Methods and Practices for Setting Speed Limits:
An Informational Report

FHWA Safety Program

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Safe Roads for a Safer Future
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16. Abstract

This informational report describes four primary practices and methodologies that are used in establishing speed limits (engineering approach, expert systems, optimization, and injury minimization). It also reviews the basic legalities of speed limits and presents several case studies for setting speed limits on a variety of roads.

Despite the general acceptance and wide-spread use of speed limits throughout the world, there has been no consensus among practitioners concerning the methods and techniques that should be used to select the most appropriate speed limit for a particular facility. At the current time, it appears unlikely that any consensus will be achieved in the near future. This leaves practitioners without definitive guidance on this important issue, and in search of information to assist them. This report provides the information necessary for practitioners to make informed decisions in selecting a method for setting speed limits in their jurisdiction.

This report presents the procedures that highway agencies can and do use to set speed limits. As an informational report it provides a broad overview of the different speed limit setting methods that are available for use, but it makes no specific policy recommendations or suggestions.

Special situations, such as advisory, school zone, and work zone speeds are discussed. Speed limit enforcement and reevaluation of speed limits are discussed briefly. The design speed for the roadway will not be discussed, except as it may relate to the setting of speed limits. This is because design speed is a characteristic of the roadway that is essentially "built-in" to the road, and is not easily modified.

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SI* (Modern Metric) Conversion Factors

Approximate Conversions to SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
Length				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
Area				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
Volume				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
Mass				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
Temperature (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
Illumination				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
Force and Pressure or Stress				
lbf	pound force	4.45	Newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Approximate Conversions from SI Units				
Symbol	When You Know	Multiply By	To Find	Symbol
Length				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
Area				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
Volume				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
Mass				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
Temperature (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
Illumination				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
Force and Pressure or Stress				
N	Newtons	0.225	pound force	lbf
kPa	kilopascals	0.145	pound force per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
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TABLE OF CONTENTS

TABLES

FIGURES

BACKGROUND

In 1885, Karl Friedrich Benz revealed the first gasoline-powered automobile on the public street system.[1] The fastest his car could go was about 13 mph (21 km/h). Since that time, advances in science and technology have brought faster vehicles and better roads, both of which have served to increase travel speeds for automotive travel. Today, attainable speeds are far higher than the maximum speeds that society generally accepts as reasonable for motorized travel on public streets, yet the speedometers on most motor vehicles display maximum speeds that far exceed the maximum legal speed limits on most roads.

Speeding, commonly defined as exceeding the posted speed limit or driving too fast for conditions, is a primary crash causation factor across the globe. Based on a survey of road safety performance, speeding is the number one road safety problem in many countries, often contributing to as many as one-third of fatal crashes and serving as an aggravating factor in most crashes.[2] According to the National Highway Traffic Safety Administration (NHTSA), speeding-related crashes account for over 13,000 fatalities per year in the United States, making speeding one of the most often-cited contributing factors for fatal crashes.[3]

One of the most frequently used methods of managing travel speeds is the posted speed limit. The setting of speed limits predates the automobile by some 200 years, when Newport, Rhode Island, prohibited the horses galloping on major thoroughfares to prevent pedestrian deaths. Similarly, Boston, Massachusetts, limited horse-drawn carriages to "foot pace" on Sundays to protect church-goers.

The English Parliament is credited with setting the world's first speed limit for mechanically-propelled vehicles in 1861.* At that time, the Locomotive Act (automobiles were considered "light locomotives") limited the speed of all "locomotives" on public highways to 10 mph (16 km/h)–5 mph (8 km/h) through any City, town, or village.[4] The Act was later amended to set speed limits of 4 mph (6 km/h) outside of towns and 2 mph (3 km/h) within them. These new operating speeds also required three operators for each vehicle—two traveling in the vehicle and one walking ahead and carrying a red flag to warn pedestrians and equestrians.[5]

Selecting an appropriate speed limit for a facility can be a polarizing issue for a community. Residents and vulnerable road users generally seek lower speeds to promote quality of life for the community and increased security for pedestrians and cyclists; motorists seek higher speeds that minimize travel time. Despite the controversy surrounding maximum speed limits, it is clear that the overall goal of setting the speed limit is almost always to increase safety within the context of retaining reasonable mobility.

The principal exception to the safety objective of speed limits was the oil crisis in the early 1970s, when speed limits were lowered as a means of conserving fuel. This rationale for lower speed limits was revived in Spain in early 2011, where the government lowered the maximum speed limit of 75 mph (120 km/h) to 70 mph (110 km/h) in an attempt to curb fuel consumption in the face of rising oil prices.[6] However, the measure lasted only four months before the top speed limit was returned to the former 75 mph (120 km/h).

Maximum speed limits are laws; therefore, speed limits are set for the protection of the public and the regulation of unreasonable behavior on the part of individuals.

* This still predates the gasoline-powered automobile and was enacted for steam-powered vehicles.

PURPOSE AND SCOPE

Despite the wide-spread acceptance and use of speed limits throughout the world, there has been no consensus among practitioners concerning the methods and techniques that should be used to select the most appropriate speed limit for a particular facility. Currently, it appears unlikely that consensus will be achieved in the near future. This leaves practitioners without definitive guidance on this important issue, and in search of information that may assist them. This report provides the information necessary for practitioners to make informed decisions concerning the method that is selected for setting speed limits in their jurisdiction.

This report presents the various procedures that highway agencies can and do use to set speed limits. It is an informational report and provides a broad overview of the different speed limit setting methods that are available, but makes no specific recommendations or suggestions.

Special situations, such as advisory, school zone, and work zone speeds are discussed. Speed limit enforcement and periodic reevaluation of speed limits are discussed briefly. The design speed for the roadway will not be discussed, except as it relates to the setting of speed limits. This is because design speed is a characteristic of the roadway that is essentially "built-in" to the road, and is not easily modified.

Technical terms are defined in Appendix A.

REPORT ORGANIZATION

The remainder of this report is organized into eight sections as follows:

THE SAFETY OF SPEED: As speed limits are first and foremost a road safety measure, a discussion on the effects of speed on crash risk is provided for the information of the user.

SPEED LIMIT BASICS: An introduction to the broad categories and types of speed limits, including statutory speed limits, prima facie speed limits, and speed zoning.

SETTING SPEED LIMITS: A detailed description of the various methods that are available for setting speed limits, a brief discussion of special types of speed limits (i.e., nighttime speed limits, school zone speed limits, truck speed limits, etc.), and information on minimum lengths of speed zones.

SPEED LIMIT SIGN DESIGN AND PLACEMENT: Criteria that are used in selecting sign types and in the placement of the signs for speed zones and speed transitions. Also included is some information on Speed Feedback signs.

SPEED STUDY DATA COLLECTION: An outline of the data required for determining a posted speed limit with emphasis on spot speed data collection and analysis.

SPEED LIMIT ENFORCEMENT: A brief discussion on the role of engineering practitioners in assisting with the enforcement of speed limits.

CASE STUDIES: Two case studies that demonstrate the use of several available methods for setting speed limits.

REFERENCES AND APPENDICES: Supporting information and additional details for the reader.

THE SAFETY OF SPEED

It is important to understand how speed impacts safety, because setting speed limits is primarily a road safety measure. While the laws of physics make it very clear that speed and crash severity are inextricably linked (i.e., severity increases geometrically as speed increases), there has been a good deal of controversy over the impact of speed on crash occurrence. This is primarily because the variety of road design and operating characteristics can obscure the precise relationship between speed and crash occurence. Numerous studies and research efforts on this topic that have presented conflicting results on this important relationship. However, the most recent and statistically robust research on speed and crash occurrence fairly definitively indicates that, all other factors being equal, increased speeds increase crash occurrence.[7] The magnitude of the increase is dependent on the specifics of each case, with urban areas having the most pronounced relationship and controlled-access facilities the weakest.

One of the most statistically robust efforts to uncover the relationship between speed and safety was a meta-analysis conducted by the Norwegian Institute of Transport Economics.[7] The information and conclusions from the meta-analysis form the basis for the statements made in this section.

For a given roadway type, there is a strong statistical relationship between speed and crash risk for speeds in the range of 15 mph to 75 mph (25 km/h to 120 km/h). When the mean speed of traffic is reduced, the number of crashes and the severity of injuries will almost always go down. When the mean speed of traffic increases, the number of crashes and the severity of injuries will usually increase. The relationship between mean travel speed and crash risk can be adequately described in terms of the following model:

$$CMF = \left(\frac{V_a}{V_b}\right)^x$$

CMF = Crash modification factor

V_a = Mean speed in the after condition

V_b = Mean speed in the before condition

X = 3.6 for fatal crash frequency
2.0 for injury crash frequency
1.0 for property-damage-only crash frequency
4.5 for fatalities
2.7 for personal injuries

The relationship between speed and crash risk can be modified to some extent by road environment, vehicle-related factors, and driver behavior. But, the effects of speed on crash risk are remarkably consistent across different contexts.

The above relationship between speed and crash risk is significantly different from the traditional U-shaped relationship that has defined much of the current North American thinking on speed limits and speed management. The U-shaped relationship (Solomon curve) between speed and crash risk can be questioned for two reasons:

1. The U-shape is generally expected to be an artifact of errors in the measurement of speed[8,9]; and
2. There is a strong correlation between mean speed and speed variance, so it is difficult to separate the effects of mean speed and speed variance on crash risk.[10]

This discussion describes the relationship between travel speed and crash risk, but it does not necessarily reflect the relationship between speed limits and crash risk.

A change in the speed limit almost always changes the mean speed of traffic. However, the changes are not always proportional. For the most part, the change in the mean speed of traffic created by a change in speed limit is around 25 percent of the change in the speed limit.[7] In other words, a speed limit increase or reduction of 6 mph (10 km/h) yields about a 1.5 mph (2.5 km/h) raising or lowering of the mean speed, respectively. When this statistic is combined with the power formula equating change in mean speed to crash risk, it is evident that lowering the speed limit will reduce crash risk, and raising the speed limit will increase crash risk.

Whether the safety gains/losses associated with the change in the speed limit is worthwhile must be examined in the context of maintaining reasonable mobility, and other system objectives. In addition, the policy context must be considered because the relationship between travel speed and speed limits indicates that the percentage of violators increases when speed limits are lowered and decreases when speed limits are increased.

SPEED LIMIT BASICS

Setting speed limits in the United States has always been a responsibility of State and local governments. The unrestricted freedom to exercise that authority was interrupted by the Federal Government during World War II, and more recently with the National Maximum Speed Limit of 55 mph (90 km/h). The National Maximum Speed Limit was repealed in 1995.

Every State has a basic speed statute requiring drivers to operate their vehicles at a speed that is reasonable and prudent for conditions. This basic rule is contained in the *Uniform Vehicle Code (UVC)*, which provides a model set of motor vehicle laws to encourage uniformity in State traffic regulation. State statutes authorize maximum speed limits that may vary by highway type (e.g., interstate highways) or location (e.g., urban district).[11]

The *UVC* is a set of model traffic laws that was originally developed by the National Committee on Uniform Traffic Laws and Ordinances (NCUTLO), a now defunct, private, non-profit organization. The NCUTLO's members were mainly State governments and some related organizations. The extent to which the code is used varies by State. The *UVC* and most State motor vehicle laws include a basic speed law with wording similar to the following: No person shall drive a vehicle at a speed greater than is reasonable and prudent under the conditions and having regard for the weather, visibility, traffic, and the surface and width of the roadway.[11]

Article VIII—Speed Restrictions

11-801—Basic rule

No person shall drive a vehicle at a speed greater than is reasonable and prudent under the conditions and having regard to the actual and potential hazards then existing. Consistent with the foregoing, every person shall drive at a safe and appropriate speed when approaching and crossing an intersection or railroad grade crossing, when approaching and going around a curve, when approaching a hill crest, when traveling upon any narrow or winding roadway, and when special hazards exist with respect to pedestrians or other traffic or by reason of weather or highway conditions. (Revised, 1968)

Uniform Vehicle Code and Model Traffic Ordinance, 2000, National Committee on Uniform Traffic Laws and Ordinances, Evanston, Illinois.

Section 11-803 of the *UVC* recommends States establish speed zones upon the basis of an engineering and traffic investigation. Section 11-804 outlines recommended practices on how local authorities may alter maximum limits.[12]

Types of Speed Limits

Speed limits may be classified as default/statutory regulations, or speed zoning regulations established on the basis of engineering studies. In all cases, a speed limit must be legislated (i.e., established by legislative authority).

Statutory Speed Limits

Statutory limits are based on the concept that uniform categories of highways can operate safely at certain maximum speeds under ideal conditions. State motor vehicle laws specify speed limits on specific categories of streets and highways. For example, a vehicle code might limit speeds to 25 mph (40 km/h) in residential areas, 30 mph (50 km/h) in business districts, and 55 mph (90 km/h) on all other roads. Generally, statutory limits apply throughout a political jurisdiction.[11] Table 1 contains examples of statutory limits for three States and for the *Uniform Vehicle Code*.

Table 1. Examples of Speed Limit Statutes

Jurisdiction	Speed Limit Statute
Uniform Vehicle Code	55 mph (90 km/h) in locations other than urban districts 35 mph (60 km/h) in urban districts
Delaware	Where no special hazard exists, the following speeds shall be lawful, but any speed in excess of such limits shall be absolute evidence that the speed is not reasonable or prudent and that it is unlawful: All types of vehicles: 25 mph (40 km/h) in any business district 25 mph (40 km/h) in any residential district 20 mph (30 km/h) at all school zones where 20 mph (30 km/h) regulatory signs are in effect during specific periods 50 mph (80 km/h) on 2-lane roadways 55 mph (90 km/h) on 4-lane roadways and on divided roadways
Minnesota	10 mph (15 km/h) in alleys 30 mph (50 km/h) on streets in urban districts 70 mph (110 km/h) on rural interstate highways 65 mph (105 km/h) on urban interstate highways 65 mph (105 km/h) on expressways 55 mph (90 km/h) on other roads
Oregon	15 mph (25 km/h) – alleys; narrow residential roadways 20 mph (30 km/h) – business districts, school zones 25 mph (40 km/h) – residential districts, public parks, ocean shores 55 mph (90 km/h) – open rural highways, trucks on interstate highways 65 mph (105 km/h) – passenger vehicles, light trucks, motor homes, and light duty commercial vehicles on interstate highways.

Statutory speed limits allow for speed limits to be in effect even when it is not practical to post them.

There are two types of statutory speed limits: (a) absolute limits and (b) *prima facie* limits. The principle difference between the two types is whether someone who is charged with driving over the speed limit can defend her/his actions. An absolute speed limit is a limit above which it is unlawful to drive regardless of roadway conditions, the amount of traffic, or other influencing factors. There is no recourse to contend a charge. A *prima facie* speed limit is one above which drivers are presumed to be driving unlawfully but, if charged with a violation, they may contend that their speed was safe for conditions existing on the roadway at that time. And, therefore, that they are not guilty of a speed limit violation.

Prima facie limits provide greater flexibility to drivers to determine an appropriate speed for conditions and place a greater burden of proof on the enforcement community that a violation has occurred.

Approximately two-thirds of the States have absolute speed limits.[11]

Speed Zones

Where statutory limits do not fit specific road, traffic, or land uses conditions, most road authorities have the power to establish speed zones to reflect the safe maximum reasonable speed. These alternative speed limits may be higher or lower than those prescribed by the *UVC* or the statutory limits of the jurisdiction. Alternative maximum legal speed limits are established by legislating the speed zone, typically founded on the basis of an engineering study, and becoming effective when the limits are posted and properly recorded.[11] Agencies process resolutions, traffic control orders, or other formal documents to properly record the legal speed limit. An example of a Traffic Control Order is shown in Appendix B.

To encourage compliance and effectively manage risk, many agencies set speed limits to reflect the "reasonable and prudent" behavior of the majority of motorists acting in an appropriate manner. This encourages drivers to obey the posted speed limit and travel at a reasonable speed. It also targets limited enforcement resources at the occasional violator who disproportionately contributes to crash risk. The concept of a rational speed limit involves a formal engineering review, during which drivers' free-flowing speeds are observed. The assumption is that by reflecting actual driver speeds, most people will consider the speed limit appropriate. Such speed limits are desirable because they encourage public compliance, reduce speed differences among drivers, and offer a defensible enforcement tool.

SETTING SPEED LIMITS

This section describes the main objectives and guiding principles of setting speed limits and provides a detailed description of the principal available methods.

Speed limits are set to inform motorists of appropriate driving speeds under favorable conditions. Drivers are expected to reduce speeds under certain conditions (e.g., poor visibility, adverse weather, congestion, warning signs, or presence of bicyclists and pedestrians). Legislation and statutes generally reflect this requirement. All speed control regulations provide the legal basis for adjudication and sanctions for violations of the law. Road authorities may also post advisory speed signs, which do not have the force of law but warn motorists of suggested safe speeds for specific conditions at a particular location (e.g., a turn or an intersection approach).[11] Having stated the above, however, a motorist exceeding an advisory speed could still be cited under the basic speed rule (i.e., driving too fast for the prevailing conditions).

The primary purpose of the speed limit is to advise drivers of the maximum reasonable and safe operating speed under favorable conditions. It provides a basis for enforcement and ought to be fair in the context of traffic law.

Methodologies for setting speed limits typically are designed to result in recommended speed limits that:

- Are related to crash risk;
- Provide a reasonable basis for enforcement;
- Are fair in the context of traffic law; and
- Are accepted as reasonable by a majority of road users.

The selected methodology is generally applicable on all road types and capable of being implemented with existing resources.

Factors that affect safe speeds along roadways, and also influence the speed selected by motorists, include:

- A vehicle's mechanical condition and characteristics;
- Driving ability/capabilities;
- Traffic volume: vehicles, pedestrians, and bicycles;
- Weather and visibility;
- Roadway design elements, including:
  - » Road function/purpose;
  - » Lane and shoulder width;
  - » Horizontal and vertical curves;
  - » Available sight distances;
  - » Driveways with restricted visibility and other roadside developments;

    - High driveway density;
    - Rural residential or developed areas; and
    - Paved or improved shoulders.
- Pavement conditions; and
- Crash frequency and severity.

All of these factors should be considered when designing appropriate speed limits at locations where the speed limits need to be varied from the statutory limits. Special situations also exist that necessitate nighttime, school zone, work zone, minimum and variable speed limits or advisory speeds.

The above-mentioned factors to be considered in selecting a speed limit are also heavily influenced by geometric design features of the road and roadside development/activity. This is largely because drivers tend to select operating speeds based on the visual scene presented to them. Therefore, the speed limit and design of the road must work in concert if desired operating speeds are to be achieved.

Due to the lack of specific guidance and procedures from the *Manual on Uniform Traffic Control Devices* (MUTCD) and other documents, engineers often rely on their experience and judgment when considering factors that affect decisions about setting appropriate speed limits. The use of subjective procedures by decision-makers with various levels of experience, and the use of different procedures across jurisdictions, may lead to inconsistencies in how speed limits are set in different jurisdictions.

Methods of Setting Speed Limits

Within the traffic engineering community, there are four general approaches to setting speed limits:

- **Engineering approach:** A two-step process where a base speed limit is set according to the 85th percentile speed, the design speed for the road, or other criterion. This base speed limit is adjusted according to traffic and infrastructure conditions such as pedestrian use, median presence, etc. Within the engineering approach there are two approaches; 1) Operating Speed Method and 2) Road Risk Method.
- **Expert system approach:** Speed limits are set by a computer program that uses knowledge and inference procedures that simulate the judgment and behavior of speed limit experts. Typically, this system contains a knowledge base containing accumulated knowledge and experience (knowledge base), and a set of rules for applying the knowledge to each particular situation (the inference procedure).
- **Optimization:** Setting speed limits to minimize the total societal costs of transport. Travel time, vehicle operating costs, road crashes, traffic noise, and air pollution are considered in the determination of optimal speed limits.
- **Injury minimization or safe system approach:** Speed limits are set according to the crash types that are likely to occur, the impact forces that result, and the human body's tolerance to withstand these forces.

Engineering and expert system approaches are widely used in North America, injury minimization methods are gaining wide-spread use in countries that are at the forefront of global road safety (i.e., Sweden,

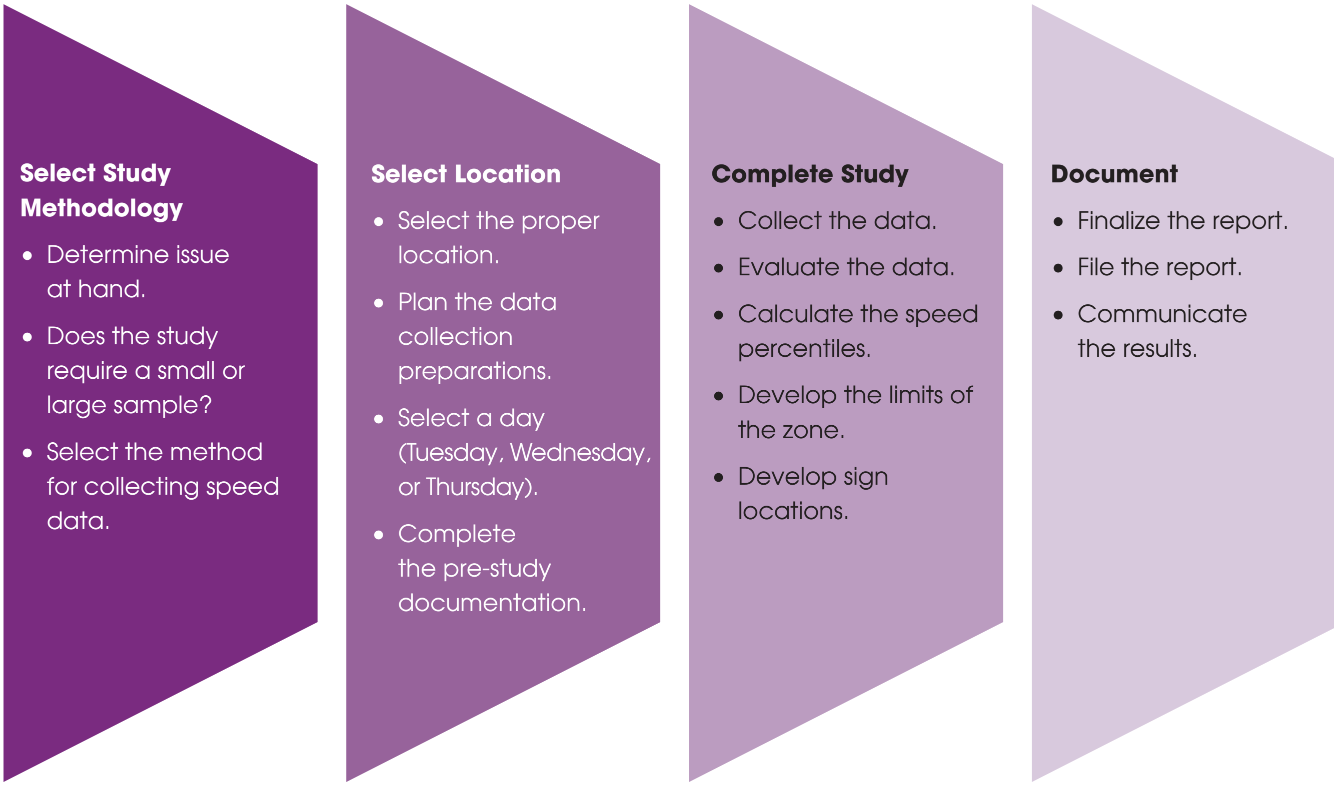

Figure 1. Speed Limit Study Process for Engineering and Expert Systems Methods.

Australia, etc.). The concept of setting optimal speed limits has been studied by some jurisdictions, but is not known to have been adopted by any road authority. However, the optimal speed limits approach seems applicable within the context of providing context sensitive solutions (CSS)—an approach that considers the total context within which a facility will exist—and has been considered for application on some New Jersey roads.[13]

Speed limits set by either an engineering method or an expert system use similar basic tenets. The engineering method is often limited to a basic study, while the expert system approach employs a more structured set of decision and judgment rules. For both methods, the speed limit is determined by considering the existing speed, roadway, and crash information. Figure 1 shows the steps that lead to producing the final report for either an engineering or an expert systems type of speed study.

Speed limit studies are most often undertaken in response to a request for a lower speed limit than currently posted. In some instances, however, the road authority finds itself in the position of recommending a higher speed limit than the one currently posted. In these latter instances, some jurisdictions require a road safety audit be conducted prior to a higher speed limit being approved.[14]

The following sections detail the steps to setting speed limits using the four methods.

Engineering Approach

The steps in the engineering approach to setting speed limits include planning, coordination, data collection and analysis, and finally, determination of the speed limits. A traffic engineering study is the observation and analysis of road and traffic characteristics to guide the application of traffic engineering principles. The study of speed limits includes the following:

- Review of the road's environment, features, and condition and traffic characteristics.
- Observation and measurement of vehicle speeds at one or more representative spots along the road in ideal weather and under free-flowing traffic conditions.
- Analysis of vehicle speeds to determine 85th percentile speed and other characteristics.
- Review of the road's crash history.
- Review of any unusual conditions not readily apparent.

Setting speed limits is complex and often controversial. The engineering approach requires the use of engineering judgment based on the engineering and traffic investigation. Quality data and good documentation provides support for the judgments that are made.

Within the engineering approach to setting speed limits there are two basic methods: the operating speed method and the road risk method. Each of these is detailed below.

Operating Speed Method

Most engineering approaches to speed limit setting are based on the 85th percentile speed—the speed at which 85 percent of free-flowing traffic is traveling at or below. The typical procedure is to set the speed limit at or near the 85th percentile speed of free-flow traffic. Adjustments to either increase or decrease the speed limits may be made depending on infrastructure and traffic conditions.

Setting a speed limit based on the 85th percentile speed was originally based on safety. Specifically, research at the time had shown that traveling at or around one standard deviation above the mean operating speed (which is approximately the 85th percentile speed) yields the lowest crash risk for drivers. Furthermore, crash risk increases rapidly for drivers traveling two standard deviations or more above or below the mean operating speed. Therefore, the 85th percentile speed separates acceptable speed behavior from unsafe speed behavior that disproportionately contributes to crash risk.*

The 85th percentile speed method is also attractive because it reflects the collective judgment of the vast majority of drivers as to a reasonable speed for given traffic and roadway conditions. This is aligned with the general policy sentiment that laws (i.e., speed limits) should not make people acting reasonably into law-breakers. Setting a speed limit even 5 mph (8 km/h) below the 85th percentile speed can make almost half the drivers illegal; setting a speed limit 5 mph (8 km/h) above the 85th percentile speed will likely make few additional drivers legal.

Under the operating speed method of setting speed limits, the first approximation of the speed limit is to set the speed limit at the 85th percentile speed. The MUTCD recommends that the speed limit be within 5 mph (8 km/h) of the 85th percentile speed of free-flowing traffic. The posted speed limit shall be in multiples of 5 mph[15], or 10 km/h for jurisdictions that employ metric.[22]

While the MUTCD recommends setting the posted speed limits near the 85th percentile speed, and traffic engineers say that agencies are using the 85th percentile speed to set speed limits, in reality the speed limit is often set much lower. At these locations, the 85th percentile operating speeds exceed the

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* The original research between speed and safety which purported that the safest travel speed is the 85th percentile speed is dated research and may not be valid under scrutiny. See the section titled "The Safety of Speed" for a synopsis of current thinking on the relationship between speed and safety.

posted speed limits; and, in many cases, the 50th percentile operating speed is either near or exceeds that posted speed limit as well.[16] Many agencies deviate from their agency's written guidelines and instead post lower speed limits. According to an ITE Engineering Council Technical Committee survey, these reduced speed limits are often the result of political pressures.[17] ***However, it is important to note that setting speed limits lower than 85th percentile speed does not encourage compliance with the posted speed limit.***[16]

The 85th percentile speed can be adjusted on the basis of engineering and traffic investigation. The following are typical adjustments made by several States:

- Adjustments made for roadway factors and/or crash data may be lower than the 85th percentile speed, but normally no more than 7 mph (11 km/h) lower.[18]
- Adjustments for roadway factors may reduce the 85th percentile speed by as much as 10 mph (16 km/h) below the 85th percentile speed based on sound and generally accepted engineering judgment that includes consideration of the following factors:
  - » Narrow roadway pavement widths (20 feet (6 m) or less, for example).
  - » Horizontal and vertical curves (possible limited sight distance).
  - » Driveways with restricted visibility and other developments (possible limited sight distance).
  - » High driveway density (the higher the number of driveways, the higher the potential for encountering entering and turning vehicles).
  - » Rural residential or developed areas (higher potential for pedestrian and bicycle traffic).
  - » Narrow shoulder widths (constricted lateral movement).
- If the crash rate for a two-year period is much higher than the average for other highways of similar classifications, adjustments are considered.[18]
- Adjustments can be made based on crash data when enforcement agencies will assure a degree of enforcement that will make the speed zone effective.[19]
- A 12 mph (20 km/h) reduction for locations where roadway factors and crash rates are higher than the statewide average.[19]

After the 85th percentile speeds and zone lengths have been selected, some jurisdictions recommend that several test runs be made through the area in both directions driving at the selected speeds. This should show any irregularities in the zoning that need correction before the speed zone is implemented.[19]

The last step in the analysis process for the operating speed method is to draw conclusions based on the observed data and to prepare a report. The report can be elaborate or very basic depending on why the study was performed and how the results will be used.

The use of the 85th percentile speed as the primary criterion for selecting a suitable speed limit is founded on the following fundamental concepts deeply rooted in government and law:

- Driving behavior is an extension of social attitude, and the majority of drivers respond in a safe and reasonable manner as demonstrated by their consistently favorable driving records.
- The normally careful and competent actions of a reasonable person should be considered legal.
- Laws are established for the protection of the public and the regulation of unreasonable behavior on the part of individuals.
- Laws cannot be effectively enforced without the consent and voluntary compliance of the public majority.[20]

The operating speed method has the added advantage that a properly set speed limit will provide residents, businesses, and pedestrians with a realistic expectation of actual vehicular speeds on the street.

Criticisms of the operating speed method of setting speed limits are largely targeted at the use of the 85th percentile speed as the starting point for establishing the speed limit. They include:

- This criterion assumes that motorists are aware of and select the safest speed.
- Drivers are generally bad at accounting for the externalities of their driving.

A further criticism that has been leveled against the 85th percentile speed as a primary determinant of the speed limit is that this practice may lead to an upward drift or creep in average operating speeds over time.[52]

The engineering approach to setting speed limits has manifested itself in North America as the setting of "rational" speed limits. The premise is that speed limits based on a formal, analytical review of traffic flow, roadway design, local development, and historical crash data will result in a high percentage of drivers complying with the speed limit and traveling at about the same speed.

Despite wide-spread use of the operating speed method for setting speed limits in North America, there are few jurisdictions that have quantitative criteria for the adjustments to the 85th percentile speed. For example, how much should a speed limit be reduced if there is a high volume of pedestrian traffic on the street? For the most part, the analyst is to use "engineering judgment" to make such valuations. Two notable exceptions to the qualitative procedures are the *Policy on Establishing and Posting Speed Limits on the State Highway System* by the Illinois Department of Transportation (DOT)[21], and the Northwestern Speed Zoning Technique (which is a procedure used by several municipalities).

The Illinois procedure considers access, pedestrian traffic, curbside parking, and safety performance, in addition to existing speed profile to establish the recommended speed limit. Specific numerical adjustments are specified in the procedure for each of the above criterion. The Illinois procedure is described in Appendix C.

The Northwestern Speed Zoning Technique is similar to the Illinois DOT procedure mentioned above, but it considers a wider range of traffic and infrastructure factors including presence of a median, lane width, vertical alignment, etc. Again, numerical direction is provided concerning the adjustments that are required for different road features, making the process repeatable and reliable. The Northwestern Speed Zoning Technique is detailed in Appendix D.

Road Risk Method

Another method of setting speed limits using an engineering approach is the road risk method in which the speed limit is determined by the risks associated with the physical design of the road and the expected traffic conditions. This method has numerous guises, but the core methodology is to set the speed limit according to the function or classification of the road (which also tends to dictate the design of the road), and then to adjust the speed limit based on the relative risk introduced by various road and roadside design features. This method is currently employed by Canada and New Zealand.

The road risk method is the same as the operating speed method in that a selected base speed limit is adjusted by various factors to determine the recommended speed limit. The main difference between the two engineering methods is that the operating speed method uses the 85th percentile speed as the base speed limit, and the road risk method uses a base speed limit that is predicated on the functional classification of the road and its setting.

Under the road risk method to setting speed limits the level of roadside development and the function of a road are the primary determinants of the appropriate speed limit.[14] Although road geometry is also a factor in determining a speed limit, it is secondary to roadside development. In situations where the road design encourages users to travel at a higher speed than the speed limit determined by roadside development, engineering techniques should be used to lower vehicle speeds. When a road in a built-up area primarily serves through traffic, engineering and access control techniques should be used to provide safety at the higher speeds that will prevail.[14]

Table 2 provides the base speed limits for different land use and road classifications as used in the road risk methodology used in Canada.[22]

Table 2. Base Speed for the Classification and Land Use Combination

<table>
<tr><th colspan="2" rowspan="4">Classification</th><th colspan="8">Land Use</th></tr>
<tr><th colspan="4">Rural</th><th colspan="4">Urban</th></tr>
<tr><th colspan="2">Undivided</th><th colspan="2">Divided</th><th colspan="2">Undivided</th><th colspan="2">Divided</th></tr>
<tr><th>1 lane per direction</th><th>2+ lanes per direction</th><th>1 lane per direction</th><th>2+ lanes per direction</th><th>1 lane per direction</th><th>2+ lanes per direction</th><th>1 lane per direction</th><th>2+ lanes per direction</th></tr>
<tr><td rowspan="2">Arterial</td><td>Major</td><td>55 mph (90 km/h)</td><td>60 mph (100 km/h)</td><td>60 mph (100 km/h)</td><td>70 mph (110 km/h)</td><td colspan="2">50 mph (80 km/h)</td><td colspan="2">55 mph (90 km/h)</td></tr>
<tr><td>Minor</td><td>50 mph (80 km/h)</td><td>55 mph (90 km/h)</td><td>55 mph (90 km/h)</td><td>60 mph (100 km/h)</td><td colspan="2">45 mph (70 km/h)</td><td colspan="2">50 mph (80 km/h)</td></tr>
<tr><td rowspan="2">Collector</td><td>Major</td><td>45 mph (70 km/h)</td><td>50 mph (80 km/h)</td><td>50 mph (80 km/h)</td><td>55 mph (90 km/h)</td><td colspan="2">45 mph (70 km/h)</td><td colspan="2">50 mph (80 km/h)</td></tr>
<tr><td>Minor</td><td>35 mph (60 km/h)</td><td>45 mph (70 km/h)</td><td>45 mph (70 km/h)</td><td>50 mph (80 km/h)</td><td colspan="2">35 mph (60 km/h)</td><td colspan="2">45 mph (70 km/h)</td></tr>
<tr><td colspan="2">Local</td><td colspan="4">35 mph (60 km/h)</td><td colspan="4">30 mph (50 km/h)</td></tr>
</table>

Lane = through lane

Divided = a median that separates travel lanes of traffic in opposing directions, which may be flush with, raised above, or depressed below adjacent travel lanes

By using the land use and functional classification of the road as the primary determinants of the desirable speed limit, road authorities that use the road risk method are attempting to reconcile the legislated speed of the road with the function of the road.

The road risk method used in New Zealand sets out the method for calculating the speed limit for a section of road from the following information:

- The existing speed limit;
- The character of the surrounding land environment (e.g., rural, fringe of city, fully developed);
- The function of a road (i.e., arterial, collector, or local);
- Detailed roadside development data (e.g., number of houses, shops, schools, etc.);
- The number and nature of side roads;
- Roadway characteristics (e.g., median divided, lane width and number of lanes, road geometry, street lighting, sidewalks, cycle lanes, parking, setback of fence line from the road);
- Vehicle, cycle, and pedestrian activity;
- Crash data; and
- Speed survey data.

The road risk method employed in New Zealand is detailed in Appendix E and includes a working example.

Despite the fact that the road risk method downplays operating speed as a factor in developing the speed limit, it is noted that the road risk method should recommend speed limits that are consistent with operating speeds.

Expert System—USLIMITS2:

An expert system is one approach that can be used to identify the appropriate speed limit for a speed zone. Transportation Research Board's (TRB) *Special Report 254* argues that the expert system approach deserves 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.[11]

Expert systems aim to mimic the expert's thought process in solving complex problems.

The original expert system for setting speed limits was developed by the Australian Road Research Board and was based on site studies at over 60 locations. The field data 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 coded into a computer program which prompts users to respond to a series of questions, which the system uses to recommend a speed limit. It is important to note that the Australian expert system logic is hard coded, and this system does not learn from previous experience, as some other "smart" expert systems do.

Federal Highway Administration (FHWA) developed a knowledge-based expert system for recommending speed limits in speed zones that are considered to be credible and enforceable. The expert system (known 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 first generation expert system developed by the Australian Road Research Board for FHWA.

USLIMITS2 is designed to determine speed limits in speed zones on all types of roadways, from rural two-lane segments to urban freeway segments. 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, USLIMITS2 employs a decision algorithm to advise the user of the speed limit for the specific road section. 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.

Overview of the Decision Rules and Data Requirements of USLIMITS2

A brief overview of the logic flow and decision rules that are used in the expert system is described in the following section, along with the data requirements. For brevity, flow charts describing the decision rules are not provided here, they are available in the National Cooperative Highway Research Program's (NCHRP) *Research Results Digest 318*.[23] The user is first asked to enter information about the location of the project and then indicate whether the road is a limited access freeway, road section in an undeveloped area, or a road section in a developed area (photographs illustrating the roadway types and definitions are provided in the User Guide, which can be downloaded from http://safety.fhwa.dot.gov/USLIMITS). The following are the roadway types:

- Limited access freeway
- Road section in undeveloped areas
- Road section in developed areas
  - » Residential subdivision/neighborhood street
  - » Residential collector street
  - » Commercial street
  - » Street serving large complexes

After users select the roadway type, they are taken to a window where they are asked to enter the site characteristics. Table 3 shows the site characteristics users are prompted to enter for each road type.

Table 3. USLIMITS2 Data Inputs for Road Types

Road Type	Site Characteristics
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. Terrain. 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. Current statutory limit for this type of road. Annual average daily traffic. Roadside hazard rating. 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. 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 pedestrian/bike activity. Crash statistics (if available).

For each roadway type, the program calculates a speed limit using one of two approaches:

Approach 1—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 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 eight States that are part of the Highway Safety Information System (HSIS) (http://www.hsisinfo.org). 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 at a 95 percent level of confidence.

If the crash or injury rate is higher than the corresponding critical rates, or at least 30 percent 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 is the 5 mph (8 km/h) multiple closest to the 85th percentile speed. If the user answers "No" or "Unknown," the recommended speed limit from this module is the 5 mph (8 km/h) increment obtained by rounding down the 85th percentile speed (if crash or injury rate is at least 30 percent higher than the average rate) or closest to the 50th percentile speed (if the crash or injury rate is higher than the critical rate).

Approach 2—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 annual average daily traffic (AADT). Based on the research team's judgment in interpreting the results of the work of Bared et al.,[24] recommended speed limits are the following:

- If AADT is higher than 180,000 and the average interchange spacing is between 0.5 and 1 mile (0.80 and 1.6 kms), the recommended speed limit from this approach will be the 5 mph (8 km/h) 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 (0.8 kms), the recommended speed limit is the 5 mph (8 km/h) multiple closest to the 50th percentile speed.

For other situations in freeways, the recommended speed limit from this approach will be the 5 mph (8 km/h) multiple closest to the 85th percentile speed.

For road sections in undeveloped areas, the roadside hazard rating[25] was selected as the safety surrogate. The recommended speed limits are the following:

- For roadside hazard ratings of 1, 2, or 3, the recommended speed limit is the 5 mph (8 km/h) multiple closest to the 85th percentile speed.
- For roadside hazard ratings of 4 or 5, the recommended speed limit is the 5 mph (8 km/h) multiple obtained by rounding down the 85th percentile speed.

- For roadside hazard ratings of 6 or 7, the speed limit is the 5 mph (8 km/h) 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 FHWA-sponsored work on the Benefits of Access Management,[26] 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 at least one of the following is true, the speed limit is the 5 mph (8 km/h) multiple closest to the 50th percentile speed:

- Signals per mile > 4.
- Pedestrian/bike activity is High (definitions are available in the USLIMITS2 User Guide).*
- Parking activity is High (definitions are available in the USLIMITS2 User Guide).*
- Driveways per mile > 60.

If Driveways per mile > 40 and ≤60, and Signals per mile > 3, and Area Type is (commercial or residential-collector) then the speed limit is the 5 mph (8 km/h) multiple obtained by rounding down the 85th.

For all other conditions, the speed limit is the 5 mph (8 km/h) multiple closest to the 85th percentile speed.

The lower value of the speed limit 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 (8 km/h) increment closest to the 85th percentile speed; it also does not recommend speed limits lower than the 5 mph (8 km/h) increment closest to the 50th percentile speed. The system also provides warnings if the 85th percentile speed is unusually low or high for a particular road type.

In 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:

- The length of the section is shorter than the minimum section length for the recommended speed limit.
- The final recommended speed limit is higher than the statutory limit for that type of road.
- There is adverse alignment in the section.
- The crash rate is higher than the critical crash rate or at least 30 percent higher than the average crash rate.
- The rate of injury and fatal crashes is higher than the critical injury rate or at least 30 percent higher than the average injury rate.

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*Available at http://Onlinepubs.trb.org/onlinepubs/trbnet/acl/NCHRP 0367_FinalReport.pdf.

Appendix F is a sample case study that outlines the data inputs and shows the applicable screens.

USLIMITS2 can be accessed through the Internet at http://safety.fhwa.dot.gov/USLIMITS.

Optimal Speeds

The concept of optimal speed limits is one that suggests speed limits that are optimized from a societal perspective considering the impacts that operating speeds have on the various societal objectives. It is recognized that individual drivers, in most instances, do not consider the risks imposed on others by their choice of driving speeds, or on the cumulative effects of their speed choice on the environment (i.e., fuel consumption, emissions, noise, etc.). The optimal speed for an individual driver may be different from the optimal speed for a community.[27]

Determining socially optimal speed limits is more complicated than calculating speed limits that have been optimized for the individual driver. However, this method is congruent with and considers overall transportation objectives and is thus appealing from a context sensitive solutions (CSS) perspective.

The optimum speed limit is the speed limit that yields the minimum total societal cost, which includes vehicle operation costs, crash costs, travel time costs, and other social costs. This method of setting speed limits is rarely used due to the difficulty of quantifying key variables.

As with any complex topic, whether a system is truly optimal is dependent on the perspective of the analyst. The road user, the taxpayer, the local community, and society all have differing views and values affecting the output of any optimization process. For example, the societal cost of noise caused by motor vehicle operation does not have a fixed price, but has a monetary value that is mainly established by means of stated preference. Motorists would likely place a lower value on noise than a local resident, perhaps leading to different optimal speeds for the same road.

In optimal speed limit setting, a total cost model is developed to express cost per mile of travel as a function of the posted speed limit. The total cost includes crash cost, travel time cost, fuel consumption cost, and vehicle emissions cost. Each of these costs varies with the posted speed limit, and cost curves are obtained based on the relationship between costs and speeds. The optimal speed limit is then determined as the minimum point on the total cost curve. This minimum total cost indicates the minimum social cost of transportation based on a particular set of conditions.

In general, the road user perspective and the taxpayer perspective result in higher speed limits, while the residential perspective results in the lowest. In some cases, particularly for motorways (freeways), variation in the total costs of travel is found to be very small for speeds in the range of 45 to 70 mph (70 to 110 km/h), making the choice of an optimal speed limit in this range almost an individual agency preference.

Optimal speed limits have been explored for use on shared-use roadways in New Jersey.[13] This method of setting speed limits seems particularly useful in situations where pedestrians, cyclists, and motorized traffic share the road, and motorists may not be fully aware of the externalities of their speed on other road users—in particular, the harm borne by pedestrians and cyclists when struck by a motor vehicle moving at a rapid speed. The Yang model for calculating the optimal speed limit is shown in Figure 2.

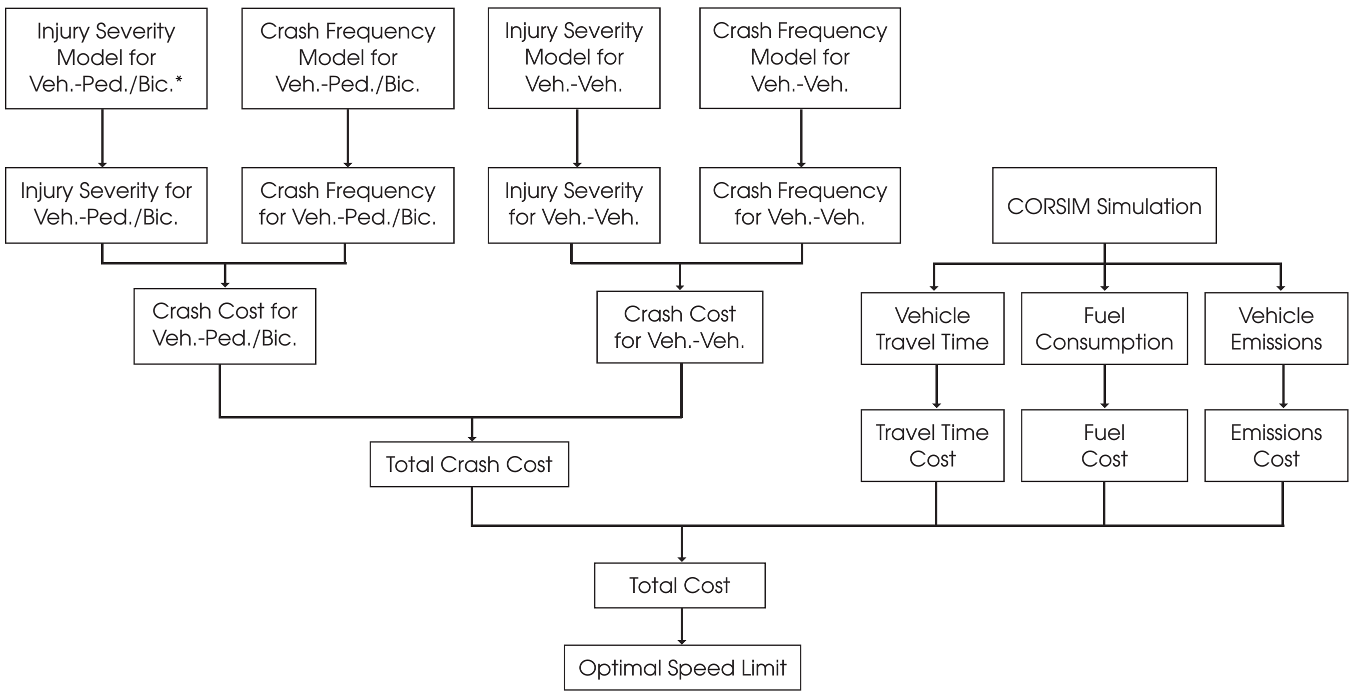

Figure 2. Optimal Speed Limit Process.[13]
*Vehicle-Pedestrian/Bicycle

In addition to the difficulty of achieving consensus on the costs, another characteristic of the optimal speed methodology is that proposed speed limits may not be immediately apparent to road users, they may not be congruent with the design of the road, and ultimately may result in an inordinate percentage of drivers exceeding the speed limit.

The optimal speed limit methodology has also been considered as an appropriate method of setting seasonal speed limits in jurisdictions with snow. The calculation showed that it is possible to apply the optimal speed limits to all road and traffic conditions, except for urban expressways for which the optimal speed limit obtained was too low to be viable.

Injury Minimization

The cornerstone of the injury minimization approach to setting speed limits is the tolerance of the human body to injury during a crash. It is based solely on a road safety platform and takes the position that it is unethical to create a situation where fatalities are a likely outcome of a crash in order to reduce delay, fuel consumption, or other societal objectives.

The principal challenge in an injury minimization approach to speed limits is to manage crash energy so that no user is exposed to impact forces capable of causing death or serious injury. Thus vehicles cannot legally travel at speeds where, in the event of a crash, the release of kinetic energy can produce a serious or fatal injury.[28] Under the current road system and vehicle fleet, this would limit speeds to those shown in Table 4.

Table 4. Speed Limits for Injury Minimization (Adapted from Reference 28)

Road type	Speed Limit, mph (km/h)
Roads with a mix of motorized and unprotected road users (i.e., pedestrians and cyclists)	20 (30)
Roads with uncontrolled access where side impact crashes can result	30 (50)
Undivided roads where head-on crashes can result	45 (70)
Controlled access facilities with a physical median separation, where at-grade access and non-motorized road users are prohibited	>60 (>100)

A safe system strategy does not imply that crashes are caused solely (or even mainly) by speed and it recognizes that any given crash event is likely to be the result of an interplay of many factors. Accordingly, a safe system approach requires that all aspects of the system work together for the safest possible outcome, with speed representing but one component, albeit a critical one.[28]

The injury minimization approach to speed limit setting results in speed limits that are lower than those traditionally used in North America (which are generally set by engineering and expert system methods). Thus implementing an injury minimization approach to speed limits would be problematic. The road authority cannot simply lower the speed limit and expect immediate or substantial compliance. Drivers are unlikely to fully respond except in the face of almost constant enforcement.

As mentioned throughout this report, speed limits need to be credible—they must generally reflect driver expectancies regarding travel speed. So while obtaining safe travel speeds is the prime objective of the injury minimization approach (as well as the major challenge), it should be noted that many jurisdictions need to understand they are starting from a point where driver expectancies result in operating speeds that are higher than the target speeds of an injury minimization approach.

In order to achieve safe speeds and make the associated speed limits credible for the driving population, road authorities need to:

- Make the road and its environment more "self-explaining" through traffic control devices, publicity and education campaigns, and reconstruction where required; and
- Build a case over time for a new paradigm as to what is regarded and legislated as a safe speed limit for the street network.

A summary of each method for setting speed limits and the advantages and disadvantages of each are shown in Table 5.

Table 5. Approaches to Setting Speed Limits

Approach	Jurisdictions	Basic Premise	Data Required	Advantages	Disadvantages
Engineering (Operating Speed)	United States	The speed limit is based on the 85th percentile speed, and may be slightly adjusted based on road and traffic conditions and crash history.	The existing speed profile as well as data on accesses, pedestrian/bicycle traffic, curbside parking, safety performance, etc.	Using the 85th percentile speed ensures that the speed limit does not place an undue burden on enforcement, and provides residents and businesses with a valid indication of actual travel speeds.	Drivers may not be adequate judges of the externalities of their actions, and may not be able to self-select the most appropriate travel speed. Speed limits are often set lower than the 85th percentile speed.
Engineering (Road Risk)	Canada, New Zealand	The speed limit is based on the function of the road and/or the adjacent land use and then adjusted based on road and traffic conditions and crash history.	Functional classification of the road, setting (urban/rural), surrounding land uses, access, design features of the road.	The speed limit and the function of the road are aligned. The function of the road also dictates many of the design elements of the road, so this method aligns the speed limits with the design of the road.	The road risk methods may result in speed limits that are well below the 85th percentile speeds, resulting in an increased burden on enforcement if remedial measures are not employed (i.e., traffic calming, etc.).
Expert System	United States, Australia	Speed limits are set by a computer program that uses knowledge and inference procedures that simulate the judgment and behavior of speed limit experts.	Data needs depend on the system, but generally expert systems require the same data as used in the engineering approaches.	A systematic and consistent method of examining and weighing factors other than vehicle operating speeds in determining an appropriate speed limit. It is reproducible and provides consistency in setting speed limits within a jurisdiction.	Practitioners may need to rely on output from the expert system without applying a critical review of the results.
Optimal Speed Limits	---	The selected speed limit minimizes the total societal costs of transport when considering travel time, vehicle operating costs, road crashes, traffic noise, air pollution, etc.	Cost models and input data to account for air pollution, crashes, delay, etc.	Provides a balanced approach to setting speed limits that is considerate of many (if not all) of the impacts that speed has on society. Allows for the consideration of pedestrian and cyclist traffic in setting speed limits. May be particularly useful in a context sensitive situation.	Data collection and prediction models may be difficult to develop and are subject to controversy among professionals. Resulting speed limits may not be immediately obvious to the user.
Injury Minimization/ Safe System	Sweden, Netherlands	Speed limits are set according to the crash types that are likely to occur, the impact forces that result, and the tolerance of the human body to withstand these forces.	Crash types and patterns for different road types, and survivability rates for different operating speeds.	There is a sound scientific link between speed limits and serious crash prevention. Places a high priority on road safety.	This method is based solely on a road safety premise and may not be accepted as appropriate in some jurisdictions.

Minimum Length of Speed Zones

The length of any section or zone set for a particular speed is typically as long as possible and still consistent with the underlying methodology. Applying minimum road lengths aims to prevent having frequent changes in speed limit along a road with varying characteristics. This section discusses the approaches several jurisdictions take in determining speed zone length.

Massachusetts and Ohio both recommend that the minimum length of a new zone, not contiguous to an existing speed zone, be greater than or equal to 0.5 miles (0.8 kms) in length.[18,29] Extensions of existing warranted zones may be shorter. In rural areas of Massachusetts, each zone in a series of graduated speed zones normally is at least 0.2 miles (0.3 kms) in length, and, if the speed limit is reduced from one zone to the next by 15 mph (25 km/h) or greater, a REDUCED SPEED AHEAD sign is erected in advance of the lower limit in order to inform motorists to adjust their speeds accordingly.[18]

The State of Florida has no required minimum length for any speed zone, rather it is suggested that engineering judgment be applied. With respect to graduated speed limits, the Florida guidelines indicate that the buffer speed zones should not be so short that they require a driver to apply his/her brakes to comply with the posted speed limit.[30]

Graduated or buffer zones may be used on approaches to cities and towns to accomplish a gradual reduction of highway speeds to the speed posted at the city limits. The change in speed between two adjacent zones should not normally be greater than 15 mph (24 km/h), because the change in speed would be too abrupt for driver observance. If adjacent 85th percentile speeds show an abrupt change of more than 15 mph (24 km/h), Texas requires graduated zones, and recommends that a transition zone of approximately 0.2 miles (0.3 kms) or more in length should be used.[19]

States may specify the minimum incremental length of a speed zone. For example, Massachusetts requires all zones to be computed to the nearest tenth of a mile (0.16 kms).[18]

In Texas, school zones are exceptions and may be as short as reasonable in urban areas, depending on approach speeds. School zones in urban areas where speeds are 30 mph (50 km/h) or less may have school zones as short as 200 to 300 feet (60 to 90 meters).[19]

Alaska's general rule for speed zone length is that the minimum length of a speed zone is the distance traveled in 25 seconds at the posted limit. While speed limit changes in Alaska are permitted in increments of 5, 10, or 15 mph (8, 16, or 24 km/h), it is preferable to use 10 or 15 mph (16 or 24 km/h) changes with relatively long zones rather than multiple short zones with 5 mph (8 km/h) increments. When multiple speed studies made on a continuous segment of road result in 85th percentile speeds within 5 mph (8 km/h) of each other, the results are typically averaged to minimize the number of speed limit changes. It may be helpful to plot a speed profile along a road using the 85th percentile speeds from the spot speed checks. Different combinations of speed zone lengths and speed limit change increments may then be compared to see which combination minimizes the number of speed limit changes while still conforming as closely as practical to spot speeds.[31]

The Canadian guidelines for setting speed limits recommend a minimum length of speed zone of 0.6 miles (one kilometer) where the speed limit is 45 mph (70 km/h) or higher. Shorter lengths may be used at slower speeds, but speed zone lengths of less than one-third of a mile (500 meters) should be avoided.[22]

Practice in Australia and New Zealand is to vary the minimum length of a speed zone with the proposed speed limit. To provide reasonable consistency while avoiding excessive variations in speed limits, a balance needs to be achieved between:

- Roadside development;
- Road environment; and
- The number of changes of speed limit.

The desirable minimum typical lengths, shown in Table 6, have been developed with these needs in mind.[32]

Table 6. Minimum Lengths of Speed Zones in New Zealand

Speed Limit, mph (km/h)	Minimum Length of Zone, miles (km)
25 (40)	0.1 (0.2)
30 (50)*	Not applicable**
30, 35 (50, 60)	0.3 (0.5)
45, 50, 55 (70, 80, 90)	1.25 (2.0)
60 (100)	2.0 (3.0)
70 (110)	6.0 (10.0)

*This is the urban default limit.
**If urban default limit is used the minimum length of the zone is not used in this procedure.

The level of development should be reasonably consistent along the entire length of a speed limit, especially in areas with sparse development. For example, it is not appropriate to install a 0.3 mile (500 m long), 45 mph (70 km/h) speed restriction in a rural area if the only development is located in a 300-foot (100 m) section of road in the middle of the proposed speed limit. In these circumstances, road users see no reason for the change in speed limit, compliance will be poor, variations in operating speeds will increase, and judgments of speed and distance become more difficult for all road users. Such conditions will usually contribute to a reduction in safety, especially for pedestrians and cyclists.[14]

Table 7. Minimum Length of Road for a Speed Limit [14]

Speed Limit, mph (km/h)	Nature of Road and Adjacent Speed Limits	Minimum Length, miles (kms)
30 (50)	Urban street, adjacent speed limits 45 mph (70 km/h) or less. Urban fringe, adjacent speed limits greater than 45 mph (70 km/h).	0.3 (0.5) 0.6 (1.0)
35 (60)	Urban arterial route, adjacent speed limits 50 mph (80 km/h) or less. Other situations.	0.6 (1.0) 0.3 (0.5)
45 (70)	Partly built-up, adjacent speed limits 50 mph (80 km/h) or less. Other situations.	0.6 (1.0) 0.3 (0.5)
50 (80)	Arterial route, adjacent speed limits 45 mph (70 km/h) or less. Other situations.	0.6 (1.0) 0.5 (0.8)
60 (100)	All situations.	1.2 (2.0)

All boundary points between speed limits must be at, or close to, a point of significant change in the roadside development or the road environment to emphasize the change in speed limit. Appropriate locations include a marked change in the level or type of roadside development, a change in the road geometry, a bridge, a threshold or other feature that affects speed (e.g., a roundabout or a curve). A threshold treatment may be necessary to reinforce a change in the speed limit where there is no obvious change in the road environment.

Special Situations

Several situations not covered earlier in this document are covered in this section. Certain geometric conditions, school zones, and work zones are examples of situations that may require considerations in addition to the concepts already presented.

Advisory Speeds

Advisory speeds are used on short sections of road where the physical conditions of the roadway restrict safe operating speed to something lower than the maximum legal speed (e.g., a horizontal curve). Advisory speeds are typically used because the feature that dictates the lower speed is isolated, and it is not feasible or desirable to adjust the legal speed for a short section of road. The posted regulatory speed limit is not lowered to conform to the advisory speed. Similarly, an advisory speed within a regulatory speed zone is not posted if the advisory speed is higher than the posted speed limit.

In erecting advisory speed signs, care should be taken not to install a regulatory speed limit sign so near the advisory speed sign that drivers may become confused by two different speed values. More importantly, regulatory speed signs should not be located between an advisory speed sign and the location to which the advisory speed applies.[19] The separation between signs should be in accordance with the MUTCD.

The most common use of advisory speeds is on horizontal curves. More information on advisory speeds can be found in the ITE Informational Report *Methodologies for the Determination of Advisory Speeds* and the FHWA handbook *Procedures for Setting Advisory Speeds on Curves*.[38, 49]

Nighttime Speed Limits

Speeds are normally posted on the basis of daylight speed values determined under good weather conditions. It is permissible, however, for different day and night speeds to be posted for speed zones where it can be shown to be necessary by an engineering study.

Nighttime speed limits generally begin 30 minutes after sunset and end 30 minutes before sunrise, although this may vary by jurisdiction. Nighttime speed limits are generally established on roads where safety problems require a speed lower than what is prescribed by the daytime limit, and the operating speed that is self-selected by drivers. Examples of roads that might require nighttime speed limits are non-illuminated roads with relatively high operating speeds and an overrepresentation of crashes during "dark" environmental conditions, or roads crossing the routes and movement patterns of large-sized, nocturnal wildlife.

Where different speed limits are prescribed for day and night, both limits shall be posted. A Night Speed Limit sign (R2-3)* may be combined with or installed below the standard Speed Limit (R2-1) sign.[15]

School Zone Speed Limits

Reduced speed limits should be considered for school zones during the hours when children are going to and from school. Usually such school speed zones are only considered for schools located adjacent to highways or visible from highways. However, school-age pedestrian activity should be the primary basis for implementing reduced school zone speed limits. This includes irregular traffic and pedestrian movements that may result from children being dropped off and picked up from school.[19]

A review of U.S. State school zone speed limits showed that most States use a school zone speed limit of 15 to 25 mph (25 to 40 km/h) in urban and suburban areas, with 20 mph (30 km/h) being the most common.[39] VicRoads Australia proposes the following:

- Outside schools on 30 mph (50 km/h) roads: A permanent 25 mph (40 km/h) speed limit. In some special cases, such as on high traffic volume streets, a time-based 25 mph (40 km/h) limit may be applied.
- Outside schools on 35 and 45 mph (60 and 70 km/h) roads: A time-based 25 mph (40 km/h) speed limit that is in effect during school entry and exit times on school days.
- Outside schools on 50, 55 and 60 mph (80, 90 and 100 km/h) roads: A time-based 35 mph (60 km/h) speed limit that is in effect during school entry and exit times on school days.[40]

Since school zone speed limits are active only for certain times of the day, it is desirable that the school zone speed limit be no more than 12 mph (20 km/h) below the speed limit on the approaches. This removes the requirement for a MAXIMUM SPEED AHEAD sign (which would only be valid when the SCHOOL ZONE MAXIMUM SPEED sign is activated).[41]

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*Numbers in parentheses refer to the corresponding sign number in the MUTCD.

Ultimately, school zone speed limits, like other speed limits, ought to be based on an engineering study and traffic investigation to determine whether they are warranted, as well as an appropriate reduced speed limit for the study area. The investigation normally considers factors such as existing traffic control, whether school crosswalks are present, the type and volume of vehicular traffic, the ages and volume of school children likely to be present, and the location of children in relation to motorized traffic. The most common factors considered in the engineering study are:

- Children walking along or crossing the roadway;
- Fencing around school property;
- Number and size of gaps in traffic for school-age pedestrians to cross the street;
- Presence of crossing guards;
- Average pedestrian demand per appropriate gap;
- Student enrollment at the school;
- Location of school property (i.e., abutting the road allowance or visible from street); and
- Presence of sidewalks.

A School Speed Limit assembly or a School Speed Limit (S5-1) sign shall be used to indicate the speed limit where a reduced speed zone for a school area has been established (in accordance with law based upon an engineering study) or where a speed limit is specified for such areas by statute.[15] The School Speed Limit assembly or School Speed Limit sign shall be placed at, or as near as practical, the point where the reduced speed zone begins. According to the MUTCD, the reduced speed zone should begin either at a point 200 ft (120 m) in advance of the school grounds, a school crossing, or other school-related activities. This distance should be increased if the reduced school speed limit is 30 mph (50 km/h) or more below the speed limit on the approach.[15] Local regulations may provide more stringent guidance, requiring greater distances than specified above.

The School Speed Limit assembly shall be either a fixed-message sign assembly or a changeable message sign. The fixed-message School Speed Limit assembly shall consist of a top plaque (S4-3P) with the legend SCHOOL, a Speed Limit (R2-1) sign, and a bottom plaque (S4-1P, S4-2P, S4-4P, or S4-6P) indicating the specific periods of the day and/or days of the week that the school speed limit is in effect.[15]

A Reduced School Speed Limit Ahead (S4-5, S4-5a) sign is normally used to inform road users of a school zone speed limit where the speed limit is 10 mph (15 km/h) or more below the speed limit on the approach road, or where engineering judgment indicates that advance notice is appropriate. If used, the advance warning assembly is typically installed not less than 150 ft (45 m) nor more than 700 ft (210 m) in advance of the school grounds or school crossings.

The end of an authorized and posted school speed zone shall be marked with an End School Speed Limit (S5-3) sign and may be marked with a standard Speed Limit sign showing the speed limit for the section of highway that follows.[15]

Work Zone Regulatory Speeds

Traffic control in work sites is designed on the assumption that drivers will only reduce their speeds if they clearly perceive a need to do so; therefore, reduced speed zoning ought to be avoided as much as practicable. Speed Limit signs are erected only for the limits of the section of roadway where speed reduction is necessary for the safe operation of traffic and protection of construction personnel. The reduced speed limits are effective only within the limits where signs are erected. If reduced speed limits are not necessary for the safe operation of traffic during certain construction operations or those days and hours when the contractor is not working, the regulatory construction Speed Limit signs are typically made inoperative. In selecting the speeds to be posted, consideration is given to safe stopping sight distances, construction equipment crossings, the nature of the construction project, and any other factors which affect the safety of the traveling public and construction workers.

The regulatory Speed Limit sign (R2-1) shall be used.[19]

Truck Speed Limits

Speeds are normally posted on the basis of all motorized traffic. It is permissible, and in some cases desirable, for trucks and other heavy commercial vehicles to have different (i.e., lower) maximum speeds than passenger cars. The need for a lower speed limit for trucks is primarily demonstrated as necessary by an engineering study considering factors such as magnitude and length of roadway grades, horizontal curvature, etc. Where different speed limits are prescribed for trucks and passenger cars, both limits shall be posted. A Truck Speed Limit sign (R2-2) may be combined with or installed below the standard Speed Limit (R2-1) sign.[15]

The safety effectiveness of differential speed limits for trucks is inconclusive.

Minimum Speed Limits

Minimum speed limits are generally justified when studies show that slow-moving vehicles on any part of a highway consistently impede the normal and reasonable movement of traffic to such an extent that they contribute to unnecessary lane changing or passing maneuvers. The maximum speed limits and the need for minimum speed limits must be determined from the same speed check data. Whenever minimum speed zones are used, the minimum posted speed should be within 5 mph (8 km/h) of the 15th percentile value.[19] The Minimum Speed Limit (R2-4) sign may be installed below a Speed Limit (R2-1) sign to indicate the minimum legal speed. If desired, these two signs may be combined on one sign panel (R2-4a).[15]

Variable Speed Limits

Variable speed limits are speed limits that change, using dynamic sign messages, based on road, traffic, and weather conditions. Variable speed limits offer considerable promise in restoring the credibility of speed limits and improving safety by restricting speeds during adverse conditions. Variable speed limit systems may use sensors to monitor prevailing traffic and/or weather conditions, and input from transportation professionals and law enforcement in posting appropriate enforceable speed limits on dynamic message signs.

The most common conditions that warrant variable speed limits are traffic congestion, road construction, incident management, fog, snow, ice, and other weather-related situations.

Variable speed limits are being successfully used in Europe, and are used or are being tested by several State departments of transportation such as Colorado, New Jersey, Utah, Washington, and Wyoming. The speed limit that is to be posted depends on the purpose for installing the variable speed limit. In cases where congestion or post-incident management are the impetus for use, the recommended speed limit for the condition is generally a function of the average speed of traffic, and an attempt to minimize speed differentials in the traffic stream. Weather-related variable speed limits often are determined by an algorithm that uses data gathered from road weather monitoring stations.

Transition Zone Speed Limits

Transition zone speed limits are generally considered when there is a speed reduction of more than 25 mph (40 km/h) between adjacent zones, and may be considered at other locations if a field assessment has determined that a transition zone speed limit may improve safety or traffic operations. The following factors may be considered in determining the need for a transition zone speed limit:

- Roadway operating speeds in advance of speed reduction.
- Existing operational/safety issues (i.e., due to speed differential between vehicles, speed exceeding that which is considered suitable for the roadway environment).
- History of overly aggressive braking at the entrance to the reduced speed limit area.
- Low speed limit compliance in the lower speed limit area.
- Expected compliance with a transition speed zone (i.e., will motorists perceive it to be justified by the surrounding roadway environment?).

In situations where rural roads approach and continue through urban areas and villages, there is a need for a commensurate reduction in the speed limit that reflects the change in the roadway and the roadside character. In many instances these speed transitions can be sizable, and the road authority needs to post an intermediate or transition zone speed limit to assist drivers in slowing down.

Transition zone speed limits are typically set to divide the overall speed reduction approximately in half. For instance, a speed limit decrease from 60 mph (100 km/h) to 30 mph (50 km/h) might use a transition speed limit of 45 mph (70 km/h) or 50 mph (80 km/h).

The minimum transition speed zone length usually allows for the placement of REDUCED SPEED AHEAD signs and a sufficient speed zone length to achieve compliance.

An excellent source of information on high-to-low speed transition zones that includes speed limits and other measures is available from the National Cooperative Highway Research Program.[50]

Seasonal or Holiday Speed Limits

A seasonal or holiday speed limit applies for a specified period or periods during a year, generally at locations with significantly different levels of roadside activity at different times—for example, a beach resort that is popular in summer, but only sparsely populated for the remainder of the year. Typically, when the level of activity is at its highest, a relatively low speed limit would be appropriate, while the level of activity would justify the relatively high speed limit otherwise.

Reevaluation

After a speed limit is established, changes in the roadway geometry, land uses, or other circumstances could prompt a need for further study to determine if the limit needs to be raised or lowered. The MUTCD recommends that engineering studies be conducted to reevaluate non-statutory speed limits on roads that have undergone significant changes since the last review, such as the addition or elimination of parking or driveways, changes in the number of travel lanes, changes in the configuration of bicycle lanes, changes in traffic control signal coordination, or significant changes in traffic volumes.[15] ITE provides similar guidance regarding the importance of revisiting sites to conduct speed studies every five years or when changes are made to roadways to ensure that the speed limits are still appropriate.[17]

In Texas, periodic rechecks of all zones are desirable at intervals of about three to five years in urban areas regardless of roadway improvements, roadside developments, or increases in traffic volumes. Trial runs or rechecks of every third speed check station may be made. In rural areas, rechecks are desirable at intervals of 5 to 10 years. In many instances, trial runs may be sufficient. If the speed checks or trial runs indicate a need for revision of the zone, rechecks of speeds should be made at all speed check stations for that particular section and a revised strip map made and submitted.[19]

Massachusetts recommends that consideration be given to revising numerical limits that vary by 7 mph (11 km/h) from the 85th percentile speed when rechecks are performed. They also feel it is beneficial to make a comparison of the crash experience for zones that have been in effect for a year or more.[18]

Speed Limit Sign Design and Placement

Speed Limit signs must be correctly posted to ensure a speed limit is enforceable and to encourage compliance. Typical maximum Speed Limit signs are shown in Figure 3. In North America, the latest editions of the MUTCD and *Standard Highway Signs*[33] should be referenced when developing signing for speed zones. The MUTCD contains Standards, Guidance, and Options for the signing, and general guidelines to follow for the design and layout of the signs are contained in *Standard Highway Signs*. The general guidelines show different standard sizes depending on the type of highway or facility where the sign is intended to be.

In general, *Standard Highway Signs* states that signs for regulatory speed zones shall be of the appropriate design—including size, text, and color.[33] The MUTCD states that the speed limits shown shall be in multiples of 5 mph (8 km/h).[15]

Section 2A of the MUTCD discusses standardization of location, mounting height, lateral offset, orientation, posts, and mountings. Speed Limit (R2-1) signs, indicating speed limits for which posting is required by law, shall be located at the points of change from one speed limit to another. At the end of the section to which a speed limit applies, a Speed Limit sign showing the next speed limit shall be installed. Additional Speed Limit signs shall be installed beyond major intersections, downstream of egresses from major traffic generators, and at other locations where it is necessary to remind road users of the speed limit that is applicable. Speed Limit signs indicating the statutory speed limits shall be installed at entrances to the State and at jurisdictional boundaries of metropolitan areas.[15] In rural areas, on two-lane highways, Washington State recommends locating Speed Limit signs at 10 to 20 mile (16 to 32 km) intervals.[34]

Figure 3. International Speed Limit Signs.

The preferred location for the beginning and ending points of speed zones is where there are definite changes in the character of the roadside development, like rural and urban boundaries. It is often desirable to begin and end a speed zone to encompass an important road intersection or driveway of a major generator like schools or residential developments. It is important to note the location of other traffic control devices in the segment and coordinate Speed Limit signs with them effectively.[35]

For all highways in Washington State, signs for both directions of travel should be located opposite one another at speed zone boundaries. Furthermore, signs should be installed on both sides of the traveled way on multi-lane divided highways. If existing highway features prohibit opposite installations, the signs may be installed a maximum distance of 300 feet (100 meters) apart, or offset up to 150 feet (50 meters) in either direction from the speed zone boundary. If these distance parameters cannot be met, the speed zone boundary may need to be adjusted to allow for sign installation.[34]

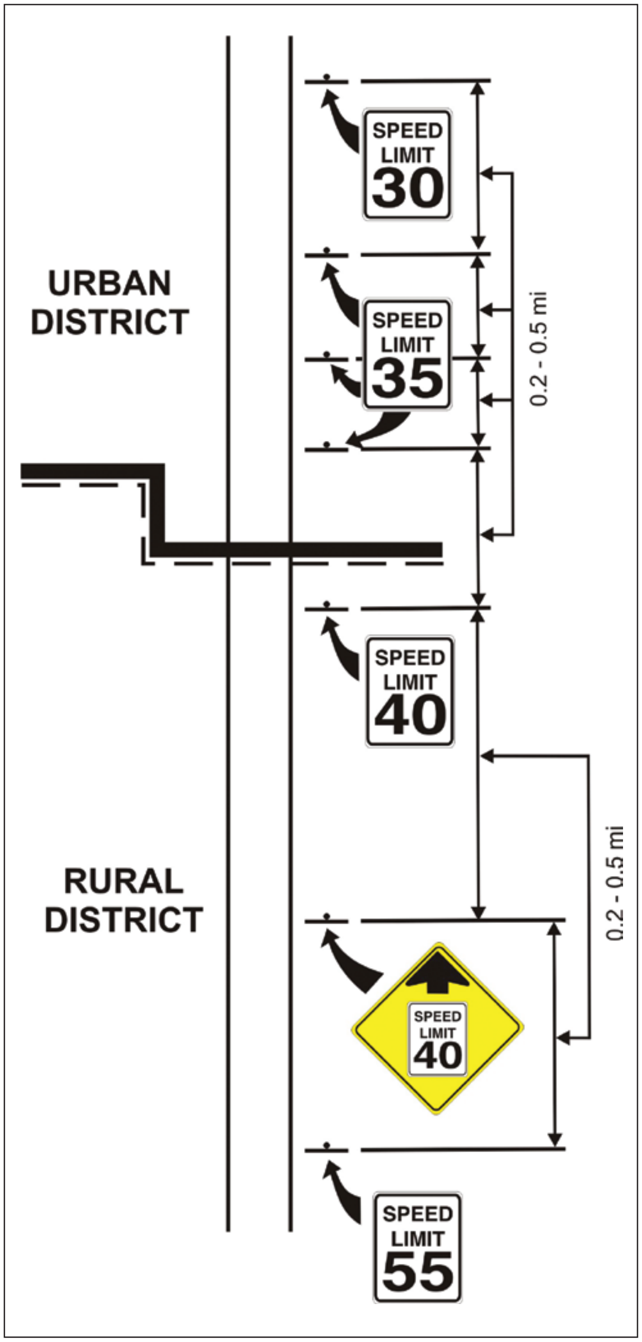

Figure 4. Example Regulatory Speed Zone Application Showing Spacing of Signs Transitioning from Rural District to Urban District and Within the Urban District. (Source: Adapted from the Texas Department of Transportation.[19])

Figure 4 illustrates the typical location and frequency of signs for regulatory speed zones established by the Texas DOT. Distances shown between Speed Limit signs are minimums and may be greater, depending on the results of speed checks.[19]

The following six States offer guidance concerning repetition of Speed Limit signs:[36]

- **Alaska:** Intermediate Speed Limit signs should be placed at least once every two minutes of travel time on urban roads, and no more than ten minutes apart on rural roads (except on low volume rural roads where the signs may be up to 30 minutes apart).
- **Arizona:** Where the speed limit is less than 55 mph (90 km/h), the recommended maximum spacing is given by the formula S = V/6, where S is the maximum distance between Speed Limit signs in miles and V is the speed limit in miles per hour. In rural areas where the speed limit is 55 mph (90 km/h) or greater, the formula is modified to S = V/5.
- **California:** On freeways with limits of 65 or 70 mph (105 or 110 km/h), spacing is to be no more than 25 miles (37 km) apart. Where the freeway speed limit is reduced to 55 mph (90 km/h), Speed Limit signs are to be no more than 3 mi (5 km) apart. On conventional roads, the maximum spacing between Speed Limit signs is no more than 5 to 10 miles (8 to 16 km).

- **Minnesota:** Speed Limit signs are to be repeated at intervals of 60 seconds of travel at the posted speed where speed is reduced. The repetition may be less in dense urban areas. The maximum spacing between Speed Limit signs in rural areas is 10 miles (16 km).
- **New York:** Where a roadway speed limit is restricted relative to the State speed limit, a second Speed Limit sign is placed within 1100 ft (336 m) of the first. Subsequent Speed Limit signs are to be no further apart than 100 times the posted speed limit (e.g., for a restricted speed of 35 mph (60 km/h) the maximum separation is 3500 ft (1068 m)).
- **Pennsylvania:** Where special speed limits are in effect, the spacing between Speed Limit signs must be no more than 0.5 miles.

International practices include:[36]

- **United Kingdom and Ireland:** Place Speed Limit signs at approximately half-mile intervals where speed is restricted to less than the national speed limit for that class of road.
- **British Columbia, Canada:** On long, uninterrupted sections of rural highways, it is recommended that Speed Limit signs be repeated at least every 9 to 12 miles (15 to 20 km). Additionally, a repeater Speed Limit sign should be placed 1000 to 2000 ft (300 to 600 m) downstream of wherever the speed limit changes.

Speed Feedback Signs

A Speed Feedback sign (also called a driver feedback sign, or variable message sign) is an interactive sign, generally constructed of a series of light emitting diodes (LEDs), that displays actual vehicle speed to drivers as they approach the sign (see Figure 5). The purpose of this sign is to reduce vehicle speeds by making drivers aware of their speed relative to the posted speed limit.[30] Studies have found that Speed Feedback signs can be effective in reducing mean and 85th percentile speeds in a variety of situations.

If used, the changeable message sign legend should be "YOUR SPEED XX MPH" or similar wording. The legend should be yellow on a black background or the reverse of these colors. Installation of a Speed Feedback sign is optional, but if used it should be installed in conjunction with a Speed Limit sign.[15]

Speed Feedback signs are particularly useful at speed reductions where drivers have been traveling for some time at a higher speed. The phenomenon known as "speed adaptation" causes drivers

Figure 5. Speed Feedback Sign. (Source: Richard Drdul)

to underestimate their actual operating speeds in these instances, and the Speed Feedback sign can assist them in achieving the necessary speed reduction.

Speed Feedback signs may be permanent or temporary installations. However, permanent installations are usually restricted to selected locations since a proliferation of Speed Feedback signs could lessen the effectiveness of the signs when they are needed most.

Speed Feedback signs typically operate as follows:

- A blank display is shown when no vehicles are approaching the sign.
- An approaching vehicle's speed is displayed as a solid numeral (non-flashing numeral) if the approach speed is at or below the posted speed limit.
- The approach speed is shown as a flashing numeral if the approach speed exceeds the posted speed limit by 3 mph (5 km/h) or more.
- To discourage racing, the sign must be programmed to not display speeds that are well in excess of the posted speed limit. In these instances, the sign is most often blank. The maximum speed that a Driver Feedback sign may display is outlined in the table below:

Table 8. Maximum Speeds to Trigger a Speed Feedback Sign

Posted Speed Limit, mph (km/h)	Maximum Speed Display Threshold, mph (km/h)
20 (30) or less	30 (50)
25 (40)	35 (60)
30 (50)	50 (80)
35 (60)	55 (90)
45 (70)	70 (110)
50 (80)	75 (120)
55 (90) or more	80 (130)

Source: Alberta Transportation[37]

Speed Feedback signs are most effective when combined with enforcement activities.

Speed Study Data Collection

Data collection is an integral part of setting speed limits. Adequate planning and coordination must occur to ensure the data collection process is as complete, efficient, and effective as possible. This section describes typical activities that highway agencies will undergo to plan and implement a data collection effort. Several types of data, including speed, crash, and roadway environment information, are vital to this process. The ITE *Manual of Transportation Engineering Studies*[44] provides guidance in this regard.

The data collection requirements depend on the methodology selected by a jurisdiction in setting posted speed limits. The Safe Systems approach, for instance, requires very little data collection since it is based on very basic road design parameters (e.g., number and frequency of accesses, presence of a raised median, etc.) and general traffic characteristics (e.g., type and frequency of road users). The data collection effort is relatively minor.

The Optimal Speed Limit methodology has a more intensive data collection effort. While the data required for the particular roadway under study is generally manageable, there is a large volume of local data that is required to calibrate the prediction equations and models that are used assessing the societal impacts of the different speed limit alternatives. A discussion concerning the models and their calibration is beyond the scope of this document. Project-specific data that is required as input to these models is detailed in the following subsections of this chapter.

The remainder of this chapter describes the collection process for data that is *most often used* in the engineering and expert systems methodologies. The exact data needs are determined by the method employed by the road authority—more or less data than described herein may be required.

Data Collection Planning and Coordination

Speed zoning studies are conducted to evaluate safety issues and identify appropriate speed limits for specific roadway segments. In addition to actual travel speeds, there are several other types of information that may be appropriate input to the process of setting speed limits. Therefore, coordination within an agency performing the study and with other agencies that may have additional information may be needed to ensure all the appropriate inputs are considered. Crash data, recent and planned roadway or adjacent land use changes, and even anecdotal information can be obtained from safety, planning, enforcement, and other stakeholders. The data collected will be used to examine the speeds of free-flowing traffic, as well as information on roadway geometry, crash characteristics, land use, and access. The studies provide details regarding some or all of the following:

- Average annual and hourly vehicular, bicycle, and pedestrian traffic volume.
- Traffic speeds for each flow direction by hour of day.
- Road design elements that may be crash factors, such as horizontal and vertical road curvature, access points, drainage, pavement condition, sight distance restrictions, roadside objects, signage, markings and delineation, etc.
- Road lighting and traffic control devices, including signals, signal timing, and STOP signs.
- Summary of crashes and crash causes over a multiyear period.

- Plans for expected new development, changes in the type of development, or major closing of existing development that may change the traffic flow characteristics in the future.

- Recommendations for the speed limit.[19]

When planning the data collection activity, it is important to document and control any aspect of the collection that might have an impact on the measured speed. Measurable physical features, roadway surface characteristics and conditions, and traffic characteristics and control are items to be inventoried. If conditions are not relatively consistent throughout the zone under study, consideration can be given to splitting the study area into shorter sections. For example, if the road transitions from a 2-lane to a 4-lane divided facility, or from on-street parking to no parking, or from rural agricultural land use to a commercial or residential land use, then speed samples are typically taken in each section. Factors such as roadway lighting and delineation are reflective of road geometry and land use, but are not necessarily factors that warrant splitting a study area into shorter sections.

Variables considered for documentation of the site include (but may not be limited to):

- Location and roadway configuration.

- Lanes, delineation, shoulders, medians, grade separation, roadside objects, driveways or entrances, curvature or grades, lighting, etc.

- Posted speed limit.

- Weather (limiting measurements to fair weather is preferable).

- Direction.

- Restricted sight distance.

- Pedestrian activity.

- Cyclist activity.

- Date and time (in a common format among collections).

- Traffic control devices (regulatory and warning).

- Type and condition of pavement surfaces.

- Businesses, advertising, or residential developments.

- Proximate schools and school routes.

- Surrounding area changes in travel habits or influences.

- Vegetation changes.

In most instances, the variables collected by a particular road authority are dependent on the methodology used in that jurisdiction to set speed limits, the expected effect of the variable on operating speeds, and available resources.

When undertaking data collection efforts, it is important to understand if there are activities or conditions outside of the study area that may affect measurements, including construction or maintenance activities in the area, road closures, detours, the presence of enforcement, and whether proximate schools are in session.

Study Area

A speed zone study can be initiated in response to a public request for a speed limit review, as a result of network screening (for crash prone locations), or for any other reason. In all situations, a general study area is identified through the initial request or data analysis. The study area can then be divided into homogeneous sections for analysis. A homogeneous section is one where:

- The roadside development is consistent (residential vs. commercial; type and frequency of businesses and driveways, etc.); and
- The roadway features are consistent (lane widths, medians, shoulders, surface roughness, curvature, intersection spacing, etc.).

The data collection area will typically extend 500 feet beyond each end of the proposed speed zone in order to include nearby features. These features will help to determine the homogeneity of the proposed speed zone, and whether the study area limits should be extended. It may be helpful to take photographs of features in the intended speed zone and the extended study area, as they may be helpful in describing any concerns within the study area.

A scaled area map, sketch, or aerial view is usually developed to show the study area and the field conditions. Generally, a speed zone study used to support a request for alteration of a speed limit would include this exhibit to identify the location of the proposed zone and any features of interest. A strip map, or line diagram, is an example of an appropriate format for the exhibit, and details the information that can be shown on the map. The data points can be collected using a Geographic Information Systems (GIS) unit, which helps improve the accuracy of the strip map. Figure 6 shows an example of a strip map that is appropriate for a speed zone study. Table 9 shows the information that should be shown on a strip map.

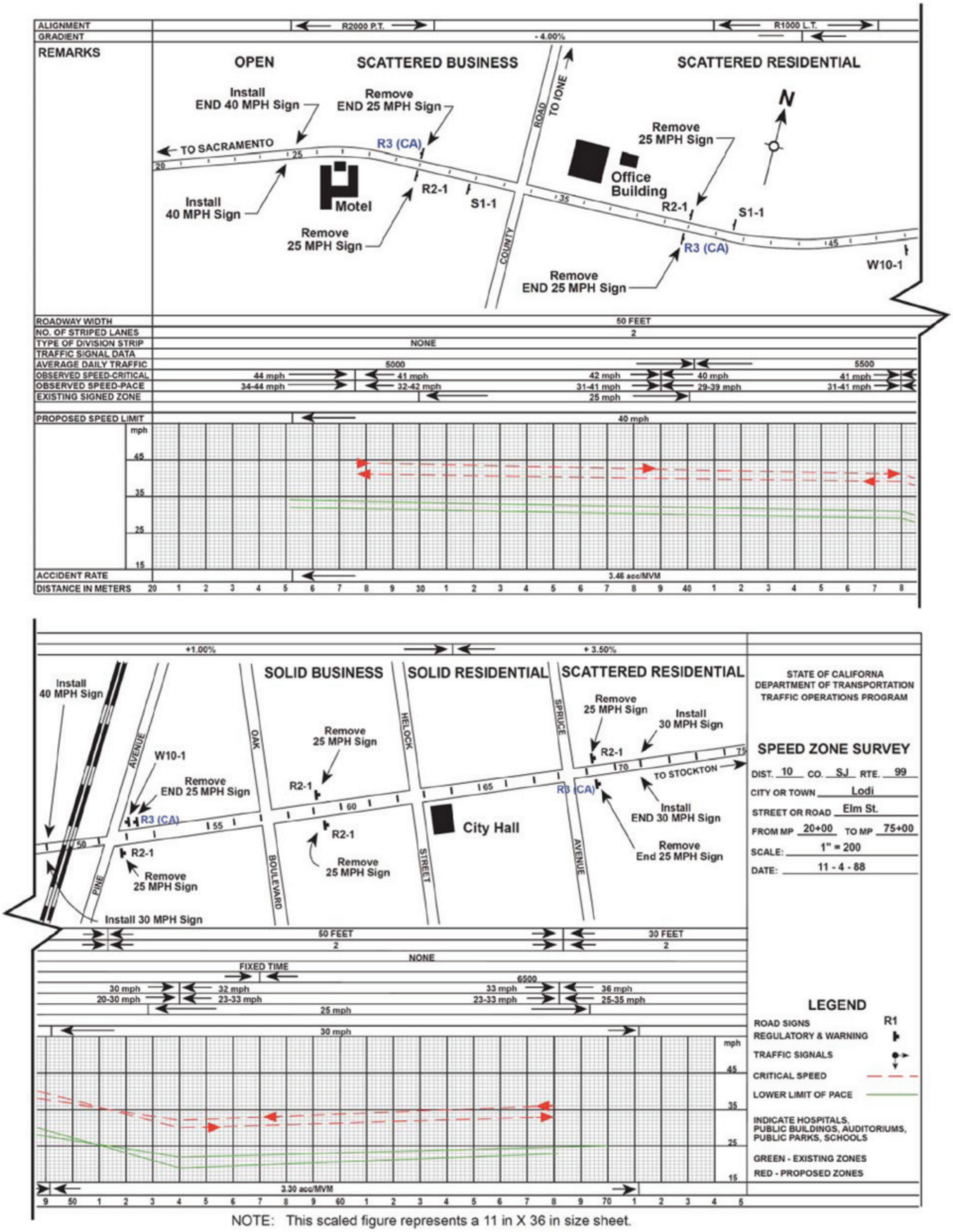

Figure 6. An Example of a Strip Map of a Study Area Showing Existing Conditions. (Source: CalTrans, 2009)

Table 9. Information to Show on Strip Map

Information Item	Notes
Name and highway number of the route to be zoned	Show all names and/or highway numbers. Indicate sections to be zoned with a wide center line on the strip map.
Cross section	Width of the roadway/lanes. Pavement markings. Number of lanes. Parking restrictions.
Crossroads, cross streets, and driveway access points	Show all names and highway numbers.
Limits of the speed zone	Indicate reference marker, milepoint, control, and/or section numbers.
Adjoining speed zone(s) of connecting map(s)	Note speed limit information for adjoining roadway sections.
Limits of any incorporated city or town	Show reference marker, milepoint, control, and section numbers.
Names and approximate limits of the developed area of unincorporated towns	Indicate by "Beginning of Developed Area" and "End of Developed Area" under the heading, "Development"—not as "City Limits."
Urban districts	Indicate any urban district clearly under the heading "Development." The territory contiguous to and including any highway or street which is built up with structures devoted to business, industry or dwelling houses, situated at intervals of less than 100 feet for a distance of 0.25 mile or more on either side.
Schools and school crossings	Show schools abutting the highway and those in the vicinity of the highway. Show location of schools. Show all school crosswalks.
Traffic signals	Show location of existing devices to aid in proper spacing and placement of speed zone signs.
Important traffic generators	Show all factories, shopping centers/malls, and any other establishments that attract large volumes of traffic.
Ball bank readings	Show readings for each direction of travel for all curves.
Railroad crossings	Indicate the number of tracks and type of grade crossing protection (crossbucks, cantilevers, crossbucks with signals, gates). Show the name of the railroad at each crossing.
Bridges	Indicate if the roadway on the bridge is narrower than the roadway on either side of it.

Source: Adapted from the Texas Department of Transportation.[19]

Speed Data Collection

The result of the speed data collection effort is an accurate picture of the range of vehicles and driver behavior in the study area. In addition to collecting spot speeds of vehicles traveling through the study area, test runs can be used to confirm free-flow speeds and compare study area speeds to adjacent areas outside the speed zone. These data, combined with other crash, roadway environment, and enforcement information, feed into the data analysis and the determination of the speed limit as discussed in the next section.

Vehicle Speeds

A variety of methods are available to measure speeds. These methods can generally be grouped into three categories based on the installation location of the collection equipment:

- Manually-operated, handheld devices that are portable and can be used in most places (e.g., stopwatch, radar gun, and lidar gun).
- In-road devices that are installed into or on top of the roadway surface (e.g., pneumatic road tube).
- Out-of-road devices that are installed overhead or to the side of the roadway surface (e.g. radar recorders).

The advantages and disadvantages for several common speed collection devices are shown in Table 10, and should be considered when selecting a device for use at a particular location.

Ideally, data collection:

- Uses techniques that capture typical traffic behavior without affecting it.
- Collects free-flow vehicles and ignores platoons (less than 5 seconds separation from the vehicle ahead*).
- Collects vehicle type along with the speed so that speed profiles for different vehicle types can be identified, if desired.

The vehicles checked should be only those in which drivers are choosing their own speed or are free-flowing. When a line of vehicles moving closely behind each other passes the speed check station, only the speed of the first vehicle is checked, since the other drivers may not be choosing their own speed. Vehicles involved in passing or turning maneuvers are not to be checked, because they are probably driving at an abnormal rate of speed. Turning lanes, or other special lanes, are not normally used to collect speed data.

* Some analysts prefer to discard a speed measurement if a vehicle is following another vehicle within five seconds, as the lead driver may be slower than they would ordinarily be traveling in an open road situation.

Table 10. Advantages and Disadvantages of Speed Collection Devices (Adapted from Reference 43)

Method	Data Collected	Labor	Equipment Cost*	Advantages	Disadvantages
Radar Recorders	Instantaneous speed, traffic volumes, vehicle class, traffic flow gaps**	Low	High	Little labor required to collect and tabulate data: can collect data for long periods of time; other traffic-related data may be collected at the same time; can be used when snowplows may be present without risk of damage; less visible to traveling public than road tubes	User cannot randomly select vehicles for data set; some devices may not accurately collect data for multi-lane roadways and/or determine directionality of observed vehicles; equipment-intensive method; maintenance/ calibration required
Pneumatic Road Tube	Instantaneous speed, traffic volumes, vehicle class, traffic flow gaps**	Low	Medium	Little labor required to collect and tabulate data; can collect data for long periods of time; other traffic-related data may be collected at the same time	Visible to traveling public which may change driver behavior; user cannot randomly select vehicles for data set; use discouraged when snowplows may be present; most equipment-intensive method; maintenance/calibration required
Laser Gun	Instantaneous speed	Medium	High	Equipment is easily portable; user controls vehicles sampled as a more focused laser beam limits the number of readings for non-target vehicles as compared to radar	Cosine error limits horizontal/vertical deployment; scopes and sights may not be user-friendly; laser beams more sensitive to environmental variances than radar; maintenance/calibration required
Radar Gun	Instantaneous speed	Medium	Medium	Equipment is easily portable; user controls vehicles sampled; accurate data collection method; widespread equipment availability has lowered its cost	Cosine error limits horizontal/vertical deployment; closely-spaced and larger vehicles may create readings for non-targeted vehicles; maintenance/ calibration required
Stopwatch	Travel time over a distance	High	Low	Little equipment to purchase and maintain; easy to perform data collection process	Labor-intensive; collects time data that needs to be converted to speed data; typically low accuracy

**Equipment costs reflect the initial purchasing costs of the equipment and not future maintenance and calibration costs.*

***The amount of additional data collected varies for each device. Consult the device's user manual for a better understanding of the capabilities.*

Due to different physical and operational characteristics of trucks and buses, data for these vehicles are usually recorded separately. If separate speed limits are believed warranted for large trucks or other vehicle classifications, a separate count and analysis of these vehicles may be needed.

Data collection forms help organize data for the spot speed study. Appendix G (Example Speed Study Forms) contains a sample "Vehicle Spot Speed Study" data collection sheet from the Florida DOT.[30]

The speed profile for a particular road section can only be estimated by measuring individual speeds through a spot speed study. Prior to conducting these studies, the minimum number of vehicles for which speed data are needed to sufficiently estimate speed parameters should be estimated. The minimum number of vehicles required to accurately estimate the speed profile is dependent on the level of confidence required for the statistical analysis of the data. The ITE *Manual of Transportation Engineering Studies*[44] presents the following equation to calculate the minimum sample size for estimating the 85th percentile speed:

$$N = \frac{S^2 K^2 (2 + U^2)}{2E^2}$$

Where:

N = minimum number of measured speeds

S = estimated sample standard deviation, mph

K = constant corresponding to desired confidence level

U = constant corresponding to the desired percentile speed

E = permitted error in the speed estimate, mph

The *Manual of Transportation Engineering Studies* provides tables for determining the values for S, K, and U. Table 11 shows an example sample size calculation for estimating the 85th percentile speed, using this formula.[44]

Table 11. Example Calculation of Sample Size for Study to Determine 85th Percentile Speed

Assumptions:	
The average standard deviation is rounded to 5.0 mph	S = 5.0 mph
The desired confidence level is 95 percent	K = 1.96
The study will determine 85th percentile speed	U = 1.04
The permitted error is 2 mph	E = 2 mph
Calculation:	
Sample Size	N = 37
Analysis:	
Using a sample size of 37, the 85th percentile speed can be determined within 2 mph at a 95 percent confidence level.	

Performing the same calculation with a permitted error of 1 mph (E = 1 mph) results in a sample size of 148. A common sample size for many jurisdictions is 100 vehicles. Assuming a standard deviation of 5 mph, and using a 95 percent level of confidence, the 100 vehicle sample size will yield between a 1 and 2 mph error in the 85th percentile speed, and it makes calculation of the 85th percentile fairly simple (refer to Appendix H).

Table 12 lists the sample sizes and sample periods used by three States. Most States use 100 or more vehicles in each direction for each station. Since meeting the minimum collection data on low-volume roads can be difficult, adjustments on the sample size can be made based on the duration of the collection period. On highways carrying low traffic volumes, the speed checks at any one station are usually discontinued after two hours, even if a minimum of 100 vehicles have not been recorded.

Table 12. Sample Sizes and Data Collection Periods Used by Three States

State	Sample Size	Exceptions
MASSACHUSETTS[18]	100 or more vehicles in each direction should be checked at each station.	On highways carrying low traffic volumes, the checks at any one station may be discontinued after two hours although a minimum of 100 vehicles have not been timed.
OHIO[29]	Record speeds of 100 vehicles for each direction of travel.	Observation need not exceed one hour even if less than 100 vehicles are recorded traveling in each direction.
TEXAS[19]	A minimum of 125 cars in each direction, at each station.	Discontinue after two hours if radar is used, or after four hours if a traffic counter that classifies vehicles by type is used—even if 125 cars have not been timed.

The *Manual of Transportation Engineering Studies* formula for determining a spot speed sample size is premised on a random sample of vehicles over the course of the time. Since the analyst is usually stationed at the study site for a limited time, the speed data is actually assembled from a cluster sample. Cluster sampling generally increases the variability of sample estimates above that of simple random sampling, and for this reason cluster sampling usually requires a larger sample than simple random sampling to achieve the same level of accuracy. Therefore, sample sizes that are slightly larger than those predicted by the *Manual of Transportation Engineering Studies* formula would increase the accuracy of the 85th percentile speed estimate. Furthermore, the times at which the spot speed sample is conducted should include observable speeds that are representative of the operating speeds for all times of the day.

If automated collection of speed data is employed, then it is possible to collect data for extended periods. Collecting data for a 24-hour period will account for variation in traffic patterns and will allow for determination of different speed limits for different times of the day, if needed. For example, a time-limited school zone speed limit or a nighttime speed limit.

Care must be exercised when using automated data collection to ensure that only free-flow speeds are collected, and that data collection units are placed sufficiently far from intersections and other points of access where vehicles that are accelerating/decelerating may influence the speed profile.

Speed check stations need to be located to show all the important changes in prevailing speeds. The data collector should pick a location that will not influence the behavior of the drivers. Table 13 shows recommendations for speed check stations for three States for both urban and rural areas. While these States provide some guidance in the form of set distances between speed check stations, it is important to remember that it is not the distance between stations that is critical—rather it is the changes in the road, traffic, and environment that may lead to different speed profiles and operating speeds. Distances between speed check stations may be increased or decreased from those provided accordingly.

Figure 7. Radar Setup.

Radar speed meters, which operate on the Doppler principle, or lidar, which operates on a laser principle, are normally used for making manual speed checks. These devices typically operate from the power of an automobile battery and give direct readings of vehicle speeds which are accurate to within 2 mph (3 km/h).[19] The operating instructions for the radar unit will provide factors for calibration, optimum distance of survey, and optimum angle of survey. Speed measurement should be done in an unobtrusive, undetectable manner so as to obtain a sample of normal traffic speeds. If the radar operation is detected by drivers, there is the potential for the data to be biased as drivers change their speeds.[45] Figure 7 shows an example of a radar operation setup.

Automatic speed classification equipment technology may be used in determining vehicular speeds for use in calculating 85th percentile speed. Examples of technologies are counter-classifiers with the capability of classifying vehicles, determining vehicular speeds, and differentiating the gap between vehicles. These devices may include video imaging, tube counters, magnetic counters, inductive counters, etc.[19] Figure 8 shows an example of a portable traffic analyzer. With automatic data collection equipment, speed data is normally collected at sites for at least a 24-hour period.

Figure 8. Portable Traffic Analyzer.

The reason for collecting spot speed data is to estimate the free-flow speed of a facility for use in setting speed limits. Ordinarily, it is only necessary to collect spot speed data once during the time-of-day, and the day-of-week that will yield the best estimate of free-flowing speeds. Collecting speed data at more than one time-of-day or day-of-week is dependent on the analyst's confidence in the single measurement representing the true free-flow speed for the facility. Additional spot speed studies at a single location may also be conducted if the analyst is considering a variable speed limit, or a speed limit that is time-limited (i.e., a school zone speed limit).

Table 13. Speed Check Stations for Three States

State		Speed Check Station Layout Information
MASSACHUSETTS[18]	URBAN	• Speed check stations should be strategically located to show all the important changes to municipalities; speed check stations should generally be located at intervals not to exceed 0.25 miles, depending upon the locality and the uniformity of physical and traffic conditions. Much closer spacing than this may be necessary to obtain an accurate picture of the speed pattern.
	RURAL	• In rural areas, the spacing of speed check stations may be at much greater intervals provided they properly reflect the general speed pattern. There should be at least one observation for each direction of travel in each zone of a different numerical limit.
OHIO[29]		• Speed checks may be taken with any device that will indicate vehicle speed with an accuracy of +/-10 percent. • Speed checks should be taken at the 1/3 point (total of four checks) for zones 0.25-1.00 mile in length, and at 0.5-0.75 mile intervals for zones over 1 mile in length.
TEXAS[19]	URBAN	• Should generally be located at intervals of 0.25 mile or less if necessary to ensure an accurate picture of the speed patterns. • Should be located midway between signals or 0.2 miles from any signal, whichever is less, to ensure an accurate representation of speed patterns. • Should take into account locality, and the uniformity of physical and traffic conditions may be determined by trial runs through the area if volumes are too low or if a recheck of speeds is all that is needed. • Should be checked midway between interchanges on the main lanes of expressways and freeways.
	RURAL	• May be at intervals greater than 0.25 mile, as long as the general speed pattern is followed and may only be necessary at each end and the middle point if the characteristics of the roadway are consistent throughout the entire section. • May be determined by trial runs through the area if the characteristics of the roadway are consistent throughout the entire section and a speed check in that section indicates that 125 vehicles cannot be checked within the two hours if radar is used, or after four hours if a traffic counter that classifies vehicles by type is used.

Speed Test Runs

The purpose of the test runs is to generate an operating speed profile and ensure that measured spot speeds are representative of speeds throughout the section.

The general idea is to perform several runs at free-flow speeds as a way to confirm the speed data collected for use in determining 85th percentile speed and compare spot speeds to the test run speeds for the full study section. When planning test runs, in general:

- Test runs should be made by driving as fast as it is comfortably safe.
- Test runs should be made so that other traffic will not delay the test car.
- The speed should be recorded at a range of 0.10 to 0.25 mile (.15 km to .45 km) interval or more.
- The average speed of three test runs should be determined in each direction.[29]

An alternative methodology for conducting a speed test run is the floating car method, i.e., following cars and recording their speeds or journey times through the study area. This method allows an assessment of a driver's free-flow speed, and not the desired speed of the person conducting the survey (as this might differ from the general population).

To counter arguments that the 85th percentile spot speed studies are not representative of the operating speeds along the entire street, a test run speed profile can be combined with the spot 85th percentile speeds to obtain an 85th percentile speed profile.[51] The speed profile is established by an individual driving the road in his or her usual manner, while an observer records the time for the vehicle to travel a set interval (e.g., 100 m). Then the following procedure can be used to develop an 85th percentile speed profile (the data in Table 14 is referenced to demonstrate method):

- For each location where a spot speed is measured, comparison factors are calculated by dividing the 85th percentile speed by the test run speeds and the average test run speeds for the same location. In the example, there are two locations where spot speeds were measured—Station 0+600 and Station 1+600.
- The variation of comparison factors for each test run is determined separately. In the example, there are only two comparison factors for each test run, so the difference between the two factors is used as the measure of variance.
- The comparison factors for the test run with the lowest variation are then averaged and this average factor becomes the correction factor. In the example, Test Run 1 has the lowest variation.
- The average test run speed for each location is multiplied by the correction factor to yield an estimated 85th percentile speed for each location.[51]

Table 14. Example of Using Speed Test Runs to Confirm 85th Percentile Speeds (km/h)

		Test Run			Comparison Factor			
Station	Spot Speed 85th Percentile	1	2	Average	1	2	Average	Estimated 85th Percentile Speed
0+000		85	86	86				88
0+200		87	86	87				89
0+400		84	79	82				84
0+600	83	80	88	84	1.038	0.943	0.988	86
0+800		82	84	83				85
1+000		80	78	79				81
1+200		75	78	77				78
1+400		62	63	63				64
1+600	71	70	66	68	1.014	1.076	1.044	70
1+800		69	71	70				72
2+000		72	70	71				73
				Variation	***0.023***	0.133	0.056	
				Correction Factor	1.026			

Data Analysis

The ITE Traffic Engineering Council Technical Committee surveyed the speed zoning practices used by agencies across the United States. The committee collected speed zoning guidelines from 40 States and conducted 124 surveys with ITE members serving as traffic engineers in State and local agencies. Based on the results of the survey, the most important factors considered for recommending a speed limit are: 85th percentile speed; followed by roadway geometry, crash exposure, and roadside development.[17] This section discusses the compilation of speed and crash data used to develop the inputs to the speed limit setting process.

85th Percentile Speed

The *Manual on Uniform Traffic Control Devices* (MUTCD) lists the current speed distribution of free-flowing vehicles as a primary factor to consider when establishing speed limits. The MUTCD also states that the speed limit should be within 5 mph (8 km/h) of the 85th percentile speed.[15]

The 85th percentile speed is the speed at or below which 85 percent of the free-flowing vehicles travel, and has traditionally been considered in an engineering study to establish a speed limit. Traffic engineers have assumed that this high percentage of drivers will select a safe speed on the basis of the conditions at the site. The 85th percentile speed is considered the first approximation for the speed limit.

The Ohio Department of Transportation collects vehicle speeds even if it is not possible to observe free-flow conditions. Then the 85th percentile speed of all vehicles is increased 5 to 10 mph (8 to 16 km/h) to approximate the free-flow 85th percentile speed. If the 85th percentile speed of several speed checks varies considerably, the 85th percentile speeds are averaged, or the most representative speed is selected.[19]

A convenient way to determine speed percentiles is a frequency distribution table. An example, with an explanation of how to use it, is provided in Appendix H.

10 mph (16 km/h) Pace

The speeds of individual vehicles on a highway vary. Speed dispersion refers to this spread in vehicle speeds. The 10 mph (16 km/h) pace is the ten mile-per-hour range of speeds containing the greatest number of observed speeds and is a measure of speed dispersion. It is described by both the speed value at the lower end of the range and the percentage of all vehicles that are within the range; and, thus, is an indicator of speed dispersion.

A normal speed distribution contains approximately 70 percent of the vehicles within the pace, with approximately 15 percent of the vehicles below and 15 percent above the limits of the pace speed. The upper limit of the 10 mph (16 km/h) pace speed is therefore approximately the 85th percentile speed in most cases. However, the upper limit of the pace speed may vary from the 85th percentile speed, depending on the distribution curve of the vehicle speeds.

There is general agreement that the safest conditions occur when all vehicles at a site are traveling at about the same speed.[11]

Crash Data

Crash data are typically considered in establishing speed limits. The factors potentially contributing to the crashes should be examined to determine whether speeding was involved, or whether the speeds were too high for a specific condition or feature. Speed contributes to the severity of a crash, and sites with a history of severe injury or fatal crashes may be locations with high levels of speeding. The National Highway Traffic Safety Administration (NHTSA) considers a crash to be speeding-related if the driver was charged with a speeding-related offense or if an officer indicated that racing, driving too fast for conditions, or exceeding the posted speed limit was a contributing factor in the crash.[46]

Crash data may be accessed via State, local, county or community-wide databases. These databases may be housed within State agencies including the Department of Safety, Department of Transportation, or State Highway Patrol, within local law enforcement agencies, or within the court system. In some cases there may be some information missing from the database. For example, if a database is not GPS-based, or does not include detailed information regarding the location of a crash, it may be difficult to locate the site. In some communities the data is still maintained in paper format, and manually reviewing paper records is time consuming and costly. Coordinating field data collection and crash analysis prior to the start of the program is one way to minimize costs.

A review of crash data can show whether the study area has a higher than average crash experience, and whether the portion of crashes that appear to be related to speeding is higher than average. The MUTCD recommends reviewing reported crash experience for at least a 12-month period.[15] Twelve months is considered a short-term crash count and is insufficient as a basis for making sound safety decisions. The implications of crash frequency fluctuation and variation of site conditions are often in conflict. On one hand, the year-to-year fluctuation in crash frequencies tends toward acquiring more years of data to determine the expected average crash frequency. On the other hand, changes in site conditions can shorten the length of time for which crash frequencies are valid for considering averages. This conflict between crash data variations and changing site conditions requires considerable judgment in selecting an analysis period.

Typically, road authorities review crash data for a three- to five-year period.

When crash data are collected, it is important to consider the following factors before interpreting existing data or gathering new data:

- Only consider data collected on road segments that are within the study area.
- Gather categorized details about the site geometry, traffic control devices, signage, weather, lighting conditions, time of day, day of week, interaction with other vehicles, etc.
- Minimize the amount of emphasis placed on individual (severe) crashes rather than trends or clusters of crashes.
- Differentiate between mid-block and intersection crashes.
- When comparing crash datasets, ensure that the same filtering criteria are used to develop the datasets.
- Watch for data format issues between data sources and collection periods to avoid difficulties in coding and analysis.
- Although data should be sanitized for driver identity before reporting, maintaining a link to the raw data source until the data is ready to be published or used for the last time will make it possible to go back to the source easily to supplement and verify details for analysis and report generation.
- Note extenuating circumstances that may preclude or overshadow typical trends and analyses and be prepared to filter or caveat them (e.g., long-term construction zones, new developments, major changes or reconstruction, etc.).

Some measure of the crash experience of the study site can be developed and compared to the average of that measurement for similar sites in a jurisdiction. Examples are crash frequency, crash density, and crash rate. Some agencies factor crash severity into safety analyses by giving a higher weight to injury and fatal crashes. The average of this frequency, rate, or other measure, for all roadways of a similar type (such as urban 4-lane undivided arterials) in a State would be a good value for comparison. A discussion of how the analyzed data are used in determining speed limits is presented in the next section.

Isolating the effect of one crash factor, such as speed, can be a challenge. Often it is difficult to identify the role of speed in crashes, and for this reason it is thought that speed-related crashes are often under-reported.[47] For this reason, all crashes may be considered in setting speed limits.

A crash diagram is often prepared as a part of the safety analysis to help identify patterns and trends in the crash data.

The state-of-the-art in crash data analysis and determining the safety performance of a facility is contained in the *Highway Safety Manual*. This document provides analytical tools and techniques for estimating the expected crash risk of different facilities, and it can also be used in assessing the safety effects of a change in the posted speed limit.

SPEED LIMIT ENFORCEMENT

While a properly selected speed limit is hopefully self-enforcing, the reality is that an effective speed limit generally relies in part on enforcement of the limit. The engineering community has four main roles in speed enforcement:

- Communicate with those responsible for enforcement during the setting of speed limits;
- Provide data to enforcement officials so they may effectively deploy enforcement resources;
- Provide and maintain automated speed enforcement (ASE) equipment and technologies (where allowed); and
- Integrate features in the road design to facilitate speed enforcement (i.e., laybys and median openings that assist enforcement personnel).

Because speed limits and enforcement are intertwined, it is important for the road authority to liaise with enforcement personnel before setting a speed limit for a facility. Enforcement personnel have experience and unique insights into the enforceability of speed limits that may be used to ensure that rational speed limits are applied.

Speed enforcement is essentially a crash countermeasure and therefore benefits from a proper understanding of the persons, place, time, and conditions that foster speeding. Engineering personnel can provide speed and crash data as well as citizen complaints to enforcement personnel so that appropriate enforcement strategies are identified. This data-driven approach to resource deployment can target specific scenarios of speeding or types of speeding activities (e.g., commuters, after-school, racing, deliveries, etc.).

Automated speed enforcement uses equipment to monitor speeds and photograph offenders to produce citations that are mailed to the registered owner of the vehicle. ASE is particularly effective at locations where the roadway geometry or traffic volumes make it difficult to use more traditional methods (e.g., requiring a traffic stop). This strategy requires enabling legislation, if such legislation has not already been passed. NHTSA's *Speed Enforcement Camera Systems Operational Guidelines* is a useful reference.[48]

The engineering community is generally involved in ASE, as it requires speed cameras that are maintained by the road authority. In all cases, enforcement personnel need to be involved and an integral part of any ASE activities.

A combination of the various enforcement strategies described above, in addition to engineering and communications countermeasures, may contribute to ongoing compliance with the speed limit. When an effective speed enforcement program is sustained, it can continue to deter speeders. The NHTSA and FHWA *Speed Enforcement Program Guidelines* is a useful reference.[42]

CASE STUDIES

To demonstrate the application of some of the principles and methods presented in this informational report, two case studies are presented. The case studies use existing roads and real data. In both cases, the posted speed limit is determined by the engineering, expert system, optimal speed, and safe systems methods. It is noted that not all of the data was collected for each of the methods, and for the sake of presenting each of the speed limit setting methods, reasonable assumptions were made about some values.

The outcomes may or may not match with the actual posted speed limit as determined by the governing road authority. This does not suggest that the road authorities are using outdated or incorrect methods in setting their speed limits. On the contrary, the methods used to set the initial and/or revised speed limits were in compliance with State statutes and requirements and the guidance provided in the federal MUTCD.

It must be remembered that in all speed limit setting studies, the tools and techniques that are available to the practitioner are intended to assist the practitioner in making a decision—it is guidance and not direction as to the speed limit to be posted. Engineering judgment must be applied.

CASE STUDY 1: Urban Collector Road

As part of a speed limit reevaluation process, the City of Palm Bay, Florida, identified Eldron Boulevard from Jupiter Boulevard to Raleigh Road for analysis. The study area was selected based on the following considerations:

- The roadside development is consistent throughout the study area;
- The physical features of the road are consistent throughout the study area; and
- The study area is bounded by signalized intersections at both ends of Eldron Boulevard, which form a natural break-point for speed zoning.

Eldron Boulevard is a north-south collector road approximately 2.3 miles long and located in a northeastern portion of the City. The study segment is essentially straight and flat, with a design speed of 50 mph or more. It is a two-lane, undivided facility with no shoulder and an 8-foot wide sidewalk on the east side of the road, located about eight feet from the edge of the pavement. The lane widths are 12 feet each.

The contiguous and surrounding land use is single-family residential. There are 85 single-family residential driveways, one minor commercial driveway, and 26 two-way, stop controlled intersections that access Eldron Boulevard. The area is basically fully developed, and traffic volumes are relatively stable over time.

Eldron Boulevard is a municipal transit route. Parking is not prohibited, but happens very infrequently. Pedestrian volumes are typical for a residential street, and cyclist volumes are considered low. Street lighting is present throughout the study area.

Given the consistent physical features throughout the study area, a single spot speed measurement location was deemed sufficient. However, given the length of the study area, and as an extra precaution, the analysts decided to measure spot speeds at two locations. The spot speed stations were spaced evenly in the study area, and were located away from intersections or major driveways that would include vehicles changing speeds while using these accesses. Pneumatic road tubes were used to collect spot speed data at two locations in the study area; the results are as follows:

	North Station	South Station
Posted Speed Limit	40	40
Median Speed (50th Percentile)	38.8	37.2
Average (Mean) Speed	39.3	32.2
85th Percentile Speed	43.4	43.0
10-mph Pace	35 – 44	35 – 44
Percent Exceeding the Speed Limit	48.3	32.2

Five test runs were undertaken through the study area, and the average test run speed was 41 mph.

From January 2009 to July 2010 (19 months), there were 19 crashes in the study area. Two of these crashes resulted in personal injuries, none in fatalities. The average daily traffic volume during this time was 9200 vehicles per day. The crash rate for this road is 1.55 crashes per million-vehicle-miles (MVM). The average crash rate for these types of facilities is 2.22 crashes/MVM.

Engineering Method Using Operating Speed

Using the Illinois DOT Method

STEP 1: Establish the Prevailing Speed

The prevailing speed is the average of the 85th percentile speed, the upper limit of the 10 mph pace, and the average test run speed, rounded to the nearest 5 mph increment.

	A	B	C	(A+B+C)/3
Station	85th Percentile Speed (mph)	Upper Limit of the 10-mph Pace (mph)	Average Test Run Speed (mph)	Prevailing Speed (mph)
North	43.4	44	41	42.8
South	43.0	44	41	42.7

The prevailing speed rounded to the nearest 5 mph increment is 45 mph for both locations in the study area.

STEP 2: Supplementary Investigations

Adjustment factors for determining the proposed posted speed limit as determined by further investigation of the following four conditions:

- Elevated Crash Risk: The speed zone being studied has a crash rate of 1.55 crashes/MVM, which is lower than the statewide average of 2.22 crashes/MVM for these types of roads. Hence, there is no adjustment required for crash risk.
- Access Control: The access conflict number (ACN) is calculated for the speed zone, based on 85 single–family, residential driveways, one minor, commercial driveway, and 27 two-way, stop-controlled intersections in the study area:

ACN*	Reduction (%)
< 40	0
41 to 60	5
> 60	10

$$* \ ACN = \frac{N_s + 5N_m + 10N_i}{L}$$

Where:

N_s = Number of field entrances and driveways to single-family dwellings

N_m = Number of driveways to minor commercial entrances, multi-family residential units, and minor street intersections

N_i = Number of driveways to major commercial entrances, large multi-family developments, and major street intersections

Therefore, based on accesses, it is appropriate to lower the prevailing speed (from Step 1) by 10 percent.

- Pedestrian Activity: The pedestrian activity is typical for a residential area, is accommodated by a sidewalk on one side of the street, and is not considered "significant pedestrian activity." No further adjustment is required for this factor.
- Parking: Parking is negligible and is not a factor in determined the posted speed limit.

The total adjustment from the 4 different factors is 10 percent.

Step 3: Selection of Preliminary Speed Limit

The preliminary speed limit is either the calculated prevailing speed (from Step 1), or if the optional investigation was undertaken, it is the prevailing speed as adjusted by application of the percentage corrections from the optional investigation (Step 2). Since Step 2 was undertaken, the preliminary posted speed limit is:

- 45 mph – (0.1*45 mph) = 41 mph

The following rules apply to the outcome:

- The preliminary posted speed limit should be the closest 5 mph increment to the (adjusted) prevailing speed. This results in a preliminary posted speed of 40 mph.
- The preliminary posted speed limit shall not differ from the prevailing speed (from Step 1) by more than 9 mph or by more than 20 percent, whichever is less. This condition is satisfied by the 40 mph preliminary posted speed limit.

Therefore, the proposed preliminary speed limit is 40 mph.

Step 4: Violation Check

The proposed speed limit should be either the preliminary posted speed limit or the 50th percentile speed, whichever is greater. In this case, the median speeds are 38 to 39 mph, so the preliminary posted speed limit of 40 mph is valid.

It is noted that the statutory speed limit for Eldron Boulevard is 30 mph, which is less than the preliminary posted speed limit determined above. At this point, the road authority has the option of either posting at the statutory speed, or the proposed speed limit.

The Illinois method of setting speed limits results in a recommended speed limit of 40 mph.

Using the Northwestern Speed Zoning Technique

Step 1: The Minimum Speed Study

Station	85th Percentile Speed, km/h (mph)	Upper Limit of the 10-mph Pace, km/h (mph)	Average Test Run Speed, km/h (mph)
North	43.4 (70)	71 (44)	66 (41)
South	43.0 (69)	71 (44)	66 (41)

For the minimum speed study, speed measurements yield the following:

Criteria	Justified Speed Limit (from Table 18)	Weight	Weighted Limit
85th Percentile Speed	70	3	210
Upper Limit of the Pace	70	3	210
Average Test Run Speed	80	4	320
		Sum	740

The weighted average is 740/10 = 74 km/h, which suggests a speed limit of 75 km/h based solely on the speed data.

The suggested speed limit needs to be checked against the major physical features of the road. The design speed of Eldron Boulevard is 50 mph (80 km/h), and the length of road under study is 2.3 miles (3.7 kms). The average distance between intersections is:

$$D = \frac{2.3\,miles}{26\,intersections} * 5280\frac{feet}{mile} = 467\,feet = 142\,meters$$

Design Speed (km/h)	Average Distance Between Intersections (m)	Length of Proposed Zone (km)	Maximum Speed Limit (km/h)
110	400	1.5	110
100	300	1.0	100
90	250	0.8	90
90	175	0.7	80
70	125	0.6	70
70	100	0.5	60
50	75	0.4	50
50	60	0.3	40
30	45	0.2	30

All three criteria are satisfied by a 70 km/h (45 mph) speed limit. Therefore the minimum study recommends a speed limit of 70 km/h (45 mph).

Continuing on with the detailed analysis, the factors determined from the various tables are:

Adjustment Factors			
Non-commercial Access (Table 20)		-5	
Commercial Access (Table 20)	+5		
Lane Width (Table 21)	+5		
Functional Classification (Table 22)		-5	
Median Type (Table 23)	0		
Shoulder Type and Width (Table 24)	0		
Pedestrian Activity (Table 25)		-15	
Parking Activity (Table 26)	0		
Roadway Alignment (Table 27)	+10		
Crash Rate (Table 28)	+10		
Totals	**+30**	**-25**	**=+5**

The overall adjustment factor (OAF) is +5 which can be used to determine the multiplication factor (MF) as:

MF = (100+OAF)/100 = (100+5)/100 = 1.05

The multiplication factor is less than 1.25 and greater than 0.75; therefore, the recommended speed limit (SL) is the speed limit from the minimum study multiplied by the multiplication factor and rounded to the nearest 10 km/h:

SL = 70 km/h * 1.05 = 73.5 km/h → 75 km/h or 45 mph

The recommended speed limit based on the Northwestern Speed Zoning method is 45 mph.

Expert Systems Approach Using USLIMITS2

The data from the Eldron Boulevard speed limit study was entered into the USLIMITS2 program to determine the recommended speed limit for this section of road. The entered data and the recommended speed limit are shown in the boxed area below. The speed limit recommended by the USLIMITS2 approach is 40 mph.

USLIMITS2 Data Output

Top of Form

Basic Project Information

Project Name – **Case Study 1**
Project Number –
Project Date – 09-21-2011
State – Florida
County – Brevard County
City – Palm Bay City
Route – Eldron Boulevard
Route Type – Road Section in Developed Area
Termini from – Jupiter Boulevard
Termini to – Raleigh Road
Route Status – EXISTING
Description – FHWA/ITE Informational Report Case Study

Roadway Information
85th Percentile Speed – 43 mph
50th Percentile Speed – 39 mph
Section Length – 2.30 mile(s)
Statutory Speed Limit – 30 mile(s)
AADT – 9200
Adverse Alignment – No
Lanes and Presence/Type of Median – Two-lane road or undivided multi-lane.
Number of Lanes – 2
Area Type – Residential Collector
Number of Driveways – 112
Number of Signals – 0
On Street Parking and Usage – Not High
Pedestrian / Bicyclist Activity – High

Crash Data Information
Crash Data Months/Years – 1.58
Crash AADT – 9200
Total Number of Crashes – 19
Total Number of Injury Crashes – 2
Section Crash Rate – 155
Section Injury Rate – 16
Crash Rate Average for Similar Sections – 222
Injury Rate Average for Similar Sections – 73

Comments –

Recommended Speed Limit is: 40

Note:
The final recommended speed limit is higher than the statutory speed limit for this type of road. The statutory limit is 30 mph.

Optimal Speed Limit

The optimal speed limit is determined by calculating and selecting the speed that produces the lowest societal cost. In this case study only crash costs and fuel costs will be considered to demonstrate the method. In a full analysis, other societal costs would be analyzed, including time travel costs, automobile emissions, etc.

Step 1: Calculate the Crash Costs

The road authority has developed the following crash prediction models using regression techniques, traffic, infrastructure, and historic crash data for roads under their control:

$$N_{P+B} = EXP\left(2.75 - 0.089SL - 0.815UMA + \frac{43.8 * ADT * L}{10^6}\right)$$

$$N_{v-v} = EXP\left(0.95 + 0.13X + 0.71X_s + 0.000014ADT - 0.026SL - 0.0069W + 0.19NOL - 0.38GM - 0.42UMA - 1.19UC - 2.5UL\right)$$

Where: N_{P+B} = Number of pedestrian and bicyclist crashes per year, per mile

N_{v-v} = Number of vehicle-vehicle crashes per year, per mile

SL = Posted Speed Limit (mph)

X = Number of intersections in the segment

X_s = Number of signalized intersections on the segment

W = Pavement width (feet)

NOL = Number of lanes

GM = 1 if median, 0 if no median

UMA = 1 if urban minor arterial, 0 if not

UC = 1 if urban collector street, 0 if not

UL = 1 if urban local road, 0 if not

ADT = Average daily traffic

L = Length (miles)

Additionally, the road authority has examined its severity distributions of the two crashes types based on speed, and has produced the following probabilities using the KABCO severity scale. The KABCO severity scale was developed by the National Safety Council, and is used by the investigating officers to classify injury severity for occupants into one of five categories: K – killed; A – disabling injury; B – evident injury; C – possible injury; O – no apparent injury. These definitions may vary slightly for different police agencies.

Probability of Crash Severity for Vehicle-Pedestrian/Cyclist Crashes

Speed Limit (mph)	Crash Severity				
	K	A	B	C	O
20	0.0028	0.0339	0.2053	0.5631	0.1949
25	0.0040	0.0435	0.2335	0.5555	0.1635
30	0.0057	0.0549	0.2622	0.5415	0.1357
35	0.0080	0.0684	0.2905	0.5219	0.1112
40	0.0110	0.0841	0.3178	0.4970	0.0901
45	0.0150	0.1020	0.3432	0.4677	0.0721
50	0.0202	0.1221	0.3657	0.4349	0.0571
55	0.0268	0.1443	0.3846	0.3997	0.0446
60	0.0351	0.1682	0.3993	0.3630	0.0344

Probability of Crash Severity for Vehicle-Pedestrian/Cyclist Crashes

Speed Limit (mph)	Crash Severity				
	K	A	B	C	O
20	0.002	0.0006	0.0081	0.0862	0.9049
25	0.0004	0.0009	0.0116	0.1081	0.879
30	0.0006	0.0015	0.0158	0.1313	0.8508
35	0.001	0.0022	0.0218	0.1591	0.8159
40	0.0016	0.0031	0.0289	0.187	0.7794
45	0.0025	0.0044	0.0386	0.2188	0.7357
50	0.0037	0.0062	0.0495	0.2491	0.6915
55	0.0055	0.0088	0.0635	0.2816	0.6406
60	0.008	0.0117	0.0788	0.3105	0.591

The City of Palm Bay uses the societal costs of crashes shown below:

Crash Severity	Societal Cost ($)
K	3,366,388
A	233,100
B	46,620
C	24,510
O	2,590

Therefore, employing the crash model for vehicle-pedestrian/cyclist, the probability distributions for the different crash severities, and the societal costs for the different crash severities, the cost of vehicle-pedestrian/cyclist crashes for the different available speed limits is shown below.

Speed Limit (mph)	No. of Ped/ Cyclist Crashes	Crash Costs by Severity ($)					
		K	A	B	C	O	Total
20	6.7	62,820	52,664	63,787	91,982	3,364	274,617
25	4.3	57,509	43,306	46,491	58,149	1,809	207,263
30	2.7	52,516	35,024	33,455	36,324	962	158,280
35	1.8	47,233	27,963	23,752	22,435	505	121,888
40	1.1	41,618	22,033	16,652	13,691	262	94,256
45	0.7	36,368	17,124	11,524	8,256	134	73,407
50	0.5	31,385	13,136	7,869	4,920	68	57,378
55	0.3	26,684	9,948	5,303	2,897	34	44,867
60	0.2	22,395	7,431	3,528	1,686	17	35,058

It is noted that under this particular crash model, the number of pedestrian and cyclist crashes decreases as the speed limit increases. This is likely due to the fact that higher speed roads have lower pedestrian and cyclist traffic than similar lower speed roads. In other words, exposure to these types of crashes decreases as speed increases.

The same methodology is employed to identify the societal cost of vehicle-vehicle crashes for the different speed limit alternatives.

Speed Limit (mph)	No. of Vehicle-Vehicle Crashes	Crash Costs by Severity ($)					
		K	A	B	C	O	Total
20	19.4	—	2,256	5,145	32,599	46,386	86,386
25	17.0	114,456	2,378	6,419	35,916	39,842	199,011
30	14.9	20,101	3,132	8,073	39,551	33,984	104,839
35	13.1	26,475	4,583	9,655	42,183	28,884	111,780
40	11.5	38,746	5,902	11,698	44,883	24,322	125,552
45	10.1	54,437	7,303	13,617	46,323	20,402	142,082
50	8.9	74,689	9,102	15,970	47,593	16,910	164,265
55	7.8	97,064	11,262	17,983	47,578	13,957	187,845
60	6.8	126,696	14,037	20,257	47,229	11,353	219,572

It is noted that the number of crashes decreases as the speed limit increases. This is likely due to the fact that the design of higher speed roads affords more generous dimensions and greater safety features than similar lower speed facilities.

The total crash costs are the sums of the vehicle-vehicle crash costs and the vehicle-pedestrian/cyclist crash costs.

Speed Limit (mph)	Ped/Cyclist Crash Costs ($)	Vehicle-Vehicle Crash Costs ($)	Total Crash Costs ($)
20	274,617	86,386	361,003
25	207,263	199,011	406,275
30	158,280	104,839	263,120
35	121,888	111,780	233,669
40	94,256	125,552	219,808
45	73,407	142,082	215,489
50	57,378	164,265	221,642
55	44,867	187,845	232,712
60	35,058	219,572	254,630

According to published data on the fuel efficiency of late model passenger cars and light trucks according to speed, the annual fuel consumption for different speed limits can be calculated. Assuming a cost for gas of $3.50/gallon yields an annual fuel cost. This annual fuel cost can be added to the annual crash costs to determine the net societal cost for the different speed limit alternatives. The results are shown below.

Speed Limit (mph)	Fuel Economy (mpg)	Annual Fuel		Annual Crash Cost ($)	Total Cost ($)
		Gallons	Fuel Cost (at $3.50/gal)		
20	26.4	292,553	1,023,936	361,003	1,384,939
25	30.2	255,848	895,467	406,275	1,301,741
30	31.8	243,161	851,063	263,120	1,114,183
35	32.7	236,190	826,664	233,669	1,060,332
40	32.6	236,733	828,564	219,808	1,048,372
45	32.8	235,559	824,457	215,489	1,039,946
50	32.1	240,698	842,443	221,642	1,064,086
55	31.1	248,441	869,542	232,712	1,102,254
60	29.0	266,095	931,332	254,630	1,185,961

Under an optimal speed limit approach to Eldron Boulevard, the recommended speed limit is 45 mph. The subsequent analysis does not include the cost of travel time, or automobile emissions, which would typically be included in the thorough analysis.

Safe Systems Approach

Under the safe systems approach to setting the speed limit, the critical factor is the type of crashes that can be expected to occur given the physical features of the road, and the types of road users that are expected to be encountered.

In this instance, pedestrians and cyclists are permitted to use Eldron Boulevard but cyclists are very infrequent, and pedestrians walking along the road are provided with a sidewalk that is set back from the edge of pavement. The fact is that pedestrian-vehicle and cyclist-vehicle interactions are uncommon, and are not a significant factor in determining a "safe speed limit."

However, there are 26 two-way, stop controlled intersections and 86 driveways (85 residential and one minor commercial) along this section of Eldron Boulevard. This means that the potential for right-angle crashes, which have the greatest potential for causing serious injury to vehicle occupants, is significant. Therefore, under a safe systems approach to setting speed limits, speeds on Eldron Boulevard from Jupiter Road to Raleigh Road should be limited to those speeds where a right-angle crash will not cause any serious injuries. This being the case, research on human biomechanical tolerance, and vehicle crashworthiness studies indicate that speeds should be limited to 30 mph.

The recommended speed limit under the safe systems approach is 30 mph.

The recommended speed limits yielded by each speed limit setting method, and the actual speed limit enacted by the road authority are shown in Tables 15 and 16.

Table 15. Recommended Speed Limits for the Eldron Boulevard Case Study

	Eldron Boulevard, Florida
Actual Speed Limit	40
Illinois DOT	40
Northwestern	45
USLIMITS2	40
Optimal Speed	45
Safe System Speed	30

CASE STUDY 2: Rural Arterial Road

Roadway improvements undertaken in an 11.5-mile segment of State Route 67 between Milepost 11.3 and 22.8 in California prompted the need for a re-examination of the existing 55 mph speed limit. This is an existing road with consistent road and land use characteristics throughout.

State Route 67 is a 24.4-mile road running primarily in a north-south direction between the City of El Cajon and the community of Ramona. The study segment is a 2-lane highway, which traverses hilly terrain, resulting in undulating vertical grades and winding horizontal curves. Strategically-located passing lanes are present through the study area.

Traffic volumes are as follows:

Milepost	2011 AADT
13.56	24,900
15.20	25,500
20.87	25,000
21.35	29,500
Average	25,350

The roadway is asphalt with varying shoulder widths throughout. Shoulders are generally paved and range from 3 feet (1.0 meter) to 8 feet (2.4 meters).

A painted median is provided that includes a median rumble strip and raised pavement markers. The median is typically three feet wide.

In addition to the appropriate traffic control devices and traffic barriers, 11 digital Speed Feedback signs are employed.

There are three signalized intersections in the study area.

A Doppler radar system was used to conduct spot speed studies at five different locations within the study area.

Milepost	85th Percentile Speed (mph)	Median Speed (mph)	Mean Speed (mph)	Upper Limit of the 10 mph Pace (mph)	Percent Exceeding the 55 mph
11.30	61	56	56	61	57
15.00	63	57	57	60	60
18.10	65	60	60	64	83
19.70	59	56	56	60	59
21.00	54	51	51	55	8
Average	60.4	56.0	56.0	60.0	

Based on a review of the horizontal alignment in the study section, the design speed is 50 mph. None of the curves require an advisory speed warning.

The 3-year crash rate for the entire study area is 0.80 crashes per million-vehicle-miles, which is lower than the statewide average crash rate of 1.51 crashes per million-vehicle-miles. However, there have been 17 fatal crashes in the 3-year analysis period that have been evenly distributed throughout the study section. The fatal crash rate is 0.46 crashes per million-vehicle-miles (MVM), which is almost double the statewide average fatal crash rate of 0.25 crashes/MVM.

Public and private accesses to State Route 67 were inventoried and consist of the following:

	NBND (milepost)	SBND (milepost)
Private Access	12.10	11.49
	12.17	11.96
	12.38	12.78
	12.76	13.69
	13.80	13.78
	13.96	14.06
	14.07	14.89
	14.10	15.56
	14.34	16.19
	14.36	16.28
	14.89	16.45
	15.46	17.43
	15.67	17.51
	15.89	18.16
	16.13	18.27
	16.96	18.37
	17.00	18.54
	17.89	18.92
	18.05	
	18.14	
	18.21	
	20.25	
Public Road	14.35 (Iron Mountain Trail)	13.56 (Scripps Poway Parkway)
	17.73 (Rockhouse Road)	15.15 (Poway Road)
	20.87 (Mussey Grade Road)	18.11 (Mount Woodson Road)
		18.55 (Archie Moore Road)

All of the private accesses are to single family residential dwellings or small-scale agricultural operations.

State Route 67 has a rural cross-section, so there are no sidewalks. Pedestrians and cyclists are not prohibited from the facility, but the volume of both user groups is extremely low.

Parking is permitted, but there are no significant roadside attractions, so parking activity is negligible.

Five test runs were undertaken during off-peak periods, and the average test run speed was 63 km/h.

Engineering Method Using Operating Speed

Using the Illinois DOT Method

STEP 1: Establish the Prevailing Speed

The prevailing speed is the average of the 85th percentile speed, the upper limit of the 10 mph pace, and the average test run speed, rounded to the nearest 5 mph increment.

	A	B	C	(A+B+C)/3	
Milepost	*85th Percentile Speed (mph)*	*Upper Limit of the 10 mph Pace (mph)*	*Avg. Test Run Speed (mph)*	*Prevailing Speed*	*Rounded*
11.30	61	61	63	62	60
15.00	63	60	63	62	60
18.10	65	64	63	64	65
19.70	59	60	63	61	60
21.00	54	55	63	57	55

STEP 2: Supplementary Investigations (Optional)

Adjustment factors for determining the proposed posted speed limit may be determined by further investigation of any or all of the following four conditions:

- Elevated Crash Risk: The speed zone being studied has a crash rate that is lower than the statewide average for similar facilities. However, it is still deemed a high-crash segment based on the elevated fatal crash rate, which is double the statewide average. Therefore, a 10 percent reduction in the prevailing speed is appropriate.

- Access Control: The access conflict number (ACN) is calculated for the speed zone, based on 40 private accesses to residential driveways and farms, and 7 public road intersections.

ACN*	Reduction (%)
< 40	0
41 to 60	5
> 60	10

$$* ACN = \frac{40*1+7*5}{11.5\, miles} = 6.5$$

Therefore, no adjustment is required for access concerns.

- Pedestrian Activity: There is no significant pedestrian activity, so no further adjustment is required for this factor.
- Parking: Parking is negligible and is not a factor in determining the posted speed limit.

The total adjustment from the 4 different factors is 10 percent.

Step 3: Selection of Preliminary Speed Limit

The preliminary speed limit is either the calculated prevailing speed (from Step 1), or if the optional investigation was undertaken, it is the prevailing speed as adjusted by application of the percentage corrections from the optional investigation (Step 2).

Milepost	Prevailing Speed (Step 1), mph	Adjusted Speed (Step 2), mph	Preliminary Speed Limit (Rounded), mph
11.30	60	54	55
15.00	60	54	55
18.10	65	59	60
19.70	60	54	55
21.00	55	50	50

The following rules apply to the outcome:

- The preliminary posted speed limit should be the closest 5 mph increment to the (adjusted) prevailing speed.
- The preliminary posted speed limit shall not differ from the prevailing speed (from Step 1) by more than 9 mph or by more than 20 percent, whichever is less.

Both of these conditions are satisfied by the preliminary speed limits reported above.

Step 4: Violation Check

The proposed speed limit should be either the preliminary posted speed limit or the 50th percentile speed, whichever is greater. In all cases, the preliminary speed limit and the median speeds yield the same speed limit (rounded to the nearest 5 mph increment).

Milepost	Preliminary, mph	Median, mph
11.30	55	56
15.00	55	57
18.10	60	60
19.70	55	56
21.00	50	51

If the proposed speed limit exceeds the statutory speed limit for the highway in question, either the statutory speed or the proposed speed limit may be posted. If the selected speed limit results in a violation rate greater than 50 percent, the appropriate police agency(ies) should be notified that extra enforcement efforts may be necessary.

It is noted that differences in posted speeds between adjacent speed zones should not be more than 10 mph. However, the Illinois policy permits a larger difference provided that adequate speed reduction signs are posted.

Using the Northwestern Speed Zoning Technique

Milepost	85th Percentile Speed (mph) (km/h)	Upper Limit of the 10 mph Pace (mph) (km/h)	Average Test Run Speed (mph) (km/h)
11.30	61 (98)	61 (98)	63 (101)
15.00	63 (101)	60 (97)	63 (101)
18.10	65 (105)	64 (103)	63 (101)
19.70	59 (95)	60 (97)	63 (101)
21.00	54 (87)	55 (88)	63 (101)

For the minimum speed study, the speed measurements yield the following:

	Justified from Table 13				
Milepost	85th Percentile Speed (mph) (km/h)	Upper Limit of the 10 mph Pace (mph) (km/h)	Average Test Run Speed (mph) (km/h)	Weighted Limit (mph) (km/h)	Speed Limit (Rounded), mph (km/h)
11.30	60 (100)	65 (110)	65 (110)	635 (1070)	65 (110)
15.00	60 (100)	65 (110)	65 (110)	635 (1070)	65 (110)
18.10	65 (110)	65 (110)	65 (110)	650 (1100)	65 (110)
19.70	55 (90)	65 (110)	65 (110)	620 (1040)	60 (100)
21.00	55 (90)	60 (100)	65 (110)	605 (1010)	60 (100)

The recommended speed limit based on the minimum study is 60 to 65 mph depending on the location within the study area. The lower speeds being produced at the higher mileposts may cause the analyst to review the site and traffic conditions to determine if the speed zone should be divided into two separate zones. The conditions are consistent through the study area, and the difference in the speed limit recommended by the minimum study is only 5 mph. Therefore, the study area will be considered as one speed zone.

The speed limit from the minimum study needs to be checked against the major physical features of the road. The design speed of State Route 67 is 50 mph (80 km/h), and the length of the road under study is 11.5 miles (18.5 kms). The average distance between intersections is:

$$D = \frac{11.5\ miles}{7\ intersections} * 5280 \frac{feet}{mile} = 8674\ feet = 2643\ meters$$

Design Speed (km/h)	Average Distance Between Intersections (m)	Length of Proposed Zone (km)	Maximum Speed Limit (km/h)
110	400	1.5	110
100	300	1.0	100
90	250	0.8	90
90	175	0.7	80
70	125	0.6	70
70	100	0.5	60
50	75	0.4	50
50	60	0.3	40
30	45	0.2	30

All three criteria are satisfied with the 70 km/h speed limit. Therefore, the minimum study recommends a speed limit of 45 mph (70 km/h).

Continuing on with the detailed analysis, the factors determined from the various tables are:

Adjustment Factors			
Non-commercial Access (Table 20)		-5	
Commercial Access (Table 20)	+5		
Lane Width (Table 21)	+5		
Functional Classification (Table 22)		-5	
Median Type (Table 23)	0		
Shoulder Type and Width (Table 24)	0		
Pedestrian Activity (Table 25)		-15	
Parking Activity (Table 26)	0		
Roadway Alignment (Table 27)	+10		
Crash Rate (Table 28)	+10		
Totals	**+30**	**-25**	**=+5**

The overall adjustment factor (OAF) is +30 which can be used to determine the multiplication factor (MF) as:

MF = (100+OAF)/100 = (100+30)/100 = 1.30

The multiplication factor is greater than the maximum allowed, so it is reduced to 1.25. Therefore, the recommended speed limit (SL) is the speed limit from the minimum study multiplied by the multiplication factor and rounded to the nearest 10 km/h:

SL = 70 km/h * 1.25 = 87.5 km/h → 90 km/h or 55 mph

The recommended speed limit based on the Northwestern Speed Zoning method is 55 mph.

Expert System (USLIMITS2)

The data from the State Route 67 speed limit study was entered into the USLIMITS2 program to determine the recommended speed limit for this section of road. The entered data and the recommended speed limit are shown in the boxed area below. The recommended speed limit is 55 mph.

The speed data at Mileposts 18.10 and 21.00, if entered into USLIMITS2 using the same traffic and geometric data as above, will produce recommended speed limits of 60 mph and 50 mph, respectively. These are only 5 mph different from the other mileposts, and it is desirable to use a consistent 55 mph throughout the study area to encourage speed limit compliance.

Optimal Speed Limit

The optimal speed limit is determined by calculating and selecting the speed that produces the lowest societal cost. In this case study, only crash and fuel costs will be considered, to demonstrate the method. In a full analysis, other societal costs would be analyzed, including time travel costs, automobile emissions, etc.

Step 1: Calculate the Crash Costs

The road authority has developed the following crash prediction models using regression techniques and traffic, infrastructure, and historic crash data for roads under its control:

$$N = L * EXP\left(0.000016 + 0.0102SL + 0.00045X + 0.0000015ADT\right)$$

Where: *N* = Number of crashes per year, per mile

SL = Posted Speed Limit (mph)

X = Number of intersections on the segment

ADT = Average daily traffic

L = Length (miles)

Additionally, the road authority has examined the severity distributions of the two crash types based on speed, and has produced the following probabilities using the KABCO severity scale. The KABCO severity scale was developed by the National Safety Council, and is used by investigating officers to classify injury severity for occupants into one of five categories: K – killed; A – disabling injury; B – evident injury; C – possible injury; O – no apparent injury. These definitions may vary slightly for different police agencies.

USLIMITS2 Data Output

Top of Form

Basic Project Information

Project Name – **Case Study 2**
Project Number –
Project Date – 09-21-2011
State – California
County – San Diego County
City –
Route – State Route 67
Route Type – Road Section in Undeveloped Area
Termini from – Milepost 11.3
Termini to – Milepost 22.8
Route Status – EXISTING
Description – FHWA/ITE Informational Report Case Study

Roadway Information
85th Percentile Speed – 61 mph
50th Percentile Speed – 56 mph
Section Length – 11.50 mile(s)
Statutory Speed Limit – 55 mile(s)
AADT – 23500
Adverse Alignment – No
Lanes and Presence/Type of Median – Two-lane road or undivided multi-lane
Number of Lanes – 2
Roadside Hazard Rating – 3

Crash Data Information
Crash Data Months/Years – 3.00
Crash AADT – 25000
Total Number of Crashes – 252
Total Number of Injury Crashes – 145
Section Crash Rate – 80
Section Injury Rate – 46
Crash Rate Average for Similar Sections – 151
Injury Rate Average for Similar Sections – 25

Comments –

Recommended Speed Limit is: 55

The crash rate of the section is 80 per 100 MVMT. The average rate for similar sections is 151 per 100 MVMT, and the critical rate is 169 per 100 MVMT. The crash rate of this section is 47 percent lower than the average crash rate for similar sections. The rate of injury crashes for the section is 46 per 100 MVMT. The average rate for similar sections is 25 per 100 MVMT, and the critical rate is 32 per 100 MVMT. The rate of injury crashes for this section is 84 percent higher 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.

Probability of Crash Severity for Different Speeds

Speed Limit (mph)	Crash Severity				
	K	A	B	C	O
40	0.0016	0.0031	0.0289	0.187	0.7794
45	0.0025	0.0044	0.0386	0.2188	0.7357
50	0.0037	0.0062	0.0495	0.2491	0.6915
55	0.0055	0.0088	0.0635	0.2816	0.6406
60	0.0080	0.0117	0.0788	0.3105	0.5910
65	0.0116	0.0160	0.1001	0.3390	0.5333
70	0.0200	0.1250	0.3651	0.4349	0.0550
75	0.0350	0.1500	0.3846	0.4010	0.0294

The road authority uses the societal costs of crashes shown below:

Crash Severity	Societal Cost ($)
K	3,366,388
A	233,100
B	46,620
C	24,510
O	2,590

Therefore, by employing the crash model, the probability distributions for the different crash severities, and the societal costs for the different crash severities, the cost of crashes for the different available speed limits is shown below.

Speed Limit (mph)	No. of Crashes	Crash Costs by Severity ($)					
		K	A	B	C	O	Total
40	18.1	97,627	13,098	24,421	83,075	36,589	254,810
45	19.1	160,524	19,563	34,324	102,288	36,344	353,044
50	20.1	250,006	29,008	46,319	122,547	35,948	483,829
55	21.1	391,076	43,327	62,529	145,784	35,045	677,760
60	22.2	598,601	60,619	81,655	169,156	34,023	944,054
65	23.4	913,386	87,236	109,154	194,346	32,308	1,336,429
70	24.6	1,657,202	717,189	418,953	262,370	3,506	3,059,219
75	25.9	3,051,845	905,657	464,421	254,576	1,972	4,678,471

It is noted that the number of crashes increases as the speed limit increases. This is as expected.

According to published data on the fuel efficiency of late model passenger cars and light trucks according to speed, the annual fuel consumption for different speed limits can be calculated. An annual fuel cost can be calculated assuming a gasoline cost of \$3.50/gallon. This annual fuel cost can be added to the annual crash costs to determine the net societal cost for the different speed limit alternatives. The results are shown below.

Speed Limit (mph)	Fuel Economy (mpg)	Annual Fuel		Annual Crash Cost (\$)	Total Cost (\$)
		Gallons	Fuel Cost (at \$3.50/gal)		
40	28.6	3,448,995	1,2071,482	254,810	12,326,291
45	29.2	3,378,125	11,823,438	353,044	12,176,481
50	***30.9***	***3,192,273***	***11,172,957***	***483,829***	***11,656,786***
55	31.1	3,173,020	11,105,569	677,760	11,783,329
60	29.0	3,398,493	11,894,724	944,054	12,838,778
65	26.5	3,720,556	13,021,947	1,336,429	14,358,376
70	24.1	4,090,876	14,318,066	3,059,219	17,377,286
75	21.8	4,524,828	15,836,898	4,678,471	20,515,369

Under an optimal speed limit approach to State Route 67, the recommended speed limit is 50 mph. The preceding analysis does not include the cost of travel time or automobile emissions, which would typically be included in the thorough analysis and may affect the outcome of the analysis.

Safe Systems Approach

Under the safe systems approach to setting the speed limit, the critical factor is the type of crashes that can be expected to occur given the physical features of the road, and the types of road users that are expected to be encountered. Pedestrian and cyclists, while permitted on State Route 67, are infrequent. Pedestrian-vehicle and cyclist-vehicle conflicts are rare, and do not factor into setting a speed limit using the safe systems approach.

The controlling criteria in this instance are the presence of at-grade intersections and driveways (which permit right-angle crashes), and the undivided cross-section (which permits head-on crashes). State Route 67 has several at-grade intersections that are two-way stop controlled. The volumes on these intersections are generally low and do not result in a significant right-angle crash risk because of extremely low exposure. This being the case, the most significant crash type is the head-on crash. Therefore, the appropriate speed limit under a safe system approach is about 50 mph (80 km/h).

The recommended speed limits yielded by each speed limit setting method and the actual speed limit enacted by the road authority for State Route 67 are shown in Table 16.

Table 16. Recommended Speed Limits for the State Route 67 Case Study

	State Route 67, California
Actual Speed Limit	55
Illinois DOT	55
Northwestern	55
USLIMITS2	55
Optimal Speed	50
Safe System Speed	50

SUMMARY OF RESULTS

Table 17 shows the recommended speed limits yielded by each speed limit setting method and the actual speed limit enacted by the road authority for both case studies are shown below.

Table 17. Recommended Speed Limits for the Case Studies

	Eldron Boulevard, Florida	State Route 67, California
Actual Speed Limit	40	55
Illinois DOT	40	55
Northwestern	45	55
USLIMITS2	40	55
Optimal Speed	45	50
Safe System Speed	30	50

With the exception of the safe systems approach, the recommended speed limit from each of the methodologies used are within 5 mph of each other. On the one hand, this suggests an inter-method consistency that is reassuring. However, it needs to be remembered that these are only two specific examples, and this consistency may not endure in other cases. In fact, the optimal speed and the safe systems approaches are known to produce results that have a more pronounced difference from the other methods in certain situations. This is perhaps not surprising since the Illinois DOT method, the Northwestern method, and USLIMITS2 all start from the 85th percentile speed.

As expected, the safe speed approach resulted in speed limits that are at the low end of the range. This becomes very apparent in the urban case on Eldron Avenue, where the potential for more frequent right-angle crashes requires a more dramatic decrease in operating speeds to be consistent with the zero tolerance for injury-producing crashes.

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APPENDIX A: GLOSSARY

The following definitions are provided to aid in the understanding of setting speed limits. They may or may not coincide with terms and definitions found in related State statutes.

10 mph Pace: The 10 mph pace is the 10 mph range encompassing the greatest percentage of all the measured speeds in a spot speed study.

85th Percentile Speed: The 85th percentile speed is the speed at or below which 85 percent of the free-flowing vehicles travel.

Advisory Speed: Advisory speeds warn drivers to proceed at a speed lower than the speed limit due to geometrics, surface, sight distance, or other conditions.

Annual Average Daily Traffic: Commonly abbreviated as AADT, the total number of vehicles traversing a point or facility in one year divided by 365.

Average Speed: The average (or mean) speed is the most common measure of central tendency. Using data from a spot speed study, the average is calculated by summing all the measured speeds and dividing by the sample size.

Design Speed: The design speed is a selected speed used to determine the various geometric design features of the roadway.

Differential Speed Limit: A system that prescribes different maximum speed limits for different vehicle types or user groups. This is usually applied as one maximum speed limit for light passenger vehicles, and a lower maximum speed limit for trucks and heavy commercial vehicles.

Free-flow Speed: Free-flow speed is the speed a driver chooses when there are no influences from other vehicles, conspicuous enforcement, or environmental factors; in other words, this is the speed the driver finds comfortable based on the appearance of the road.

Injury Minimization Speed Limit: Also known as a speed limit for safe systems, it is a speed limit that is set so that the forces experienced by the human body in the event of a crash will not exceed biomechanical tolerances resulting in death or a severe personal injury.

Optimal Speed Limit: A speed limit that yields the minimum total cost to society, including vehicle operating costs, crash costs, travel time costs, and other societal costs.

Rational Speed Limit: A speed limit that is based on a formal, analytical review of traffic flow, roadway design, local development, and crash data. For existing roads, it uses the 85th percentile speed of free-flowing vehicles operating under normal traffic, weather, and roadway conditions as the speed limit, adjusted down by factors that can affect safety, such as road design features and roadside development and are not readily apparent to the motorist. The analysis also considers crash history and the influence of speed as a contributing factor. The 85th percentile speed is based on the premise that the vast majority of drivers will select a speed that is reasonable, safe, and prudent for a given road. Drivers who exceed the 90th percentile have a significantly higher risk of crashing.

Road Safety Audit: A formal safety performance examination of an existing or future road or intersection by an independent audit team.

Speed Dispersion: The speed dispersion refers to the normal spread in vehicle speeds observed in a study section.

Speed Limit, Absolute: An absolute speed limit is a numerical value, the exceeding of which is always in violation of the law, regardless of the conditions or hazards involved.

Speed Limits, Environment: An environmental speed limit is a speed limit created for the purpose of meeting federal air quality standards.[19]

Speed Limit, Posted: The posted speed limit is the value conveyed to the motorist on a black-on-white regulatory sign. Standard engineering practice is to post speed limits for freeways, arterials, and any roadway or street where speed zoning has altered the limit from the statutory value.

Speed Limit, Prima Facie: A prima facie speed limit is one above which drivers are presumed to be driving unlawfully. Nevertheless, if charged with a violation, drivers have the opportunity to demonstrate in court that their speed was safe for conditions at the time and not in violation of the speed limit, even though they may have exceeded the numerical limit.

Speed Limits, Statutory: Numerical speed limits specifically provided for under a State's traffic codes that apply to various classes or categories of roads (e.g., rural expressways, residential streets, primary arterials, etc.). State laws may or may not require that these limits be posted.[15]

Speed Zoning: Speed zoning is the process of performing and engineering a study and establishing a reasonable and safe speed limit for a section of roadway where the statutory speed limits given in the motor vehicle laws do not fit the road or traffic conditions at a specific location.

Speeding: The legal definition of speeding is exceeding the posted speed limit. In the road safety community, speeding is defined as exceeding the posted speed limit or speed too fast for conditions.

Test Run: A speed test run is performed by driving through a study area (potential speed zone) at a reasonable free-flow speed and collecting speed data, then using this data to confirm speed limits or speed data collected from other vehicles in the study area.

APPENDIX B: EXAMPLE TRAFFIC CONTROL ORDER

CITY OF NOWHERE
TRAFFIC CONTROL ORDER

X	**SPEED**	**DATE OF ORDER:**	**August 24, 2010**
	PARKING		
	OTHER	**CONTROL NUMBER:**	**10-41**

PURSUANT TO CHAPTER NO. 33 OF THE CODE OF ORDINANCES OF THE CITY OF NOWHERE, MICHIGAN, SAME BEING THE UNIFORM TRAFFIC CODE FOR CITIES, TOWNSHIPS AND VILLAGES OF MICHIGAN AND IN THE INTEREST OF PUBLIC SAFETY AND CONVENIENCE THE FOLLOWING TRAFFIC CONTROL ORDER IS HEREBY ISSUED BY JOHN PUBLIC, CHIEF TRAFFIC ENGINEER, DULY AUTHORIZED AS TRAFFIC ENGINEER, BY SEC. 33.141 OF THE AFORESAID CHAPTER.

ISSUANCE OF THIS TRAFFIC CONTROL ORDER WAS PRECEDED BY STUDY AND INVESTIGATION OF TRAFFIC CONDITIONS ON THE FOLLOWING PUBLIC ROAD OR ROADS IN THE CITY OF NOWHERE, MICHIGAN.

FORBES ROAD

AND AFTER SAID INVESTIGATION, IT IS HEREBY ORDERED AND DIRECTED THAT THE DEPARTMENT OF PUBLIC SERVICES ERECT AND MAINTAIN THE SPEED LIMIT SIGN (S) IN ACCORDANCE WITH THE MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES AS REQUIRED BY SEC. 33.217 OF THE AFORESAID CHAPTER, SAID SIGNS TO GIVE NOTICE OF THE FOLLOWING DETERMINATION:

SPEED LIMIT FOR FORBES ROAD FROM FONTANA ROAD TO CARUSO STREET TO BE 45 MPH

____
John Public, P.E. – Chief Traffic Engineer

Dated: August 16, 2010

APPROVED BY CITY COUNCIL
TRAFFIC CONTROL ORDER NUMBER 10-41 HAVING BEEN PRESENTED TO THE COUNCIL OF THE CITY OF NOWHERE, MICHIGAN FOR STUDY AND APPROVAL, IS HEREBY APPROVED AND IT IS HEREBY ORDERED AND DIRECTED THAT THIS ORDER BE FILED IN THE OFFICE OF THE CITY CLERK AND A COPY THEREOF IN THE OFFICE OF THE CHIEF OF POLICE OF SAID CITY.

IT IS FURTHER ORDERED AND DIRECTED THAT THIS ORDER SHALL BECOME EFECTIVE UPON BEING FILED WITH THE CLERK AND UPON ERECTION OF ADEQUATE SIGNS GIVING NOTICE OF THE EXISTENCE OF AFORESAID,

SPEED LIMIT FOR FORBES ROAD FROM FONTANA ROAD TO CARUSO STREET TO BE 45 MPH

By: _________________________________
David Politician, Mayor

ADOPTED AT THE REGULAR MEETING OF CITY COUNCIL ON August 23, 2010.

By: _________________________________
Jane Staffer, City Clerk

APPENDIX C: ILLINOIS POLICY ON SETTING SPEED LIMITS

(The material in this section is adapted from Policy on Establishing and Posting Speed Limits on the State Highway System, *published by the Illinois Department of Transportation (March 2011).)*

Illinois statutes and the *State Manual on Uniform Traffic Control Devices* require that speed limits other than statutory speed limits be based on "… an engineering study that has been performed in accordance with traffic engineering practices. The engineering study shall include an analysis of the current speed distribution of free-flowing vehicles."

The following procedure ***shall*** be used to determine speed zones on streets and highways under the jurisdiction of the DOT. The same procedure is recommended for local agencies.

STEP 1: Establish the Prevailing Speed

The prevailing speed is the average of the following three metrics, measured during free-flowing traffic conditions:

- *85th Percentile Speed:* The speed at or below which 85 percent of the vehicles are traveling.
- *Upper Limit of the 10 mph Pace:* The 10 mph range containing the most vehicles.
- *Average Test Run Speed:* Determined on the basis of five vehicle runs in each direction over the length of the proposed speed zone.

The prevailing speed is the nearest 5 mph increment to the average of the above three values.

STEP 2: Supplementary Investigations (Optional)

Adjustment factors for determining the proposed posted speed limit may be determined by further investigation of any or all of the following four conditions:

- Elevated Crash Risk: If the speed zone being studied contains a portion of a high-crash segment or contains a high-crash intersection as determined by the Bureau of Safety Engineering, the prevailing speed may be reduced by 10 percent.
- Access Control: The access conflict number (ACN) is calculated for the speed zone, and this number is used to determine the percent reduction of the prevailing speed as shown below.

ACN*	Reduction (%)
< 40	0
41 to 60	5
> 60	10

$$* \, ACN = \frac{N_s + 5N_m + 10N_i}{L}$$

Where:

N_s = Number of field entrances and driveways to single-family dwellings

N_m = Number of driveways to minor commercial entrances, multi-family residential units, and minor street intersections

N_i = Number of driveways to major commercial entrances, large multi-family developments, and major street intersections

- Pedestrian Activity: Where no sidewalks are provided or where sidewalks are located immediately behind the curb and the total pedestrian traffic exceeds 10 per hour for any 3 hours within any 8-hour period, the prevailing speed may be reduced by 5 percent. Pedestrians crossing the route at intersections or established crossing points may be included if the point of crossing is not controlled by a STOP or YIELD sign on the route in question, or does not have traffic signals.
- Parking: The prevailing speed may be reduced by 5 percent where parking is permitted adjacent to the traffic lanes.

The adjustment factors from the four different factors are added together to produce a single percentage adjustment that shall not exceed 20 percent.

Step 3: Selection of Preliminary Speed Limit

The preliminary speed limit is either the calculated prevailing speed (from Step 1), or if the optional investigation was undertaken, it is the prevailing speed as adjusted by application of the percentage corrections from the optional investigation (Step 2). The following rules apply to the outcome:

- The preliminary posted speed limit should be the closest 5 mph increment to the (adjusted) prevailing speed.
- The preliminary posted speed limit shall not differ from the prevailing speed (from Step 1) by more than 9 mph or by more than 20 percent, whichever is less.

Step 4: Violation Check

Using the spot speed data collected in Step 1, determine the median speed (the 50th percentile). The proposed speed limit should be either the preliminary posted speed limit or the 50th percentile speed, whichever is greater.

If the proposed speed limit exceeds the statutory speed limit for the highway in question, either the statutory speed or the proposed speed limit may be posted. If the selected speed limit results in a violation rate greater than 50 percent, the appropriate police agency(ies) should be notified that extra enforcement efforts may be necessary.

It is noted that differences in posted speeds between adjacent speed zones should not be more than 10 mph. However, the Illinois policy permits a larger difference provided that adequate speed reduction signs are posted.

APPENDIX D: NORTHWESTERN SPEED ZONING TECHNIQUE

The Northwestern Speed Zoning Technique is an example of an engineering method that can be used to calculate a recommended speed limit for a particular facility. It is based on the 85th percentile operating speed, and uses adjustments for different traffic, roadway, and performance characteristics.

The general sentiment in the Northwestern Speed Zoning Technique is that the 85th percentile speed is a safe, self-selected speed that also provides a reasonable basis for enforcement. However, it must be recognized that the driver selects a speed based on her/his evaluation of the perceived hazard, and if there are hazards of which the driver is unaware, then the selected speed may be too high. The commonly encountered hazards and the crash history of the road can be used to determine if the 85th percentile speed is a suitable legislated speed limit.

The Northwestern Speed Zoning Technique provides adjustments for various features of the road—these are generally applicable to most roads, but can be altered to suit local conditions and policies.

The procedure consists of two parts—a minimum study and a detailed analysis. The minimum study is always carried out; the detailed analysis is undertaken when unusual road or land use characteristics make the speed limit as determined by the minimum study seem inappropriate.

Minimum Speed Study

The data required for the minimum speed study are:

- Speed data:
  - » 85th percentile speeds
  - » Upper limit of the 15 km/h pace
  - » Average test run speed
- Physical Road data:
  - » Design speed
  - » Length of the proposed speed zone
  - » Average distance between intersections (not including alleys, driveways, or entrances unless they are controlled by STOP signs or traffic signals).

The procedure used in the minimum speed study is to determine the speed limit based on the speed data, subject to a maximum as determined by the physical features of the road.

The steps are as follows:

1. For each of the three speed measurements, use Table 18 to select the justified speed limit.
2. Compute a weighted average speed limit using the following weights, and round down to the nearest 10 km/h:

- Justified speed limit from the 85th percentile speed: Weight = 3.

- Justified speed limit from the upper limit of the pace: Weight = 3.
- Justified speed limit from the average test run speed: Weight = 4.

$$SL = \frac{3SL_{85} + 3SL_{pace} + 4SL_{run}}{10}$$

Where: SL = Weighted average speed limit

SL_{85} = Speed limit justified by the 85th percentile speed using Table 18

SL_{pace} = Speed limit justified by the upper limit of the 15 km/h pace using Table 18

SL_{run} = Speed limit justified by the average test run speed using Table 18

3. Using Table 19, select the highest speed limit that will satisfy all three conditions of design speed, average distance between intersections, and length of the proposed speed zone.
4. The recommended speed limit is the lower of the weighted average (from Step 2) and the maximum speed limit (from Step 3).

Table 18. Speed Limit Justified by Speed Data

85th Percentile Speed (km/h)	Upper Limit of the 15 km/h Pace	Average Test Run Speed (km/h)	Justified Speed Limit (km/h)
< 34	< 33	< 30	30
34 – 44	33 – 42	30 – 38	40
45 – 54	43 – 52	39 – 48	50
55 – 64	53 – 62	49 – 56	60
65 – 74	63 – 72	57 – 65	70
75 – 84	73 – 80	66 – 75	80
85 – 94	81 – 88	76 – 85	90
95 – 104	89 – 96	86 – 94	100
> 104	> 96	> 94	110

Table 19. Speed Limit Based on Road Parameters

Design Speed (km/h)	Average Distance Between Intersections (m)	Length of Proposed Zone (km)	Maximum Speed Limit (km/h)
110	400	1.5	110
100	300	1.0	100
90	250	0.8	90
90	175	0.7	80
70	125	0.6	70
70	100	0.5	60
50	75	0.4	50
50	60	0.3	40
30	45	0.2	30

Detailed Analysis

The data required for the minimum speed study are:

1. Using the recommended speed limit from the Minimum Speed Study and the other collected data, consult Tables 3 to 11 and determine the adjustment factors based on additional traffic and roadway features.
2. Add all of the adjustment factors together to obtain an overall adjustment factor.
3. Calculate the multiplier as follows:

$$MF = \frac{100+OAF}{100}$$

Where: MF = Multiplication Factor

OAF = Overall Adjustment Factor (from Step 2)

4. If the Multiplication Factor is greater than 1.25, set it to 1.25. If the Multiplication Factor is less than 0.75, set it to 0.75.
5. Multiply the recommended speed limit from the minimum speed study by the multiplication factor and round to the nearest 10 km/h to produce the recommended speed limit.

Note: Table 20 will yield two adjustment factors—one for commercial, and one for non-commercial driveways.

Also, if a detailed study is to be undertaken, then all of the information and tables must be included in the analysis. It is not good practice to include selected items and ignore others.

Table 20. Adjustment Factors for Access Density

No. of Driveways per kilometer		Speed Limit from Minimum Study (km/h)								
Non-Commercial	Commercial	30	40	50	60	70	80	90	100	110
0 – 3	0	+15	+15	+15	+10	+10	+5	+5	0	0
4 – 6	0	+10	+10	+10	+5	+5	0	0	0	-5
7 – 12	1	+10	+10	+5	+5	0	0	0	-5	-5
13 – 21	2 – 3	+5	+5	0	0	0	-5	-5	-10	-10
22 – 30	4 – 5	+5	0	0	0	-5	-10	-10	-15	-15
> 30	> 5	0	0	-5	-10	-10	-15	-15	-20	-20

Table 21. Adjustment Factors for Lane Width

Lane width (m)	Speed Limit from Minimum Study (km/h)								
	30	40	50	60	70	80	90	100	110
< 2.8	0	0	0	-5	-5	-10	-10	-10	-15
2.8 – 3.2	+5	+5	0	0	0	-5	-5	-5	-10
3.3 – 3.5	+10	+10	+5	+5	0	0	0	0	-5
> 3.5	+15	+15	+10	+10	+5	+5	+5	0	0

Table 22. Adjustment Factors for Functional Classification

Functional Classification (Urban Areas Only)	Speed Limit from Minimum Study (km/h)								
	30	40	50	60	70	80	90	100	110
Local	0	0	0	-5	-10	-10	-15	-15	-20
Collector	+5	0	0	0	-5	-5	-10	-10	-15
Arterial	+10	+5	+5	0	0	0	-5	-5	-10
Expressway	+15	+10	+10	+5	0	0	0	0	-5
Freeway	+25	+20	+15	+10	+5	+5	0	0	0

Table 23. Adjustment Factors for Median Type

Functional Classification	Median								
	None	*Flush or Painted*		*Mountable*		*Barrier*		*Depressed Unpaved*	
		0.6m – 1.8m	> 1.8m	0.6m – 1.8m	> 1.8m	0.6m – 1.8m	> 1.8m	1.8m – 6.0m	> 6.0m
Local	0	+5	+10	—	—	—	—	—	—
Collector	0	+5	+5	+10	+15	—	—	—	—
Arterial	-10	0	0	+5	+10	+15	+20	—	—
Expressway	—	-10	-5	0	0	+5	+10	+15	+20
Freeway	—	—	-10	-10	-5	0	0	0	0

Table 24. Adjustment Factors for Shoulder Type and Width

Functional Classification	Shoulder Type			
	None	Turf or Gravel	Stabilized	Paved
Local	0	+5	+10	+20
Collector	0	0	+5	+10
Arterial	-5	0	0	+5
Expressway	-10	-5	0	0
Freeway	-20	-10	-5	0

Table 25. Adjustment Factors for Pedestrian Activity

Pedestrian Activity	Sidewalk Setback from Edge of Pavement (m)				
	None	0 – 0.5	0.6 – 2.5	2.6 – 4.5	> 4.5
Age < 12					
Heavy	-25	-20	-15	-10	-5
Medium	-20	-15	-10	-5	0
Light	-15	-10	-5	0	0
If none, consider ages over 12 **Age > 12**					
Heavy	-10	-5	0	0	0
Medium	-5	0	0	0	0
Light	-5	0	0	0	0
None	0	0	0	0	0

Table 26. Adjustment Factors for Parking Activity

Functional Classification	Parking Activity			
	No Parking	Low Turnover	Medium Turnover	High Turnover
Local	+10	0	-10	-10
Collector	+10	0	-10	-15
Arterial	+15	0	-10	-15
Expressway	0	-10	-15	-20

Table 27. Adjustment Factors for Roadway Alignment

Number of Curves per Kilometer with Advisory Speed < Speed Limit from Minimum Study	Vertical Alignment			
	Level	Rolling	Hilly	Mountainous
0	+10	+5	0	0
1	0	0	-5	-5
2	-10	-10	-10	-10
> 2	-20	-20	-20	-20

Table 28. Adjustment Factors for Crash Rate

Crash Rate as a Percent of Area-wide Rate for Similar Facilities	Adjustment
< 75%	+10
76% – 125%	0
126% – 200%	-10
> 200%	-20

Example Calculation

The following is an example calculation using the Northwestern Speed Zoning Technique:

Input Data: 85th Percentile Speed = 66.4 km/h

The 15 km/h pace = 45 to 60 km/h

Average test run speed = 56 km/h

Design Speed = 100 km/h

Average Intersection Spacing: 200 meters

Length of Proposed Speed Zone = 0.6 kms

For the minimum speed study, the speed measurements yield the following:

Criteria	Justified Speed Limit (from Table 18)	Weight	Weighted Limit
85th Percentile Speed	70	3	210
Upper Limit of the Pace	60	3	180
Average Test Run Speed	60	4	240
		Sum	**630**

The weighted average is 630/10 = 63 km/h, which suggests a speed limit of 60 km/h.

The suggested speed limit needs to be checked against the major physical features of the road using Table 19.

Design Speed (km/h)	Average Distance Between Intersections (m)	Length of Proposed Zone (km)	Maximum Speed Limit (km/h)
110	400	1.5	110
100	300	1.0	100
90	250	0.8	90
90	175	0.7	80
70	125	0.6	70
70	100	0.5	60
50	75	0.4	50
50	60	0.3	40
30	45	0.2	30

All three criteria are satisfied with the 60 km/h speed limit. Therefore the minimum study recommends a speed limit of 60 km/h.

For the detailed analysis, the following data is collected:

- Functional classification – Arterial
- Number of non-commercial driveways – 10/km
- Number of commercial driveways – 4.5/km
- Lane width – 3.65 m
- 4.3 m painted median
- No shoulders, and barrier curbs on both sides of the road
- Light pedestrian activity for age < 12

- A sidewalk with a 0.3 meter setback
- No parking allowed
- Rolling terrain
- Crash rate = 7.4 crashes per million-vehicle-kilometers (average is 5.1 crashes per million-vehicle-kilometers for arterial roads)

The factors determined from the various tables are:

Adjustment Factors			
Non-commercial Access (Table 20)	+5		
Commercial Access (Table 20)	0		
Lane Width (Table 21)	+10		
Functional Classification (Table 22)	0		
Median Type (Table 23)	0		
Shoulder Type and Width (Table 24)		-5	
Pedestrian Activity (Table 25)		-10	
Parking Activity (Table 26)	+15		
Roadway Alignment (Table 27)	+5		
Crash Rate (Table 28)		-10	
Totals	**+35**	**-25**	**=+10**

The overall adjustment factor (OAF) is +10, which can be used to determine the multiplication factor as:

MF = (100+OAF)/100 = (100+10)/100 = 1.10

The multiplication factor is less than 1.25 and greater than 0.75, therefore the recommended speed limit is the speed limit from the minimum study multiplied by the multiplication factor and rounded to the nearest 10 km/h:

SL = 60 km/h * 1.10 = 66 km/h ➔ 70 km/h

APPENDIX E: SPEED LIMITS NEW ZEALAND (ROAD RISK METHODOLOGY)

The speed limit policy in New Zealand is a national policy that aims to balance mobility and safety by setting speed limits that are safe, appropriate, and credible for the level of roadside development and the category of road.

The information required to determine the speed limit for a particular road is:

The existing speed limit;

- The character of the surrounding land environment (e.g., rural, fringe of city, fully developed);
- The function of a road (i.e., arterial, collector or local);
- Detailed roadside development data (e.g., number of houses, shops, schools, etc.);
- The number and nature of side roads;
- Carriageway characteristics (e.g., median divided, lane width and number of lanes, road geometry, street lighting, footpaths, cycle lanes, parking, setback of fence line from carriageway);
- Vehicle, cycle and pedestrian activity;
- Crash data; and
- Speed survey data.

Calculating a speed limit using Speed Limits New Zealand (SLNZ) methods requires road and roadside data collection, and the application of the set procedures specified in the policy.

Once a section of road has been identified for analysis, data collection should be commenced. The survey should extend at least 200 meters in each direction beyond the section of road under consideration. This is to ensure the appropriate boundary point between speed limits is identified and features that may influence sign location are included.

Step 1: Determine Development Rating

Different types of development are allocated for the rating values as shown in Table SLNZ4. The ratings are based on the expected number of vehicle, pedestrian and cycle movements generated each day. For example, a house is allocated one rating unit and a large shop is given four rating units.

Development ratings are allocated for the road being surveyed (frontage development) and for the first 500 meters of side roads (side road development). For each 100-meter section of road, the development rating subtotal is the sum of the frontage and the side road development ratings. The total development rating is calculated by adding the 100-meter subtotals for the length of road being assessed for a speed limit.

Table E1. Development Rating

Development Type	Frontage Development	Rating Units
A	Property or access point* with 1 or 2 dwellings**; church; small hall; playground; beach; sports ground; camping ground; holiday cabins; cycle path or pedestrian way that intersects with the roadway.	1
B	Property or access point* with 3 or 4 dwellings**; business or office with fewer than ten employees; small shop; large hall; cinema; small public swimming pool.	2
C	Property or access point* with 5 or more dwellings**; business or office with 10 to 30 employees; general store; takeaway shop; bank; service station; cinema complex; hotel; restaurant; large swimming pool.	3
D	Business or office with more than 30 employees; large shop; post office; hospital; tertiary education establishment.	4
E	Access point* serving two or more developments.	1 to 4***
F	Primary school or kindergarten.	1 for every 15 students
G	Secondary school.	1 for every 30 students

** An access point includes a private driveway and a public entrance or exit.*

*** A dwelling includes a house, a home unit in a block, a semi-detached home unit, and a motel unit. Each unit in a block of units counts as one dwelling.*

**** When two or more developments other than dwellings, or if dwellings and other developments share a common access point or service road, the correct rating is the greatest of:*

- *the rating for a development type A, B, or C according to the number of dwellings served by the access point; or*
- *the highest rating for any one development, other than dwellings, served by the access point; or*
- *the rating determined by treating the access point as a side road and allocating the rating specified in Table SLNZ5.*

Multiple access points are handled in the following manner:

- Where a ***single development or a small group of developments*** has more than one access point on the same road, the development should be rated once only and additional access points ignored. Developments with separate entrance and exit points should also be treated as having only one access point. Examples include service stations, motels, schools, and a small group of shops with off-street parking.
- Where a ***large group of developments***, such as a shopping mall or a service road, share more than one access point, a rating is assigned to each access point. In these situations, a proportional number of the developments should be allocated to each access point, and each one rated as a Development Type E.
- Separate ratings may be assigned to each access point when there are at least four individual developments or one type D development for each access point. These conditions ensure that

the sum of the access point ratings does not exceed the sum of the ratings for the individual developments in the group.

Step 2: Determine side road development rating

The side road development rating is calculated on the first 500 meters of a side road by applying the rating values outlined in Table E1 to the development and then entering Table E2 to determine the side road rating.

A notable difference in this step is that each school or kindergarten fronting on a side road is calculated (differently) as follows:

- Use half the normal frontage rating (from Table E1) if a school or kindergarten is within 500 meters from the road being surveyed; and
- Use a quarter of the frontage rating (from Table E1) if a school or kindergarten is between 500 and 1000 meters from the road being surveyed.

Note that a cross intersection is treated as two side roads.

Table E2. Side Road Development Rating

Traffic Volume on Side road (Vehicles per Day)	Side Road Development Rating Units According to the Frontage Development Rating (R) on the First 500 m of the Side Road		
	R < 8	8 < R < 20	R > 20
< 4000	1	2	3
> 4000	2	3	4

Step 3: Roadway Rating

The roadway rating is calculated by summing the ratings related to roadway activities and traffic control. Tables E3 to E8 show the ratings that apply according to the nature and use of the road. Note that where usage or provision of facilities is different on each side of the road, the rating is the average of the ratings for each side.

Roadway ratings are calculated for each 100-meter section of road and the sub-total is the sum of the ratings for each roadway activity per 100-meter section. The total roadway rating is calculated by adding the 100-meter sub-totals for the length of road being assessed for a speed limit.

Step 4: Calculate the Rating

The average rating is calculated by summing the total development and roadway rating for the length of road being assessed and then dividing by the number of 100-meter sections of road. However, the total roadway rating must not exceed the total development rating for the length of road being assessed. If the total roadway rating is higher, it must be reduced to that of the development rating.

Table E3. Pedestrians

Pedestrian Facilities	Pedestrian Volume (Pedestrians per Day)	
	< 200	> 200
Sidewalks behind boulevards or no pedestrian access	0	0
Sidewalks adjacent to the roadway	0	1
No sidewalk but useable shoulder	1	2
Pedestrians must walk on road	1	3

Table E4. Cyclists

Cycling Facilities	Cyclist Volume (Pedestrians per Day)	
	< 200	> 200
Bicycle path separated by a boulevard or fence or no cyclist access	0	0
Wide road, cyclists clear of moving traffic	0	1
Narrow road, cyclists impede moving traffic	1	2

Table E5. Parking

Parking Facilities	Normally Two Parked Vehicles or Fewer per 100 Meters	Frequent Parking on Both Sides, Long Duration	Frequent Parking on Both Sides, Short Duration
Vehicles can park 2 meters from moving traffic	0	0	1
Vehicles park close to moving traffic but do not obstruct it	1	2	3
Parked vehicles obstruct moving traffic, i.e., remaining traffic lane is 3 meters or less	2	3	4

Table E6. Road Geometry

Type of Roadway	Alignment		
	Open Visibility	Average Visibility	Limited Visibility
One-way traffic or divided roadway (solid median or barrier)	0	0	0
4 or more lanes (flush median or undivided)	0	1	1
2 or 3 lanes (flush median or undivided)	0	1	2
1 lane (two-way)	3	4	5

Table E7. Traffic Control

Traffic control (applying to traffic on the road surveyed)	Rating Unit
Pedestrian crossing	3
"Stop" control	3
YIELD Sign	2
Traffic signals	2
Railway level crossing	1
Traffic islands	1

Table E8. Development

Type of Development	Status of Road		
	Local Road	Collector Road	Arterial Road
Residential	2	1	0
Industrial	1	0	0
Commercial	0	0	0
Rural Residential	1	0	0
Rural	0	0	0

Step 5: Determine the Speed Limit

When the average rating has been calculated, the speed limit is determined as follows.

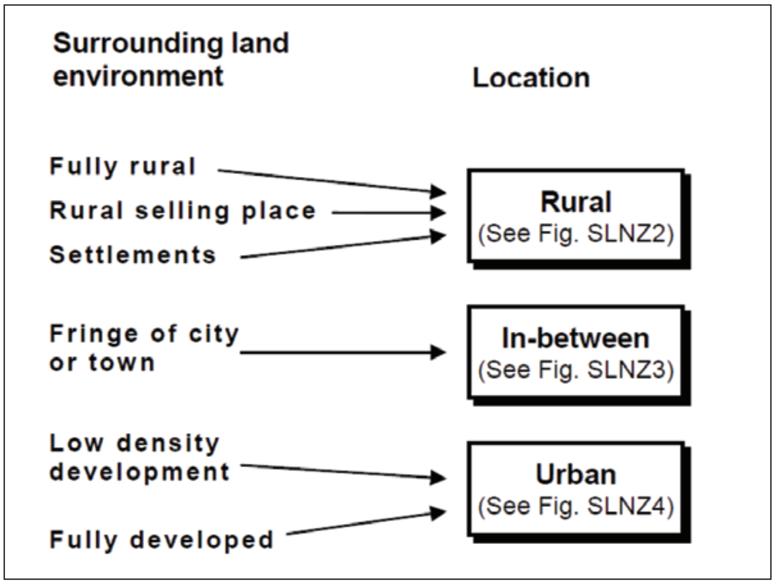


Figure SLNZ1. Determining Speed Limit.

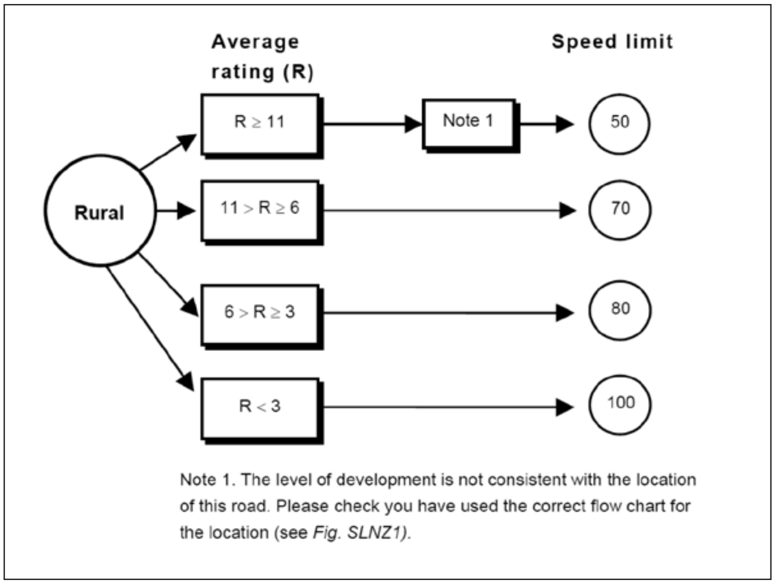


Figure SLNZ2. Speed Limit Flow Chart—Rural.

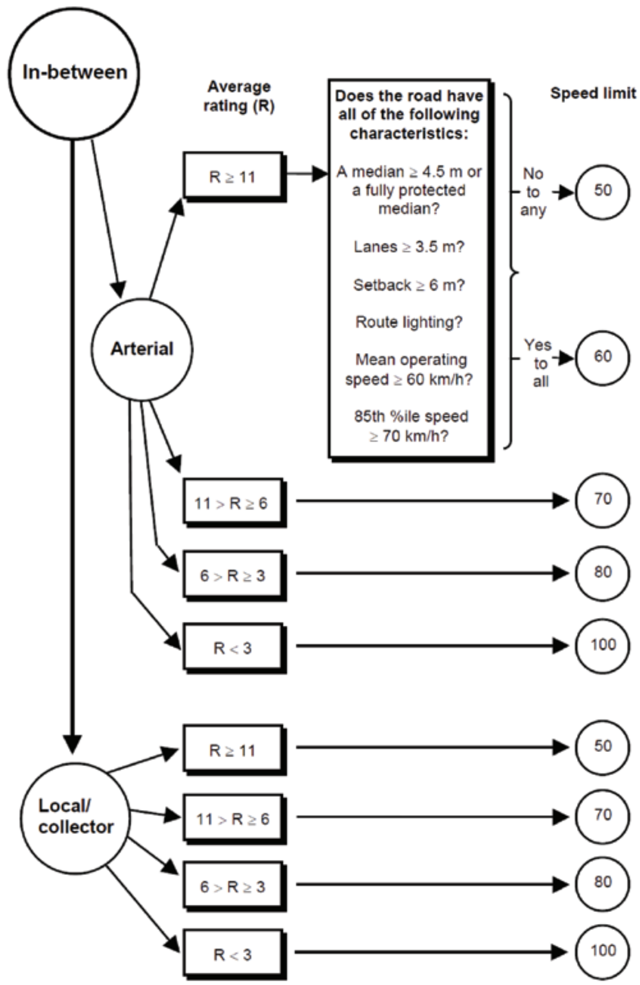


Figure SLNZ3. Speed Limit Flow Chart—In-Between.

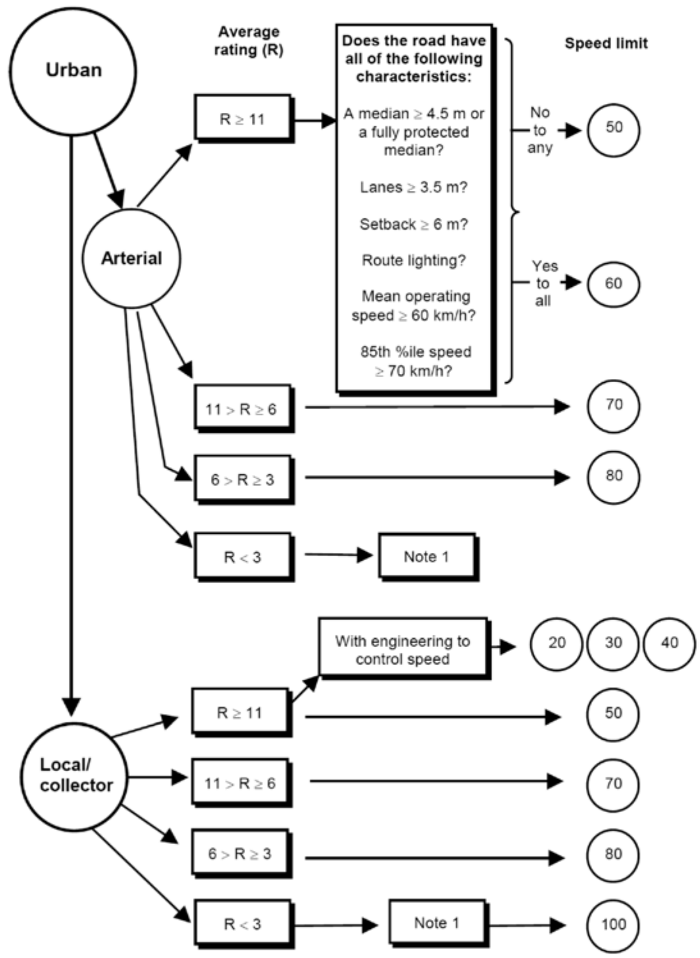


Figure SLNZ4. Speed Limit Flow Chart—Urban.

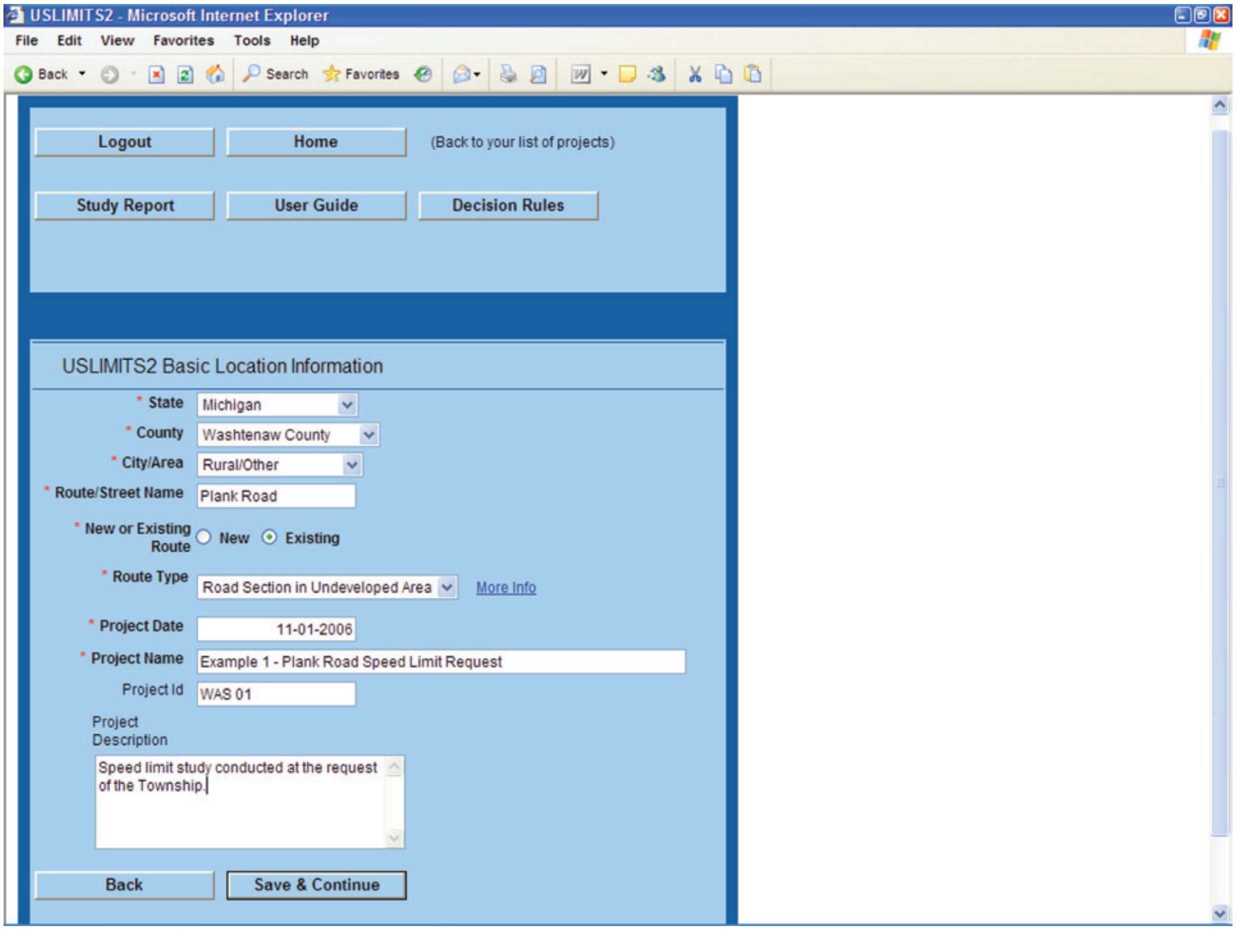
In rare instances, because of special features or activities along a road, SLNZ cannot be used or will not produce a sound result. SLNZ must always be used with reference to speed limits policy, and in conjunction with sound engineering judgment, to determine the appropriate and safe speed limit.

APPENDIX F: EXAMPLE CASE STUDY USING USLIMITS2

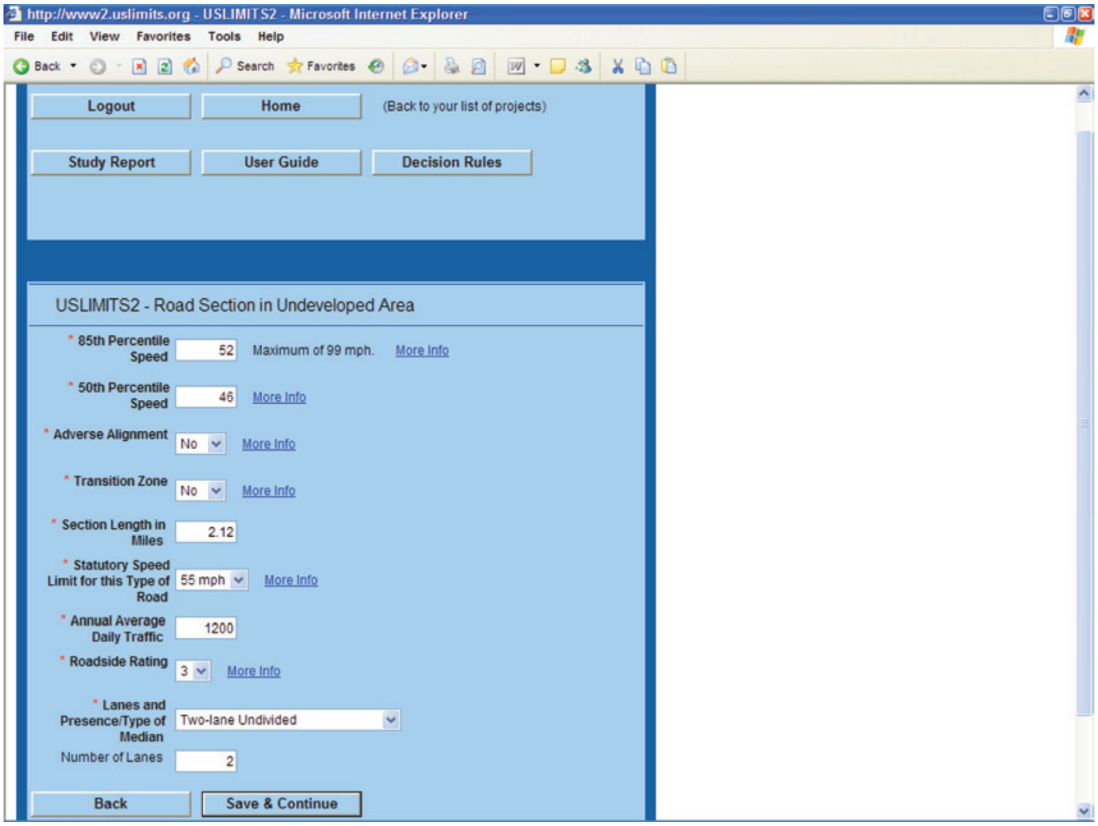
Example 1: Speed Limit Request on a Two-Lane Road in an Undeveloped Area

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.

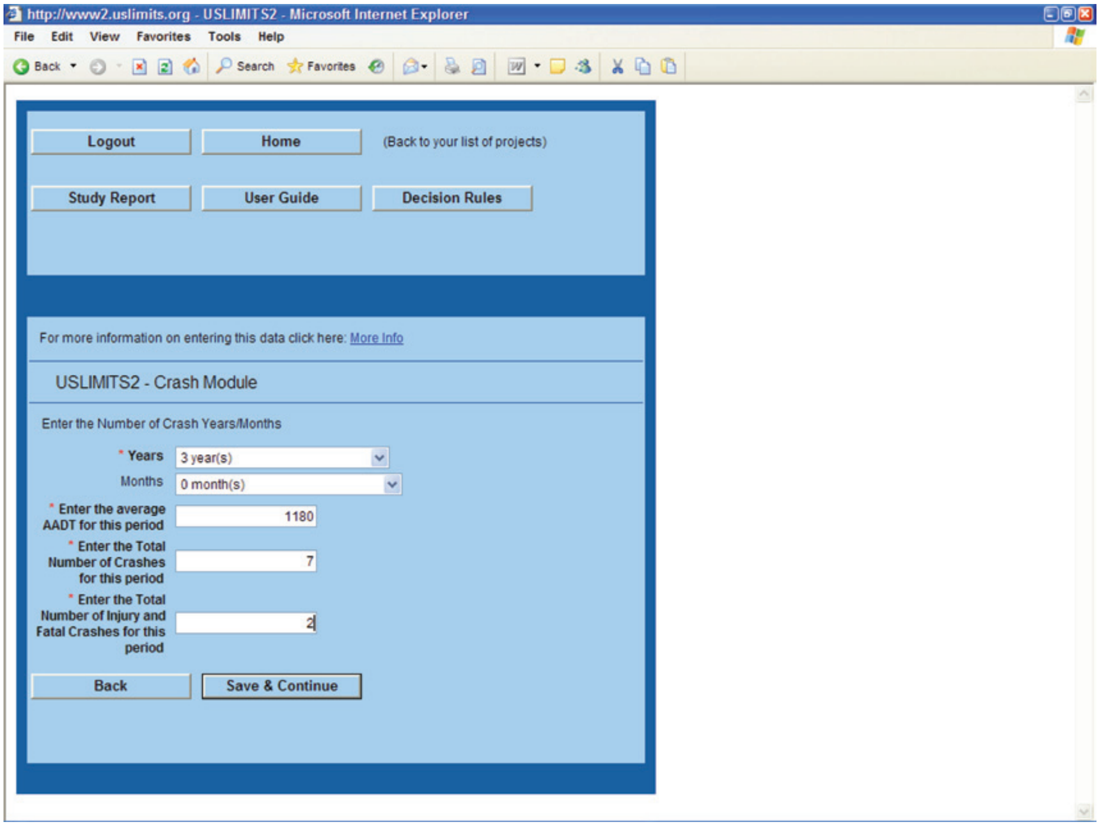
This is the Basic Location Information input screen:



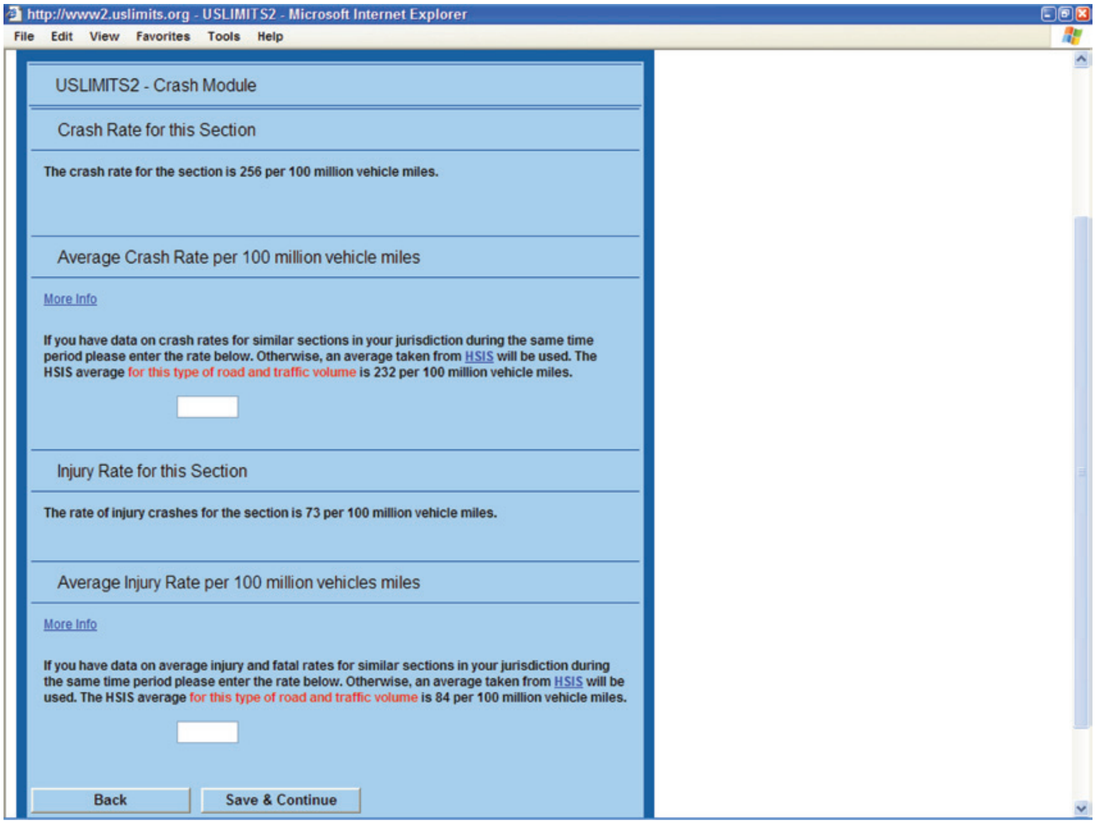
This is the basic input screen for the 85th percentile speed and other variables:



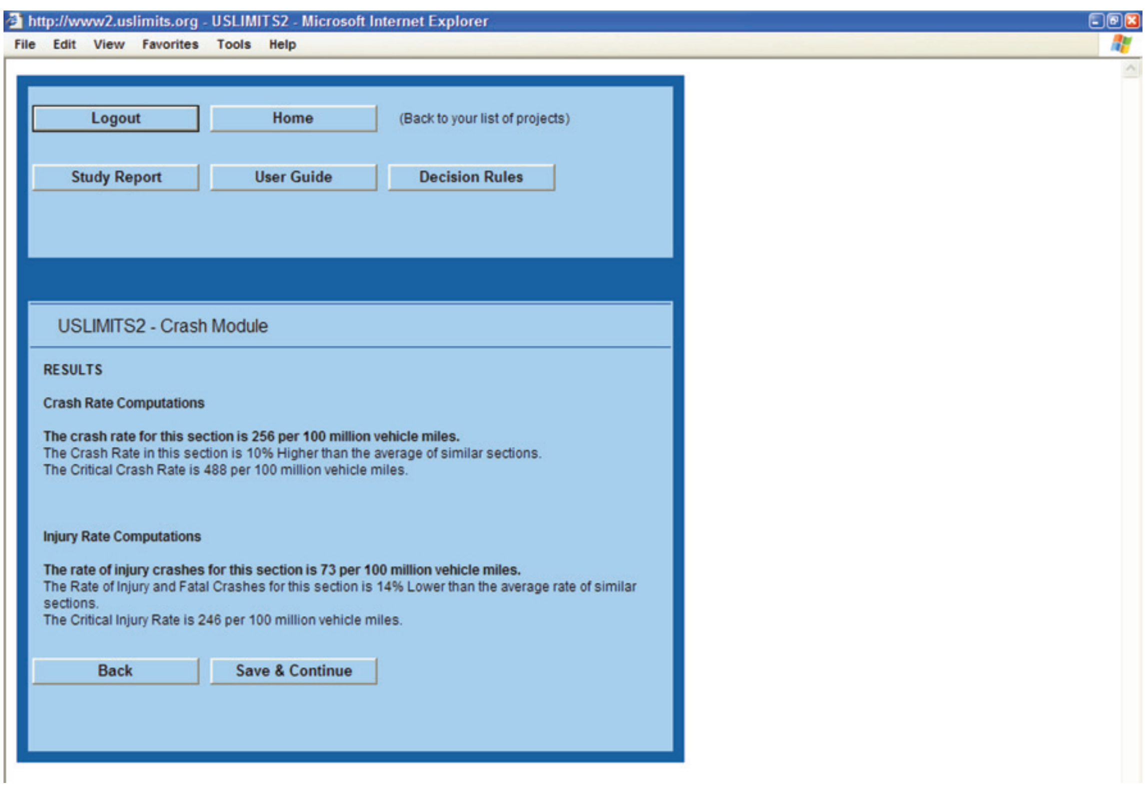
This is the input screen for the crash data:



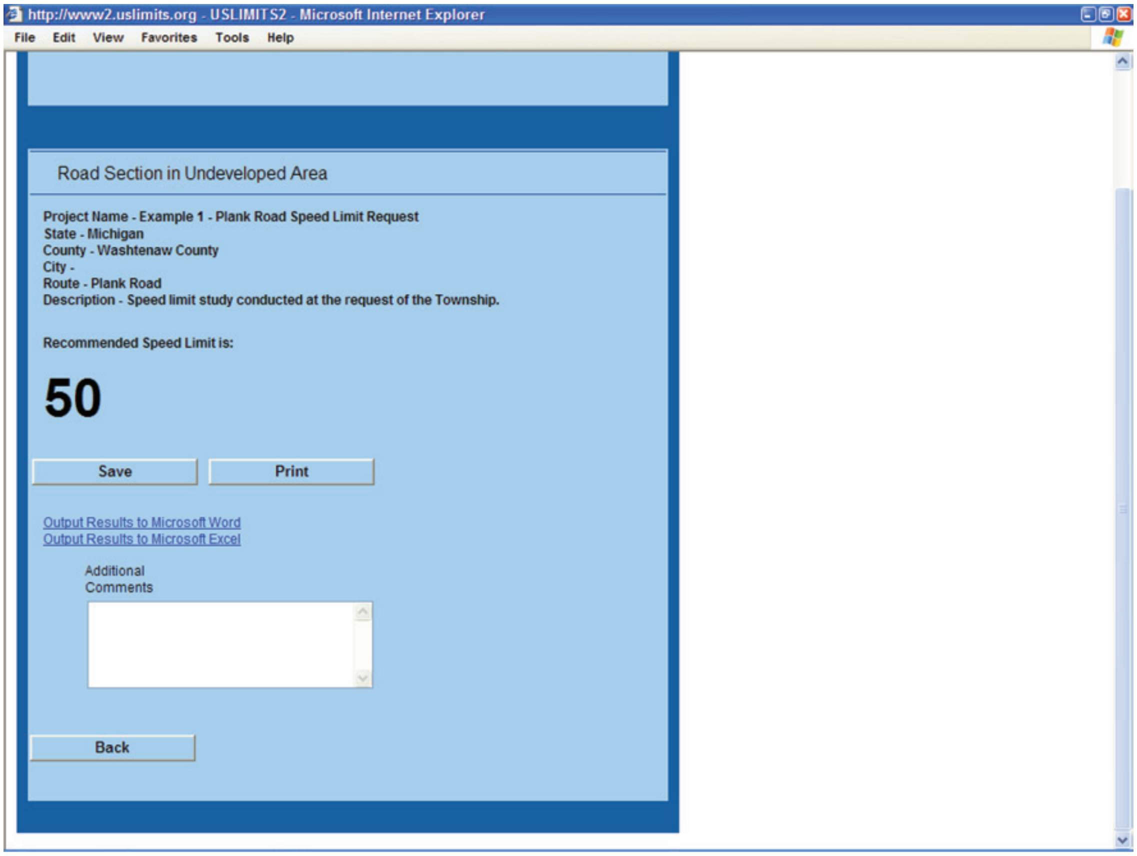
This is the crash summary generated by USLIMITS2 based on the crash data input by the user:



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

Top of Form

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 multi-lane
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

APPENDIX G: EXAMPLE SPEED STUDY FORMS

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

VEHICLE SPOT SPEED STUDY

FORM 750-010-03
TRAFFIC ENGINEERING
07/2009 ASE

LOCATION ID: Douglas Rd. - C.R. 949	**SECTION:** ----------------
LOCATION: 137 Miles East of Northfork Cr.	**MP :** 28.83
POSTED SPEED (mph): 55 MPH	**COUNTY:** Bedford
DATE: 6/4/2008	**PAVEMENT CONDITION:** Dry, Good
OBSERVER: K. Matthews	**TIME FROM:** 9:00 AM **TIME TO:** 11:00 AM

REMARKS: Concealment Quite Difficult

NUMBER OF VEHICLES ___ BOUND							SPEED	NUMBER OF VEHICLES E BOUND						BOTH DIRECTIONS	
CUM. TOTAL	TOTAL	20	15	10	5		BIN (mph)	5	10	15	20	TOTAL	CUM. TOTAL	TOTAL	CUM. TOTAL
							≥ 80								
							78 - 79.9								
							76 - 77.9								
							74 - 75.9								
							72 - 73.9								
							70 - 71.9								
							68 - 69.9								
							66 - 67.9								
							64 - 65.9								
							62 - 63.9								
							60 - 61.9								
							58 - 59.9								
							56 - 57.9								
							54 - 55.9								
							52 - 53.9					1	104		
							50 - 51.9					2	103		
							48 - 49.9					2	101		
							46 - 47.9					2	99		
							44 - 45.9					5	97		
							42 - 43.9					9	92		
							40 - 41.9					18	83		
							38 - 39.9					23	65		
							36 - 37.9					21	42		
							34 - 35.9					15	21		
							32 - 33.9					4	6		
							30 - 31.9					1	2		
							28 - 29.9						1		
							26 - 27.9					1	1		
							24 - 25.9								
							22 - 23.9								
							20 - 21.9								
							18 - 19.9								
							16 - 17.9								
							14 - 15.9								
							12 - 13.9								
							10 - 11.9								
							≤ 10								
		TOTALS									TOTALS				

SPEED DATA SUMMARY	EAST BOUND			
85th PERCENTILE SPEED	42			**ENGINEER:** B. Traffic
10 mph PACE	33 - 43			**DATE:** 7/6/2008

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

SAFE CURVE SPEED STUDY

FORM 750-020-12
TRAFFIC ENGINEERING
07/99

LOCATION ID:

COUNTY: | SECTION:

POSTED SPEED (mph): | PAVEMENT CONDITION:

DATE: | OBSERVERS:

REMARKS:

DIRECTION OF TRAVEL	MILEPOST		SPEED ON CURVE	DEGREE OF DEFLECTION
	BEGIN CURVE	END CURVE		

APPENDIX H: SAMPLE 85th PERCENTILE SPEED CALCULATION

The 85th percentile is the speed at which 85 percent of the observed vehicles are traveling at or below. This percentile is used in evaluating and recommending posted speed limits. Weather conditions may affect speed percentiles. For example, observed speeds may be slower in rainy or snowy conditions.

A frequency distribution table is a convenient way to determine speed percentiles. An example, from Iowa, is given in Table 29. The frequency of vehicles is the number of vehicles recorded at each speed. The cumulative frequency is the total of each of the numbers (frequencies) added together row by row from lower to higher speed. The fourth column is a running percentage of the cumulative frequency.

Table 29. Example Frequency Distribution Table

Speed (mph)	Frequency of Vehicles	Cumulative Frequency	Cumulative Percent	Speed Percentile
15	1	1	1%	
18	2	3	3%	
21	6	9	9%	
24	12	21	21%	
27	13	34	34%	
30	20	54	54%	
33	18	72	72%	85th
36	14	86	86%	
39	6	92	92%	
42	6	98	98%	
45	1	99	99%	
48	1	100	100%	

Source: *Handbook of Simplified Practice for Traffic Studies*, Center for Transportation Research and Education, Iowa State University.

The 85th percentile speed is determined from the cumulative percent column. For the example data in Table 4, the 85th percentile falls between 33 and 36 mph. The calculation of speed percentiles is easier if a sample size of 100 vehicles is collected. When the sample size equals 100 vehicles, the cumulative frequency and cumulative percent are the same.

As can be observed from Table 29, the exact 85 percent (85th percentile) is not found in the cumulative percent column. To reach these exact percentages, a calculation is completed using percentages and speeds from the distribution table. Shown below is the equation for calculating speed percentiles:

$$S_D = \frac{P_D - P_{min}}{P_{max} - P_{min}}\left(S_{max} - S_{min}\right) + S_{min}$$

where S_D = speed at P_D, P_D = percentile desired, P_{max} = higher cumulative percent, P_{min} = lower cumulative percent, S_{max} = higher speed, and S_{min} = lower speed.

The 85th percentile of speed (P_D = 85 percent) falls between 33 and 36 mph (see Table 29), so S_{max} = 36 mph and S_{min} = 33 mph. The higher cumulative percent (P_{max}) is 86 percent, and the lower cumulative percent (P_{min}) is 72 percent. To find S_D at P_D in this case (85th percentile of speed),

$$S_D = \frac{85\%-72\%}{86\%-72\%}\left(36\,mph - 33\,mph\right) + 33\,mph = 35.8\,mph$$

On highways carrying low traffic volumes, the checks at any one station may be discontinued after 2 hours, although a minimum of 100 vehicles have not been timed.

The above procedure is generally automated in commercially available computer spreadsheets or workbooks. For example, Microsoft Excel has a PERCENTILE function that can be used to determine the 50th, 85th or any other percentile from an array of numbers.

For More Information:

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