in speed limits, that the "..changes in accident rates were most likely the result of random fluctuation due to regression-to-the-mean, rather than due to a reduction in the posted speed limit."

Parker (*10*) conducted a study for Michigan Department of Transportation to determine whether other factors in addition to the 85th percentile speed could improve safety and increase driver compliance. A before-after design with a comparison group was employed to study speed zones that were established on Michigan state highways between 1982 and 1986. The sample included 68 Michigan sites where speed limits were changed and 86 comparison sites. The analysis of the crash data revealed that the current speed zoning method used in Michigan (based on the 85th percentile) reduced total accidents by 2.2 percent (level of confidence of this estimate was 62%), and that "accidents did not increase when speed limits were raised, and accidents did not decrease when speed limits were lowered". The study concluded that the "most beneficial safety effect occurred when speed limits were posted within 5 mph of the 85th percentile speed".

Parker (*8*) (discussed earlier) also studied the effect of changes in speed limits on safety. Four different methods were employed to study the issue: multiple before-after analyses with paired comparison ratios, classical cross-product ratio or odds ratio, empirical Bayes method, and a weighted average logit method (the last method does not use a comparison group). Based on the results of the statistical analysis, Parker (*8*) concluded that "there is not sufficient evidence to reject the hypothesis that total crashes or fatal and injury crashes changed when posted speed limits were either raised or lowered".

Kloeden et al. (*49*) tried to estimate the effect of changing speed limits in urban areas in Adelaide, Australia. This project initially established a mathematical curve to define the relationship between free traveling speed and the risk of involvement in an injury, for sober drivers in an urban setting. Data collected in a case control study where the speeds of passenger vehicles involved in casualty crashes (estimated based on crash reconstruction techniques) were compared with the speeds of passenger vehicles not involved in crashes but traveling in the same direction, at the same location, time of day, day of week, and time of year. All sites considered in the study had a 60 km/h speed limit (approx. 37 mph). Using logistic regression modeling, a relationship was established between the relative risk of involvement in an injury crash and traveling speed. This relationship indicated that the risk of casualty crash involvement approximately doubled for each 5 km/h (3 mph) increase in traveling speed. Using this information, the change in the frequency of these crashes if the general speed limit was lowered from 60 km/h to 50 km/h (37 to 31 mph) was estimated. In order to accomplish this, a series of assumptions were made regarding the change in the distribution of free traveling speeds from before the speed limit change to after the speed limit change. Depending on the specific assumptions, a 25 to 70% reduction in free speed injury crashes was estimated for a 10 km/h (6 mph) reduction in the speed limit. Hauer (*50*) critically reviewed this study and made two observations: (1) Results from case control studies can be biased because of the possibility of confounding. To reduce this bias, controls are selected to match the controls. However, in this study, "there was no matching between the Controls and Cases on the potential confounders of age, gender, car mass, and number of occupants", and hence the results "are vulnerable to plausible confounding". (2) Relative risk was calculated based on two speed estimates: one was based on speeds measured by a laser speed meter, and the other was based on crash reconstruction approaches. This difference in precision introduces a large systematic bias in the results and "tends to produce a U shaped relationship between estimated relative risk and speed even when the true relationship is entirely flat".

Elvik and Vaa (*11*) reviewed 52 studies (12 of these were from data in the United States) that had studied the effect of changes in speed limits. These studies were published from 1966 to

1995. Using data from these studies, Elvik and Vaa (*11*) conducted a meta-analysis to estimate the impact of the following changes in speed limits:

- Raising existing speed limits
- Reduced speed limits: transition from unrestricted speed to speed limits
- Reduction of existing speed limits

Most of the studies from the United States had looked at the effect of reductions in system-wide speed limits. Specific information about studies from the other countries is not presented, but some probably looked at changes in system-wide speed limits, while others looked at speed zones. Looking at the results of the meta-analysis for changes in speed limits from 90 to 70 km/h, 80 to 60 km/h, 70 to 60 km/h, and 60 to 50 km/h, fatal accidents were reduced more than injury accidents, the ratio was about 2:1. In general, for these ranges, a 10 km/h (6 mph) reduction in speed limit was associated with about a 10% reduction in injury crashes and a 20% reduction in fatal crashes. Similarly, a 20 km/h (12 mph) reduction in the speed limit was associated with about a 20% reduction in injury crashes and a 40% reduction in fatal crashes. The report also provides confidence intervals for these estimates.

Effect of Changes in Average Speed

Recently, Elvik (*12*) conducted a meta-analysis to determine the relationship between average speed and safety. Specifically, this study tried to evaluate the power model proposed by Nilsson (*13*). The power model can be summarised in terms of six equations that relate changes in the number of accidents or in the number of road users killed or injured in accidents to changes in the mean speed of traffic. Denote speed by V, accidents by Y, and accident victims by Z. Furthermore, subscript by 0 the values observed before a change in mean speed and by 1 the values observed after a change in mean speed. The Power model can then be stated as in equations 1 to 6 below:

Number of fatal accidents = $\boldsymbol{Y}_1 = \left(\frac{\boldsymbol{V}_1}{\boldsymbol{V}_0}\right)^4 \boldsymbol{Y}_0$ (1)

Number of fatalities = $Z_1 = \left(\frac{V_1}{V_0}\right)^4 Y_0 + \left(\frac{V_1}{V_0}\right)^8 (Z_0 - Y_0)$ (2)

Number of fatal and serious injury accidents = $\boldsymbol{Y}_1 = \left(\frac{\boldsymbol{V}_1}{\boldsymbol{V}_0}\right)^3 \boldsymbol{Y}_0$ (3)

Number of fatal or serious injuries = $Z_1 = \left(\frac{V_1}{V_0}\right)^3 Y_0 + \left(\frac{V_1}{V_0}\right)^6 (Z_0 - Y_0)$ (4)

Number of injury accidents (all) = $\boldsymbol{Y}_1 = \left(\frac{\boldsymbol{V}_1}{\boldsymbol{V}_0}\right)^2 \boldsymbol{Y}_0$ (5)

Number of injured road users (all) = $Z_1 = \left(\frac{V_1}{V_0}\right)^2 Y_0 + \left(\frac{V_1}{V_0}\right)^4 (Z_0 - Y_0)$ (6)

The objective of Elvik's meta-analysis was to estimate the exponents for equations 1, 3, and 5 using the meta-analysis to determine if they are equal to 4, 3, and 2, respectively. Data from 97 studies containing a total of 460 estimates of the relationship between speed and accidents or accident victims were included in the meta-analysis. Based on the results of the meta-analysis, Elvik (*12*) concluded that overall, the power model was a reasonable model. However, Elvik (*12*) also acknowledged that some of implications of the power model are counter-intuitive. For example, the Power model predicts that the effect on fatalities of reducing speed from 80 to 40 km/h is the same as the effect of reducing speed from 20 to 10 km/h. This seems very unlikely. Further work using the same data set is ongoing in NCHRP Project 17-25 to determine if alternative model forms can better explain the relationship between the relative change in crashes and the relative change in mean speed.

RELATIONSHIP BETWEEN SITE CHARACTERISTICS AND OPERATING SPEED

Understanding the relationship between site characteristics and operating speed can be helpful in identifying the possible factors and variables that may need to be considered in identifying the appropriate speed limit in speed zones. Fitzpatrick et al. (*14*), as part of NCHRP project 15-18, conducted a detailed review of the previous research on the relationship between operating speed and design characteristics. The review tried to determine the variables influencing operating speed in horizontal curves and tangents separately in different types of roads:

- *Rural two lane highways*: Several studies have tried to examine the relationship between site characteristics and operating speed in horizontal curves on two-lane roads, partly due to FHWA's focus on this road type as part of the Interactive Highway Safety Design Module (e.g., *51*, *52*, *53*, *54*, *55*). Collectively, the studies indicated that degree of the curve, length of curve, deflection angle, radius, and grade, had some influence on operating speeds on curves. Regarding operating speeds on tangents in rural two-lane roads, Parma (*56*) found the region of the country and grade to be statistically significant, whereas Polus et al. (*57*), found the length of the tangent section and the characteristics of preceding and succeeding curves to be statistically significant.

- *Low-speed urban streets*: Few studies have examined the relationship between site characteristics and operating speeds on low-speed urban streets. Smoker et al. (*58*) tried to establish relationships between zonal variables and operating speeds. Five zonal variables were found to be significantly associated with driver's choice of operating speeds: average curvature, percent of zone with residential land use, percent of zone with parking allowed, and percent of zone with roadside hazard rating of 4. Poe and Mason

(*21*) found that degree of curvature, lane width, and hazard rating, were statistically significant in explaining spot speeds.

- *Urban and suburban arterials*: Most of the work on urban and suburban arterials has been conducted by Kay Fitzpatrick and her colleagues at the Texas Transportation Institute. For example, Fitzpatrick et al. (*59*), analyzed speed data from 19 horizontal curve sites and 36 straight sections in Texas to assess the relationship between site characteristics and operating speeds. Models were developed with and without including existing speed limit as a covariate. Speed limits were always highly significant when they were included in the model. In horizontal curves, when speed limit was included, deflection angle, and access density were also significant; when speed limit was not included, presence and type of median, and roadside characteristics (defined as either park, school, residential, and commercial) were statistically significant. For straight sections, when speed limit was included, no other variable was significant; when speed limit was not included, lane width was statistically significant.

Fitzpatrick et al., (*14*) mailed a survey to 45 members of the AASHTO Subcommittee on Design to obtain a better understanding of definitions, policies, and values used by practicing engineers in the design of new roadways and improvements to existing roadways; 45 members representing 40 states responded. One set of questions asked members to identify geometric elements that they felt affect driver speed. Majority of the respondents indicated that lane width, shoulder width, paved/unpaved shoulders, clear zone widths, and the presence/type of median affected driver speeds.

Fitzpatrick et al., (*14*) also collected speed data from 128 sites in six states. The focus was on non-limited access roads. Only data on free-flowing vehicles were collected during daylight hours during dry pavement conditions on weekdays. Models were developed with the 85th percentile speed as a response variable, and site characteristics including speed limit as independent variables. Speed limit was the only variable that was statistically significant in these models. However, other variables, including access density, median type, parking along the street, and pedestrian activity level did show signs of influence on the 85th percentile speeds, although they were not statistically significant at the 95% confidence level.

MOTORIST COMPLIANCE WITH EXISTING SPEED LIMITS IN SPEED ZONES

Data from speed zone studies indicate that the posted speed limit is usually significantly lower than the measured 85th percentile value. Harkey et al. (*60*) collected speed data at 50 rural and urban locations in four states on roadways where the posted speed limits ranged from 25 to 55 mph. Results indicated that average speeds exceeded posted speed limits by 1 to 8 mph, 85th percentile speeds exceeded posted speed limits by 6 to 14 mph, and over 70% of drivers traveling in free-flow conditions were driving faster than the speed limit. Parker (*8*) (discussed earlier) found that, in general, posted speed limits were set at the 45th percentile value in non-limited access roads. Fitzpatrick et al., (*14*) (discussed earlier) found that in approximately two-thirds of these sites, the recommended speed limit was more than 3.6 mph below the 85th percentile value. ITE (*15*), in their survey, found that for roadways with posted speed limits of 45 mph and below, most of the measured speeds are higher than the posted speed limit. When the posted speed limit is 55 mph or more, about half of the measured speeds are above the posted speed limit.

FACTORS AND METHODS USED FOR SETTING SPEED LIMITS

Two common methods have been used to set system-wide speed limits: statutory limits and optimum speed limits. Setting speed limits in speed zones has been accomplished through engineering studies and expert systems.

Factors and methods for setting system-wide speed limits

Statutory Limits

These limits are established by legislation at the national level, state level, and the municipal level. At the national level, a maximum speed limit of 35 mph was imposed during World War II to save fuel and rubber; maximum speed limit of 55 mph was imposed during the energy crisis in 1973 to save fuel. Typically, statutory speed limits apply to a category of highways (e.g., freeways, arterials) depending on type of area (e.g., rural vs. urban) and design characteristics of the particular category of highways under consideration. In general, with statutory limits, the trade-off between safety, travel time, and other objectives are determined politically. Due to this, statutory limits may not sometimes be appropriate for certain sections. As mentioned earlier, statutory limits are outside the scope of this project.

Optimum Speed Limits

In the early 1960's, Oppenlander (*16*) proposed setting speed limits at optimal levels from a societal perspective. Oppenlander (*16*) argued that the speeds that drivers select does not take into account risks imposed on other drivers and the society. For example, excessive speeds can increase the probability and severity of crashes involving other road users, increase emissions and fuel consumption, costs that are not completely borne by the driver. Hence, the optimal speed limit from the driver's perspective will be different from socially optimal speed. Oppenlander (*16*) considered four cost categories: travel time, vehicle operating costs, crashes and service (comfort and convenience). For each category, costs curves were developed that showed the relationship between speed and cost. The socially optimal speed was obtained by solving for the minimum point in the total cost curve. This approach is most useful in determining the optimal speed limit for different classes of roads. More recently, Elvik (*61*) used a similar approach to determine optimal speed limits on public roads in Norway and Sweden.

Although this approach has conceptual appeal, it has rarely been used in practice. One problem with this approach is the estimation of the cost curves. Despite significant efforts, there is not a clear consensus on the relationship between speed and crash frequency and on appropriate costs of travel time, injuries, and fatalities. In addition, there is a concern that socially optimal speed limits would be much lower than the optimal speed limit from the driver's perspective, and hence would not be considered reasonable by the public, making them difficult to enforce (*3*).

Factors and methods for setting speed limits in speed zones

Engineering Studies

The most common approach to set speed limits in speed zones is based on an engineering study. Engineering studies will require collecting data on operating speeds, crash frequency and severity, and other information on traffic, geometric, and roadside characteristics. Some studies have shown that crash rates are lowest around the 85th percentile, and that drivers traveling significantly faster or slower than this speed are more likely to be involved in a crash (e.g., *39*, *60*, *62*, *63*). Based on this information and results from other studies, the Manual of Uniform Traffic Control Devices (MUTCD) notes that "when a speed limit is to be posted, it should be the 85th percentile speed of free-flowing traffic, rounded up to the nearest 10 km/h (5 mph) increment." However, the MUTCD also indicates that the following factors may be considered in addition to the 85th percentile speed when establishing speed limits, but does not provide specifics on how to account for these factors:

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

In addition to the 85th percentile speed, other measures of the operating speed have also been proposed. One such measure is the pace speed (mentioned in the MUTCD), defined as the 10 mph range encompassing the greatest percentage of all the speed observations at a particular site. Another measure proposed by Taylor (*64*) is based on the skewness of the speed distribution. Taylor (*64*), based on a study of 51 two-lane highways in Ohio found that crash rates were higher in sites with a non-normal speed distribution. Taylor argued that speed limits that are able to change the speed distribution from non-normal to a normal distribution would lead to lower crash rates. Joscelyn et al. (*65*) in critiquing Taylor's theory questioned the validity of the assumed relationship between normality, skewness, and accidents. Joscelyn et al. (*65*) argued that the skewness index was a measure of symmetry and not normality, and indicated that speed distributions can be bimodal (with very little skewness) near intersections.

Parker (*66*) surveyed state and local transportation officials to determine the most important factors that are used in determining appropriate speed limits. The results indicated that the 85th percentile speeds, accidents and pace speed (tied for second), and type and amount of roadside development, were the most important factors.

A recent survey conducted by the Institute of Transportation Engineers (*15*) revealed that while the 85th percentile speed is the predominant factor used in setting speed limits, both roadway geometry and accident experience are "always or usually considered" by over 90 percent of those agencies that responded to the survey (see Table A.1). Roadside development was reportedly considered ‘always or usually’ by 82 percent of the survey respondents. The survey also indicated that roadway geometry, accident experience, and politics were the three most common reasons why a speed other than the 85th percentile speed was used when setting the speed limit. Some survey responses stated that “the 85th percentile does not work and a better method is needed.” In addition, some responded that “the public has difficulty understanding how the traffic engineering profession sets speed limits,” which can lead to “difficulties when interacting with political and public groups.”

One could argue that selecting the 85th percentile of operating speeds as the speed limit is appropriate for certain types of roads such as rural interstates which are designed to the highest standards and where traffic volume is low (*3*). However, this approach may not be appropriate for urban roads having higher traffic volumes, a mix of road users and more roadside activity. On these roads, speed limits are set to facilitate access rather than reducing travel times. Thus, the 85th percentile speed may be only be part of the equation, with a need to consider other factors such as pedestrian activity, presence of school crossings, etc., that should be reviewed when selecting an appropriate speed limit.

Lu et al. (*67*) used a unique approach to identify appropriate speed limits in non-limited access highways in urban and suburban areas in Florida. This approach involved the development of mathematical models using data from 104 sites that had the following characteristics: low crash frequencies, relatively uniform traffic speed, and relatively small difference between 85th percentile speeds and posted speed limits. Data from these sites was used to assess the extent of correlation between operating speeds and site characteristics, identify critical variables, and estimate adjustment factors to adjust the maximum statutory speed for a particular facility type. Adjustment factors were developed for the following variables that the analysis identified as being critical: access density, road class, lateral clearance, lane width, and signal spacing.

Table A.1: Ratings of factors ‘always or usually considered’ when setting speed limits (*15*)

Factor	Percentage of Responses
85th percentile speed	99
Roadway geometry	92
Accident experience	92
Roadside development	82
Pedestrian activity	73
Functional class	71
Traffic volumes	70
Pavement width	69
Lane width	69
Unexpected conditions	68
Design speed	64
Public input	60
Presence of parking	56
Presence of shoulders	52
Mean speed	47
10 mph pace	47
Presence of curb and gutter	41
Average test run speed	31

Non-Motorists’s Perspective to Speeding and Speed Limits

In identifying appropriate speed limits, most of the attention has focused on the driver and the vehicle. Robertson and Warren (*68*) conducted a survey of traffic court judges in order to obtain a judicial perspective on speeding and speed limits. Thirty traffic court judges from fifteen states were contacted to obtain their opinion on different issues related to speeding. Eight judges, representing six states responded. The judges were asked to list the important factors in determining a safe and reasonable speed limit. Half the judges indicated that amount of traffic and type of road as the primary traffic for determining safe and reasonable speeds. One judge indicated that the speed of traffic was a factor. Five (out of eight) judges indicated that speed limit should reflect speeds at which the majority of drivers are traveling.

Warren and Rousseau (*69*) report on a study conducted in Berkeley, CA, to understand acceptable speeds from a pedestrian's perspective. This study involved residents on two streets in observing cars traveling in their neighborhood and rating the speed and volume of the traffic as acceptable or unacceptable. Results indicated that acceptable speeds occurred in a fairly narrow range (20-30 mph).

Expert System Approaches

In practice, engineers use their experience and judgment in considering other factors apart from the operating speed while deciding on the appropriate speed limit in a speed zone. Expert systems aim to mimic such an expert's thought process in solving complex problems. The original expert system (VLIMITS) developed by ARRB for Victoria, was a DOS-based program (*7*). Development of VLIMITS began with field measurements at over 60 locations. The data collected from the field were reviewed by a panel of experts who used this information to come up with decision rules for appropriate speed limits for different types of roads and traffic conditions. This information was reduced to a computer program. Users are prompted to respond to a series of questions, and the system responds with a recommended speed limit. VLIMITS was updated in 1992 (*3*). Since then, programs have been developed for all Australian state roads authorities and for New Zealand. These include NLIMITS (for New South Wales), SALIMITS (for South Australia), WALIMITS (for Western Australia), QLIMITS (for Queensland), TLIMITS (for Tasmania), and NZLIMITS (for New Zealand). Collectively, these are called XLIMITS. The logic in these systems is hard coded, and the system does not learn with previous experience, as some expert systems do.

The most recent version of XLIMITS takes the user through a five-step process before recommending a speed limit (*3*). The first step deals with the type of area, rural, urban, urban fringe, or rural fringe. The next step deals with roadway and roadside characteristics such as number of lanes, access control, type of road, and median width. Using the information entered in these two steps, the system develops a first approximation for the speed limit. In the next two steps this speed limit may be modified based on other factors such as schools, accidents, alignment, and the 85th percentile speed. The final outcome is the recommended speed limit with warnings about specific factors that need to be studied further.

USLIMITS was developed based on the logic used in the XLIMITS programs, but with changes made to suit the conditions in this country. One change was to force the recommended speed limits to be between the 50th to 85th percentile speeds. The USLIMITS system asks the user for information on the following factors before recommending a speed limit: roadway and roadside characteristics, abutting development, nature of road user activity, operating speeds, traffic volume, presence/absence of adverse alignment, crash rates, special situations, and adjacent speed limits (for short sections). USLIMITS can be accessed through the Internet, but a username and password are required, which can be obtained from the Federal Highway Administration.

Agencies/Personnel involved in making Speed Limit decisions for Speed Zones

With the exception of Federal speed limits established during World War II and the National Maximum Speed Limit of 55 mph set in 1973 during the Arab Oil embargo, the authority to set speed limits has been left to State and local governments. States and most local governments establish speed zones to set an appropriate speed limit for specific road and traffic conditions.

Parker (*66*) conducted a survey of States and local jurisdictions and found that speed limits are set on State highways in 40 States by the State transportation department or commissioner. In Alabama and Michigan, speed limits are set jointly by the transportation agency and the State Police. The State Speed Control Board sets speed limits in Oregon and the Registry of Motor Vehicles establishes speed limits in Massachusetts. In a survey conducted by ITE Committee TENC-97-12, it was reported that local agencies generally follow State guidelines when setting speed limits. Most State and local agencies base their decision to raise or lower a speed limit in a speed zone on the results of an engineering and traffic investigation.

While the legal authority to set speed limits has been established in every State and community, the decision on what limit is appropriate for conditions can be, and often is, influenced by other groups and individuals. Agencies and persons frequently involved in speed limit decisions are included, but not limited to, the following groups.

- Traffic engineers conducting the speed studies and interpreting the results.
- Elected officials and public policy makers that respond to community affairs.
- Drivers whose behavior is a direct reflection of the effectiveness of the system.
- Citizens living or working in the area who are directly impacted by traffic flow.
- Judges and magistrates who must address the "reasonableness" of the limit in their court decisions.
- Enforcement officials who need an objective means of separating the egregious violator from the rest of the driving population.

Conclusions

The following conclusions can be made based on this review:

- Consistent speed limits are essential even if a majority of motorists feel that they can make reasonable judgments about their driving speeds

Conclusions regarding changes to system-wide speed limits

- Increase in speed limits on interstate roads in 1987 and 1995 seem to be followed by an increase in average speeds, although the increase in average speeds was less than the increase in the speed limit. Effect of the increase in speed limits on speed dispersion is not very clear.

- Most researchers seem to argue that the increase in speed limits on interstate roads in 1987 and 1995 resulted in more fatalities.

Conclusions regarding changes to speed limits in speed zones

- Very little work has been conducted to study the effect of changes in speed limits on average speeds on non-limited access roads.

- Very little work has been conducted to study the effect of changes in speed limits on crash frequency and severity in non-limited access roads. Parker (*10*) and Parker (*8*) in their work on non-limited access roads did not find significant associations between speed limits and crash frequency/severity.

- Many studies have tried to find relationships between site characteristics and operating speed. Depending on the type of road under consideration and whether tangent sections or horizontal curves are being considered, several factors including degree of curve, deflection angle, radius, grade, lane width, presence/absence of parking, roadside hazard rating, access density, presence and type of median, pedestrian activity, and roadside characteristics, seem to be associated with operating speeds.

- In general, there is limited motorist compliance to existing speed limits.

- It is clear that posted speed limits in speed zones should be credible and enforceable. It is also clear that better methods are needed to identify appropriate speed limits especially in urban roads having higher traffic volumes, a mix of road users, and more roadside activity. Engineers have to use their experience and judgment in considering these factors. A knowledge-based expert system provides an opportunity of improving the decision making process.

APPENDIX B:

DETAILED RESULTS FROM A SURVEY OF USLIMITS USERS

1. Have you or your agency explored or applied the USLIMITS program for the purpose of setting speed limits? (select the appropriate box by typing an X)

   3 respondents have used the USLIMITS application for establishing speed limits

   11 respondents have only explored the application (not actually used for setting speed limits)

   1 had not used USLIMITS

2. Enter the number of speed zoning projects in each roadway type for which you have applied USLIMITS:

   The total number of speed zoning projects is shown below.

0	Rural Interstate highways
1	Urban Interstate highways
0	Rural multilane roads
1	Rural high-speed two lane roads
3	Urban and suburban multi-lane roads
6	Rural lower-speed two-lane roads
2	Urban residential streets
0	Other (please describe)
6	N/A- Have only explored the application

3. Apart from using USLIMITS, describe how you currently set speed limits, e.g., do you have established or written guidelines (this question applies to only those agencies that have authority to set speed limits):

   - Portland Transportation prepares the request, including collection of data and obtaining input from the neighborhood and police. This information, with justification is forwarded to the Oregon Department of Transportation, which sets the speed limit.
   - Speed survey, 85%, crash data
   - Prima Facie speed limit is 50 km/h with a Maximum Speed Limit of 80 km/h as

defined in the Motor Vehicle Act (MVA). The 50 km/h generally applies for urban conditions and 80 km/h for rural conditions. The Provincial Traffic Authority within the Dept. of Transportation and Public Works can change speed limits for highways between 80 km/h to 110 km/h as determined from design standards and observations (85^{th} percentile, pace, ball banking).

- Our task as a consultant is to develop a method for BC. Most jurisdictions in British Columbia follow the Motor Vehicle Act's specifications of 50 km/h for municipal roads, 30 km/h for school zones, and 20 km/h for alleys.

- The agency for which this work was done sets speed limits by ordinance. I think there was an interest in raising the speed limit on study rural two-lane roads. The existing speed limits were set many years ago, possibly by the county before the jurisdiction incorporated, and the logic behind why the speed limits were set they way they were had been lost over the years.

- Speed limits are established primarily using the 85^{th} percentile speed of motorists. The culture in the area as well as the accident rate also plays some part in the decision.

- We use the procedures established by the California Vehicle Code (CVC), and the California Department of Transportation (Caltrans) to establish speed limits. Essentially we use: 1. prevailing speed (usually the 85%), 2. accident records, 3. Highway, traffic and roadside conditions not readily apparent to the driver. I am the individual delegated the authority to approve the posting orders, and because of several court cases, I tend to require our staff to follow the Caltrans procedures pretty closely, and will only approve a posting more than 5 MPH below the 85%, when there is exceptional justification. I use USLIMITS as an additional "check", in cases where I have concerns, but not as an official methodology. Generally I have found that it tracks pretty close to our determinations.

- ITE's proposed recommended practice.

- NYSDOT Policy: generally establish the speed limit at the 85^{th} percentile. If setting a speed limit lower than the 85^{th} percentile, it should not be lower than 3 mph below the upper limit of the 10 mph pace and it should not place more than 1/3 in technical speed violation (not lower than the 67^{th} percentile.)

- We us the 85^{th} percentile speed, access density, road geometry and roadside features. No written guidelines.

- Based on past practices, political encouragement

4. Please rate the overall Ease of Use of the USLIMITS program (select the appropriate box by typing an X)

   11 respondents indicated that USLIMITS was Easy to Use

   2 respondents indicated that it USLIMITS Not Easy to Use.

   Ease of use can be improved by doing the following: (write or type in the space below)

   - The user manual lists a variety of factors the program works through. It is not clear to me that the program works through them in the same order as presented in the manual, or which factors the program discards as part of the process. It would be helpful if the program listed factors that are discarded based on user inputs.
   - Just easier "getting started" or introduction format.
   - Improve editing of data input. Provide less movement between screens or forms.
   - We use metric so conversion is necessary.
   - Allow data entry as an option even on a drop down list. Not all "drop down" lists apply. (for me - State does not apply)
   - Allow easier navigation among the input windows.
   - It would have been better to have a longer entering form to prevent having to wait for another screen to load before additional entries could be made.
   - For purposes of documentation, it might be better if the printouts were more complete. We have to produce the Engineering and Traffic Study (E&TS) in court if a speed posting is challenged, and the judges tend to demand complete justification for any reduced speed posting.
   - Clarify the definitions on accesses and access types (step 5).
   - Do something to stop the program from giving inconsistent speed limits at the end (sometimes, they vary from one revision to another, although operating speed remains the same).

- Define terms such as: density of surrounding development. High vs. low density.
- Better descriptions of the street classifications/types. Easier methods to put in street segments. Working with seasonal school and park limits.

5. Please comment on the clarity and completeness of the input screens, on-line help, and the Users Manual.

- Descriptions on data entry pages were short and often did not provide information expected. For example, road function is through or local. Perhaps intermediate functions could be defined. What effect does Local Traffic Management Area have on low speed road?
- Very clear
- It's been a while, but I recall that I encountered at least one unusual term – something like "carriageway." It struck me as a British term, and I was unclear about what it meant. I was unclear whether it referred to the lanes only, or the pavement width, or even something else.
- No problems encountered.
- The help for "number of accesses" is unclear.
- In put screens are clear and easy to use.
- Fine
- The manual was easy to follow and use. Does the manual instruct what is the minimum length for the "Road Length" variable?
- For the most part fairly intuitive

6. The data collection form in the USLIMITS program asks the user to input information on several variables/factors. Based on your knowledge and experience, please indicate whether you feel each of these factors are of "primary importance", "secondary importance", or "not important" (the variables are described in the USLIMITS user manual). In addition, also list additional factors that need to be considered, and indicate whether they are of primary or secondary importance (select the appropriate box by typing an X):

   Numbers in each cell show the total number of times each factor was selected as either primary importance, secondary importance or not relevant

Variable / Factor	Primary	Secondary	Not Relevant
Project Information	3	8	1
Area Definition	6	6	0
Road Length	8	3	1
Road Function	10	2	0
Low Speed	6	5	1
Number of Accesses	7	5	0
Divided	6	5	1
Lanes	7	4	1
Access Restrictions	6	5	1
Set Back	2	8	1
Median Width	0	11	1
Median Protection	1	10	1
Freeway	7	2	2
Interchange	6	3	2
Traffic Volume	8	3	1
Shoulders	6	6	0
Operating Speeds	11	1	0
Adverse Alignment	11	1	0

Special Activities	7	5	0
Crossings and Signals	7	5	0
Crash Rate	9	3	0
Adjacent Speed	6	4	1
<u>Additional variables:</u>			
1. Grade	0	1	
2. Parking	0	1	
3. Clear zone	1	0	
4. Presence of pedestrians, equestrians, or bicyclists adjacent to roadway, or crossing roadway	1	0	
5. Highway, traffic, and roadside conditions not readily apparent to the driver (these have to be 'real', not imagined, perceived, or political)	1	0	

7. Please describe problems and annoyances encountered in using USLIMITS. If you have a specific recommended solution to a problem, please provide as well.

- I received different calculations of the calculated crash rate depending on which page of the program was displayed. Revise_project.asp and create_project.asp showed one crash rate while the report showed another, lower crash rate.
- I perceive the tool is geared more toward high speed and multi-lane facilities. As I and those around me would be more likely to use the tool for lower speed, urban situations, I feel the tool may not completely capture the importance other factors besides vehicle-based criteria have on decisions.
- Improve data input – continuing forward and backward is a slow process. Why not try to place all data entry on one screen and allow better movement within that screen.
- Improve reporting

- Metric
- From my brief use of the system, the speed limit results are within approximately 5 % of the 85 percentile. I feel I could have used the 85 percentile directly and basically achieved similar results, with less work. Unless the model provides more flexibility I feel use will be restricted.
- I am not sure if some variables are affecting results more than other variables (sensitivity). Possible separate manual concerning theory and use.

- We use metric, had to convert everything! (also had to always select "Seattle" when modeling Vancouver) ☺
- I feel that one input that was sorely missed was the posted speed limit. Although the operating speeds give a good indication of the "natural" speed of the road, some drivers will base their travel speed on the posted speed limit, either not exceeding the limit, or never driving more than, say, 10 km/h over the limit. This would affect your operating speeds, which in turn are a large factor in determining the USLimits recommended speed. In short, the existing posted speed will affect the recommended posted speed. Should that be the case? I don't think so.

- Lack of clarity for terms. I see the term "set back" used above, and I left it blank. That may be one of the terms that caused me confusion when I used the application. In planning, set back refers to how far buildings are from the right-of-way line. Is this what is meant by set back? If so, I would say set back is irrelevant.
- The term shoulder is likewise unclear. Is it a continuous shoulder? What if the shoulder is intermittently interrupted with telephone poles just feet from the pavement?

- One of his findings was that the software is not sensitive to many of the variables – at least not in a reasonable range of values. For example, changing the road length did not change the results (this may not be true as the length approaches zero, but generally we do not use speed zoning on road sections less than ¼ to ½ mile long). The adjacent speed limit also had no effect (once again within a reasonable range of values). Even the crash rate had little, if any, effect on the recommended speed.

- Perhaps some of these fields could be made optional, <u>or</u> there could be categories specified so the user does not have to be concerned about precise values. A good example might be the crash rate – it may take considerable effort to determine the precise crash rate, but fairly easy for the city engineer to state whether this road section is a high, medium or low crash section. Since even the classifications might not effect the recommended speed, it may not be worth the effort to obtain VMT to calculate a rate.

- Maybe a thorough sensitivity analysis will help determine which factors are of primary and secondary importance.

- The biggest problem that we have is the political pressure to reduce speed limits. Even though we remind people that won't work, there remains a lot of political pressure to post roads at lower speeds than the surveys and other factors justify.

- I would like to see the terms defined such as large vs. small commercial properties and shopping centers.

- Can't always create reports.
- None that were very significant: I have only had limited interaction with the program

8. Was USLIMITS useful in assisting with your speed zoning decision? Explain.

- Yes

- Yes, confirmed expected speed zones

- Yes, we compared it to a locally developed system and found USLIMITS to give us more reasonable answers.

- It confirmed what the literature was telling me that speed zoning is based primarily on 85^{th} percentile speed. This seemed to be the major factor in determining speed limit using USLIMITS.

- The critical accident rate was too close to the average rate. The accident rate the program compared with was based on whether the location was urban or rural. Many locations are more of a cross between being purely urban and purely rural.

- No, I only use it as a second check for our normal procedures.
- Basically reinforced our current practice.
- It confirmed a recent decision
- Yes, it was another source of data/justification to my supervisors and political interest.

9. Would you say that speed limits recommended by USLIMITS are reasonable based on your knowledge and experience? (select the appropriate box by typing an X)

   11 respondents indicated that the speed limits recommended by USLIMITS was reasonable

   2 respondents indicated that the speed limits recommended by USLIMITS was <u>not</u> reasonable

   If No, please explain. For example, are the recommended speed limits higher or lower than what you would have recommended for certain types of roads, areas, or conditions?

   - I have not used the tool enough to make this determination.
   - We would be more confident with using the program if we knew the weight given to the various factors in determining the final recommendation.

10. Please comment on the content, completeness, and flexibility of the USLIMITS output report.

    - I was happy with it, I used part of the report in my submission to the state.
    - Report only designed for one purpose – to provide results. There may be other purposes for report. (education, explanation)
    - Output format is complete, there’s not much flexibility but no need for it either.
    - Good, when it works.

- It served my needs, but not enough experience to really say

11. Does the USLIMITS output report provide all the relevant information that you need? What changes would you suggest?

- Yes
- A review of speed setting manuals may provide additional reports.
- Looks good.
- I would suggest giving some thought to clear zone. None of the engineers I spoke to were comfortable with raising the speed limit on any or the rural roads unless sufficient clear zone were available. This is a tricky area, because clear zone is a consideration for new design, and should not be interpreted as a requirement for existing roads. However, when the question is whether to raise the speed limit, a new condition, to bring the speed limit in line with 85^{th} percentile speeds, the more conservative approach prevailed, in absence of any other clear guidance in the literature.
- Should follow the same format as either the format in the Caltrans traffic manual or some other format accepted by California courts.
- We used the US Limits model on only one project; however, we found it easy to use and understand. The summary is very helpful. It is nice to have a neat report with minimal setup.
- OK
- For the most part, yes.

APPENDIX C

EXPANDED PANEL

Last Name	First Name	Organization
Abbo	Tony	New Mexico DOT
Aboobaker	Nazhat	NCHRP Panel
Ackerman	Derek	Kansas DOT
Adams	Troy	Delaware DOT
Ashoury	Kevin	Colorado DOT
Bain	Doug	Nova Scotia Transportation & Public Works
Becker	Ronald	Wisconsin DOT
Belmonte	Louis	Pennsylvania DOT
Birriel	Elizabeth	Florida DOT
Black	George	NTSB
Black	W. Steven	Virginia DOT
Broughton	Darlene	SC DOT
Bruff	Tom	Southeast Michigan COG
Chang	Dongho	Washington DOT
Chin	George	Arizona DOT
Davis	Paul	Oregon DOT
Hicks	Tom	Maryland SHA
Jones	Carol	SC DOT
Klemm	Dawn	NYDOT
Peter	Allain	Louisiana DOT
Phillip	Allen	Georgia DOT
Wentworth	Jim	NCHRP Panel
Abraham	John	City of Troy, Michigan
Abshier	John	City of Redding, California
Balachandran	Ram	City of Murfreesboro, Tennessee
Bennett	Donald	City of Wilmington, North Carolina
Berry	Richard	City of Mesquite, Texas
Burchfield	Robert	City of Portland
Cynecki	Michael	City of Phoenix
Dryer	David	City of Madison, Wisconsin
Eshraghi	Fred	City of Norwalk, Connecticut
Ezelle	Brandy	City of Auburn, Alabama
Fox	Gary	City of Des Moines, Iowa
Futch	Kevin	City of North Las Vegas, Nevada
Godfrey	David	City of Kirkland, WA
Green	Robert	City of Lewisville, Texas
Greene	Robert	City of Aurora, Illinois
Griffith	Ronald	City of Cedar Rapids, Iowa
Hanbali, PE	Rashad	City of Cape Coral, Florida
Hashemi	Yadi	Los Angeles
Herrington, PE	Deborah	City of Tampa, Florida
Hess, PE	Douglas	City of Boca Raton, Florida

Hillier	Bob	City of Peoria
Hofer	Dallas	City of Sioux Falls, South Dakota
Kramer	David	City of Rochester, MN
Krueger	Greg	Metro Region, Michigan DOT
Mason	John	NCHRP Panel
O'Neill	Dennis	Fairfax County Police
Ranck	Fred	FHWA
Soni	Prafull	Winnebago County
Taylor	William	NCHRP Panel
Voss	Linda	City of Topeka, KS
Ward	Bruce	Town of Gilbert
Warren	Davey	FHWA
Wasserman	Melvyn	Port Authority of NY and NJ
Birdwell	Bill	City of Gilbert, AZ
Caldwell	Michael	Taylor Police Department
Caruso	Phil	ITE, NCHRP Panel
Jones	Forrest	Skagit County (WA) Public Works
Lewis	Robin	City of Bend, OR
Linan	Alonzo	City of Olathe, KS
Lom	Eric	City of Appleton, WI
Lombardo	Angelo	City of Norman, OK
Manning	Robert	Gwinnett County, GA, NCHRP Panel
Marcee	Allen	FHWA-CO
McCarthy	Kevin	City of Farmington Hills, MI
McDonald	Steven	NCHRP Panel
Medisetty	Vidya	Municipality of Anchorage, AL
Morris	Doug	City of Charlotte, NC
Newton	Randall	City of Eden Prairie, MN
Pena	Hernan	City of Charleston, SC
Pirlot	Christopher	City of Green Bay, WI
Randolph	Dennis	Calhoun County Community Development, MI
Rees	Tyre	City of Springfield, IL
Sawyerr	Olu	City of Tallahassee, FL
Schomer	Thomas	City of Broomfield, CO
Shields	Brian	City of Overland Park, KS
Smith	Chad	City of Bloomington, MN
Snyder	David	VA City Council
Sonnenberg	David	Ingham County Road Commission, MI
Thompson	Russell	City of Fayatteville, NC
Turner	Robert	City of Spokane, WA
Van Winkle	John	City of Chattanooga, TN
Van Winkle	Stephen	City of Peoria, IL

White	O.C.	City of Las Vegas, NV
Whitlock	Benard	City of Chesapeake, VA
Yauch	Peter	Pinellas County, FL
Alicandri	Beth	FHWA
Barfield	Justin	Houston County, AL
Belluz	Leanna	Transport Canada
Bretherton	Martin	Gwinnett County
Coates	June	Florida DOT
Cole	Daniel	Spotsylvania County, VA
Corbin	John	Wisconsin DOT
Crouch	Timothy	Iowa DOT
Curtit	Michael	Missouri DOT
Dean	Wes	Mississippi DOT
Ellison	James	Pierce County, WA
Frerich	Paul	TXDOT, NCHRP Panel
Gifford	Rick	Washington DOT
Gower	Brian	Kansas DOT
Haagsma	Timothy	Kent County, MI
Holland	Victoria	Wayne County, MI, Public Services
Ibarguen	Bruce	Maine DOT
Jager	Peter	Utah DOT
Keller	Alan	Pennsylvania DOT
Kirk	Timothy	West Virginia DOT
Klawon	Matthew	Macomb County, MI
Klimovitch	John	Orange County, FL
Kutz	Given	Skagit County (WA) public works
Lipps	Ron	Maryland SHA
Lockwood	Mean	Virginia DOT
Manning	Dave	Nevada DOT
Mathisen	Mario	WS DOT
Rennie	Mary	NCHRP Panel
Sherman	Larry	NY DOT
Wyatt	Tony	NCDOT
Younkin	Kurtis	Iowa DOT
Britt	Butch	County of Ventura, CA
Burke	Kevin	Illinois DOT
Coddington	Cindy	Tippecanoe County, IN
Daughtry	Haywood	NCDOT
DeCorte	Robert	Traffic Improvement Association of Oakland County
Hardy	Earl	NCHRP Panel

Hiner	Mike	WA DOT
Kirk	Tim	NCDOT
Klug	Robert	Clark County, WA
Larson	Victor	Nebraska Department of Roads
Letzkus	Albert	Pima County, AZ
Lyles	Rick	Michigan State University
Mahugh	Jim	WS DOT
Malone	William	Howard County, MD
Mora	Christopher	Indian River County, FL
Morast	Robert	Washington County, OR
Neal	Jeffrey	Lexington-Fayette County, Kentucky
Nedzesky	AJ	NCHRP Panel
O'Leary	Pat	WS DOT
Percy	Martin	New York DOT
Perkins	John	Vermont Agency of Transportation
Peters	Randall	Nebraska Department of Roads
Picha	Dale	Texas DOT
Russell	Roger	WV Division of Highways
Schaefer	John	Missouri DOT
Taylor	Timothy	Alabama DOT
Thomas	Scott	Alaska DOT
Thompson	Harold	NSC
Truet	Stephen	Delaware DOT
Tugwell	Michael	Tennessee DOT

APPENDIX D

PRELIMINARY LIST OF VARIABLES AND FACTORS

Here is a tentative list of variables and factors that were sent to the Expert Panel before the June 2004 meeting. Variables and factors have been listed for six types of highways: rural interstate highways, urban interstate highways, rural high-speed two-lane and multi-lane highways, urban and suburban multi-lane and two-lane roads, rural lower speed two-lane roads, and urban residential streets. For each variable, the tables show the estimated level of difficulty in getting the necessary data (low, medium, and high), and provide a brief discussion of the issues. These variables were identified based on the review of the literature, and the results of the survey of USLIMITS users (in Appendix B).

In reviewing the list of variables, it is important to note that many of these variables are not independent, and are probably correlated with each other, e.g., traffic volume is correlated to operating speed, design speed is related to roadway geometry, and crash frequency is correlated with traffic volume. These relationships need to be taken into account in identifying the critical factors and variables, and in developing the logic for the expert system.

Rural Interstate Highways

Roadway and traffic conditions in these roads are more uniform than other types of roads except when the roads pass through mountainous areas. Pedestrians and bicyclists are generally not present. It will be difficult to maintain high levels of enforcement in long stretches of rural interstates. In choosing an appropriate speed limit, operating speeds, safety, and presence or absence of restrictive geometry, are probably the most important.

Variable	Level of difficulty in getting necessary data (Low, Medium, High)	Discussion
Vehicle operating speeds: (85th and 50th percentile speeds)	High	Research conducted following the 1987 legislation and the 1995 repeal of NMSL have indicated that increase in speed limits does lead to an increase in operating speeds.
Design speed	Medium	Interstates are designed for the highest standards. Hence, the design speed is probably less important for this road category compared to others. However, design speed may be an issue in mountainous areas.
Geometry (grade, curvature, etc.)	Medium	Interstates are designed for the highest standards. Hence, geometry is probably a factor only under special situations such as interstates passing through mountainous areas.
Crash statistics	Medium	There is probably a trade-off between level of safety and travel times when choosing a speed limit. Research conducted following the 1987 legislation and the 1995 repeal of NMSL have indicated that increase in speed limits have usually been associated with increase in fatal crashes. However, effect on changes in speed limits on total number of crashes is still in debate. NCHRP project 17-23 is expected to throw some light on this issue. The current version of USLIMITS does not use crash statistics in developing the recommendation for the speed limit, although the user is required to provide it. 9 out of 12 respondents to the USLIMITS survey indicate that crash rates are of 'primary' importance; 3 indicate that they are of 'secondary' importance.
Number of interchanges per mile	Medium	Closer interchange spacing increases the potential for conflicts between slow and fast moving vehicles. 6 out of 11 respondents to the USLIMITS survey indicated that this variable was of 'primary' importance; 3 indicated that it was of 'secondary' importance.

Urban Interstate Highways

Compared to rural interstates, potential for vehicle conflict increases due to higher traffic volumes and more interchanges. Urban interstates have a higher injury rate (per 100 MVM) but a lower fatality rate (per 100 MVM) compared to rural interstates. Maximum speed limits should probably be lower to reduce speed dispersion. Drivers may have difficulty in determining appropriate speeds during congestion. Variable speed limits can address this situation well, and are being studied in NCHRP project 3-59.

Variable	Level of difficulty in getting necessary data (Low, Medium, High)	Discussion
Vehicle operating speeds (85th percentile and 50th percentile values)	High	According to TRB Special Report 254, some studies indicate that crash rates are lowest between the average speed and the 85th percentile speeds.
Design speed	Medium	Compared to rural interstates, urban intestates may be more restricted, and the design speed may be a useful input in determining the appropriate speed limit.
Geometry; including presence of adverse alignment.	Medium	Compared to rural interstates, roadway geometry in urban interstates may be more restricted, and that can influence safe operating speeds. 11 out 12 respondents to the USLIMITS survey indicated that adverse alignment is of 'primary' importance; 1 indicated that it was of 'secondary' importance.
Number of interchanges per mile	Medium	Closer interchange spacing increases the potential for conflicts between slow and fast moving vehicles. 6 out of 11 respondents to the USLIMITS survey indicated that this variable was of 'primary' importance; 3 indicated that it was of 'secondary' importance.
Traffic volume (including information on % of different types of vehicle)	Medium	It is obvious that traffic volume does affect operating speed. Hourly volume has a more direct effect on traffic speed compared to ADT. Apart from ADT, it may be necessary to consider the distribution of traffic, e.g., peak-hour factor. 8 out of 12 respondents to the USLIMITS survey indicated that this variable was of 'primary' importance; 3 indicated that it was of 'secondary' importance. Percentage of trucks in the traffic stream is another factor that needs some consideration.
Clear zone and shoulder width	High	Excessive speed is one factor associated with run-off-road crashes. One could argue that a larger clear zone will reduce the frequency of these

		crashes. Unlike rural interstates, some sections of urban interstates may have limited clear zones.
Crash statistics	Medium	The laws of physics indicate that higher speeds are associated with an increase in crash severities. There is probably a trade-off between level of safety and improved travel times when choosing a speed limit. Research conducted following the 1995 repeal of NMSL have indicated that increase in speed limits have usually been associated with increase fatal crashes. However, effect on changes in speed limits on crash frequency is still in debate. NCHRP project 17-23 is expected to throw some light on this issue. The current version of USLIMITS does not use crash statistics in developing the recommendation for the speed limit, although the user is required to provide it. 9 out of 12 respondents to the USLIMITS survey indicate that crash rates are of 'primary' importance; 3 indicate that they are of 'secondary' importance.

Rural high-speed multilane and two lane highways

Roads in this class range from multilane, divided highways with some access control to two-lane, undivided highways with at-grade intersections and restricted roadway geometry. These highways are not built to the same standards as interstates, and because traffic can enter and exit the roads at intersections, vehicle conflicts, and the potential for crashes are greater than for rural interstates. Roadside hazards including utility poles and trees are also present on these roads. The design speed should probably be an important factor in determining the posted speed limit, which in general should be lower than for rural interstates.

Variable	Level of difficulty in getting necessary data (Low, Medium, High)	Discussion
Vehicle operating speeds (85th percentile and 50th percentile values)	High	According to TRB Special Report 254, some studies indicate that crash rates are lowest between the average speed and the 85th percentile speeds.
Design speed	Medium	These highways are not built to the same standards are Interstate roads, and design speed is an important factor that needs to be considered.
Clear zone and shoulder width	High	Compared to interstates, clear zones in these types of roads are typically lower. Previous research by a member of the research team (Martin Parker) has indicated that the distance between a fixed object on the roadside and roadway edge-line has a significant impact on the frequency of run-off-road fixed object crashes. The Roadside Design guide also encourages designers to provide a larger clear zone. 6 out of 12 respondents to the USLIMITS survey indicated that this variable was of ‘primary’ importance; 6 indicated that it was of ‘secondary’ importance.
Crash statistics	Medium	Crash statistics should probably be an important consideration. Both severity and frequency may need to be considered. As part of the meeting with the expert panel, we need to determine the level of detail that the user needs on crash statistics, i.e., does the user need to have precise numbers (e.g., crashes per million vehicle miles) or a subjective assessment of whether the crash rate for a particular site is high, medium, or low, compared to other similar sites. The current version of USLIMITS does not use crash statistics in developing the recommendation for the speed limit, although the user is required to report it. 9 out of 12 respondents to the USLIMITS survey indicate that crash rates are of ‘primary’

		importance; 3 indicate that they are of ‘secondary’ importance.
Roadway geometry and design consistency; Adverse alignment	Medium	Work undertaken by FHWA as part of the Interactive Highway Safety Design Module (IHSDM) has shown that roadway geometry and design consistency does affect crash statistics. 11 out of 12 respondents to the USLIMITS survey indicated that adverse alignment is of ‘primary’ importance; 1 indicated that it was of ‘secondary’ importance.
Presence of median and width of median	Medium	This is primarily an issue on multi-lane roads. Head-on crashes are one of the most severe types of crashes. The presence of a median does reduce the frequency of these types of crashes. 6 out of 12 respondents to the USLIMITS survey indicated that the presence of a median was of ‘primary’ importance; 5 indicated that it was of ‘secondary’ importance. Regarding median width, 11 out of 12 respondents to the survey indicated that it was of ‘secondary’ importance. None of them felt it was of ‘primary’ importance. NCHRP report 504 reports that when no median was present, speeds were slightly lower than when a raised or depressed median was present.
Number of intersections and access points per mile	Medium	Research conducted as part of IHSDM by FHWA indicates that the number of access points is related to crash frequency on two-lane rural roads. 7 out 12 respondents to the USLIMITS survey indicated that access restrictions are of ‘primary’ importance; 5 indicated that it was of ‘secondary’ importance. Access density is strongly associated with 85th percentile speeds, according to the results reported in NCHRP report 504.
Presence of two-way left-turn lanes	Low	Work conducted by FHWA as part of IHSDM for two-lane rural roads concluded that the presence of two-way left-turn lanes provides a safety benefit. NCHRP report 504 reports that when TWLTL are present, speeds are slightly higher than when there is no median.
Number or lanes	Low	7 out of 12 respondents to the USLIMITS survey indicated that number of lanes is of ‘primary’ importance; 4 indicated that is of ‘secondary’ importance. We may have to think about a different set of factors/variables/logic for 2-lane roads as opposed to multi-lane roads.
Width of pavement	Medium	NCHRP report 504 showed that “fewer lower speeds are associated with larger total pavement widths”, indicating that wider lanes may lead some drivers to travel faster.

Traffic volume (including information on % of different types of vehicle)	Medium	It is obvious that traffic volume does affect operating speed. Hourly volume has a more direct effect on traffic speed compared to ADT. Apart from ADT, it may be necessary to consider the distribution of traffic, e.g., peak-hour factor. 8 out of 12 respondents to the USLIMITS survey indicated that this variable was of 'primary' importance; 3 indicated that it was of 'secondary' importance. Percentage of trucks is another factor that needs some consideration.
Speed limits on adjacent sections	Low	In general, speed limits on adjacent sections should not be dramatically different. 6 out of 11 respondents to the USLIMITS survey indicated that this variable is of 'primary' importance; 4 indicated that it is of 'secondary' importance.

Urban and suburban multilane and two-lane roads

This is a broad category and there is probably a large variation in roadside conditions that need to be accounted for. Maximum speed limits should probably be lower than rural multilane roads because of more access points and a higher risk for vehicle conflicts from vehicle traffic and pedestrians/bicycles. Enforcement is easier compared to rural multilane roads because there are fewer miles of this type.

Variable	Level of difficulty in getting necessary data (Low, Medium, High)	Discussion
Vehicle operating speeds (85th percentile and 50th percentile values)	High	According to TRB Special Report 254, some studies indicate that crash rates are lowest between the average speed and the 85th percentile speeds.
Clear zone; presence of curb and gutter	High	Compared to interstate roads, urban and suburban multi-lane and two-lane roads have more roadside hazards. Some roads also have curb and gutter for drainage, delineating the edge of the pavement, and providing sidewalks. NCHRP project 22-17 will provide some guidelines for curb and curb-barrier installations.
Roadway class	Low	NCHRP report 504 found that arterial streets and collectors are associated with higher speeds than local roads.
Special activities	Medium or High	Urban and suburban areas have several roadside activities that need to be considered. USLIMITS includes the following in developing its recommended speed limit: schools or school crossings, frequent on-street bus stops, number of pedestrians, number of cyclists, parking maneuvers, amount of uncontrolled crossing and turning traffic, recreating and tourist traffic, and unprotected pedestrian crossings. 7 out of 12 respondents to the USLIMITS survey indicated that special activities are of ‘primary’ importance; 5 indicated that they are of ‘secondary’ importance. NCHRP report 504 reports that on-street parking and pedestrian activity lead to lower average speeds.
Number of access points, intersections, and signals	Medium	In the survey of USLIMITS users, 7 out of 12 respondents indicated that ‘crossings and signals’, and ‘number of accesses’ are of ‘primary’ importance; 5 indicated that they are of ‘secondary’ importance.
Presence of median, and width	Medium	This is primarily an issue on multi-lane roads. Head-on crashes are one of

of median		the most severe types of crashes. The presence of a median does reduce the frequency of these types of crashes. 6 out of 12 respondents to the USLIMITS survey indicated that the presence of a median was of ‘primary’ importance; 5 indicated that it was of ‘secondary’ importance. Regarding median width, 11 out of 12 respondents to the survey indicated that it was of ‘secondary’ importance. None of them felt it was of ‘primary’ importance. NCHRP report 504 reports that when no median was present, speeds were slightly lower than when a raised or depressed median was present.
Presence of two-way left-turn lanes (TWLTL)	Low	Work conducted as part of IHSDM for two-lane rural roads concluded that the presence of two-way left-turn lanes provides a safety benefit. One could expect benefits even in urban roads. NCHRP report 504 reports that when TWLTL are present, speeds are slightly higher than when there is no median.
Crash statistics	Medium	Crash statistics should probably be an important consideration. Both severity and frequency may need to be considered. As part of the meeting with the expert panel, we need to determine the level of detail that the user needs on crash statistics, e.g., does the user need to have precise numbers (crashes per million vehicle miles) or a subjective assessment of whether the crash rate for a particular site is high, medium, or low, compared to other similar sites. The current version of USLIMITS does not use crash statistics in developing the recommendation for the speed limit, although the user is required to report it. 9 out of 12 respondents to the USLIMITS survey indicate that crash rates are of ‘primary’ importance; 3 indicate that they are of ‘secondary’ importance.
Width of pavement	Medium	NCHRP report 504 showed that “fewer lower speeds are associated with larger total pavement widths”, indicating that wider lanes may lead some drivers to travel faster.
Traffic volume (including information on % of different types of vehicle)	Medium	It is obvious that traffic volume does affect operating speed. Hourly volume has a more direct effect on traffic speed compared to ADT. Apart from ADT, it may be necessary to consider the distribution of traffic, e.g., peak-hour factor. 8 out of 12 respondents to the USLIMITS survey indicated that this variable was of ‘primary’ importance; 3 indicated that it

		was of 'secondary' importance. Percentage of trucks is another factor that needs some consideration.
Speed limits on adjacent sections	Low	In general, speed limits on adjacent sections should not be dramatically different. 6 out of 11 respondents to the USLIMITS survey indicated that this variable is of 'primary' importance; 4 indicated that it is of 'secondary' importance.

Rural lower-speed two-lane roads

Compared to rural high-speed multilane roads, the potential for conflicts is higher because of fewer opportunities for passing. These roads are not designed to the highest standards and the design speed needs to be considered. In addition to speed limits, warning signs may be required.

Variable	Level of difficulty in getting necessary data (Low, Medium, High)	Discussion
Vehicle operating speeds (85th percentile and 50th percentile values)	High	According to TRB Special Report 254, some studies indicate that crash rates are lowest between the average speed and the 85th percentile speeds.
Design speed	Medium	These roads are not designed to the highest standards, and design speed becomes an important consideration.
Crash statistics	Medium	Crash statistics should probably be an important consideration. Both severity and frequency may need to be considered. As part of the meeting with the expert panel, we need to determine the level of detail that the user needs on crash statistics, e.g., does the user need to have precise numbers (crashes per million vehicle miles) or a subjective assessment of whether the crash rate for a particular site is high, medium, or low, compared to other similar sites. The current version of USLIMITS does not use crash statistics in developing the recommendation for the speed limit, although the user is required to report it. 9 out of 12 respondents to the USLIMITS survey indicate that crash rates are of 'primary' importance; 3 indicate that they are of 'secondary' importance.
Presence of restrictive geometry; Adverse alignment	Medium	11 out of 12 respondents to the USLIMITS survey indicated that adverse alignment is of 'primary' importance; 1 indicated that it was of 'secondary' importance. Adverse alignment may be more prevalent in these roads.
Clear zone and roadside hazards	High	It is possible that these roads have limited clear zone and roadside hazards such as trees.
Number of accesses per mile	Medium	Research conducted as part of IHSDM by FHWA indicates that the number of access points is related to crash frequency on two-lane rural roads. 7 out 12 respondents to the USLIMITS survey indicated that access restrictions

		are of ‘primary’ importance; 5 indicated that it was of ‘secondary’ importance. Access density is strongly associated with 85^{th} percentile speeds, according to the results reported in NCHRP report 504.
Width of pavement	Medium	NCHRP report 504 showed that “fewer lower speeds are associated with larger total pavement widths”, indicating that wider lanes may lead some drivers to travel faster.
Traffic volume (including information on % of different types of vehicle)	Medium	It is obvious that traffic volume does affect operating speed. Hourly volume has a more direct effect on traffic speed compared to ADT. Apart from ADT, it may be necessary to consider the distribution of traffic, e.g., peak-hour factor. 8 out of 12 respondents to the USLIMITS survey indicated that this variable was of ‘primary’ importance; 3 indicated that it was of ‘secondary’ importance. Percentage of trucks is another factor that needs some consideration.
Speed limits on adjacent sections	Low	In general, speed limits on adjacent sections should not be dramatically different. 6 out of 11 respondents to the USLIMITS survey indicated that this variable is of ‘primary’ importance; 4 indicated that it is of ‘secondary’ importance.

Urban residential streets

In these roads, safety and enforcement practicality are probably the most important. There is a higher risk of vehicle conflicts with pedestrians and bicyclists. Frequency of intersections and the amount of roadside activity (e.g, parking activity, driveways, etc.) can influence driver speeds.

Variable	Level of difficulty in getting necessary data (Low, Medium, High)	Discussion
Crash statistics	High	Crash statistics should probably be an important consideration. Both severity and frequency may need to be considered. As part of the meeting with the expert panel, we need to determine the level of detail that the user needs on crash statistics, e.g., does the user need to have precise numbers (crashes per million vehicle miles) or a subjective assessment of whether the crash rate for a particular site is high, medium, or low, compared to other similar sites. The current version of USLIMITS does not use crash statistics in developing the recommendation for the speed limit, although the user is required to report it. 9 out of 12 respondents to the USLIMITS survey indicate that crash rates are of 'primary' importance; 3 indicate that they are of 'secondary' importance.
Number of intersections, access points, and driveways	Medium	7 out 12 respondents to the USLIMITS survey indicated that access restrictions are of 'primary' importance; 5 indicated that it was of 'secondary' importance. Access density is strongly associated with how fast people drive, according to the results reported in NCHRP report 504.
Special activities	Medium or High	USLIMITS includes the following special activities in developing its recommended speed limit: schools or school crossings, frequent on-street bus stops, number of pedestrians, number of cyclists, parking maneuvers, amount of uncontrolled crossing and turning traffic, recreating and tourist traffic, and unprotected pedestrian crossings. 7 out of 12 respondents to the USLIMITS survey indicated that special activities are of 'primary' importance; 5 indicated that they are of 'secondary' importance. NCHRP report 504 reports that on-street parking and pedestrian activity lead to lower average speeds.
Presence of traffic calming	Low	Traffic calming does influence speeds and should be considered.

APPENDIX E

SURVEY OF NCHRP PANEL AND EXPERT PANEL REGARDING THE APPROPRIATE LEVELS AND CATEGORIES FOR THE CRITICAL VARIABLES

The purpose of this enquiry is to get feedback from the NCHRP and expert panels regarding the categories and levels for the critical variables that affect the recommended speed limits. For anyof the responses that require additional space, feel free to attach supplemental pages.
Please provide your information:

NAME:	______________	TITLE:	______________
STATE:	______________	AGENCY:	______________
PHONE:	______________	EMAIL:	______________

Background
During the meeting in June 2004 in Washington, D.C., the expert panel identified a set of critical variables for freeways, multi-lane, and two-lane roads. These variables were discussed at the Interim Meeting in August with the NCHRP Panel. In order to develop the decision rules for the expert system, the NCHRP panel and the project team agreed that a comprehensive set of case studies providing all the necessary combinations of the relevant levels/values of the critical factors be developed and that the expanded expert panel provide the recommended speed limit for each case study. The results of this exercise will be used to determine if a critical factor is significantly related to the recommended speed limit, and to derive the decision rules for the recommended speed limit.

Before developing the case studies, it is important to determine the appropriate categories/levels for the different critical variables. The objective of this survey is to get feedback from you regarding the categories and levels for the critical variables that affect recommended speed limits. In this survey, for each roadway type (i.e., limited access freeways, multilane roads, and two lane roads), variables are presented along with the proposed categories, levels, and the range of appropriate values to be considered. Please indicate if you agree/disagree with the proposed categories/levels. If you do not agree, please suggest an alternative set of categories and levels for that variable and alternative ways of considering that variable. Also indicate if there are other variables that need to be considered (this is the variable set deemed necessary by the expert panel). Using the results of this survey, the research team will develop the case studies.
Attached with this survey are two files: ‘hazard rating’, and ‘development’. You will need to refer to these files to answer the questions related to roadside hazard rating and roadside development.

We would like to get your responses by December 10, 2004. However, it will be extremely helpful if you respond earlier. Should you have any questions regarding the survey, please contact Raghavan Srinivasan at (919) 962 7418 or srini@claire.hsrc.unc.edu
Please respond to the survey by email or fax, to the following address:
Raghavan Srinivasan, Ph.D.
Highway Safety Research Center, University of North Carolina, Campus Box 3430,
730 Airport Road, Chapel Hill, NC 27599-3430
Fax: (919) 962 8710; Email: srini@claire.hsrc.unc.edu
Thank you for your cooperation.

Eight individuals filled out the survey. In addition, two individuals did not fill out the survey but had the following comments:

Expert 1

A couple cross-cutting (meaning applicable across categories) observations from a non-technical perspective:

1. Q3 - Crash history. Understand conceptually; however, would caution that the history in this area suggests uncertainty with respect to accuracy of data. It's not unusual for "excessive speed" to be a catchall evaluation by police, particularly if it's a checkbox on a reporting form. Suggest someone take a look a data to determine if the precision (e.g., 0-10% above average) is warranted.

2. Q6 and Q9. It appears that Q6 is intended to address physical "hazards" and Q9 "uses" along highway. The distinction between types of terrain and buildings is reasonably clear; however, suggest that the "uses" may not get adequately at what decision-makers think about. In the latter case, a city or town council may be particularly sensitive to adjacent playgrounds, children at play, etc. Not sure I get the relationship between "unsignalized access" to either hazards or uses. Bottom line = There may be three parameters in play here -- hazards, uses, and signalization status.
(Note: I realize that Q11 deals with pedestrian/bicycle activity, which is fine; however, it doesn't cover my point above).

Having said the above, I'm comfortable that study is headed in the right direction, given its mandate.

Expert 2

Overall, I agree with the critical variables you have identified.

The only major comment I have is with the Roadside Hazard Rating. I do not disagree with what you have written but I think that the photos selected for ratings 1 through 3 do not accurately represent these conditions.

The only other question I have, is will one-way road sections be included?

LIMITED ACCESS FREEWAYS/EXPRESSWAYS

1. 85th percentile speed

The operating speed is the speed at which drivers of free-flowing vehicles choose to drive on a road section. Speed data should be collected at a location where speeds are representative of the section being evaluated over at least a 24 hour period. From these data, the 85th percentile speed can be determined.

Proposed range of consideration for freeways: 50 to 80 mph

8	Agree
	Disagree

If you disagree, indicate what the appropriate range should be:

However, some States may not allow 80 mph (our maximum speed limit allowed by State legislature is 75 mph.) I also do not think a 24 hour or more speed study is REQUIRED to establish an appropriate speed limit (Expert 3).

2. Median speed

The operating speed is the speed at which drivers of free-flowing vehicles choose to drive on a road section. Speed data should be collected at a location where speeds are representative of the section being evaluated over at least a 24 hour period. From these data, the 50th percentile speed can be determined.

Proposed range: 45 to 77 mph (Note – there is obviously a correlation between the median and 85th percentile speeds that will be built into the case studies and the decision rules.)

8	Agree
	Disagree

If you disagree, indicate what the appropriate range should be:

However, I don't believe this is a necessary variable (Expert 4). See above (While I generally agree, I am not sure I understand your statement about the speed data collection) (Expert 3).

3. Crash history

During the meeting in June, the expert panel suggested that the crash history (minimum 3 years desired) of the section be compiled. If feasible, the crash data should be reviewed to determine if the crashes are speed-related. In the absence of such a review, how should crash history be considered in determining the speed limit? One approach is to look at the crash history (e.g., the crash rate) for the section compared to the average crash rate for similar sections. We propose that the users be asked to choose from the following three categories:

- Below average
- 0-10% above average
- >10% above average

4	Agree
4	Disagree

If you disagree, indicate how crash history should be considered in a speed limit study:

0 – 10% above average; > 10% but < 50% above average; > 50% above average (Severity needs to be considered as well) (Expert 4). While 3 years of crash data is ideal, some studies may be limited to a single year of data, ESPECIALLY if there are changed roadway or traffic conditions during the prior three years. I agree with having three or four (max) ranges to be used in the analysis. I do not know what those ranges should be, but the 0-10% above average may be increased to 0-25% above average as the middle range. Also, how you calculate an acceptable 'average crash rate' for a facility is important and often difficult for an agency. (Expert 3). Crash history is very important, but only 10% over is not an issue. I want to know if I'm 50% or 100% over a statewide rate. We also need to account for severity. Since speed plays such an important role in severity level. Possible suggestions would be Severity Ratio or EPDO rate (Expert 5). You may want to add more categories – i.e. greater/lesser than 20% etc. The greater the roadway varies from the norm, the greater the problem & the greater the need to investigate why. It may not be speed & speed restriction may not solve a greater problem (Expert 6). Below average; 1-20% above average; > 20% above average (Expert 7).

4. Percentage of section length with adverse alignment

Adverse alignment includes any section of the roadway where an advisory speed limit is (or could be) posted, including severe horizontal curves, vertical curves, and locations with poor sight distance. As the percentage of mileage subject to an advisory speed limit increases within a given section, the more likely it is that the overall speed limit for the section may need to be reduced. We propose that the users be asked to choose from the following categories for the percentage of the section length with adverse alignment (i.e., advisory speed limits):

- 0-9%
- 10-29%
- 30-50%
- >50%

7	Agree
1	Disagree

If you disagree, indicate what the categories should be or how this issue should be addressed:

<30%; >30% (Expert 4) If any changes, the categories may be slightly adjusted to 0 – 10%, 11 – 30%, 31-50%, and greater than 50% (Expert 3).

5. Average advisory speed for the adversely aligned sections

On roadway sections with a large percentage of the mileage subject to advisory speed limits, it is likely that there are multiple adversely aligned sections with different advisory speed limits. We propose the following range for the average advisory speed limit for the adversely aligned sections?

Proposed range: 45 to 60 mph

6	Agree
1	Disagree

If you disagree, indicate what the appropriate range should be or how this issue to be considered:

I don’t think you can define this. I would choose a speed limit that leaves only 30% of the length needing advisory speeds (see #4 above), and then use advisory speed plates on the remaining 30% (Expert 4). Weather related hazards (fog areas) need to also be considered (Expert 8). I may not have understood the question correctly, but you are stating that design speeds for a freeway facility should never be below 45 mph at a spot. Correct?? (Expert 3). Not sure that I understand this ! (Expert 7).

6. Roadside hazard rating

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. The scale ranges from 1 to 7, with 1 representing the lowest hazard (best conditions) and 7 representing the highest hazard (worst conditions)[1]. Photographs representing hazard ratings 1 through 7 for rural and urban areas can be found in the file entitled ‘hazard-rating’.

Note: We feel that roadside conditions on freeways will not include those found in the situations representing roadside hazard ratings 5 through 7. We propose that the users be asked to choose the hazard rating that best represents the roadside conditions of the section being evaluated.

- 1
- 2
- 3
- 4

5	Agree
3	Disagree

If you disagree, please describe how roadside hazards (or the combination of roadside conditions – beyond the edgeline) should be considered:

I agree with having the users choose the rating, but I am not convinced that it can be used as a factor – unless it is captured in the accident rate (or severity) (Expert 4). In my own experience, I have been on adverse road alignments at have no reduce speed signs. These roadways were very similar to ones provided in Hazard Rating #7 (Expert 8). I presume that you referring to the only the Rural Roadside Hazard photos for this. Furthermore, I would have a difficult time being able to select between a rating condition of 1 vs. 2, or 2 vs. 3 without some practice (Expert 3). Given that this system has nationwide applicability, the range of hazards may be extensive. Thus, having a greater choice may provide more precision. I suggest we include categories 5-7 (Expert 6). Use all 7 (Expert 7).

7. Interchanges per Mile

The following categories are proposed for the number of interchanges per mile

- <1
- 1-2
- >2

[1] These rating scales are based on a study conducted by Zegeer et al., 1987 (FHWA-RD-87/008) for two lane roads.

6	Agree
2	Disagree

If you disagree, indicate what the categories should be or how this issue should be considered:

<2; >2 (and we would have to specify a minimum length of roadway – maybe > 3 miles) (Expert 4).

Less than one vs. one or more. The instances of two or more interchanges per mile will have to be very rare and unique and should not affect the speed limit of a large freeway segment (Expert 3).

8. Speed Limit on Adjacent Roadway Sections

Some jurisdictions limit the change in speed limits between adjacent sections to 10 or 15 mph. In order to address this situation, we may need to know the speed limit in the upstream and downstream sections and whether the roadway and roadside environment in the upstream and downstream sections are substantially different from the section under consideration. The following questions are proposed:

<u>Upstream Section</u>

Is the roadway and roadside environment in the upstream section substantially different from the section under consideration?

- Yes
- No

Proposed range for Speed limit in the upstream section: 50 to 75 mph

<u>Downstream Section</u>

Is the roadway and roadside environment in the downstream section substantially different from the section under consideration?

- Yes
- No

Proposed range for Speed limit in the downstream section: 50 to 75 mph

6	Agree
2	Disagree

If you disagree, indicate how this variable should be considered:

I feel a 15-mph downstream change is too severe. A 10-mph change in speed is a severe change unless enough advance notice is posted (Expert 8).

If the speed range can go to 80, why did you limit your proposed speed limit in the upstream or downstream area at 75 mph? (This would make no difference in Stats which have a maximum speed limit of 75 mph or lower) (Expert 3).

Differentiate between higher or lower and better or worse environment upstream and downstream, not just it is different (Expert 7).

MULTILANE ROADS (RURAL AND URBAN)

1. 85th percentile speed

The operating speed is the speed at which drivers of free-flowing vehicles choose to drive on a road section. Speed data should be collected at a location where speeds are representative of the section being evaluated over at least a 24 hour period. From these data, the 85th percentile speed can be determined.

Proposed range: 25 to 65 mph

7	Agree
1	Disagree

If you disagree, indicate what the appropriate range should be:

See comments above (which have nothing to do with the range). In our URBAN area, we are only allowed to have a maximum speed limit of 55 mph on arterial streets, and we have very few. Some rural areas are allowed to have a 65 mph speed limit (Expert 3).

2. Median speed

The operating speed is the speed at which drivers of free-flowing vehicles choose to drive on a road section. Speed data should be collected at a location where speeds are representative of the section being evaluated over at least a 24 hour period. From these data, the 50th percentile speed can be determined.

Proposed range: 20 to 60 mph

6	Agree
2	Disagree

If you disagree, indicate what the appropriate range should be:

However, I do not believe this variable helps (Expert 4). The range is acceptable, but I will be very surprised to see a 20 mph operating on an arterial street that is not congested or under construction (Expert 3).

3. Crash history

During the meeting in June, the expert panel suggested that the crash history (minimum 3 years desired) of the section be compiled. If feasible, the crash data should be reviewed to determine if the crashes are speed-related. In the absence of such a review, how should crash history be considered in determining the speed limit? One approach is to look at the crash history (e.g., the crash rate) for the section compared to the average crash rate for similar sections. We propose that the users be asked to choose from the following three categories:

- Below average
- 0-10% above average
- >10% above average

3	Agree
5	Disagree

If you disagree, indicate how crash history should be considered:

0 to 10 above; 10 to 50 above; >50 above; (and severity must be considered) (Expert 4). I agree with the concept of having three ranges, but the 0-10% above average may be a rather small range. Also, it is a difficult task to identify an ‘average” collision rate, and by definition, half of the roadway segments should be above that average rate (Expert 3). Crash history is very important, but only 10% over is not an issue. I want to know if I'm 50% or 100% over a statewide rate. We also need to account for severity. Since speed plays such an important role in severity level. Possible suggestions would be Severity Ratio or EPDO rate. (Expert 5). More categories needed (Expert 6). Below; 0-20% above; >20% above (Expert 7).

4. Percentage of section with adverse alignment

Adverse alignment includes any section of the roadway where an advisory speed limit is (or could be) posted, including severe horizontal curves, vertical curves, and locations with poor sight distance. As the percentage of mileage subject to an advisory speed limit increases within a given section, the more likely it is that the overall speed limit for the section may need to be reduced. We propose that the users be asked to choose from the following categories for the percentage of the section length with adverse alignment (i.e., advisory speed limits):

- 0-9%
- 10-29%
- 30-50%
- >50%

7	Agree
1	Disagree

If you disagree, indicate what the categories should be or how this issue should be considered:

0 to 30%; >30% (Expert 4). See above comments

5. Average advisory speed for the adversely aligned sections

On roadway sections with a large percentage of the mileage subject to advisory speed limits, it is likely that there are multiple adversely aligned sections with different advisory speed limits. We propose the following range for the average advisory speed limit for the adversely aligned sections:

Proposed range: 20 to 50 mph

5	Agree
2	Disagree

If you disagree, indicate what the appropriate range should be or how this issue should be considered:

OK, but see comments on freeways (Expert 4). 20 to 40 mph (Expert 9). I could see a few instances where a 15 mph advisory speed may be in order on an arterial street (Expert 3). Don't understand this! Seems like # as well as speed is important (Expert 7).

6. Roadside hazard rating

The roadside hazard rating is a measure of roadside conditions including: shoulder width and type, side-slope, clear zone distance, presence/absence of curb/gutter, and presence/absence of fixed objects. The scale ranges from 1 to 7, with 1 representing the lowest hazard (best conditions) and 7 representing the highest hazard (worst conditions)[2]. Photographs representing hazard ratings 1 through 7 for rural and urban areas can be found in the file entitled 'hazard-rating'. We propose that the users be asked to choose the hazard rating that best represents the roadside conditions of the section being evaluated:

- 1
- 2
- 3
- 4
- 5
- 6
- 7

7	Agree
1	Disagree

If you disagree, please describe how roadside hazards should be considered:

There are too many categories to be useful in setting limits, maybe: (1 & 2); (3 & 4); (5); (6 & 7) (Expert 4). Generally agree, HOWEVER, it is difficult for me to discern much of a difference between a rating of '1' or '2' without some practice, and there could be multiple ratings for an entire roadway segment, which would make it very difficult to select an overall rating for an entire segment (without a lot of practice). It would be better to only 4 or 5 (max), categories, or lump 1/2 together, 3/4 together, 5/6 together, and have 7 stand alone (or something to that effect) (Expert 3).

7. Road function

Three categories are proposed based on AASHTO's functional classification:

- Arterial: Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control.
- Collector: Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials.
- Local: Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

7	Agree
1	Disagree

If you disagree, indicate how road function should be considered:

This section is related to Multi-Lane Roadways. Most, if not all, should be arterials (Expert 5). Local could also be called neighborhood (Expert 7).

[2] These rating scales are based on a study conducted by Zegeer et al., 1987 (FHWA-RD-87/008) for two lane roads.

8. Number of signalized access points per mile

The following categories are proposed:

- <2
- 2-4
- >4

5	Agree
3	Disagree

If you disagree, indicate how this variable should be considered:

However, we would have to specify the length of roadway (minimum) to apply this factor (Expert 4). Less than equal to 1 signal per mile (Signals at the mile line only); >1 and Less than or equal to 2 signals per mile (This presumes signals at the mile line and half mile line only); > 2 signals per mile (You cannot get two-way progression typically on these types of streets) (Expert 3). If there are signals, are they coordinated, and if so what is the speed (and what would be the ideal progression speed) (Expert 5). <2; 2-6; >6 (Expert 7).

9. Roadside Development and Unsignalized access to the segment

The intent is to account for traffic that enters the segment from driveways and unsignalized intersections, and its effect on the speed limit. Four categories are proposed based on the type of surrounding development (photographs representing these conditions are available in the file entitled 'Development')

- Predominantly undeveloped: Includes some scattered development with less than 30 commercial and residential driveways per mile
- Predominantly residential: Includes mostly residential single-family homes and multifamily development with more than 30 driveways per mile
- Predominantly commercial: Includes mostly shopping and service business with more than 30 driveways per mile
- Predominantly large shopping malls, office buildings, industrial complexes, etc.: High volume driveways. The number of driveways may be less than 30 per mile

5	Agree
3	Disagree

If you disagree, indicate how roadside development and the effect of unsignalized access should be considered:

I think the last category would be determined by the number of traffic signals/mile. I would only have 2 categories: <30 driveways/mile; >30 driveways/mile (Expert 4). I agree with including the driveway counting in the descriptions for a full definition, but I don't want to be counting driveways! Also, is the Roadside hazard and roadside development somewhat inter-related. I worried about this process getting way too complex for something that is much more straight-forward (Expert 3). Already accounted for this factor in other data (crashes, no. of signals, etc.) (Expert 5). These seem applicable only for principally to arterials. Need additional depictions of collectors and local streets, e.g., on some neighborhood streets there are few or more driveways (Expert 7).

10. Median Type

Three categories are proposed:

- Undivided
- Undivided with Two-Way Left-Turn Lane (TWLTL)
- Divided

7	Agree
1	Disagree

If you disagree, please describe how presence/absence of medians should be considered:

However, can you refer to the third category as a raised or flush median separation so someone will not think that a painted centerline will result in a 'divided' roadway? (Expert 3). The divided category should included raised divider and painted divider (Expert 6).

11. Pedestrian/bicycle activity?

Two categories are proposed

- Yes (there are pedestrians and bicycles crossing and walking/riding along the section)
- No (there are no pedestrians and bicycles crossing or walking/riding along the section)

3	Agree
5	Disagree

If you disagree, please describe how ped/bike activity should be considered:

0 is not possible – stranded motorists may have to walk on the shoulder – and presumably there are intersections where pedestrians and bicycles may cross the road. I don't believe the variable can be used (Expert 4). Urban-ped/bike activity still crosses outside crosswalks. Need to evaluate total activity (Expert 8). But for the category "No" you should define it as little to no pedestrian/bike activity and leave the interpretation up to the person doing the study (Expert 3). Should not be a factor (Expert 5). Degree of pedestrian traffic should be a variable – i.e. – high, medium, low ped/bike traffic (Expert 6). Need some intermediate categories (Expert 7).

12. Unsignalized pedestrian crossings?

Two categories are proposed:

- Yes (there are unsignalized pedestrian crossings)
- No (there are no unsignalized pedestrian crossings)

5	Agree
3	Disagree

If you disagree, please describe how this variable should be considered:

I agree if you mean designated and marked pedestrian crossings (Expert 4).
Not sure what you mean by unsignalized pedestrian crossings. Are you including unmarked and marked crosswalks? Or are you referring to only marked crosswalks, or only to marked crosswalks which get some use. Also, would not this variable correlate highly with the previous one, and should you not select the best? (Expert 3).
Should not be a factor (Expert 5).
Not sure that it need to be considered, are we talking about designated crossings (.e.g, marked or unmarked crosswalks) or do pedestrians at some point(s) cross the road? (Expert 7).

13. On-street parking on one or both sides of the road

Two categories are proposed:

- Present (there is parking on at least one side of the road)
- Absent (there is no parking)

6	Agree
2	Disagree

If you disagree, please describe how this variable should be considered:

Question – If there is <u>one</u> on-street parking spot along a 2-mile road segment – would this constitute a 'Yes' or 'No'. How would you consider cars parked on a dirt shoulder along an arterial? (Expert 3).
Should only be used on new construction, because they impact of parking should be reflected in the speed studies (Expert 5).
One side; Two sides; None (Expert 7).

14. Adjacent to a school zone?

During the meeting in June, some members of the expert panel indicated that speed limits have to be reduced for sections adjacent to a school zone even though the school zone is not within the study section. This is to account for school children who may be walking or crossing in that area
Two categories are proposed:

- Yes: section is adjacent to a school zone or a school and there are school children walking and crossing
- No: section is not adjacent to a school zone or a school and there are no school children walking and crossing

3	Agree
5	Disagree

If you disagree, please describe how this issue should be considered:

On multilane roads there should be guards if there are school children present – and the reduced speed limit should be only at certain times of the day – this is outside the scope of our committee (Expert 4).
I do not feel that the speed limit should be adjusted due to a possible hazard that would present itself for only an hour or two a day for less than 200 days a year (Expert 10).
Reduced speed limits may be considered if the segment is **<u>within</u>** a school zone or a heavy school crossing area (note that the term 'school zone' has a special legal definition in Arizona that may be different in other states). Furthermore, there may be a special speed zone established for the school frontage or school crossing area (Expert 3).

School zones are allowed to post special reduced speed limits, therefore, they should not impact the speed limit (Expert 5). No – or a school and there are few or no children walkin/crossing (Expert 7).

15. Speed Limit on Adjacent Roadway Sections

Some jurisdictions limit the change in speed limits between adjacent sections to 10 or 15 mph. In order to address this situation, we may need to know the speed limit in the upstream and downstream sections and whether the roadway and roadside environment in the upstream and downstream sections are substantially different from the section under consideration. The following questions are proposed:

Upstream Section

Is the roadway and roadside environment in the upstream section substantially different from the section under consideration?

- Yes
- No

Proposed range for Speed limit in the upstream section: 25 to 65 mph

Downstream Section

Is the roadway and roadside environment in the downstream section substantially different from the section under consideration?

- Yes
- No

Proposed range for Speed limit in the downstream section: 25 to 65 mph

6	Agree
2	Disagree

If you disagree, indicate how this variable should be considered:

Success will be in part a function of good transition signing (Expert 9). Too severe of a decrease in 15 mph (Expert 8). See comments regarding freeways (Expert 7).

TWO LANE (RURAL AND URBAN)

1. 85th percentile speed

The operating speed is the speed at which drivers of free-flowing vehicles choose to drive on a road section. Speed data should be collected at a location where speeds are representative of the section being evaluated over at least a 24 hour period. From these data, the 85th percentile speed can be determined.

Proposed range: 25 to 65 mph

5	Agree
3	Disagree

If you disagree, indicate what the appropriate range should be:

Although 65 sounds high for a 2-lane road (Expert 4). 25 to 60 mph (Expert 9). See previous comments (Expert 3). 85 percentile may be greater than 65 on some back roads (Expert 6).

2. Median speed

The operating speed is the speed at which drivers of free-flowing vehicles choose to drive on a road section. Speed data should be collected at a location where speeds are representative of the section being evaluated over at least a 24 hour period. From these data, the 50th percentile speed can be determined.

Proposed range: 20 to 60 mph

5	Agree
3	Disagree

If you disagree, indicate what the appropriate range should be:

See comments on freeways and multi-lane (Expert 4). 20 to 55 mph (Expert 9). See previous comments (Expert 3). Median speed on rural roads may be higher than 60 (Expert 6).

3. Crash history

During the meeting in June, the expert panel suggested that the crash history (minimum 3 years desired) of the section be compiled. If feasible, the crash data should be reviewed to determine if the crashes are speed-related. In the absence of such a review, how should crash history be considered in determining the speed limit? One approach is to look at the crash history (e.g., the crash rate) for the section compared to the average crash rate for similar sections. We propose that the users be asked to choose from the following three categories:

- Below average
- 0-10% above average
- >10% above average

3	Agree
5	Disagree

If you disagree, indicate how crash history should be considered:

0-25% above; 25% - 75% above; >75% above (Expert 4). See previous comments (Expert 3). Crash history is very important, but only 10% over is not an issue. I want to know if I'm 50% or 100% over a statewide rate. We also need to account for severity. Since speed plays such an important role in severity level. Possible suggestions would be Severity Ratio or EPDO rate (Expert 5). More categories needed (Expert 6). See comments regarding 3 (Expert 7).

4. Percentage of section with adverse alignment

Adverse alignment includes any section of the roadway where an advisory speed limit is (or could be) posted, including severe horizontal curves, vertical curves, and locations with poor sight distance. As the percentage of mileage subject to an advisory speed limit increases within a given section, the more likely it is that the overall speed limit for the section may need to be reduced. We propose that the users be asked to choose from the following categories for the percentage of the section length with adverse alignment (i.e., advisory speed limits):

- 0-9%
- 10-29%
- 30-50%
- >50%

7	Agree
1	Disagree

If you disagree, indicate what the categories should be or how this issue should be considered:

0-30%; >30% (Expert 4). Generally agree (or am willing to accept), but see previous comments (Expert 3).

5. Average advisory speed for the adversely aligned sections

On roadway sections with a large percentage of the mileage subject to advisory speed limits, it is likely that there are multiple adversely aligned sections with different advisory speed limits. We propose the following range for the average advisory speed limit for the adversely aligned sections?

Proposed range: 20 to 50 mph

6	Agree
1	Disagree

If you disagree, indicate what the appropriate range should be or how this issue should be considered:

But the upper range is not consistent with a 65 mph, 85% speed (Expert 4) I can see some segments being posted as low as 15 mph for an advisory speed in some rare instances (Expert 3). See prior comments (Expert 7).

6. Roadside hazard rating

The roadside hazard rating is a measure of roadside conditions including: shoulder width and type, side-slope, clear zone distance, presence/absence of curb/gutter, and presence/absence of fixed objects. The scale ranges from 1 to 7, with 1 representing the lowest hazard (best conditions) and 7 representing the highest hazard (worst conditions)[3]. Photographs representing hazard ratings 1 through 7 for rural and urban areas can be found in the file entitled 'hazard-rating'. We propose that the users be asked to choose the hazard rating that best represents the roadside conditions of the section being evaluated:

- 1
- 2
- 3
- 4
- 5
- 6
- 7

7	Agree
1	Disagree

If you disagree, please describe how roadside hazards should be considered:

(1 & 2); (3 & 4); (5, 6 & 7) (Expert 4) Generally agree, but see previous comments. It would be better to group 1 &2, 3&4, 5&6, and then 7 to reduce the number of categories for ease of use (Expert 3).

7. Road function

Three categories are proposed:

- Arterial: Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control.
- Collector: Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials.
- Local: Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement.

7	Agree
1	Disagree

If you disagree, indicate how road function should be considered:

8. Number of signalized access points per mile

The following categories are proposed:

- <2
- 2-4
- >4

5	Agree
3	Disagree

If you disagree, indicate how this variable should be considered:

[3] These rating scales are based on a study conducted by Zegeer et al., 1987 (FHWA-RD-87/008) for two lane roads.

<2; >2 (Expert 4) See previous comments for the multilane sections. If the signals are limited to a maximum of one per mile is one category. Two per mile is a second category, and more than two per mile (more than signs spaced at the mile line and half-mile line) is the last category where it is difficult, if not impossible, to achieve two-way signal progression (Expert 3). If there are signals, are they coordinated, and if so what is the speed (and what would be the ideal progression speed) (Expert 3).

9. Roadside Development and Unsignalized access to the segment

The intent is to account for traffic that enters the segment from driveways and unsignalized intersections, and its effect on the speed limit. Four categories are proposed based on the type of surrounding development (photographs representing these conditions are available in the file entitled 'Development')

- Predominantly undeveloped: Includes some scattered development with less than 30 commercial and residential driveways per mile
- Predominantly residential: Includes mostly residential single-family homes and multifamily development with more than 30 driveways per mile
- Predominantly commercial: Includes mostly shopping and service business with more than 30 driveways per mile
- Predominantly large shopping malls, office buildings, industrial complexes, etc.: High volume driveways. The number of driveways may be less than 30 per mile

5	Agree
3	Disagree

If you disagree, indicate how roadside activity and unsignalized access should be considered:

<30; >30 (Expert 4). Generally agree, but see my comments above about not wanting to count driveways (Expert 3). Already accounted for this factor in other data (crashes, no. of signals, etc.) (Expert 5). 30 driveways per mile may or may not be the appropriate number, but seems high (Expert 7).

10. Pedestrian/bicycle activity?

Two categories are proposed

- Yes (there are pedestrians and bicycles crossing and walking/riding along the section)
- No (there are no pedestrians and bicycles crossing and walking/riding along the section)

3	Agree
5	Disagree

If you disagree, please describe how ped/bike activity should be considered:

There are no streets in category 2 (Expert 4). Still need to evaluate ped/bike outside of crosswalks (Expert 8). However, “Yes” should be moderate to heavy pedestrian activity, and “No” should be defined as little to no pedestrian activity, EXPECIALLY in urban areas (Expert 3). Should not be a factor (Expert 5). Categories should have range – light, medium, heavy ped/bike traffic (Expert 6). Include intermediate category(ies) (Expert 7).

11. Unsignalized pedestrian crossings?

Two categories are proposed:

- Yes (there are unsignalized pedestrian crossings)
- No (there are no unsignalized pedestrian crossings)

4	Agree
4	Disagree

If you disagree, please describe how this variable should be considered:

Crossing a 2-lane road should not be a problem for pedestrian or bicyclists (Expert 4). Not sure what you mean by “unsignalized pedestrian crossings” (See comments above) (Expert 3). Should not be a factor (Expert 5). See prior comments regarding 12 of multilane roads (Expert 7).

12. On-street parking on one or both sides of the road

Two categories are proposed:

- Present (there is parking on at least one side of the road)
- Absent (there is no parking)

7	Agree
1	Disagree

If you disagree, please describe how this variable should be considered:

See comments above (Expert 3). Should only be used on new construction, because they impact of parking should be reflected in the speed studies (Expert 5).

13. Adjacent to a school zone?

During the meeting in June, some members of the expert panel indicated that speed limits have to be reduced for sections adjacent to a school zone even though the school zone is not within the study section. This is to account for school children who may be walking or crossing in that area

Two categories are proposed:

- Yes: section is adjacent to a school zone or a school and there are school children walking and crossing
- No: section is not adjacent to a school zone or a school and there are no school children walking and crossing

3	Agree
5	Disagree

If you disagree, please describe how this should be considered:

See multi-lane. Use of this factor could lead to lower speed limits on these streets (in the non-school opening and closing times) then in the school zone itself, which would only reduce speeds at certain hours. (Expert 4). For the same reason as cited for multilane roads (Expert 10). See comments to the similar question on multi-lane streets above (Expert 3). School zones are allowed to post special reduced speed limits, therefore, they should not impact the speed limit (Expert 5). 'No' should be section is not adjacent to a school zone or a school and there few or no children walking or crossing (Expert 7).

14. Speed Limit on Adjacent Roadway Sections

Some jurisdictions limit the change in speed limits between adjacent sections to 10 or 15 mph. In order to address this situation, we may need to know the speed limit in the upstream and downstream sections and whether the roadway and roadside environment in the upstream and downstream sections are substantially different from the section under consideration. The following questions are proposed:

Upstream Section

Is the roadway and roadside environment in the upstream section substantially different from the section under consideration?

- Yes
- No

Proposed range for Speed limit in the upstream section: 25 to 65 mph

Downstream Section

Is the roadway and roadside environment in the downstream section substantially different from the section under consideration?

- Yes
- No

6	Agree
2	Disagree

If you disagree, let us know how this variable should be addressed:

15-mph speed change is too severe (Expert 8). See prior comments (Expert 7).

APPENDIX F:

DESCRIPTION OF WEB-BASED PILOT TESTS AND RESULTS

Table F.1 Case Studies and Scenarios used in the Pilot

Case study / scenarios	85th % speed	50th % speed	Hazard Rating	Median	Signals	Length (miles)	Roadside Development	Ped/Bike	Parking
01a	31	27	6	Undivided	5	1.7	Commercial	Medium	Two sides
01b	34	28	6	Undivided	5	1.7	Commercial	Medium	Two sides
01c	38	33	6	Undivided	5	1.7	Commercial	Medium	Two sides
01d	42	37	6	Undivided	5	1.7	Commercial	Medium	Two sides
02a	38	33	3	Undivided	5	1	Commercial	Low	None
02b	38	33	3	Undivided	5	1	Residential	Low	None
02c	38	33	3	Undivided	5	1	Large shopping	Low	None
03a	34	29	5	TWLTL	6	1	Commercial	High	None
03b	34	29	6	TWLTL	6	1	Commercial	High	None
03c	34	29	7	TWLTL	6	1	Commercial	High	None
03d	34	29	1	TWLTL	6	1	Commercial	High	None
03e	34	29	2	TWLTL	6	1	Commercial	High	None
03f	34	29	3	TWLTL	6	1	Commercial	High	None
03g	34	29	4	TWLTL	6	1	Commercial	High	None
04a	31	25	4	TWLTL	5	3	Residential	Medium	None
04b	31	25	4	Undivided	5	3	Residential	Medium	None
04c	31	25	4	Divided	5	3	Residential	Medium	None
05a	32	27	5	Divided	10	2	Commercial	High	One side
05b	32	27	5	Divided	5	3	Commercial	High	One side
05c	32	27	5	Divided	6	2	Commercial	High	One side
06a	42	36	2	TWLTL	6	1.4	Large shopping	High	None
06b	42	36	2	TWLTL	6	1.4	Large shopping	Medium	None
06c	42	36	2	TWLTL	6	1.4	Large shopping	Low	None
07a	37	31	5	Undivided	4	1.4	Large shopping	Low	None
07b	37	31	5	Undivided	4	1.4	Large shopping	Low	One side
07c	37	31	5	Undivided	4	1.4	Large shopping	Low	Two sides
08a	32	28	5	Divided	6	2	Large shopping	Low	None

08b	35	29	5	Divided	6	2	Large shopping	Low	None
08c	39	34	5	Divided	6	2	Large shopping	Low	None
08d	43	38	5	Divided	6	2	Large shopping	Low	None
08e	48	43	5	Divided	6	2	Large shopping	Low	None
09a	34	29	3	TWLTL	3	2.3	Large shopping	Medium	None
09b	34	29	3	TWLTL	3	2.3	Residential	Medium	None
09c	34	29	3	TWLTL	3	2.3	Commercial	Medium	None
10a	38	33	4	Divided	5	2	Large shopping	High	None
10b	38	33	5	Divided	5	2	Large shopping	High	None
10c	38	33	6	Divided	5	2	Large shopping	High	None
10d	38	33	7	Divided	5	2	Large shopping	High	None
10e	38	33	1	Divided	5	2	Large shopping	High	None
10f	38	33	2	Divided	5	2	Large shopping	High	None
10g	38	33	3	Divided	5	2	Large shopping	High	None
11a	32	26	3	Undivided	6	1.1	Residential	High	Two sides
11b	32	26	3	TWLTL	6	1.1	Residential	High	Two sides
11c	32	26	3	Divided	6	1.1	Residential	High	Two sides
12a	39	33	7	TWLTL	9	2	Commercial	Medium	None
12b	39	33	7	TWLTL	6	2.2	Commercial	Medium	None
12c	39	33	7	TWLTL	5	3.8	Commercial	Medium	None
13a	36	30	4	Undivided	3	2	Residential	Low	One side
13b	36	30	4	Undivided	3	2	Residential	High	One side
13c	36	30	4	Undivided	3	2	Residential	Medium	One side
14a	40	35	5	Undivided	6	1.9	Commercial	Medium	Two sides
14b	40	35	5	Undivided	6	1.9	Commercial	Medium	None
14c	40	35	5	Undivided	6	1.9	Commercial	Medium	One side
15a	51	47	1	Divided	2	2	Undeveloped	Low	None
15b	48	44	1	Divided	2	2	Undeveloped	Low	None
15c	46	41	1	Divided	2	2	Undeveloped	Low	None

Background

A total of 23 individuals accessed the link to fill out the survey. Out of these, 20 actually completed the survey, while 3 individuals completed only the first two case studies.

Table F.2 shows the following information for each scenario:

- Scenario number
- 85^{th} percentile speed
- 50^{th} percentile speed
- Average of the speed limits provided by the experts (Av_SL)
- Standard deviation of the speed limits provided by the experts (SD_SL). A relatively low value of SD_SL implies that the responses from the experts were more consistent with each other.
- The maximum speed limit provided by any expert for that scenario (Max_SL)
- The minimum speed limit provided by any expert for that scenario (Min_SL)
- The proportion of responses where the 85^{th} percentile speed was selected as a critical factor (P_85^{th}). Overall, the 85^{th} percentile speed was selected as a critical factor in about 97% of the responses.
- The proportion of responses where the 50^{th} percentile speed was selected as a critical factor (P_50^{th}). Overall, the 50^{th} percentile speed was selected as a critical factor in about 56% of the responses.

Figure F.1 shows the average speed limit, the 50^{th} percentile, and the 85^{th} percentile speeds for each scenario in a chart. It is clear from Table F.2 and Figure F.1 that the average of the speed limits provided by the experts is in most cases between the 85^{th} and 50^{th} percentile speeds, and typically much closer to the 85^{th} percentile value. In a few cases, the average speed limit is higher than the 85^{th} percentile value: one case study where this happened consistently is in case study 15, which represents an undeveloped area with a divided road. It is important to note that for the pilot case studies, we assumed that the crash rate is average or below average, and this may have influenced the relationship between the speed limit and the 85^{th} percentile speed.

Tables F.3A through F3.G show the proportion of responses where the remaining factors (i.e., hazard rating, median type, number of signals, section length, ped-bike activity, and parking) were identified by the experts as a critical factor. The tables also provide the number of observations in each level of these factors.

Here is a summary of the findings from these tables:

- Roadside Hazard rating. Overall, this factor was selected as being critical in about 46% of cases. The table indicates that when the hazard rating was very low (i.e., 1) or very high (i.e., 7), it had a slightly higher chance of being selected as critical.
- Median type. Overall, this factor was selected as being critical in about 54% of cases. When the median type was Divided or TWLTL, it was identified as being more critical than when it was Undivided.

- Signals and section length. Both these variables were selected as being critical about 30 percent of the time. These two variables may be harder to interpret independently. It is possible that the experts looked at the ratio of the two variables to determine the number of signals per mile in making their decision.
- Roadside development. Overall, this factor was selected as being critical in about 60% of cases. When the median type was Residential or Undeveloped, it was identified as being more critical compared to the other two categories.
- Ped-Bike activity. Overall, this factor was selected as being critical in about 64% of the cases. When ped-bike activity was high, this factor was identified as being more critical.
- Parking. Overall, this factor was selected as being critical in about 59% of the cases. When parking was present (one side or two sides), it was selected as being more critical compared to when parking was not present.

Table F.2: Average speed limit, 85th percentile and 50th percentile speeds

Case study / scenarios	85th percentile speed	50th percentile	Av_SL	SD_SL	Max_SL	Min_SL	P_85th	P_50th
01a	31	27	30.23	2.43	35	25	0.91	0.52
01b	34	28	32.50	2.56	35	30	0.91	0.52
01c	38	33	35.00	2.67	40	30	0.87	0.61
01d	42	37	38.50	3.28	45	30	0.92	0.63
02a	38	33	36.04	2.54	40	30	1.00	0.52
02b	38	33	35.63	2.24	40	30	0.96	0.58
02c	38	33	36.09	2.59	40	30	1.00	0.58
03a	34	29	33.10	2.49	35	30	0.95	0.59
03b	34	29	32.62	2.56	35	30	0.91	0.59
03c	34	29	32.62	2.56	35	30	0.95	0.57
03d	34	29	33.57	2.80	40	30	0.95	0.64
03e	34	29	34.00	2.62	40	30	1.00	0.57
03f	34	29	33.95	2.09	35	30	1.00	0.60
03g	34	29	33.95	2.09	35	30	1.00	0.60
04a	31	25	31.05	2.09	35	30	1.00	0.50
04b	31	25	30.00	2.29	35	25	1.00	0.50
04c	31	25	32.11	3.03	40	30	1.00	0.50
05a	32	27	30.50	2.24	35	25	1.00	0.60
05b	32	27	31.00	2.62	35	25	1.00	0.55
05c	32	27	31.00	2.62	35	25	1.00	0.55
06a	42	36	40.00	1.58	45	35	0.90	0.52
06b	42	36	40.00	2.36	45	35	1.00	0.55
06c	42	36	41.50	2.86	45	35	1.00	0.50
07a	37	31	36.25	2.75	40	30	1.00	0.50
07b	37	31	34.50	1.54	35	30	1.00	0.50
07c	37	31	34.00	2.05	35	30	1.00	0.55
08a	32	28	32.25	2.55	35	30	1.00	0.50
08b	35	29	35.25	1.97	40	30	1.00	0.55
08c	39	34	38.95	2.09	40	35	1.00	0.50
08d	43	38	42.22	2.56	45	40	1.00	0.60
08e	48	43	45.28	2.70	50	40	1.00	0.55

Case study / scenarios	85th percentile speed	50th percentile	Av_SL	SD_SL	Max_SL	Min_SL	P_85th	P_50th
09a	34	29	34.00	2.62	40	30	0.95	0.50
09b	34	29	33.50	2.86	35	25	0.85	0.50
09c	34	29	34.50	2.24	40	30	0.95	0.50
10a	38	33	37.00	2.99	40	30	0.95	0.55
10b	38	33	36.43	2.80	40	30	0.95	0.57
10c	38	33	35.24	2.49	40	30	0.95	0.62
10d	38	33	35.00	2.81	40	30	0.95	0.65
10e	38	33	37.38	3.01	40	30	1.00	0.62
10f	38	33	37.50	3.03	40	30	0.95	0.65
10g	38	33	37.50	3.03	40	30	0.95	0.60
11a	32	26	30.00	1.58	35	25	0.95	0.62
11b	32	26	30.25	1.97	35	25	0.95	0.55
11c	32	26	31.25	2.22	35	30	0.95	0.60
12a	39	33	36.67	2.89	40	30	0.95	0.57
12b	39	33	36.75	3.35	40	30	0.95	0.50
12c	39	33	37.75	3.43	45	30	0.95	0.55
13a	36	30	35.53	2.84	45	30	1.00	0.55
13b	36	30	34.00	2.62	40	30	0.90	0.55
13c	36	30	34.75	1.97	40	30	0.95	0.40
14a	40	35	37.22	2.56	40	35	0.95	0.60
14b	40	35	39.72	2.08	45	35	0.95	0.67
14c	40	35	38.06	2.51	40	35	1.00	0.55
15a	51	47	51.90	2.49	55	50	1.00	0.48
15b	48	44	48.81	2.18	50	45	1.00	0.57
15c	46	41	46.50	2.35	50	45	1.00	0.60

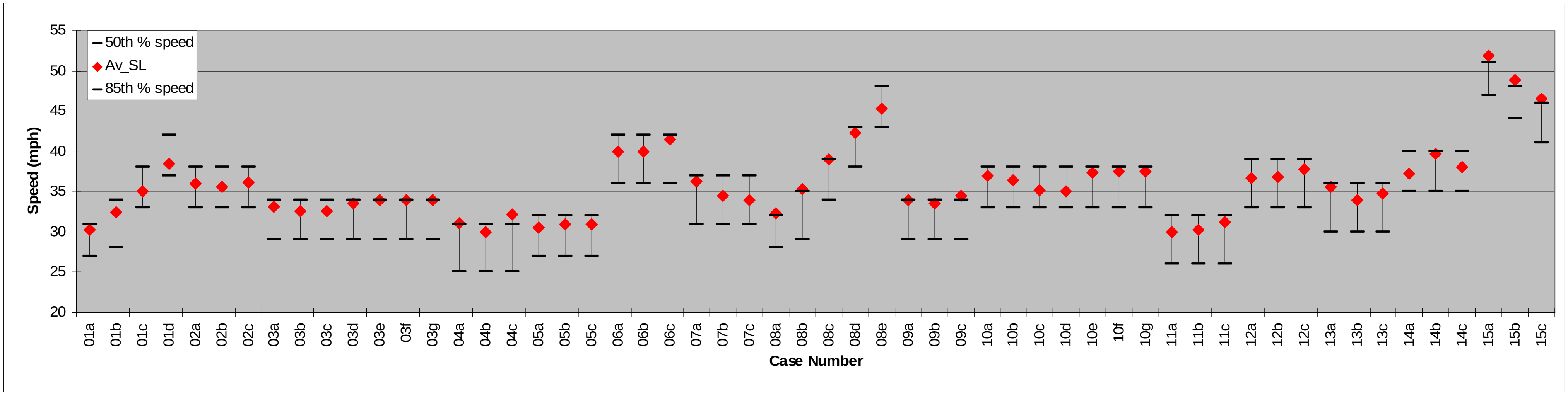


Figure F.1: Average speed limit, 50th percentile speed, and 85th percentile speeds.
The average speed limit is shown as a diamond. The 50th and 80th percentile speeds are shown as horizontal bars.

Hazard_Rating	Proportion of scenarios where hazard rating was selected as being critical	Number of Observations
1	0.495	105
2	0.441	102
3	0.453	234
4	0.456	160
5	0.454	324
6	0.456	136
7	0.520	102

Table F.3A: Hazard Rating

Type of Median	Proportion of scenarios where median type was selected as being critical	Number of Observations
Divided	0.560	405
TWLTL	0.580	370
Undivided	0.470	388

Table F.3B: Median Type

Number of Signals	Proportion of scenarios where the number of signals was selected as being critical	Number of Observations
2	0.420	62
3	0.230	120
4	0.300	60
5	0.270	409
6	0.380	471
9	0.620	21
10	0.600	20

Table F.3C: Signals

Section Length	Proportion of scenarios where the length of the section was selected as being critical	Number of Observations
1	0.230	221
1.1	0.440	61
1.4	0.340	121
1.7	0.120	93
1.9	0.340	61
2	0.320	426
2.2	0.550	20
2.3	0.230	60
3	0.240	80
3.8	0.500	20

Table F.3D: Section Length

Roadside Development	Proportion of scenarios where roadside development was selected as being critical	Number of Observations
Commercial	0.600	468
Large shopping	0.580	408
Residential	0.650	225
Undeveloped	0.660	62

Table F.3E: Development

Ped-Bike Activity	Proportion of scenarios where ped-bike activity was selected as being critical	Number of Observations
High	0.720	453
Low	0.580	335
Medium	0.600	375

Table F.3F: Ped-Bike

Parking	Proportion of scenarios where parking was selected as being critical	Number of Observations
None	0.560	809
One side	0.640	160
Two sides	0.650	194

Table F.3G: Parking

Relationship between Speed Limit and Site Characteristics

A regression model was developed with speed limit as the dependent variable and site characteristics including operating speed as independent variables. Results from two of the models are shown here: one model used the 85th percentile speed along with other site characteristics as independent variables (Table F.4); the other model used the 50th percentile speed along with the other site characteristics as independent variables (Table F.5). The t and p values in the tables indicate whether a particular variable is statistically significant in its relationship with the speed limit provided by the participants. Many of the variables are categorical in nature, and hence represented by dummy variables (coded as 1 or 0). One level within each categorical variable was selected as a reference level (reference levels are assumed to have a coefficient of zero).

Overall, the results from the two models are quite similar. Here is a summary:

- Increase in the 85th percentile or the 50th percentile speeds are associated with higher speed limits.
- Operating speed (85th percentile and 50th percentile speed) was the most important factor that was considered by the participants.
- More signals per mile is associated with lower speed limits, although this factor is only marginally significant (p value is approximately 0.2).
- The positive coefficients in both the models for most of the dummy variables for the hazard levels indicate that compared to Hazard level 7 (the most hazardous roadside hazard condition), hazard levels 1 through 5 were usually assigned higher speed limits by the participants. However, the dummy variable for hazard 3 is lower than for hazard 4 – indicating that hazard 3 is associated with lower speed limits compared to hazard 4. This is probably an anomaly due to the limited sample size of sites that were presented for each hazard level.
- The negative sign for undivided roads indicates that undivided roads are associated with lower speed limits compared to divided roads. The coefficient for TWLTL is not significant, indicating that the participants probably did not treat TWLTL and divided roads in a significantly different way.
- The coefficients for the low and medium ped/bike conditions are positive. This indicates that participants in general assigned higher speed limits for these conditions compared to the high ped/bike condition.
- The coefficient for no-parking is positive. This indicates that compared to parking on two sides, the participants assigned higher speed limits for roads with no parking. The coefficient for parking on one-side is not statistically significant. This indicates that the participants in the survey treated parking on one-side and two-sides in a similar way.

Table F.4: Regression model for speed limit with 85th percentile speed as a covariate

Variable	Coefficient	Std. Error	T value	P value
(Constant)	3.1262	1.1695	2.6732	0.0076
85th percentile speed	0.8419	0.0279	30.2108	<0.0001
Signals per mile	-0.1244	0.0917	-1.3571	0.1750
Hazard 1 (dummy)	1.7365	0.4883	3.5566	0.0004

Hazard 2 (dummy)	1.7839	0.3971	4.4927	<0.0001
Hazard 3 (dummy)	1.2353	0.3529	3.5008	0.0005
Hazard 4 (dummy)	1.6800	0.4173	4.0259	0.0001
Hazard 5 (dummy)	1.0167	0.3515	2.8929	0.0039
Hazard 6 (dummy)	0.4590	0.4036	1.1373	0.2557
Hazard 7 (dummy) (reference level)				
Undivided (dummy)	-0.9425	0.2883	-3.2693	0.0011
TWLTL (dummy)	-0.2865	0.2836	-1.0104	0.3125
Divided (dummy) (reference level)				
Low Ped/Bike (dummy)	0.8941	0.2806	3.1860	0.0015
Medium Ped/Bike (dummy)	0.4701	0.3139	1.4977	0.1345
High Ped/Bike (dummy) (reference level)				
Undeveloped (dummy)	2.0057	0.6566	3.0546	0.0023
Residential (dummy)	-0.0146	0.3649	-0.0401	0.9680
Commercial (dummy)	0.6780	0.3113	2.1781	0.0296
Large shopping (dummy) (reference level)				
No parking (dummy)	0.6372	0.3059	2.0831	0.0375
One-side Parking (dummy)	-0.1074	0.3721	-0.2887	0.7729
Two-side parking (dummy) (reference level)				

R-square = 0.759; Based on 1155 observations

Table F.5: Regression model for speed limit with 50th percentile speed as a covariate

Variable	Coefficient	Std. Error	T value	P value
(Constant)	8.5756	1.0279	8.3429	<0.0001
50th percentile speed	0.8282	0.0280	29.6272	<0.0001
Signals per mile	-0.1117	0.0924	-1.2083	0.2272
Hazard 1 (dummy)	1.2778	0.4912	2.6015	0.0094
Hazard 2 (dummy)	1.5808	0.4008	3.9440	0.0001
Hazard 3 (dummy)	0.5847	0.3517	1.6622	0.0968
Hazard 4 (dummy)	1.3652	0.4189	3.2591	0.0012
Hazard 5 (dummy)	0.5707	0.3520	1.6213	0.1052
Hazard 6 (dummy)	-0.2069	0.4038	-0.5124	0.6085
Hazard 7 (dummy) (reference level)				
Undivided (dummy)	-0.7479	0.2899	-2.5800	0.0100
TWLTL (dummy)	0.0801	0.2873	0.2789	0.7804
Divided (dummy) (reference level)				
Low Ped/Bike (dummy)	1.0367	0.2824	3.6711	0.0003
Medium Ped/Bike (dummy)	0.5958	0.3160	1.8856	0.0596
High Ped/Bike (dummy) (reference level)				
Undeveloped (dummy)	1.5025	0.6706	2.2405	0.0253
Residential (dummy)	0.1563	0.3703	0.4221	0.6730
Commercial (dummy)	0.2728	0.3112	0.8765	0.3809
Large shopping (dummy) (reference level)				
No parking (dummy)	0.2477	0.3102	0.7984	0.4248
One-side Parking (dummy)	-0.2027	0.3755	-0.5399	0.5894
Two-side parking (dummy) (reference level)				

R-square = 0.755; Based on 1155 observations

Difference between rounded-85th percentile speeds and Speed Limit

The previous analysis indicated that the 85th percentile speed was the single most important factor that the participants used in assigning a speed limit for a section. In order to understand the other factors that may influence the speed limit decision, the research team looked at the difference between the rounded-85th percentile speed (the 85th percentile speed was rounded to the nearest 5 mph multiple) and speed limit. Figure F.2 is a histogram that shows the rounded-85th percentile speed minus the speed limit. Positive values indicate that the participants assigned speed limits that were lower than the rounded-85th percentile speed. Negative values indicate that participants assigned speed limits that were higher than the rounded-85th percentile speeds.

In about 61% of the cases, the rounded-85th percentile speed and the speed limit are the same. In about 30% of the cases, the speed limit is 5 mph below the rounded-85th percentile speed. In about 2% of the cases, the speed limit is 10 mph below the rounded-85th percentile speed. In the remaining (about 7%), the speed limit is 5 or 10 mph above the rounded-85th percentile speed.

Table F.6 shows the mean of this difference (along with the minimum, maximum, and standard deviation) for each scenario. If a particular scenario has a higher mean value, then the average speed limit for that scenario was lower than the rounded-85th percentile speed. Looking at groups of scenarios with high positive values, scenarios 1b-1d, 2a-2c, 3a-3c, 8d-8e, 9a-9c, 10a-10g, 12-12c, and 14a-14c, have higher positive values. Further examining the characteristics of these scenarios (Table F.1), many of these scenarios (not all) have either medium or high ped/bike activity.

To study this further, a binary logit model was developed where the dependent variable was coded as 1 if the assigned speed limit was 5 or 10 mph below the rounded-85th percentile value; when the speed limit was equal to or higher than the rounded-85th percentile values, the dependent variable was coded as zero. The independent variables included site characteristics such as hazard rating, median type, development, parking, and ped/bike activity. Overall, some results from the logit model were similar to the results from the linear regression models discussed earlier, e.g.:

- Medium and High ped/bike activities are associated with lower speed limits
- Hazard ratings 1, 2, 4, and 5, are associated with higher speed limits compared to hazard rating 7
- Undeveloped roads are associated with higher speed limits compared to roads with large shopping areas.

Figure F.2: Rounded 85th percentile speed minus the speed limit

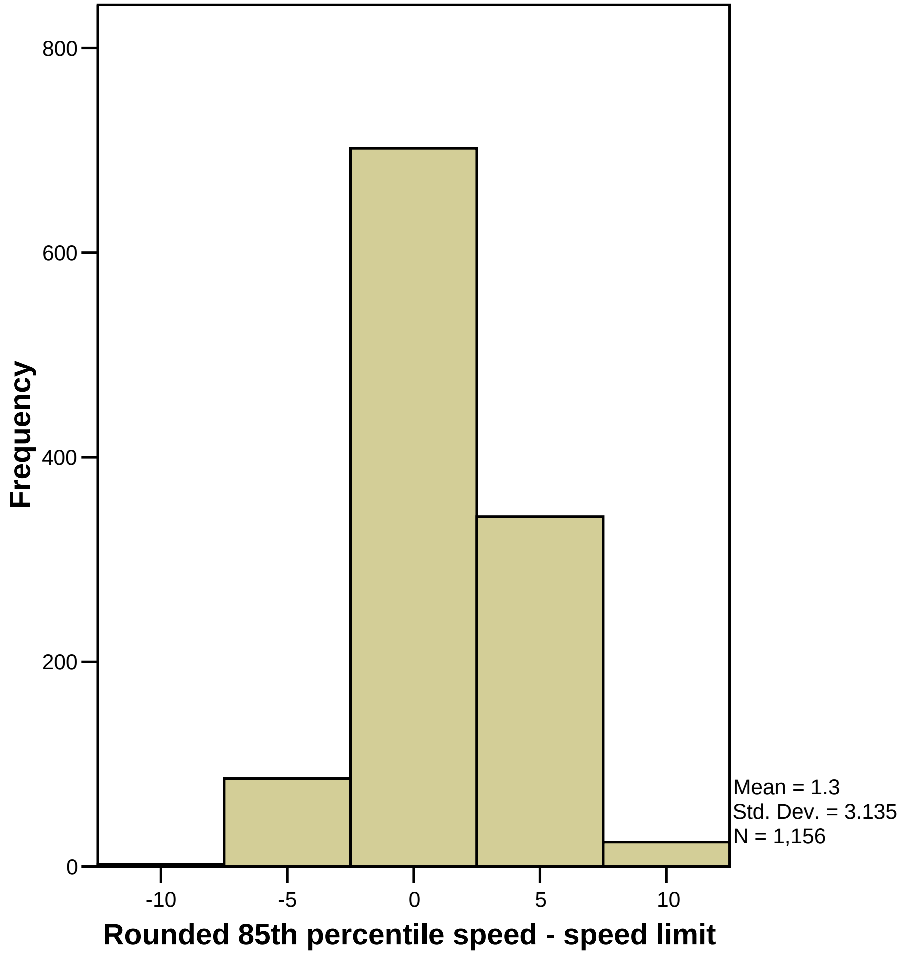


Table F.6: Average of the difference between rounded-85th percentile speed and speed limit

	Rounded 85th percentile speed - speed limit			
	Mean	Minimum	Maximum	Std Deviation
01a	-0.23	-5	5	2.43
01b	2.50	0	5	2.56
01c	5.00	0	10	2.67
01d	1.50	-5	10	3.28
02a	3.86	0	10	2.64
02b	4.35	0	10	2.29
02c	3.86	0	10	2.64
03a	1.90	0	5	2.49
03b	2.38	0	5	2.56
03c	2.50	0	5	2.56
03d	1.43	-5	5	2.80
03e	1.19	-5	5	2.69
03f	1.25	0	5	2.22
03g	1.25	0	5	2.22

04a	-1.00	-5	0	2.05
04b	0.00	-5	5	2.24
04c	-2.00	-10	0	2.99
05a	-0.48	-5	5	2.18
05b	-0.95	-5	5	2.56
05c	-0.95	-5	5	2.56
06a	0.00	-5	5	1.62
06b	0.00	-5	5	2.36
06c	-1.43	-5	5	2.80
07a	-1.25	-5	5	2.75
07b	0.50	0	5	1.54
07c	1.00	0	5	2.05
08a	-2.14	-5	0	2.54
08b	-0.24	-5	5	1.92
08c	1.25	0	5	2.22
08d	2.89	0	5	2.54
08e	4.74	0	10	2.62
09a	1.19	-5	5	2.69
09b	1.67	0	10	2.89
09c	0.71	-5	5	2.39
10a	3.10	0	10	2.95
10b	3.81	0	10	2.69
10c	4.75	0	10	2.55
10d	5.00	0	10	2.81
10e	2.62	0	10	3.01
10f	2.62	0	10	3.01
10g	2.62	0	10	3.01
11a	0.00	-5	5	1.58
11b	-0.24	-5	5	1.92
11c	-1.19	-5	0	2.18
12a	3.25	0	10	2.94
12b	3.25	0	10	3.35
12c	2.25	-5	10	3.43
13a	-0.50	-10	5	2.76
13b	0.95	-5	5	2.56
13c	0.24	-5	5	1.92
14a	2.89	0	5	2.54
14b	0.53	-5	5	2.29
14c	2.11	0	5	2.54
15a	-1.67	-5	0	2.42
15b	1.19	0	5	2.18
15c	-1.43	-5	0	2.31

APPENDIX G:
LIST OF CASE STUDIES FOR THE FINAL ROUND OF WEB-BASED SURVEYS

Table G.1: Two-Lane Undeveloped

Case study / scenarios	85th % speed	50th % speed	Terrain	Hazard Rating	Overall injury	Speed-related injury	Adverse alignment?	Advisory speed (mph)	Length (miles)	Adjacent speed limits (mph)
01a	56	47	Flat	7	average	100% above	No	NA	1.5	55,55
01b	54	48	Flat	7	average	100% above	No	NA	1.5	55,55
01c	58	53	Flat	7	average	100% above	No	NA	1.5	55,55
01d	62	57	Flat	7	average	100% above	No	NA	1.5	55,55
02a	68	62	Flat	5	80% above	50% above	5%	45	3	55,65
02b	68	62	Rolling	5	80% above	50% above	5%	45	3	55,65
02c	68	62	Mountain	5	80% above	50% above	5%	45	3	55,65
03a	44	39	Mountain	5	25% above	45% above	10%	30	2.4	45,50
03b	44	39	Mountain	7	25% above	45% above	10%	30	2.4	45,50
03c	44	39	Mountain	2	25% above	45% above	10%	30	2.4	45,50
03d	44	39	Mountain	3	25% above	45% above	10%	30	2.4	45,50
04a	47	41	Mountain	1	average	60% above	20%	25	2.2	40,50
04b	47	41	Mountain	1	15% above	60% above	20%	25	2.2	40,50
04c	47	41	Mountain	1	35% above	60% above	20%	25	2.2	40,50
04d	47	41	Mountain	1	65% above	60% above	20%	25	2.2	40,50

04e	47	41	Mountain	1	90% above	60% above	20%	25	2.2	40,50
05a	50	45	Mountain	6	30% above	average	No	NA	3.8	40,45
05b	50	45	Mountain	6	30% above	20% above	No	NA	3.8	40,45
05c	50	45	Mountain	6	30% above	50% above	No	NA	3.8	40,45
05d	50	45	Mountain	6	30% above	75% above	No	NA	3.8	40,45
05e	50	45	Mountain	6	30% above	100% above	No	NA	3.8	40,45
06a	57	53	Rolling	2	85% above	65% above	15%	30	2	50,50
06b	57	53	Rolling	2	85% above	65% above	40%	30	2	50,50
06c	57	53	Rolling	2	85% above	65% above	60%	30	2	50,50
07a	55	51	Mountain	4	average	average	40%	25	3	45,55
07b	55	51	Mountain	4	average	average	40%	30	3	45,55
07c	55	51	Mountain	4	average	average	40%	35	3	45,55
08a	65	60	Flat	1	average	95% above	No	NA	0.8	65,65
08b	65	60	Flat	1	average	95% above	No	NA	2	65,65
08c	65	60	Flat	1	average	95% above	No	NA	3	65,65
08d	65	60	Flat	1	average	95% above	No	NA	4	65,65
09a	61	56	Flat	7	20% above	average	No	NA	1.6	50,55
09b	61	56	Flat	7	20% above	average	No	NA	1.6	45,50
09c	61	56	Flat	7	20% above	average	No	NA	1.6	45,60

09d	61	56	Flat	7	20% above	average	No	NA	1.6	55,65
10a	47	43	Rolling	5	35% above	15% above	25%	40	3.1	55,60
10b	50	44	Rolling	5	35% above	15% above	25%	40	3.1	55,60
10c	54	49	Rolling	5	35% above	15% above	25%	40	3.1	55,60
10d	58	53	Rolling	5	35% above	15% above	25%	40	3.1	55,60
10e	63	58	Rolling	5	35% above	15% above	25%	40	3.1	55,60
11a	48	43	Rolling	4	90% above	25% above	No	NA	3.7	50,50
11b	48	43	Rolling	5	90% above	25% above	No	NA	3.7	50,50
11c	48	43	Rolling	6	90% above	25% above	No	NA	3.7	50,50
11d	48	43	Rolling	1	90% above	25% above	No	NA	3.7	50,50
12a	55	50	Flat	3	average	average	No	NA	3.4	60,60
12b	55	50	Flat	3	5% above	average	No	NA	3.4	60,60
12c	55	50	Flat	3	45% above	average	No	NA	3.4	60,60
12d	55	50	Flat	3	70% above	average	No	NA	3.4	60,60
12e	55	50	Flat	3	100% above	average	No	NA	3.4	60,60
13a	48	43	Rolling	5	70% above	average	50%	30	0.8	45,55
13b	48	43	Rolling	5	70% above	10% above	50%	30	0.8	45,55
13c	48	43	Rolling	5	70% above	40% above	50%	30	0.8	45,55

13d	48	43	Rolling	5	70% above	70% above	50%	30	0.8	45,55
13e	48	43	Rolling	5	70% above	95% above	50%	30	0.8	45,55
14a	48	42	Rolling	4	average	85% above	5%	35	3	45,45
14b	48	42	Rolling	4	average	85% above	45%	35	3	45,45
14c	48	42	Rolling	4	average	85% above	70%	35	3	45,45
15a	49	44	Rolling	5	100% above	average	70%	25	2	50,55
15b	49	44	Rolling	5	100% above	average	70%	30	2	50,55
15c	49	44	Rolling	5	100% above	average	70%	35	2	50,55
16a	67	62	Flat	5	60% above	35% above	No	NA	2.8	45,50
16b	67	62	Flat	5	60% above	35% above	No	NA	2.8	65,70
16c	67	62	Flat	5	60% above	35% above	No	NA	2.8	50,60
16d	67	62	Flat	5	60% above	35% above	No	NA	2.8	55,55
17a	60	56	Rolling	3	10% above	5% above	No	NA	1.5	50,50
17b	60	56	Rolling	3	10% above	5% above	No	NA	2.5	50,50
17c	60	56	Rolling	3	10% above	5% above	No	NA	3.5	50,50
17d	60	56	Rolling	3	10% above	5% above	No	NA	5	50,50
18a	63	57	Rolling	6	55% above	80% above	65%	45	4	60,70
18b	63	57	Flat	6	55% above	80% above	65%	45	4	60,70

18c	63	57	Mountain	6	55% above	80% above	65%	45	4	60,70

Table G.2: Multilane Undeveloped

Case study / scenarios	85th % speed	50th % speed	Terrain	Hazard Rating	Overall injury	Speed-related injury	Adverse alignment?	Advisory speed (mph)	Length (miles)	Adjacent speed limits (mph)	Median
01a	56	47	Flat	6	average	80% above	No	NA	1.5	55,55	Undivided
01b	54	48	Flat	6	average	80% above	No	NA	1.5	55,55	Undivided
01c	58	53	Flat	6	average	80% above	No	NA	1.5	55,55	Undivided
01d	62	57	Flat	6	average	80% above	No	NA	1.5	55,55	Undivided
02a	63	57	Flat	7	55% above	85% above	No	NA	4	60,70	Divided
02b	63	57	Rolling	7	55% above	85% above	No	NA	4	60,70	Divided
02c	63	57	Mountain	7	55% above	85% above	No	NA	4	60,70	Divided
03a	44	39	Rolling	5	50% above	30% above	15%	35	2.4	45,50	TWLTL
03b	44	39	Rolling	7	50% above	30% above	15%	35	2.4	45,50	TWLTL
03c	44	39	Rolling	1	50% above	30% above	15%	35	2.4	45,50	TWLTL
03d	44	39	Rolling	4	50% above	30% above	15%	35	2.4	45,50	TWLTL
04a	47	41	Rolling	1	average	75% above	No	NA	2.2	40,50	Undivided
04b	47	41	Rolling	1	20% above	75% above	No	NA	2.2	40,50	Undivided
04c	47	41	Rolling	1	45% above	75% above	No	NA	2.2	40,50	Undivided
04d	47	41	Rolling	1	70% above	75% above	No	NA	2.2	40,50	Undivided

04e	47	41	Rolling	1	100% above	75% above	No	NA	2.2	40,50	Undivided
05a	50	45	Mountain	6	45% above	average	5%	35	3.8	40,45	TWLTL
05b	50	45	Mountain	6	45% above	15% above	5%	35	3.8	40,45	TWLTL
05c	50	45	Mountain	6	45% above	35% above	5%	35	3.8	40,45	TWLTL
05d	50	45	Mountain	6	45% above	65% above	5%	35	3.8	40,45	TWLTL
05e	50	45	Mountain	6	45% above	100% above	5%	35	3.8	40,45	TWLTL
06a	57	53	Rolling	2	100% above	65% above	10%	40	2	50,50	Divided
06b	57	53	Rolling	2	100% above	65% above	40%	40	2	50,50	Divided
06c	57	53	Rolling	2	100% above	65% above	60%	40	2	50,50	Divided
07a	56	50	Mountain	7	60% above	5% above	35%	30	2.5	40,45	Undivided
07b	56	50	Mountain	7	60% above	5% above	35%	35	2.5	40,45	Undivided
07c	56	50	Mountain	7	60% above	5% above	35%	40	2.5	40,45	Undivided
08a	65	60	Flat	1	average	90% above	No	NA	0.8	65,65	TWLTL
08b	65	60	Flat	1	average	90% above	No	NA	2	65,65	TWLTL
08c	65	60	Flat	1	average	90% above	No	NA	3	65,65	TWLTL
08d	65	60	Flat	1	average	90% above	No	NA	4	65,65	TWLTL
09a	61	56	Flat	6	5% above	average	No	NA	1.6	55,60	Undivided
09b	61	56	Flat	6	5% above	average	No	NA	1.6	50,55	Undivided

09c	61	56	Flat	6	5% above	average	No	NA	1.6	50,65	Undivided
09d	61	56	Flat	6	5% above	average	No	NA	1.6	60,70	Undivided
10a	46	43	Mountain	3	65% above	25% above	20%	35	5	40,40	Divided
10b	46	43	Mountain	3	65% above	25% above	20%	35	5	40,40	Undivided
10c	46	43	Mountain	3	65% above	25% above	20%	35	5	40,40	TWLTL
11a	47	43	Rolling	5	40% above	55% above	10%	40	3.1	55,60	Divided
11b	50	44	Rolling	5	40% above	55% above	40%	40	3.1	55,60	Divided
11c	54	49	Rolling	5	40% above	55% above	40%	40	3.1	55,60	Divided
11d	58	53	Rolling	5	40% above	55% above	40%	40	3.1	55,60	Divided
11e	63	58	Rolling	5	40% above	55% above	40%	40	3.1	55,60	Divided
12a	48	43	Mountain	3	95% above	15% above	No	NA	3.7	50,50	TWLTL
12b	48	43	Mountain	5	95% above	15% above	No	NA	3.7	50,50	TWLTL
12c	48	43	Mountain	6	95% above	15% above	No	NA	3.7	50,50	TWLTL
12d	48	43	Mountain	2	95% above	15% above	No	NA	3.7	50,50	TWLTL
13a	55	50	Flat	4	average	average	No	NA	3.4	60,60	Divided
13b	55	50	Flat	4	10% above	average	No	NA	3.4	60,60	Divided
13c	55	50	Flat	4	40% above	average	No	NA	3.4	60,60	Divided
13d	55	50	Flat	4	65% above	average	No	NA	3.4	60,60	Divided

13e	55	50	Flat	4	90% above	average	No	NA	3.4	60,60	Divided
14a	48	43	Rolling	5	70% above	average	30%	25	0.8	45,55	TWLTL
14b	48	43	Rolling	5	70% above	25% above	30%	25	0.8	45,55	TWLTL
14c	48	43	Rolling	5	70% above	50% above	30%	25	0.8	45,55	TWLTL
14d	48	43	Rolling	5	70% above	75% above	30%	25	0.8	45,55	TWLTL
14e	48	43	Rolling	5	70% above	100% above	30%	25	0.8	45,55	TWLTL
15a	48	42	Mountain	3	average	100% above	15%	35	3	45,45	Undivided
15b	48	42	Mountain	3	average	100% above	45%	35	3	45,45	Undivided
15c	48	42	Mountain	3	average	100% above	65%	35	3	45,45	Undivided
16a	47	40	Rolling	2	15% above	40% above	70%	25	3.5	45,55	TWLTL
16b	47	40	Rolling	2	15% above	40% above	70%	30	3.5	45,55	TWLTL
16c	47	40	Rolling	2	15% above	40% above	70%	35	3.5	45,55	TWLTL
17a	67	62	Flat	5	35% above	50% above	No	NA	2.8	55,65	Divided
17b	67	62	Flat	5	35% above	50% above	No	NA	2.8	55,65	Divided
17c	67	62	Flat	5	35% above	50% above	No	NA	2.8	55,65	Divided
17d	67	62	Flat	5	35% above	50% above	No	NA	2.8	55,65	Divided
18a	68	62	Flat	5	80% above	45% above	No	NA	3	55,65	Undivided
18b	68	62	Rolling	5	80% above	45% above	No	NA	3	55,65	Undivided

18c	68	62	Mountain	5	80% above	45% above	No	NA	3	55,65	Undivided
19a	60	56	Rolling	4	25% above	10% above	35%	45	1.5	50,50	Divided
19b	60	56	Rolling	4	25% above	10% above	35%	45	2.5	50,50	Divided
19c	60	56	Rolling	4	25% above	10% above	35%	45	3.5	50,50	Divided
19d	60	56	Rolling	4	25% above	10% above	35%	45	5	50,50	Divided
20a	62	56	Flat	3	average	95% above	No	NA	2.8	55,55	TWLTL
20b	62	56	Flat	3	average	95% above	No	NA	2.8	55,55	Undivided
20c	62	56	Flat	3	average	95% above	No	NA	2.8	55,55	Divided

Table G.3: Two-Lane Developed

Case study / scenarios	85th % speed	50th % speed	Hazard Rating	Development	Ped/Bike	Parking?	Overall injury	Speed-related injury	Length (miles)	Signals per mile	Adjacent speed limits (mph)	Through vs. Local
01a	31	27	6	Commercial	High	Yes	average	75% above	1.5	1.3	25, 30	Through
01b	34	28	6	Commercial	High	Yes	average	75% above	1.5	1.3	25, 30	Through
01c	38	33	6	Commercial	High	Yes	average	75% above	1.5	1.3	25, 30	Through
01d	42	37	6	Commercial	High	Yes	average	75% above	1.5	1.3	25, 30	Through
02a	38	33	1	Residential	Low	No	25% above	55% above	2	1.5	35, 45	Local
02b	38	33	1	Commercial	Low	No	25% above	55% above	2	1.5	35, 45	Local
02c	38	33	1	Large complexes	Low	No	25% above	55% above	2	1.5	35, 45	Local
03a	36	31	3	Commercial	High	No	30% above	30% above	2.4	2.5	30, 40	Local
03b	36	31	6	Commercial	High	No	30% above	30% above	2.4	2.5	30, 40	Local
03c	36	31	1	Commercial	High	No	30% above	30% above	2.4	2.5	30, 40	Local
03d	36	31	5	Commercial	High	No	30% above	30% above	2.4	2.5	30, 40	Local
04a	42	36	2	Large complexes	High	No	average	average	2.2	1.4	40, 40	Through
04b	42	36	2	Large complexes	Low	No	average	average	2.2	1.4	40, 40	Through
05a	37	31	5	Residential	Low	No	20% above	50% above	2.6	1.5	35, 35	Local
05b	37	31	5	Residential	Low	Yes	20% above	50% above	2.6	1.5	35, 35	Local

06a	32	26	1	Residential	Low	Yes	average	60% above	2.2	4.1	30. 35	Local
06b	32	26	1	Residential	Low	Yes	20% above	60% above	2.2	4.1	30, 35	Local
06c	32	26	1	Residential	Low	Yes	40% above	60% above	2.2	4.1	30. 35	Local
06d	32	26	1	Residential	Low	Yes	70% above	60% above	2.2	4.1	30, 35	Local
06e	32	26	1	Residential	Low	Yes	100% above	60% above	2.2	4.1	30, 35	Local
07a	33	28	7	Commercial	High	Yes	15% above	average	3.8	1.3	35, 40	Local
07b	33	28	7	Commercial	High	Yes	15% above	15% above	3.8	1.3	35, 40	Local
07c	33	28	7	Commercial	High	Yes	15% above	45% above	3.8	1.3	35, 40	Local
07d	33	28	7	Commercial	High	Yes	15% above	80% above	3.8	1.3	35, 40	Local
07e	33	28	7	Commercial	High	Yes	15% above	100% above	3.8	1.3	35, 40	Local
08a	35	31	2	Large complexes	High	Yes	75% above	65% above	1	3.0	45, 45	Local
08b	35	31	2	Large complexes	High	Yes	75% above	65% above	2	3.0	45, 45	Local
08c	35	31	2	Large complexes	High	Yes	75% above	65% above	3	3.0	45, 45	Local
08d	35	31	2	Large complexes	High	Yes	75% above	65% above	4	3.0	45, 45	Local
09a	41	37	3	Residential	High	Yes	average	85% above	2	1.0	35,45	Through
09b	41	37	3	Residential	High	Yes	average	85% above	2	2.5	35,45	Through
09c	41	37	3	Residential	High	Yes	average	85% above	2	3.5	35,45	Through
09d	41	37	3	Residential	High	Yes	average	85% above	2	5.0	35,45	Through

10a	40	35	6	Residential	Low	No	10% above	average	1.6	3.1	25, 30	Local
10b	40	35	6	Residential	Low	No	10% above	average	1.6	3.1	30, 35	Local
10c	40	35	6	Residential	Low	No	10% above	average	1.6	3.1	35, 40	Local
10d	40	35	6	Residential	Low	No	10% above	average	1.6	3.1	40, 45	Local
11a	43	39	5	Residential	Low	Yes	55% above	15% above	0.5	4.0	40, 50	Through
11b	43	39	5	Residential	Low	Yes	55% above	15% above	0.5	4.0	40, 50	Local
12a	32	28	4	Large complexes	Low	No	35% above	70% above	3.1	1.6	40, 50	Through
12b	35	29	4	Large complexes	Low	No	35% above	70% above	3.1	1.6	40, 50	Through
12c	39	34	4	Large complexes	Low	No	35% above	70% above	3.1	1.6	40, 50	Through
12d	43	38	4	Large complexes	Low	No	35% above	70% above	3.1	1.6	40, 50	Through
12e	48	43	4	Large complexes	Low	No	35% above	70% above	3.1	1.6	40, 50	Through
13a	34	29	3	Commercial	Low	No	65% above	100% above	4	2.8	35, 35	Local
13b	34	29	3	Residential	Low	No	65% above	100% above	4	2.8	35, 35	Local
13c	34	29	3	Large complexes	Low	No	65% above	100% above	4	2.8	35, 35	Local
14a	38	33	4	Residential	High	No	85% above	25% above	3.7	1.6	40, 40	Through
14b	38	33	5	Residential	High	No	85% above	25% above	3.7	1.6	40, 40	Through
14c	38	33	7	Residential	High	No	85% above	25% above	3.7	1.6	40, 40	Through
14d	38	33	2	Residential	High	No	85% above	25% above	3.7	1.6	40, 40	Through

15a	36	30	4	Large complexes	Low	Yes	40% above	5% above	0.7	4.3	35, 40	Local
15b	36	30	4	Large complexes	High	Yes	40% above	5% above	0.7	4.3	35, 40	Local
16a	39	34	5	Commercial	High	No	90% above	45% above	1.9	2.1	35, 40	Through
16b	39	34	5	Commercial	High	Yes	90% above	45% above	1.9	2.1	35, 40	Through
17a	45	39	3	Large complexes	Low	No	average	average	3.4	2.9	25, 35	Through
17b	45	39	3	Large complexes	Low	No	10% above	average	3.4	2.9	25, 35	Through
17c	45	39	3	Large complexes	Low	No	50% above	average	3.4	2.9	25, 35	Through
17d	45	39	3	Large complexes	Low	No	75% above	average	3.4	2.9	25, 35	Through
17e	45	39	3	Large complexes	Low	No	100% above	average	3.4	2.9	25, 35	Through
18a	36	31	5	Commercial	High	No	70% above	average	1.2	3.3	30, 40	Through
18b	36	31	5	Commercial	High	No	70% above	25% above	1.2	3.3	30, 40	Through
18c	36	31	5	Commercial	High	No	70% above	45% above	1.2	3.3	30, 40	Through
18d	36	31	5	Commercial	High	No	70% above	90% above	1.2	3.3	30, 40	Through
18e	36	31	5	Commercial	High	No	70% above	100% above	1.2	3.3	30, 40	Through
19a	41	34	7	Residential	Low	No	average	90% above	0.5	2.0	40, 45	Through
19b	41	34	7	Residential	Low	No	average	90% above	1.5	2.0	40, 45	Through
19c	41	34	7	Residential	Low	No	average	90% above	2.5	2.0	40, 45	Through
19d	41	34	7	Residential	Low	No	average	90% above	3.5	2.0	40, 45	Through

20a	42	37	5	Commercial	High	No	50% above	40% above	2.8	2.1	20, 30	Through
20b	42	37	5	Commercial	High	No	50% above	40% above	2.8	2.1	30, 40	Through
20c	42	37	5	Commercial	High	No	50% above	40% above	2.8	2.1	40, 45	Through
20d	42	37	5	Commercial	High	No	50% above	40% above	2.8	2.1	45, 50	Through
21a	40	33	1	Large complexes	Low	Yes	100% above	20% above	1.5	1.3	45, 45	Through
21b	40	33	1	Large complexes	Low	Yes	100% above	20% above	1.5	1.3	45, 45	Local
22a	39	33	1	Commercial	Low	No	5% above	average	3	0.7	40,45	Local
22b	39	33	2	Commercial	Low	No	5% above	average	3	2.0	40,45	Local
22c	39	33	2	Commercial	Low	No	5% above	average	3	3.0	40,45	Local
22d	39	33	2	Commercial	Low	No	5% above	average	3	3.7	40,45	Local

Table G.4: Multilane Developed

Case study / scenarios	85th % speed	50th % speed	Hazard Rating	Development	Ped/Bike	Parking?	Overall injury	Speed-related injury	Length (miles)	Signals per mile	Adjacent speed limits (mph)	Through vs. Local	Median
01a	31	27	7	Commercial	Low	Yes	average	100% above	1.5	2.0	25, 30	Through	Undivided
01b	34	28	7	Commercial	Low	Yes	average	100% above	1.5	2.0	25, 30	Through	Undivided
01c	38	33	7	Commercial	Low	Yes	average	100% above	1.5	2.0	25, 30	Through	Undivided
01d	42	37	7	Commercial	Low	Yes	average	100% above	1.5	2.0	25, 30	Through	Undivided
02a	38	33	1	Commercial	Low	No	5% above	55% above	2	2.0	35, 45	Local	Undivided
02b	38	33	1	Residential	Low	No	5% above	55% above	2	2.0	35, 45	Local	Undivided
02c	38	33	1	Large complexes	Low	No	5% above	55% above	2	2.0	35, 45	Local	Undivided
03a	34	29	5	Commercial	High	No	50% above	50% above	2.4	2.1	30, 40	Local	TWLTL
03b	34	29	7	Commercial	High	No	50% above	50% above	2.4	2.1	30, 40	Local	TWLTL
03c	34	29	2	Commercial	High	No	50% above	50% above	2.4	2.1	30, 40	Local	TWLTL
03d	34	29	4	Commercial	High	No	50% above	50% above	2.4	2.1	30, 40	Local	TWLTL
04a	36	31	4	Residential	High	No	60% above	10% above	5	1.8	25, 25	Through	Divided
04b	36	31	4	Residential	High	No	60% above	10% above	5	1.8	25, 25	Through	Undivided
04c	36	31	4	Residential	High	No	60% above	10% above	5	1.8	25, 25	Through	TWLTL
05a	42	36	2	Large complexes	High	No	average	average	2.2	2.7	40, 40	Through	TWLTL

05b	42	36	2	Large complexes	Low	No	average	average	2.2	2.7	40, 40	Through	TWLTL
06a	37	31	5	Large complexes	Low	No	15% above	45% above	2.6	3.1	35, 35	Local	Undivided
06b	37	31	5	Large complexes	Low	Yes	15% above	45% above	2.6	3.1	35, 35	Local	Undivided
07a	32	26	1	Residential	Low	Yes	average	60% above	2.2	4.5	30. 35	Local	Undivided
07b	32	26	1	Residential	Low	Yes	20% above	60% above	2.2	4.5	30, 35	Local	Undivided
07c	32	26	1	Residential	Low	Yes	35% above	60% above	2.2	4.5	30. 35	Local	Undivided
07d	32	26	1	Residential	Low	Yes	65% above	60% above	2.2	4.5	30, 35	Local	Undivided
07e	32	26	1	Residential	Low	Yes	90% above	60% above	2.2	4.5	30, 35	Local	Undivided
08a	35	30	6	Large complexes	High	Yes	10% above	average	3.8	3.2	35, 40	Local	TWLTL
08b	35	30	6	Large complexes	High	Yes	10% above	15% above	3.8	3.2	35, 40	Local	TWLTL
08c	35	30	6	Large complexes	High	Yes	10% above	35% above	3.8	3.2	35, 40	Local	TWLTL
08d	35	30	6	Large complexes	High	Yes	10% above	70% above	3.8	3.2	35, 40	Local	TWLTL
08e	35	30	6	Large complexes	High	Yes	10% above	95% above	3.8	3.2	35, 40	Local	TWLTL
09a	42	38	2	Commercial	High	Yes	80% above	65% above	1	2.5	45, 45	Local	Divided
09b	42	38	2	Commercial	High	Yes	80% above	65% above	2	2.5	45, 45	Local	Divided
09c	42	38	2	Commercial	High	Yes	80% above	65% above	3	2.5	45, 45	Local	Divided
09d	42	38	2	Commercial	High	Yes	80% above	65% above	4	2.5	45, 45	Local	Divided
10a	41	37	3	Residential	High	Yes	average	90% above	2	1.0	35,45	Through	Undivided

10b	41	37	3	Residential	High	Yes	average	90% above	2	2.5	35,45	Through	Undivided
10c	41	37	3	Residential	High	Yes	average	90% above	2	3.5	35,45	Through	Undivided
10d	41	37	3	Residential	High	Yes	average	90% above	2	5.0	35,45	Through	Undivided
11a	40	35	7	Residential	Low	No	20% above	average	1.6	2.5	25, 30	Local	Undivided
11b	40	35	7	Residential	Low	No	20% above	average	1.6	2.5	30, 35	Local	Undivided
11c	40	35	7	Residential	Low	No	20% above	average	1.6	2.5	35, 40	Local	Undivided
11d	40	35	7	Residential	Low	No	20% above	average	1.6	2.5	40, 45	Local	Undivided
12a	43	39	5	Large complexes	Low	Yes	65% above	15% above	0.5	4.0	40, 50	Through	TWLTL
12b	43	39	5	Large complexes	Low	Yes	65% above	15% above	0.5	4.0	40, 50	Local	TWLTL
13a	32	28	5	Large complexes	Low	No	45% above	70% above	3.1	2.9	40, 50	Through	Divided
13b	35	29	5	Large complexes	Low	No	45% above	70% above	3.1	2.9	40, 50	Through	Divided
13c	39	34	5	Large complexes	Low	No	45% above	70% above	3.1	2.9	40, 50	Through	Divided
13d	43	38	5	Large complexes	Low	No	45% above	70% above	3.1	2.9	40, 50	Through	Divided
13e	48	43	5	Large complexes	Low	No	45% above	70% above	3.1	2.9	40, 50	Through	Divided
14a	34	29	4	Commercial	Low	No	70% above	80% above	4	2.8	35, 35	Local	TWLTL
14b	34	29	4	Residential	Low	No	70% above	80% above	4	2.8	35, 35	Local	TWLTL
14c	34	29	4	Large complexes	Low	No	70% above	80% above	4	2.8	35, 35	Local	TWLTL
15a	38	33	3	Large complexes	High	No	90% above	20% above	3.7	2.4	40, 40	Through	Divided

15b	38	33	5	Large complexes	High	No	90% above	20% above	3.7	2.4	40, 40	Through	Divided
15c	38	33	6	Large complexes	High	No	90% above	20% above	3.7	2.4	40, 40	Through	Divided
15d	38	33	1	Large complexes	High	No	90% above	20% above	3.7	2.4	40, 40	Through	Divided
16a	32	26	3	Residential	High	Yes	average	85% above	2.8	3.6	35, 40	Local	Divided
16b	32	26	3	Residential	High	Yes	average	85% above	2.8	3.6	35, 40	Local	TWLTL
16c	32	26	3	Residential	High	Yes	average	85% above	2.8	3.6	35, 40	Local	Undivided
17a	36	30	4	Residential	Low	Yes	40% above	25% above	0.7	5.7	35, 40	Local	Undivided
17b	36	30	4	Residential	High	Yes	40% above	25% above	0.7	5.7	35, 40	Local	Undivided
18a	40	35	5	Commercial	High	No	100% above	40% above	1.9	2.6	35, 40	Through	Undivided
18b	40	35	5	Commercial	High	Yes	100% above	40% above	1.9	2.6	35, 40	Through	Undivided
19a	33	26	3	Commercial	Low	No	average	average	3.4	3.2	25, 35	Through	Divided
19b	33	26	3	Commercial	Low	No	25% above	average	3.4	3.2	25, 35	Through	Divided
19c	33	26	3	Commercial	Low	No	50% above	average	3.4	3.2	25, 35	Through	Divided
19d	33	26	3	Commercial	Low	No	75% above	average	3.4	3.2	25, 35	Through	Divided
19e	33	26	3	Commercial	Low	No	100% above	average	3.4	3.2	25, 35	Through	Divided
20a	36	31	5	Large complexes	High	No	75% above	average	1.2	5.0	30, 40	Through	TWLTL
20b	36	31	5	Large complexes	High	No	75% above	25% above	1.2	5.0	30, 40	Through	TWLTL
20c	36	31	5	Large complexes	High	No	75% above	50% above	1.2	5.0	30, 40	Through	TWLTL

20d	36	31	5	Large complexes	High	No	75% above	75% above	1.2	5.0	30, 40	Through	TWLTL
20e	36	31	5	Large complexes	High	No	75% above	100% above	1.2	5.0	30, 40	Through	TWLTL
21a	43	37	6	Residential	Low	No	average	95% above	0.5	2.0	40, 45	Through	Undivided
21b	43	37	6	Residential	Low	No	average	95% above	1.5	2.0	40, 45	Through	Undivided
21c	43	37	6	Residential	Low	No	average	95% above	2.5	2.0	40, 45	Through	Undivided
21d	43	37	6	Residential	Low	No	average	95% above	3.5	2.0	40, 45	Through	Undivided
22a	42	37	5	Commercial	High	No	35% above	35% above	2.8	1.8	20, 30	Through	Divided
22b	42	37	5	Commercial	High	No	35% above	35% above	2.8	1.8	30, 40	Through	Divided
22c	42	37	5	Commercial	High	No	35% above	35% above	2.8	1.8	40, 45	Through	Divided
22d	42	37	5	Commercial	High	No	35% above	35% above	2.8	1.8	45, 50	Through	Divided
23a	45	38	1	Residential	Low	Yes	75% above	30% above	1.5	1.3	45, 45	Through	Divided
23b	45	38	1	Residential	Low	Yes	75% above	30% above	1.5	1.3	45, 45	Local	Divided
24a	39	33	2	Commercial	Low	No	25% above	average	3	0.7	40,45	Local	TWLTL
24b	39	33	2	Commercial	Low	No	25% above	average	3	2.0	40,45	Local	TWLTL
24c	39	33	2	Commercial	Low	No	25% above	average	3	3.0	40,45	Local	TWLTL
24d	39	33	2	Commercial	Low	No	25% above	average	3	3.7	40,45	Local	TWLTL

Table G.5: Freeway

Case Studies / Scenarios	85th percentile	Median speed	Terrain	Overall injury	Speed-related injury	Hazard Rating	Interchanges per Mile	Length (miles)	Adjacent speed limits (mph)
01a	57	52	Rolling	55% above	average	4	0.6	5	65,65
01b	66	60	Rolling	55% above	average	4	0.6	5	65,65
01c	69	61	Rolling	55% above	average	4	0.6	5	65,65
01d	73	68	Rolling	55% above	average	4	0.6	5	65,65
01e	78	71	Rolling	55% above	average	4	0.6	5	65,65
01f	81	73	Rolling	55% above	average	4	0.6	5	65,65
02a	68	62	Flat	70% above	average	1	1.7	3.0	60,65
02b	68	62	Rolling	70% above	average	1	1.7	3.0	60,65
02c	68	62	Mountain	70% above	average	1	1.7	3.0	60,65
03a	66	63	Mountain	average	70% above	2	0.7	3	60,70
03b	66	63	Mountain	25% above	70% above	2	0.7	3	60,70
03c	66	63	Mountain	50% above	70% above	2	0.7	3	60,70
03d	66	63	Mountain	75% above	70% above	2	0.7	3	60,70
03e	66	63	Mountain	100% above	70% above	2	0.7	3	60,70
04a	56	49	Mountain	10% above	average	4	1.0	1.0	50,55

04b	56	49	Mountain	10% above	25% above	4	1.0	1.0	50,55
04c	56	49	Mountain	10% above	50% above	4	1.0	1.0	50,55
04d	56	49	Mountain	10% above	75% above	4	1.0	1.0	50,55
04e	56	49	Mountain	10% above	100% above	4	1.0	1.0	50,55
05a	69	63	Flat	20% above	30% above	1	1.3	4	65,65
05b	69	63	Flat	20% above	30% above	2	1.3	4	65,65
05c	69	63	Flat	20% above	30% above	3	1.3	4	65,65
05d	69	63	Flat	20% above	30% above	4	1.3	4	65,65
06a	57	53	Mountain	average	80% above	1	0.5	2	50,55
06b	57	53	Mountain	average	80% above	1	1.5	2	50,55
06c	57	53	Mountain	average	80% above	1	2.5	2	50,55
07a	71	64	Flat	average	40% above	1	1.5	1.5	65,70
07b	71	64	Flat	average	40% above	1	1.5	3	65,70
07c	71	64	Flat	average	40% above	1	1.5	4.5	65,70
07d	71	64	Flat	average	40% above	1	1.5	6	65,70
08a	73	65	Flat	45% above	20% above	3	2.3	3.5	50,55
08b	73	65	Flat	45% above	20% above	3	2.3	3.5	55,60
08c	73	65	Flat	45% above	20% above	3	2.3	3.5	50,60

08d	73	65	Flat	45% above	20% above	3	2.3	3.5	55,65
09a	54	50	Rolling	average	60% above	4	2.2	1.8	60,65
09b	58	52	Rolling	average	60% above	4	2.2	1.8	55,60
09c	61	56	Rolling	average	60% above	4	2.2	1.8	55,60
09d	66	60	Rolling	average	60% above	4	2.2	1.8	55,60
09e	70	63	Rolling	average	60% above	4	2.2	1.8	55,60
09f	76	72	Rolling	average	60% above	4	2.2	1.8	55,60
10a	63	58	Flat	80% above	35% above	2	2.4	5.0	55,70
10b	63	58	Rolling	80% above	35% above	2	2.4	5.0	55,70
10c	63	58	Mountain	80% above	35% above	2	2.4	5.0	55,70
11a	70	64	Flat	average	90% above	1	0.9	4.3	65,70
11b	70	64	Flat	15% above	90% above	1	0.9	4.3	65,70
11c	70	64	Flat	35% above	90% above	1	0.9	4.3	65,70
11d	70	64	Flat	65% above	90% above	1	0.9	4.3	65,70
11e	70	64	Flat	95% above	90% above	1	0.9	4.3	65,70
12a	65	60	Flat	65% above	average	3	2.4	3.3	65,65
12b	65	60	Flat	65% above	15% above	3	2.4	3.3	65,65
12c	65	60	Flat	65% above	35% above	3	2.4	3.3	65,65

12d	65	60	Flat	65% above	65% above	3	2.4	3.3	65,65
12e	65	60	Flat	65% above	90% above	3	2.4	3.3	65,65
13a	78	73	Flat	90% above	25% above	1	2.6	2.3	65,65
13b	78	73	Flat	90% above	25% above	2	2.6	2.3	65,65
13c	78	73	Flat	90% above	25% above	3	2.6	2.3	65,65
13d	78	73	Flat	90% above	25% above	4	2.6	2.3	65,65
14a	71	64	Flat	100% above	average	2	0.7	6.0	55,65
14b	71	64	Flat	100% above	average	2	1.3	6.0	55,65
14c	71	64	Flat	100% above	average	2	2.2	6.0	55,65
15a	62	55	Rolling	35% above	65% above	2	0.5	1.0	50,60
15b	62	55	Rolling	35% above	65% above	2	0.5	2.0	50,60
15c	62	55	Rolling	35% above	65% above	2	0.5	3.0	50,60
15d	62	55	Rolling	35% above	65% above	2	0.5	4.0	50,60
16a	76	71	Flat	50% above	10% above	3	1.9	3.1	60,70
16b	76	71	Flat	50% above	10% above	3	1.9	3.1	70,75
16c	76	71	Flat	50% above	10% above	3	1.9	3.1	55,60
16d	76	71	Flat	50% above	10% above	3	1.9	3.1	60,65

APPENDIX H:

RESULTS OF THE FINAL ROUND OF WEB-BASED SURVEYS

This document was sent to the expert panel prior to the December 2005 meeting. The first part of this document provided some background about the project. The second part is a summary of results from the final round of web surveys.

PROJECT BACKGROUND & HISTORY

Appropriately set and enforced speed limits are essential for managing speeds and improving highway safety. In a recent study of current practice for setting speed limits, a TRB special committee concluded that setting speed limits primarily on the basis of the 85th-percentile speed may not be appropriate on roads in built-up areas with a mix of road users, high traffic volumes, and roadside activity. There are many factors bearing on reasonable and safe speed, and there is little agreement about their relative importance among residents, drivers, public officials, enforcement officers, and engineers. This absence of consensus has contributed to unrealistic and inconsistent speed limits. *TRB Special Report 254: Managing Speed: Review of Current Practices for Setting and Enforcing Speed Limits* recommends that an expert system approach be developed to advise and assist practitioners in setting speed limits in speed zones.

The expert system developed in this project will be used by practitioners to analyze specific segments of all types of roads from rural local roads to urban freeways (statutory limits that apply to a category of roads within a jurisdiction are not included). Part-time and temporary speed limits (e.g., school zones, work zones) are outside the scope of the project. The speeds recommended by the system should enhance safety and efficiency. The system's rationale for the recommended speed must enhance the practitioner's ability to justify it to the body responsible for setting speed limits and the public.

Enforcement is crucial to the success of speed limits. If law enforcement officers and the courts are confident that the system and its outputs are reasonable, their enforcement of the limit will be more effective. It is expected that use of the system will reduce the number of unrealistically low speed limits that draw on enforcement resources but do not commensurately improve safety and may, in fact, degrade safety by widening the distribution of speeds. Use of the system will allow enforcement agencies to better target the truly egregious drivers that pose a greater risk.

Expert Panel Meeting (June 2004)

The research team assembled a panel of experts for a meeting in Washington, D.C. in June 2004. The primary objective of this meeting was to use the knowledge and experience of the group to identify the critical factors and variables needed to make a decision concerning the appropriate speed limit to post in a speed zone. In addition, once the major factors were identified, the second major objective was to obtain a preliminary understanding of how the variables were evaluated and used in making the speed limit decision.

To identify which variables the Expert Panel felt were critical to the decision making process, a series of case studies were introduced through photographs, and the attendees were asked to tell the research team which variables they felt were critical for the particular road section under study. Thus, the Panel members had to examine the photographs, which were projected on the screen for all members to review, and then decide what information, or variables they needed to determine the speed limit for the section.

After identifying the critical variables for each case study, the expert panel was subdivided into break-out groups and asked to categorize each variable by high, medium, or low importance. Each breakout group was presented with photographs of different types of roadway segments and asked to develop the list of factors for which data would be necessary in order to identify the appropriate speed limit for a particular roadway section.

In subsequent exercises, the expert panel was asked to consider the quantitative information for each section and to recommend a speed limit for the section. This was done to examine the decision logic used to arrive at the recommended speed limit. Most members felt that the operating speed was an important factor in obtaining an initial speed limit, but there were significant differences on how the other variables should be considered.

Interim Meeting with the NCHRP 3-67 Panel (August 2004)

The results of the June 2004 expert panel meeting were presented to the NCHRP 3-67 Panel in August 2004 in Washington, D.C. The NCHRP 3-67 Panel indicated that in order to develop the decision rules for this expert system, the research team should develop a series of hypothetical case studies, and an expanded panel of practitioners should be asked to provide the speed limit for each scenario. The results of this exercise can then be used to develop the decision rules for this expert system. The NCHRP Panel also recommended that the results of this exercise be reviewed by the expert panel in a face to face meeting before final decisions are made to the decision rules.

Survey of NCHRP Panel and Expert Panel (Fall and Winter 2004)

Before developing the case studies, the research team felt that it is important to determine the appropriate categories/levels for the different critical variables. In order to get feedback from the NCHRP panel and the expert panel regarding the categories and levels for the critical variables, a survey was developed and distributed. In this survey, for each roadway type (i.e., limited access freeways, multilane roads, and two lane roads), variables were presented along with the proposed categories, levels, and the range of appropriate values to be considered. The respondents were asked to indicate if they agree/disagree with the proposed categories/levels. If they did not agree, they were asked to suggest an alternative set of categories and levels for that variable and/or alternative ways of considering that variable.

Eight individuals filled out the survey. In addition, two individuals made some general comments about the survey.

Case Studies for the Web-Based Pilot Tests (Spring and Summer 2005)

During the Interim Meeting in August, the NCHRP panel had suggested that a limited set of case studies and scenarios be developed in order to pilot test the methodology and the format in which the case studies and scenarios can be presented to the experts. The research team developed 14 case studies with about 56 scenarios for the Pilot Tests. Each case study had between 3 and 7 scenarios. Within each case study, one factor was modified while keeping other factors constant. Respondents were asked to select a speed limit for each scenario, indicate which critical factors were required for making their decision, and identify other data/factors that are critical to make a speed limit recommendation.

For the Pilot Tests, the following assumptions were made:

- Sections are in urban/suburban areas
- Sections are multi-lane
- The crash rate for the sections under consideration is below average, compared to similar sections.
- There is no adverse alignment in these sections

Respondents were able to access these case studies through a link to a website. Several members of this expert panel responded to these case studies.

Final Round of Web-Based Case Studies (Fall 2005)

Using the results of the pilot case studies, the research team developed case studies for five different roadway types. Links to these case studies were sent to 148 individuals that included traffic engineers, enforcement personnel, and researchers. This included the NCHRP 3-67 and the expert panel. These 148 individuals were divided into five groups corresponding to the five roadway types (freeway, two-lane undeveloped, multilane undeveloped, two-lane developed, multilane developed). State DOT personnel were primarily assigned to the freeway group. City engineers and practitioners were assigned to the developed roadway types. County engineers and practitioners were assigned to either the developed or the undeveloped roadway types. Enforcement personnel and researchers were randomly assigned to one of the roadway types. Here is the link to the case studies for the five roadway types:

Freeway
http://www.pedbikeinfo.org/speedlimits/speed2/fway.cfm

Two-lane Undeveloped Roads
http://www.pedbikeinfo.org/speedlimits/speed2/twolan_undv.cfm

Multilane Undeveloped Roads
http://www.pedbikeinfo.org/speedlimits/speed2/multilan_undv.cfm

Two-lane Developed Roads
http://www.pedbikeinfo.org/speedlimits/speed2/twolan_dv.cfm

Multilane Developed Roads
http://www.pedbikeinfo.org/speedlimits/speed2/multilan_dv.cfm

After filling out the case studies for the roadway type that they were assigned to, all respondents were encouraged to fill out the case studies for the other four roadway types.

Here is the number of experts who completed the case studies for the five different roadway types:

Freeway – 8
Two-lane Undeveloped – 8
Multilane Undeveloped – 12
Two-lane Developed – 9
Multilane Developed – 7

In addition, there were some individuals who started doing the case studies, but did not complete them. One researcher completed the case studies for three roadway types. Four individuals completed the case studies for two roadway types.

The following table shows the variables that were considered in the five different roadway types. Each cell in this table gives an indication of how often a variable was considered critical by the experts in the different roadway types. For example, for freeways, you will see 0.88 in the first row (corresponding to the 85^{th} percentile speed) – this indicates that the 85^{th} percentile speed was considered critical in about 88% of observations.

Further results of this web-based case study survey are discussed in the next several pages.

Variables considered for each roadway type

	Freeway	Multilane Undeveloped	Two-lane Undeveloped	Multilane Developed	Two-lane Developed
85^{th} percentile speed	0.88	0.95	0.94	0.92	0.91
50^{th} percentile speed	0.52	0.54	0.68	0.71	0.38
Terrain (Flat, Rolling, Mountain)	0.30	0.33	0.56		
Roadside Hazard Rating (1 through 7; 7 being the worst)	0.53	0.44	0.39	0.16	0.64
Roadside Development (Large complexes, commercial, and residential-collector streets)				0.38	0.61
Ped/Bike Activity (High or Low)				0.53	0.68
Parking (Yes or No)				0.40	0.50
Overall Injury rates (Defined based on % above average)	0.63	0.49	0.59	0.52	0.38
Speed-related Injury rates (Defined based on % above average)	0.55	0.51	0.56	0.46	0.55
% Adverse Alignment (% of section that is adversely aligned)		0.34	0.57		
Advisory Speed (advisory speed in the portion of the section that is adversely aligned)		0.18	0.29		
Signals Per Mile (Defined as the number of signals divided by the section length)				0.00	0.15
Interchanges Per Mile (Defined as the number of interchanges divided by section length)	0.25				
Section Length (in miles)	0.61	0.31	0.57	0.20	0.17
Adjacent Speed Limits (Speed limits in the two adjacent sections)	0.71	0.64	0.71	0.45	0.52
Through-vs-Local (Through or Local Road)				0.30	0.32
Median Type (Undivided, TWLTL, Divided)		0.42		0.28	

GENERAL RESULTS AND POSSIBLE APPROACH FOR THE EXPERT SYSTEM

In order to determine the effect of individual factors in the recommended speed limit for a facility, the research team analyzed the responses to the web survey in a couple of ways. The first approach was to calculate the average value of the speed limit recommended by the different experts for each scenario. In addition, for each scenario, the minimum speed limit, the maximum speed limit, and standard deviation of the speed limit were recorded for each scenario – this provided some indication of the extent to which the experts agreed or disagreed with each other in providing the recommended speed limit. Within each case study, one variable was modified while keeping the other variables a constant. Hence, by comparing the average speed limit for a particular scenario with the average speed limit for another scenario within a case study, it was possible to make a preliminary assessment of the effect on that variable (which was modified in that case study) on the speed limit.

A second approach regression models were utilized to assess the effect of different factors on the speed limit. In this approach, the recommended speed limit was included as a dependent variable, and the site characteristics were included as independent variables.

Using the results of these two approaches and the judgment of the research team, following is a possible approach for the decision rules of the expert system that has been formulated by the research team.

The decision rules work in two different levels. The first level involves constraints that may define the boundaries, i.e., the maximum and minimum speed limits for different roadway types. Level 1 constraints were developed primarily based on the judgment of the research team. The second level is a mathematical equation (developed based on regression analysis) that will calculate the recommended speed limit based on site characteristics.

Level 1 Constraints

1. The recommended speed limit cannot exceed the absolute maximum speed limit for a particular roadway type in a jurisdiction or a State. In the expert system, we plan to ask the user to enter this value before they start entering the site characteristics.
2. The recommended speed limit cannot be higher than the 85th percentile speed rounded to the nearest higher 5 mph increment. For example, if the 85th percentile speed is 61 mph, the recommended speed limit cannot exceed 65 mph.
3. The recommended speed limit cannot be lower than the 50th percentile speed rounded to the nearest lower 5 mph increment. For example, if the 50th percentile speed is 44 mph, the recommended speed limit cannot be lower than 40 mph.
4. In addition, there may be constraints for certain types, e.g., (a) roads with High pedestrian/bicycle activities and/or parking on the side of the road cannot have speed limits higher than 35 mph, (b) two lane roads (one lane in each direction without a median) cannot have a speed limit higher than 60 mph, (c) collector roads where the surrounding development is residential cannot have a speed limit higher than 40 mph.

Level 2 mathematical equations to calculate the speed limit

The correction factors (underlined) that are mentioned for different site characteristics were derived through regression. As you review these results, please understand that they are subject to the limitations in the data and the sample size that we were dealing with.

Freeways

The equation for freeways can be illustrated using an example:

- 85^{th} percentile speed for the section = 63 mph
- 50^{th} percentile speed for the section = 58 mph
- Overall injury rate = 60% above the average rate for similar sections
- Section length = 3 miles
- Adjacent speed limits = 55 and 65 mph

85^{th} percentile speed

Take the 85^{th} percentile speed and multiply 1.0. For our section whose 85^{th} percentile speed is 63 mph, and we get 63*1.0 = 63 mph.

Correction for overall injury rate

This correction will be necessary only if the overall injury crash rate for the section under consideration is higher than the average injury crash rate for similar sections. For the section in the example where the injury rate is 60% above the average injury crash rate for similar sections, we need to multiply 60 by -0.03, and we will get -1.8 mph.

Correction factor based on speed limits in adjacent sections

This correction is only for sections shorter than 5 miles. Two different correction factors were estimated: one for sections shorter than 2 miles, and the other for sections between 2 and 5 miles long. Here is how the correction factors work:

The first step here is to identify the lower value of the speed limits in adjacent sections, e.g., in our case, the two adjacent sections have a speed limit of 55 and 65 mph,; we take the 55 mph. Then round the 85^{th} percentile speed of the section under consideration to the nearest 5 mph increment – in our case, the 85^{th} percentile speed is 63 mph, and the nearest 5 mph increment is 65 mph. From 55 mph, subtract 65 mph: we get 55 – 65 = -10 mph. If the section is shorter than 2 miles, multiply this number by 0.44. If the section is between 2 and 5 mph, multiply this number by 0.26. Since our section is 3 mph long, the correction will be 0.26*(-10) = -2.6 mph.

Add the numbers and round-off to the nearest 5 mph increment

Adding the 85^{th} percentile speed with the correction factors, we get 63 – 1.8 – 2.6 = 58.6 mph. Rounding to the nearest 5 mph, we get 60 mph as the recommended speed limit. This number should then be compared with the Level 1 constraints for that particular roadway type to get the final recommended speed limit.

Multilane Undeveloped

The equation for multilane undeveloped roads can be illustrated using an example:

- 85th percentile speed = 56 mph
- 50th percentile speed = 50 mph
- Roadside hazard rating = 4
- Median type = Undivided road
- Overall injury rate = 30% above average
- Speed-related injury rate = 50% above average
- Adjacent speed limits = 50, 55 mph
- Length of a section = 2.5 miles
- There is adverse alignment in 35% of the section; the advisory speed in the adversely aligned portion of the section is 40 mph

85th percentile speed

Take the 85th percentile speed and multiply 1.0. For our section, the 85th percentile speed is 56 mph, and we get 56*1.0 = 56 mph.

Correction for roadside hazard rating

This correction is only applied if the roadside hazard rating is 6 or 7 (the correction in this case is -0.67). For our case, since the roadside hazard rating is 4, and there is no correction.

Correction of median type

This correction is applied only if this is an undivided road (instead of Divided or TWLTL). The correction for undivided roads is -1.03. In our case, since we have an undivided road, the correction is -1.03 mph.

Correction for overall injury rate

This correction will be necessary only if the overall injury crash rate for the section under consideration is higher than the average injury crash rate for similar sections. For our section, the injury crash rate is 30% above the average injury crash rate for similar sections, and we need to multiply 30 by -0.01, and get 30*(-0.01) = -0.30 mph.

Correction of speed-related injury rate

This correction will be necessary only if the injury crash rate of speed-related injury crash rates for the section under consideration is higher than the average speed-related injury crash rate for similar sections. For our example, the speed-related injury crash rate is 50% above the average injury crash rate for similar sections, and we need to multiply 50 by -0.02, and get 50*(-0.02) = -1 mph.

Correction factor based on speed limits in adjacent sections

This correction is only for sections shorter than 4 miles. Two different correction factors were estimated: one for sections shorter than 3 miles, and the other for sections between 3 and 4 miles long. Here is how the correction factors work:

The first step here is to identify the lower value of the speed limits in adjacent sections; in our section the adjacent speed limits are 50 and 55 mph; we take the 50 mph. Then round the 85th percentile speed of the section under consideration to the nearest 5 mph increment – in our case, since the 85th percentile speed is 56 mph, the nearest 5 mph increment is 55 mph. From 50 mph, subtract 55 mph: we get 50 - 55 = -5 mph. If the section is shorter than 3 miles, multiply this number by 0.19. If the section is between 3 and 4 mph, multiply this number by 0.11. Since our section is 2.5 miles long, the correction will be 0.19*(-5) = -0.95 mph.

Correction for adverse alignment in the section

This correction is only for sections where a portion of it has some adverse alignment. The first step here is to subtract the 85th percentile of the section (the portion without the adverse alignment) rounded to the nearest 5 mph increment, from the advisory speed in the adversely aligned portion of the section. Since the advisory speed is 40 mph and the 85th percentile rounded to the nearest 5 mph increment is 55 mph, we get 40 – 55 = -15 mph. Then calculate the correction by multiplying this number by the proportion of the section which is adversely aligned (in our case that will be 30/100) and by a correction factor which is 0.14; we will get -15*(30/100)*0.14 = -0.63 mph.

Add the numbers and round-off to the nearest 5 mph increment

Adding the 85th percentile speed with the correction factors, we get 56 – 0.67 - 1.03 - 0.3 – 1 -0.95 – 0.63 = 51.42 mph. Rounding to the nearest 5 mph, we get 50 mph as the recommended speed limit. This number should then be compared with the Level 1 constraints for that particular roadway type to get the final recommended speed limit.

Two-lane Undeveloped

Following is an example for two lane undeveloped roads

- 85th percentile speed = 52 mph
- 50th percentile speed = 47 mph
- Overall injury rate = 30% above average
- Speed-related injury rate = 50% above average
- Adjacent speed limits = 45, 55 mph
- Length of a section = 2.5 miles

85th percentile speed

Take the 85th percentile speed and multiply 1.0. For our section, the 85th percentile speed is 52 mph, and we get 52*1.0 = 52 mph.

Correction for overall injury rate

This correction will be necessary only if the overall injury crash rate for the section under consideration is higher than the average injury crash rate for similar sections. For our section, the injury crash rate is 30% above the average injury crash rate for similar sections, and we need to multiply 30 by -0.02, and get 30*(-0.02) = -0.6 mph.

Correction of speed-related injury rate

This correction will be necessary only if the injury crash rate of speed-related injury crash rates for the section under consideration is higher than the average speed-related injury crash rate for similar sections. For our example, the speed-related injury crash rate is 50% above the average injury crash rate for similar sections, and we need to multiply 50 by -0.025, and get 50*(-0.025) = -1.25 mph.

Correction factor based on speed limits in adjacent sections

This correction is only for sections shorter than 4 miles. Two different correction factors were estimated: one for sections shorter than 3 miles, and the other for sections between 3 and 4 miles long. Here is how the correction factors work:

The first step here is to identify the lower value of the speed limits in adjacent sections; in our section the adjacent speed limits are 45 and 55 mph; we take the 45 mph. Then round the 85th percentile speed of the section under consideration to the nearest 5 mph increment – in our case, since the 85th percentile speed is 52 mph, the nearest 5 mph increment is 50 mph. From 45 mph, subtract 50 mph: we get 45 - 50 = -5 mph. If the section is shorter than 3 miles, multiply this number by 0.36. If the section is between 3 and 4 mph, multiply this number by 0.29. Since our section is 2.5 miles long, the correction will be 0.36*(-5) = -1.8 mph.

Add the numbers and round-off to the nearest 5 mph increment

Adding the 85th percentile speed with the correction factors, we get 52 – 0.6 - 1.25 – 1.8 = 48.35 mph. Rounding to the nearest 5 mph, we get 50 mph as the recommended speed limit. This number should then be compared with the Level 1 constraints for that particular roadway type to get the final recommended speed limit.

Multilane Developed

Following is an example for multilane developed road:

- 85th percentile speed = 47 mph
- 50th percentile speed = 42 mph

- Commercial development
- Low ped/bike activity
- No parking along the road
- Overall injury rate = 40% above average
- Speed-related injury rate = 55% above average
- Adjacent speed limits = 35, 45 mph
- Length of a section = 2.5 miles

85th percentile speed

Take the 85th percentile speed and multiply 1.0. For our section, the 85th percentile speed is 47 mph, and we get 47*1.0 = 47 mph.

Correction of type of development

In the surveys, three types of development were presented: commercial, large complexes (includes large shopping complexes and large industrial complexes), and residential-collector (includes collector roads with residential development on the side). For residential collectors, a correction of -0.38 is applied. There is no correction for other types of development. Since our example has commercial development, there is no correction.

Correction of Ped-Bike Activity

This correction is applied only if the Ped-Bike Activity is considered High; the correction factor is -0.56. Since, the ped-bike activity is Low in our example, there is no correction.

Correction for Parking

This correction is applied only if there is parking along the sides of the road. The correction factor is -0.33. In our example, there is no parking and so there is no correction for this variable.

Correction for overall injury rate

This correction will be necessary only if the overall injury crash rate for the section under consideration is higher than the average injury crash rate for similar sections. For our section, the injury crash rate is 40% above the average injury crash rate for similar sections, and we need to multiply 40 by -0.011, and get 40*(-0.011) = -0.44 mph.

Correction of speed-related injury rate

This correction will be necessary only if the injury crash rate of speed-related injury crash rates for the section under consideration is higher than the average speed-related injury crash rate for similar sections. For our example, the speed-related injury crash rate is 55% above the average injury crash rate for similar sections, and we need to multiply 55 by -0.018, and get 55*(-0.018) = -0.99 mph.

Correction factor based on speed limits in adjacent sections

This correction is only for sections shorter than 2 miles. Here is how the correction factors work:

The first step here is to identify the lower value of the speed limits in adjacent sections; in our section the adjacent speed limits are 34 and 45 mph; we take the 35 mph. Then round the 85th percentile speed of the section under consideration to the nearest 5 mph increment – in our case, since the 85th percentile speed is 47 mph, the nearest 5 mph increment is 45 mph. From 35 mph, subtract 45 mph: we get 35 - 45 = -10 mph. Multiply this number by 0.13. Since our section is 2.5 miles long, there is no correction for adjacent speed limits.

Add the numbers and round-off to the nearest 5 mph increment

Adding the 85th percentile speed with the correction factors, we get 47 – 0.44 – 0.99 = 45.57 mph. Rounding to the nearest 5 mph, we get 45 mph as the recommended speed limit. This number should then be compared with the Level 1 constraints for that particular roadway type to get the final recommended speed limit.

Twolane Developed

Here is an example for two lane developed roads:

- 85th percentile speed = 39 mph
- 50th percentile speed = 34 mph
- Roadside hazard rating = 4
- Residential-collector development
- Parking allowed along the road
- Overall injury rate = 30% above average
- Adjacent speed limits = 30, 40 mph
- Length of a section = 2.5 miles

85th percentile speed

Take the 85th percentile speed and multiply 1.0. For our section, the 85th percentile speed is 39 mph, and we get 39*1.0 = 39 mph.

Correction of roadside hazard rating

Correction is applied if roadside hazard rating is 2 or higher. If rating is 2, the correction is -0.93, if rating is 3 or 4, the correction is -1.75, and if the rating is between 5 and 7, the correction is -2.05. For our section, the hazard rating is 4, and so the correction factor is -1.75 mph.

Correction of type of development

In the surveys, three types of development were presented: commercial, large complexes (includes large shopping complexes and large industrial complexes), and residential-collector (includes collector roads with residential development on the side). For residential collectors, a correction of -0.84 is applied. There is no correction for other types of development. Since our example has residential-collector development, the correction is -0.84 mph.

Correction for Parking

This correction is applied only if there is parking along the sides of the road. The correction factor is -2.02. In our example, there is parking along the sides of the road, and hence the correction is -2.02 mph.

Correction for overall injury rate

This correction will be necessary only if the overall injury crash rate for the section under consideration is higher than the average injury crash rate for similar sections. For our section, the injury crash rate is 30% above the average injury crash rate for similar sections, and we need to multiply 30 by -0.01, and get 30*(-0.01) = -0.30 mph.

Correction factor based on speed limits in adjacent sections

This correction is only for sections shorter than 4 miles. Two different correction factors were estimated: one factor for sections shorter than 2 miles, a second factor for sections between 2 and less than 3 miles, and the third for sections between 3 and 4 miles long. Here is how the correction factors work:

The first step here is to identify the lower value of the speed limits in adjacent sections; in our section the adjacent speed limits are 30 and 40 mph; we take the 30 mph. Then round the 85^{th} percentile speed of the section under consideration to the nearest 5 mph increment – in our case, since the 85^{th} percentile speed is 39 mph, the nearest 5 mph increment is 40 mph. From 30 mph, subtract 40 mph: we get 30 - 40 = -10 mph. Multiply this number by either 0.19 (if section is shorter than 2 miles; by 0.14 (if section is between 2 and 3 miles long), and by 0.09 (if section is between 3 and 4 miles long). Since our section is 2.5 miles long, the correction is -10*(0.14) = -1.4 mph.

Add the numbers and round-off to the nearest 5 mph increment

Adding the 85^{th} percentile speed with the correction factors – we get 39 – 1.75 – 0.84 – 2.02 – 0.30 – 1.4 = 32.69 mph. Rounding to the nearest 5 mph, we get 35 mph as the recommended speed limit. This number should then be compared with the Level 1 constraints for that particular roadway type to get the final recommended speed limit.

ISSUES and QUESTIONS FOR THE EXPERT PANEL

Having reviewed the results of the survey and the framework for the decision rules for the expert system, we would like you to consider the following issues and questions:

Overall framework of the expert system

Does the overall framework for the decision rules for the expert system seem reasonable to you?

Critical factors

Do you feel that the framework considers all the critical factors for the different roadway types? Are there other critical factors that need to be considered?

Consideration of safety

What effect should crash rate have on the recommended speed limit? We realized that not all experts may agree on this issue. In the web surveys, we included two variables 'injury crash rate' and 'speed-related injury crash rate'. These variables were expressed as 'average', or higher than average by a particular percentage. Ideally, this 'average' represents the average injury crash rate for sites with similar geometric and traffic conditions within the same jurisdiction. Is it reasonable to expect the practitioner to have access this level of information for each jurisdiction? Should the expert system provide national averages for different roadway types?

Some respondents to the survey felt that they need to know more about the nature of these crashes before they can make a decision on the recommended speed limit. More discussion is necessary on this topic at the meeting.

Roadside development

Roadside development was included in the form of categories: commercial, large shopping, and residential. In the past, we have had some discussions about using the number of driveways and properties. At that time, some members of the expert panel were reluctant to collect data on the number of driveways and properties to set the speed limit. However, a few experts while responding to the web survey indicated that they would like information on the number of driveways before making the decision on the appropriate speed limit.

Adjacent speed limits

This variable was included in the web survey along with the section length to see if adjacent speed limits were considered by experts in short sections (say, less than 1 mile). We found that adjacent speed limits were considered by many experts even for sections that are 2 or 3 miles long. One expert felt that the operating speeds on the adjacent sections are more important than the adjacent speed limits and should be considered in developing the decision rules. More discussion is necessary on this topic at the meeting.

Adverse alignment

This program is not intended to develop advisory speeds for sections with adverse alignment. However, some experts have argued that the general speed limit for a section needs to be altered if there is adverse alignment in a section. Adverse alignment was one of the variables in the web survey, but there was significant disagreement among the experts on how this variable should be considered.

Interchanges per mile

This variable was included in the freeway section to distinguish between rural and urban interstates. Interchanges per mile was defined as the number of interchanges to the section length, e.g., if you have 3 interchanges in a 5 mile section, we get 3/5 = 0.6 interchanges per mile. However, one of the experts incorrectly thought that the interchange spacing was 0.6 miles. It is not clear if the other experts made the same incorrect assumption. The analysis has shown that this variable is not significant. There needs be a discussion at the meeting to determine if this variable is important and how it should be used in setting the speed limit in freeways.

Terrain

Terrain was included as a variable in the freeway and undeveloped roads. When we looked at the average of the speed limits given by experts in case studies where this variable was altered, there was some evidence to indicate that some experts reduced the speed limit for roads in mountainous areas. However, this variable was not significant in the statistical analysis.

Pedestrian and bicycle activity

This was defined as either High or Low in the web surveys. High represents pedestrian and bicycle activity that normally occurs in a CBD or downtown area. Low represents occasional pedestrian activity. One expert has indicated that he would like to know about uncontrolled pedestrian crossings before making any decisions about the recommended speed limit. This issue needs to be discussed at the meeting.

Other Issues from the Panel

-
-

APPENDIX I

DETAILED RESULTS FROM SELECTED CASE STUDIES IN THE FINAL WEB SURVEY

This document gives the speed limit recommended by individual participants in the final round of web surveys for those case studies where the overall injury rate, the speed-related injury rate, and the speed limits in adjacent sections were modified while keeping the other variables as a constant. This has been presented in order to illustrate the agreement/disagreement among the participants.

The results are presented in the form of several tables. The following information is provided for each table:

- The user identification number
- The case study number
- The values and levels of the different variables that were kept constant for all scenarios within a case study
- The speed limit recommended by each user for the different scenarios within each case study. In some cases, cells are blank – this indicates that the user did not enter any speed limit for that condition because he/she felt that not enough information was provided.

Based on the results provided by individual participants in case studies where injury rates were modified, it is clear that some participants did not feel that a higher injury rate warrants a lower speed limit. However, others did not agree with this approach – they did reduce the speed limit (usually by 5 mph) when the injury rates (overall injury rates or speed-related injury rates) were increased from average to about 100% above average. Among the participants who decreased their recommended speed limit as a response to an increase in injury rates, most of them started decreasing the speed limit only after the injury rates were at least 40 or 50% above average – some decreased the speed limit only after the injury rates were at least 60 to 80% above average.

There was disagreement among the participants when the adjacent speed limits were modified. Some participants did reduce their recommended speed limit if the adjacent speed limits were significantly lower than the operating speeds in the section under consideration, even for relatively long sections. For other participants, the adjacent speed limits did not seem to have any effect on their recommended speed limit.

FREEWAYS

Case study 3:
85th percentile speeds = 66 mph
50th percentile speeds = 63 mph
Terrain = Mountain
Speed-Related Injury Rate = 70% above average
Roadside Hazard Rating = 2
Interchanges per Mile = 0.7
Length = 1 mile
Speed Limit in Adjacent Sections = 60,70 mph
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case study	average	25% above	50% above	75% above	100% above
12	03	65	65	65	65	65
14	03	65	60	60	60	60
20	03	70	70	70	60	60
24	03					
33	03	65	65	60	60	60
34	03	60	60	60	60	60
54	03	65	65	65	65	65
61	03	65	65	65	65	

Case study 4:
85th percentile speeds = 56 mph
50th percentile speeds = 49 mph
Terrain = Mountain
Overall Injury Rate = 10% above average
Roadside Hazard Rating = 4
Interchanges per Mile = 1.0
Length = 1 mile
Speed Limit in Adjacent Sections = 50,55 mph
Speed-related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case study	average	25% above	50% above	75% above	100% above
12	04	55	55	55	50	50
14	04	55	55	55	55	55
20	04	55	55	55	50	50
24	04	55	55			
33	04	55	55	50	50	50
34	04	55	50	50	50	50
54	04	55	55	55	55	55
61	04	55	55	55	55	

Case study 8:
85th percentile speeds = 73 mph

50th percentile speeds = 65 mph
Terrain = Flat
Overall Injury Rate = 45% above average
Speed-related Injury Rate = 20% above average
Roadside Hazard Rating = 3
Interchanges per Mile = 2.2
Length = 3.5 mile
Adjacent speed limits were varied keeping other variables constant.

		Adjacent Speed Limits			
User	Case study	50,55	55,60	50,60	55,65
12	08	70	70	70	70
14	08	55	60	60	55
20	08				
24	08				
33	08		60	60	65
34	08	55	60	60	
54	08	75	75	75	75
61	08				

<u>Case study 11:</u>
85th percentile speeds = 70 mph
50th percentile speeds = 64 mph
Terrain = Flat
Speed-related Injury Rate = 90% above average
Roadside Hazard Rating = 1
Interchanges per Mile = 0.9
Length = 4.3 mile
Speed Limit in Adjacent Sections = 65, 70 mph
Overall injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case study	average	15% above	35% above	65% above	95% above
12	11	70	70	65	65	65
14	11	70	70	70	65	65
20	11	70	70	70	70	70
33	11	70	70	65	65	65
34	11	70			65	
24	11					
54	11	70	70	70	70	70
61	11	70	70	65	65	65

<u>Case study 12:</u>
85th percentile speeds = 65 mph
50th percentile speeds = 60 mph
Terrain = Flat

Overall Injury Rate = 65% above average
Roadside Hazard Rating = 3
Interchanges per Mile = 2.4
Length = 3.3 mile
Speed Limit in Adjacent Sections = 65,65 mph
Speed-related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case study	average	15% above	35% above	65% above	90% above
12	12	65	65	65	60	60
14	12	65	65	65	60	60
20	12	65	65	65	65	65
33	12	65	65	65	65	65
34	12	65	65			
24	12	65	65	65		
54	12	65	65	65	65	65
61	12	65	65	65		

<u>Case study 16:</u>
85^{th} percentile speeds = 76 mph
50^{th} percentile speeds = 71 mph
Terrain = Flat
Overall Injury Rate = 50% above average
Speed-related Injury Rate = 10% above average
Roadside Hazard Rating = 3
Interchanges per Mile = 1.9
Length = 3.1 mile
Adjacent speed limits were varied keeping other variables constant.

		Adjacent Speed Limits			
User	Case study	60,70	70,75	55,60	60,65
12	16	75	75	75	75
14	16	70	70	60	65
20	16		75		
24	16	70	70	60	65
33	16	70	75		
34	16	70			
54	16	75	75	75	75
61	16	70	70		

MULTILANE UNDEVELOPED

Case study 4:
85th percentile speeds = 47 mph
50th percentile speeds = 41 mph
Terrain = Rolling
Speed-Related Injury Rate = 75% above average
Roadside Hazard Rating = 1
No adverse alignment; Advisory speed in the adversely aligned portion = NA
Length = 2.2 miles
Undivided Road
Speed Limit in Adjacent Sections = 40,50 mph
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case study	average	20% above	45% above	70% above	100% above
20	04	50	50	45	45	45
26	04	45	45	45	45	45
27	04	40	40	40	40	40
29	04	45	45	45	45	45
30	04	45	45	45	45	45
37	04	45	45	40	40	40
42	04	45	40	40	40	35
47	04	45	45	45	40	40
53	04	45	45	45	40	40
54	04	45	45	45	45	45
55	04	45	45	45	40	40
56	04	45	45	45	45	45
58	04	50	45	45	45	45
59	04	50	45	45	45	45
60	04	40	40			35

Case study 5:
85th percentile speeds = 50 mph
50th percentile speeds = 45 mph
Terrain = Mountain
Overall Injury Rate = 45% above average
Roadside Hazard Rating = 6
5% of section is adversely aligned; Advisory speed in the adversely aligned portion = 35 mph
Length = 3.8 miles
Median = TWLTL
Speed Limit in Adjacent Sections = 40,45 mph
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case study	average	15% above	35% above	65% above	100% above
26	05	45	45	45	45	45

27	05	45	45	45	45	45
29	05	50	50	50	50	50
30	05	50	50	50	45	45
37	05	45	45	45	45	45
42	05	45	45	40	40	40
47	05	50	50	45	45	45
53	05	50	50	50	45	40
54	05	50	50	50	50	50
55	05	50	50	50	45	45
56	05	45	45	45	45	45
58	05	45	45	45	45	45
59	05	45	45	45	45	45
60	05	45	45	40	40	40

<u>Case study 9:</u>
85th percentile speeds = 61 mph
50th percentile speeds = 56 mph
Terrain = Flat
Overall Injury Rate = 5% above average
Speed-Related Injury Rate = average
Roadside Hazard Rating = 3
No adverse alignment; Advisory speed in the adversely aligned portion = NA
Length = 3.8 miles
Median = TWLTL
Adjacent speed limits were varied keeping other variables as constant.

		Adjacent Speed Limits			
User	Case study	55,60	50,55	50,65	60,70
26	09	60	60	60	60
29	09	60	60	60	60
30	09	55	55	55	55
37	09	60	55	60	60
42	09	55	55	55	60
47	09	60	55	60	60
53	09	60	55	60	60
54	09	60	60	60	60
55	09	60	55	60	60
56	09	60	55	60	60
58	09	55	55	50	60
59	09	60	60	60	60
60	09	60	60	60	60

<u>Case study 13:</u>
85th percentile speeds = 55 mph
50th percentile speeds = 50 mph
Terrain = Flat
Speed-Related Injury Rate = average
Roadside Hazard Rating = 4

No adverse alignment; Advisory speed in the adversely aligned portion = NA
Length = 3.4 miles
Divided Road
Speed Limit in Adjacent Sections = 60,60 mph
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case study	average	10% above	40% above	65% above	90% above
26	13	45	45	45	45	45
29	13	55	55	55	55	55
37	13	55	55	55	50	50
42	13	55	55	55	55	50
47	13	55	55	55	50	50
53	13	55	55	55	50	50
54	13	55	55	55	55	55
55	13	55	55	55	50	50
56	13	55	55	55	55	55
58	13	55	55	55	55	55
59	13	60	55	55	55	55
60	13	55	55	50	50	45

Case study 14:
85^{th} percentile speeds = 48 mph
50^{th} percentile speeds = 43 mph
Terrain = Rolling
Overall Injury Rate = 70% above average
Roadside Hazard Rating = 5
30% of section is adversely aligned; Advisory speed in the adversely aligned portion = 25 mph
Length = 0.8 miles
Median = TWLTL
Speed Limit in Adjacent Sections = 45,55 mph
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case study	average	25% above	50% above	75% above	100% above
26	14	45	45	45	45	45
29	14	50	50	50	50	50
37	14	45	45	45	45	40
42	14	45	45	45	40	40
47	14	45	45	40	40	40
53	14	45	45	40	40	40
54	14	50	50	50	50	50
55	14	40	40	35	40	40
56	14	50	50	50	50	50
58	14	45	45	45	45	40
59	14	45	45	45	45	45
60	14	45	40	40	35	35

TWO-LANE UNDEVELOPED

Case study 4:
85^{th} percentile speeds = 47 mph
50^{th} percentile speeds = 41 mph
Terrain = Mountain
Speed-Related Injury Rate = 60% above average
Roadside Hazard Rating = 1
20% of section is adversely aligned; Advisory speed in the adversely aligned portion = 25 mph
Length = 2.2 miles
Speed Limit in Adjacent Sections = 40,50 mph
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case study	average	15% above	35% above	65% above	90% above
15	04	45	45	40	40	40
16	04					
18	04	45	45	45	40	40
20	04					
39	04	45	45	45	40	40
43	04	45	45	45	45	45
46	04	50	50	50	45	40
49	04	45	45	45	45	40

Case study 5:
85^{th} percentile speeds = 50 mph
50^{th} percentile speeds = 45 mph
Terrain = Mountain
Overall Injury Rate = 30% above average
Roadside Hazard Rating = 6
No adverse alignment; Advisory speed in the adversely aligned portion = NA
Length = 3.8 miles
Speed Limit in Adjacent Sections = 40,45 mph
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case study	average	20% above	50% above	75% above	100% above
15	05	45	45	40	40	40
16	05	50	45	45	45	45
18	05	50	50	50	45	45
20	05	50	50	50	50	45
39	05	50	50	45	45	45
43	05	50	50	50	50	50
46	05	45	45	45	45	45
49	05	45	45	45	45	45

Case study 9:

85th percentile speeds = 61 mph
50th percentile speeds = 56 mph
Terrain = Flat
Overall Injury Rate = 20% above average
Speed-Related Injury Rate = average
Roadside Hazard Rating = 7
No adverse alignment; Advisory speed in the adversely aligned portion = NA
Length = 1.6 miles
Adjacent speed limits were varied keeping other variables as constant.

		Adjacent Speed Limits			
User	Case study	50,55	45,50	45,60	55,65
15	09	55	50	60	55
16	09	55	55	55	55
18	09	55	55	55	55
20	09			60	
39	09	55	55	55	55
43	09	60	60	60	60
46	09	55	50	55	55
49	09	55	60	60	60

Case study 12:
85th percentile speeds = 55 mph
50th percentile speeds = 50 mph
Terrain = Flat
Speed-Related Injury Rate = average
Roadside Hazard Rating = 3
No adverse alignment; Advisory speed in the adversely aligned portion = NA
Length = 3.4 miles
Speed Limit in Adjacent Sections = 60, 60 mph
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case study	average	5% above	45% above	70% above	100% above
15	12	60	60	60	60	60
16	12	55	55	55	55	55
18	12	55	55	55	55	50
20	12					
39	12	55	55	55	50	50
43	12	55	55	55	55	55
46	12	60	60	55	55	50
49	12	55	55	55	55	55

Case study 13:
85th percentile speeds = 48 mph
50th percentile speeds = 43 mph
Terrain = Rolling

Overall Injury Rate = 70% above average
Roadside Hazard Rating = 4
50% of section is adversely aligned; Advisory speed in the adversely aligned portion = 30 mph
Length = 0.8 miles
Speed Limit in Adjacent Sections = 45,55 mph
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case study	average	10% above	40% above	70% above	95% above
15	13	45	45	45	45	45
16	13	45	50	50	50	50
18	13	45	45	45	45	40
20	13	45	45	45	45	45
39	13	45	45	45	40	40
43	13	45	45	45	45	45
46	13	45	45	45	45	45
49	13	45	45	45	45	45

<u>Case study 16:</u>
85th percentile speeds = 67 mph
50th percentile speeds = 62 mph
Terrain = Flat
Overall Injury Rate = 60% above average
Speed-Related Injury Rate = 35% above average
Roadside Hazard Rating = 5
No adverse alignment; Advisory speed in the adversely aligned portion = NA
Length = 2.8 miles
Adjacent speed limits were varied keeping other variables as constant.

		Adjacent Speed Limits			
User	Case study	45,50	65,70	50,60	55,55
15	16	50	65	60	55
16	16				
18	16	55	55	55	55
20	16		65		
39	16	55	55	55	55
43	16	60	60	60	60
46	16	55	55	55	55
49	16	65	65	65	65

MULTILANE DEVELOPED

Case study 7:
85th percentile speeds = 32 mph
50th percentile speeds = 26 mph
Roadside Hazard Rating = 1
Development = Residential
Ped_Bike = Low
Parking = Yes
Speed-Related Injury Rate = 60% above average
Length = 2.2 miles
Signals per mile = 4.5
Speed Limit in Adjacent Sections = 30,35 mph
Through_vs_Local = Local
Median = Undivided
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case Study	average	20% above	35% above	65% above	90% above
12	07	30	30	30	30	30
13	07	30	30	30	30	25
26	07	30	30	30	30	30
35	07	30	30	30	30	30
36	07	35	35	30	25	25
43	07	30	30	35	30	30
44	07	30	25	25	25	25
51	07	30	30	30	30	30
52	07	30	30	30	30	30

Case study 8:
85th percentile speeds = 35 mph
50th percentile speeds = 30 mph
Roadside Hazard Rating = 6
Development = Large complexes
Ped_Bike = High
Parking = Yes
Overall Injury Rate = 10% above average
Length = 3.8 miles
Signals per mile = 3.2
Speed Limit in Adjacent Sections = 35,40 mph
Through_vs_Local = Local
Median = TWLTL
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case Study	average	15% above	35% above	70% above	95% above
43	08	35	35	35	35	35

12	08	30	30	30	30	30
13	08	35	35	35	35	35
26	08	35	35	35	35	35
35	08	35	35	30	30	30
36	08	35	35	35	30	30
44	08	35	35	30	30	30
51	08	30	30	30	30	30
52	08	35	35	35	35	35

<u>Case Study 11:</u>
85^{th} percentile speeds = 40 mph
50^{th} percentile speeds = 35 mph
Roadside Hazard Rating = 7
Development = Residential
Ped_Bike = Low
Parking = No
Overall Injury Rate = 20% above average
Speed-Related Injury Rate = average
Length = 1.6 miles
Signals per mile = 2.5
Through_vs_Local = Local
Median = Undivided
Adjacent speed limits were varied keeping other variables constant.

		Adjacent Speed Limits			
User	Case Study	25,30	30,35	35,40	40,45
43	11	40	40	40	40
12	11	40	40	40	40
13	11	35	35	40	40
26	11	35	35	40	40
35	11	35	40	40	40
36	11	40	40	40	40
44	11	40	40	40	40
52	11	35	35	35	40

<u>Case study 19:</u>
85^{th} percentile speeds = 33 mph
50^{th} percentile speeds = 26 mph
Roadside Hazard Rating = 3
Development = Commercial
Ped_Bike = Low
Parking = No
Speed-Related Injury Rate = average
Length = 3.4 miles
Signals per mile = 3.2
Speed Limit in Adjacent Sections = 25,35 mph
Through_vs_Local = Through

Median = Divided
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case Study	average	25% above	50% above	75% above	100% above
12	19	35	35	35	30	30
13	19	35	35	35	35	35
26	19	35	35	35	35	35
35	19	35	35	30	30	30
36	19	35	35	35	30	30
43	19	35	35	35	35	30
44	19	30	30	25	25	25
52	19	35	35	35	35	30

Case Study 20
85th percentile speeds = 36 mph
50th percentile speeds = 31 mph
Roadside Hazard Rating = 5
Development = Large complexes
Ped_Bike = High
Parking = No
Overall Injury Rate = 75% above average
Length = 1.2 miles
Signals per mile = 5.0
Speed Limit in Adjacent Sections = 30,40 mph
Through_vs_Local = Through
Median = TWLTL
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case Study	average	25% above	50% above	75% above	100% above
12	20	35	35	30	35	35
13	20	35	35	35	35	35
26	20	35	35	35	35	35
35	20	35	35	30	30	30
36	20	35	35	35	35	35
43	20	35	35	35	35	35
44	20	30	30	30	30	30
52	20	35	35	35	35	35

Case Study 22:
85th percentile speeds = 42 mph
50th percentile speeds = 37 mph
Roadside Hazard Rating = 5
Development = Commercial
Ped_Bike = High
Parking = No

Overall Injury Rate = 35% above average
Speed-Related Injury Rate = 35% above average
Length = 2.8 miles
Signals per mile = 1.8
Through_vs_Local = Through
Median = Divided
Adjacent speed limits were varied keeping other variables constant.

		Adjacent Speed Limits			
User	Case Study	20,30	30,40	40,45	45,50
12	22	40	40	40	40
13	22	40	40	40	40
26	22	35	40	40	45
35	22	40	40	40	40
36	22	40	40	40	40
43	22	40	40	40	40
44	22	35	35	35	35
52	22	35	35	40	40

TWO-LANE DEVELOPED

Case study 6:
85^{th} percentile speeds = 32 mph
50^{th} percentile speeds = 26 mph
Roadside Hazard Rating = 1
Development = Residential
Ped_Bike = Low
Parking = Yes
Speed-Related Injury Rate = 60% above average
Length = 2.2 miles
Signals per mile = 4.1
Speed Limit in Adjacent Sections = 30,35 mph
Through_vs_Local = Local
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case Study	average	20% above	40% above	70% above	100% above
12	06	30	30	30	30	25
19	06	30	25	25	25	25
21	06	30	30	30	30	30
22	06	30	30	30	30	30
28	06	30	30	30	25	25
31	06	30	30	30	25	25
32	06	30	30	30	30	30
38	06	25	25	25	25	25
45	06	25	25	25	25	25
48	06	30	30	30	30	30

Case study 7:
85^{th} percentile speeds = 33 mph
50^{th} percentile speeds = 28 mph
Roadside Hazard Rating = 7
Development = Commercial
Ped_Bike = High
Parking = Yes
Overall Injury Rate = 15% above average
Length = 3.8 miles
Signals per mile = 1.3
Speed Limit in Adjacent Sections = 35,40 mph
Through_vs_Local = Local
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case Study	average	15% above	45% above	80% above	100% above
12	07	30	30	30	30	30
21	07	30	30	30	30	30

22	07	30	30	30	30	30
28	07	30	30	25	25	25
31	07	25	25	25	25	
32	07	25	25	25	25	25
38	07	25	25	25	25	25
45	07	30	30	30	30	30
48	07	30	30	30	30	30

<u>Case Study 10:</u>
85th percentile speeds = 40 mph
50th percentile speeds = 35 mph
Roadside Hazard Rating = 6
Development = Residential
Ped_Bike = Low
Parking = No
Overall Injury Rate = 10% above average
Speed-Related Injury Rate = average
Length = 1.6 miles
Signals per mile = 3.1
Through_vs_Local = Local
Adjacent speed limits were varied keeping other variables constant.

		Adjacent Speed Limits			
User	Case Study	25,30	30,35	35,40	40,45
12	10	40	40	40	40
21	10	35	35	35	35
22	10	30	30	35	40
28	10	30	30	35	35
31	10	30	35	35	40
32	10	30	30	35	35
38	10	30	30	30	30
45	10	40	40	40	40
48	10	35	35	35	40

<u>Case study 17:</u>
85th percentile speeds = 45 mph
50th percentile speeds = 39 mph
Roadside Hazard Rating = 3
Development = Large complexes
Ped_Bike = Low
Parking = No
Speed-Related Injury Rate = average
Length = 3.4 miles
Signals per mile = 2.9
Speed Limit in Adjacent Sections = 25,35 mph
Through_vs_Local = Through
Overall Injury rate was varied keeping other variables constant.

		Overall Injury Rate				
User	Case Study	average	10% above	50% above	75% above	100% above
12	17	45	45	40	40	40
21	17	45	45	45	45	45
22	17	40	40	40	40	35
28	17	45	45	40	40	35
31	17	40	40	40		
32	17	45	45	45	40	40
38	17	40	40	40	40	40
45	17	45	45	45	45	45
48	17	40	40	40	40	35

<u>Case Study 18</u>
85^{th} percentile speeds = 36 mph
50^{th} percentile speeds = 31 mph
Roadside Hazard Rating = 5
Development = Commercial
Ped_Bike = High
Parking = No
Overall Injury Rate = 70% above average
Length = 1.2 miles
Signals per mile = 3.3
Speed Limit in Adjacent Sections = 30,40 mph
Through_vs_Local = Through
Speed-Related Injury rate was varied keeping other variables constant.

		Speed-Related Injury Rate				
User	Case Study	average	25% above	45% above	90% above	100% above
12	18	35	35	35		
21	18	35	35	35	35	35
22	18	35	35	35	30	30
28	18	30	30	30	25	25
31	18	35	35	30	30	
32	18	35	35	35	30	30
38	18	30	25	25	25	25
45	18	35	35	35	35	35
48	18	35	35	35	35	30

<u>Case Study 20:</u>
85^{th} percentile speeds = 42 mph
50^{th} percentile speeds = 37 mph
Roadside Hazard Rating = 5
Development = Commercial
Ped_Bike = High
Parking = No
Overall Injury Rate = 50% above average

Speed-Related Injury Rate = 40% above average
Length = 2.8 miles
Signals per mile = 2.1
Through_vs_Local = Through
Adjacent speed limits were varied keeping other variables constant.

		Adjacent Speed Limits			
User	Case Study	20,30	30,40	40,45	45,50
12	20	40	40	40	40
21	20	40	40	40	40
22	20	35	40	40	40
28	20	35	35	40	40
31	20	30	35	40	40
32	20	35	35	35	35
38	20	30	30	30	30
45	20	40	40	40	40
48	20	40	40	40	40

APPENDIX J

SUMMARY NOTES FROM DECEMBER 15-16, 2005 EXPERT PANEL MEETING IN WASHINGTON, D.C.

GENERAL DISCUSSION OF ALL VARIABLES

One expert panel member (Expert 6) strongly felt that lane width and design speed should be considered. Others did not agree. Some felt that since design speed is usually correlated with operating speed, there is no need to consider design speed in addition to operating speed. The expert also noted that he had used USLIMITS and found that generally the program was not sensitive to any variables except the 85th percentile speed. Expert 5 indicated Expert 6 may not have tested USLIMITS with the full range of variables and considerations such as heavy pedestrian activity in urban centers – in such conditions, Expert 5 felt that USLIMITS recommends speed limits below the 85th percentile speed.

Based on the results of the web-survey, the research had team suggested that speed limits (SL) on roads with high ped-bike activity should not exceed 35 mph. Most expert panel members did not agree with such a blanket restriction. They felt that speed limits on roads with high ped-bike activity can be higher than 35 mph depending on crash statistics and the separation between motorized and non-motorized traffic.

Expert 6 argued that parking turnover is important, i.e., information about parking present/absent is not sufficient.

One expert panel member (Expert 10) argued that some States do not post sections higher than 45 mph if it has a curb and gutter due to a directive from FHWA. However, Expert 5 said that he was not aware of any such directive from FHWA. Further discussion revealed that based on AASHTO design requirements and the requirements for 3R projects adopted by some states requires a shoulder for speeds above 45 mph, thus to use a curb and gutter section for speeds above 45 mph may require a design exception.

DISCUSSION OF INDIVIDUAL VARIABLES

Crash information

The research team spent a significant amount of time discussing this variable because safety is a very important issue related to operating speeds.

Expert 6

Expert 6 strongly felt that 3 years of data are not sufficient (in a smaller urban area) to determine if a particular section is a high-crash location. He suggested that at least 5 years data are required.

Expert 9

Expert 9 argued that 3 years of crash data are sufficient (in larger urban areas). Expert 9 would be willing to reduce the speed limit if crash rate is 50% higher than the average.

Expert 8

Expert 8 indicated that he will be reluctant to increase the current speed limit if the crash rate is above average. He said that his decision rules are different for increasing versus decreasing the speed limit.

Expert 7

Expert 7 said that three years of crash data are sufficient. However, he needs to know if crashes are speed-related before deciding on the appropriate speed limit.

Expert 4

Expert 4 supported the approach used by Expert 8. He felt that any crash value above the statewide average should be considered in deciding on the speed limit.

Expert 5

Expert 5 felt that it is important to look at the trends in crash rates apart from the average value in the last 3 years. For expert 5, if crash rate was above the critical rate, then he would post the speed limit at the median speed; if crash rate was above average, but below the critical rate, he would post at the 85^{th} percentile speed, rounded-down to the nearest 5 mph increment.

Expert 3

Expert 3 felt that there was a need to look at crash types apart from just the overall number of crashes.

Expert 1

Expert 1 felt that it may be useful to look at single-vehicle run-off-road crashes apart from the overall crash rate.

Expert 11

If the crash rate is 67% (or more) above average, and the current posted speed limit is equal to the 85^{th} percentile speed, then Expert 11 would agree to reduce the posted speed limit by 5 mph. If the crash rate is 67% above average, but the current posted speed limit is less than the 85^{th} percentile speed, he would not lower the speed limit.

85^{th} percentile and Median speed

There was some discussion about how these parameters should be defined. For both these parameters, we could consider free-flowing traffic only, or all traffic. Most experts seem to be in favor of including all traffic. If it is not possible for the user to collect 24 hour speed data, the experts felt that the expert system should provide guidelines on how to collect this data.

Most experts agreed that Tuesday through Thursday seemed to be the preferred days of the week for collecting speed data.

Regarding the use of median speed, there was some discussion about rounding-up or rounding-down to the nearest 5 mph increment. Expert 5 and Expert 11 argued against rounding down unless the difference between the median speed and the nearest 5 mph increment is 1 mph or less. For example, they argued that if the median speed is 31 mph, they would be willing to post a section at 30 mph; however, if the median speed is 32 mph or higher, 30 mph would be too low for that section, and they will not be willing to post below 35 mph for that section.

Terrain

This variable did not seem to be a critical variable for most participants. Expert 6 argued that in States where cars and trucks have uniform speed limits, there may be a need to reduce speed limits in two-lane mountainous roads if truck volumes are high. Expert 6 felt that it would be important to look at the 15^{th} percentile speeds for these sections.

Interchanges per mile

Most of the experts felt that this variable is correlated with crash statistics, and hence need not be considered separately.

Ped-Bike Activity

Expert 6 argued that the effect of ped-bike activity on speed limit depends on the separation of these non-motorists from the regular traffic. Expert 6 also felt that the number of lanes and the presence of median refuge should make a difference in such sections. Expert 5 tends to recommend speed limits close to the median speed for sections with high ped-bike activity.

Parking

Expert 6 noted that parking turnover is important. He felt that there is a need to define parking activity as rare, common, or consistent.

Expert 11 suggested that parking activity will be correlated with operating speed, and hence there is no need to consider this variable unless there are a significant number of parking-related crashes.

One expert argued that on multilane roads with parking, one should only consider the operating speeds on the right most lanes – others did not agree with this suggestion.

Roadside Hazard Index

Some of the traffic engineers in the panel suggested not using the word ‘hazard’ in this variable due to the possible legal implications that this may invoke.

Expert 6 felt that this variable could be important if reliable crash data are not available. Expert 11 indicated that he will need information on run-off-road crashes before making use of the roadside hazard index in reducing the speed limit.

Most of the experts felt that we may not need 7 categories for this variable. They felt that 6 and 7 could be combined into one category; similarly, 4 and 5 could be combined into one category.

CASE STUDIES

Six case studies were presented by the research team to the experts on Friday. The cases were drawn from actual speed limit studies made on a variety of road types with different factors. Each expert was asked to recommend a speed limit and to indicate why they made the decision.

Freeway

Existing SL = 55 mph
2 mile section
Adjacent SLs = 50, 70 mph
85th percentile speed = 65, 66 mph
Median speed = 60, 61 mph
Below average crash rate

Recommended speed limit by each expert

Expert 1: 65 mph
Expert 2: 65 mph
Expert 3: 65 mph
Expert 4: not present
Expert 5: 65 mph
Expert 6: 65 mph
Expert 7: 65 mph
Expert 8: 65 mph
Expert 9: 65 mph
Expert 10: 65 mph
Expert 11: not present

Conclusion: For freeway sections with below average crash rates, the speed limit could be posted closest to the 85th percentile value. Although this was a short (2 mile) section, the section length and speed limits posted on the adjacent sections were not considered important.

Two-lane Undeveloped

5 mile section
85th percentile: 62-63 mph
Median: 57 mph
25% of crashes are deer crashes
Statutory limit = 55 mph
Current SL = 55 mph
Below average crash rate
Undivided road

Recommended speed limit by each expert:

Expert 1	60 mph
Expert 2	55 mph
Expert 3	60 mph
Expert 4	55 mph
Expert 5	60 mph
Expert 6	60 mph
Expert 7	60 mph
Expert 8	60 mph
Expert 9	60 mph
Expert 10	60 mph

Conclusion: For undivided roads, there seems to be reluctance to go to 65 mph even though the 85th percentile speed is 62-63 mph and crash rates are below average. It looks like experts where rounding down the 85th percentile speed to the nearest 5 mph increment because the road is undivided. On the other hand, two experts felt that the posted limit could not exceed the statutory limit (absolute maximum speed limit set by law) for that state.

Four-lane Undeveloped

3 mile section
85th percentile speed = 63 mph
50th percentile speed = 58 mph
Adjacent speed limits = 35, 55 mph
Undivided road

Recommended speed limit by each expert based on information about crash rates

	Below average crash rate	Crash rate is 30% above average, but below critical rate	Crash rate is 70% above average, and above critical rate
Expert 1	60 mph	55 mph	55 mph
Expert 2	60 mph	55 mph	55 mph

Expert 3	60 mph	55 mph	55 mph
Expert 4	45 mph	--	--
Expert 5	65 mph	60 mph	60 mph
Expert 6	60 mph	60 mph	55 mph
Expert 7	60 mph	55 mph	55 mph
Expert 8	60 mph	55 mph	55 mph
Expert 9	60 mph	60 mph	60 mph
Expert 10	60 mph	60 mph	60 mph

Conclusion: Again, since the road is undivided, experts seem to be rounding down the 85th percentile speed and/or choosing the closest 5 mph to the median speed even if the crash rate is below average (expert 4 is considered an outlier here). When the crash rate was 30% above average, 5 out of the 9 experts reduced the recommendation to 55 mph, although this implies that they are rounding down the median speed, which many of the experts were not in favor of during the initial discussion. For crash rate of 70% above average, 6 out of the 9 experts recommended 55 mph. Overall, there is disagreement among the experts about how to deal with sections with high crash rates.

Two-lane urban commercial

1 mile
Existing SL = 35 mph
Adjacent SL = 35, 25 mph
85th percentile speed = 31, 32 mph
Median speed = 26 mph
ADT = 12,000 – 13,000
Parking on both sides of the road. There is pedestrian activity.
Crash rate is below average. Almost no injuries.

Recommended speed limit by each expert

Expert 1	30 mph
Expert 2	25 mph
Expert 3	30 mph
Expert 4	--
Expert 5	25 mph
Expert 6	30 mph
Expert 7	30 mph
Expert 8	25 mph
Expert 9	25 mph
Expert 10	30 mph

Conclusion: Almost half the experts voted for 30 mph, while the other half voted for 25 mph. Those that voted for 30 mph argued that there is no need to reduce the speed limit below the 85th percentile speed since crash rates are below average. Those that voted for 25 mph felt that roads with parking and ped-bike activity should not be posted higher than the median speed. Most experts added that in the absence of reliable crash information to indicate that the crash rate is below average, they would have voted for a speed limit of 25 mph!

Two-lane Developed

2.5 mile section
5 signals in this section
Existing SL = 25 mph
Adjacent SL = 25, 35 mph
85^{th} percentile = 35, 36 mph
Median = 30, 31 mph
Some ped-bike activity due to parks on one side of the road
Crash rate is below average

Recommended speed limit by each expert

Expert 1	30 mph
Expert 2	30 mph
Expert 3	35 mph
Expert 4	--
Expert 5	35 mph
Expert 6	35 mph
Expert 7	35 mph
Expert 8	35 mph
Expert 9	35 mph
Expert 10	35 mph

Conclusion: 35 mph was the consensus. With crash rate below average and not much of ped-bike or parking activity, most went with the 85^{th} percentile speed. Expert 1 went with 30 mph because the speed limit in one of the adjacent sections was 25 mph.

Four-lane developed with TWLTL

2 mile section
Adjacent SL = 35, 40 mph
Existing SL = 40 mph
85^{th} percentile speed = 41-42 mph
Median = 35-36 mph
ADT = 40,000 – 42,000
Low Ped-Bike
Crash rate was 50% above average
Injury rate was 60% above average
Fatalities concentrated at one intersection

Recommended speed limit by each expert

Expert 1	35 mph
Expert 2	40 mph
Expert 3	40 mph
Expert 4	30 mph
Expert 5	40 mph
Expert 6	40 mph
Expert 7	40 mph
Expert 8	40 mph
Expert 9	40 mph
Expert 10	40 mph

Conclusion: Most seem to be in favor of a 40 mph limit which is closest to the 85th percentile value although crash rates are high – the fact that fatalities are concentrated at one intersection seemed to influence the experts not to reduce the speed limit as a countermeasure.

CLOSURE

Concluding comments from expert panel members regarding the meeting and the project

Expert 1

The program goal is very good i.e., to strive towards consistency and uniformity in setting speed limits. Similar roads in similar conditions in different parts of the country should have the same speed limits. Realistic limits must be based on factual data. Speed limits in adjacent sections should be considered.

Expert 2

The program should be usable by technicians and not a cumbersome tool. It may be better to focus on the median speed instead of the 85th percentile speed in some cases. It is should be user friendly.

Expert 3

It may be useful if the program allows the user to decide which factors are important and to weight the factors. For example, if a particular user feels that crash statistics or presence of pedestrian and bicycle activity is more important than the 85th percentile speeds, then the program should allow this.

Expert 4

It is important to include non-practitioners in the mix when decision rules are developed.
The program should not just focus on the 85th percentile speed. If the program is set up just to raise speed limits, it looses credibility. It is important to include safety and other factors and the process should not be driven by the 85th percentile speed.

Expert 5

The research team needs to obtain data on average crash rates for city streets to use as default values in cases where the jurisdiction does not have comparison data. Average crash rates for state maintained roads could be obtained from the Highway Safety Information System.

Expert 6

Unlike USLIMITS, the program should indicate which factors are more important than others when decisions are made regarding the recommended speed limit. Regression analysis may not always be a reasonable approach to analyzing the web-based case studies due to correlation among some variables.

Expert 7

The program needs to distinguish between crashes that could be corrected by engineering treatments versus crashes that could be corrected by changes in speed limits. One may need national crash rates for comparison data. The program should also show information that has been considered in the decision-making process.

Roads that look similar with similar traffic and surrounding development should have the same posted speed limit.

Expert 8

The tool should aim to move towards consistency in how speed limits are set in different parts of the country.

Expert 9

Guidance is badly needed for practitioners on how to set speed limits. The program should address important factors and instill confidence in the user. He would like to see this procedure become part of the MUTCD.

Expert 10

Results should be engineering driven based on measured facts and not on political considerations. Speed limits should be uniform and consistent. Different engineers should be able to give the same result (posted speed limit) for the same section of road. The regression results presented at the meeting were based on a relatively small sample size and hence not very reliable.

APPENDIX K

FLOW CHARTS ILLUSTRATING DECISION RULES

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.

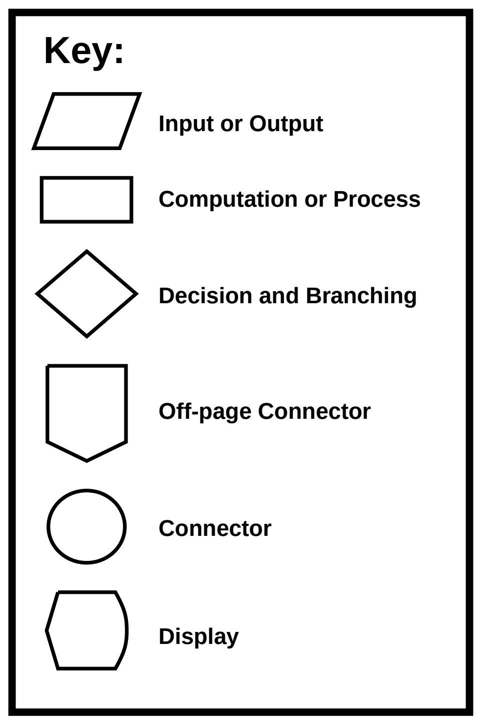
Limited Access Freeway

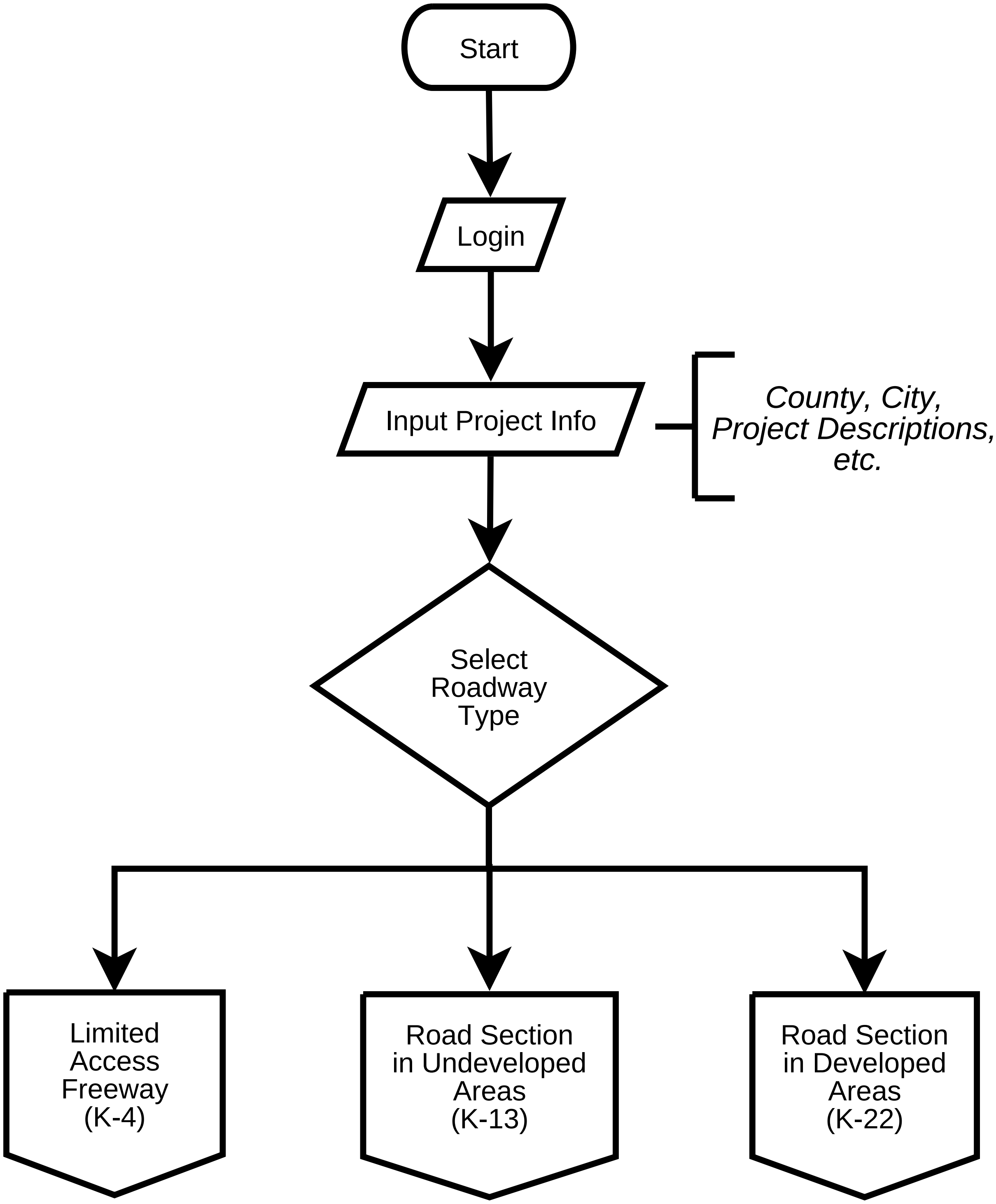
R.S.I.U.A.

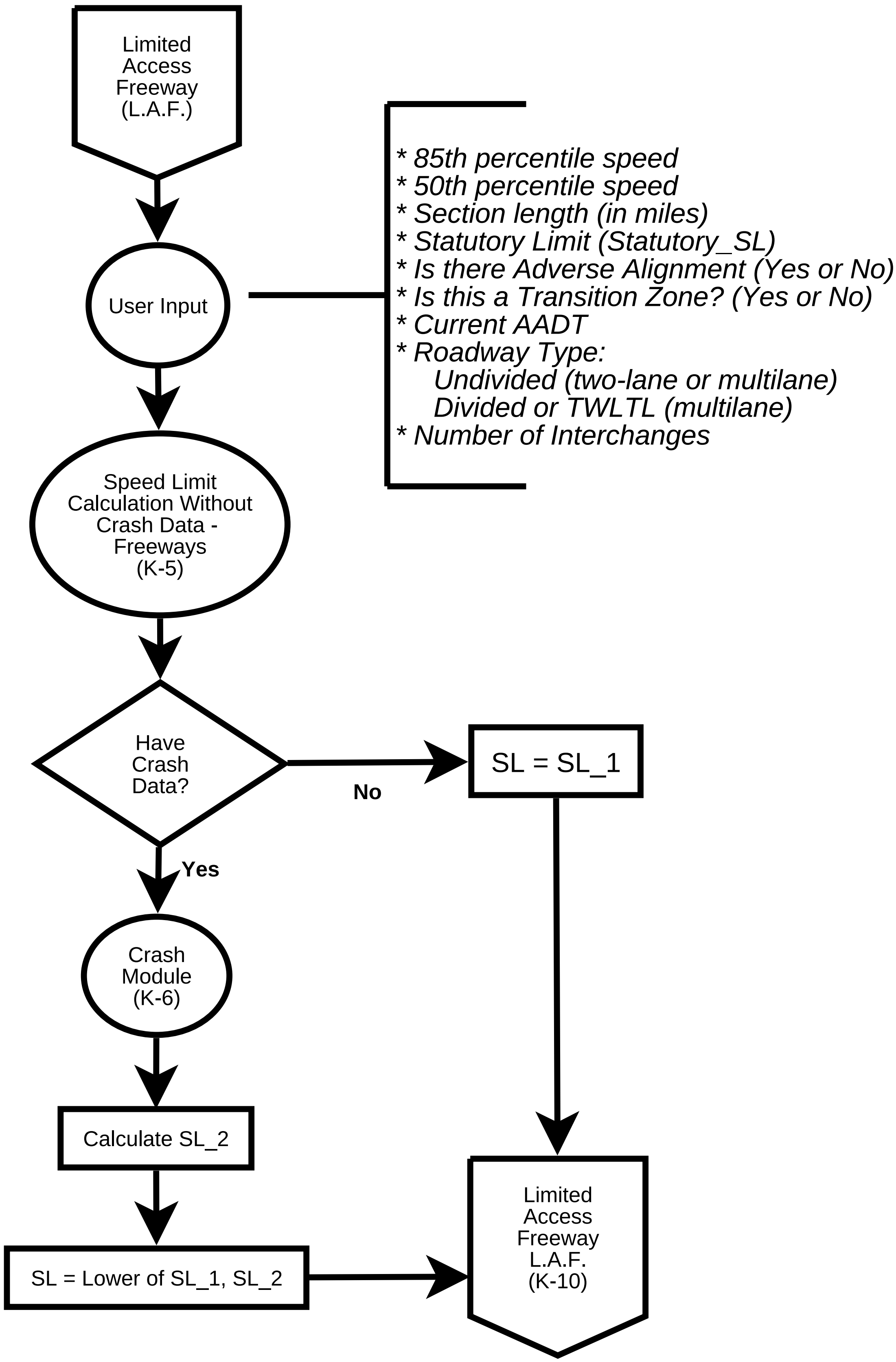
Road Sections in Undeveloped Areas

R.S.I.D.A.

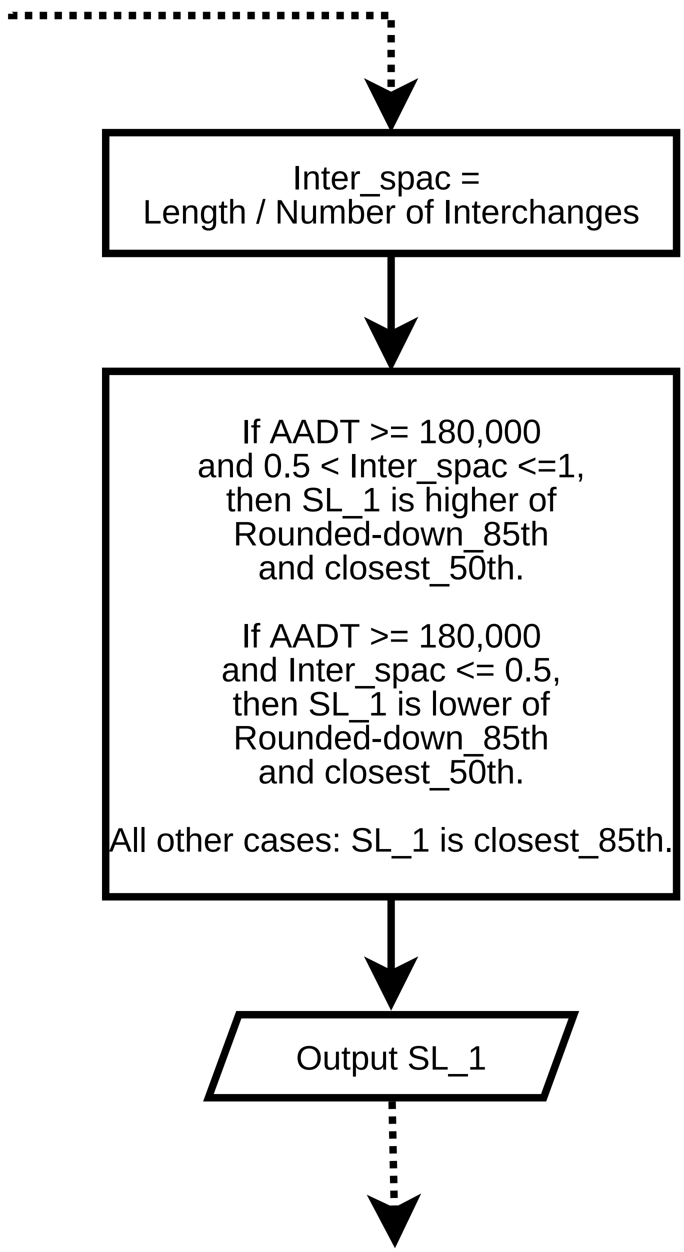
Road Sections in Developed Areas



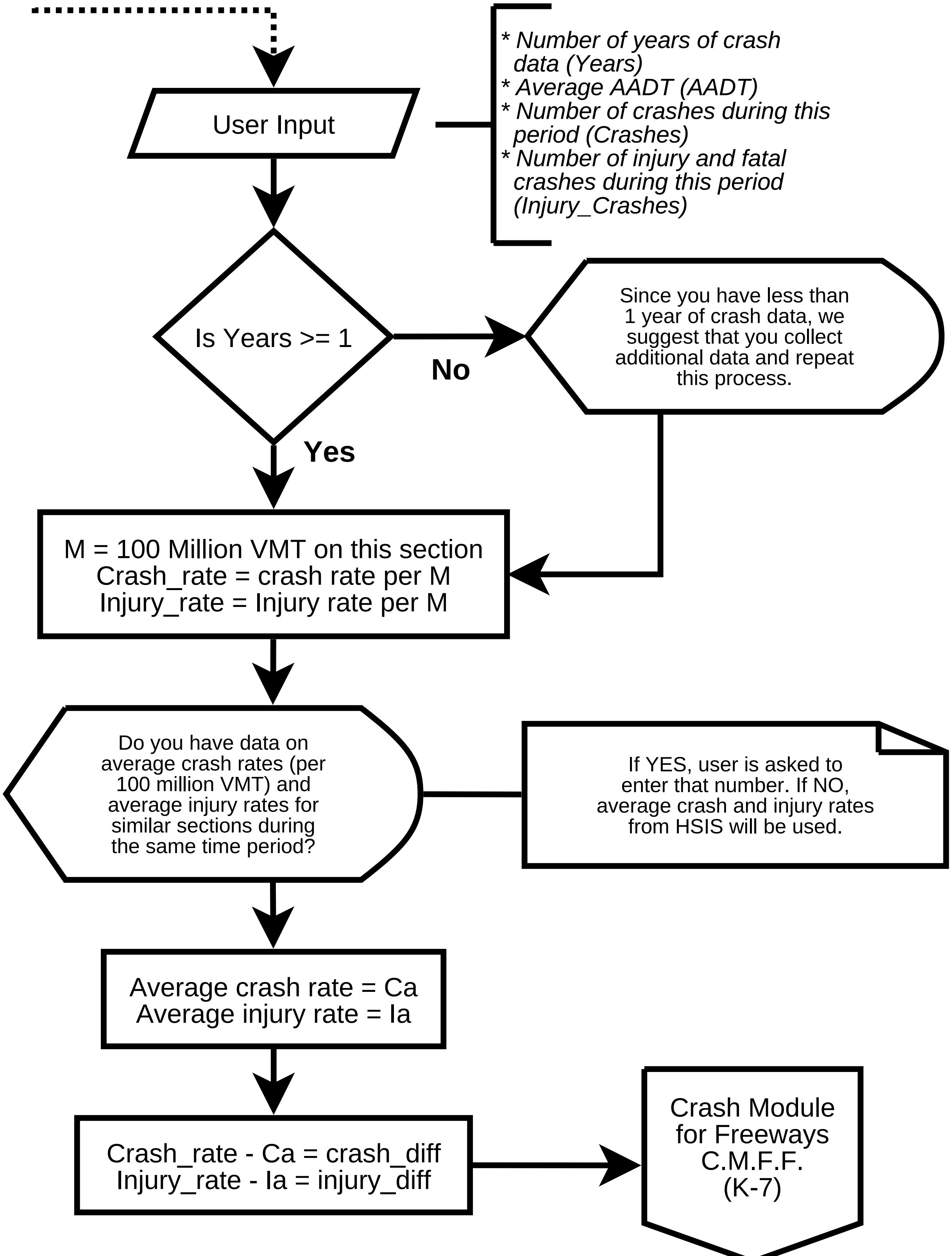

Start
Login
Input Project Info
County, City, Project Descriptions, etc.
Select Roadway Type
Limited Access Freeway (K-4)
Road Section in Undeveloped Areas (K-13)
Road Section in Developed Areas (K-22)

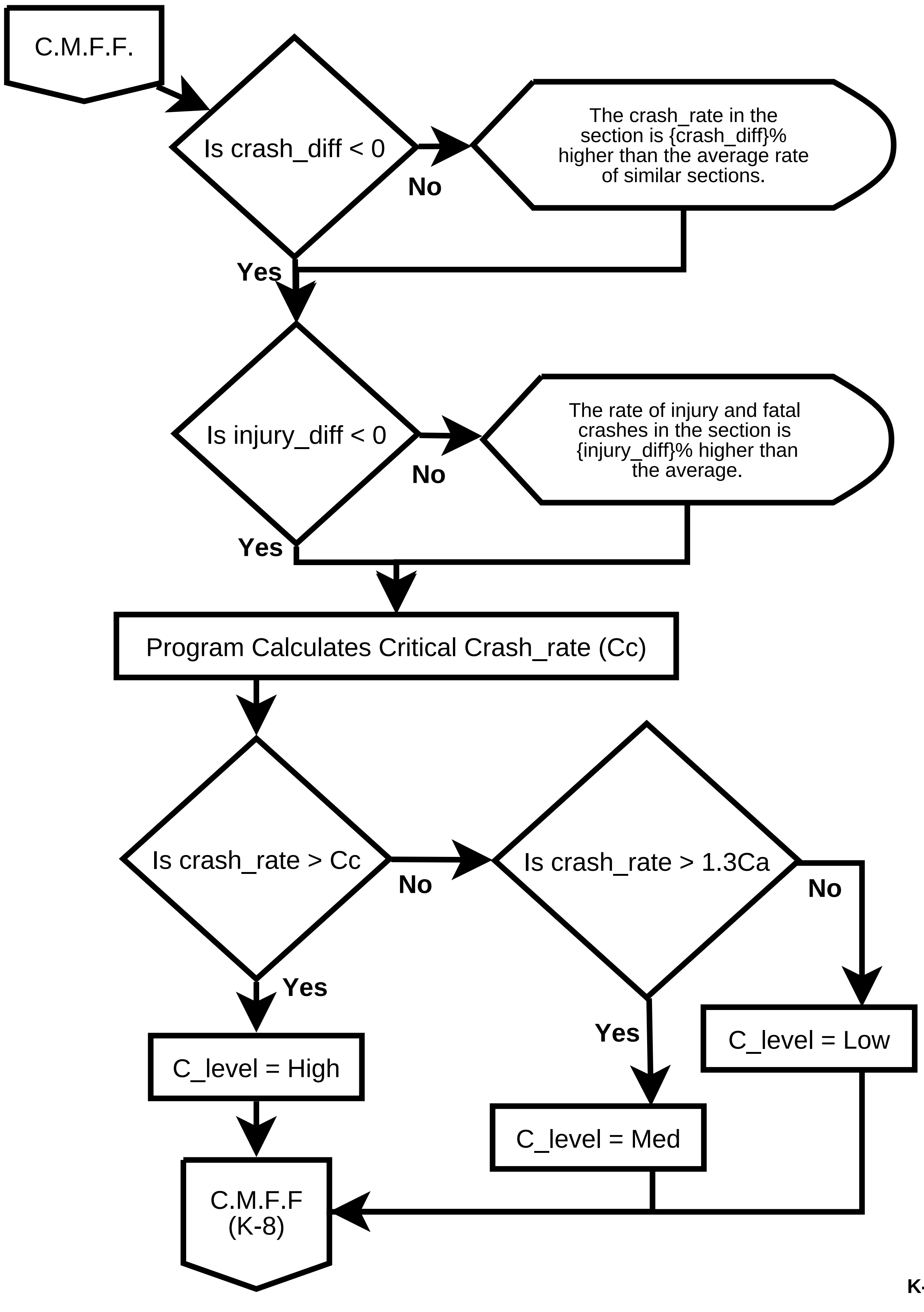

Limited Access Freeway (L.A.F.)
User Input
* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Is this a Transition Zone? (Yes or No)
* Current AADT
* Roadway Type:
Undivided (two-lane or multilane)
Divided 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)

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

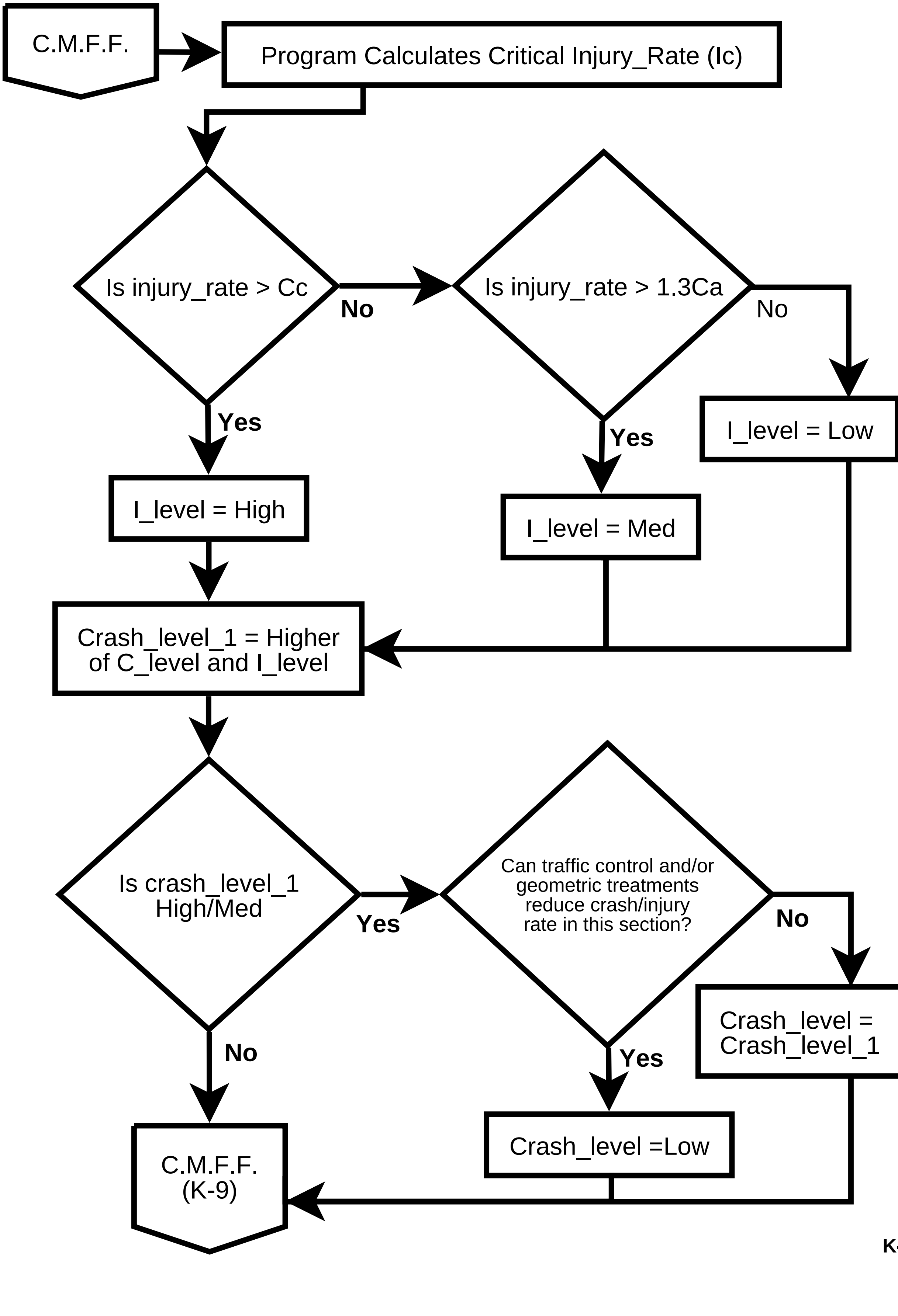


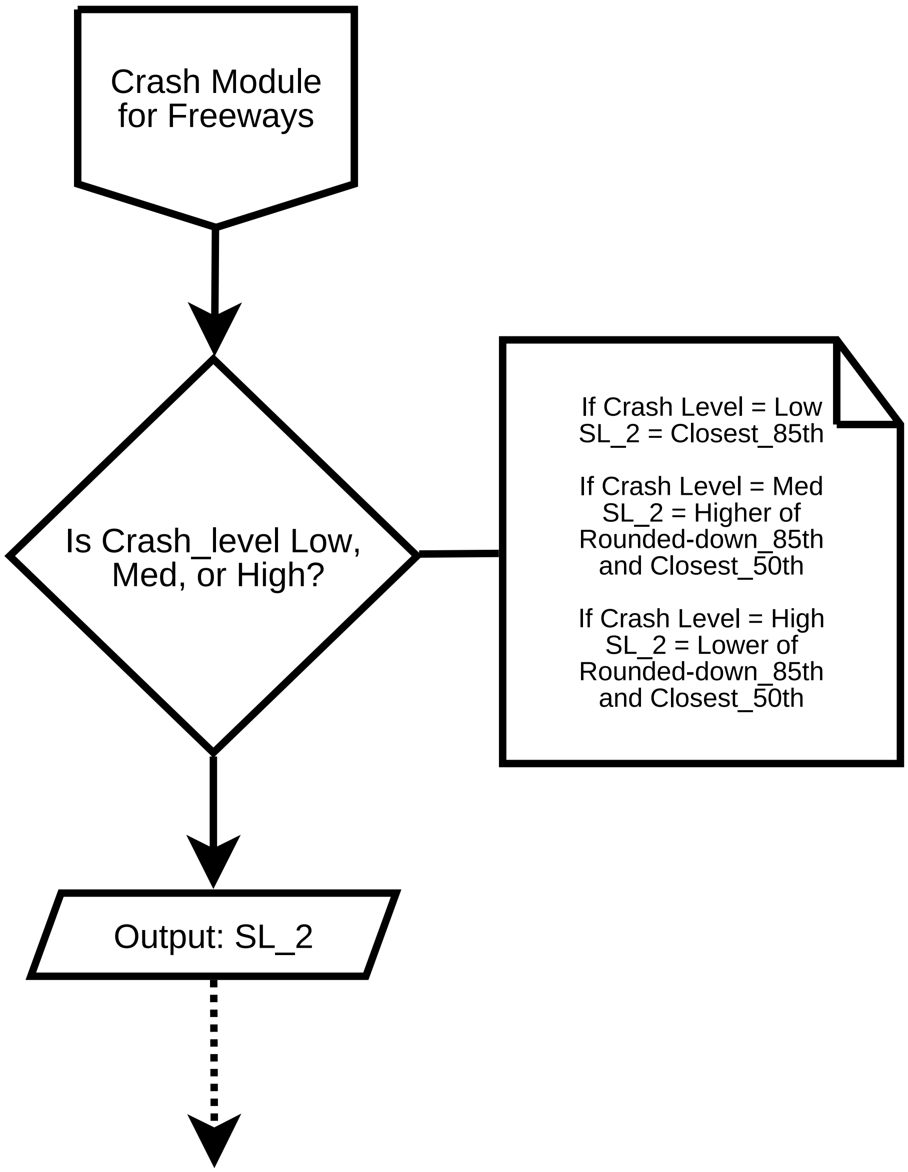
Crash Module for Freeways (to calculate SL_2)

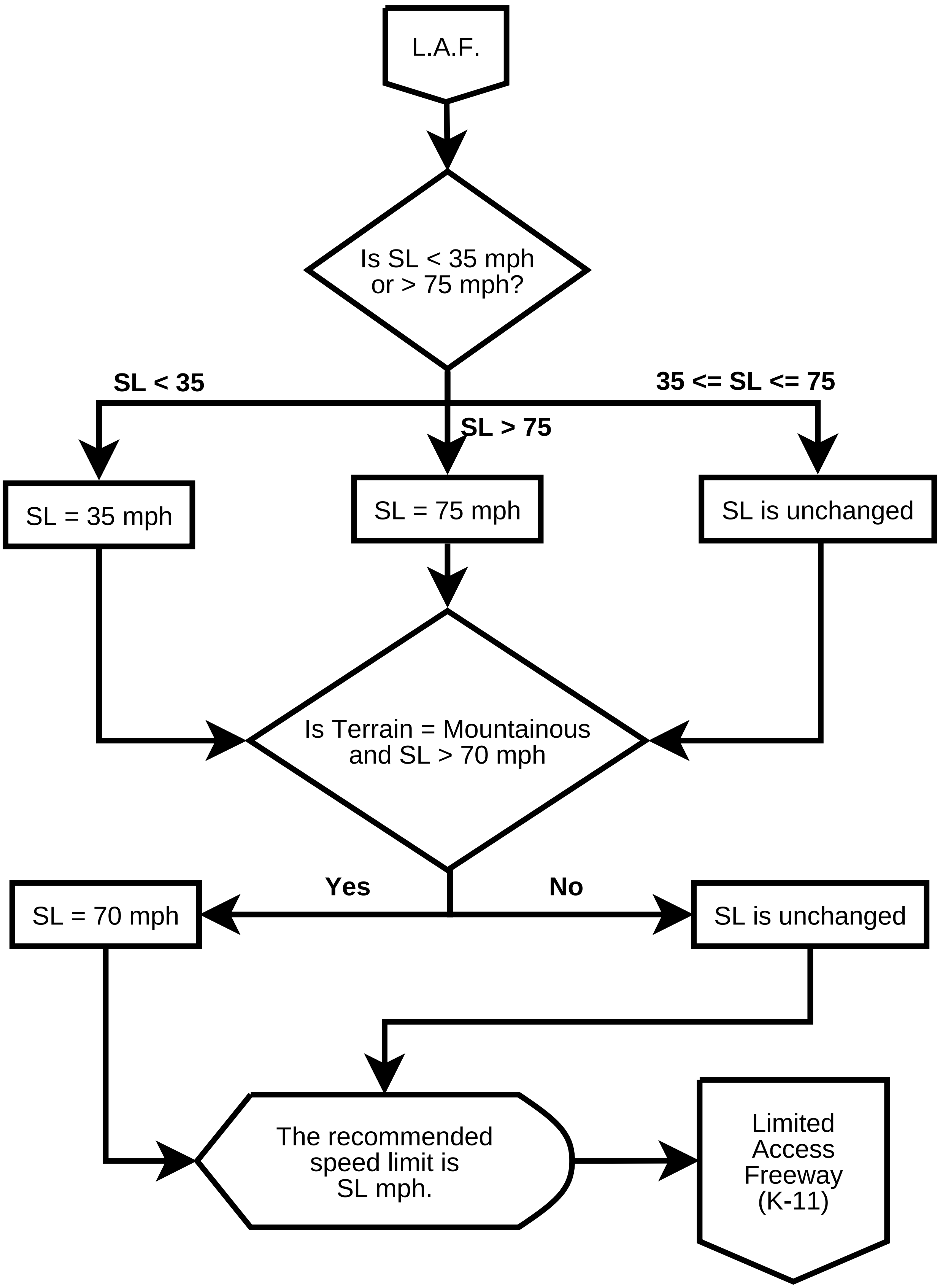


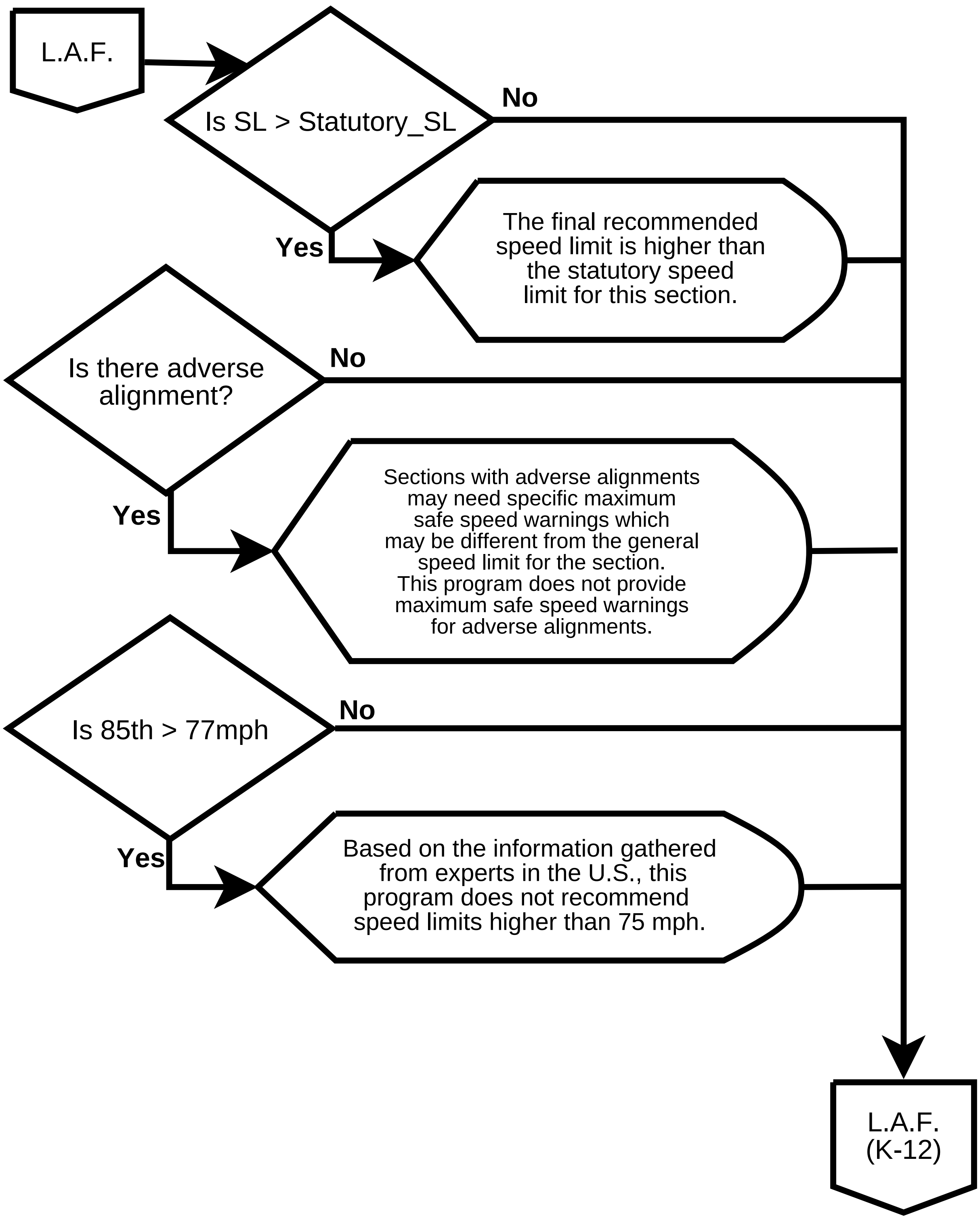


C.M.F.F.
Is crash_diff < 0
No
The crash_rate in the section is {crash_diff}% higher than the average rate of similar sections.
Yes
Is injury_diff < 0
No
The rate of injury and fatal crashes in the section is {injury_diff}% higher than the average.
Yes
Program Calculates Critical Crash_rate (Cc)
Is crash_rate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

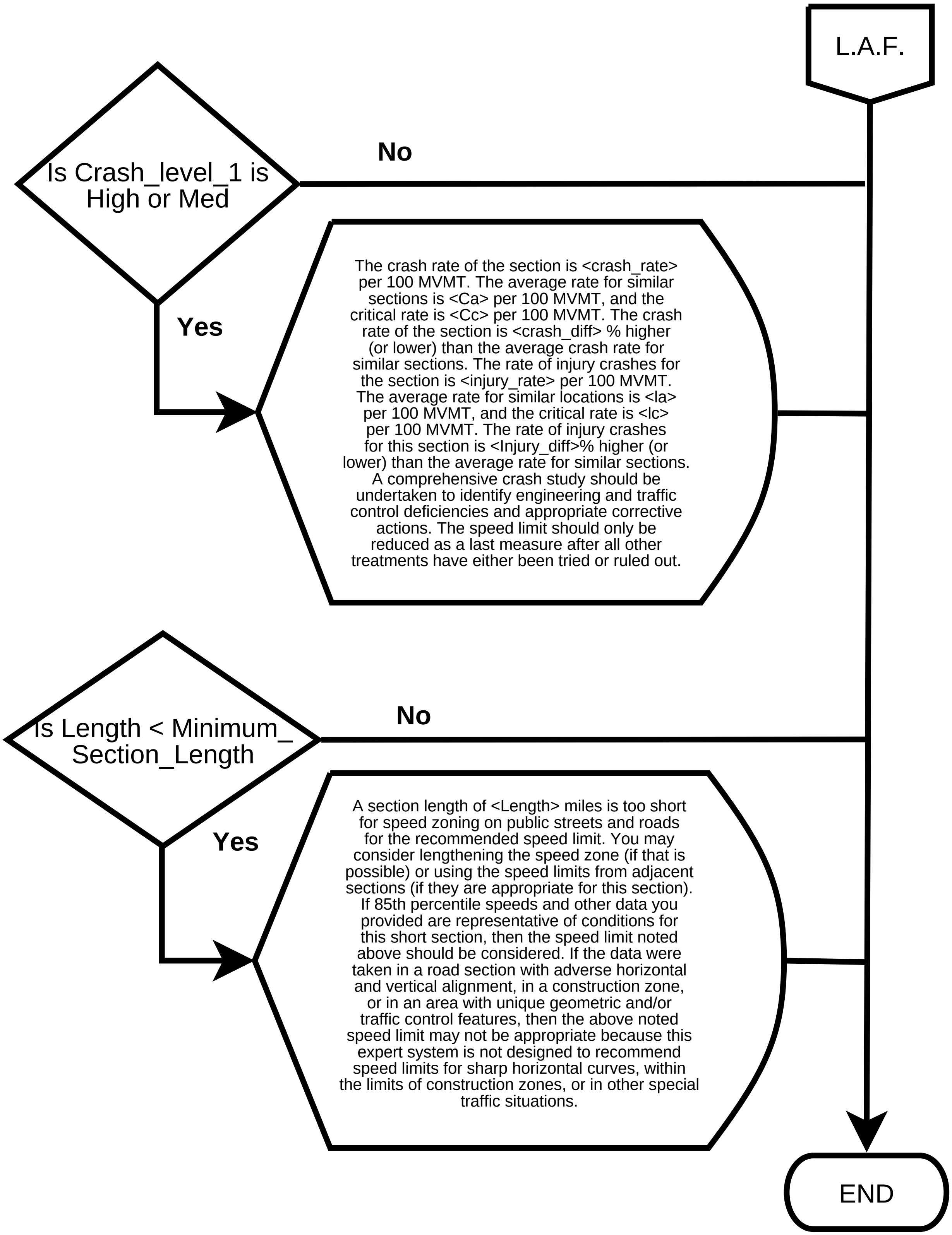

C.M.F.F.
Program Calculates Critical Injury_Rate (Ic)
Is injury_rate > Cc
No
Is injury_rate > 1.3Ca
No
Yes
Yes
I_level = Low
I_level = High
I_level = Med
Crash_level_1 = Higher of C_level and I_level
Is crash_level_1 High/Med
Yes
Can traffic control and/or geometric treatments reduce crash/injury rate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

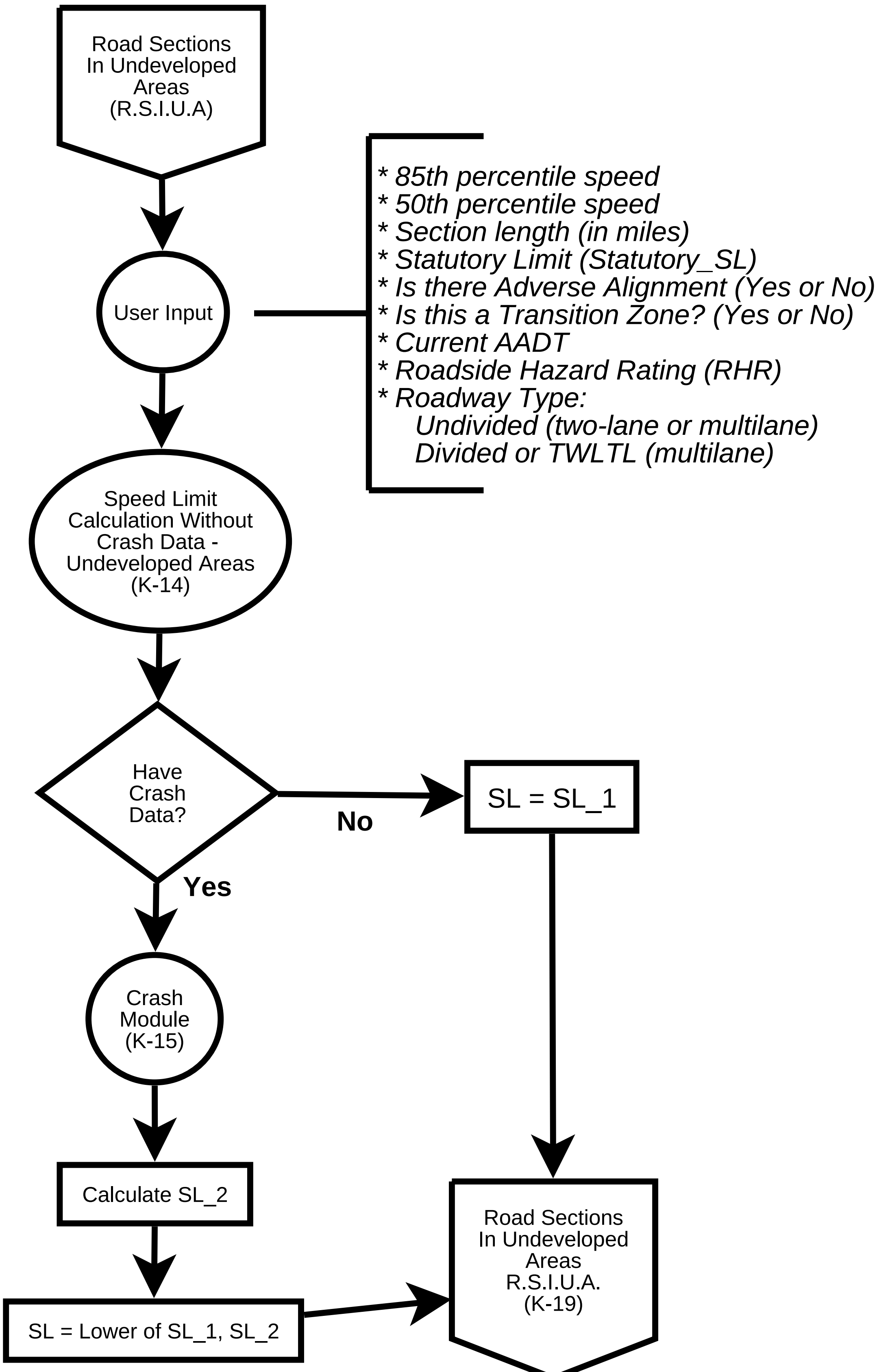

Crash Module for Freeways
Is Crash_level Low, Med, or High?
If Crash Level = Low
SL_2 = Closest_85th
If Crash Level = Med
SL_2 = Higher of Rounded-down_85th and Closest_50th
If Crash Level = High
SL_2 = Lower of Rounded-down_85th and Closest_50th
Output: SL_2


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)



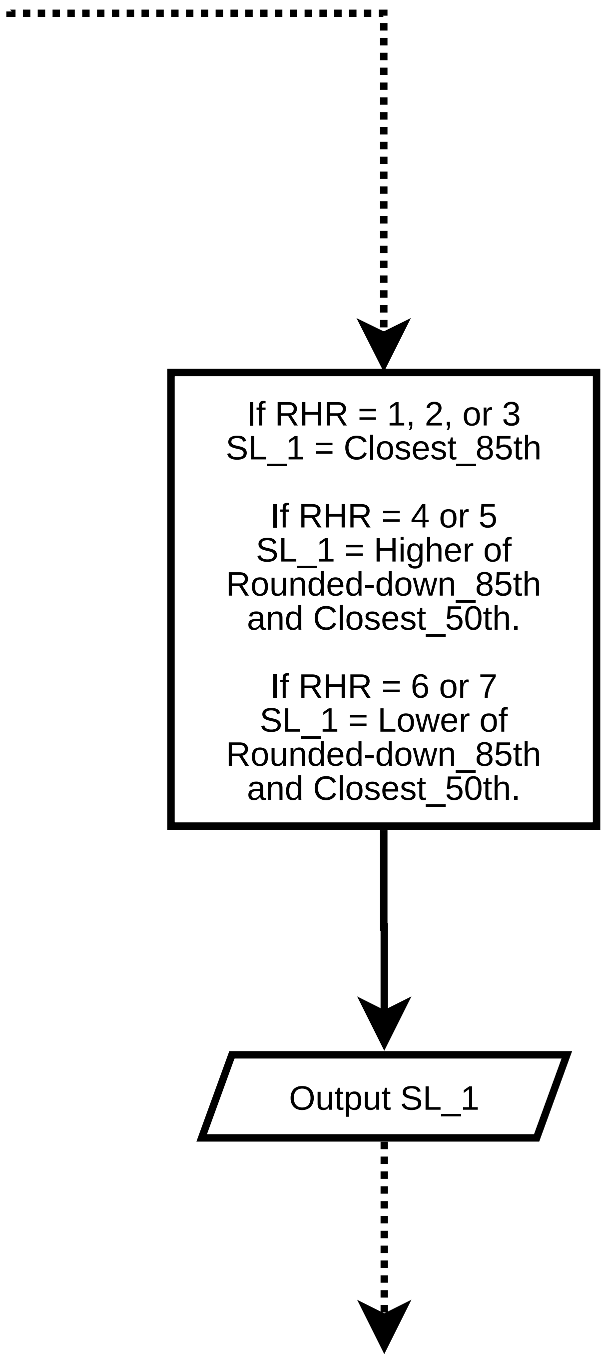
L.A.F.
Is SL > Statutory_SL
No
Yes
The final recommended speed limit is higher than the statutory speed limit for this section.
Is there adverse alignment?
No
Yes
Sections with adverse alignments may need specific maximum safe speed warnings which may be different from the general speed limit for the 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)


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

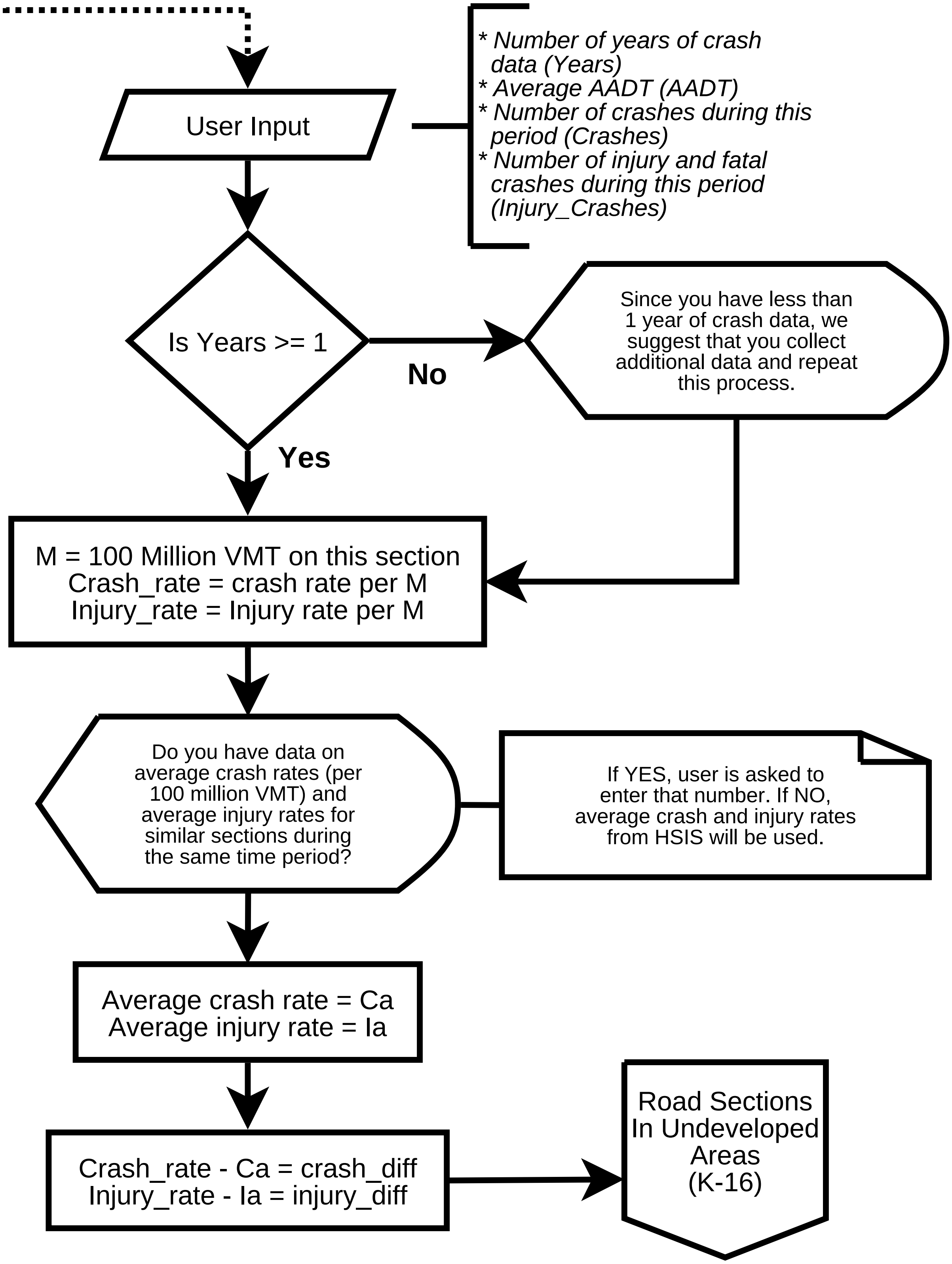


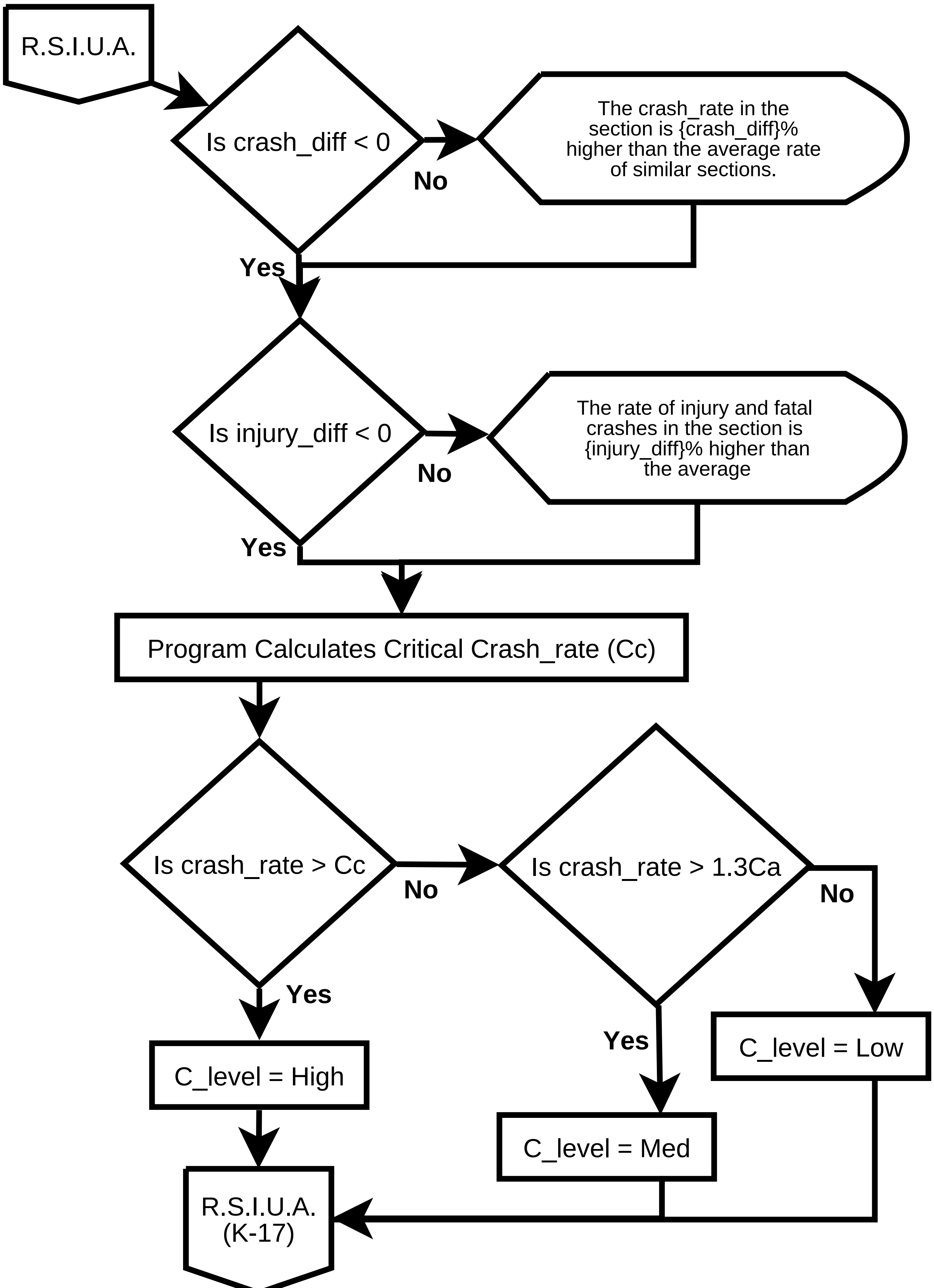
Road Sections In Undeveloped Areas (R.S.I.U.A)
User Input
* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Is this a Transition Zone? (Yes or No)
* Current AADT
* Roadside Hazard Rating (RHR)
* Roadway 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)

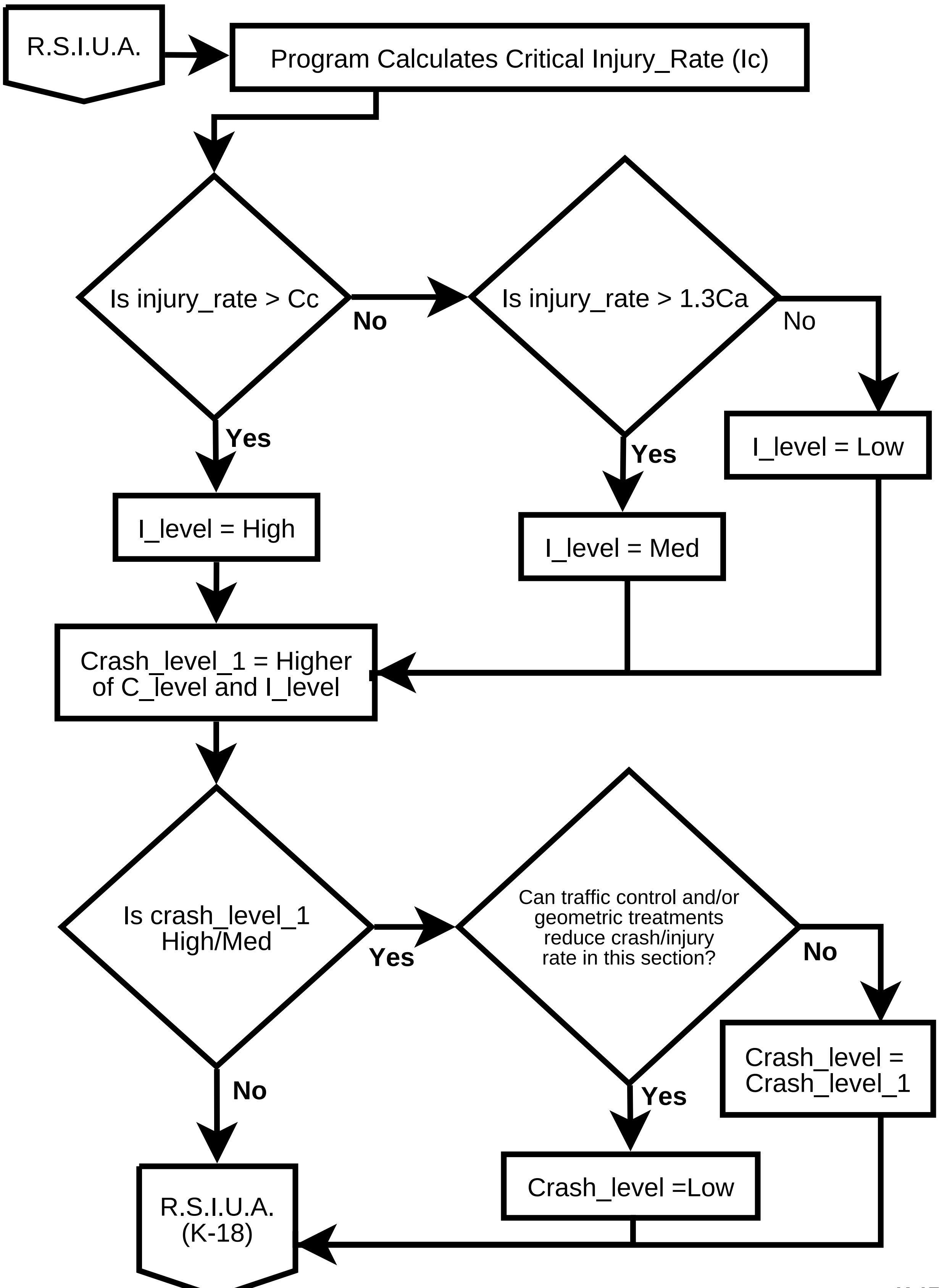
Speed Limit Calculation Without Crash Data (to calculate SL_1)
(Roadway Section In Undeveloped Areas)

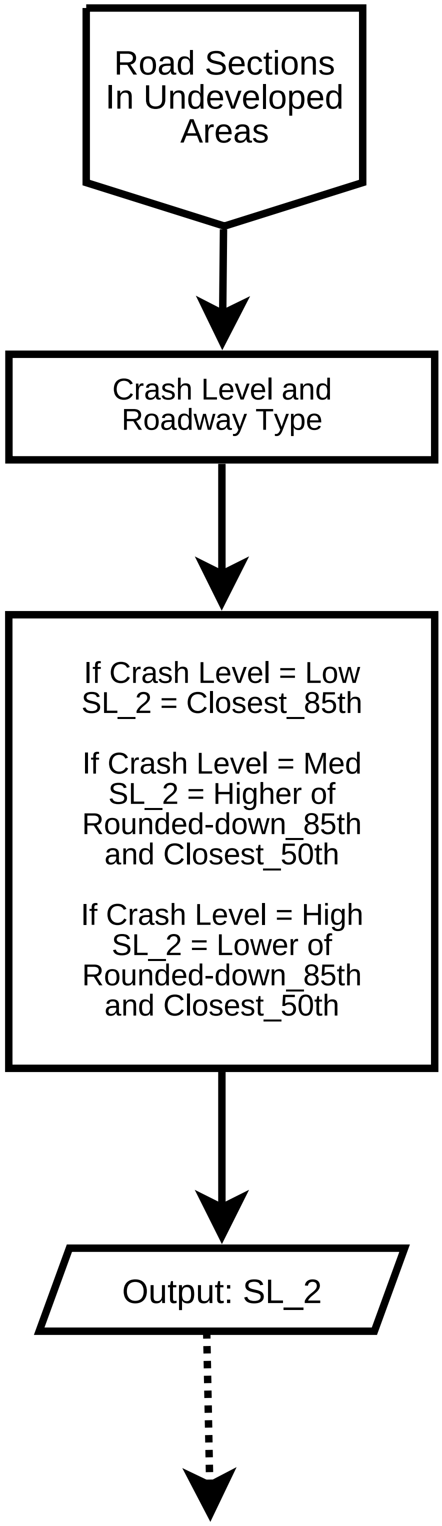


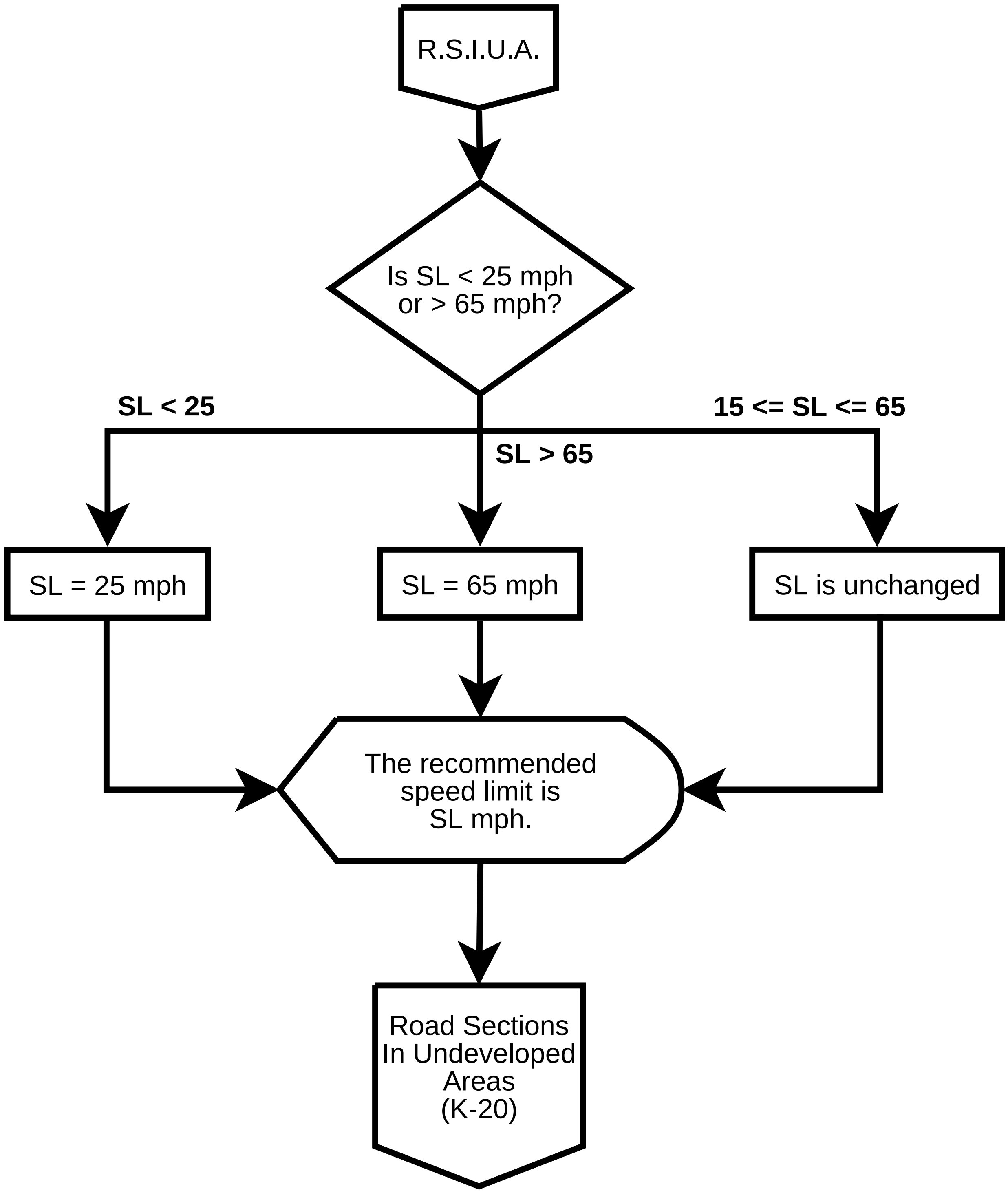
Crash Module for Roads in Undeveloped Areas (to calculate SL_2)

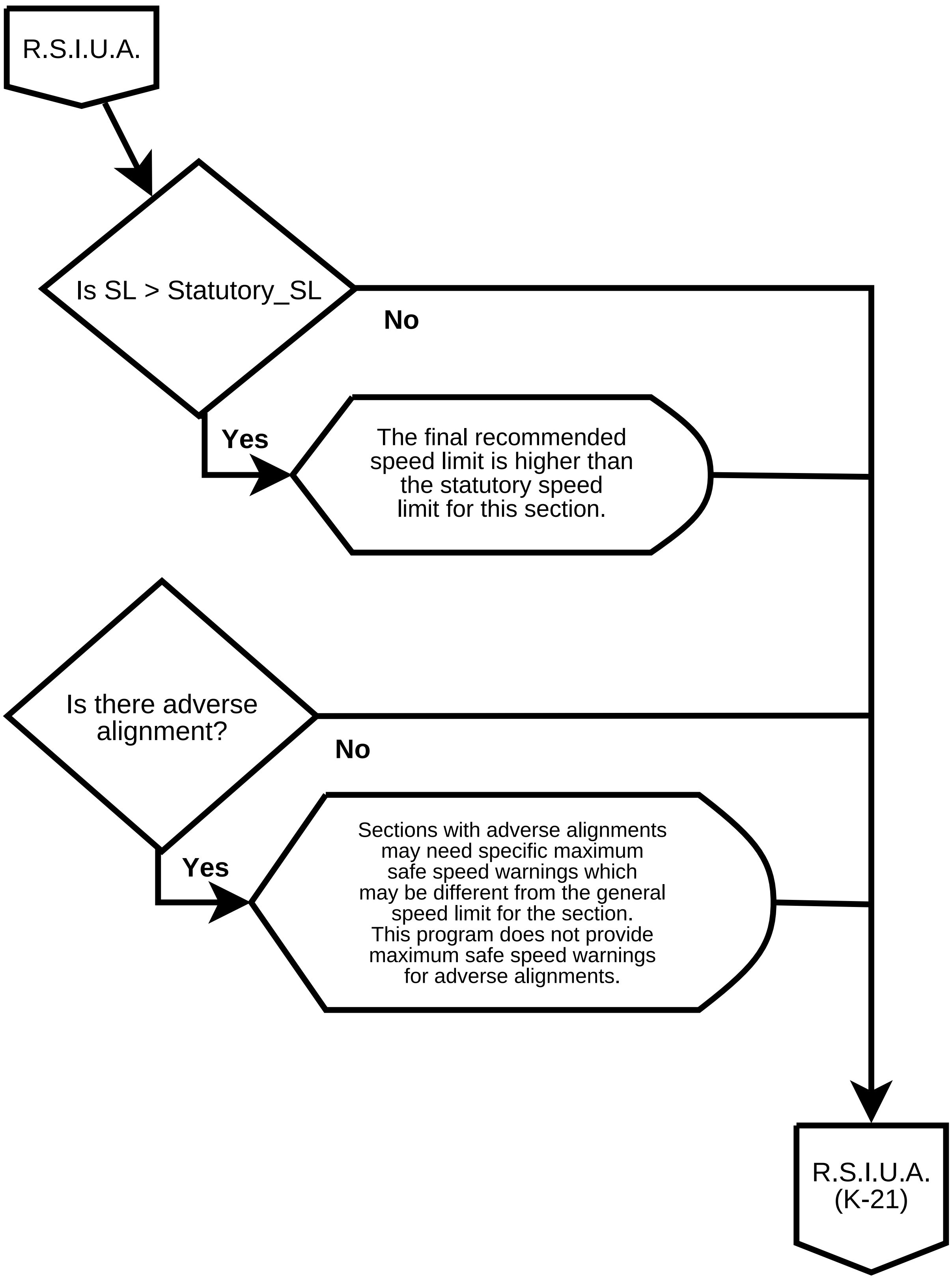


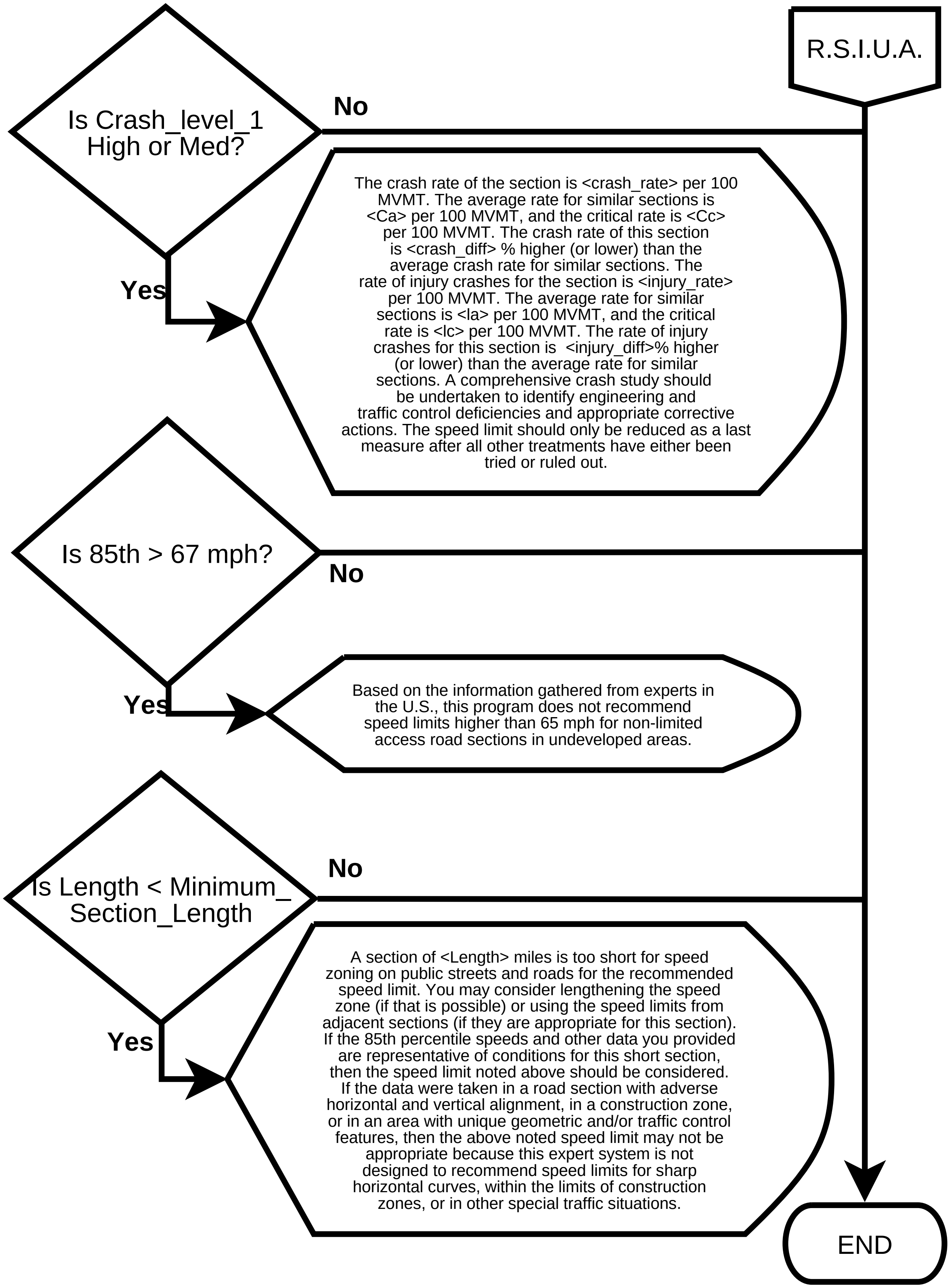

R.S.I.U.A.
Is crash_diff < 0
No
The crash_rate in the section is {crash_diff}% higher than the average rate of similar sections.
Yes
Is injury_diff < 0
No
The rate of injury and fatal crashes in the section is {injury_diff}% higher than the average
Yes
Program Calculates Critical Crash_rate (Cc)
Is crash_rate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

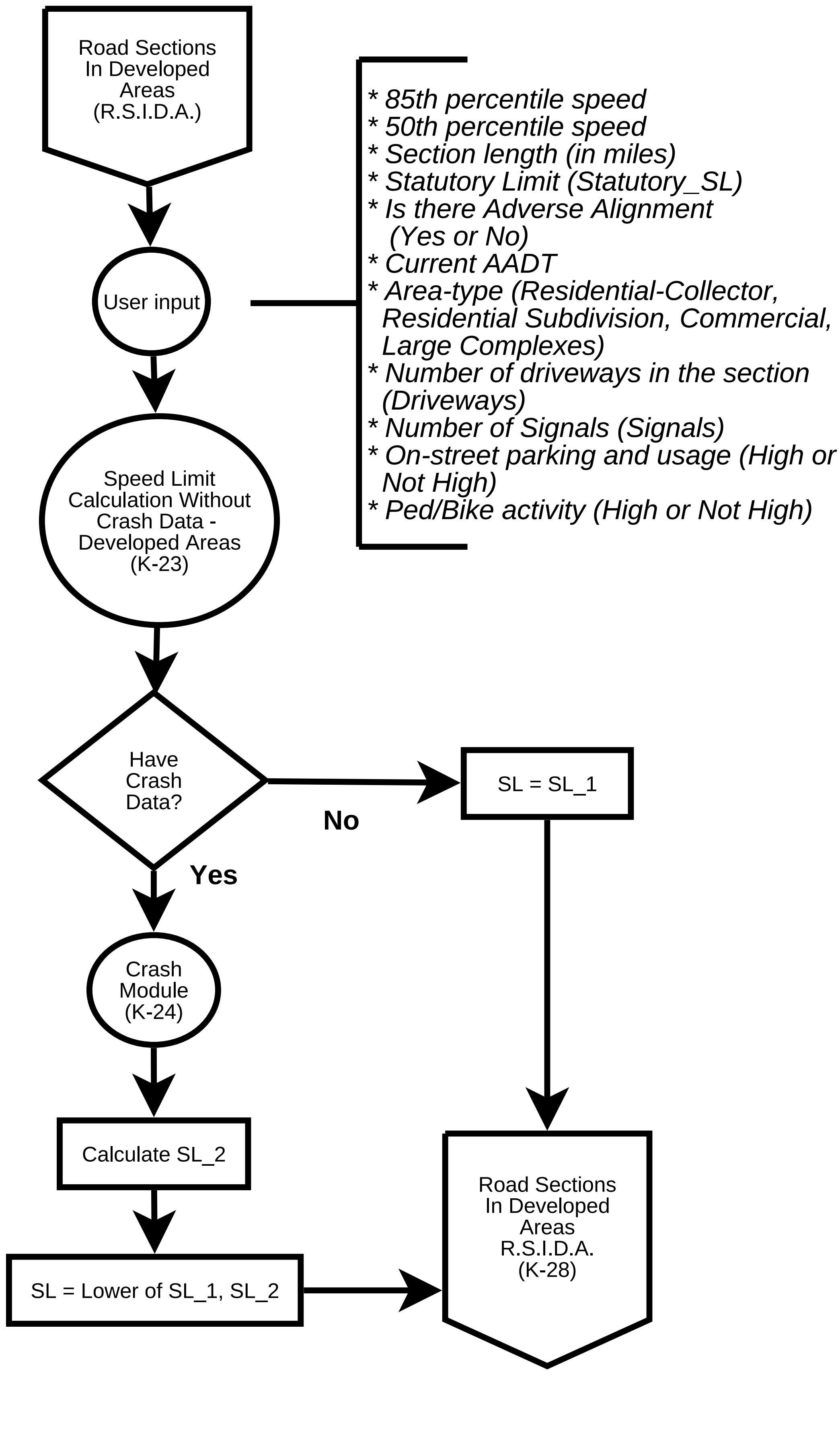

R.S.I.U.A.
Program Calculates Critical Injury_Rate (Ic)
Is injury_rate > Cc
No
Yes
Is injury_rate > 1.3Ca
No
Yes
I_level = High
I_level = Med
I_level = Low
Crash_level_1 = Higher of C_level and I_level
Is crash_level_1 High/Med
Yes
No
Can traffic control and/or geometric treatments reduce crash/injury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


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

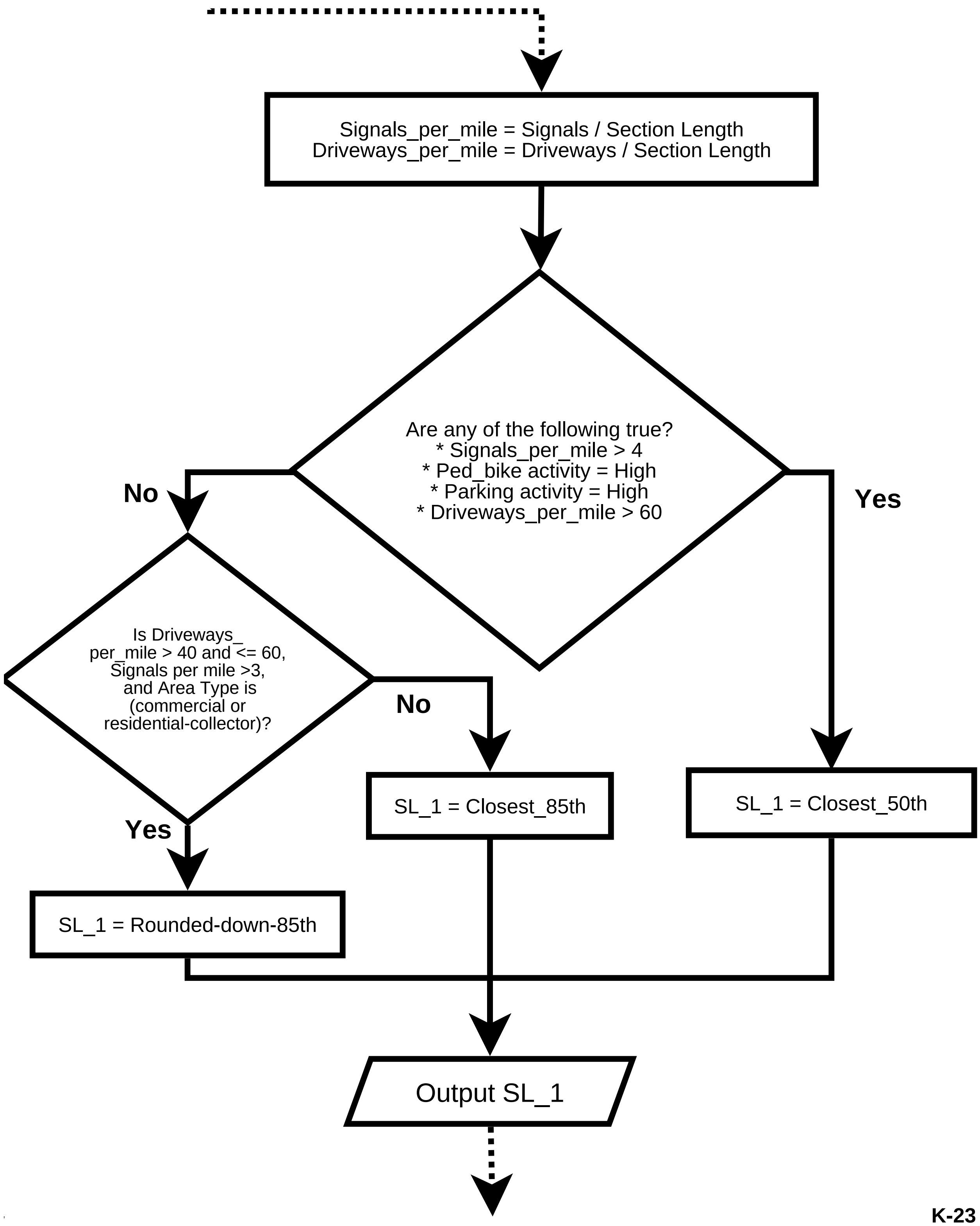

R.S.I.U.A.
Is SL < 25 mph
or > 65 mph?
SL < 25
SL > 65
15 <= SL <= 65
SL = 25 mph
SL = 65 mph
SL is unchanged
The recommended
speed limit is
SL mph.
Road Sections
In Undeveloped
Areas
(K-20)


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)

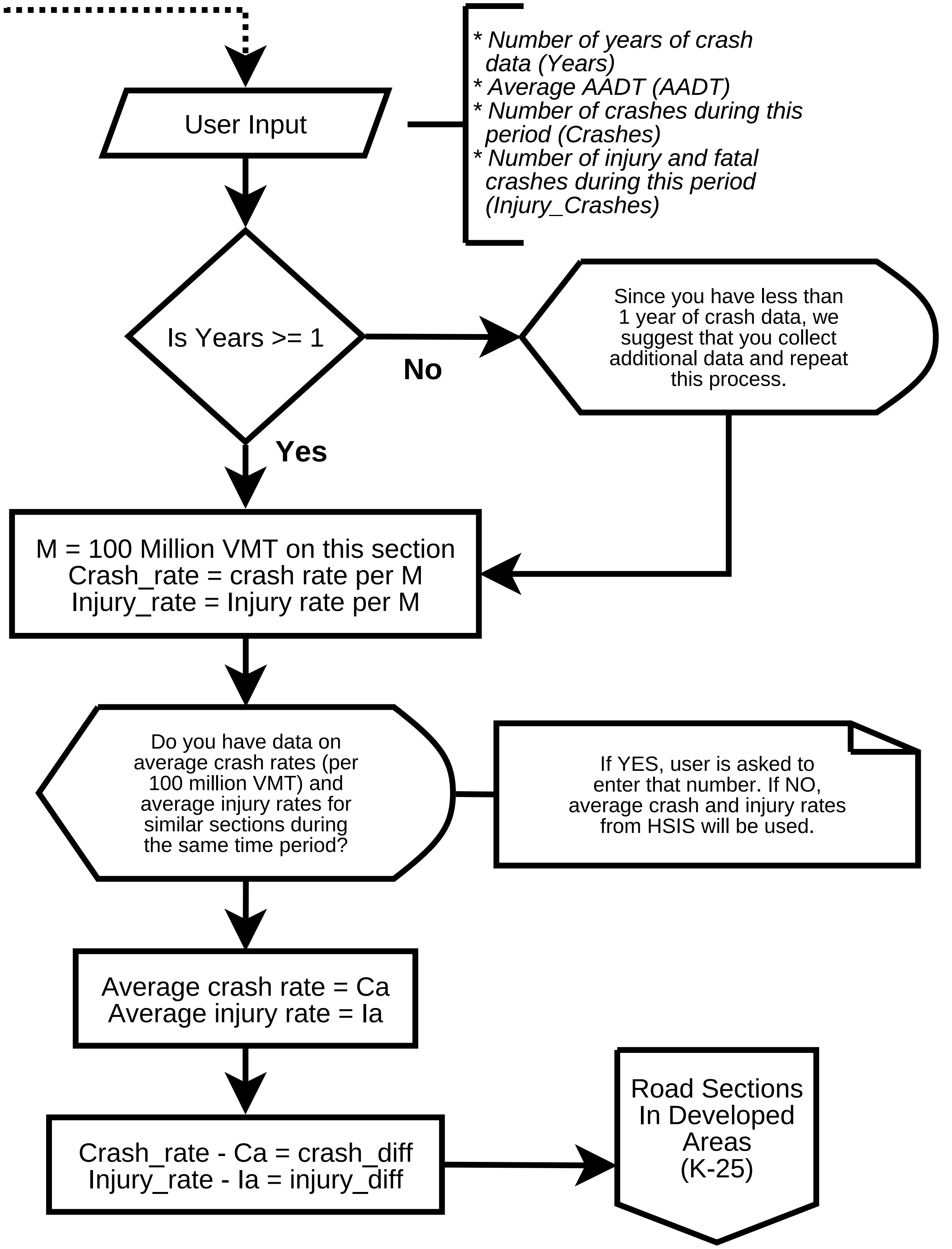

Is Crash_level_1 High or Med?
No
R.S.I.U.A.
Yes
The crash rate of the section is <crash_rate> per 100 MVMT. The average rate for similar sections is <Ca> per 100 MVMT, and the critical rate is <Cc> per 100 MVMT. The crash rate of this section is <crash_diff> % higher (or lower) than the average crash 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

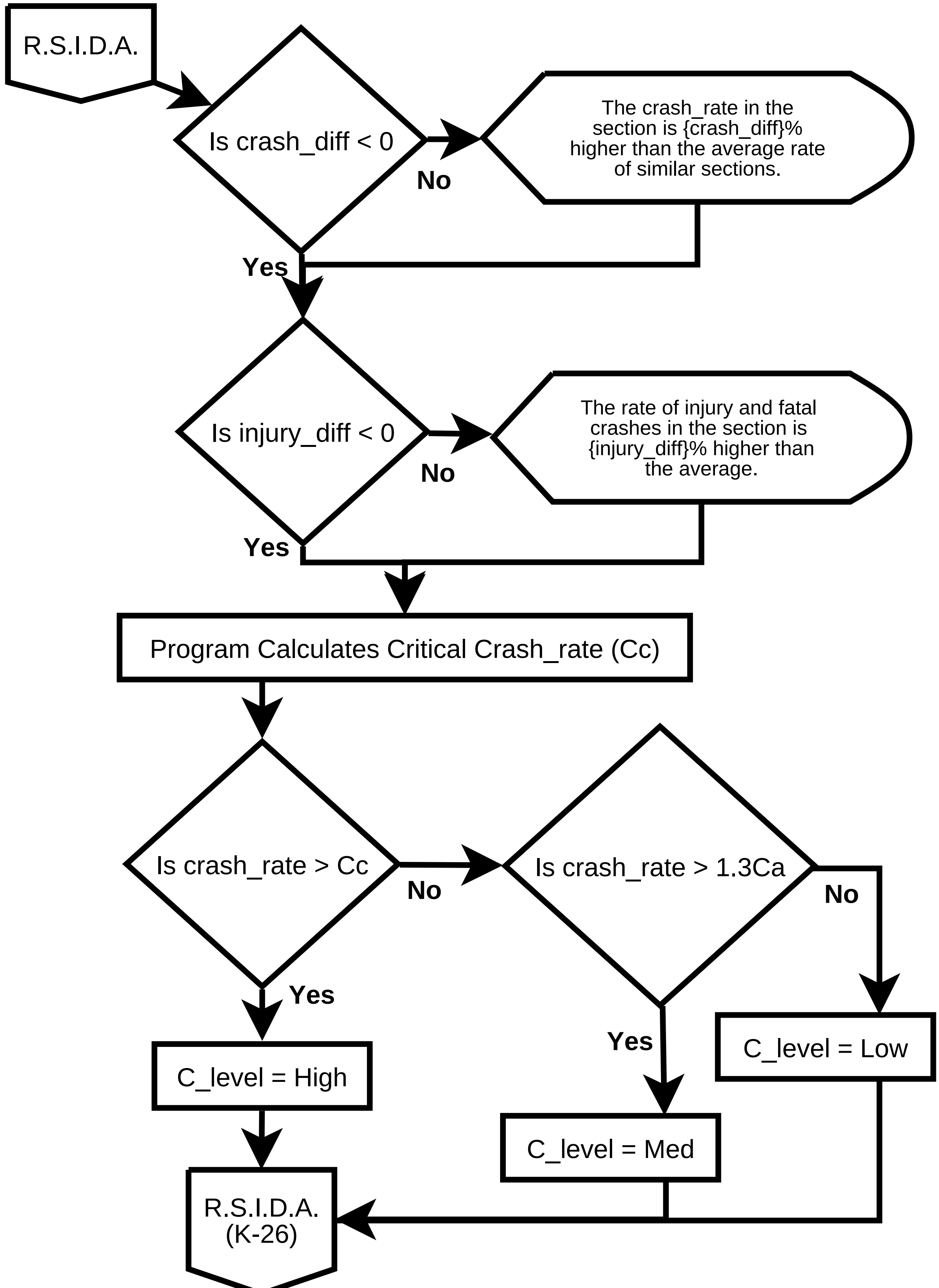

Road Sections In Developed Areas (R.S.I.D.A.)
User input
* 85th percentile speed
* 50th percentile speed
* Section length (in miles)
* Statutory Limit (Statutory_SL)
* Is there Adverse Alignment (Yes or No)
* Current AADT
* Area-type (Residential-Collector, Residential Subdivision, Commercial, Large 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)

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

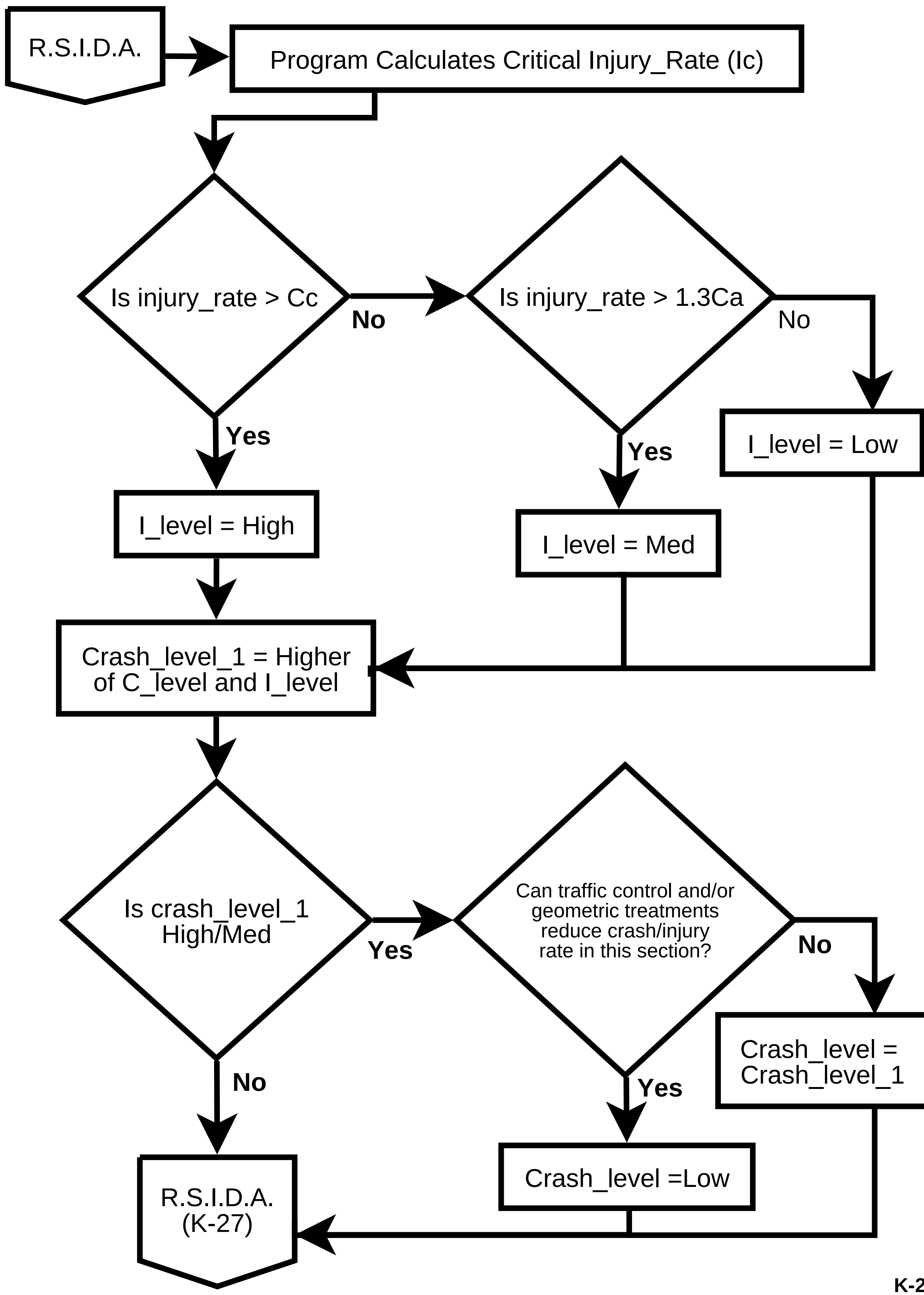


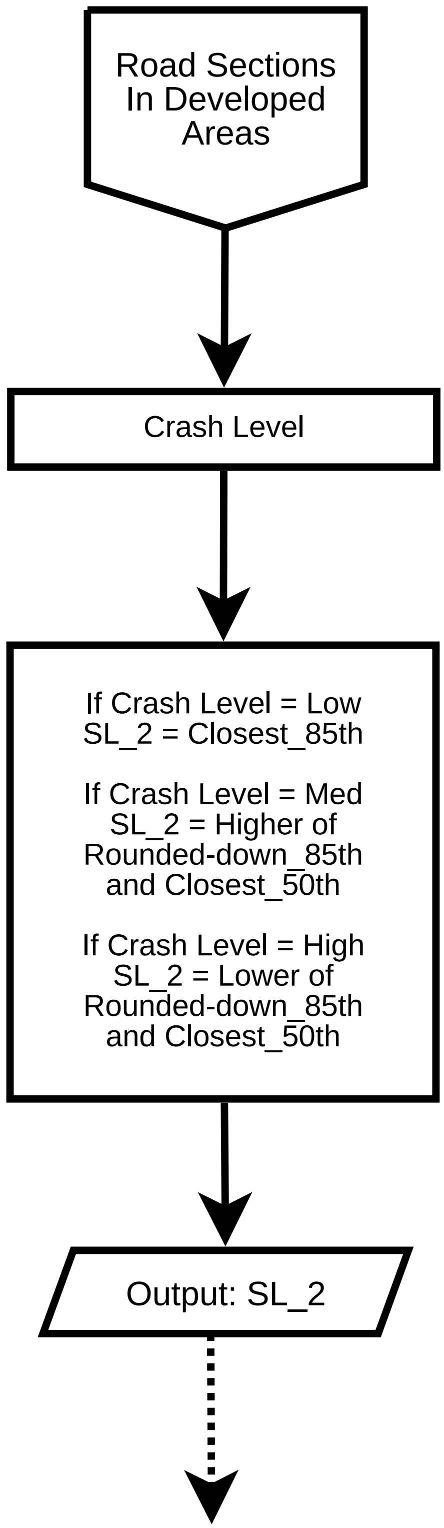
Crash Module for Roads in Developed Areas (to calculate SL_2)

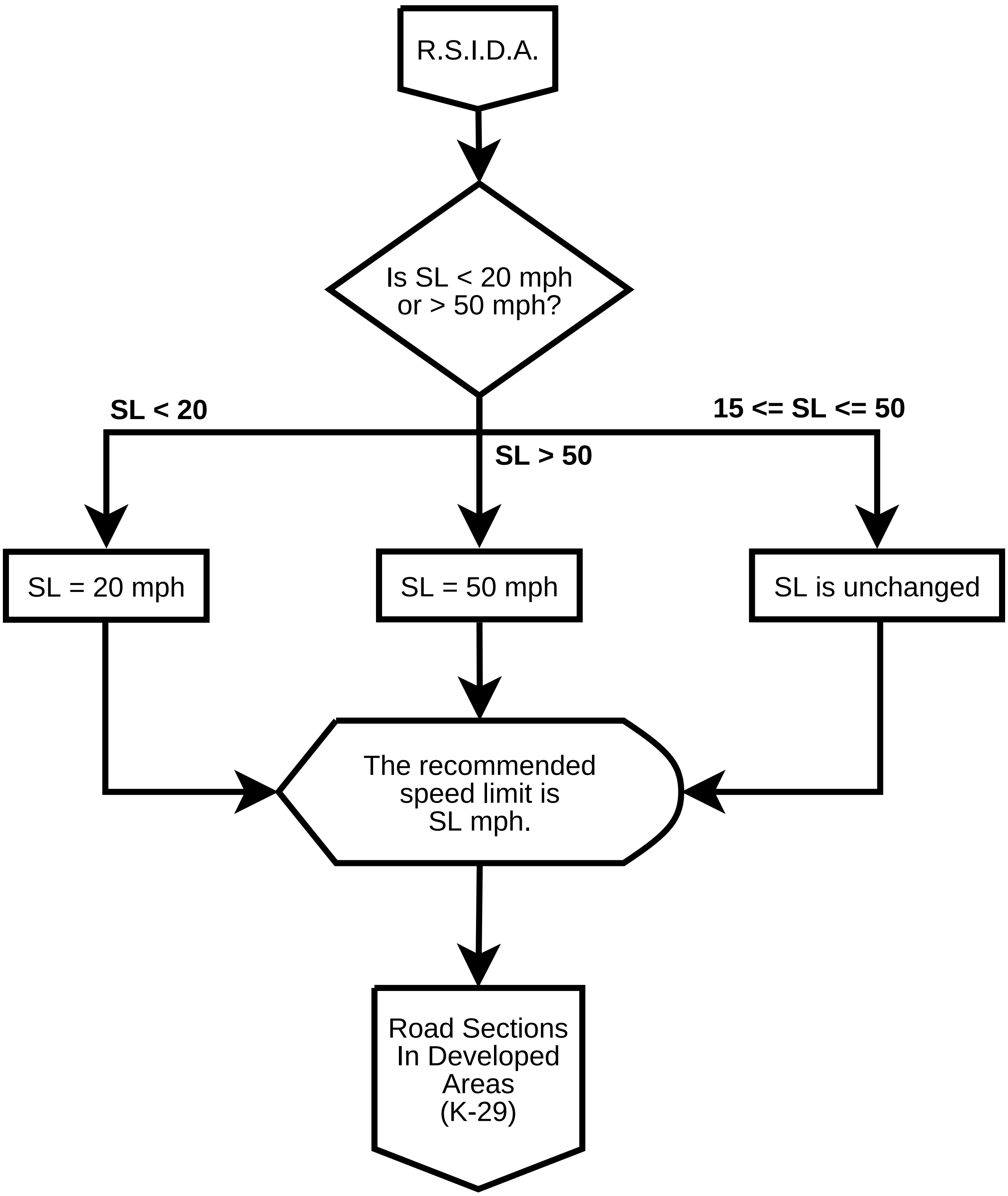


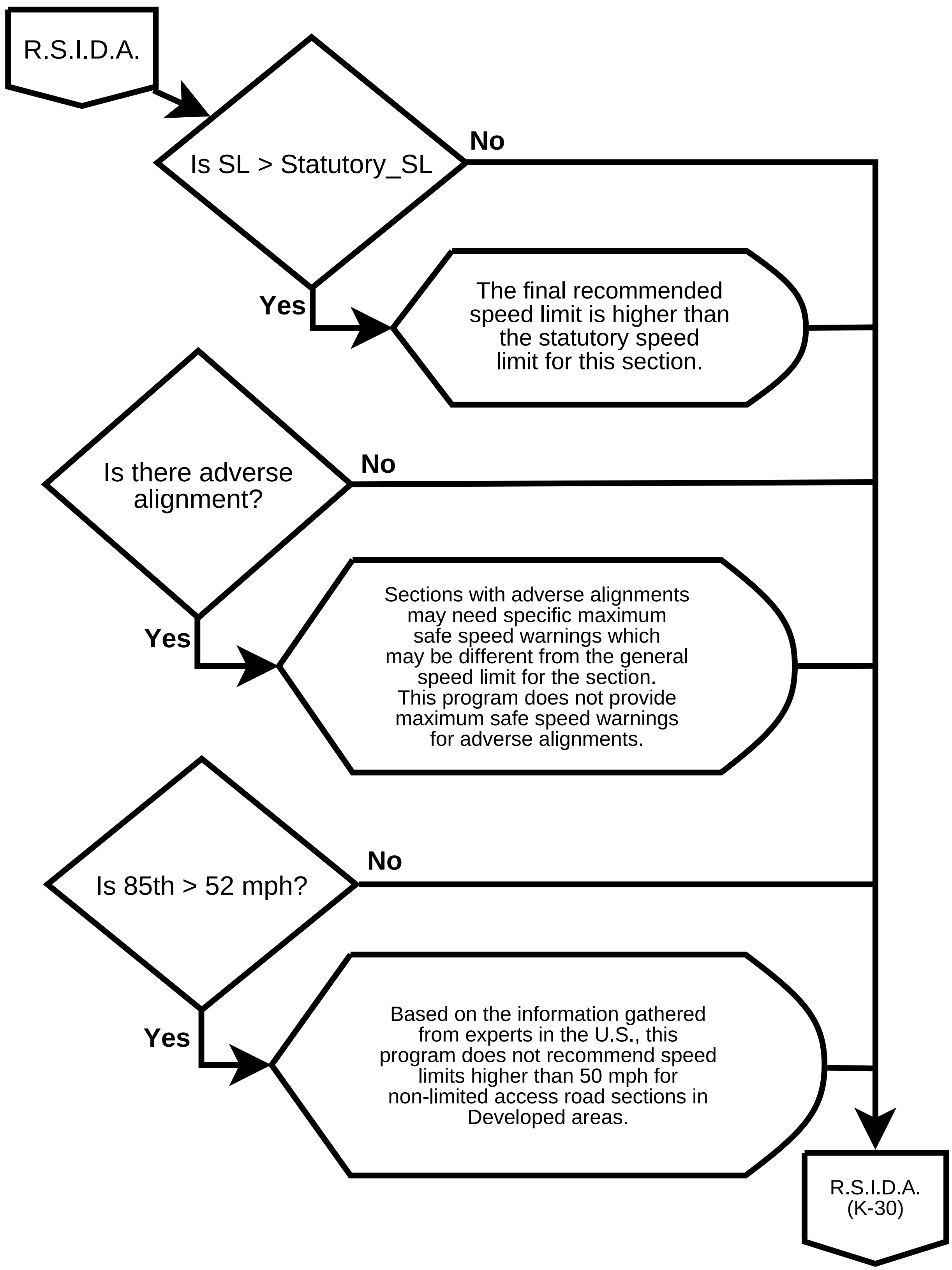


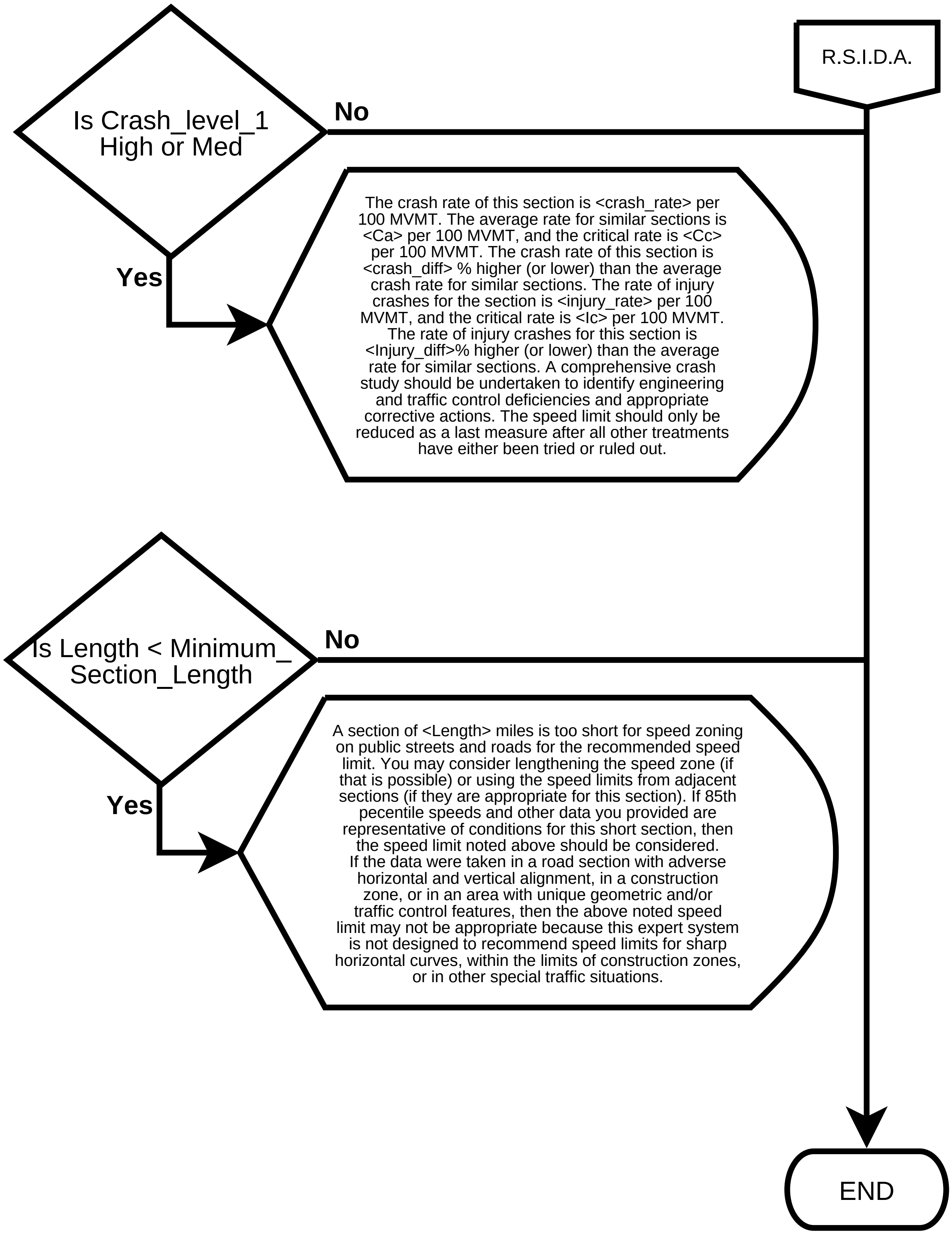
R.S.I.D.A.
Is crash_diff < 0
No
The crash_rate in the section is {crash_diff}% higher than the average rate of similar sections.
Yes
Is injury_diff < 0
No
The rate of injury and fatal crashes in the section is {injury_diff}% higher than the average.
Yes
Program Calculates Critical Crash_rate (Cc)
Is 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)


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)


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


R.S.I.D.A.
Is SL < 20 mph or > 50 mph?
SL < 20
SL > 50
15 <= 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)


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)


R.S.I.D.A.
Is Crash_level_1 High or Med
No
Yes
The crash rate of this 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, 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 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 pecentile 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

APPENDIX L

USER GUIDE

TABLE OF CONTENTS

Background

Speed limits are selected to balance travel efficiency versus safety. It can be argued that a rational speed limit is one that is safe, that most people consider appropriate, that will protect the public, and can be enforced. Many practitioners also feel that better methods are needed to identify appropriate speed limits especially in urban roads having higher traffic volumes, a mix of road users, and more roadside activity. Many practitioners and researchers have argued that a knowledge-based expert system can provide assistance to the practitioner in coming up with the appropriate speed limit.

Expert systems for recommending maximum posted speed limits have been used in Australia for more than a decade starting in the late 1980's. The first expert system (VLIMITS) was developed for the province of Victoria by the Australian Road Research Board (ARRB). Subsequently systems were developed for different provinces in Australia and New Zealand. These systems are collectively referred to as the XLIMITS programs. FHWA contacted ARRB to develop a program for use in the USA. This resulted in the USLIMITS program. Hereafter, this will be called as the first generation USLIMITS system or the FHWA-USLIMITS program. FHWA-USLIMITS was developed by ARRB based on their experience in developing the XLIMITS programs, but with changes made to suit the conditions in this country.

The expert system described in this user guide (hereafter called USLIMITS2 system or the NCHRP-USLIMITS program) employs a decision algorithm to advise the user of the appropriate maximum speed limit for the specific road section of interest. Unlike FHWA-USLIMITS, this expert system was developed based on input from a panel of experts in the USA that included traffic engineers, enforcement personnel, decision makers, and researchers from different parts of the country. The expert system is accessed through the Internet and has been designed to address the establishment of speed limits in speed zones on all types of roadways from rural two-lane roads to urban freeway segments. The types of speed limits not addressed by the system include statutory limits such as maximum limits set by State legislatures for Interstates and other roadways, temporary or part-time speed limits such as limits posted in work zones and school zones, and variable speed limits that are raised or lowered based on traffic, weather, and other conditions.

Objective of this Guide

The primary objective of this guide is to provide a detailed description of the variables that will be used in the expert system, describe the data that need to be collected by the user to use this system, and the results that can be expected from this program. For details regarding the decision rules that were used to develop this expert system, users should refer to the Decision Rules document that can also be downloaded from the expert system.

Accessing the Expert System

Since this program is accessed through the Internet (http://www2.uslimits.org), the user is only required to have a computer with web-browsing software connected to the Internet. Any web browser version developed in 2003 or later would be sufficient. Examples include Netscape

(Version 6.0 or later), MS Explorer (Version 5.5 or later), and Firefox (Version 0.8 or later). The final results are output to the user's computer screen and can also be saved in a Microsoft Word file and a Microsoft Excel file. Users do not need any special skills to access and use the system. However, the user will be required to provide specific information about the road section that is being examined.

Getting Started

After accessing the link to the expert system, the first step is to create an account. This can be done by clicking on the 'click here to subscribe' link. Users will be asked to create a username and password and also enter your full name, affiliation, and email address. Users can also opt to enter other information including your address, title, and phone number.

Creating New Projects and Editing Existing Projects

After creating a username, password, and entering the address, title, and phone number, users will be asked to log-in using the username and password. First time users will be asked to enter information for a new project. If one or more projects have already been created, the user can either edit the information for a previously created project or create a new project. For all projects, information on project location, project name (for identification purposes), project date, and route type, are necessary.

Route and Area Type

This expert system has three sets of decision rules corresponding to the following three route types: Limited Access Freeway, Road Sections in Undeveloped Areas, and Road Sections in Developed Areas. Here is a description of these route types:

Limited Access Freeway **–** This route type includes U.S. and state numbered freeways and expressways and Interstate routes where access to and from the facility is limited to interchanges with grade separations. These high-speed routes typically have posted speed limits ranging from 55 mph in urban areas to 75 mph in some rural states. Some urban areas may have short segments directly connecting the freeway to surface streets where the posted speed limit is as low as 35 mph. In rural western Texas, an 80 mph limit has recently been posted on selected segments of I-10 and I-20. As of September 2006, this is the highest posted speed limit on a freeway segment in the United States. This program will not recommend speed limits higher than 75 mph for limited access freeways.

Road Section in Undeveloped Area **–** An undeveloped area is generally an area where the human population is low and the roadside primarily consists of the natural environment. Access is not restricted and posted speed limits are typically in the 40 mph to 65 mph range depending upon terrain and road design features. Road sections with lower speed limits usually have narrower pavement widths, little or no shoulders, and horizontal and vertical curvature that limits driver speeds. Road sections with higher speed limits usually have 12-foot lanes, 8-foot or greater shoulders which may be paved, and horizontal and vertical curvature that supports higher speed travel. In this program, the maximum speed limit for road sections in undeveloped areas is 65 mph.

Road Section in Developed Area – A developed or built-up area is an area where the human-built environment has generally replaced most of the natural environment. Access is not restricted and posted speed limits are usually in the 25 mph to 50 mph range depending on the degree of human activity that interacts with vehicular travel, the road design, and degree of traffic control used. Road sections with lower speed limits are found in downtown and residential areas with considerable pedestrian and other non-motorized movements and on-street parking activity. Road sections with higher speed limits have little pedestrian activity, no on-street parking, and traffic control which favors through traffic movement. In this program, the maximum speed limit for road sections in developed areas is 50 mph. Roads in developed areas are further subdivided into residential subdivision/neighborhood street, residential collector street, commercial street, and a street serving a large complex such as a large shopping mall:

Residential Subdivision/Neighborhood Street – A residential neighborhood street is a public street located within a subdivision or group of homes that serves the motorized and non-motorized activities of residents. Posted speed limits generally range from 25 to 35 mph. Two-way traffic operations are permitted along with on-street parking on both sides of the road, however, the pavement width is too narrow to allow unimpeded bidirectional traffic and on-street parking. These streets do not carry through traffic. Commercial development is not permitted in the area.

Residential Collector Street – A residential collector street carries both through traffic from residential neighborhoods and local traffic generated by residents who live along the corridor. Posted speed limits generally range from 25 mph to 45 mph. The pavement widths permit full time operation of bidirectional traffic. On-street parking on one or both sides may or may not be permitted. Development along the street is primarily single- and multi-family homes. Typically there are more than 30 residential driveways per mile. The corridor may contain a small amount of commercial development; usually convenience stores at major intersections.

Commercial Street – A commercial street is a street that serves both through traffic and local shopping needs. Development along the corridor is primarily commercial with more than 30 business driveways per mile. Posted speed limits generally range from 25 mph to 45 mph. The streets usually tend to be multilane and on-street parking on one or both sides may or may not be permitted.

Street Serving Large Complexes – Large area business developments typically include shopping malls, office buildings and industrial complexes. Streets that serve large complexes generally are designed to carry large volumes of traffic to and from the complex and typically are designed to manage access to carry through volumes. The streets tend to be multilane facilities and the number of access driveways is usually less than 30 per mile. Posted speed limits generally range from 35 mph to 50 mph.

Photographs illustrating the different road and area types are shown in the following pages:

Limited Access Freeway

Road Section in Undeveloped Area: Includes some scattered development with typically less than 30 commercial and residential driveways per mile. Posted speed limits are typically in the 40 to 65 mph range.

Road Section in Developed Area – Includes roads in built-up areas. Posted speed limits typically range from 25 to 50 mph depending upon road and development conditions. Specific categories of roads in developed areas include;

1. Residential Subdivision/Neighborhood Street
2. Residential Collector Street
3. Commercial Street
4. Street Serving Large Complexes

Residential Subdivision/Neighborhood Street – Predominately includes streets serving a group of homes that provides motorized and non-motorized trips for local residents. Posted speed limits usually range from 25 to 35 mph.

Residential Collector – Includes mostly residential single-family homes and multi-family development with more than 30 driveways per mile.

Commercial Street – Includes mostly shopping and service business with typically more than 30 driveways per mile.

Street Serving Large Complexes – Includes shopping malls, office buildings, industrial complexes, etc. There are high volume driveways. The number of driveways is usually less than 30 per mile

For each route type, the following input variables are required:

Limited Access Freeway

Operating Speed: 85th percentile speed and 50th percentile speed
Presence/absence of adverse alignment
Is this section transitioning to a non-limited access highway?
Section Length
Current statutory limit for this type of road
The terrain
Annual Average Daily Traffic
Number of Interchanges within this section
Crash Statistics

Road Sections in Undeveloped Areas

Operating Speed: 85th percentile speed and 50th percentile speed
Presence/absence of adverse alignment
Is this section transitioning to a road section in a developed area?
Current statutory limit for this type of road
Annual Average Daily Traffic
Roadside Rating
Number of lanes and presence/type of median
Crash Statistics

Road Sections in Developed Areas

Operating Speed: 85th percentile speed and 50th percentile speed
Current statutory limit for this type of road
Annual Average Daily Traffic
Presence/absence of adverse alignment
Area type
Number of driveways in the section
Number of traffic signals within the section
Presence/usage of on-street parking
Extent of ped/bike activity
Crash Statistics

Following is a detailed description of each of these input variables

Input Variables

Operating Speed

85th Percentile Speed – The 85th percentile speed is the speed at or below which 85 percent of the drivers travel on a road segment. The 85th percentile speed should be taken from speed data collected during a 24-hour weekday period. Typically the data are collected with commercially available roadside units which sort and present the results in text as well as graphical format.

Speed studies should be conducted using the format and procedures described in your jurisdiction's publications for establishing speed zones. If your jurisdiction does not have a specific written procedure, additional information is found in ***Chapter 3 of the ITE Manual of Transportation Engineering Studies, 1994***.

The road cross section of the speed zone segment being studied should be uniform with similar roadside development. If the number of lanes, road function, or development changes with a study section, the segment should be further subdivided with the measurement of 85th percentile speeds in each segment. Another factor that should be taken into consideration when determining the start and end points of a speed zone is the location of adverse-alignment such as sharp horizontal curves, where the advisory speed may be less than the speed limit. The 85th percentile speed used in the analysis for a general speed limit should not be taken from the adversely aligned section

This program is not designed to handle the unusual situations where the 85th percentile speed on limited access freeways is less than 35 mph, less than 25 mph in road sections in undeveloped areas, or less than 20 mph in road sections in developed areas. If a portion of the section has adverse alignment or the section is a transition zone, the program will allow users to enter 85th percentile speeds less than 45 mph (but higher than 35 mph) on freeways, and less than 35 mph (but higher than 25 mph) on road sections in undeveloped areas.

50th Percentile Speed – The 50th percentile speed is the speed at or below which 50 percent of the drivers travel on a road segment. The 50th percentile speed should be taken from speed data collected during a 24-hour weekday period. In this program, the difference between the 85th percentile speed and the 50th percentile speed cannot exceed 15 mph.

Adverse Alignment

Adverse alignment of the road includes road features with vertical and/or horizontal alignments which differ significantly from the alignment of the general road. Adverse alignment segments typically have poor sight distance, reverse curves, and other features such as narrow pavement widths and shoulders that reduce operating speeds below the general speed limit for the section. If adverse alignment is present in this section, a warning will be provided along with the general recommended speed limit for the section. Sections with adverse alignment typically require posting maximum safe speed advisory warnings which may be lower than the general speed limit for the section. This program does not suggest numerical values that can be used to determine the maximum safe speed warnings for adverse alignment. If adverse alignment is present, the system gives the following warning at the end:

> Sections with adverse alignment many 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.

<u>Transition Zone</u>

For projects in limited access freeways, users are asked to indicate if this section is transitioning to a non-limited access road. For projects in 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 allowed for transition zones.

<u>Section Length</u>

This refers to the length of the section in miles.

<u>Statutory Limit</u>

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 that you are interested in. 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 gives a warning at the end.

<u>Terrain</u>

Terrain can be Level/Flat, Rolling, or Mountainous.

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 busy the road is.

Number of Interchanges

This input variable is applicable 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) will be 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), Ohio (2002-2004), Utah (1998-2000), and Washington (2002-2004). Table L.1 shows the average crash and injury rates calculated based on HSIS data.

ROADWAY CLASS	AADT category	Crash-rate per 100MVM	Injury and fatal rate per 100MVM
Urban Freeways (interchange spacing <= 1 mile)	0 - 24,999	103.58	30.36
	25,000 - 49,999	90.39	27.52
	50,000 - 74,999	97.41	29.66
	75,000 - 99,999	102.29	31.04
	100,000 - 149,999	108.57	32.53
	150,000 - 199,999	113.34	33.60
	200,000+	116.63	32.16
Urban 2 lane roads (Developed areas)	0 - 2,499	366.41	101.29
	2,500 - 4,999	223.05	73.52
	5,000 - 7,499	217.15	71.86
	7,500 - 9,999	222.49	73.24
	10,000 - 14,999	250.38	80.57
	15,000 - 19,999	277.84	89.48
	20,000+	280.83	85.70
Urban multilane divided non freeways (Developed areas)	0 - 9,999	327.34	111.27
	10,000 - 14,999	248.60	86.05
	15,000 - 19,999	282.36	94.13
	20,000 - 24,999	305.39	99.84
	25,000 - 29,999	341.35	109.94
	30,000 - 34,999	355.14	111.86
	35,000 - 44,999	325.49	107.62
	45,000+	260.07	85.48
Urban multilane undivided non freeways (developed areas)	0 - 9,999	394.68	126.61
	10,000 - 14,999	383.00	121.22
	15,000 - 19,999	376.86	119.54
	20,000 - 24,999	414.71	127.40
	25,000+	412.30	124.49
Rural Freeways (Interchange spacing >1 mile)	0 - 24,999	55.30	17.99
	25,000 - 49,999	55.70	16.65
	50,000+	55.31	18.10
Rural 2 lane roads (Undeveloped areas)	0 - 1,249	232.45	84.46
	1,250 - 2,499	165.13	57.78
	2,500 - 3,749	142.02	49.86
	3,750 - 4,999	134.01	46.88
	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	0 - 4,999	147.75	48.26

non freeways (Undeveloped areas)	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

Table L.1: Average crash and injury rates based on data from HSIS States

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 the causes and the 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 comes up with a recommended speed limit.

Roadside Rating (only for Undeveloped Roads)

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. 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 verbal description of ratings 1 through 7. Photographs illustrating these ratings are provided following the verbal 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.

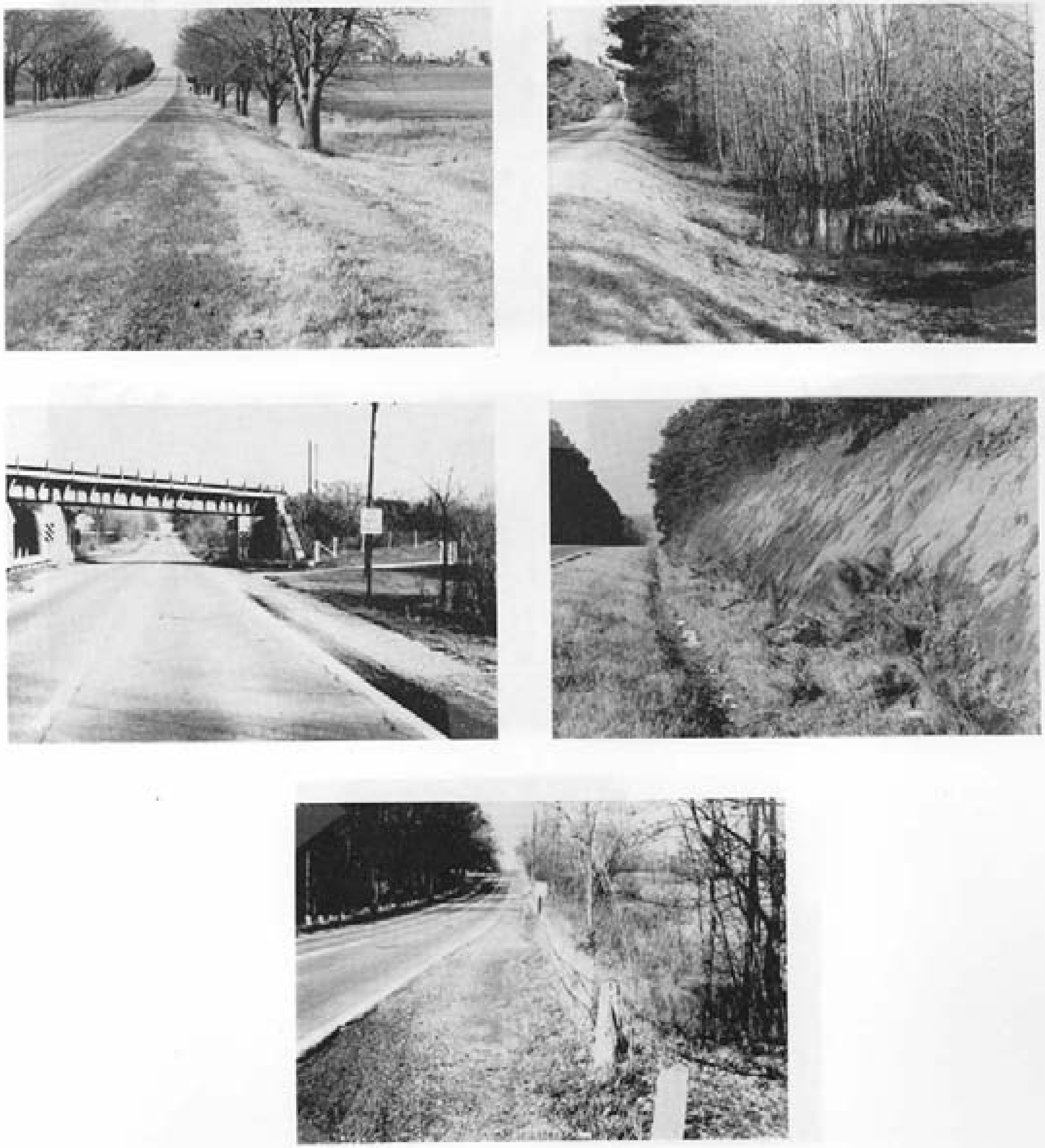




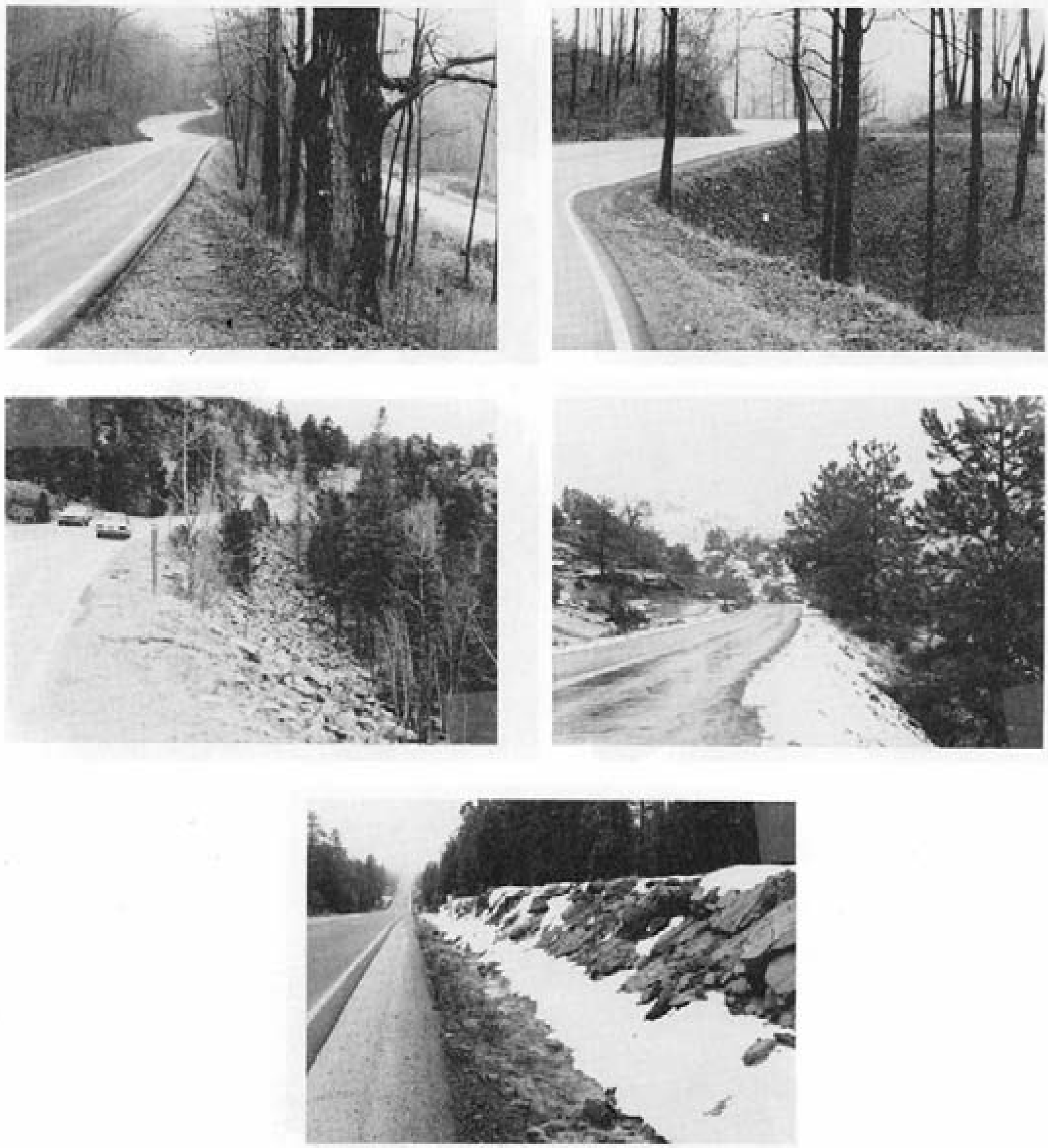
Rural roadside hazard rating of 2.

Rural roadside hazard rating of 3.

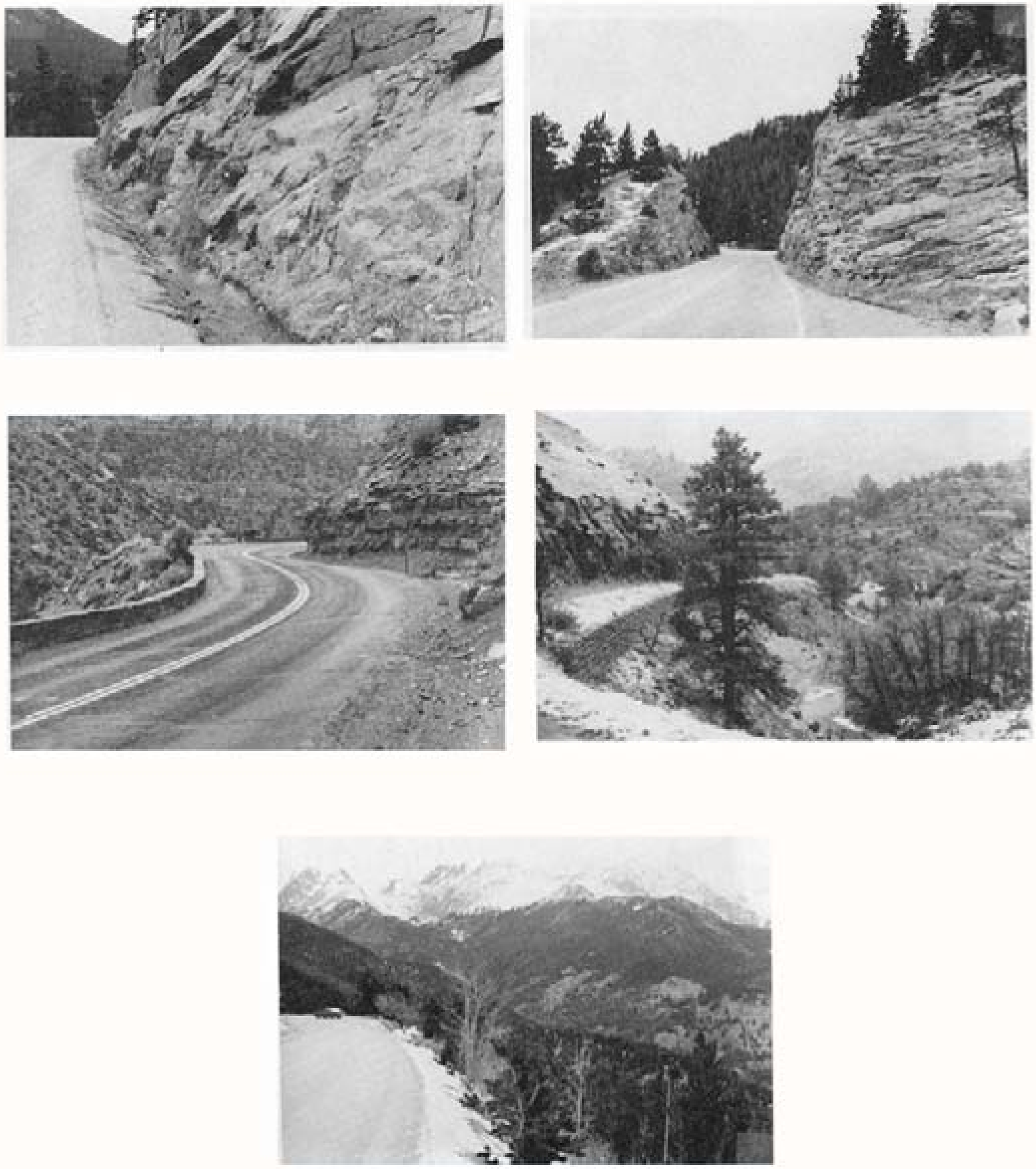
Rural roadside hazard rating of 4.



Rural roadside hazard rating of 5.



Rural roadside hazard rating of 6.



Rural roadside hazard rating of 7.

Number of Lanes and Presence/Absence of Median

Based on the number of lanes and the presence/absence of a median, the user is asked to select between three categories of roads:

Two-lane Undivided
Multilane with Two-Way Left-Turn-Lane (TWLTL)
Multilane Divided

Number of Driveways in the Section

This refers to the number of driveways and unsignalized access points in the section. This information is used to calculate the number of driveways per mile in the section (number of driveways divided by section length).

Number of Traffic Signals within the Section

This refers to the number of traffic signals in the section. This information is used to calculate the number of signals per mile (number of signals divided by section length).

Presence/Usage of On-Street Parking

Users are asked to select between 'High' and 'Not High'. 'High' parking activity and usage typically occur in downtown and/or CBD areas. These areas usually have parking on both sides of the road with parking time limits that do not exceed 60 minutes, with at least 30 percent of parking spaces occupied during weekdays.

Extent of Ped/Bike Activity

Users are asked to select between 'High' and 'Not High'. Examples of areas with 'High' pedestrian and bicycle activity include:
(1) Residential developments with four or more housing units per acre interspersed with multifamily dwellings,
(2) Hotels located with 1/2 mile of other attractions such as retail stores, recreation areas, or senior centers,
(3) Downtown or CBD areas, and
(4) Usually have paved sidewalks, marked crosswalks, and pedestrian signals.

Output

The expert system provides an advisory recommended speed limit along with the necessary warnings. The output can be printed and saved in a Microsoft Word file and a Microsoft Excel file. The Microsoft Word and Excel files also show the data that were input by the user for a particular project. The Word file can be formatted depending on the needs of the user. The primary purpose of the Excel output is to create a database of projects that can be used for future research.

It is well known that driver response to speed limits is at least partially dependent on the level of enforcement and the enforcement tolerance. With regard to enforcing the speed limit, there is a wide range of unofficial enforcement tolerances used throughout the US ranging from 5 to 20 mph. However, a speed limit set with the assistance of this expert system should be enforced within 5 to 7 mph of the posted speed limit. This allows only for reasonable speed odometer and instrument errors. Above this limit, the motorist is exceeding the safe and reasonable speed of traffic.

In addition to the recommended speed limit, the following warnings are provided:

Warnings for All Roadway Types

If the final recommended speed limit is higher than the statutory limit, the following warning is provided to the user:

> The final recommended speed limit is higher than the statutory speed limit for this type of road.

If the user indicates that there is adverse alignment in the section:

> 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.

If Length of Section is shorter than the Minimum Section Length, then the following message is provided:

> 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 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.

> The minimum section length for a particular speed limit is based on Table L.2 (this is the same guideline that is used in FHWA-USLIMITS)

Speed Limit	**Minimum Length**
30mph	0.30 miles
35mph	0.35 miles
40mph	0.40 miles

45mph	0.45 miles
50mph	0.50 miles
55mph	0.55 miles
60mph	1.20 miles
65mph	3.00 miles
70mph	6.20 miles
75mph	6.20 miles

Table L.2 Minimum Section Lengths

If the user does not enter crash data, the following warning is provided:

> Crash data were not entered for this project. A comprehensive crash study is a critical component of any traffic engineering study. We suggest that you repeat this process when crash data become available.

If Crash or Injury Level is High or Medium, the following message is provided:

> 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.

<u>Warnings for Limited Access Freeways</u>

If 85^{th} percentile speed is > 77 mph, then the following warning:

> Based on the information gathered from experts in the U.S., this program does not recommend speed limits higher than 75 mph.

<u>Warnings for Road Sections in Undeveloped Areas</u>

If 85^{th} percentile speed is > 67 mph, then the following warning:

> 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.

<u>Warnings for Road Sections in Developed Areas</u>

If 85^{th} percentile speed is > 52 mph, then the following warning:

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.

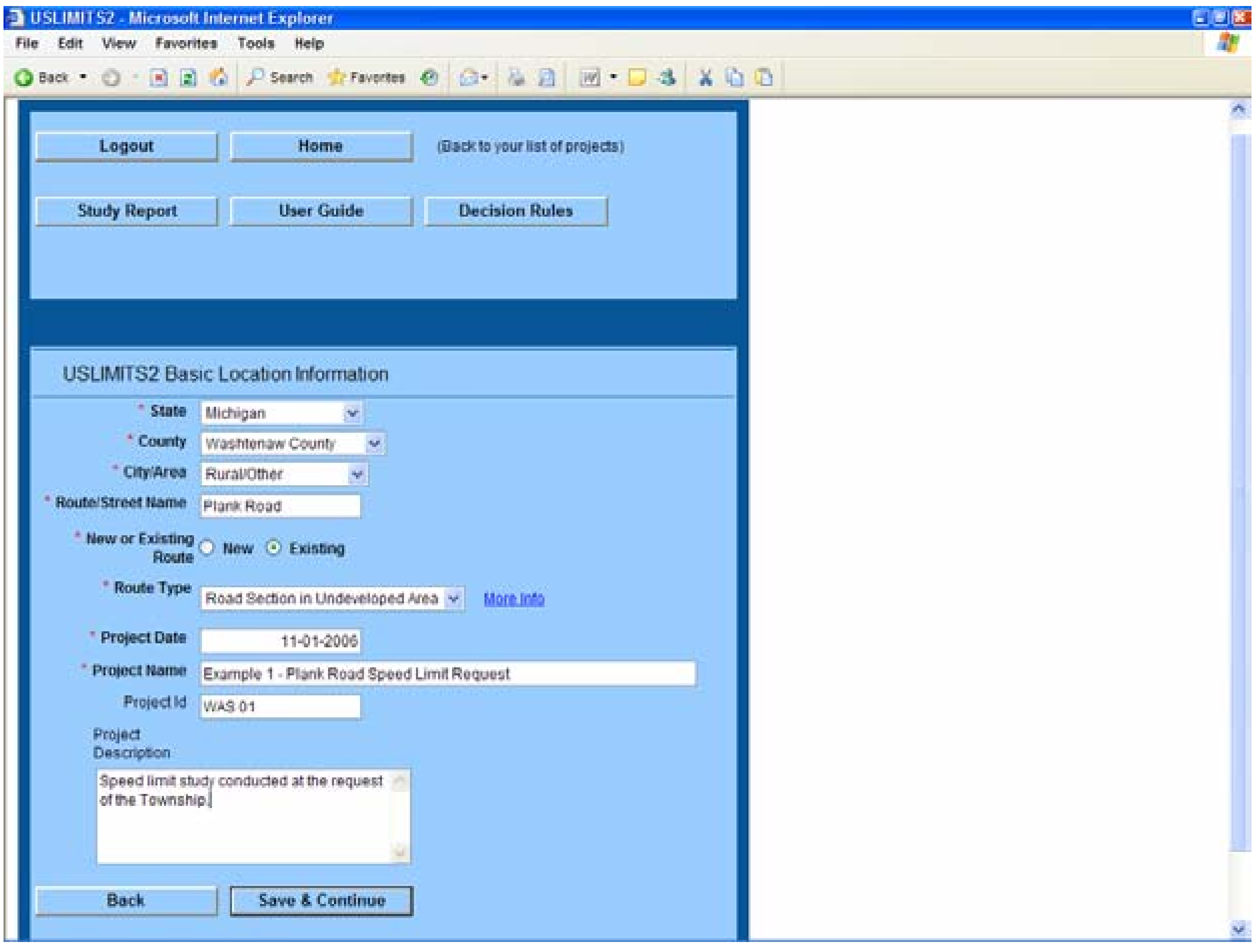
Three examples are presented for illustrative purposes.

Examples

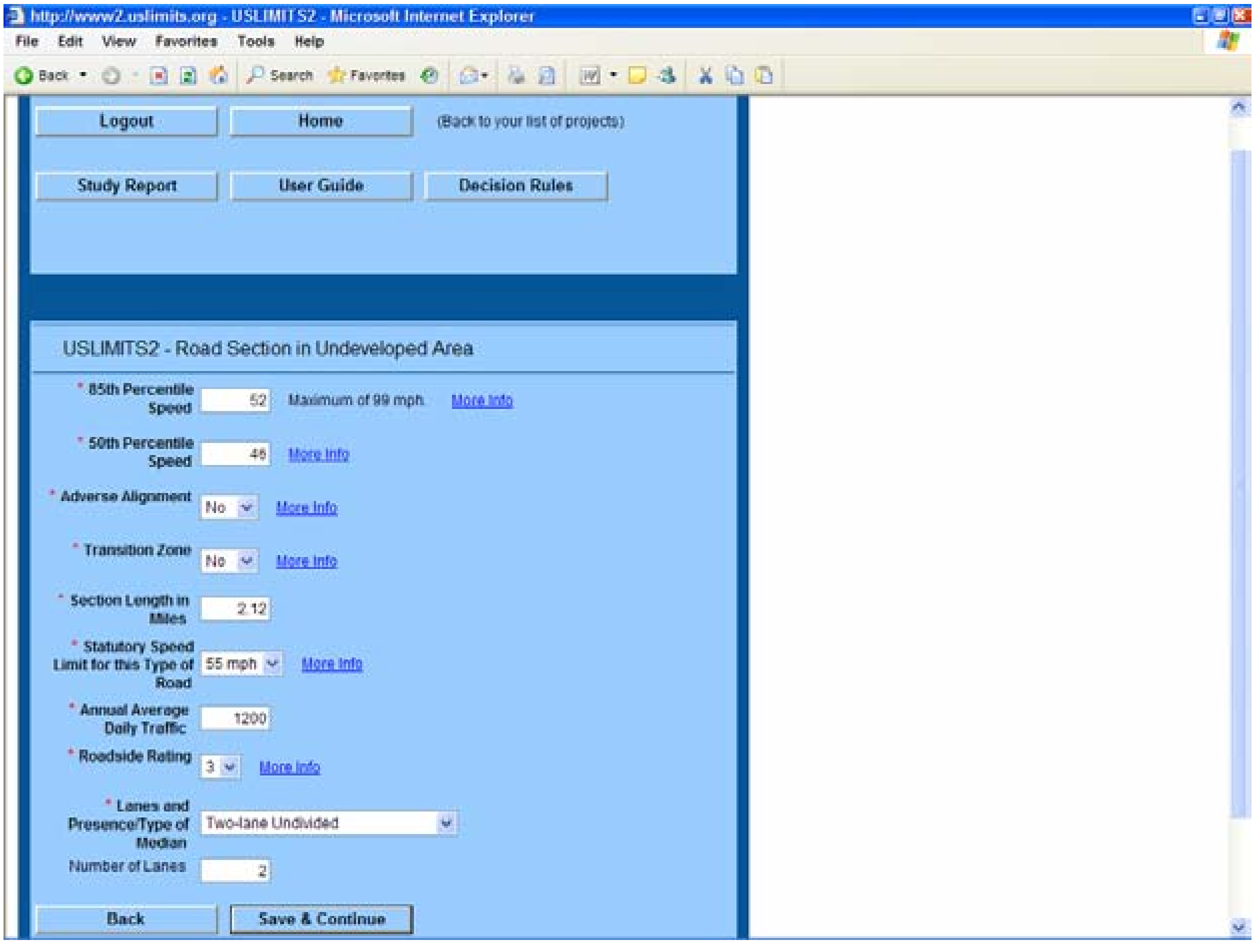
Example 1 – Speed Limit Request on a Two-Lane Road in an Undeveloped Area

The first example is a two-lane road in a rural area. At the request of the Township officials, the engineer has been asked to conduct a traffic and engineering investigation to determine if the existing maximum 50 mile per hour speed limit should be lowered. Based on data collected during the investigation, the USLIMITS2 screens below show the input variables and final suggested speed limit for this road section.

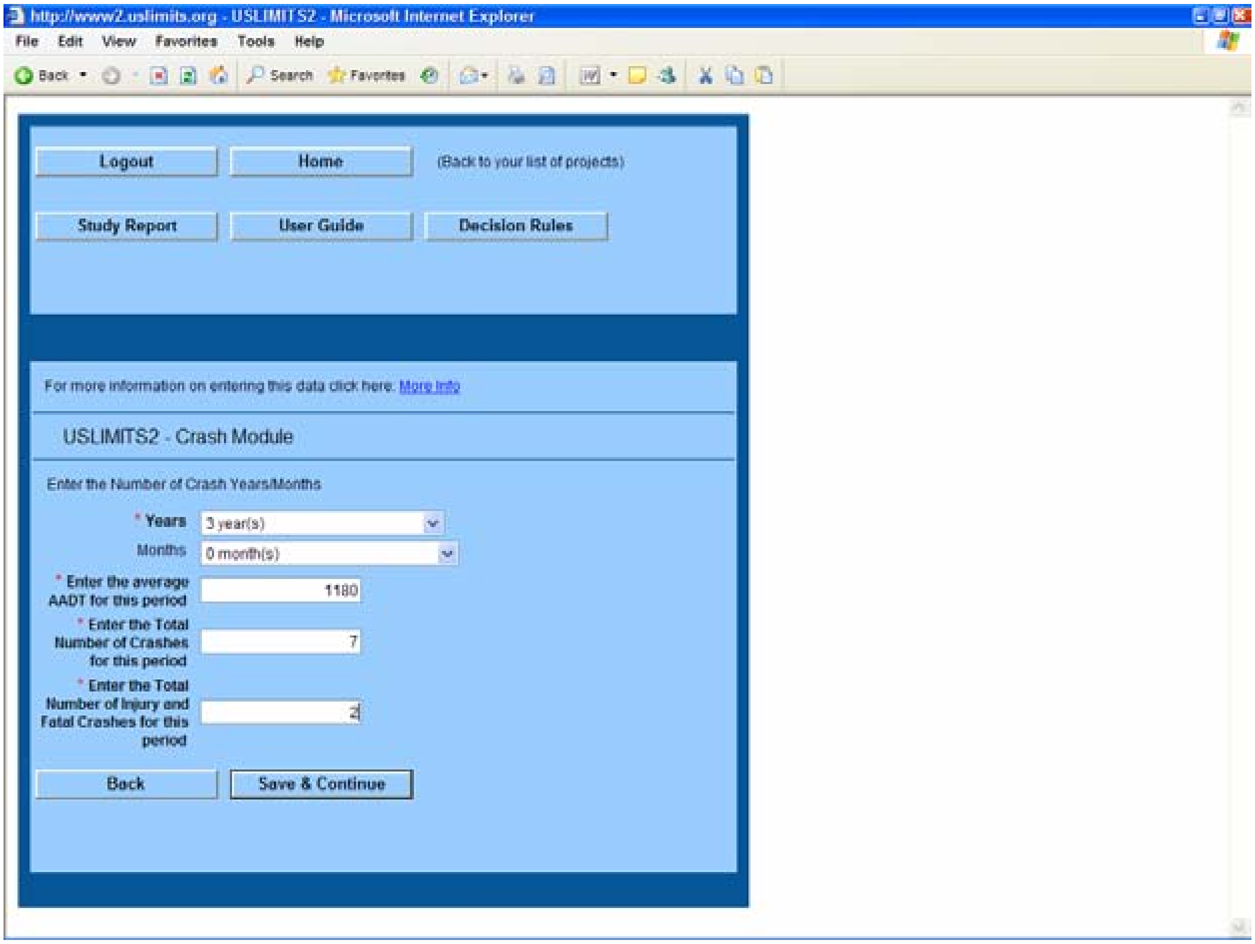
This is the Basic Location Information input screen.



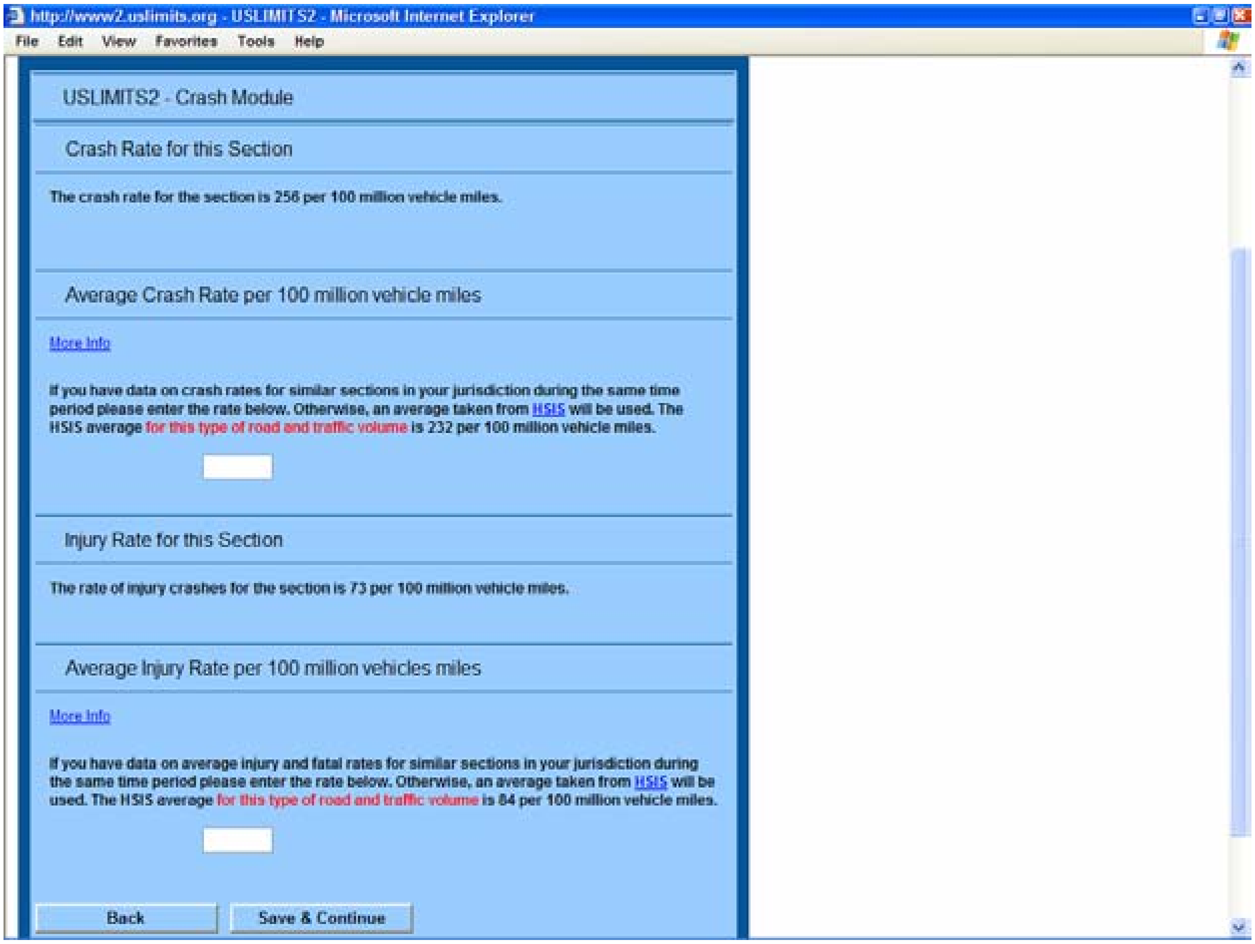
This is the basic input screen for the 85th percentile speed and other variables.



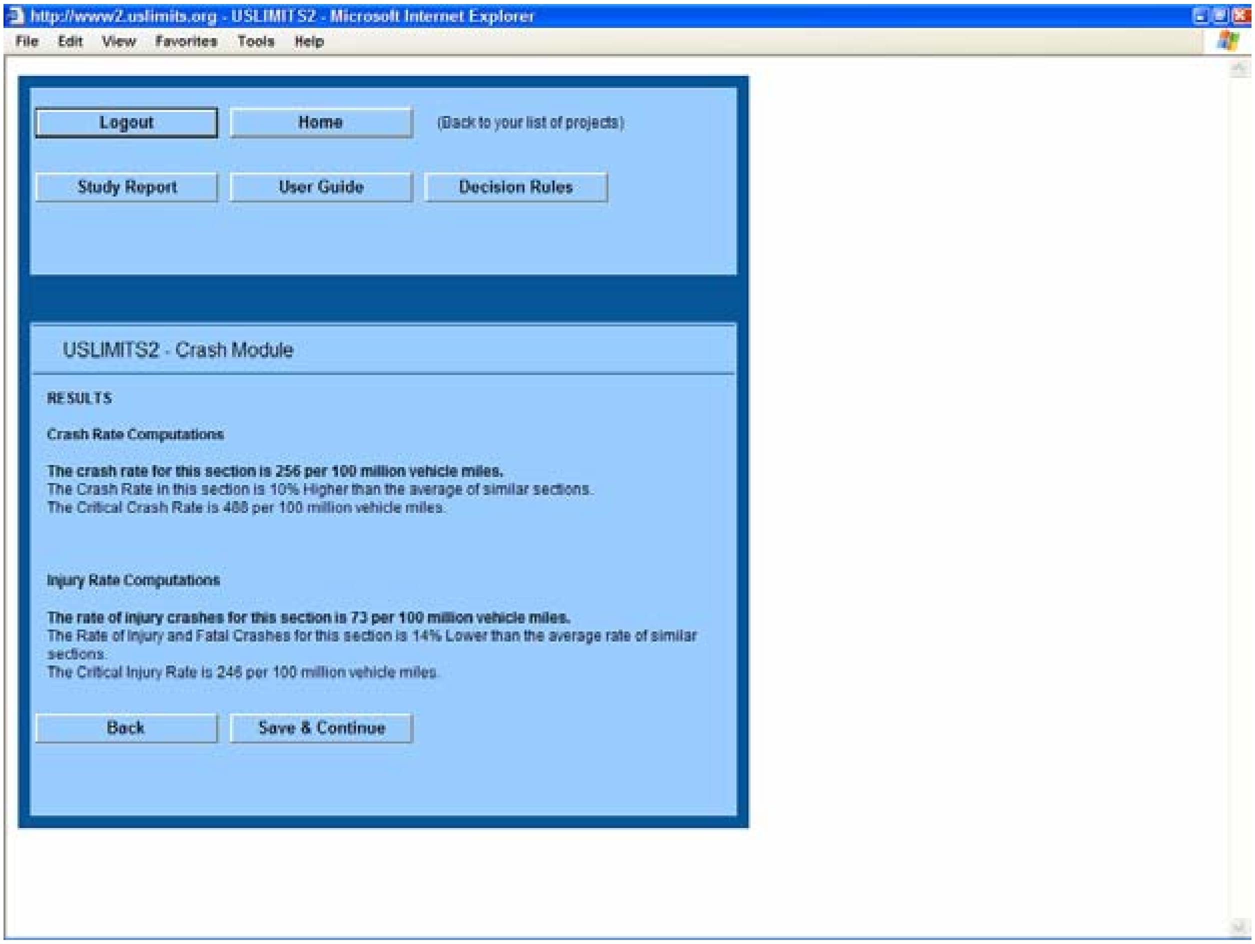
This is the input screen for the crash data.



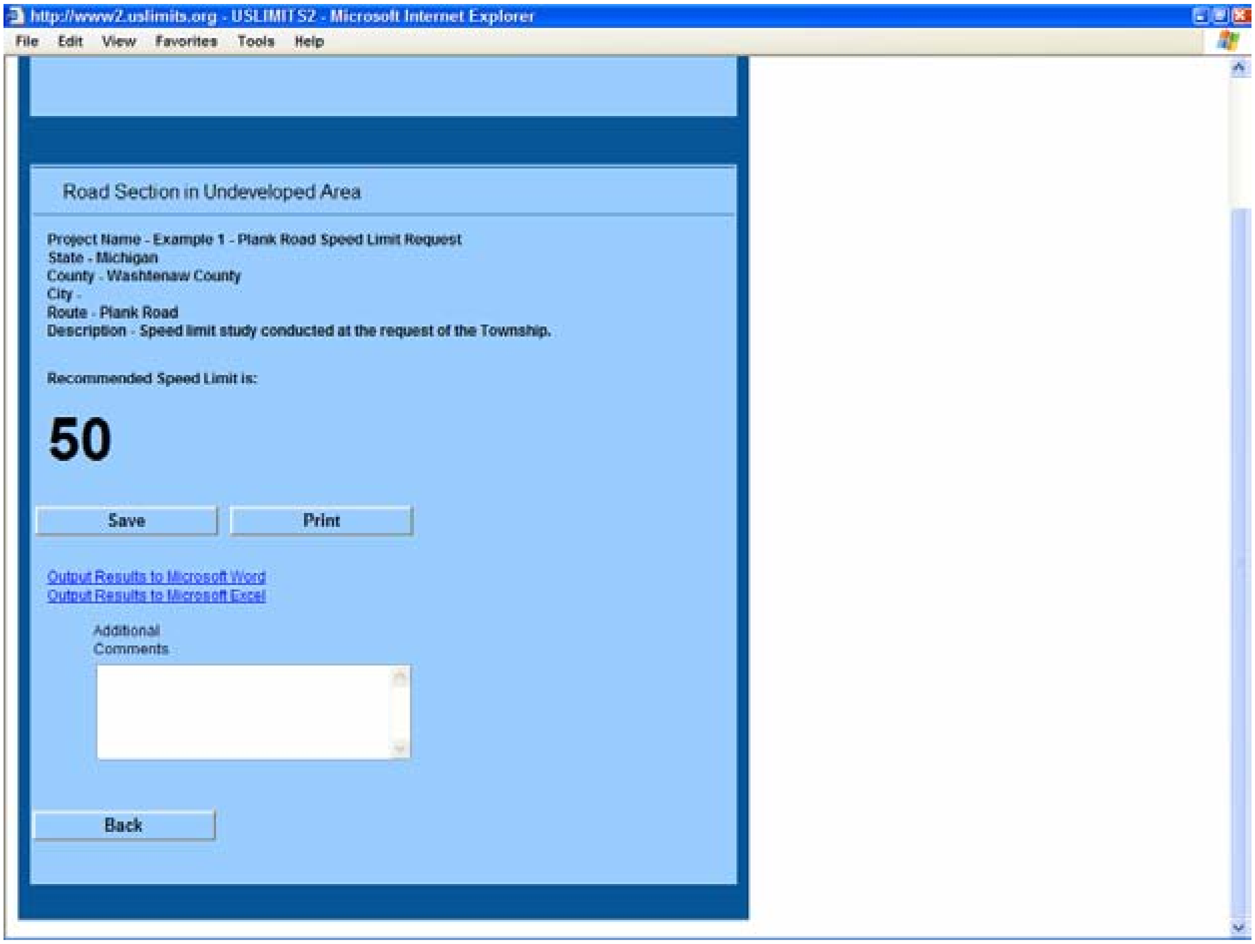
This is the crash summary generated by USLIMITS2 based on the crash data input by the user.



This screen provides a summary of the crash calculations.



This is the final output screen showing the advisory recommended speed limit for this rural road section.



The results can also be printed to a Microsoft Word file as shown below.

USLIMITS2 Data Output

Basic Project Information

Project Name - Example 1 - Plank Road Speed Limit Request
Project Number - WAS 01
Project Date - 11-01-2006
State - Michigan
County - Washtenaw County
City -
Route - Plank Road
Route Type - Road Section in Undeveloped Area
Route Status - EXISTING

Roadway Information

85th Percentile Speed - 52 mph
50th Percentile Speed - 46 mph
Section Length - 2.12 mile(s)
Statutory Speed Limit - 55 mile(s)
AADT - 1200
Adverse Alignment - No
Lanes and Presence/Type of Median - Two-lane road or undivided multilane.
Number of Lanes - 2
Roadside Hazard Rating - 3

Crash Data Information

Crash Data Months/Years - 3.00
Crash AADT - 1180
Total Number of Crashes - 7
Total Number of Injury Crashes - 2
Section Crash Rate - 256
Section Injury Rate - 73
Crash Rate Average for Similar Sections - 232
Injury Rate Average for Similar Sections - 84

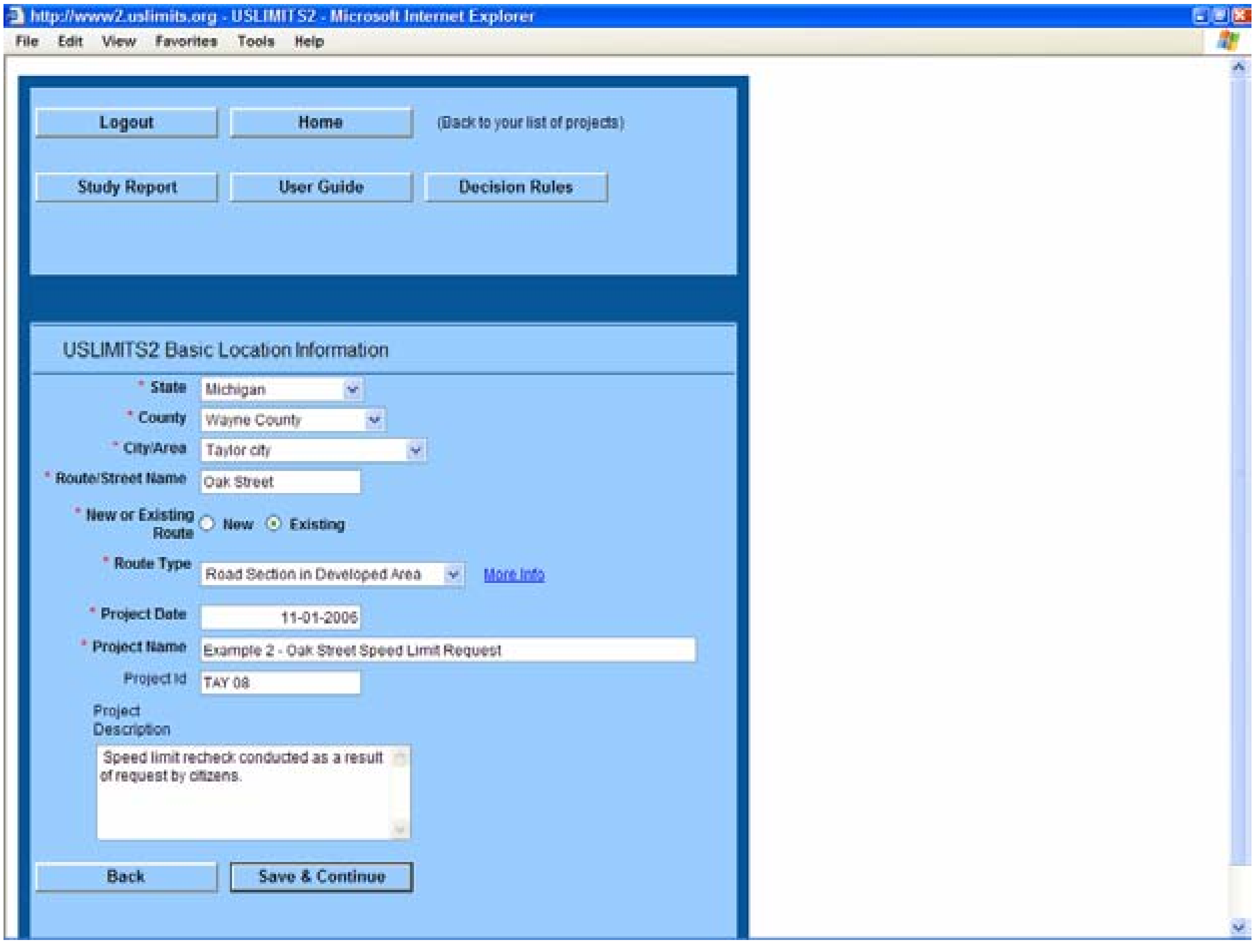
Comments -

Recommended Speed Limit is:50

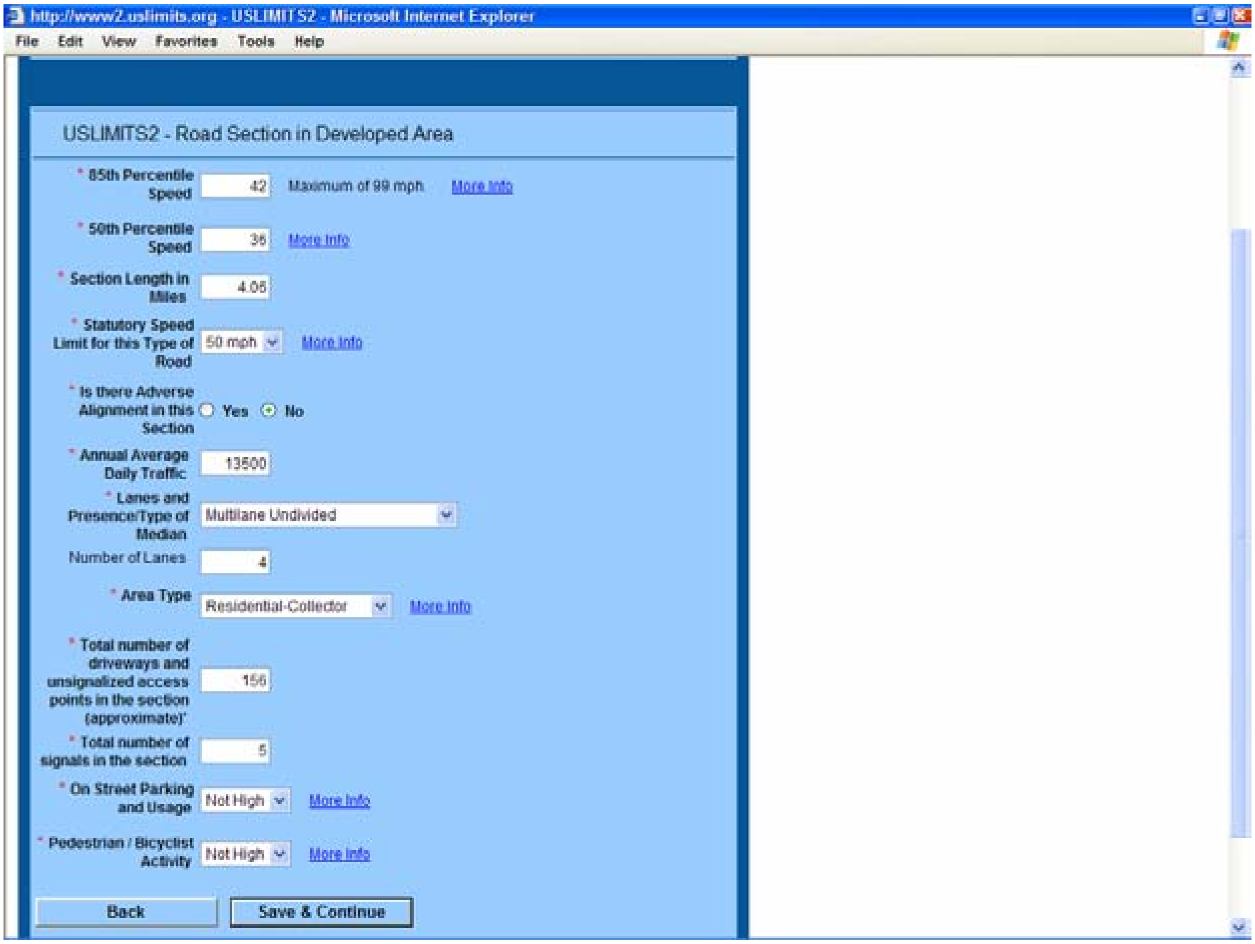
Example 2 – Speed Limit Request on a Multilane Road in a Developed Area

The second example is multilane residential collector street. Based on citizen's requests, the City Engineer has been asked to conduct a traffic and engineering investigation to determine if the existing 35 mile per hour speed limit is appropriate. Utilizing the data collected during the investigation, the USLIMITS2 screens below show the input variables and final suggested speed limit for this road section.

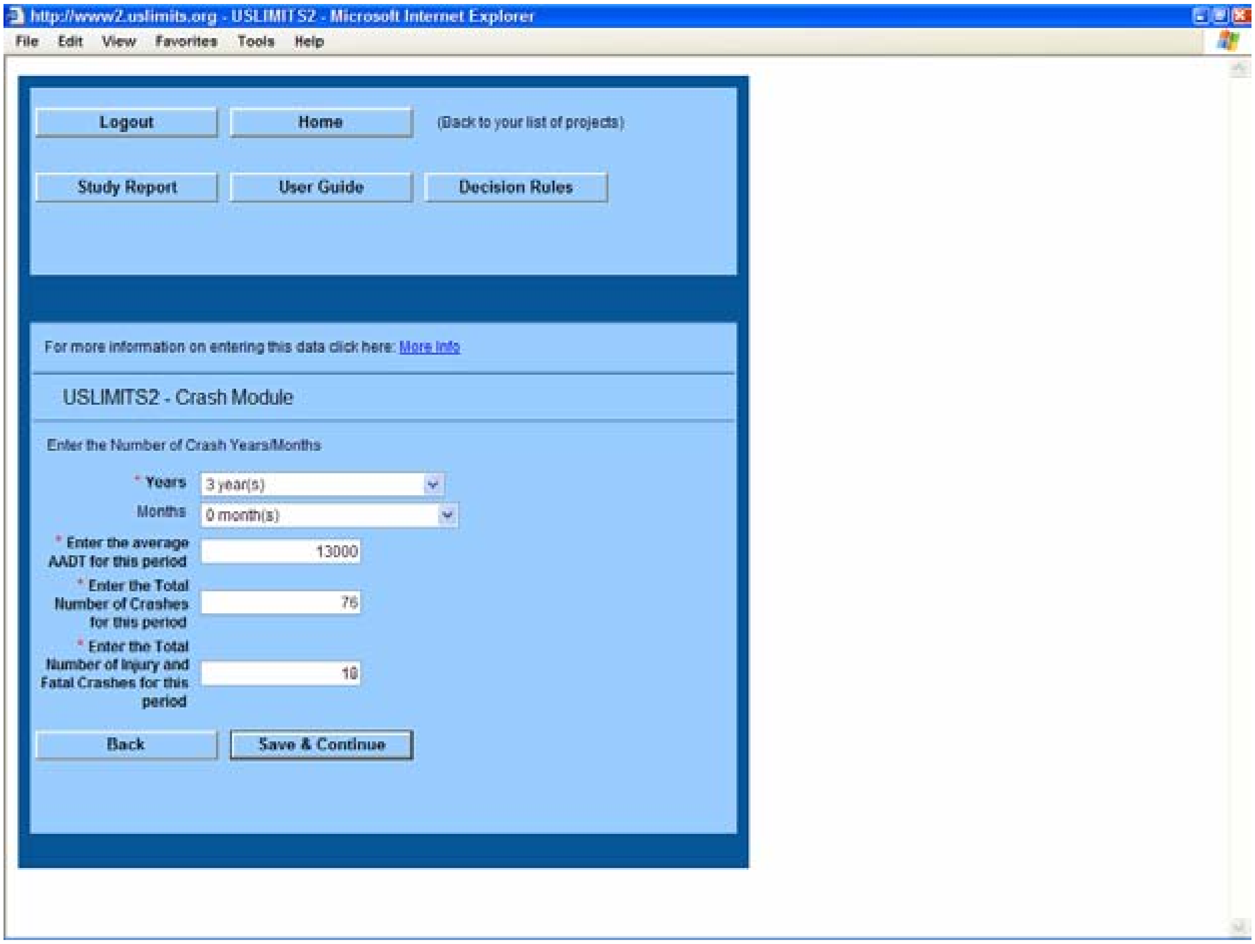
This is the Basic Location Information input screen.



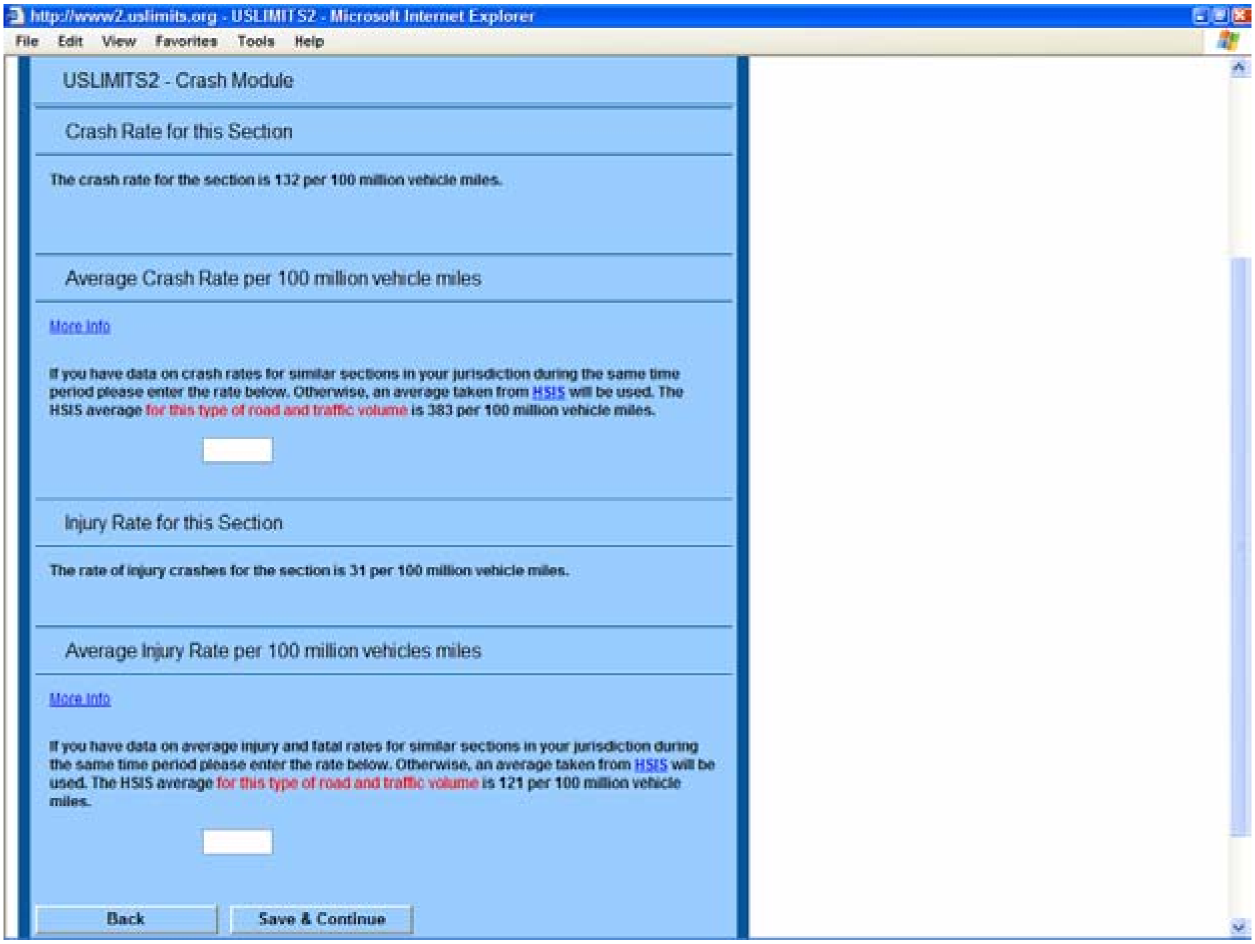
This is the basic input screen for the 85th percentile speed and other variables.



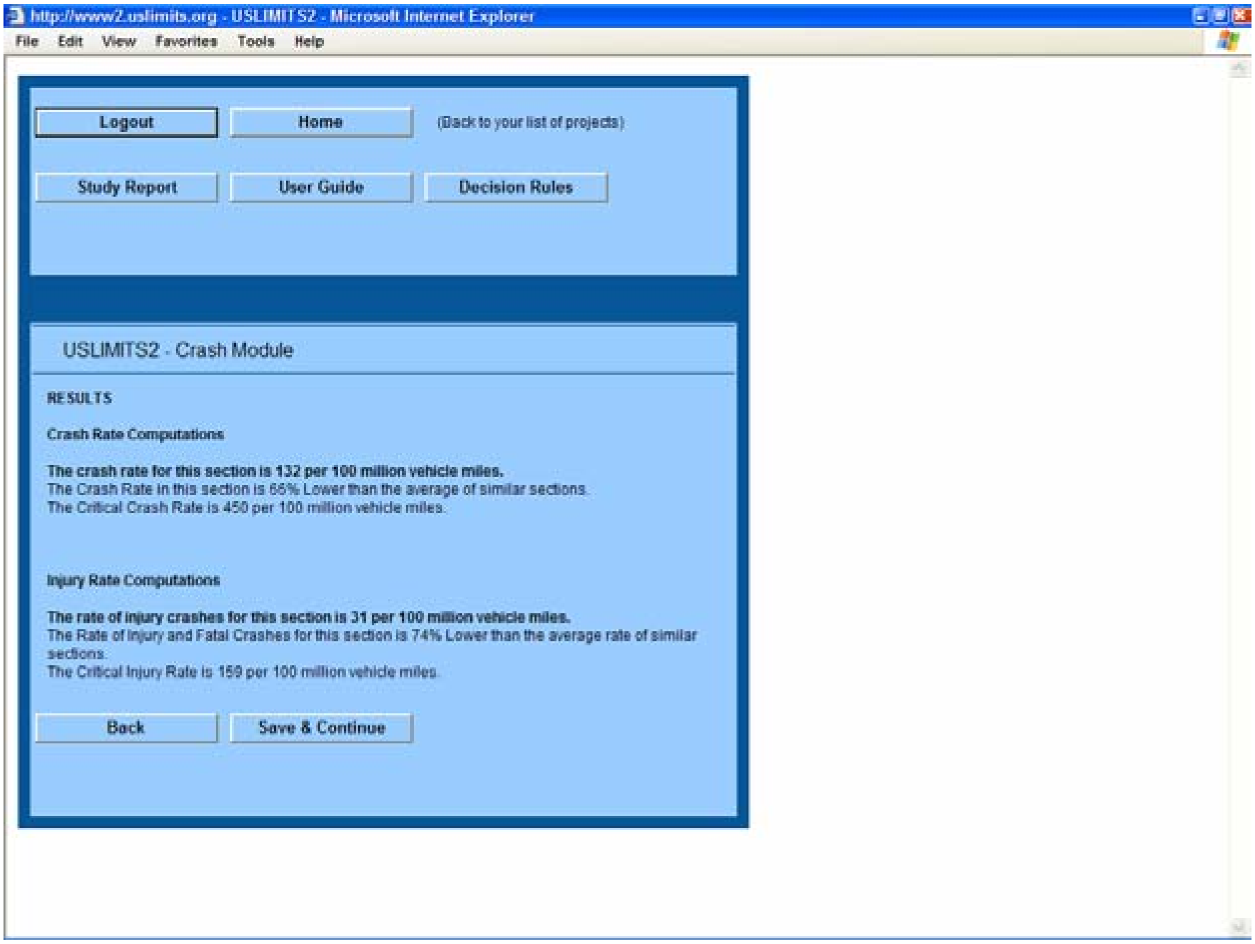
This is the input screen for the crash data.



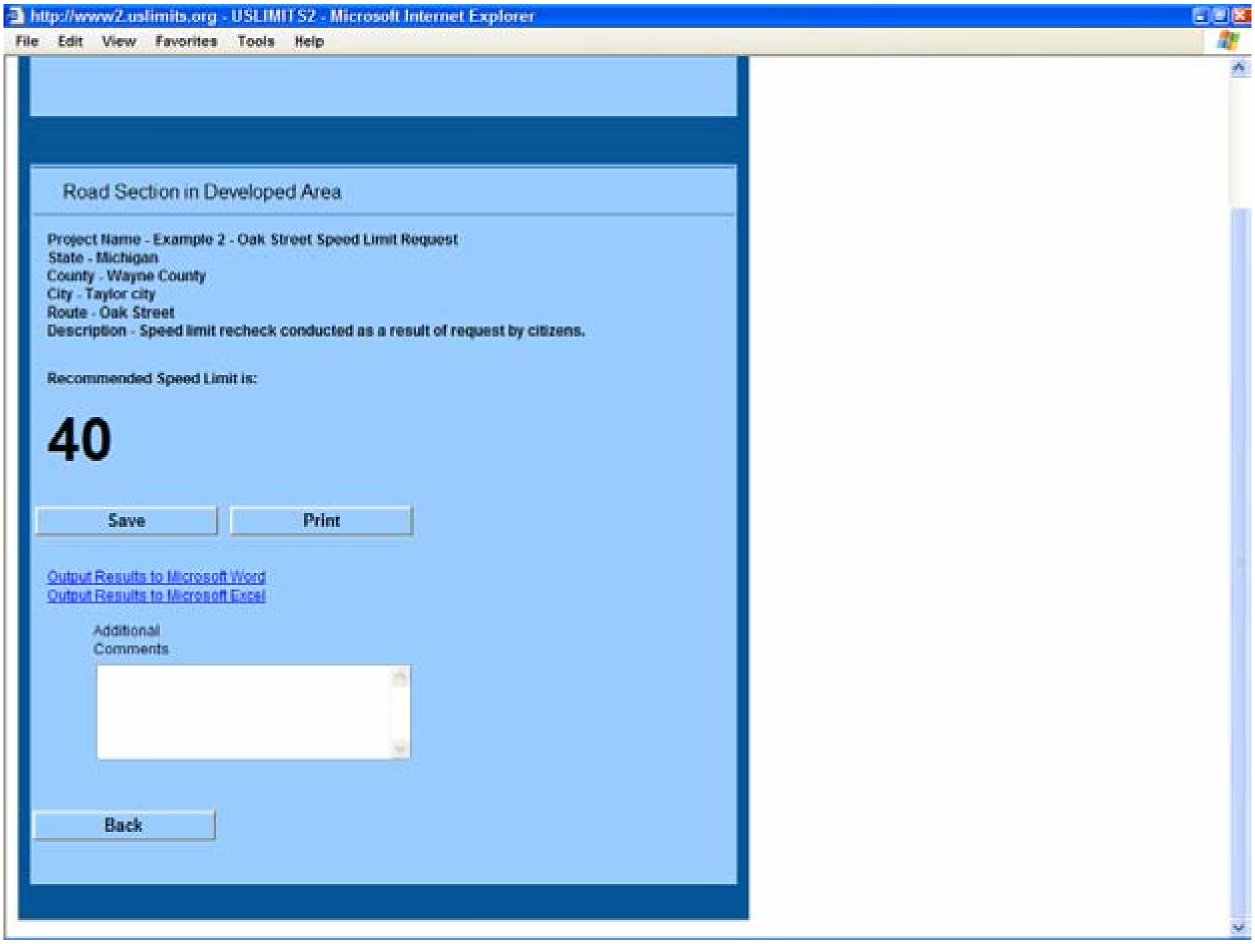
This is the crash summary generated by USLIMITS2 based on the crash data input by the user.



This screen provides a summary of the crash calculations.



This is the final output screen showing the advisory recommended speed limit for this urban multilane street.



The results can also be printed to a Microsoft Word file as shown below.

USLIMITS2 Data Output

Basic Project Information

Project Name - Example 2 - Oak Street Speed Limit Request
Project Number - TAY 08
Project Date - 11-01-2006
State - Michigan
County - Wayne County
City - Taylor city
Route - Oak Street
Route Type - Road Section in Developed Area
Route Status - EXISTING

Roadway Information

85th Percentile Speed - 42 mph
50th Percentile Speed - 36 mph
Section Length - 4.06 mile(s)
Statutory Speed Limit - 50 mile(s)
AADT - 13500
Adverse Alignment - No
Lanes and Presence/Type of Median - Multilane road that is divided or has TWLTL
Number of Lanes - 4
Area Type - Residential-Collector
Number of Driveways - 156
Number of Signals - 5
On Street Parking and Usage - Not High
Pedestrian / Bicyclist Activity - Not High

Crash Data Information

Crash Data Months/Years - 3.00
Crash AADT - 13000
Total Number of Crashes - 76
Total Number of Injury Crashes - 18
Section Crash Rate - 132
Section Injury Rate - 31
Crash Rate Average for Similar Sections - 383
Injury Rate Average for Similar Sections - 121

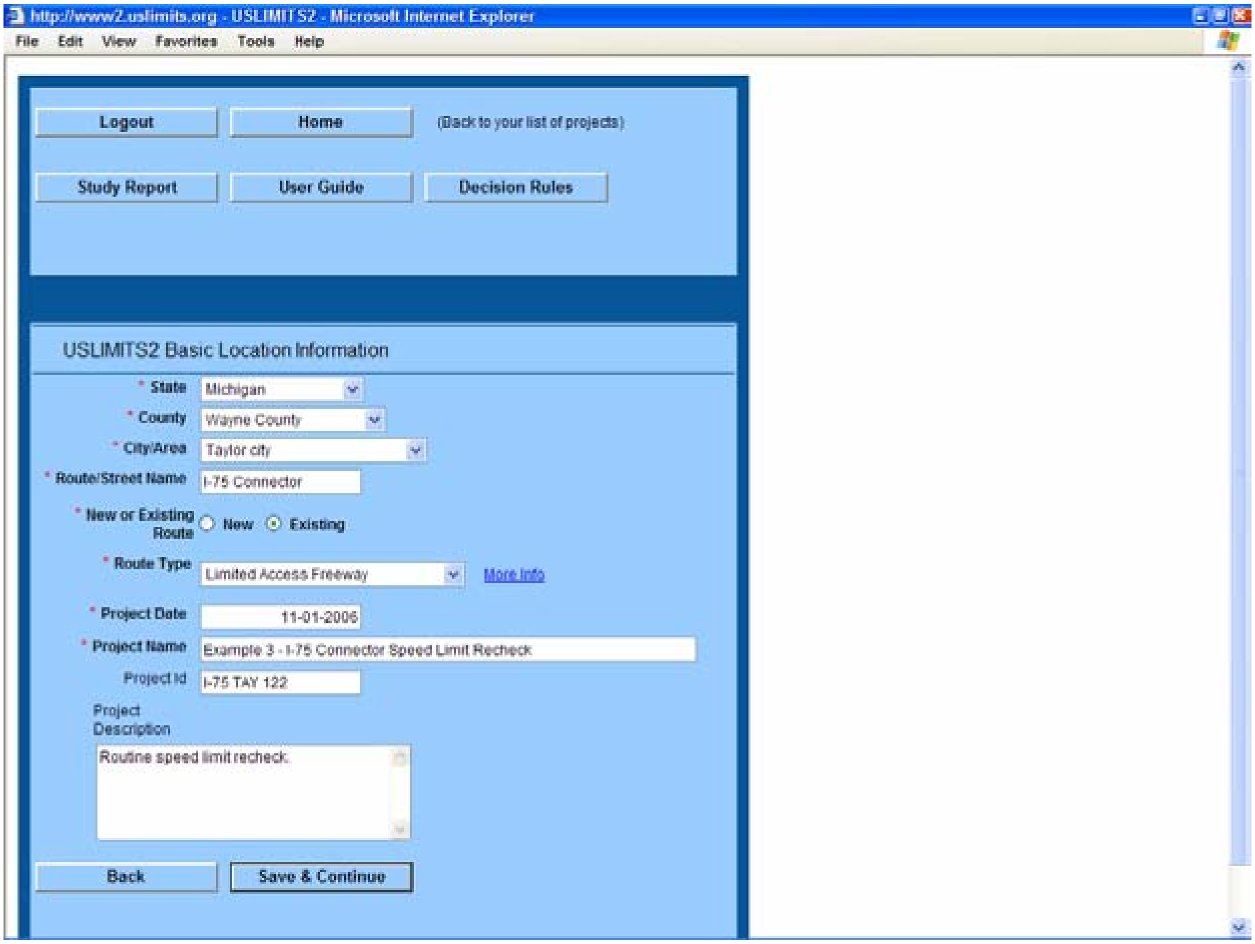
Comments -

Recommended Speed Limit is:40

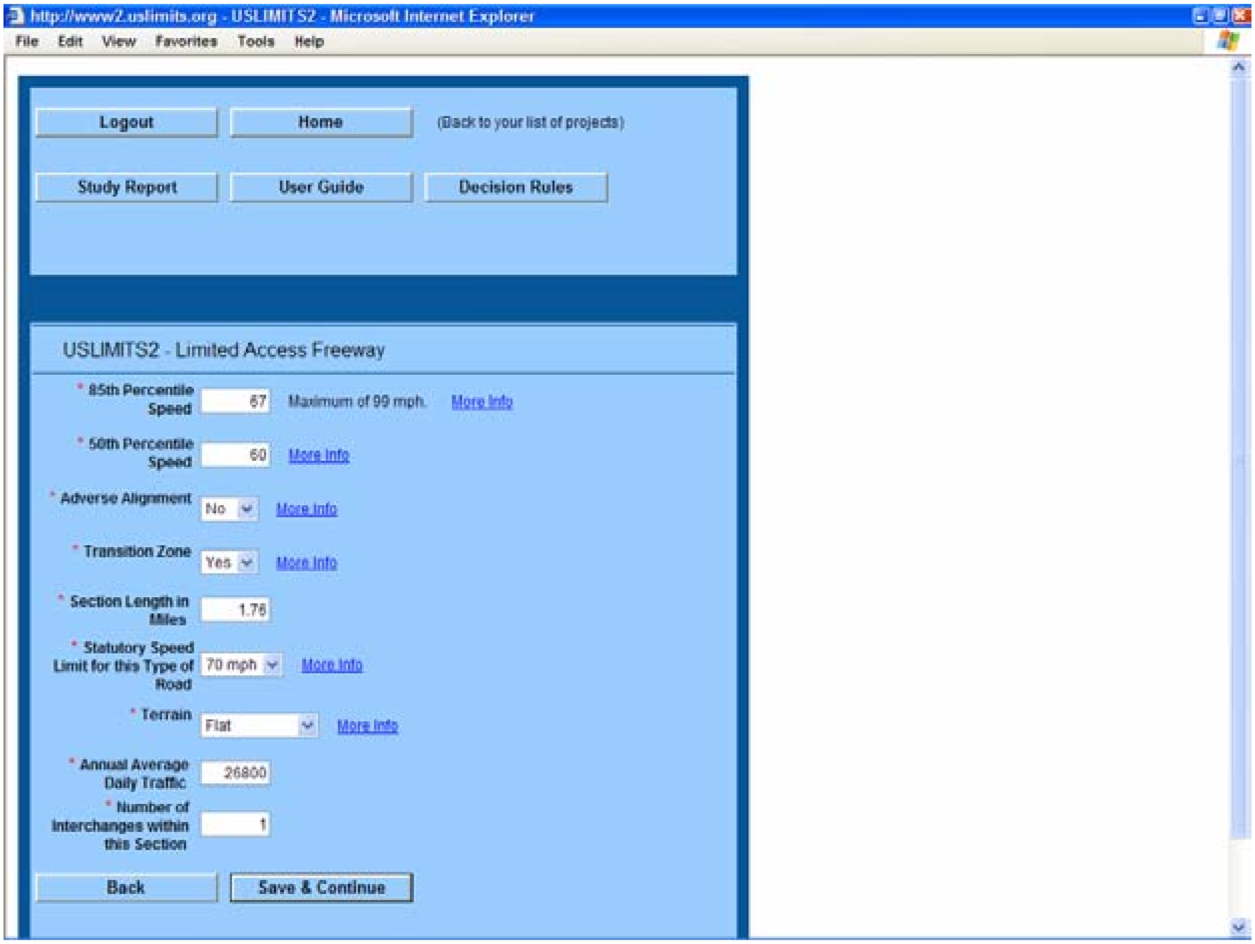
Example 3 – Speed Limit Recheck on an Urban Freeway Connector

This final example is a short freeway connector that runs between a high-volume, high-speed Interstate route and a non-limited access multilane urban arterial corridor. As a routine recheck of posted speed limits conducted every five years, the traffic engineer has been asked to conduct a traffic and engineering investigation to determine if the existing maximum 55 mile per hour speed limit is appropriate for conditions. Based on data collected during the investigation, the USLIMITS2 screens below show the input variables and final suggested speed limit for this freeway connector.

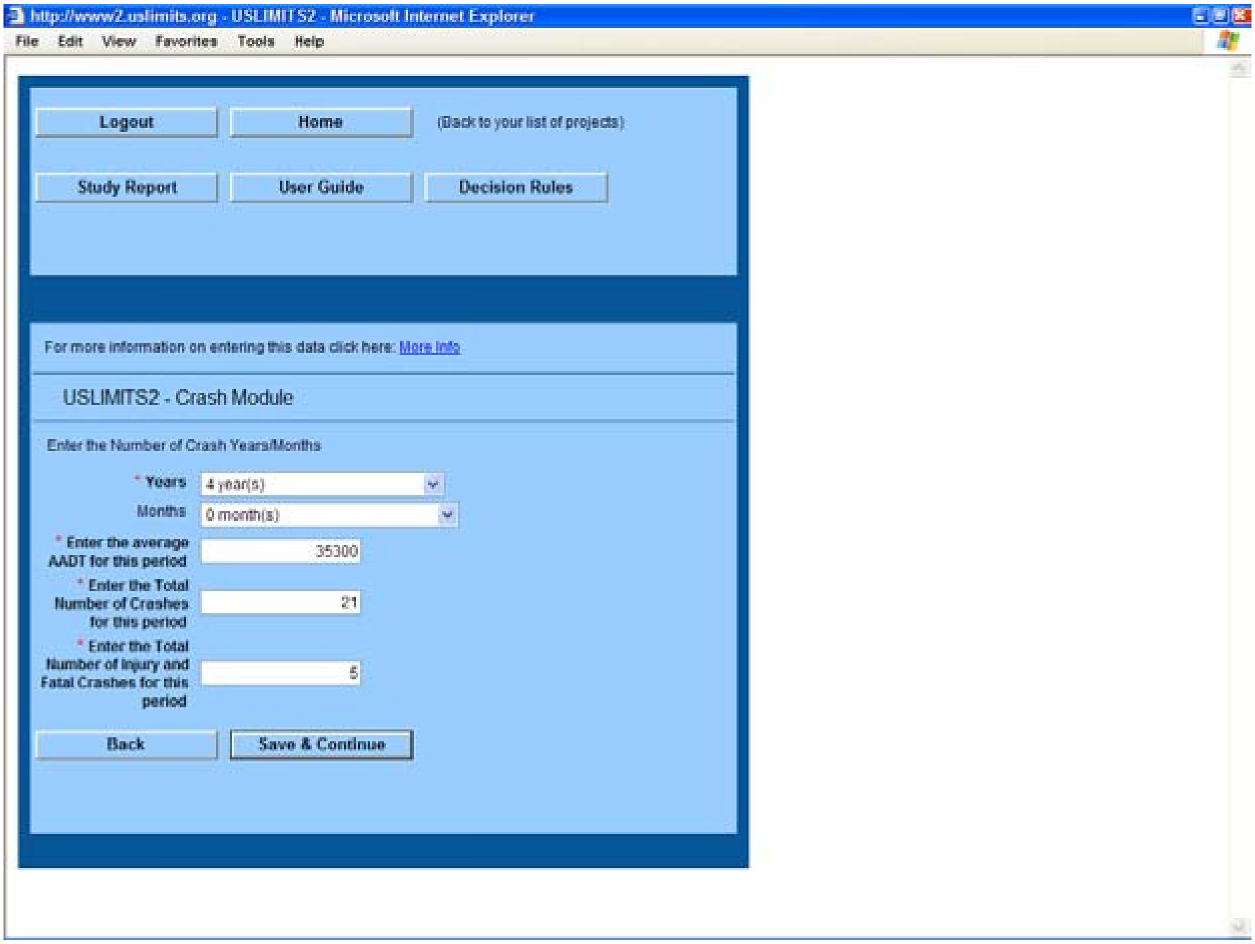
This is the Basic Location Information input screen.



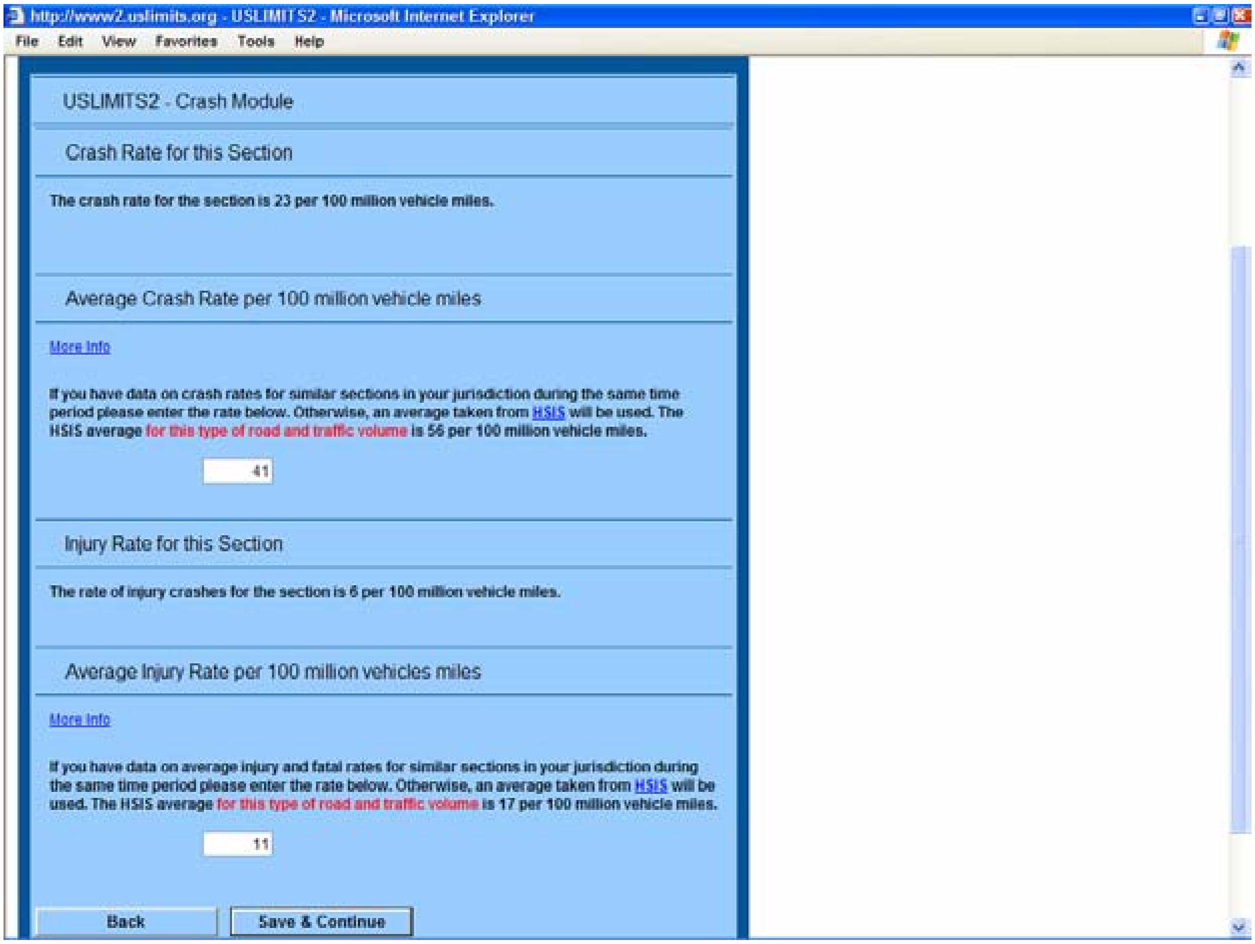
This is the basic input screen for the 85th percentile speed and other variables.



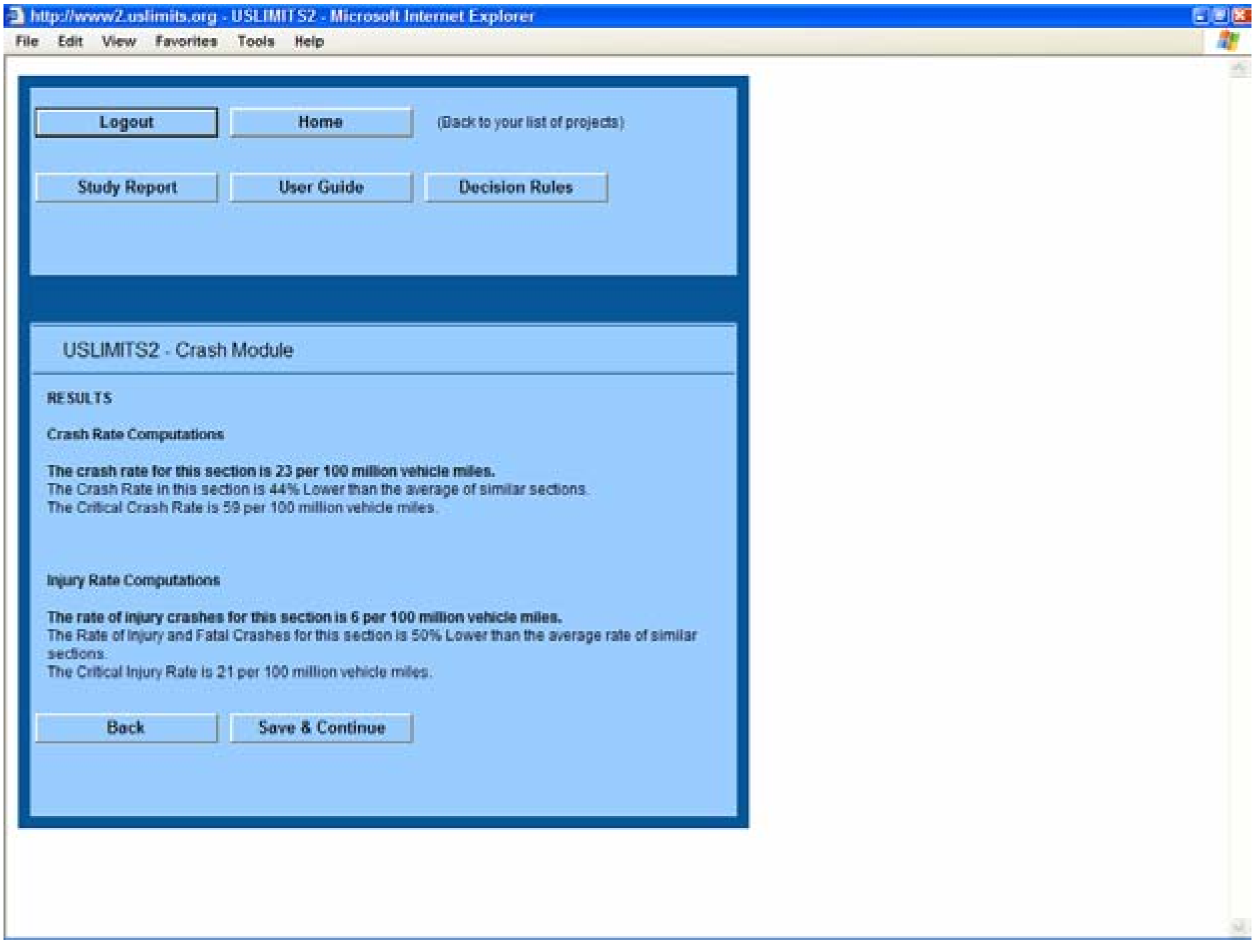
This is the input screen for the crash data.



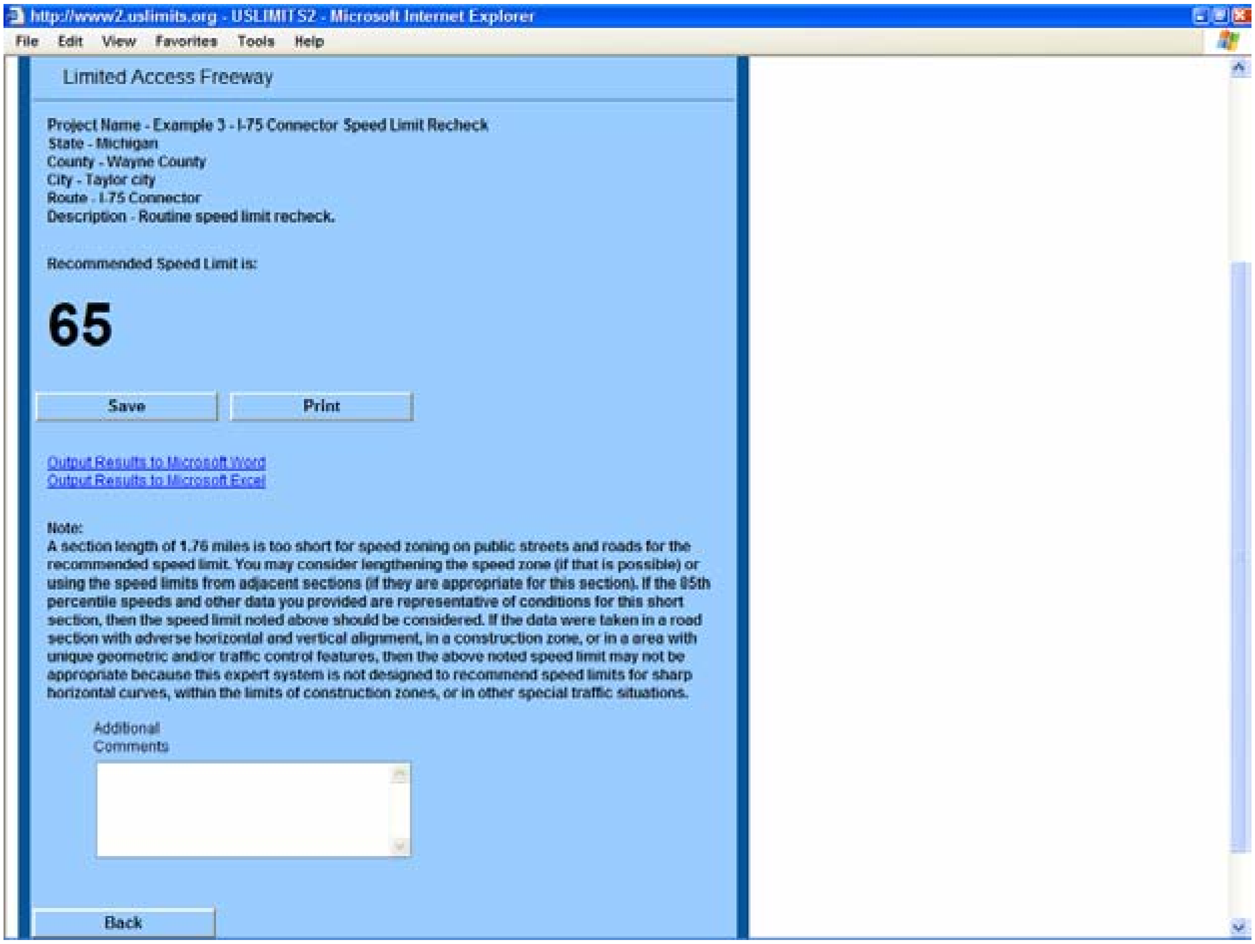
This is the crash summary generated by USLIMITS2 based on the crash data input by the user.



This screen provides a summary of the crash calculations.



This is the final output screen showing the advisory recommended speed limit and the appropriate notes for this freeway connector.



The results can also be printed to a Microsoft Word file as shown below.

USLIMITS2 Data Output

Basic Project Information

Project Name - Example 3 - I-75 Connector Speed Limit Recheck
Project Number - I-75 TAY 122
Project Date - 11-01-2006
State - Michigan
County - Wayne County
City - Taylor city
Route - I-75 Connector
Route Type - Limited Access Freeway
Route Status - EXISTING

Roadway Information

85th Percentile Speed - 67 mph
50th Percentile Speed - 60 mph
Section Length - 1.76 mile(s)
Statutory Speed Limit - 70 mile(s)
AADT - 26800
Terrain - Flat
Adverse Alignment - No
Interchanges - 1

Crash Data Information

Crash Data Months/Years - 4.00
Crash AADT - 35300
Total Number of Crashes - 21
Total Number of Injury Crashes - 5
Section Crash Rate - 23
Section Injury Rate - 6
Crash Rate Average for Similar Sections - 41
Injury Rate Average for Similar Sections - 11

Comments -

Recommended Speed Limit is:65

Note:
A section length of 1.76 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 a 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.