NDOT Research Report

Report No. 255-11-803

Guidelines for Speed Reduction in Towns Along Rural Highways

May 2013

Nevada Department of Transportation
1263 South Stewart Street
Carson City, NV 89712

Disclaimer

2013

Guidelines for Speed Reduction in Towns along Rural Highways

Pramen P. Shrestha, Aly Said, Ying Tian, and Krishna Shrestha,
Department of Civil and Environmental Engineering and Construction,
Howard R. Hughes College of Engineering,
University of Nevada, Las Vegas (UNLV)
5/30/2013

GUIDELINES FOR SPEED REDUCTION IN TOWNS ALONG RURAL HIGHWAYS

Final Report on Research Sponsored by

Nevada Department of Trasnportation

Carson City, Nevada

October 2013

Pramen P. Shrestha Aly Said Ying Tian Krishna Shrestha

Department of Civil and Environmental Engineering and Construction
Howard R. Hughes College of Engineering
University of Nevada, Las Vegas
4505 Maryland Parkway
Las Vegas, NV 89154-4054

UNLV | Department of CIVIL & ENVIRONMENTAL ENGINEERING & CONSTRUCTION

TECHNICAL REPORT DOCUMENTATION PAGE

Report No.	2. Government Accession No.	3. Recipients Catalog No.

4. Title and Subtitle Guidelines for Speed Reduction in Towns along Rural Highways	5. Report Date October 2013
6. Performing Organization Code	
7. Author(s) Pramen P. Shrestha, Aly Said, Ying Tian, and Krishna Shrestha	8. Performing Organization Report No.
9. Performing Organization Name and Address Civil and Environmental Engineering and Construction Department, University of Nevada Las Vegas	10. Work Unit No.
11. Contract or Grant No. P255-11-803	
12. Sponsoring Agency Name and Address **Nevada Department of Transportation**	13. Type or Report and Period Covered
14. Sponsoring Agency Code **NDOT**	
15. Supplementary Notes	

16. Abstract

This report presents the results of the study undertaken to develop a guideline for setting up speed limit in towns along rural highways of Nevada. Generally, speed zones are provided in towns along rural highways to reduce speed-related crashes. However, a guideline is necessary for a consistent procedure to set up speed zones throughout the state. The main objectives of this study are to determine factors associated with crashes and to identify the best practices for setting up speed zones in towns along rural highways.

The Nevada Department of Transportation (NDOT) Technical Advisor Panel (TAP) identified 11 towns along rural highways of Nevada for crash data analysis. Ten years of crash data for these towns were collected and analyzed. The results showed that the percentage of fatal crashes in these towns was 0.89% of the total crashes. For all the rural areas in Nevada, the percentage of fatal crashes in 2010 was 2.00% of the total crashes occurred in Nevada. Regression analyses showed a strong correlation between the number of crashes and the percentage of vehicles exceeding posted speed limits in these towns.

Based on state DOT traffic engineers' survey data and various state DOT speed limit guidelines, the 85th percentile speed was the most important factor for determining the speed limit for a speed zone. Other factors, such as crash history and road characteristics, also should be considered while determining the speed limit. The review of literature showed that if proper enforcement is ensured, speed zones can be effective to reduce the number of speed-related crashes in towns along rural highways. Guidelines for setting up speed zones in towns along rural highways are included in this report.

17. Key Words Speed zone, rural highways, 85^{th} percentile speed, crashes, speed limit.	18. Distribution Statement **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161**

19. Security Classif is report)	20. Security Classif. (of this page)	21. No. Of Pages	22. Price
Unclassified	**Unclassified**	275	

NDOT RESEARCH PROJECT: P255-11-803 TECHNICAL ADVISORY PANEL

Kenneth Chambers, Research Director, NDOT

Manjunathan Kumar, Research Coordinator, NDOT

Randy D. Travis, Traffic Information Chief, NDOT

Hoang Hong, Traffic Operations, NDOT

Kevin Lee, Rural County Representative, NDOT

Ken W. Mammen, Principal Safety Engineer, NDOT

Robert Madwell, Traffic Information, NDOT

David Leegard, Traffic Information, NDOT

Xuan Wang, Traffic Information, NDOT

Sen Loyd, Research Library, NDOT

Acknowledgements

The research team would like to acknowledge the Nevada Department of Transportation (NDOT) for funding this study. The Technical Advisory Panel (TAP) of this research has played a very important role in this study, including the selection of the 11 towns for crash data, coordinating the NDOT personnel for interviews, and providing radar guns and a measuring wheel for data collection at each site.

We are very thankful to the representatives of various state Departments of Transportation in the U.S. for providing questionnaire responses despite their busy work schedules. Their responses were very useful in identifying best practices for setting up speed zones in towns along rural highways.

Acronyms

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Offials
CART	Classification and Regression Tree
CAS	Curve Advisory Software
CSRC	Collaborative Safety Research Center
DOT	Department of Transportation
DSL	Differential Speed Limit
DUI	Driving Under Influence
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GPS	Global Positioning System
ITD	Idaho Transportation Department
ITE	Institute of Transportation Engineers
LCL	Latent Class Logit
LED	Light-emitting-diode
MassDOT	Massachusetts Highway Department
MNL	Multinomial Logit
MoDOT	Missouri Department of Transportation
MUTCD	Manual on Uniform Traffic Control Devices
NCATS	Nevada Citation and Accident Tracking System
NDOT	Nevada Department of Transportation
NHCRP	National Cooperative Highway Program
NHTSA	National Highway Traffic Safety Administration
ODOT	Oregon Department of Transportation
OP	Ordered Probit
PDO	Property Damage Only
PennDOT	Pennsylvania Department of Transportation
PIO	Public Information Officer
RRR	Relative Risk Ratio
SVM	Support Vector Mechanics
TAP	Technical Advisory Panel
TRB	Transportation Research Board
TxDOT	Texas Department of Transportation
USL	Uniform Speed Limit
VMT	Vehicle Miles Travelled
VSL	Variable Speed Limit
WYDOT	Wyoming Department of Transportation

Contents

Figures

Tables

Summary

This report presents the results of the study undertaken to develop a guideline for setting up speed limit in towns along rural highways of Nevada. Generally, speed zones are provided in towns along rural highways to reduce speed-related crashes. However, a guideline is necessary for a consistent procedure to set up speed zones throughout the state. The main objectives of this study are to determine factors associated with crashes and to identify the best practices for setting up speed zones in towns along rural highways.

The Nevada Department of Transportation (NDOT) Technical Advisor Panel (TAP) identified 11 towns along rural highways of Nevada for crash data analysis. Ten years of crash data for these towns were collected and analyzed. The results showed that the percentage of fatal crashes in these towns was 0.89% of the total crashes for 9 years. For all the rural areas in Nevada, the percentage of fatal crashes in 2010 was 2.00% of the total crashes occurred in Nevada. Regression analyses showed a strong correlation between the number of crashes and the percentage of vehicles exceeding posted speed limits in these towns.

Based on state DOT traffic engineers' survey data and various state DOT speed limit guidelines, the 85th percentile speed was the most important factor for determining the speed limit for a speed zone. Other factors, such as crash history and road characteristics, also should be considered while determining the speed limit. The review of literature showed that if proper enforcement is ensured, speed zones can be effective to reduce the number of speed-related crashes in towns along rural highways.

Guidelines for setting up speed zones in towns along rural highways is included in Chapter 7 of this report. The guidelines cover a wide range of issues including the following:

- Overview of other state DOTs guideline and definitions of terms used in speed limit guidelines
- A review of Nevada statutes related to speed limits and the process used to set up and modify speed zones
- A process to identify whether a speed zone is necessary in the study area
- Guiding principles to determine a speed limit in the study area
- A process to determine speed-zone features
- The importance of transition-zone design along the speed zone
- A description of various types of sign posts provided in the transition zone to reduce the speed of vehicles approaching the speed zone
- An overview of the approval process for speed zone changes

- Importance of speed-limit enforcement to reduce the speed of vehicles travelling in the speed zone
- Follow up speed study

The major objective of this speed limit guideline is to create the steps that can be used to reduce the speed of vehicles in rural communities. The reduction of crashes in rural towns is only possible if the speed limit is enforced; in addition, drivers, pedestrians, and bicyclists should be educated about their role in the crashes. The intent of this guideline is not to replace any current practices used by NDOT to establish speed zones in rural communities, but to assist in making this process more consistent. While using this guideline, NDOT traffic engineers should use their experience and lessons learned in providing speed zones in rural communities so that the speed zones will be more effective.

1 Introduction

1.1 Background

Half a century back, the number of traffic fatalities in United States (U.S.) was increasing rapidly (NHTSA, 2012). However, the number of such fatalities has been decreasing since 2005. The Nevada Department of Transportation (NDOT) report shows that the number of fatalities in Nevada had been decreasing from 2006 to 2009 (NDOT, 2012). Nevertheless, the number of fatal crashes per 100 million Vehicle Miles Traveled (VMT) in Nevada was higher than the national averages from 2001 to 2009. Nevada is among the top ten states with the highest crash rates in the U.S. In 2010, about 9% of the crashes occurred in rural areas of the Nevada. However, if only fatal crashes are considered, 41% of those fatal crashes occurred in rural areas.

The major reasons for crashes can be divided into four main categories: the vehicle factor, the driver factor, the roadway factor, and the roadside factor. As evident by Toyota's $50 million investment for Toyota Collaborative Safety Research Center (CSRC) in 2011, huge investments have been made to develop better and safer technologies for motor vehicles (Toyota Motor Sales, U.S.A., Inc. Toyota, 2013). Some of the technologies developed for active safety include the anti-lock brake system, the brake assistant, traction control, vehicle stability control, radar cruise control, the lane-keeping assist, the navigation-brake assist, night view, and approaching vehicle audible system (Toyota Motor Corporation, 2013). However, the development of vehicle safety technologies alone is not enough for a safer road. A driver education program is crucial for safer roads, especially with regard to youthful drivers (NHTSA, 1994).

Various studies had been conducted to determine the causes of crashes and their severity. Idaho Transportation Department (IDT) states that the severity of crashes depends on the vehicle speed (IDT, 1997). However, the probability of crashes depends more on differential speeds than on absolute speeds. Various treatments of transition zones have been investigated and practiced to reduce the speed of vehicles approaching towns along rural highways (Torbic et al., 2012). This speed reduction in transition plays an important role in reducing the speed within the speed zone of rural communities.

1.2 Overview of the Study

In 2010, 51,664 crashes occurred in Nevada. Out of those crashes, Property Damage Only (PDO), injury, and fatal crashes were 63.40%, 36.15%, and 0.45%, respectively. About 9% of those crashes occurred in rural areas. Among all these categories of crashes that occurred in Nevada, 10% of PDO crashes, 8% of injury crashes, and 41% of fatal crashes occurred in rural areas of the state (NDOT, 2012). This shows that a higher percentage of the fatal crashes occurred in the rural areas as compared to injury crashes and PDO crashes. Therefore, in order to reduce speed-related crashes in the towns along rural highways in Nevada, it is necessary to identify the best practices in setting up speed zones in these areas.

Many states already have some form of speed-zone guideline or manual to quickly process and resolve complaints related to speed zones. However, the NDOT does not yet have such a guideline or manual. A guideline for setting up speed zones in towns along the rural highways is necessary for consistent procedures to set up speed zones throughout the state. The guideline, once prepared, could be followed by all the district traffic engineers of the NDOT.

The NDOT Technical Advisory Panel (TAP) identified 11 towns along the rural highways of Nevada for this study: Alamo, Austin, Beatty, Fernley, Goldfield, Luning, McGill, Panaca, Schurz, Tonopah, and Searchlight (Figure 1-1). Crash data of these towns from April 1, 2001 to April 10, 2011 were obtained from the Nevada Citation and Accident Tracking System (NCATS). The crash data were analyzed to determine the factors associated with the crashes and the severity of these crashes. Site visits were made to these towns to collect spot speed data and highway characteristics. These data also were used to determine their association with the crashes.

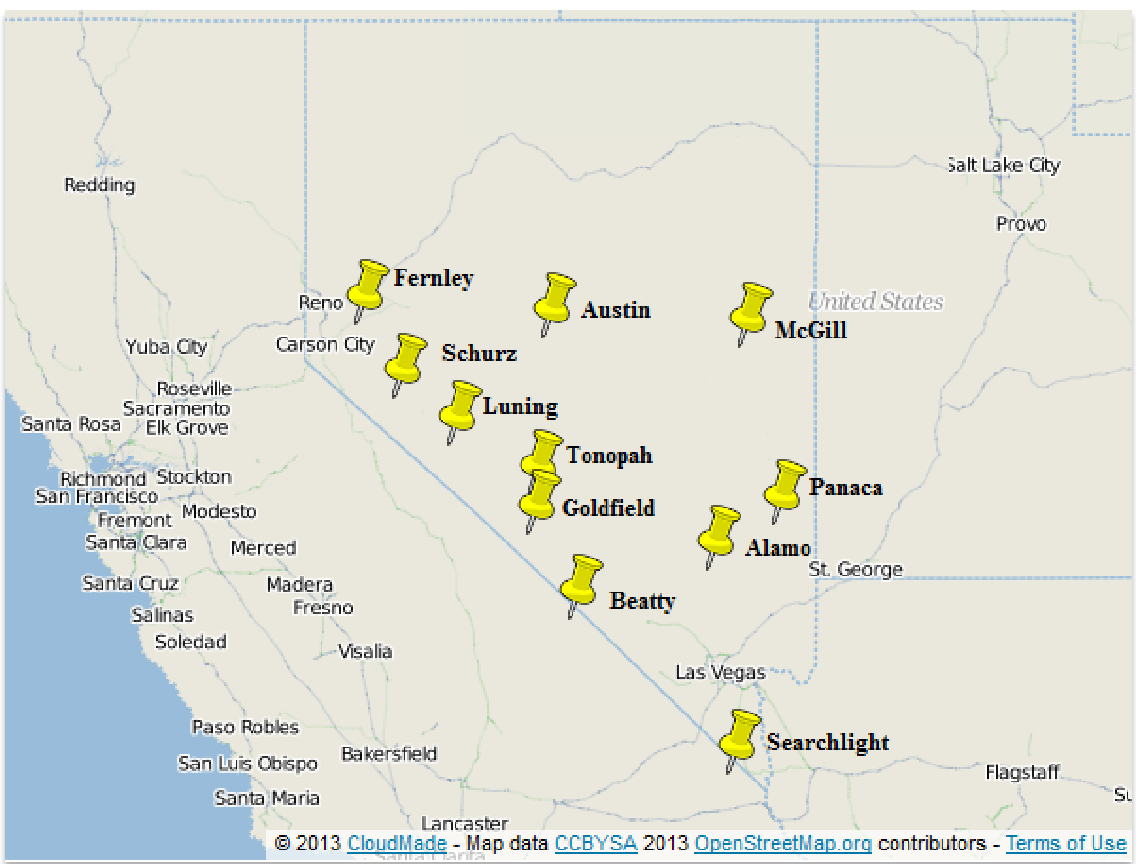

Figure 1-1. Locations of The 11 Towns Under Study (Open Street Map, 2013; CloudMade, 2013).

All the state DOTs of the U.S., except Nevada, were contacted for a questionnaire survey. The questionnaire survey was prepared in order to identify the best practices used in various states to set up speed zones. The results of the questionnaire survey can be used to formulate a speed-zone guideline for towns along the rural highways of Nevada. Once the guideline is prepared, it will aid NDOT officials in their decision-making process to efficiently handle community requests related to speed zones. Conclusions and recommendations regarding speed-zone guidelines as well as a discussion of the limitations of the study are provided.

1.3 Study Objectives

The overall goal of this study is to determine the factors that must be considered while setting up speed zones in towns along the rural highways. The main objectives of this study are:

1) To review literature related to the factors associated with crashes and speed limits,
2) To determine the factors associated with crashes by analyzing crash data of 11 rural towns of Nevada,
3) To identify the best practices used by other state DOTs when setting up the speed zones in towns along their rural highways; and
4) To prepare a speed-zone guideline for towns along the rural highways in Nevada.

1.4 Research Methodology

The study was divided into six phases, as shown in Figure 1-2. During Phase I, the scope and the objectives of the study were defined. In Phase II, various studies were reviewed related to factors affecting speeds and crashes, techniques for crash data analysis, speed-zone guidelines, and speed-reduction techniques. In Phase III, crash data were collected from NDOT. The research team visited the 11 towns under study to collect the spot data for speed and road characteristics of those towns. A questionnaire survey was conducted to determine the best practices used by state DOTs of the U.S. while setting up speed zones in towns along their rural highways. The traffic engineers of three districts were interviewed by means of a structured questionnaire. In Phase IV, the crash data, site data, survey data, and interview data all were analyzed. The information gathered in Phase III was used to identify the best practices and factors affecting the speed zone in Phase V. Finally, in Phase VI, a guideline in setting up speed zone in towns along rural highways of Nevada was prepared. Conclusions and recommendations also were presented in this final phase.

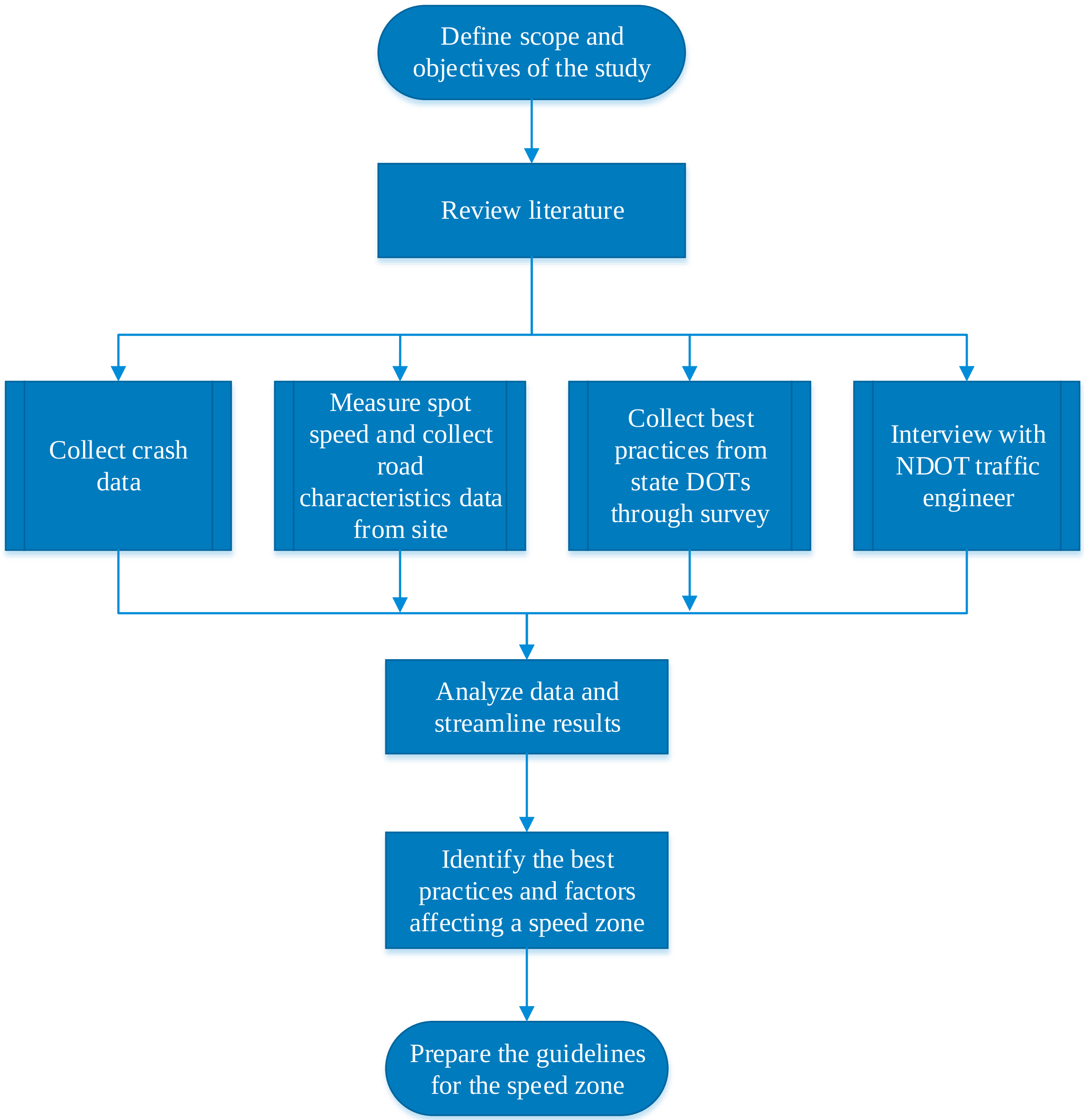

Figure 1-2. Overview of The Research Methodology.

1.4.1 Limitations

The results of the study are applicable only to the towns under study and cannot be generalized. While developing the ordinary least squares models, the spot-speed data collected in 2012 were correlated with the historical crash statistics (2002-2010) to determine the association between the number of crashes and speed parameters. The assumptions made in this analysis are that the drivers' behaviors in the vehicles passing through the towns under study have not changed significantly nor have the roadways and roadside characteristics. The crash data of Schurz were obtained from US 95 and US 95A, and the speed data were collected only from US 95. Also, for Tonopah, the crash data were obtained from US 95 and US 6, and the speed data were collected only from US 6.

The sample sizes of the data were very small. Use of data from more towns would produce more accurate statistical analysis and results. Not all the predictor variables considered for developing a multinomial logit model (MNL) may have a causal effect.

The crash data of the towns used for comparison purpose consist of the crashes that occurred only in the vicinity of the towns in one or two highways, whereas crash data from all the rural areas of Nevada include the crashes that occurred in all the rural areas of Nevada.

1.5 Outline of the Report

The report is organized as follows.

- Chapter 1 focuses on the research needs, objectives, and research methodology.
- Chapter 2 summarizes the findings of the literature review regarding the factors affecting the speed limit, crash severity, speed reduction techniques as well as guidelines for establishing the speed limit.
- Chapter 3 describes the crash data analysis of 11 towns under study and presents the factors associated with crashes.
- Chapter 4 describes the results of the site data analysis, the correlation between the crashes, and the speed data for these 11 towns.
- Chapter 5 presents the results of the questionnaire survey with state DOTs regarding the current practices used for establishing speed limits on rural highways.
- Chapter 6 provides the findings of structured interviews with NDOT traffic engineers of all the three divisions. This section also provides the results of the speed-related complaints presented by local residents and commuters from rural communities.
- Chapter 7 presents the guidelines for establishing speed zones in towns along the rural highways of Nevada.
- Chapter 8 provides the conclusions and recommendations for next steps to be taken.

2 Literature Review

A study by the Federal Highway Administration (FHWA, 2000) showed that people travel 1.5 times more on urban roads in comparison to rural roads. However, in 1999, more than half the total fatalities as well as more than half the speed-related fatalities occurred in rural areas. The reason for higher fatalities in rural roads was that rural roads had a higher incidence of severe crashes than urban roads; they also had rougher terrain; longer intervals between a crash and the time of discovery, and a lower level of available trauma care.

The FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD) (2012, p. 21) defined a design speed as "a selected speed used to determine the various geometric design features of a roadway." According to the Idaho Transportation Department, some transportation professions have cited the design speed as a limiting factor for determining a maximum speed limit (ITD, 1997). However, determination of speed limits for realistic speed zones should not be associated with the design speeds of the road. The design speed is selected to determine the geometry of a roadway; on the other hand, a speed limit should be determined based on the prevailing speeds of freely-flowing vehicles. This is based on a fundamental concept that the majority of motorists drive at a reasonably safe and prudent speed for existing roadway and roadside conditions. This results in voluntary compliance of the posted speed limit. However, if the posted speed limit is higher or lower than the speed dictated by roadway and traffic conditions, it will result in decreased compliance and more difficulty in speed-limit enforcement.

Najjar et al. (2000) suggested that most motorists tend to drive at a speed that depends upon the roadway conditions rather than the speed limit. Hence, setting an unrealistically low speed limit is likely to result in more variations in speed, resulting in more crashes. Dudek and Ullman (1987) found that the reduction in speed limit had a detrimental effect on driver compliance to the speed limits for both local and non-local drivers.

A number of studies were reviewed related to factors affecting the operating speed, crash and their severities, determination of a realistic speed limit, various speed reduction techniques, and various state DOT guidelines for establishing speed zones. These studies are summarized in following sections.

2.1 Factors Affecting the Operating Speeds and Speed Limits

The operating speed is affected by various factors that can be categorized into three main categories: 1) road characteristics, 2) roadside environment, and 3) human factors.

A speed limit acceptable to all parties (drivers, residents, legislators, and enforcement officers) is the one that is determined under favorable weather and prevailing traffic conditions (AASHTO, 1994). For changes in speed limits, the Institute of Transportation Engineering (ITE, 1993) suggested that an unbiased engineering study is needed to examine following conditions: roadside development, road and shoulder characteristics, pedestrian and bicycle activity, speed limits on adjoining road segments, crash experience or potential, and population density.

Jarvis and Hoban (1989) found that the speed limit depended upon the road cross section, abutting development, intersections, traffic signals, presence of parks, and pedestrian or cycle activities. Other numerous studies have found that the speeds at which drivers operate their vehicles depended upon road and roadside characteristics. The findings of those studies are presented in following sections.

2.1.1 Road Characteristics

The literature related to the relationship between road characteristics and operating speed is summarized in Table 2-1.

Table 2-1. Summary of Literature Related to the Effects of Road Characteristics on Speed

No.	Reference	State/ Country	Major findings of the study
1	Cruzado and Donnell (2010)	Pennsylvania , USA	The change in road characteristics, such as the paved shoulder width, total numbers of lanes, and presence of horizontal curves affect the operating speed of drivers in rural highways.
2	Esposito et al. (2011)	Italy	The 85^{th} percentile speed depends on shoulder width, lane width, radius of horizontal curve, straight section length, curve length, presence of pavement distress, and presence of road signs.
3	Fitzpatrick et al. (2001)	Texas, USA	For a horizontal curve site, the operating speed was significantly affected by the curve radius, deflection angle, the presence of median, access density, roadside development, and posted speed limit.
4	Wisconsin DOT (1999)	USA	The speed limits depend upon land use, including cross streets; traffic volume; the presence of pedestrians, bikes, weather, and road conditions; vehicle types; driver capability; public attitude; enforcement; and speed zoning.
5	European Transport Safety Council (1995)	European Union	Width, gradient, alignment, and layout of the roads significantly affect driver speed on particular sections of a roadway.
6	Fildes et al. (1991)		The road width and the number of lanes were the most important factors in choosing a speed in particular sections of a roadway.
7	Cooper et al. (1980)		The speed depends upon the surface conditions of the road.
8	Warren (1982)		The road curvature, grade, the length of grade, the number of lanes, surface conditions, sight distance, lateral clearance, the number of intersections, and built-up areas near the road were the most significant factors affecting the speed of the drivers.

2.1.2 Roadside Environment

An operating speed of the vehicles depends on the roadside environment. A study conducted by Horst and Ridder (2007) showed that the roadside infrastructure – trees, guardrails, barriers, panels, and emergency lanes – impacts drivers' behaviors on speed and lane positioning. The speed of a car was dependent upon how far the trees or guardrail was from the road. For more than 4.5-m away, there was no impact upon the speed; however, the shorter the distance, the slower the speed of the car. When there was a combination of trees and a guardrail, drivers tended to keep their cars away from the right side; nevertheless, if there were only trees, there was no influence on the lateral position. Tignor and Warren (1990) found that the number of access points and also nearby commercial development were the most important factors in determining the speed of the drivers.

2.1.3 Human Factors

Two studies were reviewed related to the association between human factors and the operating speed. Hassan and Abdel-Aty (2012) used a questionnaire survey to measure aberrant driving behavior of young drivers. The study found that young drivers drive very fast because of their habit of being late and their habit of racing the cars. Elvik (2002) found four factors that affect the choice of optimum speed limits: societal, types of road user, taxpayer, and residential. The author mentioned that while increasing or decreasing optimum speed limit will have an impact on road accident costs and environmental costs. He argued that this cost will be governed by the taxpayer. However, interest group often argue that these costs are covered by tax revenues paid by the motorists. The authors mentioned that 100% and 20% of these costs are covered in taxes paid by motorists in Norway and Sweden respectively.

2.2 Factors Affecting Crashes and Their Severities

Elvik (2012) stated that speed is one of the most important factors causing injury crashes. Rämä (1999) found that crashes occurred more during rain and snowfall. Jonah (1986) and Evans Wasielewski (1983) concluded that young drivers took more risks while driving, and hence were more likely to get involved in injury crashes. Lee and Mannering (2002) found that such roadside features as median width, shoulder width, vertical curve length, and guardrail distance from the shoulder have a significant correlation with the frequency and severity of crashes. Jordan (1998) found that the children were injured by car crashes more frequently after they returned home than when on school premises. The author determined that about 50% of the people involved in the pedestrian crashes are below 18 years old. The study did not analyze the driver's age involved in the pedestrian crashes.

2.2.1 Statistical Models to Determine Factors Affecting Crash Severities

Some studies had used various modeling approaches like binary logistic regression and the multinomial logit model to determine the factors associated with the severity of crashes. These study findings are summarized below.

2.2.1.1 Binary logistic regression

Chen et al. (2012) determined the factors that had a significant effect on the severity of intersection crashes. Twelve factors related to driver characteristics, vehicle features, environmental and road conditions, and crash characteristics were considered for analysis. Using binary logistic regression, a total of 12,144 cases were analyzed to determine the significant factors that affected the severity of intersection crashes. Initially, univariate analysis was performed for each variable to determine the significant factors that contributed to the fatal crashes. Twelve variables – namely, driver gender, driver age, vehicle type, weather condition, light condition, speed zone, traffic control type, month, day of week, time of day, crash type, and seat belt usage – were considered for univariate analysis. Those factors that were significantly correlated with severities of intersection crashes at alpha level 0.05 were selected for the multivariate model.

Ten factors, except the month and day of the week, were found to be significant; these were used for the multivariate analysis. The results showed that seven factors significantly affected the severity of intersection crashes: driver gender, age, speed zone, traffic control type, time of crash, crash type, and seatbelt use. The results showed that crashes involving males and old drivers (age 65 and above) had higher odds of a fatal outcome. Similarly, crashes were more fatal when they involved pedestrians, drivers not wearing seatbelts, speeds of more than 50 kph, and those occurring between midnight and early morning (12:00 AM to 5:59 AM). The results also showed that crashes occurring in intersections that had no traffic control devices were more fatal than in intersections with some kind of traffic control devices.

2.2.1.2 Multinomial logit model

Xie et al. (2012) analyzed injury severities involved in single-vehicle crashes on rural highways in Florida. A total of 4,285 crash data from 2005 were used for the analysis. To determine the significant correlation with the level of injuries, 53 explanatory variables were collected relating to driver information, vehicle information, crash information, weather and lighting, roadway, and speed. The MNL model and a latent class logit (LCL) model, based on MNL model, were used for data analysis.

Five injury outcomes were considered in terms of severity, namely, no injury, possible injury, non-incapacitated injury, incapacitated injury, and fatal injury. For MNL and LCL modeling, 53 potential explanatory variables were selected for analysis. Thirty one explanatory variables were found to have significant correlation with the severity level of injury at alpha level 0.05. The results showed that such factors as driver age, driving under the influence, seatbelt usage, points of impact, lighting condition, speed, the first and second most harmful events, and ethnicity all had a significant correlation with the severity level of the driver's injury.

The authors compared the results of the MNL and LCL models by analyzing the marginal effect and prediction accuracy of these models. The marginal effect quantifies the overall effect of variables under consideration on the crash injury outcomes. The authors found no difference in marginal effects of these two models. However, the test for prediction accuracy, which evaluates the goodness-of-fit of the models, showed that the LCL model predicted the injury severity outcomes better than the MNL model by about 37%.

2.2.2 Effect of the Speed Limit on Crashes

The literature related to the effect of increased posted speed limit on the crashes and their severities have been reviewed, and the main findings of these studies are summarized in Table 2-2.

Table 2-2. Summary of Literature Related to the Effect of Increase in Posted Speed Limit on Crashes

No.	Reference	State/ Country	Major findings of the Study
1	Malyshkina and Mannering (2008)	Indiana, USA	A speed limit did not significantly affect crash severities on interstate highways. For non-interstate highways, the likelihood of injury, fatality, or both increased with higher speed limits.
2	Renski et al. (1999)	North Carolina, USA	An increase in speed limit from 55 mph to 60 or 65 mph increased the probability of being injured and the probability of sustaining Class B, C, or A injuries.
3	Zahabi et al. (2011)	USA	A significant relationship exists between the speed limit and the severity of injury.
4	Agent et al. (1998)	Kentucky, USA	No significant changes in the number of crashes as a result of a speed limit increase.
5	Haselton et al. (2002)	California, USA	An increase in speed limit significantly increased the total number of crashes.
6	Raju et al. (1998)	Iowa, USA	An increase in speed limit led to an increase in fatal crashes on rural Interstates highway.
7	TRB (1984)	USA	Some studies have found no significant changes in crashes due to a speed-limit increase.
8	Kockelman et al. (2006)	USA	There is no broad consensus on the effects of the changes in speed on crashes.
9	Thornton and Lyles (1996)	USA	A higher speed limit does not necessarily lead to more crashes; however, some crashes will be more severe at higher speeds.
10	Wisconsin (1999)	Wisconsin, USA	High speed may not necessarily cause crashes; however, it affects the severity of the crashes.
11	Garber et al. (2003)	USA	No significant differences in the crash rates were found to occur in rural interstate highways that use the uniform speed limit (USL) and the differential speed limit (DSL).
12	Lee et al. (2004)	Canada	Lower speed limits generally reduced the average total crash potential when using a dynamic display system.

2.3 Speed Reduction Techniques

This section includes the studies evaluating the effectiveness of different types of police enforcement, radar technologies, speed-camera technology, dynamic-speed display systems, and various traffic calming methods used in arterial roads and transition zones.

A project called "Managing Speeds of Traffic on European Roads" determined three key issues related to the speed of traffic in that continent (Kallberg et al., 1999). The study determined 1) the acceptable ranges of speeds for drivers on various types of roads and under various traffic conditions and 2) factors affecting the drivers' choices of speed.

Speed behavior is not only driven by motivation, but also by external feedback factors as perceived by the driver, such as road design elements and the behavior of other road users in his or her surroundings. Factors affecting the driver's choice of speed have been investigated mainly by means of interviews with drivers and pedestrians. Factors contributing to higher speeds are the speeds of other vehicles, the mood of the driver, the acceptability of the present speed, enforcement, and road design.

The study also summarized a variety of measures and tools that are currently used for speed management. These measures were divided into three categories. The first involved informative and legal measures, including posted speed limits, variable speed limits, vehicle and driver-type specific speed limits, penalty systems for speeding, speed recommendation signs, in-vehicle information of the prevailing speed limit, feedback on speed (roadside or in-vehicle), and education and publicity campaigns. The second involved measures related to road design, including speed reduction measures, such as speed humps, road narrowing, and horizontal deflections; roundabouts, village gateways, pavement markings, rumble strips; and other pavement treatments; visibility and visual guidance; traffic calming; and self-explaining roads. The final measures were intervening measures, including conventional speed enforcement, automated speed enforcement, adaptive cruise control, and in-vehicle speed limiters.

Recommendations for speed management on different kinds of roads outlined the process for determining target speeds for roads. During this process, such factors as the impact of speed on travel time, vehicle operating costs, crashes, and pollution must be assessed. Once the speed limit is decided, then various speed management measures should be applied in order to bring the speed of the vehicles within the targeted speed. The authors recommended speed management measures and tools, such as harmonization of speed limits in different European countries, development of European guidelines for urban speed management, wider use of speed enforcement, and adaption of in-vehicle speed limiters.

In 1998, the Transportation Research Board (TRB) formed a committee to review current practices for setting and enforcing speed limits (TRB, 1998). This study was conducted to provide guidance to state and local governments on appropriate methods of setting speed limits as well as other related enforcement strategies. The report summarized six critical areas of setting and enforcing speed limits. They are:

- Factors affecting the determination of appropriate speed limits;
- Effects of speed on safety, travel time, and operating costs;
- Methods for setting up speed limits;
- Speed enforcement;

- Speed management strategies; and
- Guidance on setting and enforcing speed limits.

2.3.1 Effect of Police Enforcement on Speed Reduction

Various studies have found that police enforcement can significantly reduce the speed of the driver in speed zones. The findings of these studies are summarized in Table 2-3..

Table 2-3. Summary of Literature Related to the Effect of Police Enforcement on Speed

No.	Reference	State/ Country	Major findings of the study
1	Hauer et al. (1982)	Toronto, Canada	Due to the presence of the police, the mean speed as well as the standard deviation of the vehicle's speed dropped significantly.
2	Armour (1986)	New South Wales, Australia	Speed enforcement symbols on urban roads helped to significantly reduce the speed of vehicles. The number of vehicles exceeding the speed limit was reduced by 33%.
3	Vaa (1997)	Norway	The average speed of the cars was significantly reduced due to the presence of police on the road. The percentage of drivers exceeding the speed limit also decreased significantly.
4	Raub (1985)	Illinois, USA	Police using patrol vehicles with roof-mounted emergency lights were more effective in issuing speeding tickets than the police using the patrol vehicles without roof-mounted emergency lights.
5	Shinar and Stiebel (1986)	Israel	The study measured the effectiveness of speed limit enforcement, using stationary and moving police vehicles. Both enforcement methods were successful in reducing the speed of the vehicles. For the 'halo effect', the moving police vehicles were more effective than stationary police vehicles.
6	Benekohl et al. (1992)	Illinois, USA	The police presence on the road showed a net decrease in the average speed of cars and trucks. The percentage of cars and trucks exceeding the posted limit also was reduced due to the presence of police on the road.
7	Stuster (1995)	California, USA	California's aerial speed enforcement program significantly reduced speed-related crashes. It also significantly reduced the number of vehicles exceeding the speed limits. However, aerial enforcement was found to be costly.

2.3.2 Effect of Radar Technology on Speed and Crash Reduction

Table 2-4 summarizes study findings related to the use of various radar technologies to reduce the vehicle speeds and crashes.

Table 2-4. Summary of Literature Related to the Effect of Radar Technology on Speed and Crashes

No.	Reference	State/ Country	Major findings of the study
1	Blackburn et al. (1989)	Missouri, USA	The study determined the most efficient speed enforcement devices and strategies for red-light violations by drivers. The study found that cross-the-road radar systems were found to be most sophisticated, and had better quality in detecting speeding in heavier traffic as well as the ability to identify speeding vehicles.
2	Streff et al. (1995)	Michigan, USA	The study measured the effectiveness of drone radars with and without police enforcement in reducing the mean speed of vehicles. The results showed that drone radars helped to significantly reduce the mean speed of the vehicles. However, the presence of police patrols did not make a difference in the speed limit.
3	Elvik (1997)	Norway	The study determined the effectiveness of photo radar in reducing crashes. The results showed that crashes were reduced by 20%, which is significant at alpha level 0.05.
4	Hajbabaie (2009)	Illinois, USA	The study measured the performance of four speed enforcement techniques, namely, speed photo-radar enforcement, a speed-display trailer, police car with lights off, and a speed-display trailer plus a police car with lights off in work zones and extensive speeding zones. For work zones, a trailer plus police was the most effective method; for extensive speeding zones, speed photo radar and trailer plus police performed best.
5	Bloch (1998)	California, USA	A display board without a police presence was the most cost-effective solution to reduce vehicle speeds, followed by display board with police presence, and finally, the photo radar.
6	Freedman et al., 1994	Missouri, USA	The presence of drone radar in high-crash, construction, and maintenance zones of rural and urban highway reduces the mean speed of passenger and heavy vehicles.

2.3.3 Effect of Speed-Camera on Speed Reduction

Rogerson et al. (1994) determined the effect of the presence of speed cameras on the mean speed of vehicles and the number of crashes. The results showed that due to the presence of a speed camera, the percentage of vehicles exceeding their speed limits reduced; however, no significant reduction in the mean speed of the vehicles was found. In addition, no significant change occurred in the crash frequency at the test sites.

Teed and Lund (1993) found more speed limit violations where new laser device was used as compared to similar locations where conventional police radar were used. However, the difference was not significant at alpha level 0.10. The study also found that most of the cars that speeded 20 mph over the limit had radar detectors in their vehicles.

2.3.4 Effect of Dynamic Speed Display on Speed Reduction

Numerous studies related to the use of dynamic speed displays in reducing the speed showed that this method is effective in reducing speed. The findings related to these studies are summarized in Table 2-5..

Table 2-5. Summary of Literature Related to the Effect of Dynamic Display on Speed Reduction

No.	Reference	State/ Country	Major findings of the study
1	Winnett and Wheeler (2002)	United Kingdom	This study evaluated the efficiency of four types of vehicle-activated signs to reduce the mean speed and number of crashes on rural roads. The results showed that these signs reduced the mean speed ranging from 4 mph to 9 mph, and also reduced the number of crashes by one third.
2	Oei (1996)	Netherland	A flashing sign was the most effective warning system as compared to a permanent sign or a continuous sign.
3	Sandberg et al. (2006)	Minnesota, USA	The use of permanent dynamic feedback displays on rural highways significantly reduced the 85th percentile speed of the vehicles by about 7 mph.
4	Arnold and Lantz (2007)	Virginia, USA	A flashing light-emitting-diode (LED) stop sign and optical speed bars significantly reduced the mean speed by 1 to 3 mph.
5	Cruzado and Donnell (2009)	Pennsylvania, USA	Dynamic speed display signs significantly reduced the mean speed of vehicles on rural two-lane highway by 6 mph.

2.3.5 Traffic Calming

Traffic calming is a technique used to reduce the speed of vehicles. A summary of literature related to the functionality as well as the cost effectiveness of different types of traffic-calming techniques is presented in Table 2-6..

Table 2-6. Summary of Literature Related to the Traffic Calming

No.	Reference	State/ Country	Major findings of the study
1	Herrstedt et al. (1993)	Denmark, France, and Germany	Traffic calming measures significantly reduced the mean speed, crash rates, and number of people injured in the crashes.
2	Sarkar et al. (1997)	N/A	The study recommended various traffic calming measures on urban streets in order to reduce fatalities of pedestrians and bicyclists.
3	Kamyab et al. (2003)	Minnesota, USA	The speed reduction techniques consisting of removable pedestrian islands and pedestrian crossing devices significantly reduced the mean speed of vehicles travelling on rural roadways.
4	Pyne et al. (1995)	United Kingdom	Results from using a driving simulator showed that a combination of treatments provided in transition zones of a rural highway approaching a village could significantly reduce the mean speed and 85th percentile speed of vehicles.
5	Parham and Fitzpatrick (1998)	Texas, USA	This study synthesized the various speed management techniques used in U.S. and other countries. The survey results showed that speed enforcement is the best way to control the speed of vehicles in towns along rural roads, followed by the installation of traffic signals in transition zones.
6	Stuster and Coffman (1998)	USA	The report concluded that more research related to traffic calming should be conducted to determine the impact of these countermeasures on the speed of the vehicles.
7	Torbic et al. (2012)	USA	Roundabouts and traverse pavement markings increase the speed compliance of vehicles by 11 to 20 percentages at the end of a transition zone.
8	Houten and Huten (1987)	Dartmouth, Canada	The research results showed that introducing a sign that stated 'Begin Slowing Here' reduced the number of speeding vehicles travelling in the transition zones.
9	Forbes (2011)	U.S. and Canada	The report found that the majority of the state DOTs did not have standard approaches for treating high-to-low speed limits in transition zones.
10	Lamberti et al. (2009)	Ontario, Canada	The simulation experiment showed that the road treatments significantly reduced the speed of the vehicles by 7 to 11 mph.
11	U.K. Department for Transport (2005)	United Kingdom	A new version of the transverse rumble strip is an effective traffic calming device that can be used in transition zones. Results showed that this strip reduced the mean speed and 85th percentile of traffic speed by 1% to 6%.
12	Russell and Godavarthy (2010)	Kansas, USA	The effectiveness of four different speed management techniques on rural roads was determined. The measures used were colored pavement, solar speed displays, a mobile speed trailer, and optical speed bars. The mobile speed trailer was the most effective measure to reduce the mean speed and 85th percentile speed of the vehicles.

2.4 Guidelines for Establishing Speed Zones

The objective of speed zoning, as stated in the Uniform Vehicle Code, is to fix the speed limit that is "reasonable and safe for a given section of roadway" (ITE 1993). According to a survey by the Institute of Transportation Engineerings (1993), there are inconsistencies in speed zoning provided by various agencies in counties and municipalities as well as state DOTs. The inconsistencies were related to the location of speed zones, posted speed limits in zones, and enforcement tolerance. The report emphasized that speed zones only are established on the basis of an engineering study. The posted speed limit in speed zoning should be 85^{th} percentile speed. Each speed zone should be restudied within five years to determine the appropriate speed limit. While establishing the speed limit, it was recommended that the nearest 5-mph increment to the 85^{th} percentile speed be set. The engineering study also should take into account various factors, for example, geometric design, roadside development, road and shoulder surface types, pedestrian and bicycle activity, and crash history of the location. The government agency should coordinate properly for the implementation of speed zones and the enforcement policies.

Srinivasan et al. (2006) helped Federal Highway Administration (FHWA) to develop an expert system to determine the speed limits in speed zones (Srinivasan et al., 2006). This study reviewed previous studies related to the impact of speed limit changes, the relationship between site characteristics and operating speeds, enforcement, and methods to set speed limits. The system is now available online as a USLIMITS2 (2013).

Various state Departments of Transportation have developed speed-zone guidelines or manuals to set up speed zones in particular stretches of arterial roads. The summary of guidelines and manuals of Florida, Oregon, Massachusetts, Texas, Wyoming, Wisconsin, North Carolina, Montana, Missouri, Louisiana, Kentucky, Idaho, Georgia, Arizona, and California are presented in this section.

2.4.1 Arizona DOT Speed-Zone Guidelines

The Arizona Department of Transportation's *Traffic Engineering Policies, Guidelines, and Procedures* (2000) points out the need of setting speed limits that the drivers will consider prudent and reasonably safe. It recommends not setting unreasonable speeds based on design speed. Several factors are required to be considered along with the 85^{th} percentile in order to determine proper speed limits. Those factors are:

- Length of section
- Alignment
- Roadway width and shoulders
- Surface condition
- Sight distance
- Traffic volume
- Accident experience

- Maximum comfortable speed on curves
- Side friction (roadside development)
- Parking practices and pedestrian activity
- Signal progression

For such locations as horizontal curves, warning signs with an advisory speed sign may be used. For other locations where speed zones are deemed necessary, first speed data are to be collected. If electrical or mechanical devices are used for data collection, then data has to be collected for 24 hours. In case of radar, if average daily traffic is less than 2,000, a minimum of 50 vehicles in each direction has to be collected within a maximum of two hours' time limit. If the average daily traffic is at least 2000, a sample of at least 100 per direction must be collected within a maximum time limit of two hours.

To establish a speed zone, the state traffic engineer has to submit speed regulations, a transmittal memorandum, and the traffic engineering study to the appropriate regional traffic engineer. If approved, then installation or confirmed dates will be entered into the speed regulation database.

2.4.2 California DOT Speed-Zone Manual

The *California Manual on Uniform Traffic Control Devices* (2012) is FHWA's MUTCD 2009 Edition as amended for use in California. It has a few modifications related to speed limits in Section 2B.13 Speed Limit Sign as compared to original one. This manual emphasizes the need for engineering and traffic surveys instead of an engineering study for setting a speed limit. Also, it provides support for the 85th percentile as a basis of setting the speed limit, since setting speeds arbitrarily low will result in more violators. According to the manual, the studies should be conducted at least once every 5, 7 or 10 years for revising the speed limits. There was no fixed time period mentioned in original manual for revising speed limit. Instead of setting a speed limit within 5 mph of the 85th percentile, the manual provides the option to reduce the posted speed by 5 mph if justified or if the speed limit is obtained by rounding up the 85th percentile speed.

The manual lists requirements of engineering and traffic survey as:

- A speed study,
- Crash records, and
- Highway, traffic, and roadside conditions not readily apparent to the driver.

The manual also lists requirement of speed studies, some of which are as listed below:

- There should not be alteration of driver speed because of concentrated law enforcement, or other reasons.
- Spot speed location should be representative of driver speed for whole section. If required, multiple sections can be chosen for single section. The location of those spot should be chosen so that there is minimum effect stop sign or traffic signals.
- Study should be conducted off-peak hours on the weekend.

- Weather should be fair and usual.
- Speed data of minimum of 50 vehicles is required.
- The speed zone should be at least 0.5 miles in length, except in transition areas.

Speed zoning should be in 10-mph increments for rural areas. For urban areas, a 5-mph increment is preferable.

2.4.3 Florida DOT Speed-Zone Manual

In 2010, Florida Department of Transportation (FDOT) prepared a manual, entitled *Speed Zoning for Highways, Roads, and Streets in Florida*. This manual is used by the state traffic engineering and operations office, district traffic operations offices, Florida counties, and municipalities. The intent of this manual is to improve traffic safety by establishing standard speed limits on various types of roads. This manual explains in detail the principles, philosophies, and procedures of realistic speed zoning.

Florida has a statute for allowable speed limits on various types of roads. For example, 65 mph is the limit for highways outside an urban area of 5,000 or more persons and having at least four lanes divided by a median strip. For county roads, the limit is 60 mph. If any alterations of speed should be done in any section of the road, Florida Statutes require an engineering and traffic investigation to be conducted. Basic investigations should be conducted to determine the 85th percentile speed, the upper limit of 10-mph pace, and the average test-run speed.

The manual recommended measuring the speed of vehicles during traffic investigations by conducting a spot speed check. The spot speed should be checked in such a way that drivers will not realize that their speeds are being monitored. Otherwise, distorted data will be collected, and the speed data analysis will be unrealistic.

This manual also highlighted the importance of the location and timing of the spot speed check during traffic investigations, and suggested the sample size of the spot speeds. The manual showed how to calculate the 85th percentile speed and how to determine the speed limit. It emphasized requiring speed reduction traffic signs in speed zones in compliance with the MUTCD.

Finally, the manual recommended the use of variable speed limit (VSL) systems at speed zones. VSL is a type of Intelligent Transportation System that utilizes real-time traffic speed and volume detection, weather information, crash, and congestion, and road surface conditions in order to determine the appropriate safety driving speed. The manual recommended that the traffic engineering study should determine the length of graduated speed zones. The manual stressed uniform speed zoning and enforcement throughout the State of Florida.

2.4.4 Georgia DOT Speed-Zone Guidelines

Speed data, road geometrics and design, other conditions of roadway, and crash history are the factors considered for setting up speed limits based on the guidelines prepared by Georgia Department of Transportation (2012). The speed determined using those factors is finally confirmed by test driving. The manual does not allow a speed limit below 25 mph in state routes. For state highway segments, the minimum allowed speed limit is 35 mph. The manual does not provide specific details about how the speed limit is calculated and how the factors affecting the speed limits are taken into account.

For school zones, there should be multiple grades and enrollment of over 250 students and staff. A change in speed limit is not allowed within a school zone. The speed limit should not be reduced at the same mile point as the beginning of school zone. Also, a speed zone change should occur at least 0.02 miles farther from school zone to allow sufficient spacing between the school zone and the speed limit sign.

2.4.5 Idaho Transportation Department Speed-Zone Guidelines

Speed Limits and Speed Zones: A Guide to Establishing Speed Zones in Idaho (ITD, 1997) presents concepts and methods that have been based on over 40 years of engineering experience and observations. Speed zones are not the solution to all traffic problems nor will they be effective without enforcement and education. These guidelines point out that the speed limit should be set so that most of the drivers follow it voluntarily. In turn, this eliminates the need for heavy law enforcement. According to the manual, in general, such factors as accident rates or geometric features do not need to be considered separately or in combination with other data because the effect of all those factors are already reflected in the 85th percentile speed. Also an upper limit of a 10-mph pace might be a better alternative to 85th percentile speed when the 10-mph pace contains a high percentage of vehicles and the 85th percentile speed appears inappropriately high.

The manual emphasizes uniformity and consistency of the speed limit throughout the state so that it is easy to support and defend speed zoning to local officials, the courts, or the public when revisions or changes are requested. The manual follows the MUTCD for the factors to be considered in engineering studies to set speed limits. These factors are:

- 85th percentile speed, pace, speed distribution
- Other factors that may require to be considered
    - Roadway characteristics
    - Roadside development
    - Curves and hazardous locations
    - Parking, pedestrians, and bicycle
    - Crash record

The factors besides speed data are generally reflected in the speed data itself. Hence, they do not need to be considered unless the conditions are unusual and not readily apparent to the drivers. Those factors, however, should not be considered as a sole basis to increase or decrease the speed limit. Curves and hazardous locations can be accompanied with advisory speed limits. Crash record may suggest not only decreasing speed limit but also increasing limit depending upon nature of crashes.

The manual includes description of automatic traffic recorders, radar method, test run method, and car-follow method for speed study. Advisory speed recommended by for a given ball-bank reading is provided in Table 2-7.

Table 2-7. Ball-Bank Reading and Speed Limit, Adapted From ITD (1997)

Ball-bank reading	Speed limit
10°	35 mph or higher
12.5°	25 mph and 30 mph
15°	20 mph and below

The manual does not provide any specific guidelines for the school zones. It recommends not setting different speed limits for various classes and types of vehicles. Different levels of parking and pedestrian activities are defined in the Table 2-8..

Table 2-8. Levels of Parking and Pedestrian Activities, Adapted From ITD (1997)

Level	Parking activity	Pedestrian activity
Low	1 – 5 turnovers per hour during highest hour	1 – 5 per hour during highest hour
Medium	6 – 10 turnovers per hour during highest hour	6 – 10 per hour during highest hour
High	11 or more turnovers per hour during the highest hour	11 or more per hour during the highest hour

The manual includes two appendices for "Speed Zoning Methodology (Detailed Study)" and "Speed Study for Low Volume Roadways (<=400 AADT)." A list of factors for which data must be collected is provided in the appendix, "Speed Zoning Methodology (Detailed Study)". The weighted average for a speed limit is calculated using 85th percentile speed (factor/weight 3), upper limit of 10 mph pace (factor/weight 3), and average test run speed (factor/weight 4). A correction factor is determined using tables for different factors. The corrected speed limit should not be off from the original speed limit by more than 25%. Finally, the recommended speed limit can be obtained by rounding to nearest 5 mph. For low-volume roadways, the car-follow method and test run method are suggested.

2.4.6 Kentucky DOT Speed-Zone Manual

The Kentucky *Traffic Operation Guidance Manual* (2012) recommended conducting engineering study in accordance with the *Manual on Uniform Traffic Control Devices* to set up speed zones. The 85th percentile speed of vehicles, crash history, and location of speed zone are required data for setting up speed zones. The speed limit should be reasonable, adequate, and appropriate and should be reviewed regularly by the district. The manual states that advisory speed warning signs should be provided in road intersections and in turning roads, instead of speed zones. Normal transitions, as mentioned in the manual are 55 mph to 45 mph and 35 mph to 25 mph.

The manual recommended reducing to a 10-mph speed in school zones from normal posted speed limit. Generally, the speed limits in school zones should not be less than 25 mph nor more than 45 mph. However, lower speed limits can be provided based on factors like sight distance, roadway conditions, and crash history of the road.

2.4.7 Louisiana DOT Speed-Zone Manual

The Louisiana Department of Transportation and Development developed the *Engineering Directives and Standards Manual* (1981) to describe the process of setting up speed zones. The manual states that major factor in setting up speed limit in speed zones is the 85th percentile speed of the traffic, determined by conducting a speed study. During the speed study, the spot speed of at least 100 vehicles in each direction must be measured. If the traffic volume is low, then the spot speed of the vehicles passing during at least a two-hour period must be measured. The spot speed study should not be conducted during peak hours. The speed limit recommended after the study should not be below the upper limit of the 10-mph pace. Documents providing details about the location and existing site condition, including speed study data, are required for setting a new speed zone.

The manual recommended providing a minimum length of a speed zone as 1,000 ft for a 25-mph and 30-mph speed limit. For a 50-mph speed limit, the recommended minimum length of speed zone is 2,500 ft. The manual recommended up to six speed changes per mile while setting up transition zones. The interval of speed changes should be less than 10 mph.

It also states that traffic engineers can consider some of the following factors while setting up the speed limit.

- Road surface characteristics, shoulder condition, grade alignment, and sight distance
- 50th percentile speed and the pace speed
- Roadside development and road surface friction
- Safe speed for curves or hazardous locations within the zone
- Parking practices and pedestrian activity

Other factors that can be considered include traffic volumes, crash history of last year, and traffic control devices.

2.4.8 Massachusetts DOT Speed-Zone Manual

In 2005, the Massachusetts Highway Department (MassDOT) developed *Procedures for Speed Zoning on State and Municipal Roadways*. The manual states that the “speed limit shall be established only after engineering and traffic investigation has been conducted in compliance with established traffic engineering practices” (MassDOT, 2005). One of the prerequisites for establishing a speed zone is that a comprehensive engineering study at that location should be conducted. This is necessary to determine a safe speed limit that is reasonable for motorists as well as for enforcing officers.

The guide identified the 85th percentile speed of vehicles as the national standard for establishing safe speed limits. In the engineering study, the data of speed of vehicles, conditions of roads, crash records, etc., must be collected before establishing the speed zones. The manual also stated that in rural highways, the minimum length of speed zone should be one-half mile, when possible. It also recommended that speed limit signs be provided in speed zones. Finally, the manual stated that every speed-zone regulation should be approved by the Chief Deputy Registrar for the Register of Motor Vehicles and the State Traffic Engineer for Massachusetts Highways.

2.4.9 Missouri DOT Speed-Zone Guideline

The Missouri *Speed Limit Guidelines* (2010) recommended setting up at least two-mile long speed zones for unincorporated or 'non-community' areas. The guidelines consist of a procedure for conducting traffic study. During a traffic study, the 85th percentile speed, upper limit of the 10 mph pace, and average test run speed data is collected to determine the speed limits of speed zones. The guidelines recommended selecting speed limits in 5-mph increments; however, the speed limit cannot be more than 3 mph of the prevailing speed. In an average test-run method, at least two runs in each direction of highways should be conducted and speeds are to be recorded at 0.1 miles interval.

The guidelines mentioned that traffic engineers have the discretion to reduce the speed limits derived from the traffic study in any speed zones, based on certain factors. Table 2-9. lists those factors as well as the corresponding speed reduction methods.

The spot speed of vehicles should be measured as close to the center of the speed zone as possible. If the speed-zone length is more than a mile, at least two spots should be chosen for spot speed measurement. If the difference between these two measured speeds is less than 5 mph, then the minimum value should be selected or two speed zones with two different speed limits can be provided.

Table 2-9. Prevailing Speed Reduction, Adapted From Missouri Department of Transportation (Missouri DOT, 2010)

Factor	Condition	Prevailing speed reduction
Crash rate for fatal or disabling crashes	> 1.5 statewide average	5%
	> 2.0 statewide average	10%
Pedestrian traffic	- no sidewalk > 10 pedestrians per hour for 3 hours of any 8 hour period	5%
Parking	- On-street parking present	5%
Adjacent development (Driveway conflict number*)	> 40 per mile	5%
	> 60 per mile	10%

*Driveway conflict number is calculated as sum scores given to access roads – 1 for private or field entrance, 5 for each minor commercial entrances, 10 for major commercial entrances or public road. Also Poisson Curve should be used to test significance of accident reduction before applying this reduction.

2.4.10 Montana DOT Speed-Zone Manual

The *Montana Traffic Engineering Manual (2007)* includes a stepwise process for setting up speed limits in their highways. The steps to set up the speed limit are:

- Request for speed study
- Meet with local officials
- Local concurrence to conduct speed study
- Determine study parameters
- Collection of data
- Analyze data
- Disseminate study results
- Review and comment on study
- Presentation to Montana transportation commission
- Implementation of special speed zone

The manual has identified some primary factors to be considered while setting up a speed limit: 85^{th} percentile speed, pace, and speed profile. Such factors as development, transition zones, adjacent sections, crashes/hazardous conditions, highway geometrics, pedestrian/school/senior centers, parking, traffic mix, and seasonal factors should be considered while setting up speed limits in highways. They provided a detailed explanation for conducting traffic studies. The manual recommended collecting spot speed data of at least 100 vehicles in each direction during traffic study.

2.4.11 North Carolina DOT Speed-Zone Guidelines

The North Carolina *Guidelines for the Establishment of Restrictive Speed Limits* (1995) recommended conducting a traffic study to setup a speed limit in rural highways other than speed limit provided by the statutes. The following factors should be considered while setting up speed limit:

- 85th percentile speed
- Roadway characteristics including roadway surface characteristics and shoulder characteristics
- Alignment of roadway
- Roadside development
- Intersections

The manual recommended providing a speed limit of 35 mph or less in a road if the roadside development is at least 75%. The manual also recommended providing a speed limit of 35 mph or less in soil or gravel roads.

The manual does not allow establishing a school zone in interstate and controlled-access highways. Along other highways, school zone will be allowed if the school property abuts the highways. The maximum suggested length of the school speed zone is 500 ft upstream and downstream of the school. The speed limit in the school-zone can be up to

10 mph less than the 85^{th} percentile speed. However, it should not be less than 25 mph in any case.

2.4.12 Oregon DOT Speed-Zone Manual

The *Speed Zone Manual*, prepared by the Oregon Department of Transportation (ODOT, 2011), identifies practices that should be followed for completing speed zones in Oregon. The manual stresses setting an appropriate balance between travel time and risk for the specific highway section. The manual specifically mentions that speed zoning must be set based on an engineering study, required by statute. The speed limit should be changed if there is road construction, if there is a change in roadside development, or significant changes in traffic volumes.

The engineering studies that the manual specifies need to be conducted are statistical analyses of the following:

- The speed distribution of free flowing vehicles;
- Change in roadway geometric features;
- Pedestrians and bicycle movements; and
- Types and density of adjacent land use, enforcement, crash history, public testimony, traffic volumes, and number of access points.

The manual emphasizes that speed zones should not be treated as a tool to warn motorists of hazardous conditions. It also requires that enforcement of speed limits within the speed zones should be uniform. This manual gives a step-by-step process of when and how to set the speed zones.

2.4.13 Texas DOT Speed-Zone Manual

The Texas Department of Transportation (TxDOT) also developed a manual for establishing speed zones (TxDOT, 2011), entitled *Procedures for Establishing Speed Zones*. This manual has a comprehensive set of guidelines for TxDOT traffic engineers to follow when establishing speed zones. The manual consists of various traffic engineering studies that have been conducted as an aid to help decide about speed zones, the speed-zone approval process, and application of advisory speeds. The manual has the following procedures that should be followed to set speed limits for Texas highways.

- Speed limits on all roadways should be based on 85^{th} percentile of the speed.
- The posted speed limit should be based on the 85^{th} percentile speed; even the inferred design speed is lower than the resulting posted speed limit.
- Setting arbitrarily lower speed limits is not good engineering practice.
- The appropriate warning signs should be posted if a section of road has a posted speed limit in excess of the roadways' inferred design speed.
- New roads should be designed to accommodate the highest anticipated posted speed limit, based on the roadways' initial or ultimate function.

2.4.14 Wisconsin DOT Speed-Zone Manual

Wisconsin DOT's *Traffic Guidelines Manual* (2009) provides detailed information regarding setting up speed zones. The manual defines a speed zone as "a section of street or highway where speed limit different than the statutory speed limit has been established."

Wisconsin DOT conducts the speed studies to setup speed zones based on residents' complaints or number of crashes. The factors taken under consideration in setting up speed zones are:

- Speed parameters: 85^{th} percentile speed, and mean speed
- Crash record
- Road's geometrics (lane widths, curves, roadside hazards, sight distances, etc.)
- Density and roadside development in terms of the number of driveways and access points
- Shoulder widths as well as roadway and shoulder conditions
- Conflicts with parking practices, and pedestrian and bicycle activity
- Current level of enforcement

The manual recommended providing speed limits at increments of 10 mph rather than 5 mph. However, it does allow the use of speed limits at an increment of 5mph when justified. It recommends a minimum of a 0.3-mile-long speed zone. The transitional/step-down speed zones cannot be used unless there is a change in the physical characteristics of the roadway. Even if transitional speed zones are used, there should not be more than two step-downs. The speed limits of those step-downs should be based on the 85^{th} percentile speed.

The manual recommended measuring the spot speed of at least 15 vehicles during light to medium traffic conditions, instead of during rush hours in each direction. The spot speed should not be measured in intersections. If the speed test resulted in new speed limit, all the documents related to speed studies should be submitted to the department for approval. The manual also provides guidelines for setting up speed zones in schools zones and in intersections.

2.4.15 Wyoming DOT Speed-Zone Manual

To determine appropriate speed limit, the Wyoming DOT's *Traffic Studies Manual* (WYDOT, 2011) recommended the use of the FHWA (2012) MUTCD as well as a web-based tool developed by FHWA as part of National Cooperative Highway Research Program Project 3-67. WYDOT's traffic studies manual provides a separate section for determining the advisory speed for curves. The manual describes the two methods to determine the advisory speed for curves: the design speed method and the ball-bank indicator method. The ball banking method can be used for older roads without design detail; for newer roads with design details, the design speed equation can be used. Design speed method can be calculated if the curve radius, super-elevation, and side friction factor are known. For the ball-banking method, field experiments still have to be conducted. The manual also provides a method to determine advisory speeds for truck.

2.4.16 FHWA Manual on Uniform Traffic Control Devices (MUTCD)

The FHWA (2012) has prepared the MUTCD, which is approved as the National Standard. Section 2B.13 deals with speed limit signs, and gives some information about the procedure to establish a speed zone. According to the manual, a speed zone shall be established on the basis of an engineering study. The engineering study shall include an analysis of speed distribution of the traffic. If the speed limit is reduced by more than 10 mph, then a 'Reduced Speed Limit Ahead' sign should be posted to aware drivers. To reevaluate non-statutory speed limits, states and local agencies should conduct engineering studies for any significant changes in number of travel lanes, parking lanes, bicycle lanes, traffic control signal coordination, and traffic volumes.

It recommends a speed limit within 5 mph of the 85th percentile speed. For signalized intersections, speed studies should be conducted at about ½ mile from the intersection to avoid obtaining skewed results because of traffic control. Some of the factors that may be considered for setting new speed limit or revising existing ones are:

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

A changeable message sign displaying the speed limit or the speed of approaching driver may be installed. A sign displaying the speed of the approaching driver should be accompanied by the speed limit sign.

2.4.17 Institute of Transportation Engineers (ITE) Recommended Practices

In 1987, a taskforce was formed to develop guidelines in selecting segments of highway where the national speed limit of 55 mph could be raised (ITE, 1987). The proposal to upgrade the speed limit of a highway depended upon many factors; for example, it would not be appropriate to allow a speed limit of more than 55 mph for those interstate highways whose design speeds are lower in some segments. The task force found that after the U.S. Congress enacted the 55-mph national maximum speed limit in 1974, the U.S. fatality rate dropped abruptly. Nonetheless, the sharp drop in fatalities also was due to improvements in vehicle design, highway design, medical capability, availability of emergency medical service, driver behavior, and other factors. However, several factors relating to the 55-mph speed limit led to the reduced fatality rate. This speed limit reduced the average driving speed and variations in speed, and allowed more time to understand, react to situations and stop the vehicles.

2.4.18 NHTSA Highway Speed Management Guidelines No. 19

The NHTSA (2006) published the *Highway Safety Program Guideline No. 19* regarding speed management. This guideline describes the necessity of speed management and the various engineering countermeasures; communication strategies; enforcement countermeasures; and legislation, regulations, and policies to reduce the speed of vehicles. The guideline emphasizes compliance with the FHWA (2012) *Manual on Uniform Traffic Control Devices* (MUTCD) to establish speed limits, train traffic engineers related to speed management, and apply appropriate traffic-calming techniques for reducing speed in pedestrian areas. This report also stressed communication strategies to let drivers and road users know the consequences of speeding traffic. It also discussed the importance of enforcement measures in managing the speed of the vehicles. Finally, the report demanded that effective public policies be developed to support speed management strategies and countermeasures.

3 Crash Data Analysis

3.1 Crash Data Collection

In order to analyze the crash data, the 11 towns along rural highways of Nevada were identified by NDOT TAP. The towns under study were Alamo, Austin, Beatty, Fernley, Goldfield, Luning, McGill, Panaca, Schurz, Tonopah, and Searchlight. Crash data from April 1, 2001 to April 10, 2011 were obtained from the Nevada Citation and Accident Tracking System (NCATS), used by NDOT. However, data from only 9 calendar years, from 2002 to 2010, were analyzed to identify the factors associated with the crashes; in addition, the data was collected from crashes that occurred within the boundaries of these 11 communities.

The data obtained from NDOT contained a total of 38 variables, out of which 16 were independent variables. It should be noted that some data for these variables were not recorded for a number of crashes. Also, some variables were not applicable to all the crashes. For example, variables related to a secondary vehicle, such as, 'Secondary Vehicle Type' and 'Secondary Vehicle Action' were not applicable to crashes involving only one vehicle. Also, such variables as 'Factors Non-motor' was recorded for a very few crashes. Thus, those variables that have a very limited data set were not used in the analysis.

3.2 Crash Data Results

Overall statistics of the study are shown in Table 3-1. This table indicates that there were a total of three fatal crashes in all those towns combined. That means, on an average, one fatal crash occurred in each of the three years (= 9/3) in those towns. There was total of four fatalities in these towns, which results in one fatality in every two and a quarter years (=9/4). There were 11 non-fatal, injury-causing crashes and 26 PDO crashes per year. Overall, there are 37 crashes per year. Also, 15 people every year got injured in road crashes in those towns.

Table 3-1. Overall Crash Statistics of the 11 Towns Under Study

Details	No. of crashes				Fatalities & injuries		
	Fatal	Non-fatal injury-causing	PDO	Total	Fatalities	Injuries	Total
Total	3	96	238	337	4	134	138
Average/year	0.3	10.7	26.4	37.4	0.4	14.9	15.3

3.2.1 Crash Data by Town

The crash data of the 11 towns under study were compared and are presented as follows. Comparisons were based on the total crashes per year, total fatal crashes, and total non-fatal crashes (non-fatal injury causing crashes, PDO crashes, and average injuries) per year. Tabulated data are presented in the Appendix.

3.2.1.1 Total crashes per year

The average number of crashes per year that occurred in these towns is illustrated in Figure 3-1. Fernley had the highest number of crashes per year (10 per year), while Luning had the least (less than 1 per year).

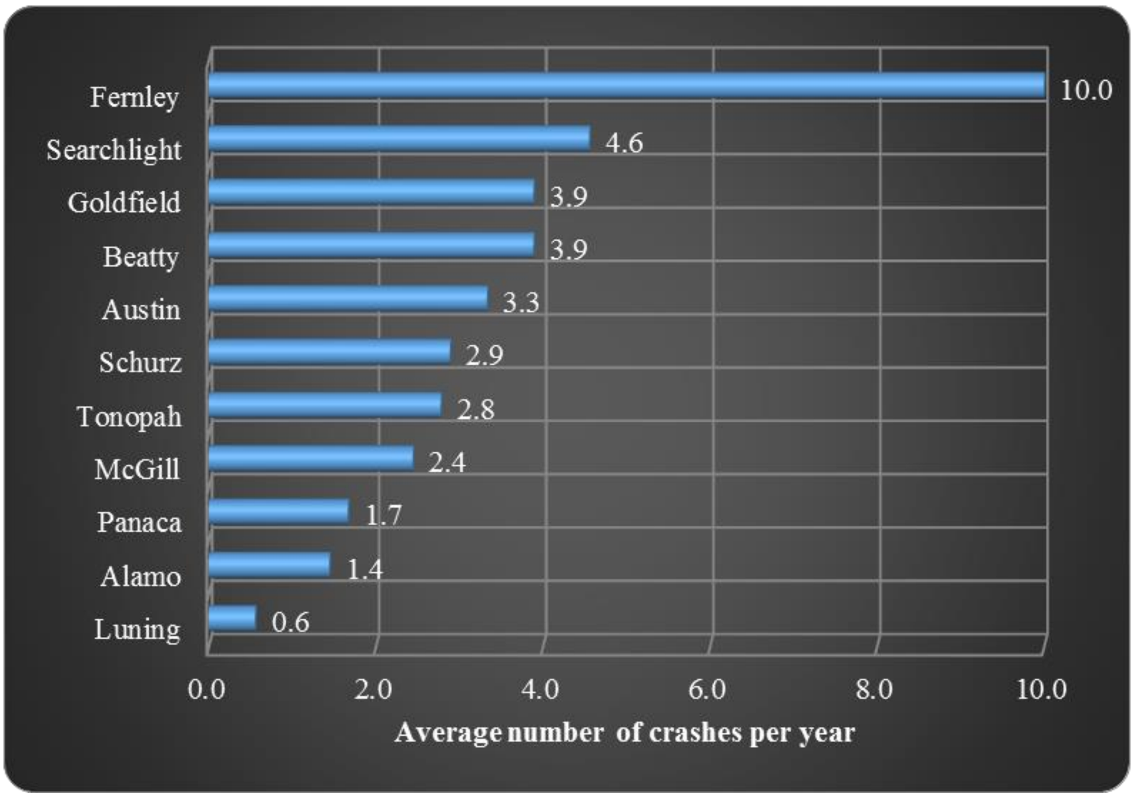

Figure 3-1. Average Number of Crashes per Year by Town.

3.2.1.2 Total fatal crashes during the 9-year period

Table 3-2 gives an overview of fatal crashes and fatalities. Fernley and Goldfield are the only towns where fatal crashes occurred during the 9-year period. There were a total of three fatal crashes, two in Fernley and one in Goldfield. The total number of fatalities in Fernley and Goldfield were three and one, respectively. No other towns had any fatal crashes during the 9-year period.

Table 3-2. Fatal Crashes and Fatalities by Towns

Town	No. of fatal crashes	No. of fatalities
Fernley	2	3
Goldfield	1	1
Total	**3**	**4**

3.2.1.3 Total non-fatal crashes per year

The non-fatal crashes were divided into non-fatal injury-causing crashes and PDO crashes. These crash data for each of these towns were analyzed to compare among the 11 towns. Figure 3-2 shows the average number of PDO crashes and non-fatal injury-causing crashes per year that occurred in these towns. The data showed that Fernley had the highest number of PDO crashes and non-fatal injury-causing crashes per year among all the towns under study.

The average number of PDO crashes per year per town was two. There were 7 PDO crashes per year in Fernley, whereas, the number of such crashes per year in Luning was less than one.

Twenty-two non-fatal injury-causing crashes occurred in Fernley, which accounted for about a quarter of all the non-fatal injury-causing crashes in all the towns, combined. There were no non-fatal injury-causing crashes occurring in Luning. Other towns had 3 to 13 non-fatal injury-causing crashes.

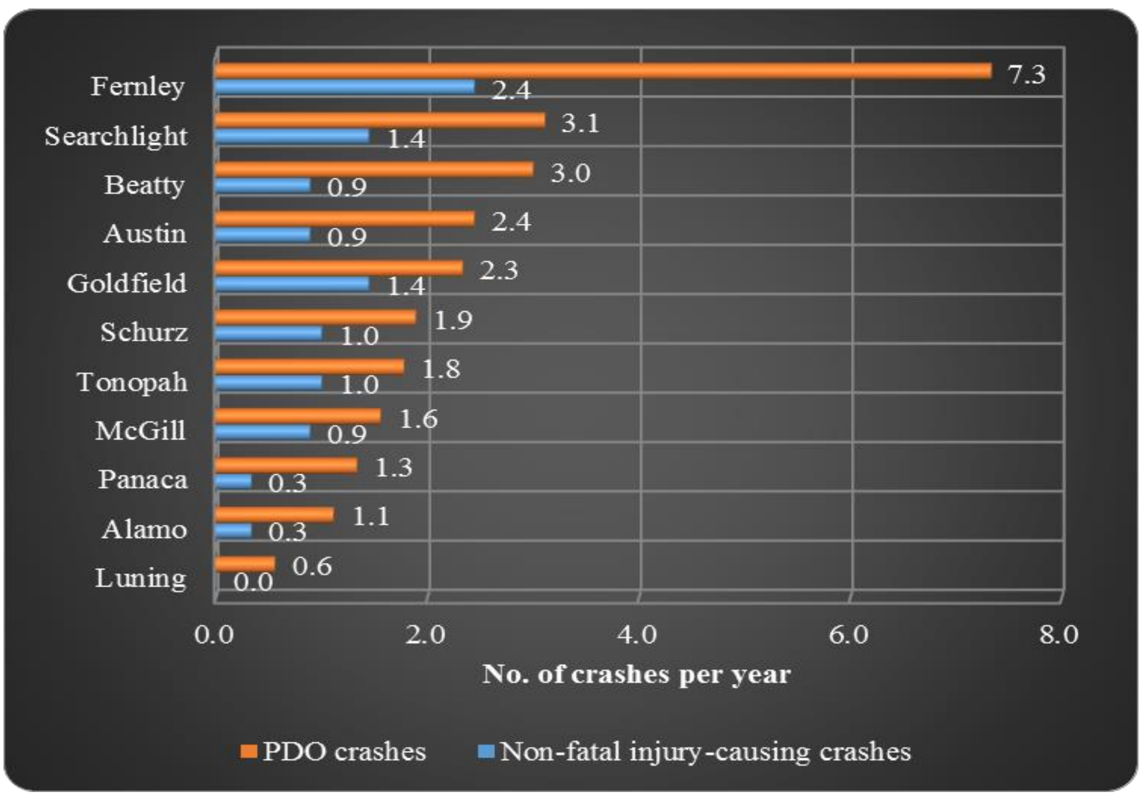

Figure 3-2. PDO Crashes and Non-fatal Injury-Causing Crashes per Year by Town.

Figure 3-3 shows the total number of injuries per year sustained due to the crashes. Fernley had the highest number of injuries per year (3.8/year) and Luning has zero injuries per year. There were 34 injuries caused by crashes in Fernley, whereas there were no injuries caused by crashes in Luning during the 9-year period.

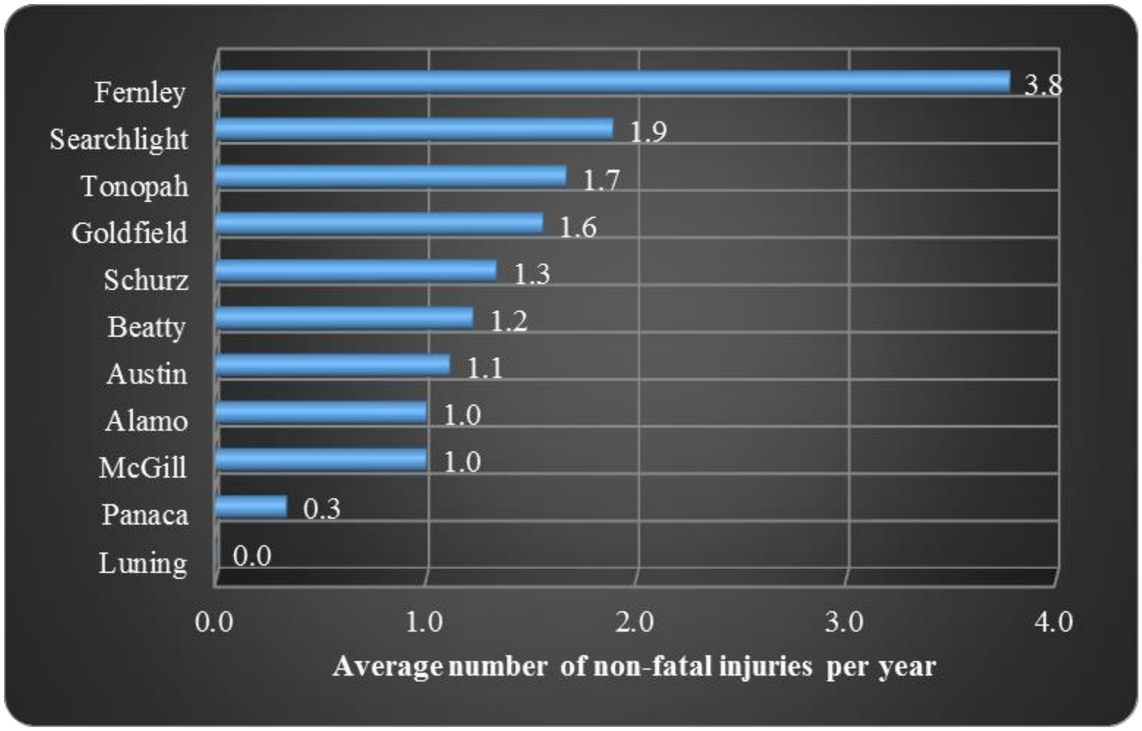

Figure 3-3. Number of Non-fatal Injuries per Year by Town.

3.2.2 Distribution of Crashes Based on Various Crash Factors

The crashes were analyzed in relation to various factors available in the crash data obtained from NDOT. The factors analyzed were road conditions, primary vehicle types, date and time variables, weather conditions, road lightning, primary driver factors, most harmful events, primary vehicle actions, crash types, and the total number of vehicles involved. The original crash data obtained from NDOT had various values for each of the factors under consideration. For simplification in this study, the number of possible values under each factor were combined together to create larger categories. For example, for the 'road conditions' factor, 13 unique values in the original crash data were combined together to create only 5 larger values. For instance, 'Wet' and 'Other: Wet' were combined together in the 'Wet' value to cover more conditions.

3.2.2.1 Road conditions

The various road conditions during the crashes are presented in Table 3-3. The data analysis showed that 87% of the crashes occurred while the road was dry. Six percent of the crashes occurred when there was snow or ice or slush on the road.

Table 3-3. Distribution of Crashes Based on Road Conditions

Roadway conditions	Crash count	Percentage
Dry	292	87%
Snow/Ice/Slush	19	6%
Wet	12	4%
Unknown	9	3%
Not recorded	3	1%
Sand/Mud/Dirt/Oil/Gravel	2	1%
Total	**337**	**100%**

3.2.2.2 Weather conditions

More than two thirds of the crashes occurred during clear weather (Table 3-4). About 16% of crashes occurred in cloudy conditions. The crashes that occurred during 'snow/silt/hail', rain, and severe crosswind were 4%, 2%, and 2%, respectively.

Table 3-4. Distribution of Crashes Based on Weather Conditions

Weather	Crash count	Percentage
Clear	235	70%
Cloudy	54	16%
Snow/slit/hail	15	4%
Unknown/others	12	4%
Rain	8	2%
Mixed	6	2%
Severe crosswinds	7	2%
Total	**337**	**100%**

3.2.2.3 Road lighting

Table 3-5 presents the percentage of crashes that occurred in various lighting conditions. More than half the crashes occurred in the daylight. About 16% of crashes occurred under dark conditions without any lighting.

Table 3-5. Distribution of Crashes Based on Road Lighting

Road Lighting	Crash count	Percentage
Daylight	201	60%
Dark - no lighting	55	16%
Dark - unknown lighting	36	11%
Dark - spot lighting	20	6%
Dusk	11	3%
Unknown	7	2%
Dawn	3	1%
Dark - continuous lighting	2	1%
Blank/Not reported	2	1%
Total	**337**	**100%**

3.2.2.4 Primary vehicle's most harmful events

Table 3-6 shows that 29% of total crashes occurred when the primary motor vehicle was in transport (i.e., in motion). Overturn and rollover together contributed to 14% of the total crashes. Crashes with slow and stopped vehicles accounted for 12% of the total crashes. Crashes because of animals (i.e., burros, cattle, and deer combined) accounted for 8% of total crashes.

Table 3-6. Distribution of Crashes Based on the Primary Vehicle's Most Harmful Events

Primary vehicle most harmful event	Crash count	Percentage
Motor vehicle in transport	99	29%
Overturn/rollover	46	14%
Slow/stopped vehicle	42	12%
Other	37	11%
Ran off road right	23	7%
Deer	18	5%
Other movable object	13	4%
Guardrail	11	3%
Highway traffic sign post	11	3%
Fence/wall	7	2%
Cattle	5	1%
Other non-collision	5	1%
Burro	4	1%
Other post, pole or support	4	1%
Parked motor vehicle	4	1%
Pedal cycle	4	1%
Ran off road left	4	1%
Total	**337**	**100%**

3.2.2.5 Collision types

More than half of the crashes were non-collision types. Seventeen percent of the crashes were rear-end collision crashes followed by angle and sideswipe (Table 3-7). Head-on collision crashes constituted just 2% of total crashes.

Table 3-7. Distribution of Crashes Based on Collision Types

Collision type	Accident count	Percentage
Non-collision	173	51%
Rear-end	56	17%
Angle	53	16%
Sideswipe	35	10%
Others	14	4%
Head-on	6	2%
Total	**337**	**100%**

3.2.2.6 Primary driver factor

Sixty-three percent of total crashes occurred when the primary vehicle driver was in a normal condition (Table 3-8). Eleven percent of crashes occurred because of the inattention of the primary vehicle driver. 'Falling asleep' accounted for the about 4% of crashes.

Table 3-8. Distribution of Crashes Based on the Primary Vehicle Driver Factor

Driver factor	Crash count	Percentage
Normal	212	63%
Others	54	16%
Inattention	38	11%
Had been drinking	20	6%
Fall asleep	13	4%
Total	**337**	**100%**

3.2.2.7 Primary vehicle actions

Fourteen types of primary vehicle actions that cause crashes have been categorized into seven larger categories. As shown in ion, 9%, involved turning left.

Table 3-9, about three-quarter of the crashes occurred while the primary vehicle was going straight. The second largest portion, 9%, involved turning left.

Table 3-9 Distribution of Crashes Based on the Primary Vehicle's Actions

Primary vehicle action	Crash count	Percentage
Going straight	249	74%
Turning left	31	9%
Turning right	16	5%
Passing other vehicle	15	4%
Other	14	4%
Changing lane	8	2%
Backing up	4	1%
Total	**337**	**100%**

3.2.2.8 Primary vehicle types

The top three types of primary vehicles – each involved in at least a tenth of the total number of crashes – were Sedans, Pickups, and Trucks with 38%, 24%, and 12% share of total crashes, respectively (Table 3-10). Vans accounted for the least number of crashes.

Table 3-10. Distribution of Crashes Based on Primary Vehicle Types Involved in the Crashes

Vehicle type	Crash count	Percentage
Sedan	129	38%
Pickup	80	24%
Truck	39	12%
Carry-all	26	8%
Semi	18	5%
Motorcycle	13	4%
Utility	12	4%
Others	9	3%
Van	7	2%
Unknown	4	1%
Total	**337**	**100%**

3.2.2.9 Total vehicles involved

Almost all of the crashes involved either one or two vehicles, as shown in

Table 3-11. Crashes involving one vehicle (52%) were more prominent than crashes involving two vehicles (45%). The crash data analyzed had only one crash that involved four vehicles.

Table 3-11. Distribution of Crashes Based on Number of Vehicles Involved

No. of vehicles involved	Crash count	Percentage
One	174	51.6%
Two	152	45.1%
Three	10	3.0%
Four	1	0.3%
Total	**337**	**100%**

3.2.2.10 Time factors

Crashes were categorized according to the time of the day, day, and month in which the crashes occurred. Tabulated data of time factors associated with crashes are presented in the Appendix. Figure 3-4 presents the hourly time distribution of the crashes that occurred in the nine years from 2002 to 2010. During the time interval of 2:00 PM to 3:00 PM and 4:00 PM to 5:00 PM, the maximum number of crashes occurred in these time intervals, which was about 8% of the total crashes. The number of crashes that occurred in the four hours of the peak zone from 2:00 PM to 6:00 PM accounted for about one third of the total crashes. The number of crashes (7%) that occurred during the time interval of 7:00 AM to 8:00 AM was also higher than any other time interval.

When the crash data were analyzed based on the days of the week (Figure 3-5). , the highest number of crashes (18%) occurred on Wednesday The minimum number of crashes can be observed on Saturday followed by Sunday with 11% and 13% of the total crashes respectively.

The crash data were also analyzed based on the month on which the crashes occurred. Figure 3-6 shows the distribution of crashes by months. The maximum number of crashes occurred during the month of October (12%) while the least number of crashes occurred during the month of February (4%). The number of crashes that occurred on March, June, September, and October exceeded 10% of the total crashes.

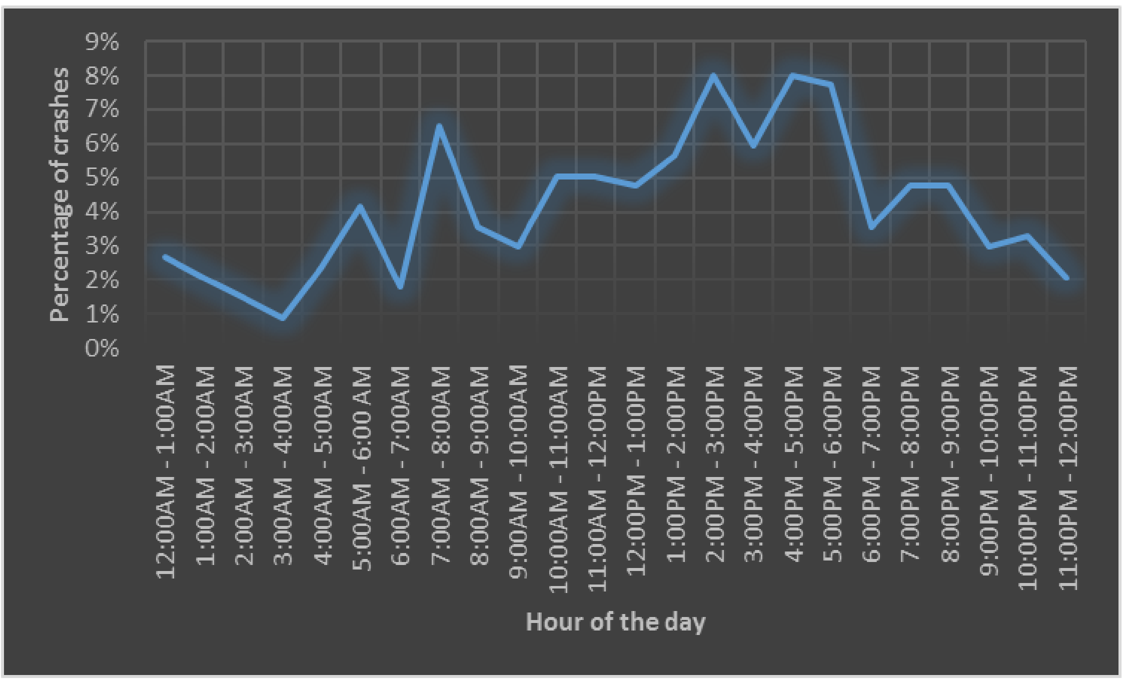

Figure 3-4. Distribution of Crashes by Hour.

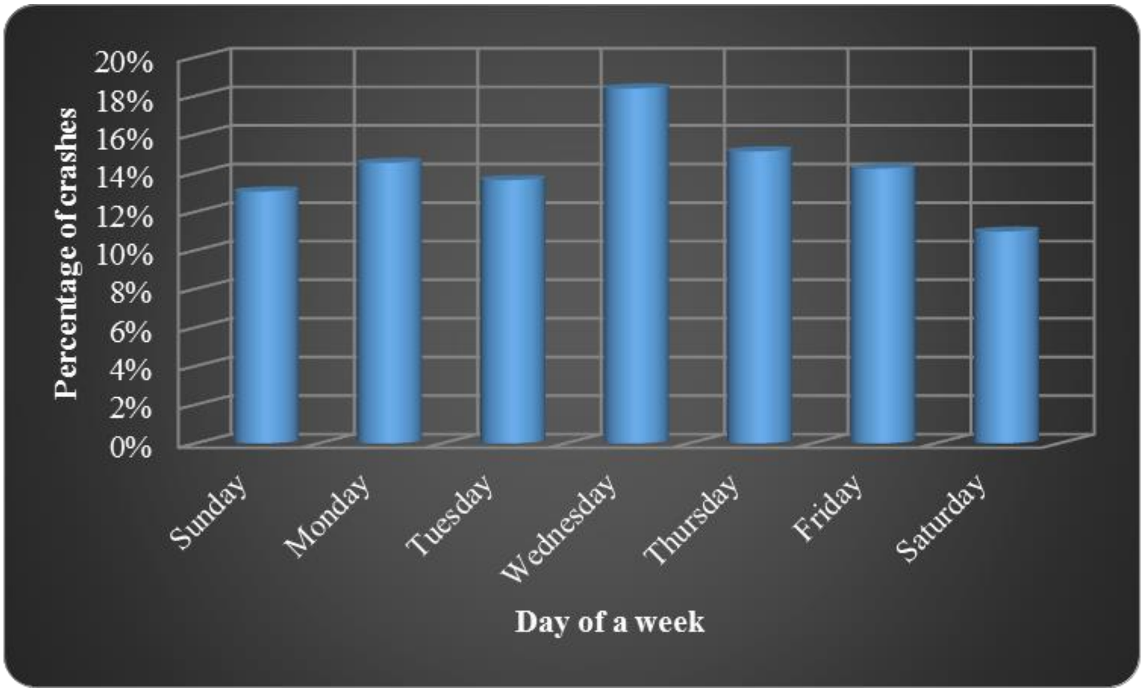

Figure 3-5. Distribution of Crashes by Day.

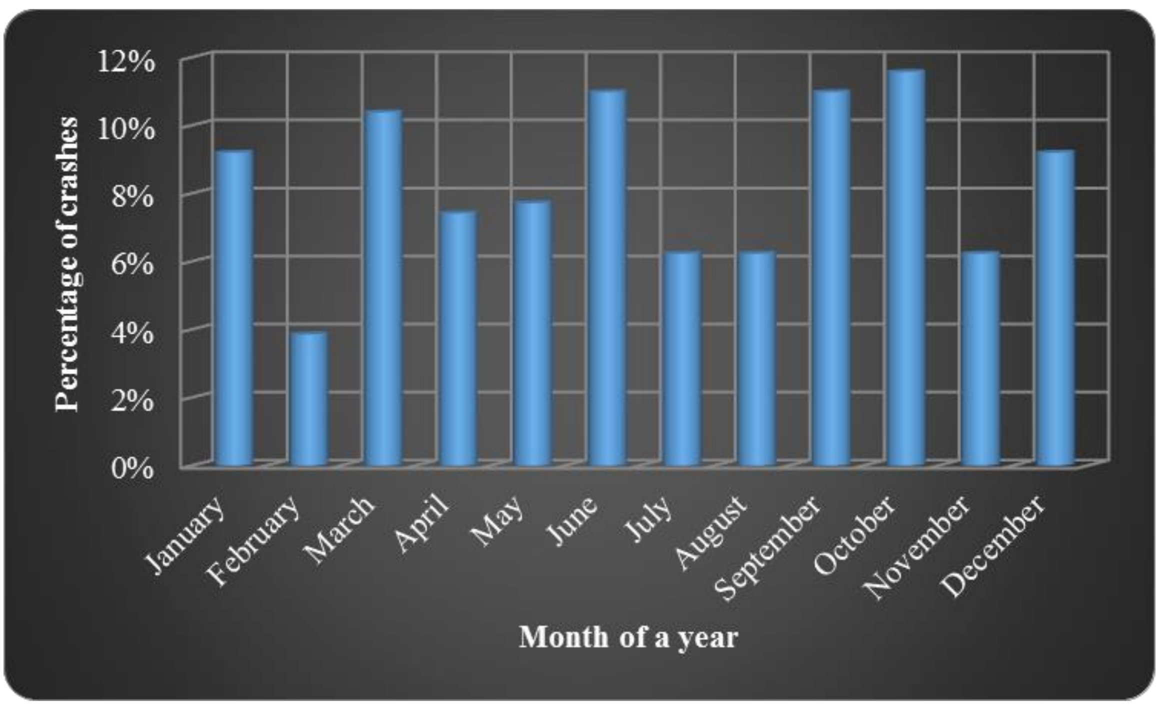

Figure 3-6. Distribution of Crashes by Month.

3.2.3 Crash Data Comparison

Additional data obtained from various sources were combined with the crash data obtained from NDOT in order to compare the crash statistics. The crash data of these towns were compared to NDOT statistics based on road mileage, population and percentage of fatalities.

3.2.3.1 Mileages and crashes

The 11 towns' crash data was analyzed based upon the crashes per 100 lane miles. Center line mileages for each town were calculated based on the length of highway for which crash data were obtained.

Table 3-12 shows the crashes per 100 lane mileages for these towns. The data showed that Fernley had the highest number of crashes per 100 miles, while Luning had the least.

Table 3-12. Mileage and Crash Statistics of the 11 Towns Under Study

Towns	Total crash count (2002-2010)	Center line mileage	No. of lanes	Total lane mileage	Crashes per 100 lane mileages
Fernley	90	3.12	2	6.24	1,442
Searchlight	41	3.00	2	6.00	683
Goldfield	35	4.00	2	8.00	438
Alamo	13	2.00	2	4.00	325
Schurz	26	2.00	4	8.00	325
Austin	30	5.00	2	10.00	300
McGill	22	4.00	2	8.00	275
Beatty	35	5.00	4	20.00	175
Panaca	15	3.00	4	12.00	125
Tonopah	25	5.16	4	20.64	121
Luning	5	3.00	2	6.00	83
Total	**337**	**39**		**109**	**310**

3.2.3.2 Annual Average Daily Traffic and Crashes

The number of crashes of these towns per 1,000 annual average daily traffic (AADT) is shown in Table 3-13. The data showed that Alamo has the highest number of crashes per 1,000 AADT (7.5), whereas Tonopah has the lowest crashes per 1,000 AADT (0.3). The highest number of crashes occurred in Fernley in between 2002 to 2010, however in terms of crashes per AADT, it is ranked 5th out of 11 towns.

Table 3-13. AADT and Crash Statistics of the 11 Towns Under Study

Name of Towns	Average Number of Crashes per year (2002-2010)	AADT (2000-2011)	Average Crashes per 1,000 AADT
Alamo	7.5	1,733	7.5
Austin	3.3	1,178	3.3
Goldfield	3.8	2,017	1.8
Panaca	1.7	1,064	1.6
Fernley	9.8	6,574	1.5
Beatty	3.9	3,000	1.3
Luning	2.2	2,285	0.9
Schurz	2.9	3,726	0.8
McGill	2.4	3,225	0.8
Searchlight	4.6	7,955	0.6
Tonopah	2.8	9,806	0.3

A comparative study of crash statistics per 100 miles of the 11 towns under study and all rural areas of Nevada is presented in Table 3-17. Those 11 towns combined had 44% more crashes per 100 miles than all the rural areas of Nevada combined. However, since very short mileages of the highways and corresponding areas of towns were considered for the 11 towns under study, the crashes per lane mile resulted in higher numbers. It should be noted that data from different years were used; i.e., the total rural crash count was from 2010, while the total rural lane mileage data was from the year 2009.

Table 3-14. Comparisons of Mileage and Crash Statistics Between Towns Under Study and All Rural Areas of Nevada

Towns	Total rural crash count (2010)	Rural lane mileage (2009)	Crashes per 100 miles
Eleven towns under study	28	109	26
All rural areas of Nevada	4,860	27,561	18

Source: NDOT (2012), FHWA (2011)

3.2.3.3 Populations and crashes

The average number of crashes per 1,000 population for a 9-year period was calculated for each town; these data are presented in Table 3-15. The data showed that Austin had the highest number of crashes per 1,000 population. Fernley had the lowest number of crashes per 1,000 population but highest number of total crashes during this 9-year period.

Table 3-15. Population and Crash Statistics of the 11 Towns Under Study

Town	Population (2010)	Total crash count (2002-2010)	Crashes per 1,000 population
Austin	192	30	156
Goldfield	268	35	131
Luning	50*	5	82
Searchlight	539	41	76
Schurz	658	26	40
Beatty	1,010	35	35
McGill	1,148	22	19
Panaca	963	15	16
Alamo	1,080	13	12
Tonopah	2,478	25	10
Fernley	19,368	90	5
Total	**27,754**	**337**	**12**

Source: U.S. Census Bureau (2012), Sperling (2013)
* Population of Luning as of 2012

Table 3-16 depicts a comparative overview of total crash statistics of the 11 towns under study and all rural areas of Nevada for the year 2010. For all 11 towns combined, there was only one crash for 1,000 population per year. For all the rural areas of Nevada, there were 31 crashes per 1,000 population per year. Comparing the statistics, fewer crashes occurred in the towns under study as compared to all rural areas of Nevada.

It should be noted that the populations of these eleven towns under study included the whole population of the town, while the crashes were only for limited mileages within these towns. In addition, for all rural areas of Nevada, the crash data were not limited to highways.

Table 3-16. Comparisons of Population and Crash Statistics (2010) between Towns under Study and All Rural Areas of Nevada

Location	Population	Crash count	Crashes per 1,000 populations per year
Eleven Towns under study	27,754	28	1
All rural areas of Nevada	156,754	4,860	31

Source: U.S. Census Bureau (2012), NDOT (2012)

3.2.3.4 Percentage of fatalities

Table 3-17 presents the fatality statistics of the 11 towns under study (2002 – 2010) and all rural areas of Nevada (2010). The data showed that there was higher percentage of fatal crashes with respect to total crashes in Nevadan rural areas (2%) than these 11 towns (0.89%). Due to the lack of data, crash statistics of only one year is used for all the rural areas of Nevada. It may be noted that during the nine-year period, two fatal crashes occurred in 2006 and one in 2003 in these 11 towns. Thus, there was no fatal crash from 2007 to 2010.

Table 3-17. Comparison of Percentage of Fatalities between towns under study and all rural areas of Neavada

Location	Fatal crashes	Crash count	Percentage of fatal crashes
Eleven towns under consideration (2002-2010)	3	337	0.89%
All rural areas of Nevada (2010)	97	4,860	2.00%

Source: NDOT (2012)

3.2.4 Crash Severity Prediction Models Using MNL Model

A MNL statistical model was developed to analyze the crash data to predict the 5 different levels of severity of crashes. The five levels of severities analyzed in the multinomial logit model were no injury or PDO, claimed, non-incapacitating, incapacitating, and fatal. In binary logit model, only non-fatal crashes were analyzed, and the response variable was no injury or PDO and injury. In the first model, 337 crash data were used; for the second model, 334 non-fatal crash data were used. The category codes used for the analysis are listed in Table 3-18.

Table 3-18. Category Codes Used to Develop Statistical Models for Predicting Crash Severities

Category code	Categories
weather	Weather
ctype	Crash Type
action	V1 Action
lighting	Lighting
vcount	Total Number of Vehicles
tgroup	4Hourly Time Categorization
day	Day Number of Week
month	Month Number
v1type	V1 Type
v1driverf	V1 Driver Factor
v1harmful	V1 Most Harmful Event
v1vehiclef	V1 Vehicle Factor

3.2.4.1 Multinomial logit model (MNL)

Four models were developed using MNL: claimed injury crash relative to PDO crash, non-incapacitating injury crash relative to PDO crash, incapacitating injury crash relative to PDO crash, and fatal crash relative to PDO crash. Only two models: claimed injury crashes relative to PDO crashes and non-incapacitating injury crashes relative to PDO crashes had statistically significant ($p < 0.05$) predictor variables. The model was developed using STATA software. In this model, the Relative Risk Ratios (RRRs) of the factors that significantly affect the crash severity were calculated. RRR showed the amount of relative risk involved in each variable considered.

The results showed that the crashes in January were nine times more likely to be claimed injury crashes as compared to crashes in June. In comparison to crashes on October, crashes on January were eight times more likely to be claimed injury crashes than PDO. The crashes being claimed were very high for motorcycles as compared to crashes involving cars, pickups/vans, or heavy vehicles. Also, the crashes caused by speeding were 18 times more likely to be a claimed crash than crashes caused by inattention.

Crashes caused by a primary vehicle passing another vehicle were 46 times more likely to be non-incapacitating crashes than crashes that occurred when primary vehicle was going straight. The results also showed that crashes that occurred on weekdays were 36 times more likely to be non-incapacitating than crashes that occurred on weekends.

Drunk drivers were seven times more likely to be involved in the non-incapacitating crashes than were the drivers during normal conditions. Speeding was less likely to cause non-incapacitating crashes as compared to inattention. In other words, inattention was likely to result in more severe crashes than speeding.

4 Site Data Collection and Analysis

4.1 Site Data Collection

For all the 11 towns under study, road-surface and roadside characteristics as well as spot speeds for the section of highways were collected. A simple measuring wheel was used to measure distances of various points along the highways. A guideline provided by NDOT was followed for spot speed data collection. A radar gun was used to collect speed data. Spot-speed data were collected separately for cars, trucks, and buses in each direction. Two locations were selected to collect spot speed data in Fernley, Searchlight, and Tonopah, in order to keep the angle between line of sight of the radar and travel direction of the vehicles less than 15°. In the remaining towns, only one location was chosen for each town. The spot speed locations were chosen so that the 85^{th} percentile speed, mean speed, median speed, and percentage exceeding posted speed were calculated from the spot speed data.

4.1.1 Location of Data Collection

Some of the site data collected included step down speed limits, school-zone speed limits, the overall roadside development environment, the presence of schools, the presence of pedestrian facilities, the type of median separator, weather conditions, the number of lanes, and lane widths. The forms used to collect site data are presented in the Appendix. Speed-zone maps were drawn for all the sites using the collected data and Google Maps. The details of the location of each towns where the spot speed was measured are presented in Table 4-1.

Table 4-1. Spot Speed Data Collection Location Details

Name of towns	Name of highway	District	Proposed by
Alamo	US 93	District I	NDOT
Austin	US 50	District III	NDOT
Beatty	US 95	District I	NDOT
Fernley	US 50A	District II	NDOT
Goldfield	US 95	District I	NDOT
Luning	US 95	District I	Researchers
McGill	US 93	District III	NDOT
Panaca	SR 319	District I	Researchers
Schurz	US 95	District II	Researchers
Searchlight	US 95	District I	Researchers
Tonopah	US 95	District I	Researchers

Most of the data were collected in July 2012 (Table 4-2). The scheduled date of data collection at Luning was July 13, 2012. However, due to the adverse weather on that day, the partial data collected during the day were not considered and spot speed data were recollected again on July 16. The spot speed survey in Panaca was conducted on October 8, 2012.

Table 4-2. Spot Speed Data Collection Time and Conditions

Town	Date	Day	Time	Weather
Alamo	7/232012	Mon	11:00 AM - 12:45 PM	Sunny
Austin	7/11/2012	Wed	12:00 AM - 4:00 PM	Sunny
Beatty	7/26/2012	Thu	10:30 AM - 12:48 PM	Sunny
Fernley	7/10/2012	Tue	8:30 AM onwards	Clear and sunny
Goldfield	7/17/2012	Tue	11:30 AM onwards	Sunny
Luning	7/13/2012	Fri	8:30 PM - 10:36 PM	Sunny
McGill	7/25/2012	Wed	8:45 AM - 10:19 AM	Sunny
Panaca	10/8/2012	Mon	12:45 PM - 3:30PM	Sunny
Schurz	7/12/2012	Thu	11:08 AM-12:08 PM	Sunny with partial cloud
Searchlight	7/27/2012	Fri	10:00 AM onwards	Sunny
Tonopah	7/16/2012	Mon	3:00 PM onwards	Little windy

4.1.2 Spot Speed Data Collection Criteria

A radar gun was used for collecting spot speed for the study. Two standard bars of 33.33 mph and 77.77 mph were provided for checking the calibration/accuracy of the radar gun. These radar guns were provided by NDOT. The set of criteria provided by NDOT was used for collecting spot speed data for this study. The criteria used are listed below:

- Spot speed data of a minimum of 50 vehicles per lane should be collected. However, the total duration of data collection should not exceed an hour per lane.
- The location of data collection should not be near an intersection, at a sharp horizontal curve, within a school zone, or near a cross walk.
- The angle between line of sight of the radar and travel direction of the vehicle should not be more than 15°.
- Every effort should be made to conceal the fact that speeds of the vehicles are being recorded. Speeds should be measured from an anonymously parked car so that drivers do not change their speed.
- The spot speed survey should be conducted on the weekdays from 8:00 AM to 5:00 PM.
- The survey should be conducted in favorable driving conditions. The spot speed data should not be collected during strong wind, snow, road maintenance, and other unfavorable driving conditions.

4.2 Site Data Results

Some of the roadway and roadside characteristics collected during the field visit included the width of roadway, number of lanes, number of access roads, number of buildings/houses/stores, the presence of pedestrian facilities, and the speed transition zone. Drawings were prepared showing the transition zones, their lengths, and the roadside environments, based on the data recorded in the field and the Google maps. The site drawings are presented in the Appendix.

4.2.1 Descriptive Statistics of Spot Speed Data

Table 4-3 shows that posted speed limits, 85^{th} percentile speeds, mean speeds, median speeds, and percentages of vehicles exceeding posted speed in these towns. The data showed that 85^{th} percentile speed limits were higher than the posted speed limits in all the towns except Alamo and Goldfield. The data also showed that mean speed was higher than the posted speed limit in six towns, namely, Austin, Beatty, Fernley, Panaca, Schurz, and Searchlight. Also, the median speed was higher than the posted speed limit in Beatty, Fernley, Panaca, Searchlight, and Schurz. Except for Goldfield and Alamo, more than 15% of traffic was travelling faster than the posted speed limit in all other towns. The percentage of traffic exceeding the posted speed limit ranged from 12% in Alamo to 84% in Fernley. For towns with a posted speed limit of 25 mph (Austin, Beatty, Fernley, Goldfield, McGill, and Searchlight), the 85^{th} percentile speed ranged from 25 to 30 mph. The mean speed as well as median speed for those towns ranged from 22 to 28 mph. The cumulative spot speed graph used to calculate the 85^{th} percentile speed is presented in the Appendix.

Table 4-3. Descriptive Statistics of Spot Speed Analysis

Town	Highway number	Posted speed (mph)	85^{th} percentile (mph)	Mean speed (mph)	Median speed (mph)	Percentage of vehicles exceeding posted speed
Alamo	US 93	50	49	45	45	12%
Austin	US 50	25	28	26	25	46%
Beatty	US 95	25	30	26	26	52%
Fernley	US 50A	25	30	28	28	84%
Goldfield	US 95	25	25	22	22	15%
Luning	US 95	35	37	34	34	36%
McGill	US 93	25	27	25	24	35%
Panaca	SR 319	25	33	27	26	52%
Schurz	US 95	30	35	32	31	54%
Searchlight	US 95	25	30	27	27	62%
Tonopah	US 6	25	28	25	25	43%

The percentage of vehicles exceeding posted speed limit by more than 0 mph, 5 mph, 10 mph, and 15 mph were calculated to determine the severity of the speeding problem in the towns. The results are shown in Table 4-4.

Table 4-4. Percentage of Vehicles Exceeding Speed Limit

Town	Highway number	Posted speed (mph)	85th percentile (mph)	Percentage of vehicles exceeding posted speed by more than			
				0 mph	5 mph	10 mph	15 mph
Alamo	US 93	50	49	11.7%	2.0%	0.4%	0.0%
Austin	US 50	25	28	45.8%	7.7%	0.0%	0.0%
Beatty	US 95	25	30	51.6%	15.2%	3.0%	0.3%
Fernley	US 50A	25	30	84.2%	15.2%	1.8%	0.0%
Goldfield	US 95	25	25	14.8%	1.3%	0.0%	0.0%
Luning	US 95	35	37	35.8%	6.6%	2.0%	1.3%
McGill	US 93	25	27	35.3%	1.7%	0.4%	0.0%
Panaca	SR 319	25	33	52.1%	24.6%	8.1%	1.9%
Schurz	US 95	30	35	53.9%	17.3%	3.7%	0.0%
Searchlight	US 95	25	30	62.3%	16.9%	2.1%	0.0%
Tonopah	US 6	25	28	42.6%	5.7%	0.6%	0.0%

4.2.2 Road and Roadside Characteristics

Road and roadside characteristics of the highways in towns under study were collected to determine any discrepancies in the transition speed zones of those towns. The characteristics of transition zones as a whole – speed zone and transition or step-down speed zone – as well as characteristics of speed zones only are presented in Table 4-5 through Table 4-11.

The transitional zones and speed zones of highways under study had varying lengths from 2,112 to 15,530 ft. There was a minimum of 18 to a maximum of 109 buildings nearby the highway. The closest building was at 8 ft from the roadway edge. On an average, the distance between neighboring access points was anywhere from 139 ft to 894 ft.

Table 4-5. Longitudinal Properties of the Highways Under Study

City	Highway no.	Length (ft)	Access points	Number of buildings	Distance of the closet building (ft)	Average distance per access point
Alamo	US 93	6,624	18	18	> 20	368
Austin	US 50	7,478	25	59	16	299
Beatty	US 95	11,766	27	74	10	436
Fernley	US 50A	15,530	42	20	14	370
Goldfield	US 95	5,279	38	53	16	139
Luning	US 95	2,112	8	21	13	264
McGill	US 93	11,270	24	109	8	470
Panaca	SR 319	9,488	16	20	> 20	593
Schurz	US 95	15,192	17	14	>20	894
Searchlight	US 95	9,450	13	23	15	727
Tonopah	US 6	9,690	38	71	> 20	255

The lane width and shoulder width of highways are presented in Table 4-6. The widths of the shoulders vary at different locations of each highway. The table shows the range of road width along the town.

Table 4-6. Road Sectional Properties of the Highways Under Study

City	Highway no.	Lane width (ft)	Shoulder width (ft)
Alamo	US 93	12	11 or less
Austin	US 50	12	11 or less
Beatty	US 95	12	5.5 or less
Fernley	US 50A	12	11 or less
Goldfield	US 95	12	11 or less
Luning	US 95	12	11 or less
McGill	US 93	12	8 or less
Panaca	SR 319	12	3
Schurz	US 95	12	6 or less
Searchlight	US 95	12	11 or less
Tonopah	US 6	12	11 or less

The number of access points in Table 4-7 included access points on both sides of the road. Any street with access on both sides of the highway was counted as two access points. The access point count included paved as well as unpaved roads. Alamo was the only town without the pedestrian access (e.g., a crosswalk) within the transitions and speed zone.

Table 4-7. Surrounding Characteristics of the Highways

City	Highway no.	Access points	Number of buildings	Distance of closest building (ft)	Presence of bus stop	Presence of pedestrian access
Alamo	US 93	18	18	> 20	No	No
Austin	US 50	25	59	16	No	Yes
Beatty	US 95	27	74	10	No	Yes
Fernley	US 50A	42	20	14	No	Yes
Goldfield	US 95	38	53	16	No	Yes
Luning	US 95	8	21	13	No	Yes
McGill	US 93	24	109	8	Yes	Yes
Panaca	SR 319	16	20	> 20	Yes	Yes
Schurz	US 95	17	14	>20	No	Yes
Searchlight	US 95	13	23	15	No	Yes
Tonopah	US 6	38	71	> 20	No	Yes

4.2.3 Traffic Sign and Traffic Control Devices along Transition Zone of the Towns

None of the transition and speed zones of the towns under study had speed humps. There was an electronic speed display system at Searchlight, displaying the speeds of travelling vehicles. The speed-up (which is same as step down in reverse order) for two transition zones of each towns and traffic signs used in the transition zones of each towns are shown in Table 4-8.

Table 4-8. Speed Reduction Signs along the Transition Zone of the Towns

Town	Highway no.	Speed signs in transition zone I (mph)	Speed signs in transition zone II (mph)	Speed reduction signs	Speed humps
Alamo	US 93	70, 50	50, 70	Reduced speed ahead	No
Austin	US 50	45, 35, 25	25, 35, 45, 55, 70	Reduced speed ahead	No
Beatty	US 95	75, 50, 45, 35, 25*	25, 45, 70	-	No
Fernley	US 50A	65, 55, 45, 35, 25	25, 35, 45, 55, 70	Reduced speed ahead	No
Goldfield	US 95	70, 45, 35, 25	25, 35, 45, 70	Reduced speed ahead	No
Luning	US 95	70, 50, 35	35,50, 70	Reduced speed ahead	No
McGill	US 93	60, 45, 35, 25	25, 35, 45, 55, 70	Reduced speed ahead, Flashing light for school zone	No
Panaca	SR 319	45, 25	25, 55, 65	-	No
Schurz	US 95	70, 55, 45, 40, 30	30, 40, 50, 60, 70	Reduced speed ahead	No
Searchlight	US 95	70, 50, 25	25, 35, 45, 50, 65	Reduced speed ahead with flash light, Flashing speed of vehicle	No
Tonopah	US 6	70, 55, 45, 35, 25	25, 35, 45, 70	Reduced speed ahead	No

* In transition zone I, Beatty have 75, 50, 35, and 25 when stepping down but when stepping up, the speed limits are 25, 35, 45, and 75.

All the highways under study had undivided, painted medians, and the number of lanes varied from two to four (Table 4-9). Fernley, Searchlight, Tonopah, and Alamo had left-turning traffic lanes. The length of speed zones varied from a minimum of 3,081 ft to a maximum of 9,880 ft.

Table 4-9. Characteristics of the Speed Zones

Town	Posted speed limit (mph)	Total number of lanes	Divided/ Undivided	Median Type	Left turning traffic lane	Speed-zone length (ft)
Alamo	50	2	Undivided	Painting	Yes	6,624
Austin	25	2	Undivided	Painting	No	6,590
Beatty	25	4	Undivided	Painting	No	7,845
Fernley	25	2	Undivided	Painting	Yes	4,540
Goldfield	25	2	Undivided	Painting	No	6,350
Luning	35	2	Undivided	Painting	No	3,935
McGill	25	2	Undivided	Painting	No	6,350
Panaca	45	2	Undivided	Painting	No	4,720
Schurz	30	2	Undivided	Painting	No	3,081
Searchlight	25	4	Undivided	Painting	Yes	4,150
Tonopah	25	4	Undivided	Painting	Yes	9,880

The presence of horizontal and vertical curve in the transition zones are presented in Table 4-10.

Table 4-10. Presence of Curves in Transition Zone

Town	Highway no.	Presence of horizontal curve	Presence of vertical curve
Alamo	US 93	Yes	Yes
Austin	US 50	Yes	Yes
Beatty	US 95	Yes	No
Fernley	US 50A	Yes	No
Goldfield	US 95	Yes	Yes
Luning	US 95	Yes	Yes
McGill	US 93	Yes	No
Panaca	SR 319	Yes	Yes
Schurz	US 95	Yes	Yes
Searchlight	US 95	Yes	Yes
Tonopah	US 6	Yes	Yes

Table 4-11 presents the speed-zone data: whether the pedestrian interaction and train crossing was controlled or uncontrolled along with the length of the speed zone.

Table 4-11. Highway Speed-Zone Data – Pedestrian Interaction, Train Crossing, and Speed-Zone Length

Town	Pedestrian/Cyclist Interaction (Controlled/Uncontrolled)	Train Crossing (Controlled/Uncontrolled)	Speed-zone length (ft)
Alamo	Uncontrolled	No	6,624
Austin	Uncontrolled	No	6,590
Beatty	Controlled	No	7,845
Fernley	Uncontrolled	Controlled	4,540
Goldfield	Controlled	No	6,350
Luning	Uncontrolled	No	3,935
McGill	Controlled	No	6,350
Panaca	Uncontrolled	No	4,720
Schurz	Uncontrolled	Controlled	3,081
Searchlight	Controlled	No	4,150
Tonopah	Uncontrolled	No	9,880

4.2.4 Correlations Between Crashes and Speed Values

A correlation analysis was performed to determine the relationship between different types of crash counts and the number of injuries, with various speed related factors, such as 85th percentile speed, percentage of vehicles exceeding speed limit, mean speed, and median speed. The coefficient of correlation shows the relationship between two variables. A positive value of coefficient of correlation represents that an increase in value of one variable increases the value of the other variable, and vice versa. The speed data of 2012 was used to determine the correlation with historical crash records from 2002-2010. The assumption was that the trend of speeding has remained the same over time in each of those towns.

Table 4-12 shows the results of the correlation test. The results showed that the number of crashes decreases as the posted, 85th percentile, mean, and median speed increases. However, none of the results were significant at alpha level 0.05. The correlation test results also showed that the number of crashes increases as the percentage of vehicles exceeding posted speed limit increases. The result is significant at alpha level 0.05. Figure 4-1 shows the scatter plot between the number of crashes and percentage of vehicles exceeding posted speed limit. Thus, the increase in percentages exceeding the posted speed increases the number of different types of crashes. This correlation is significant at alpha level 0.05, except for non-fatal injury-causing crashes. The tabulated data as well as corresponding scatterplots are presented in the Appendix.

Table 4-12. Overview of All Coefficients of Correlation

Coefficient of correlation between two parameters	Percentage of vehicles exceeding posted speed	Posted speed (mph)	85th percentile speed (mph)	Mean speed (mph)	Median speed (mph)
No. of crashes	0.69	-0.41	-0.39	-0.32	-0.30
p-value	0.01*	0.20	0.24	0.34	0.37
No. of non-fatal injury-causing crashes	0.57	-0.49	-0.52	-0.44	-0.42
p-value	0.06	0.12	0.10	0.17	0.19
No. of injuries	0.58	-0.30	-0.30	-0.22	-0.20
p-value	0.05*	0.37	0.36	0.51	0.55
No. of PDO crashes	0.72	-0.38	-0.33	-0.26	-0.25
p-value	0.01*	0.24	0.32	0.43	0.46

* significant at alpha level 0.05

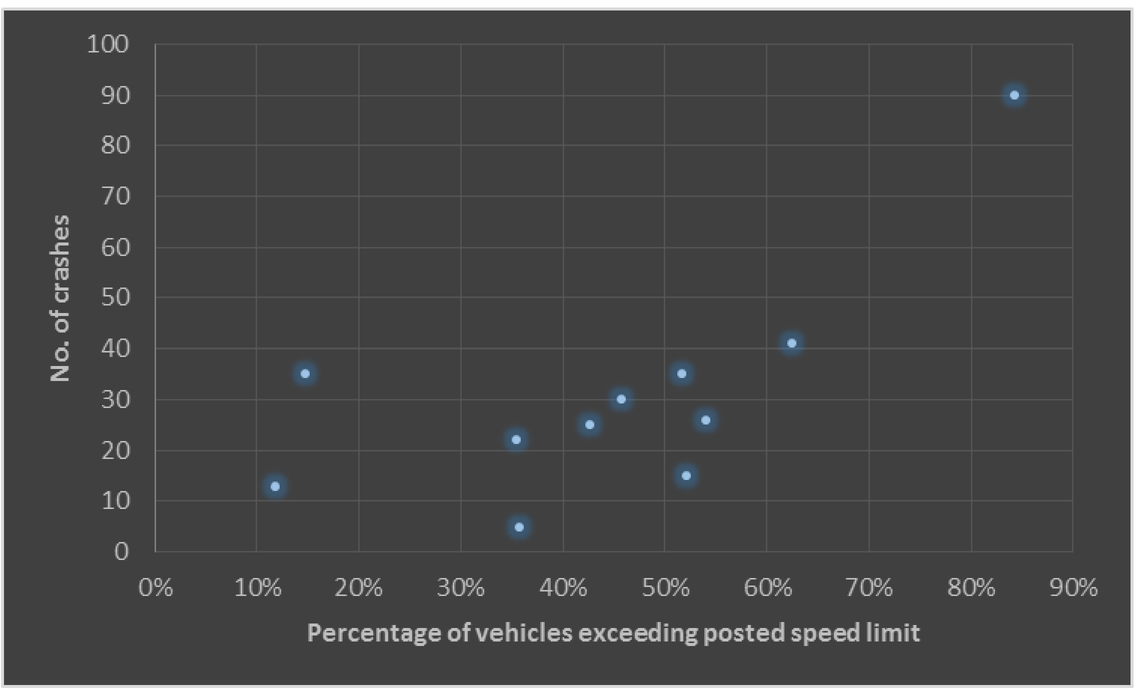

Figure 4-1. Scatterplot of the Number of Crashes Versus the Percentage of Vehicles Exceeding the Posted Speed Limit.

5 Questionnaire Survey Data Analysis

5.1 Data Collection

To determine the recent best practices for providing speed zones, a questionnaire was prepared and sent to NDOT TAP for their feedback. After the feedback, the questionnaire was updated and sent to state DOT representatives. The questionnaire contained six different sections:

- General information
- Rural state highways and crash data
- Speed-zone legislature
- Speed-zone guidelines or manuals
- Traffic engineer's personal view
- Issues of local communities

The first section of the survey contained questions regarding contact information of the state DOT representatives who responded to the questionnaire. The information collected in this section was not used for any analysis. The second section included seven questions related to the total mileage of highways and crash statistics of the state. The information collected in this section was used to compare crash statistics of different states. The third and fourth sections were designed to collect information about current speed-zone manuals and legislation related to speed zones in various states. Personal views of traffic personnel were collected in the fifth section. This section collects the opinions of traffic personnel regarding various issues related to speed zones. The last section contained questions about the current scenario of community complaints regarding speed zones in their states.

The questionnaire was prepared and sent as a document file. It allows multiple persons in each DOT to fill in different sections of the questionnaire. Also, it allowed each DOT to stop and continue the questionnaire at any time, as compared to online surveys. The full questionnaire is in the Appendix.

5.2 Survey Questionnaire Results

All 49 state DOTs, except NDOT, were contacted by email for the questionnaire. Questionnaires were sent during the summer of 2012, and follow ups were conducted until October 2012 by means of emails and phone calls. As shown in Table 5-1, 37 questionnaire responses were received; two states refused to fill out the questionnaire because of their limited time and resources. The remaining 10 states did not provide any response, even after multiple follow-ups.

Table 5-1. Questionnaire Survey Response Statistics

Detail	Count	Percentage
Questionnaire response received	37	76%
Refused to fill out questionnaire	2	4%
Not responded after multiple follow ups	10	20%
Total questionnaire sent	**49**	**100%**

5.2.1 Crashes and Fatalities vs. Miles

DOT representatives were asked to provide average annual crash records from the past five years. Some DOTs provided partial answers while others did not provide any numbers. In addition, few DOTs provided data based on fewer than five years' duration.

Table 5-3 presents a general overview of crash statistics. Michigan had the highest average annual crashes per 1,000 miles on rural state highways, while Maine had the lowest average annual crashes per 1,000 miles. Similarly, Arizona had the highest average annual fatalities per 1,000 miles on rural state highways, while Maine had the lowest. Seventy-five percent of crashes in West Virginia occurred on rural state highways. Only one percent of crashes in Massachusetts occurred on rural state highways. It also can be seen that 89% of the total fatalities that occurred on rural highways in Montana was the highest among all the states. Massachusetts had only 4% of the total crashes that occurred on rural state highways, which is the least of all.

Statistics for Nevada were calculated for 2010 from NDOT (2012) and FHWA (2011). Nevada had 176 average annual crashes per 1000 mile for rural state highways. This is the least number of crashes compared to any other states listed in the table. The average annual fatalities per 1000 mile for rural state highways of Nevada was nine; this is more than that of other three states (West Virginia, Pennsylvania, and Maine) and equal to that of Maryland. The average annual crashes (rural/total) was 9%. This is more than that for Massachusetts, Rhode Island, and Maine. The average annual fatalities (rural/total) was 41% which is higher than that of 8 other states, and equal to Arkansas and Iowa.

Table 5-2. Crashes and Fatalities per 1,000 Miles in Rural State Highways for Different States

States	Average annual crashes/1,000 miles for rural state highways	Average annual fatalities/1,000 miles for rural state highways	Average annual crashes (rural/total) %	Average annual fatalities (rural/total) %
Michigan	4,855	23	11%	17%
Arizona	3,938	84	20%	55%
Wisconsin	3,781	28	44%	54%
Rhode Island	3,750	33	3%	19%
Indiana	3,241	29	47%	63%
Georgia	2,492	34	11%	35%
Colorado	2,399	27	39%	67%
South Carolina	2,146	18	60%	61%
Mississippi	2,023	44	27%	57%
Massachusetts	1,993	19	1%	4%
Hawaii	1,949	47	25%	34%
Kentucky	1,834	19	37%	58%
Alabama	1,719	51	10%	44%
Delaware	1,598	-	23%	-
Iowa	1,414	21	20%	41%
Louisiana	1,386	25	19%	52%
North Carolina	1,247	12	43%	69%
Kansas	1,213	16	50%	72%
Ohio	1,135	24	58%	83%
Wyoming	1,044	17	42%	73%
Oregon	1,021	26	40%	76%
West Virginia	978	8	75%	71%
Missouri	838	15	33%	53%
Pennsylvania	823	6	27%	17%
Arkansas	765	17	21%	41%
Texas	713	20	21%	54%
New Mexico	681	31	18%	-
Nebraska	654	11	49%	85%
Virginia	644	11	24%	64%
Montana	617	13	68%	89%
Maryland	584	9	19%	32%
Maine	285	2	7%	11%
Illinois	-	-	15%	44%
Average	**1,680**	**24**	**31%**	**51%**

5.2.2 Top Reasons for Crashes on Rural Highways

DOT representatives were asked to list the top reasons for crashes, based upon the crash statistics of the state. Out of 143 categories of responses, 97 were categorized into 8 categories, each with at least 5 responses. Other responses were unique; they could be categorized under any of those 8 categories, and did not have at least 5 repetitions in order to be categorized into any other categories.

Eighteen DOT representatives mentioned 'Speeding' and 'Fatigue and inattention' as the top two reasons for crashes (Table 5-3). 'Failure to yield' was seen as third most important reason. Other important reasons mentioned by the DOT representatives were 'Run off lane/road', 'Driving under Influence,' 'Following too close,' 'Animal or object in road way,' and 'Turning related.'

Table 5-3. Top Reasons for Crashes

Top reasons	Count	Percentage
Speeding (including too fast for the condition)	18	49
Fatigue and inattention	18	49
Failure to yield	17	46
Run off lane/road	11	30
Driving under influence (DUI)	10	27
Following too close	10	27
Animal/object in roadway	8	22
Turning related	5	14

The survey respondents rated the most important reasons for the crashes. The reason considered as the most important (i.e., mentioned at the top by responders) was given a rating of 5, and the reason considered as the least important was given a rating of 1. In some cases, more than one reason provided by a particular DOT were categorized into the same category.

Based on average ratings, 'Fatigue and inattention' is the most important reason for crashes followed by 'Run off lane/road,' 'Failure to yield,' 'Turning related,' and 'Animal/object in roadway' (Figure 5-1). 'Speeding' is ranked sixth in the list followed by 'DUI' and 'Following too close.'

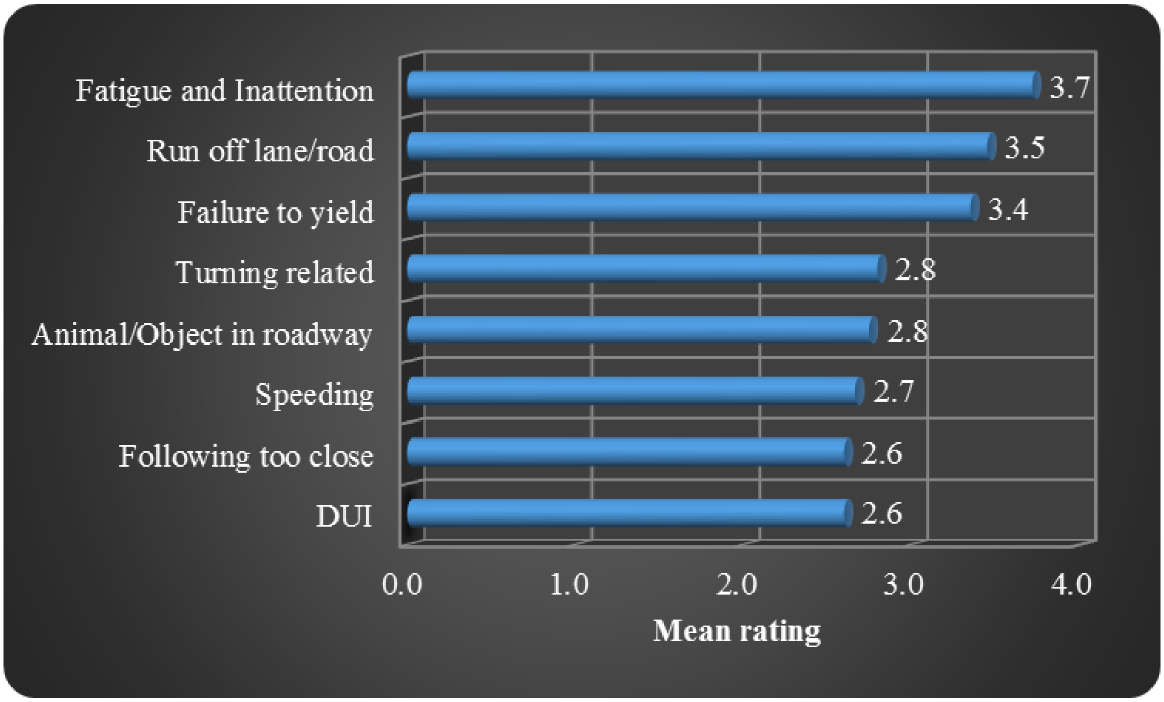

Figure 5-1. Average Ratings of Reasons for Crashes.

5.2.3 State Speed-Zone Legislature

Out of 37 DOTs that responded, 23 states mentioned that they had state statutes that mandate speed zones in the towns on rural state highways (Figure 5-2). More than half of the states that responded the survey had the speed-zone statutes.

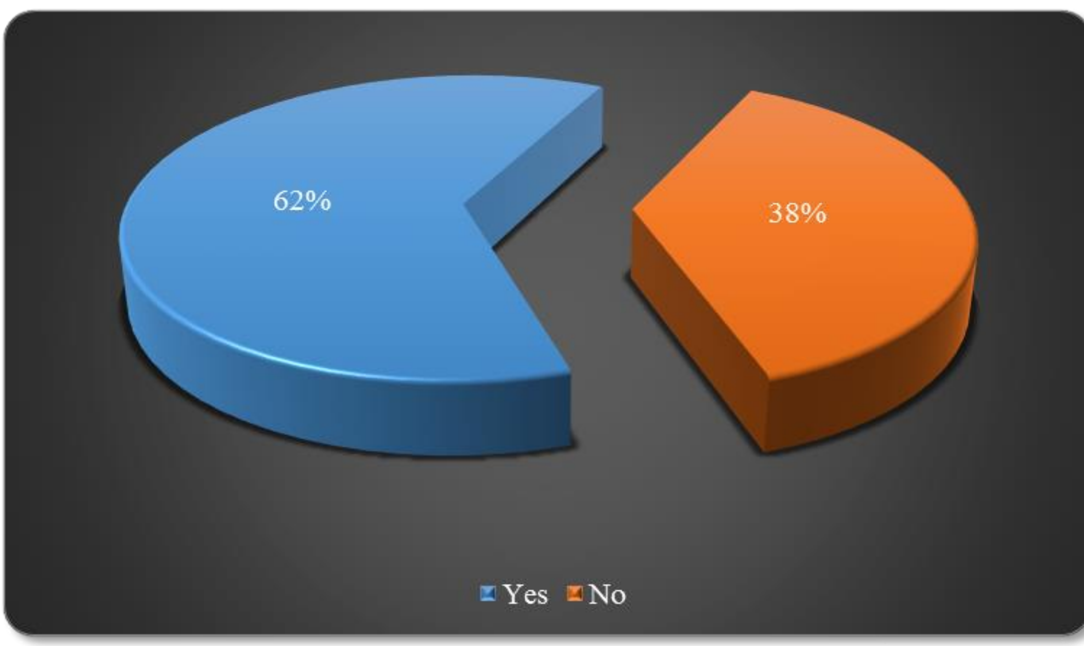

Figure 5-2. Presence of State Statutes That Mandate The Speed Zone in Towns on Rural State Highways.

The state DOTs were asked whether they required engineering and traffic investigations before changing the speed limit in highways. Almost all of the DOTs (92%) were required to conduct some sort of engineering and traffic investigation before the alteration (Figure 5-3). Only three DOTs responded that they don't need these studies to change the speed limit of highways.

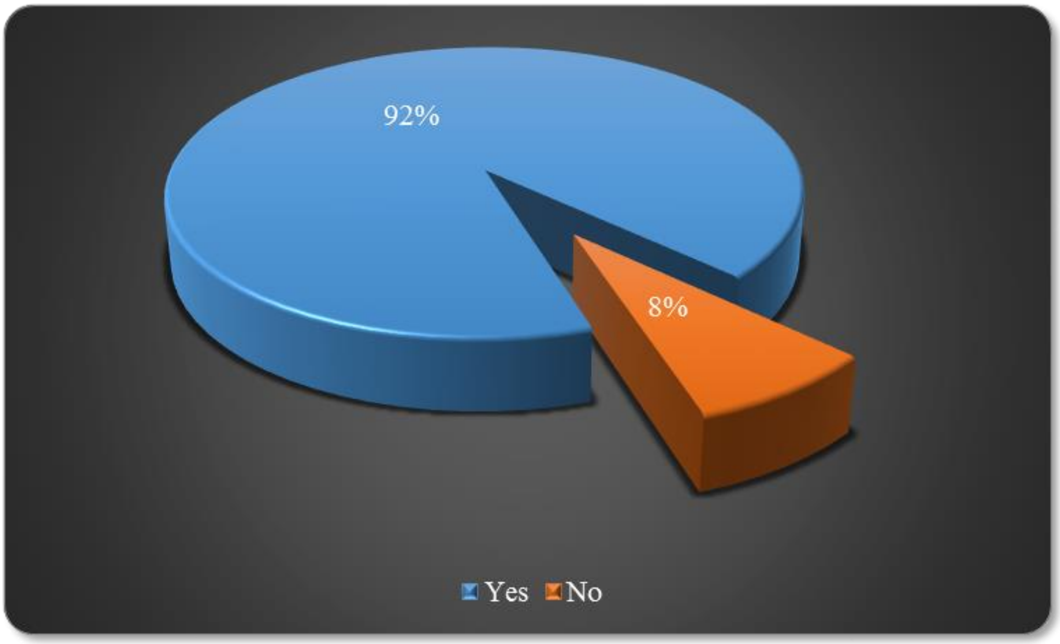

Figure 5-3. Engineering and Traffic Investigation Required Before Alteration of a Speed Zone.

Regarding the questions related to speed zone guidelines, the survey results showed that about half of the states had speed-zone guideline or manual of some form while the other half did not have such guidelines or manuals (Figure 5-4).

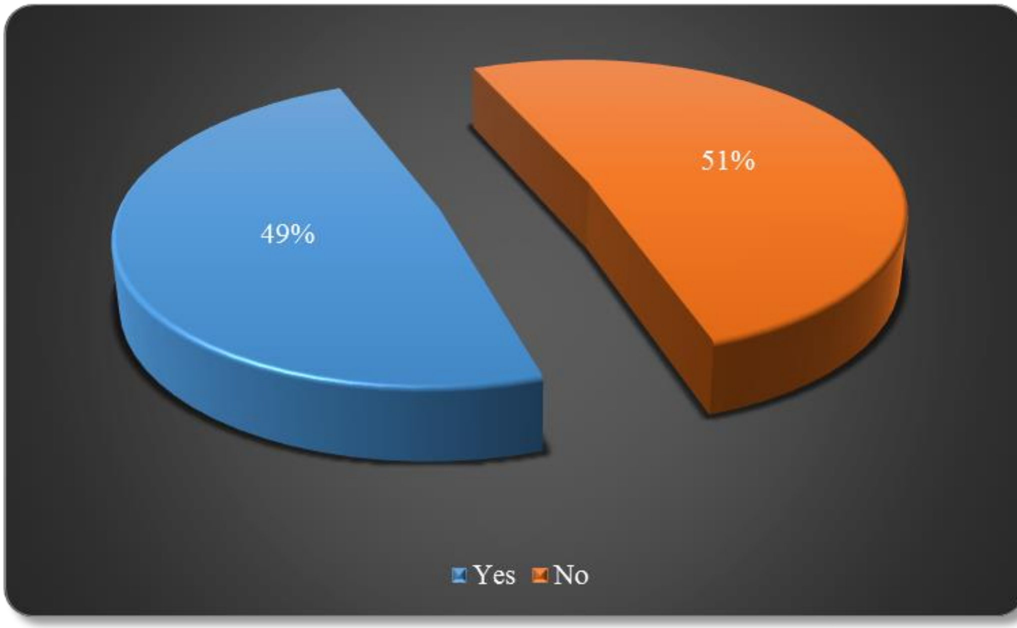

Figure 5-4. Presence of a Speed-Zone Guideline or Manual.

The survey asked whether there was a difference between the speed manual and legislature mandated speed guidelines. Out of 18 DOTs that had some form of a speed guideline or a manual, and 11 DOTs (61%) had some differences between speed-zone legislature and the speed-zone guideline or manual (Figure 5-5).

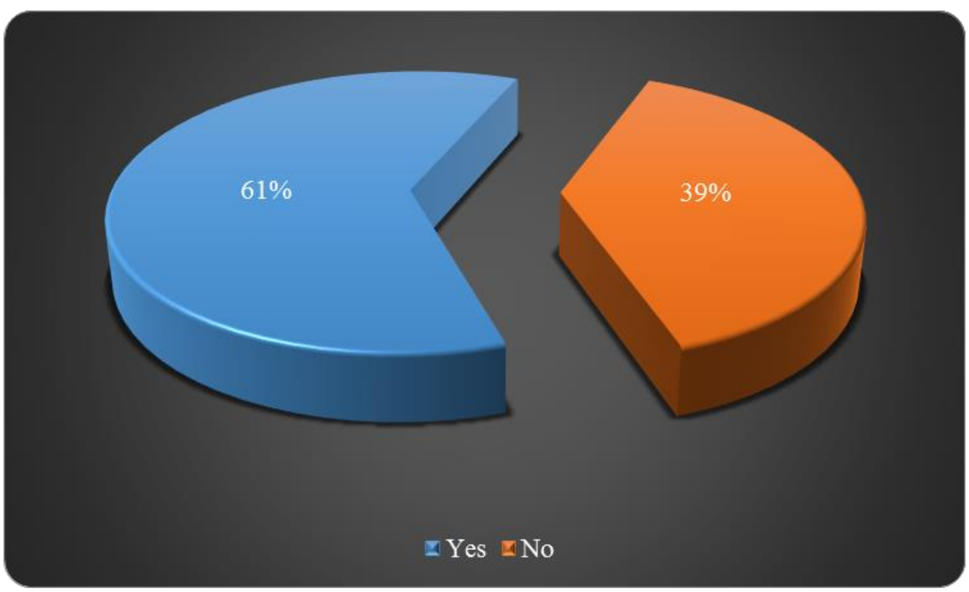

Figure 5-5. Difference Between Speed-Zone Legislation And a Speed-Zone Guideline Or Manual.

Among 18 DOTs that had some form of a speed-zone guideline or manual, only 33% of the DOTs always used it to determine the speed zone of towns in rural highways (Figure 5-6). Twenty-eight percent of DOTs used it most frequently, 5% of DOTs used it frequently and 6% seldom used it. Twenty-eight percent of DOTs did not provide any response to the question.

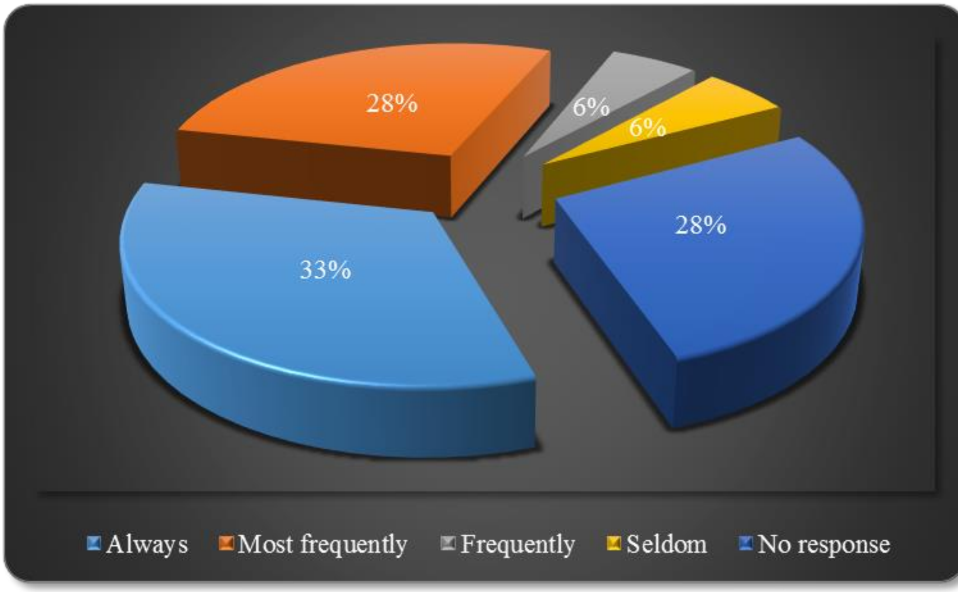

Figure 5-6. Use of a Speed-Zone Guideline Or Manual for DOTs That Had Speed-Zone Guidelines Or Manuals.

Fifty-seven percent of DOTs that provided a response to the questionnaire said they enforced speed limits in the towns (Figure 5-7). The enforcement they are referring to is police enforcement in towns that have speed limits. Most of the DOTs had some mechanism to enforce speed limits in towns along rural highways, which is essential to control the speed of vehicles in these towns.

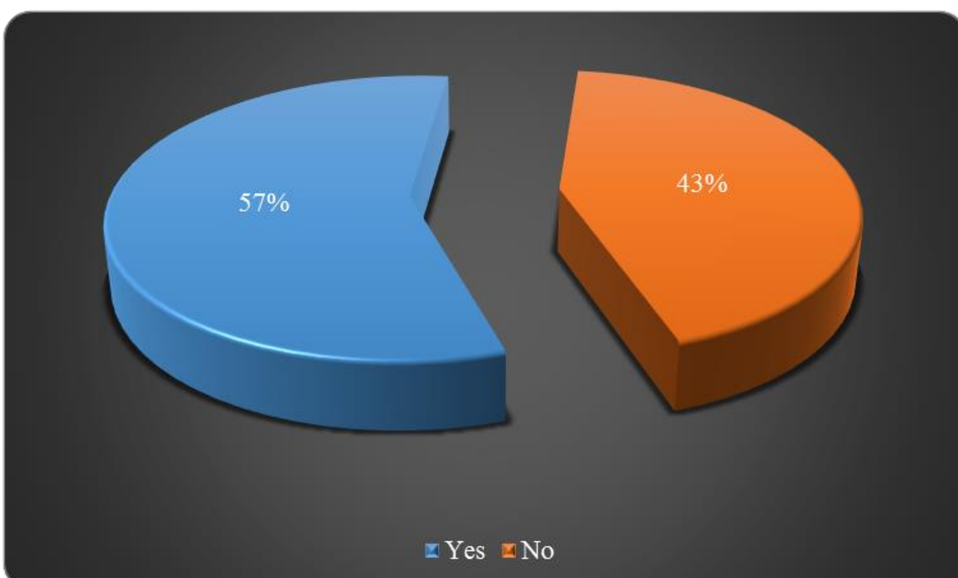

Figure 5-7. Speed-Limit Enforcement.

When the state DOT representatives were asked about whether they provide uniform speed limit in all the towns along rural highways, about 95% said they did not have a uniform speed limit in their towns along the rural state highways (Figure 5-8). Only one DOT said it had a uniform speed limit along all the towns along the rural state highways.

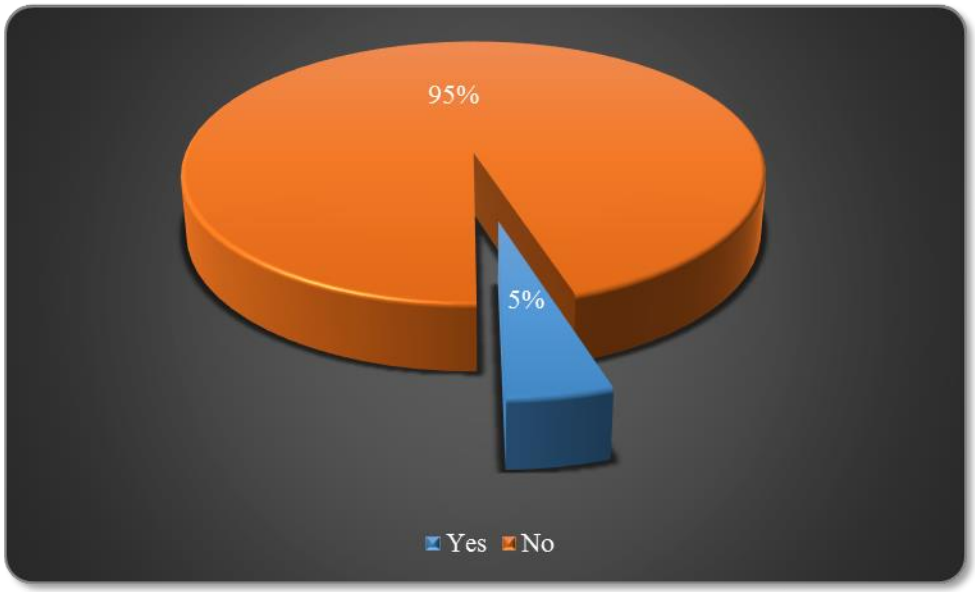

Figure 5-8. Uniform Speed Limits in All The Towns Along Rural State Highways.

5.2.4 Traffic Engineers' Personal Views

When the respondents were asked about the most important factor that influences a decision to set up a speed zone in rural highways, 167 factors were mentioned. Out of those, 143 factors were categorized into 8 categories, each with at least five responses. Other responses were too unique to be categorized under any of those 8 categories. In addition, those responses did not have at least 5 repetitions to create a new category. About 92% of the respondents mentioned that 'prevalent traffic speed' is the most important factor in making a decision to set up a speed zone in rural highways. (Table 5-4). The prevalent traffic speed, in many cases, was mentioned as an 85th percentile speed. Some DOTs also mentioned current speed, actual speed, or pace instead of the 85th percentile as a measure of the prevalent traffic speed. 'Crash history,' 'Road geometry,' 'Roadside development,' and 'Political and public influence' were the other four top factors considered in setting a speed zone in rural state highway.

Table 5-4. Top Factors Influencing a Decision in Setting up a Speed Zone

Top factors influencing a decision in setting a speed zone	Response count	Percentage
Prevalent traffic speed (usually 85th percentile)	34	92
Crash history	27	73
Road geometry	22	59
Roadside environment	22	59
Political and public influence	13	35
Pedestrian and bicycle	10	27
Access road count/density	9	24
Legislation/Directives/Statutes	6	16

Fifty-nine percentages of DOT traffic engineers mentioned that they did perceive speeding as a problem in their state rural highways (Figure 5-9). Thirty-eight percent of them said they did not observe the speeding traffic as any problem, and one DOT did not respond to the question.

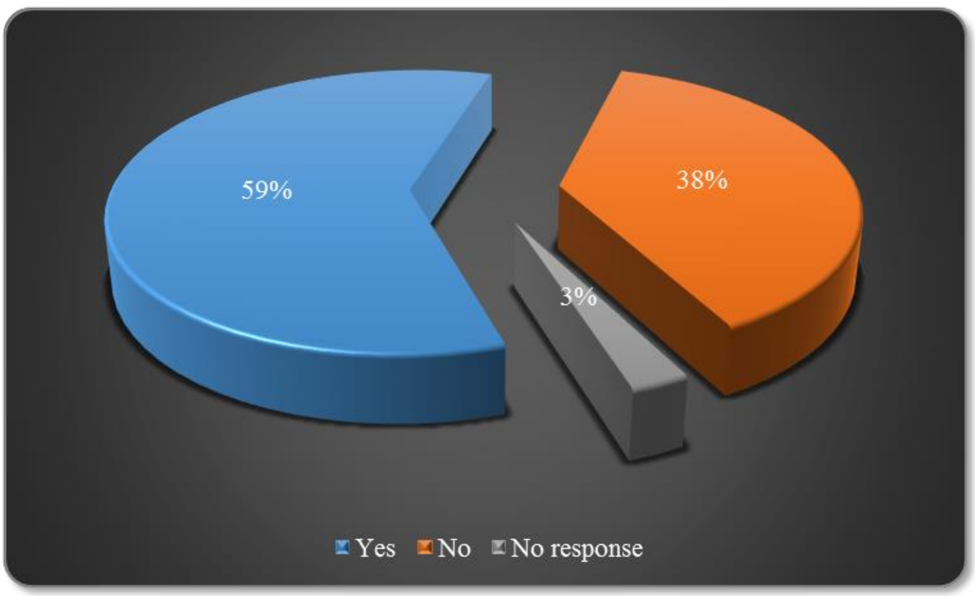

Figure 5-9. Speeding Traffic Seen As a Problem in Rural Highways.

About three-quarters of the DOTs that considered speeding as a problem mentioned that the problem was only moderately serious (Figure 5-10). Half of the remaining DOTs considered the problem as not serious and the other half considered it a very serious problem.

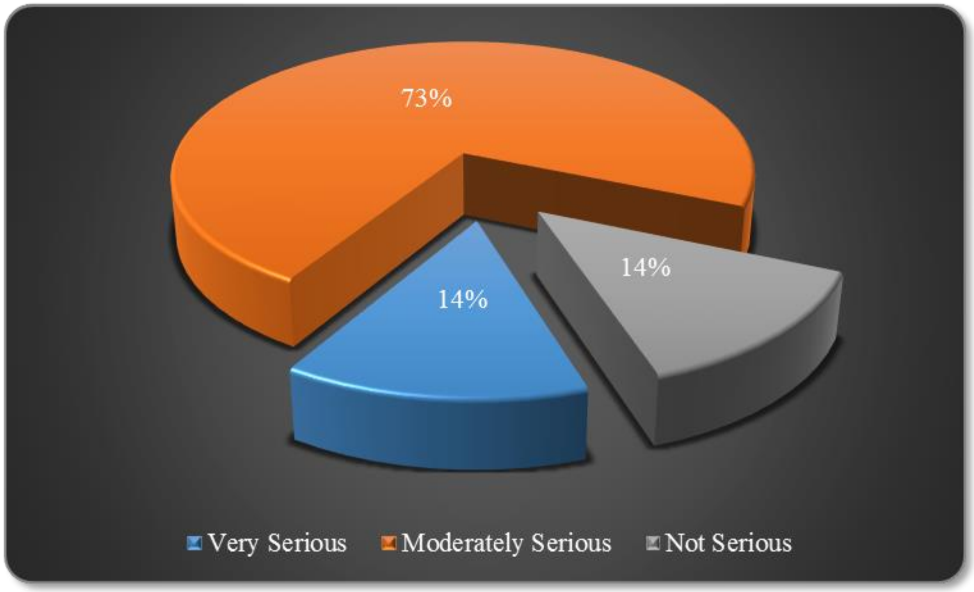

Figure 5-10. Seriousness of The Speeding Problem.

Thirteen factors that were considered to have an important influence in setting up the speed zone were listed. State DOT representatives were asked to rate the importance of each of these factors on a scale ranging from 1 to 5, with 5 being most important and 1 being least. Figure 5-11 lists the factors and their mean ratings. The '85^{th} percentile speed' was considered as the most important factor for setting up a speed limit (Rating = 4.5), followed by 'Road characteristics' (Rating 3.9) and 'Number of crashes' (Rating = 3.9). Similarly, 'School areas', 'Access points', and 'Roadside developments' were found to be important factors, according to the personal views of DOT representatives. 'Weather conditions' were considered the least important factor among all.

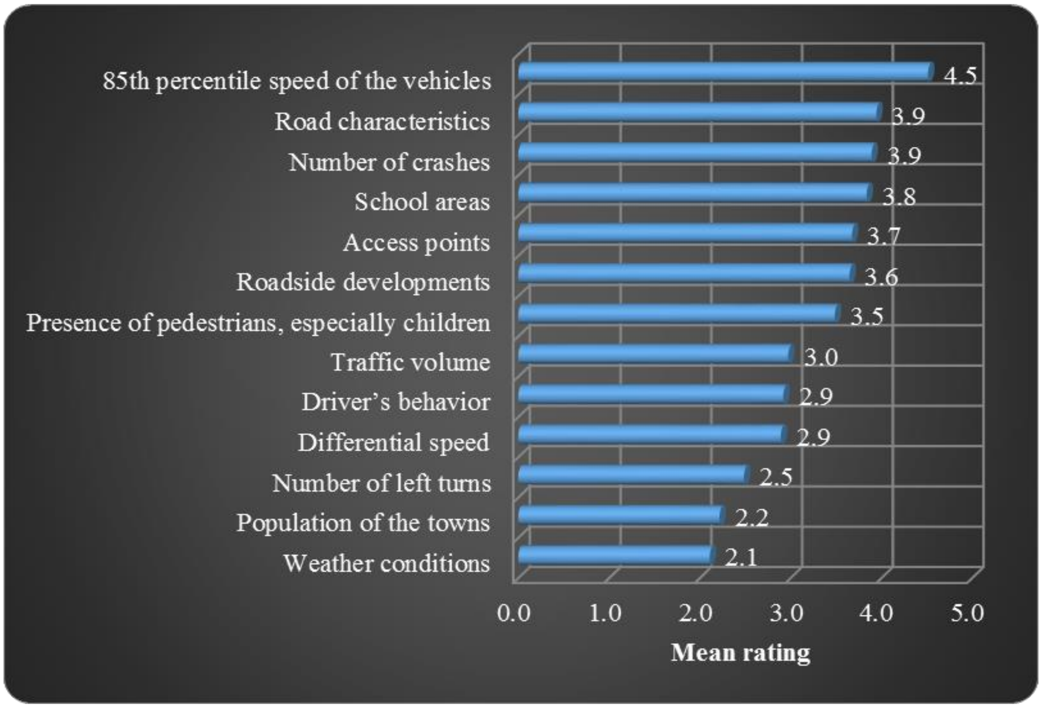

Figure 5-11. Mean Ratings of The Factors Influencing Speed Zones of Rural State Highways.

State DOT representatives rated 10 factors that were considered important to control speeding traffic on rural highways. Figure 5-13 shows the mean ratings of those factors. Increased police enforcement had the highest rating of 4.2. Installing proper speed-zone signs and changing road characteristics also were among the three most important factors. Installing variable speed limit signs was considered the least effective method to control speeding traffic and was rated with an average rating of 2.0.

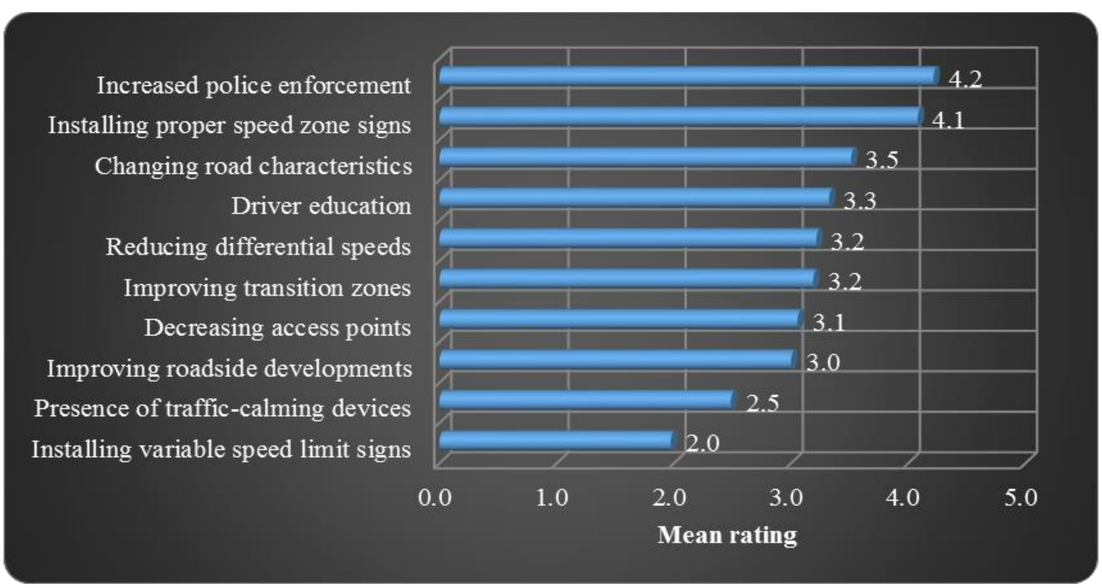

Figure 5-12. Mean Ratings of Factors to Control Speeding Traffic on Rural Highways.

Almost all of the DOT representatives (92%) agreed that increasing the speed limit did not increase the frequency of crashes (Figure 5-13). Only two of them disagreed, and one did not respond to the question.

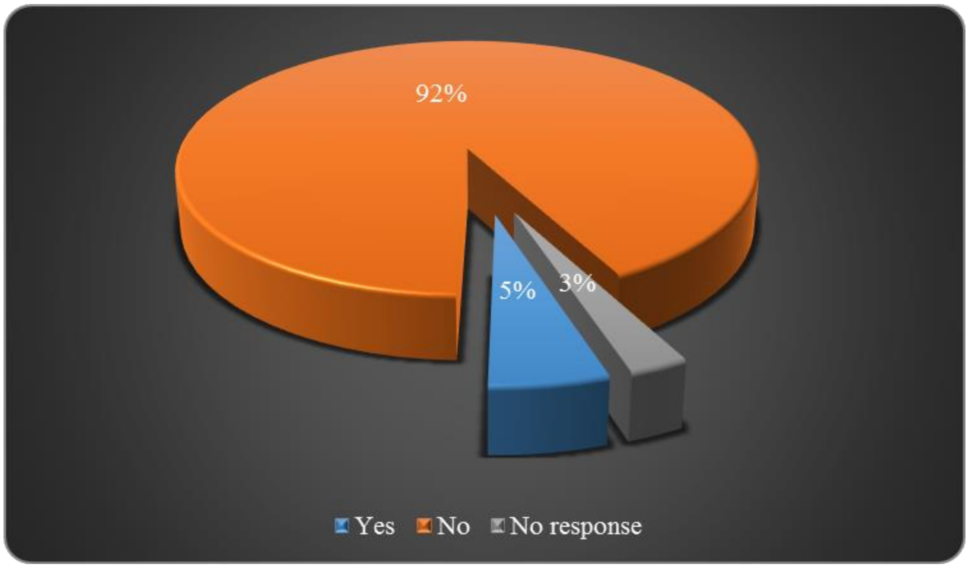

Figure 5-13. The Relationship Between An Increase in Speed Limits and An Increase in The Frequency of Crashes.

5.2.5 Issues of the Local Communities

All of the states that responded to the questionnaire had received speed limit complaints from the communities of towns along rural highways, except one state (Figure 5-14). The one state did not respond to the question.

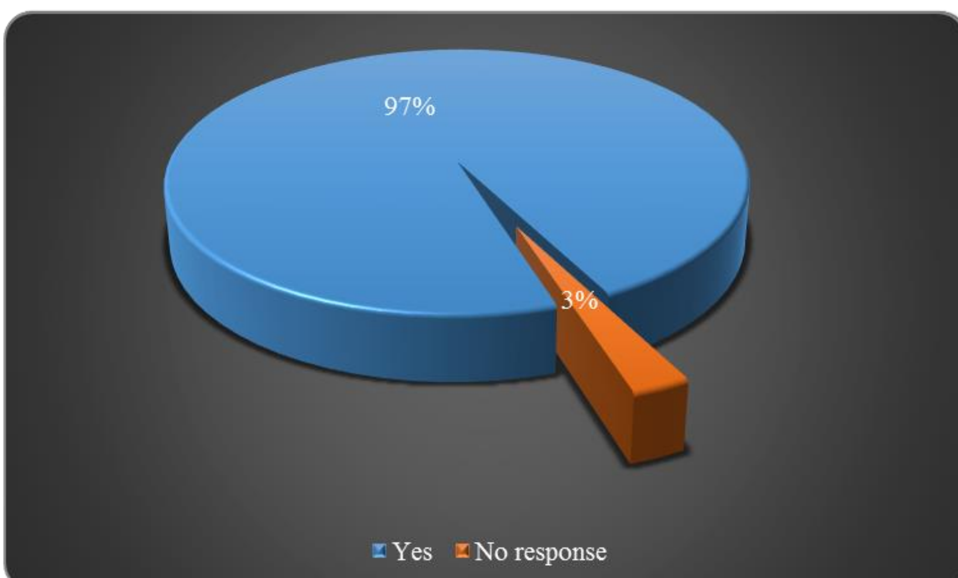

Figure 5-14. Receipt of Speed Limit Complaints From Communities of The Towns Along Rural Highways.

The DOT representatives were asked to state the estimated number of complaints they received every year regarding speed zones. Fourteen DOT (38%) representatives mentioned that they received 50 or less complaints a year, while 8 (22%) DOTs said they received more than 50 complains in a year (Table 5-5). Fifteen DOTs did not provide any quantifiable answers to the question.

Table 5-5. Number of Complaints from Communities of Towns along Rural Highways

Complaint count	DOT count	Percentage
50 or less	14	38%
More than 50	8	22%
No response	15	40%
Total	**37**	**100%**

About 89% of the communities (33 out of 37 states) were interested in decreasing the speed limits in towns along their neighboring highways (Figure 5-15). Communities from another two states did not have any interest in decreasing the speed limit, according to responses received from DOTs. Two DOT representatives did not respond to this question.

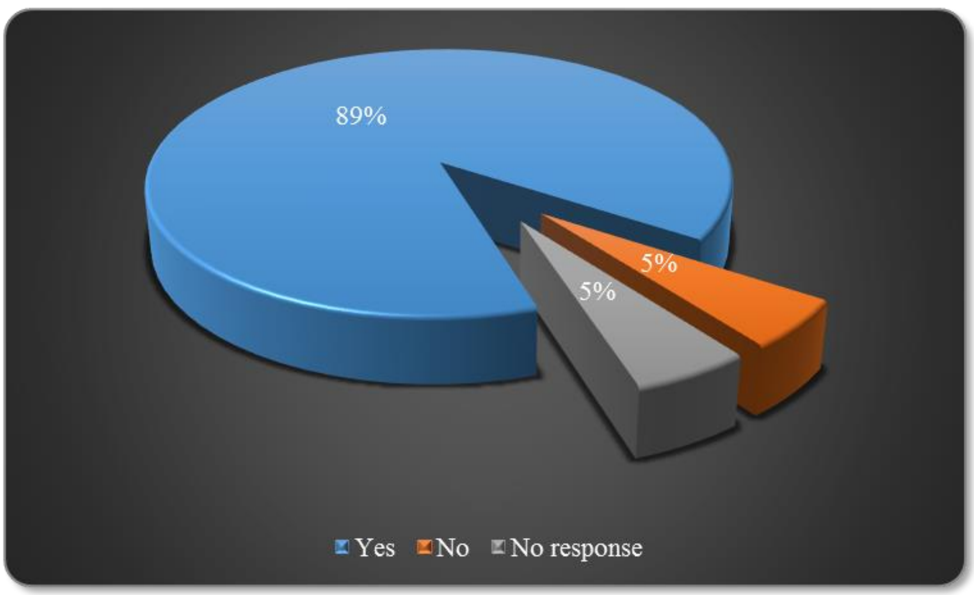

Figure 5-15. Community Interest to Decrease The Speed Limits in Towns Along Their Neighboring Highways.

More than half the DOTs reduced the speed limit in towns along rural highways based on complaints from communities (Figure 5-16). Ten DOT representatives said they did not decrease the speed limit. Four DOTs did not respond to the question.

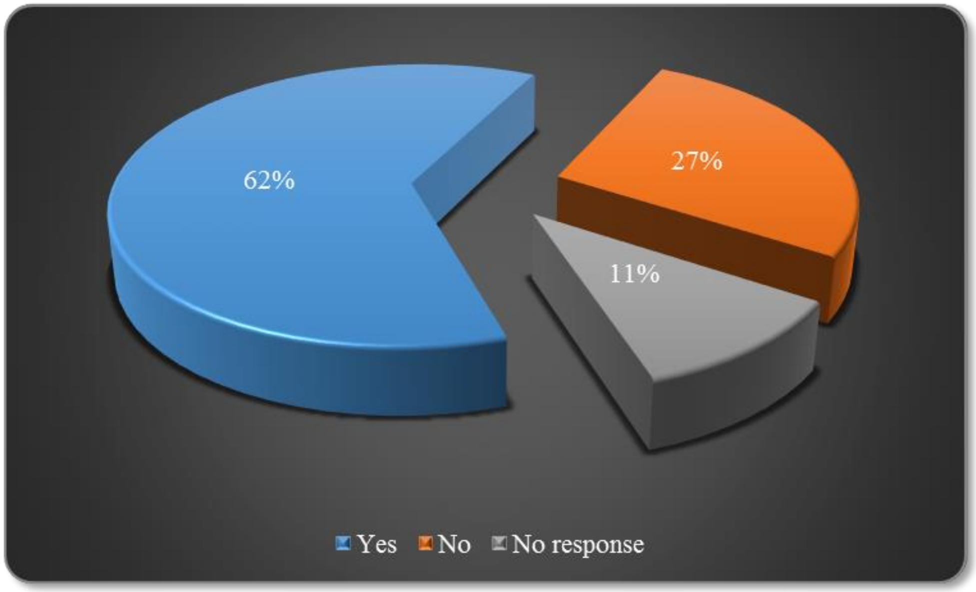

Figure 5-16. Decrease of Speed Limits Based on Complaints From Communities.

Out of 23 states that decreased the speed limit in towns along rural highways, 13 states (57%) said decreasing speed limits did not solve the problem (Figure 5-17). About 22% of the DOTs said it did solve the problem, and the remaining 22% did not provide any definite response.

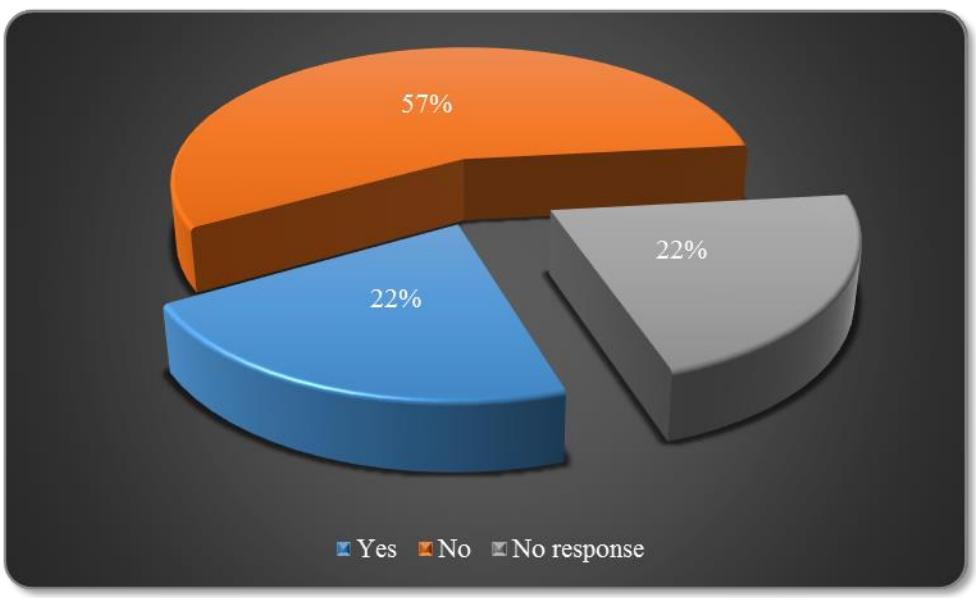

Figure 5-17. Whether Decreasing The Speed Limit Solved The Problem.

According to comments received from the DOTs, most of those DOTs, if not all, did not decrease speed limits solely based on the complaints. Most of these DOTs said that decreasing the speed limit typically did not solve the problem; nevertheless, when proper enforcement, a change in roadway conditions, and driver education are all combined, that can have the desirable effect. However, that is not generally the case, and therefore resulted in increased violations of the speed limit in those areas. Some of the notable comments from the DOT representatives are quoted below. The DOTs and their representatives are not identified to maintain their anonymity.

> *"The action often results in an appeasement and perceived improvement. Majority of cases do not indicate compliance or improved operational or safety conditions. Some corridors almost appear to utilize cyclic back and forth up and down speed limit manipulation (as a surrogate for other issues/deficiencies – like poor access management – poor planning – congestion – queuing – driver frustration – delay)."*

> *"No. Drivers have typically maintained their speed, i.e. the reduction in posted speed limit did not significantly affect a change in driver behavior."*

> *"No, in one case, lowering the speed limit increased the number of violators from 67% to 95%. The speed limit was already inadequate (too low) to begin with."*

> *"In the past, many speed limits were reduced due to local concerns. However, these unreasonable speed limits create speed traps and complaints that the speeds are too low. Over the past five years we have been trying to increase speeds based on 85th percentile speeds."*

> *"If we receive a complaint from a community, we still conduct a speed study in accordance with our policy. If the speed limit is decreased, it generally does not solve any problems as most drivers continue to drive at a speed they are comfortable with regardless of what the speed limit is."*

> *"I don't believe that just giving in to the communities and posting the lower speeds does any good, you see only small decreases in speed as a result, all it really does is change the issue from lowering the speed to one of compliance, you have to change the drivers perception by changing the roadway environment and giving the drivers a reason that they should slow down."*

"Decreases in SL are never made based solely on a complaint. They are made after investigation and conduct of engineering study. Those SL reductions based on sound engineering judgment typically do have an impact."

"It can be effective with proper enforcement. Proper engineering, education and enforcement ultimately lead to safer roads. It takes all three for success."

5.2.6 Summary of the Survey

The majority of DOTs conducted engineering and traffic investigation to set up the speed limit. They also followed their traffic manual to set up speed limits in their rural highways. They said that the following factors affect the decision to set up a speed zone:

- Spot speed studies
  - Calculation of 85th percentile
  - Upper limit of 10 mph pace
  - Trial runs
- Crash history
- Roadway characteristics
  - Design
  - Pavement
  - Width
  - Geometry
  - Traffic control device conditions
- Roadside environment
- Volume of pedestrians
- Presence of parking
- Number of access point

The state DOT representatives who reported the speed limit was not uniform in all the towns along the rural state highways mentioned that the major criteria for establishing the speed limits in towns along rural state highways were basic speed laws, roadway functional classifications, and the upper limit of the 5- or 10-mph pace. One DOT representative mentioned that that state is "in the process of removing the ability of local authorities to pass an ordinance to establish a speed limit within the city limits." This would result in a more uniform speed limit throughout the state.

Many DOT representatives mentioned that they were considering their current legislations and guidelines or manuals as a basis of setting up speed limits. Some mentioned that they performed the studies mentioned in their state speed-zone legislation.

One DOT representative expressed his doubt on whether the guideline had been followed properly or not.

Based on the responses received, the best practices to determine the speed zone in towns along rural state highways are as listed below:

- Consider statutory speed limits before setting up speed zone.
- Follow existing speed-zone guidelines.
- If guidelines are not available, then conduct an engineering and traffic study before setting up a speed zone.
- Determine reasonable, realistic, self-regulating, and defendable speed by:
    - Conducting an engineering study to determine the 85^{th} percentile speed, which is the most agreed upon measure of prevailing traffic speeds;
    - Taking proper precautions while conducting speed studies, such as choosing a proper day and time so that the collected speed data is representative of normal traffic conditions and determining if the equipment used is well maintained;
    - Taking into account, such factors as crash history, road geometry, roadside environment, and "political and public influence"; and
    - Balancing the community's desires against the speed that the traffic wishes to use.
- Use proper warning signs in high-speed to low-speed transition zone.
- Do not reduce speed limits on rural highways without engineering and traffic studies.
- Follow a consistent procedure in setting up a speed zone.
- Conduct a speed study after the speed is reduced in the speed zone in order to determine its effectiveness.
- Work with local law enforcement personnel to enforce the speed limit.
- Educate drivers to make the speed limit more effective in rural highways.

6 Speed-Related Complaints and NDOT Interviews

6.1 Speed-Related Complaints

To understand the nature and process of resolving the speed-related complaints, some complaints and their resolution process were studied in detail. In 1995, a complaint was filed in NDOT mentioning lack of a 'Reduced Speed Ahead' sign as well as step-down speed limit signs in the transition zone of US 95 southbound while approaching Beatty. NDOT investigated the issues by conducting an inventory of the existing speed limit signs and found that 45 mph speed limit sign was missing from usual high-speed to low-speed transition zone (70 mph to25 mph). The traffic engineering office was informed about the missing signposts, and a letter was sent to concerned citizen about the actions taken.

In 1996, NDOT received a complaint to increase spacing between speed limit signs in northbound US 95 north, south of Tonopah. The spacing of speed limit signs was at least 1000 ft, which is in accordance with MUTCD. No field investigation was conducted, and a letter was written to the complainant explaining the situation. A similar complaint was filed in 1997, requesting to increase the spacing between speed limit signs and the 'Reduced Speed Ahead' sign on southbound US 95, north of Goldfield, so that the drivers would have sufficient time to decrease their speed. The spacing between the sign posts, in this case, also was in accordance with MUTCD. Therefore, no actions were required related to this complaint.

A field study was conducted during March 1998 to check the possibility of increasing the speed limit on SR 319 (Panaca Road). The study was conducted in two straight locations and three curve locations within chainage of MP LN-51 to MP LN-70. The data collected during the study included vehicle speed, the roadside development scenario, and the presence of curves. In addition, AADT data was collected during the study. The study recommended increasing the speed limit from 55 mph to 65 mph on this section of the road. The recommendations were sent to the Chief Traffic Engineer by the Research Division Chief, and then forwarded to the NDOT Director.

A letter was written by the District I Traffic Engineer to Lincoln Country Sheriff, asking for the signature from the Sheriff and members of the Country Commission in order to indicate the support of the local community in increasing the speed limit. A meeting was scheduled between the Director of NDOT and the Country Commission. The recommendation of the study to increase the speed limit finally was signed and approved by the Director of NDOT, followed by the placement of a work order to put required sign posts.

A complaint was received about the speed limit being too high (45 mph) in alternative US 95, as Fernley High School was nearby and noticeable town development had occurred. The complainant requested setting up a school zone and adding a cross walk. NDOT conducted a speed study and Road Safety Audit (RSA) report was completed. The speed study report showed that the 85th percentile speed of this section was 55 mph. In addition, the RSA report mentioned that the pedestrian ramp and sidewalk were constructed but then terminated on US 95A. The report also recommend NDOT to evaluate the construction of pedestrian sidewalks along US 95A (from Canal Drive to SR 427) when this road section is to be improved.

6.2 Summary of NDOT Traffic Engineers' Interview

Phone interviews were conducted with traffic engineers of three districts of NDOT. The interview guide was prepared based on the literature review, survey with state DOTs, crash data analysis, and site data analysis. The main goals of these interviews were two-folds. The first goal was to understand the current practices NDOT was following to reduce the speed limit in towns along rural highways. The second goal was to get feedback for guidelines regarding speed reduction in these towns. The interview guide is shown in the Appendix.

6.2.1 Interview of Traffic Engineers

Before conducting phone interview, an interview guide was sent to NDOT district traffic engineers. The interview was conducted by phone for about 45 minutes, in a structured format. All the district traffic engineers were asked the same questions. The interviews were recorded by consent of the interviewees. The recorded interviews were used to analyze the data so that similar patterns among the answers could be evaluated; any disagreements among the traffic engineers were also highlighted. The interview answers are summarized below.

6.2.1.1 Current Practices

6.2.1.1.1 Please provide the NDOT practices regarding speed limit on highways. Why, when, how, is speed reduction on rural highways are considered/conducted?

Speed reductions on rural highways are considered as a result of requests from citizens, local agencies, and construction activities caused by development that change the speed zone locations. Initially, the district officers conduct informal speed studies to check the vehicles speeds; the formal study is conducted by the traffic operations crew from Carson City. The requests to conduct speed studies are prioritized, and studies are conducted for each district based on the priority. The 85th percentile speed is the major criteria to set the speed limit. However, other mitigating factors – crashes, sight distances, road design, and sometimes politics – also are considered in setting up the speed limit in a given stretch of rural highways. NDOT has no guidelines to set up the speed limit in small towns along rural highways. Generally, NDOT has lowered the speed limit in increments of 10 mph in these towns.

6.2.1.1.2 What is the current practice in addressing a community's request regarding speed reduction in towns along rural highways?

The district submits the request to the headquarters in Carson City based on such factors as the length, the availability of the crews, and the priority. As mentioned before, the requests are prioritized for one district at a time, unless a particular case is of a very high priority for some reason, for example, a high number of crashes or extensive development in the area. The speed study crew prioritizes the sites.

An objective engineering analysis is performed based on the 85^{th} percentile. One traffic engineer stated that in some cases, the speed limit is not necessarily the 85^{th} percentile speed; sometimes, due to high-speed complaints, the speed limit is set below the 85^{th} percentile speed. Such manuals as ITE [Kraft et al. (2009)] and CalTrans [California Department of Transportation (2012)] are considered while making speed-limit decisions.

6.2.1.1.3 What are the most important factors that NDOT consider while reducing the speed in towns along rural highways? (please list in order of importance)

The most important factor is the 85^{th} percentile speed. Location of the street section, volume of the traffic, current posted speed limit, crash rates, mitigation factors for congested areas, traffic generators (e.g., big stores or big development), existing traffic symbols, sight distance, and comfort for vertical curves and horizontal curves all are factors considered for speed reduction.

6.2.1.1.4 What site data are collected before the speed limit zone is adjusted?

The data collected for the speed zone adjustment includes posted speed limit, school zones, commercial and non-commercial driveway numbers, lane widths, street classification of the traffic, median type and width, shoulder type, pedestrian activities, side walk, parking, and highway alignment. Speed parameters, including mean, media, pace, and the percentage of vehicles traveling in the pace, are calculated using the spot speed data. The spot speed data are usually collected by hose tubes or radar guns. In short, the speed data is considered along with overall site conditions data. One traffic engineer stated that they rarely collect the access density and road geometry data. However, if access and road geometry need to be taken into consideration, they will be included during the phase for site data collection.

6.2.1.1.5 How many locations are chosen for spot speed data collection? During the spot speed check, how many spot speed data are taken in a site?

There is no standard in determining the number of locations for spot speed data collection. The number of locations depends upon the number of intersections and the length of section under study. A couple of locations will be selected for larger sections. At least 50 spot speed readings are taken for each lane in each direction; the preferred minimum number is 100 spot speed readings.

6.2.1.1.6 Is there any process in place to address the length of speed zone in towns?

There is no guideline followed for determining the length of speed zones. The MUTCD is followed as a guideline for determining various aspects of speed zones. The length is usually determined based on the site conditions, such as existing major intersections, school zones, business zones, and residential zones. Some of the speed zones are taken throughout the town limits from boundary to boundary.

6.2.1.1.7 How does NDOT design transition zones for speed reduction zones in towns?

There is no guideline to design the transition zone. Table 2C-4 of MUTCD is followed for signpost spacing in the transition zone. Speed increments of 10 to 15 mph are considered in transition zone. Some other states have higher speed increments. If there are any peculiar conditions, adjustments are made based on factors like grades, curves, etc.

6.2.1.1.8 Does NDOT conduct any studies before and after the speed limit is set to determine the impact of the new speed zone?

The majority of the traffic engineers thought that there were no post studies done to determine the impact of the new speed zone. Attempts are made to do yearly pre-speed studies. Various factors that change the schedule of speed studies include construction projects, citizen requests, or additional observations of the sections of the streets. Informal speed checks are made after the speed limit changes, but nothing formal. The interviewee thought that pre-speed studies and verification speed studies results might be different, depending upon the level of enforcement. Therefore, the post-speed studies should be done without aggressive enforcement.

6.2.2 Suggestions for New Guidelines

6.2.2.1 Speed Zone Identification Phase

6.2.2.1.1 Do you think the speed zone should be revised in a recurring fashion? If yes, then after how many years do you think it should be done?

Changing speed zones is a “painful” process. If there are no changes in road sections and development area around the towns, which is the case with most rural towns in Nevada, then there is no point in updating the speed zone. For example, in Alamo, Ash Springs, McGill, and Wells, there is probably not a single building newer than 20 years old. In addition, consideration should be given to the availability of limited human and economic resources in the current economy. Revision once every 5 to 10 years is strongly encouraged, especially in areas that underwent changes. If there are significant changes in the nature of road, significant residential development, or significant commercial development, consideration should be given to updating speed zone more often, even once a year.

6.2.2.1.2 In your opinion, how a speed zone re-evaluation should be started, either by local complaint or change of environment in the vicinity of the road (for example but not limited to new school addition, new sport facility addition, new community service facility addition, change in usage of a building, or any other situation that may result in change in community usage of roadside buildings)?

For some types of improvements in the right of way, a permit is required. This will trigger NDOT's attention, which might start the re-evaluation process. If there is any school constructed in the communities, then a speed zone re-evaluation should be necessary. If there are no major changes in the towns, then re-evaluating the speed zone in every five year is recommended.

6.2.2.1.3 Do you have any suggestion about the chain of command of approving the speed zone study after the local complaint is received by NDOT?

Currently complaints are received either directly by the district traffic engineer or it comes through the Public Information Officer (PIO). Not a lot of complaints are received that are annoying, and the current approval process is functional. One district traffic engineer mentioned that the district traffic engineer is allowed to make decisions on the changes in the speed zones. Two district traffic engineers mentioned that the first request for study is made to the speed study crew in headquarters. Once study is done, a recommendation is made to the Chief of Traffic Operations, who then recommends it to the Director of NDOT. Finally, the Director makes a decision based on the recommendations.

6.2.2.2 Speed Determination Phase

6.2.2.2.1 What are the most important factors to determine the speed limit? (85th percentile only or any other factors, such as crash history).

The 85^{th} percentile speed is most important factor to be considered for determining speed limits. Other factors include crash history, schools, businesses, lane width, congested areas, horizontal and vertical sight distances, pedestrians, driveway density, and development. Many times, site-specific conditions must be taken into consideration. For example, odd weather patterns in a particular location can have big role in determining the appropriate speed limit for a site. If speed limits below the 85^{th} percentile speed are preferred, then the commitment for enforcement should be guaranteed.

6.2.2.2.2 Mention the steps and precautions taken for spot speed study.

Radar gun is generally used for recording spot speeds. The spot speed should not be taken near intersection. The spot speed should be taken in normal conditions. Adverse weather conditions – snowing, heavy wind, etc. – will artificially lower the speed of the vehicles, and the data will not represent the average normal driving behavior in that section of the highway. Thus, such adverse conditions should be avoided.

6.2.2.2.3 Besides spot speed, what other data should be collected to make decision on speed limit of the towns?

Such data as crash history, access points, and road geometry in general, including sight distance review, should considered.

6.2.2.3 Transition Zone Determination

6.2.2.3.1 How important is transition zone setting up in speed zone?

The importance of the transition zone depends on the situation. A single step down can be used to decelerate vehicles if there are major intersections. The NDOT uses speed increments/decrements of 10 mph; however, 20 mph might be possible. Historically, step up and step down speed limits on both sides of a speed zone are similar. Stepping down is a much more important part of transition zones than a step up. Higher increments on a step up can be considered in a low-speed to high-speed transition zone. However, in high-speed to low-speed transition zone, lower increments of a set down speed should be used.

6.2.2.3.2 How is length of the transition zone determined?

The majority of traffic engineers did not know about any standard for determining the length of transition zones. It will be useful to have a guide to set up the length of a transition zone; however, it is necessary that the length of the transition zones is consistent and there are no speed traps.

6.2.2.3.3 How important are traffic signs of step down and step up speed in speed zone?

Traffic signs for step-up speed are not important compared to signs for step-down speed. Care should be taken to make sure the speed limits are enforceable, and people will pay attention to it. Otherwise, it will become a speed trap. The *MUTCD* should be followed for sign posts.

6.2.2.3.4 Should NDOT follow National Cooperative Highway Program (NCHRP) manual for transition zone determination?

The majority of traffic engineers are not familiar with the *NCHRP* manual. It will be helpful to have a reference to the *NCHRP* manual in this guideline.

6.2.2.4 Speed Zone Approval Process

6.2.2.4.1 Is the existing chain of command of approving speed zone change acceptable? If any change is needed, please suggest.

All the traffic engineers responded that the current chain of command is working fine.

6.2.2.5 Speed Enforcement

6.2.2.5.1 Do you think more police is needed to enforce the speed limit in towns?

Enforcement is necessary for the first time whenever a speed limit has been substantially dropped so that drivers understand the speed limit has been reduced. NDOT does coordinate with law enforcing agencies whenever NDOT changes or recommends changes in speed limits. Site conditions, crash history, and other conditions dictate whether the enforcement is necessary or not. More enforcement is required near schools and in residential areas. As mentioned before, if a speed limit is to be setup below the 85^{th} percentile speed, then a commitment is required from the law enforcement agency to enforce the speed limit.

6.2.2.6 Follow up studies

6.2.2.6.1 Do you think before-and after-study is necessary to determine the effectiveness of speed limit zone in towns?

All district traffic engineers agreed that it is a good idea to conduct follow-up studies. One of them stated that those studies may not be necessary, depending upon the site conditions; in some sites, informal studies might be necessary.

6.2.2.7 Other Questions

6.2.2.7.1 In your opinion, how often the guidelines should be revised?

The guidelines should be revised every year; however, most of the traffic engineers said that the guidelines should be updated once every five years. In NDOT, a regular meeting of the district traffic engineers with the headquarters' traffic engineers used to occur. If that group is re-established, then the manual can be revisited at least once a year.

6.2.2.7.2 Any other comments?

The 85^{th} percentile speed, pace, and percentage of vehicles in the pace are good parameters for determining the speed limits. If the percentage of vehicles in the pace is high (80% - 90%), then the speed limit based on the pace would be good. If the percentage of vehicles in the pace is low (40%-45%), then there are irregular gaps in the curve, meaning that there are some problems with the speed limits. Adjustments are required to resolve the issue. This consideration should be somewhat documented. One district traffic engineer suggested that the 75 mph speed limits on states and rural highways should be reviewed.

7 Speed Zone Guideline

This chapter provides the guidelines for setting up speed zones in towns along rural highways of Nevada. The guideline was prepared based on 1) crash data analysis of 11 towns, 2) a survey of current practices of the state DOTs regarding speed zones, and 3) structured interviews with NDOT district traffic engineers. This guideline specifically identifies practices followed by other state DOTs and addresses detailed steps in setting up speed zones in towns along rural highways of Nevada.

This guideline will assist practicing traffic engineers to set up a speed zone. However, any guideline should not be considered as complete; hence, the engineering judgment of the traffic engineer is still a very important factor when determining the speed limit. This becomes more apparent when the site under study has a peculiar condition. Any guideline should be modified and extended regularly, based on the after-effect research, other researches on the topic, development of newer technologies, etc.

The proposed guideline has eight major sections.

- Section 1 summarizes the guidelines and manuals of various state DOTs in setting up speed limits in their jurisdiction. The current practices mentioned in these guidelines and manuals are described in detail in the Appendix.
- Section 2 provides the definitions of major terms used in setting up speed zone in towns along rural highways. This chapter will help reader to understand the critical terms used in this guideline.
- Section 3 provides detailed information about Nevada statutes related to speed limits.
- Section 4 provides the detailed steps involved in setting up a new speed zone or modifying an existing speed zone in towns along rural highways of Nevada. The detailed framework for setting up a speed zone is provided, and each step involved in this framework is explained in detail. This section is critical for the Traffic and Operation Department and NDOT traffic engineers who are involved setting up speed limit in towns in rural highways. This section is further divided into seven sub-sections as described below.
    - Section 4.1 focuses on speed zone study identification phase.
    - Section 4.2 provides the steps to determine the speed limit.
    - Section 4.3 provides guidance to calculate speed zone length and location.

- Section 4.4 provides information about the transition zone. This section provides a reference for guidance in designing a transition zone, sign posts, and high-speed to low-speed transition zone treatments.
- Section 4.5 provides details on the NDOT approval process for setting up a speed zone or modifying a speed limit in the speed zone in towns of rural highways.
- Section 4.6 explains the importance of speed enforcement in speed zones in order to make a speed zone more effective.
- Section 4.7 summarizes detailed information about requirements for follow-up studies after a speed zone is set up in towns along rural highways.

7.1 Comparative Overview of Guidelines and Manuals of Different States

The guidelines used by various state DOTs have some things in common. For example, use of the 85th percentile speed is the generally agreed-upon measure for the prevailing speed when determining speed limits for speed zones. At the same time, the DOTs have various methods to take into account the effect of the road characteristics, roadside characteristics, and crash history for reducing speed limits. Some DOTs use a mathematical formula or process to quantify the speed reduction to take those factors into account; others are limited to giving the traffic engineer an opportunity to use their experience. Some DOTs have concise guidelines focused only on how to determine speed limits for speed zones; other manuals give much broader information, from procedures to select a site for speed zoning to how it will be approved.

7.2 Definitions

Speed Zone: A speed zone can be defined as a stretch of highway or roadway where the speed limit is different from other parts of the highway.

Design Speed: Over a period of time, the definition of design speed has changed from “the maximum speed that can be maintained over a specific section of highway when conditions are so favorable that the design features of the highway govern” (AASHTO Green Book, 1994) to “a selected speed used to determine the various geometric design features of the roadway” (AASHTO Green Book, 2011).

Operating Speed: The AASHTHO Green Book (2011) defines operating speed as “the speed at which drivers are observed operating their vehicles during free-flow conditions.” The 85th percentile speed is generally used as a measure of operating speed.

Posted Speed Limit: The speed limit set by government agencies as a maximum speed for given stretch of roadway. Current practice is to reduce the difference among design speed, operating speed, and the posted speed limit. This will result in a reduction of the variation of speed of vehicles in a traffic stream.

85th Percentile Speed: The speed at or below which 85% of the vehicles travel is called the 85th percentile speed. It can be determined by visual inspection of a cumulative frequency graph of speed distribution. The 85th percentile speed is the most important and most accepted speed parameter for determining appropriate speed limit for a particular stretch of highway. Research has shown that driving at this speed has the minimum potential for crashes. Driving at a speed too higher or too lower than this speed will increase the potential of a crash.

Mean Speed: Mean speed is the arithmetic average of all the observed speeds. It can be calculated by adding speeds of individual vehicles and dividing by the total number of vehicles.

Median Speed: Median speed is a speed such that the number of vehicles travelling above that speed is equal to the number of vehicles travelling below that speed.

Modal Speed: Modal speed is the speed at which highest number of vehicles travel.

Pace: Pace is a 10-mph speed range at which the highest number of vehicles travel. Pace can be determined by a visual inspection of the speed distribution chart. In determining the speed limit, an upper limit of a 10-mph pace is an important speed factor to consider besides the 85th percentile speed.

Annual Average Daily Traffic (AADT): AADT can be obtained by dividing the total number of traffic passing through a point in a highway by the total number of days in a year (365).

Transition Zones: This is defined as a section of road that connects the road section with the high-speed zone to the section with low-speed zone (Forbes, 2011).

7.3 Nevada Statutes Related to the Speed Limit

Nevada Revised Statutes includes three chapters that are related to traffic speed limits: NRS-484 – Traffic Laws (2011), NRS-484A – Traffic Laws Generally (2013), and NRS-484B Rules of the Road (2013). However, all the contents in NRS 484 have been replaced by NRS 484A and 484B. The purpose of those chapters are to “establish traffic laws which are uniform throughout the state of Nevada” and to “minimize the difference between the traffic laws of the State of Nevada and those of other states”. This statute allows the NDOT to prescribe and eliminate speed zones after necessary studies have been made. It gives a right to “establish the speed limits for motor vehicles on highways which are constructed and maintained by the NDOT.” The maximum speed allowed by the statute is 75 mph. The speed limit for school zones, as set by state statute, is 15 mph. For the school crossing zones, the speed limit, as set by the statute, is 25 mph.

7.4 Process to Set Up and Modify Speed Zones

Figure 7-1 and Figure 7-2 show the recommended processes for setting up new speed zones and modifying speed zones in towns along rural highways. The speed zone study should start as a result of public concern, a major change in roadway condition, or a major change in roadside environment. After that, a preliminary analysis should be done using existing data, such as crash data, location map, features of the location, and the number and type of public concerns/complaints related to the location. If a speed zone is to be modified, then the previous speed zone study of the location, if any, should be reviewed. The previous study might eliminate the necessity of further study in some cases, e.g., the speed limit has been low because of some special circumstances that is still known to exist.

Once the preliminary studies are complete and further study is deemed to be warranted, a field study should be conducted. Major data to be collected during the field study includes spot speed and a detailed location review with special notes on the locations of existing traffic signs, signals, and speed-reduction treatments provided in the transition zones. Also, priority should be given to collect different roadway and roadside characteristics that are not readily apparent to prudent drivers. If such characteristics are present, decreasing the speed limit below the prevalent speed of the vehicles may be necessary.

Once the study is complete, the recommendations of the study should be submitted with necessary documents for approval. After approval, the changes should be implemented in the field. After erecting the necessary sign posts and setting up other traffic control devices, the revised speed limit should be enforced. This process can be divided into seven phases; a speed-zone studies identification phase; a speed-limit determination phase; a speed-zone assessment phase; a transition-zone assessment phase; a speed-limit enforcement phase; and a follow-up study phase.

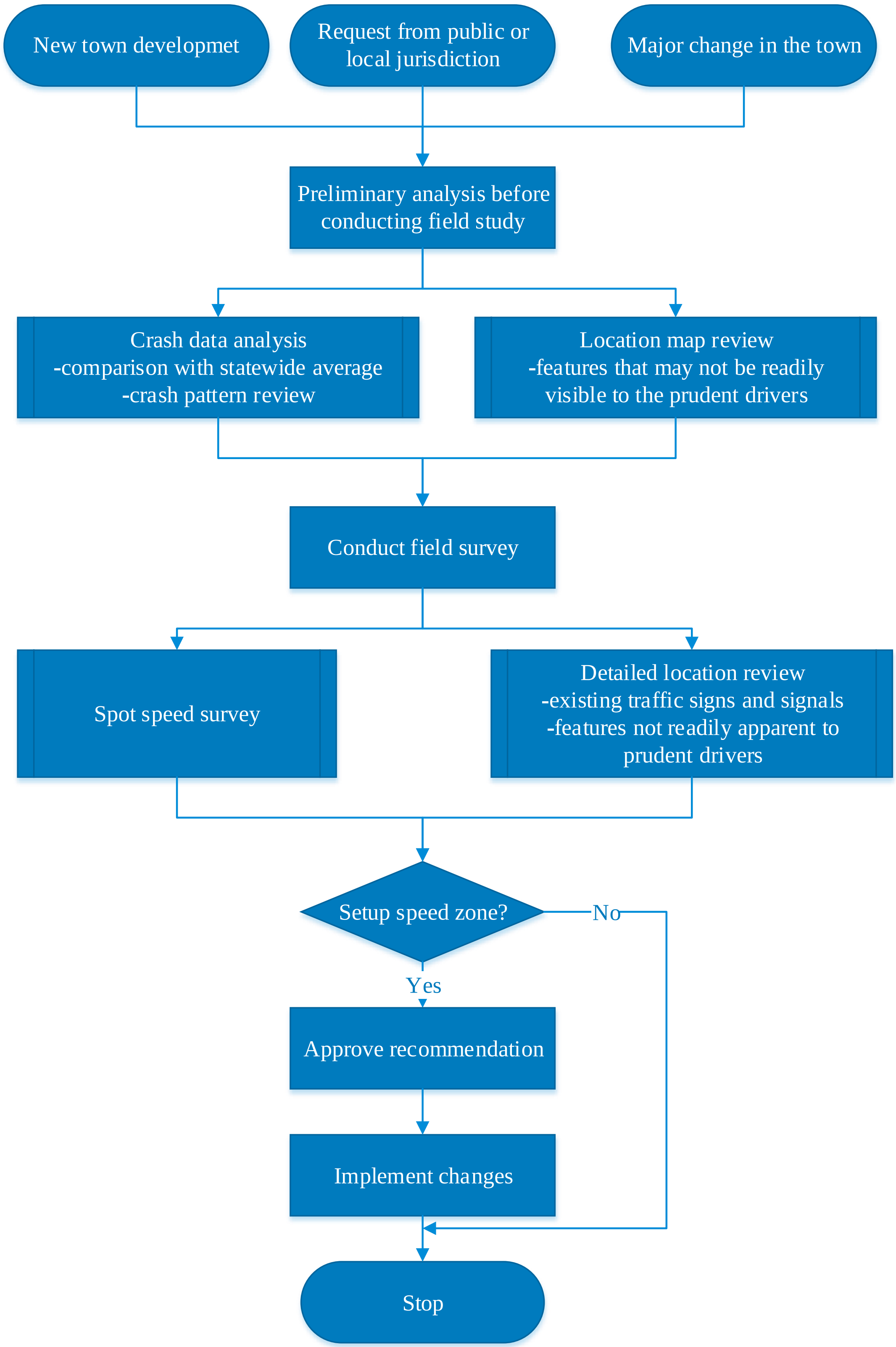

Figure 7-1. The Process for Establishing A New Speed Zone.

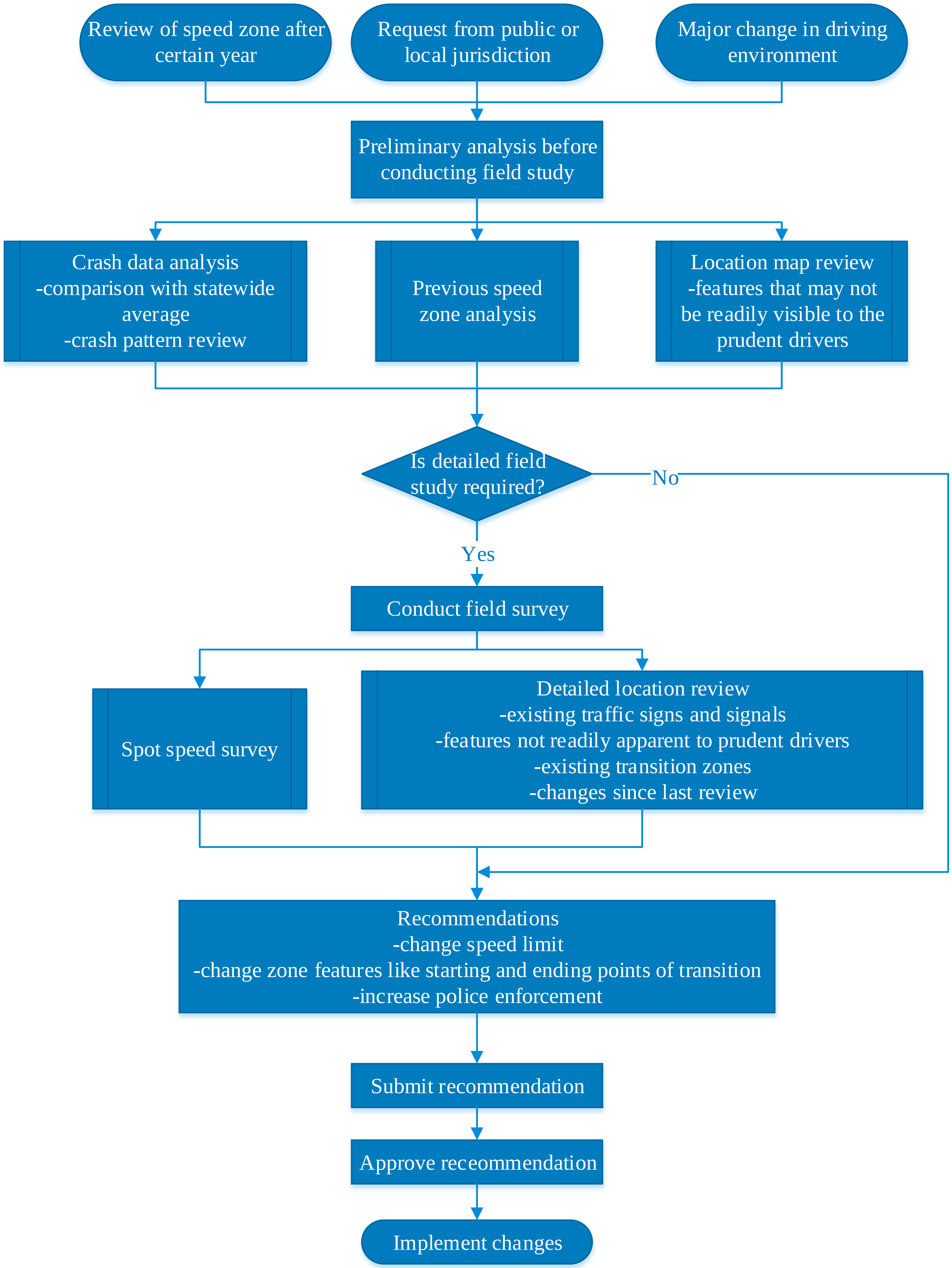

Figure 7-2. The Process for Modifying An Existing Speed Zone.

7.4.1 Speed Zone Study Identification Phase

A speed-zone study can be conducted for three main reasons. The first is in response to a public request to decrease the speed limit in a certain section of a rural highway; the second is due to a noticeable change in the driving environment along the section of a rural highway; and the third is as a result of the regular review process of the speed zone.

Traffic and engineering studies may be conducted as a result of public request regarding vehicles speeding in certain sections of rural highways. The request should be studied to justify the need of the traffic and engineering studies before going into the field. Crash data, date and location data, and a site map, can be studied to justify the need of a study.

The *MUTCD* points out that speed zones should be reviewed after changes in location occur, 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, and significant changes in traffic volumes.

Some of the state DOTs review the speed zone in regular intervals of time, for example five years or ten years.

7.4.2 Speed Limit Determination Phase

Oftentimes, speed zoning is considered to be a cure-all for crashes as well as other traffic-related problems (Automobile Club of Southern California, 1998). While crash severities increase with the speed, the probability of crashes is more dependent on differential speeds than on absolute speeds of the vehicles (ITD, 1997). The most important role of the posted speed limit is to narrow down the range of the speeds of the vehicles flowing through the road, i.e., decreasing the differential speeds of the vehicles. Thus, determining realistic speed zones is a very important aspect to be considered while setting up a speed zone. Realistic speed zones will (ITE, 2004):

1. Result in voluntary compliance of the speed limit;
2. Make it easier for law enforcement agencies to enforce the speed limit;
3. Reduce public complains about speed traps;
4. Increase uniformity in traffic speed and hence reduce crashes.

ITE (2004, p1) lists four fundamental concepts of determining speed limit:

1. "Driving behavior is an extension of social attitude, and the majority of drivers respond in a safe and reasonable manner, as demonstrated by consistently favorable driving records;
2. The normally careful and competent actions of a reasonable person should be considered appropriate;
3. Laws are established for the protection of the public and the regulation of unreasonable behavior on the part of individuals; and

4. Laws cannot be effectively enforced without the consent and voluntary compliance of the public majority."

Before setting up new speed limit, a 'Before Study' evaluation has to be conducted. The following steps could be followed to determine the speed limit of the speed zone.

7.4.2.1 Pre-Field Study Data Collection and Analysis

The following data are to be collected and analyzed before going to the field. This includes:

- Crash data
- Previous speed zone analysis report
- Location map review

7.4.2.2 Site Data Collection and Analysis

Figure 7-3 shows the steps involved in site data collection and analysis. The critical data during the site study is to collect spot speed data of the vehicles.

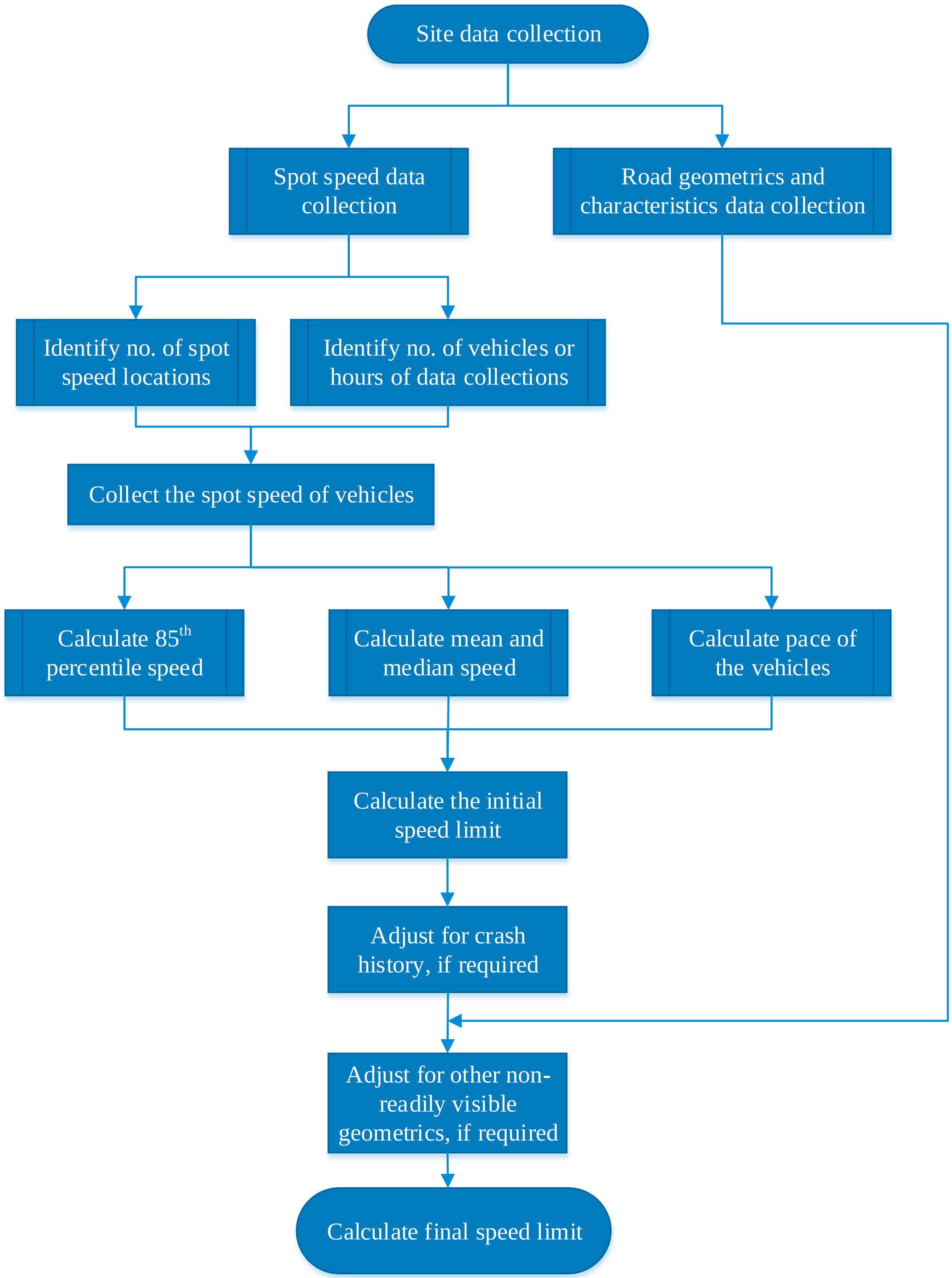

Figure 7-3. Site Data Collection Process.

7.4.2.3 Spot Speed Survey

7.4.2.3.1 Location for data collection.

Several precautions have to be taken to make sure that the data collected are obtained from free-flowing traffic. Arizona DOT (2000) defines free-flowing traffic as "a condition when drivers have relative freedom to choose a speed without interference from other traffic." The following are some of the important issues to be noted.

- For shorter speed zones, speed data should be collected at close to the midpoint of the proposed section. If it is longer than one mile, data should be collected at distance of 0.25 miles, unless the driving environment is almost same throughout the section.
- If there is major change in the driving environment in different points of the section, then data should be taken in those points as well.
- Data should be collected at the midpoint of the proposed or existing speed zone.
- Location near intersections or other traffic control devices should be avoided as far as possible; a minimum distance of ½ miles may be considered, according to the *MUTDC*. If it is not possible, data should not be collected for turning traffic and/or those stuck or slowed down because of light or other traffic control devices.

7.4.2.3.2 Time of data collection

- Rush hour should be avoided.
- Data should be collected in weekdays and not in weekends or any holidays.
- Data should not be collected following any big event in the town or nearby.

7.4.2.3.3 Other precautions

- Pavement should be dry.
- Weather should be favorable.
- Level of police enforcement should not be changed while collecting data or before collecting data.
- Locals or drivers should not be informed or aware of the data collection. Every measure has to be taken to hide the data collection.
- While collecting data of a platoon of vehicles, only the data of first vehicle should be taken.
- Data should not be collected while construction is ongoing, as it will not represent a free-flowing condition.
- It is not necessary to collect data from all the passing vehicles.

7.4.2.3.4 Data collection criteria

- Data from at least 50 free-flowing vehicles in each direction are to be collected.
- If traffic volume is too low, data from at least 4 hours are to be collected.
- If data of trucks and motorcycles are collected, it should be collected separately.
- Data should be collected separately for the two directions.

7.4.2.3.5 Choice of equipment

Radar gun or laser gun is the preferred method to collect data unless these are not available. A number of precautions must be taken before using this equipment. One important precaution is that the angle between the line of sight of the radar and the direction in which vehicle is travelling should be kept minimum. In particular, it should not be more than 10^0. The higher the angle, the greater the error will be. It is recommended to follow the equipment's manual for proper use of the equipment.

7.4.2.3.6 Safety for the data collector

While collecting roadway and roadside characteristic data, safety of the data collector should be considered. For this, necessary safety-related precautions – wearing a hard hat, wearing a reflective safety vest, etc. – should be taken.

7.4.2.4 Data Analysis

Once data collection is complete, different speed factors should be calculated:

- 85^{th} percentile speed
- Mean, median, and modal speed
- 10 mph pace

7.4.2.5 Determining the Posted Speed Limits

Various state DOTs have used differing approaches to calculate the speed limit based on existing data. Some DOTs have considered prevailing vehicle speed with side friction, roadway characteristics as well as crash history. The recommended steps to calculate posted speed limits are as follows:

- Calculate the 85^{th} percentile speed from the spot speed data.
- Check the difference between the 85^{th} percentile speed and 10 mph pace to determine whether 85^{th} percentile speed is representative of prevailing vehicle speed.
- If the spot speed data is taken at more than one points and the 85^{th} percentile speed at these points are approximately the same, then those can be averaged out; otherwise, speed zones with separate speed limits can be considered, provided that the speed zone is long enough.

- Apply reductions for a crash history. Roadway and surrounding characteristics are not to be considered unless they are not readily apparent to drivers unfamiliar with the location.
- The Missouri DOT (2010) reduces speed limit by 5% or 10% if the fatal crash rate or incapacitating injury crash rate or total crash rate for the town is more than 1.5 or 2.0 times statewide average respectively.

Additional reductions considered by Missouri DOT (2010) are listed below.

- 5% speed limit reduction if there is no sidewalk and total pedestrian exceeds 10/hour for 3 hours of any 8-hour period.
- 5% speed limit reduction if parking is allowed in adjacent traffic lane.
- 5% speed limit reduction if driveway conflict number exceeds a rate of 40 per mile, 10% if it exceeds 60 per mile. (Refer to the Missouri DOT (2010) for the process to calculate the driveway conflict number)

Note that the speed thus reduced should not be less than the average or median speed. Massachusetts DOT (2005) recommends using a lower limit of a 10-mph pace when the crash rates are much higher than average. It recommends an upper limit of a 10-mph pace in other cases. Also round up or down to the closest 5-mph increment value. Alternately, take the value closer to the upper limit of the 10-mph pace.

Idaho Transportation Department (1997) uses the upper limit of the pace as a base speed when a high percentage of vehicles travel within the pace speed and the 5th percentile speed appears inappropriately high. Idaho Transportation Department (1997) also uses an integrated approach to determine base speed by combining 85th percentile speed (30% weight, the upper limit of a 10-mph pace (30% weight), and an average test-run speed (40% weightage).

Louisiana DOT (1981) states that the value of speed limit should not be set below the upper limit of the 10 mph pace.

Massachusetts DOT (2005) recommends that the adapted speed limit is not less than 85th percentile by more than 7 mph.

- Make sure that the speed limit is more than mean and median speed. Otherwise, increase the speed limit to more than highest of the two.
- Make sure that the proposed speed limit is not higher than the critical speed. According to Massachusetts DOT (2005), the 95th percentile speed can be assumed as critical speed.
- Optionally, test runs can be conducted to check the validity of the speed limit thus determined.

The speed limit thus calculated can be compared with the speed limit obtained from USLimits, an online tool developed by FHWA (http://safety.fhwa.dot.gov/USLIMITS).

7.4.2.6 Use of Test/Trial Run to Determine the Posted Speed Limit

A trial run is done in order to make sure that the speed limit that is determined is satisfactory. For the trial run, a test vehicle should 'float' in the traffic stream, passing as many vehicles as the test car passes (Missouri DOT, 2010). Missouri DOT (2010) suggests the use of at least two runs in each direction, recording speed at 0.1-mile intervals.

Massachusetts DOT (2005) recommends at least three drivers for the trial run. It recommends averaging out the speed data by removing highest and lowest speed data.

7.4.2.7 Factors Considered by Other DOTs to Determine Posted Speed Limit

Besides the factors already considered above, some state DOTs have considered a number of different factors related to roadway and roadside characteristics, for example, shoulder conditions, grade, alignment, sight distance, road surface, shoulder width, shoulder condition, shoulder type, stopping sight distance, clearances, lane drops, lighting, traffic volumes, road width, traffic control devices, and road type. However, California Vehicle Code 22358.5 – Downward speed zoning (2011) clearly states that "physical conditions such as width, curvature, grade, and surface conditions, or other conditions readily apparent to a driver in the absence of other factors, would not require special downward speed zoning." Alaska Department of Transportation and Public Facilities (2000) also states it in a similar way: "except for traffic control zones, speed zones shall not be established where intermittent physical conditions such as width, curvature, grade, and surface conditions or any other physical conditions readily apparent to the driver are the only reason for a reduced speed."

7.4.2.8 Advisory Speed for Horizontal and Vertical Curves and other Hazardous Conditions

Horizontal and vertical curves can be treated with advisory speeds instead of speed zones. For newer roads, if the curve properties are known, such as radius and super elevation, the safe speed can be calculated by using a theoretical formula based on balancing the centrifugal speed with the friction between the tire and road surface. For older roads – or roads that have been resurfaced a number of times, which will change the super elevation – the ball banking method can be used. However, Texas DOT (2011) points out the limitations of the ball-banking method, and provides instruction on how to use three other methods. These are the direct method, the global positioning (GPS) method, and the design method. Those methods, according to the Texas DOT (2011) will provide a uniform advisory speed limit for curves.

Milstead et al. (2011) can be used as a reference manual to determine the proper speed limit for an advisory speed on curves. It also provides a Curve Advisory Software (CAS), which is an Excel template, for quick calculation of the advisory speed limit. The methods covered in the report are the direct method, the compass method, the GPS method, the design method, and the ball-bank indicator method.

For other hazardous conditions besides the curves, an attempt should be made to correct the hazardous conditions before considering zoning for speed.

7.4.3 Speed Zone Assessment Phase

7.4.3.1 Speed Zone Length and Location

Various state DOTs have adapted different processes to set up a minimum length of a speed zone. The minimum length of 0.5 mile is more common, and has been adapted for this guideline. Some DOTs also use as a minimum distance that can be travelled in a certain time while driving in the proposed speed limit. The speed limit change should not be located within 0.2 miles from major signalized at-grade intersection and 0.02 miles from other at-grade intersections.

Missouri DOT (2010) recommends a minimum of a 2-mile-long speed zone for unincorporated or non-community areas. Alaska Department of Transportation and Public Facilities (2000) recommends the use of the distance traveled in 25 seconds at the posted limit as a minimum length of speed zone. However, shorter speed zones are allowed for traffic control zones and school zones. Michigan DOT (2004) recommends a minimum of 0.5 miles for a speed zone. Massachusetts DOT (2005) also recommends a minimum of 0.5 miles for a speed zone, with all zones computed to the nearest tenth of a mile.

For a speed zone composed of graduated speed zones, the recommended minimum length of each zone is 0.2 miles in length. Georgia DOT (2012) recommends not to use differing speed limits within 0.2 miles from any major (e.g., signalized) at-grade intersecting roadway or 0.02 miles to any at-grade intersecting roadway. Connecticut DOT (2012) mentions 500 ft as a minimum length for a speed zone. Missouri DOT (2010) states that differing speed limits are not justified unless highways are divided.

7.4.3.2 School Zone and School Crossing Zone

A Nevada revised statute defines a school zone as “those sections of streets which are adjacent to school property.” The statute sets the speed limit of 15 mph in a school zone. For a school crossing zone, the statute sets the speed limit of 25 mph.

North Carolina DOT (1995) sets a limit of 500 ft as the maximum length of a school speed zone on either side of the school property. North Carolina DOT (1995) sets the speed to not less than 20 mph for a school zone.

Kentucky DOT (2012) sets the school zone speed limit of not less than 25 mph and not more than 45 mph for a school zone. The speed limit is generally set 10 mph less than the speed limit outside the school zone. Louisiana DOT (1981) reduces speed based on the speed limit outside the school zone, as shown in Table 7-1.

.

Table 7-1. Speed Limit Reduction for School Zone Based on Existing Speed Outside School Zones (Louisiana DOT, 1981)

Existing Speed Limit (mph) Outside School Zone	Reduction (mph)
25 or less	0
30	5
35-45	10
50 or above	15

7.4.3.3 Minimum Speed Limit

Idaho Transportation Department (1997) suggests the use of the 15th percentile if the minimum speed limit is to be considered. Louisiana DOT (1981) bases its minimum speed limit on the lower limit of a 10-mph pace. It also recommends the minimum speed limit to be not less than 35 mph.

7.4.4 Transition Zone Assessment Phase

There has been relatively less effort in studying and using different forms of transition zones to reduce the speed limit in U.S. as compared to European countries. Kentucky DOT (2012) uses speed transition from 55 mph to 45 mph and 35 mph to 25 mph in high-speed to low-speed transition zone. Alaska Department of Transportation and Public Facilities (2000) uses 5-, 10-, or 15-mph increments for speed reduction in transition zone; with higher values for longer transition zone portions and lower for shorter ones.

For the design of transition zones, the report on *Design Guidance for High-Speed to Low-Speed Transition Zones for Rural Highways,* prepared by the NCHRP, could be followed. To reduce the speed of the vehicles to the posted speed limit of the speed zone, the following traffic signs and devices can be used in the transition zone.

7.4.4.1 Sign Post

MUTCD can be used as a reference manual for determining proper sign posts. Important sections of the manual include Section 2B.13 Speed Limit Sign (R2-1), Section 2B.14 Truck Speed Limit Plaque (R2-2P), Section 2B.15 Night Speed Limit Plaque (R2-3P), Section 2B.16 Minimum Speed Limit Plaque (R2-4P), Section 2C.38 Reduced Speed Limit Ahead Signs (W3-5, W3-5a), Section 2C.08 Advisory Speed Plaque (W13-1P), Section 2C.10 Combination of Horizontal Alignment/Advisory Speed Signs (W1-1a, W1-2a), Section 2C.38 Reduced Speed Limit Ahead Signs (W3-5, W3-5a), Section 4L.04 Speed Limit Sign Beacon, Section 5B.03 Speed Limit Signs (R2 Series), Section 7B.15 School Speed Limit Assembly (S4-1P, S4-2P, S4-3P, S4-4P, S4-6P, S5-1) and END OF SCHOOL ZONE SPEED LIMIT Sign (S5-3), and Section 7B.16 Reduced School Speed Limit Ahead Sign (S4-5, S4-5).

7.4.4.2 Digital Messaging Board

Two types of digital messaging board can be implemented. First type is variable speed limit messaging board which will display the recommended speed limit depending upon the driving condition like weather, traffic volume etc. Another type will display the warning message depending upon whether or not the driver is following the speed limit.

7.4.5 Speed Zone Approval Phase

For the approval process, a well-documented report for each site has to be submitted to the Chief of the Traffic and Operation Division of NDOT. The documentation should include:

- Photographs of the site, with a special focus on peculiar conditions, if any.
- Details of previous speed zones.
- Reasons for conducting a speed study, including complaints or revision after a certain number of years.
- Results of speed studies.
- Specifications of new speed zones, such as speed limit(s) and the starting and ending point of each speed limit.
- Exceptions made, with reasons stated.

After it is recommended by the Traffic and Operation Division, the change in existing speed zone or new speed zone is approved by the Director of NDOT.

7.4.6 Speed Limit Enforcement Phase

FHWA (2004) shows that raising or lowering the speed limit does not have much effect on vehicle speed. More vehicles were found to be complaint to the speed limit when it was increased, and less vehicles were found to be complaint to the speed limit when it was decreased. Thus, if the speed limit is to be decreased, then proper enforcement is required. ITE (2004) mentions that high-speed roadways have less fatalities than low-speed roadways on a per-mile-driven basis. Alaska Department of Transportation and Public Facilities (2000) recommended the reduction of the speed limit coupled with police enforcement in order to make the speed limits more effective.

An European study found that the differential speeds of vehicles increased the possibility of crashes (European Road Safety Observatory, 2007). According to state DOT representatives, police enforcement is the most effective method for speed limit compliance. Better speed compliance is likely to decrease the differential speeds, hence decrease the possibility of crashes. Therefore it is necessary to work with local law enforcement agencies to enforce speed limits in speed zones.

7.4.7 Follow up Study Phase

Follow-up studies should be conducted to determine the short-term and long-term effect of the speed zoning or its modification. The study may determine a change in the speed distribution pattern, changes in crash rate, and changes in crash severities. The information thus obtained will be valuable for the further modification of the guideline.

8 Conclusions and Recommendations

NDOT has a process of conducting engineering analysis before setting up speed limits in towns along rural highways. However, the written process has not been documented, which makes it difficult for the traffic engineer to follow steps required to set up a speed zone. This guideline is a step towards establishing written documents for setting up speed zones in towns along rural highways.

The guideline was prepared based on crash and site data analyses, survey responses regarding best practices of state DOTs in setting up speed limits, and interviews with NDOT traffic engineers. The major findings of this research are described below.

8.1 Crash Data Analysis

The major findings of the crash data analysis are as follows.

- Four fatalities occurred in these 11 towns during a 9-year period.
- On average, just above three crashes occurred per year per town during a 9-year period.
- Fernely had the highest number of crashes (10 crashes per year), and Luning had the lowest number of crashes (0.5 crashes per year).
- Based on the crashes per population, Fernley had the lowest number of crashes per 1,000 population (5) and Austin had highest number of crashes per 1,000 population (156).
- Based on the crashes according to AADT, Alamo had the highest number of crashes per 1,000 AADT (7.5) and Tonopah had the lowest number of crashes per 1,000 AADT (0.3).
- The crashes per 1,000 populations per year of these towns is one, and for all of rural Nevada, 31.
- Most crashes in rural towns occurred during favorable conditions. For example, 87% of total crashes occurred when road was in a dry condition, 70% of crashes occurred in clear weather, 60% of crashes occurred in daylight, and 63% of crashes occurred when the driver was in a normal condition.
- About 74% of crashes occurred while primary vehicle was going straight.

8.2 Site Data Analysis

The major findings of the site data analysis are as follows.

- Regression analyses shows that the number of crashes, the number of injuries, and the number of PDO crashes were significantly correlated with the percentage of vehicles exceeding posted speed limits. Thus, speed enforcement is a very important factor in order to reduce the number of crashes.

- The multinomial logit model showed that the claimed injury crashes were significantly correlated with the month when the crashes occurred, vehicle types, and vehicle factors associated with the crashes.
- Non-incapacitating injuries were correlated with vehicle actions, time of the day, days of the week (weekend or weekdays), vehicle types, driver factors, and vehicle factors associated with the crashes.

8.3 Survey Data Analysis

The major findings of the survey data analysis are as follows.

- As per the responses from state DOTs, 'speeding' and 'fatigue and inattention' are two top reasons for crashes. 'Failure to yield' and 'run off lane/road' are other important reasons for crashes, followed by 'DUI'.
- Only half of the DOT representatives that responded to the questionnaire have a speed-zone guideline or manual. Many DOTs did not have a uniform process in setting up speed zones in their towns along rural highways.
- 'Prevailing speed', usually represented by the 85^{th} percentile, is the most important factor that decides features of speed zones, according to the personal views of traffic engineers surveyed. 'Crash history', 'road geometry', 'roadside environment', and 'political and public influence' are four other important factors that decide the features of speed zones.
- Fifty-nine percent of DOT representatives responded that speeding in rural highways is a problem in their state.
- Based on the average rating, increasing 'police enforcement' is the most important factor to control speeding in rural highways. Other important factors included 'installing proper speed-zone signs', 'changing road characteristics', 'driver education', and 'reducing differential speeds'.
- All the DOT representatives, but two, said that increasing speed limits will not increase the frequency of crashes.
- Communities in most of the states are interested in decreasing the speed limits in their neighboring highways.
- In more than half the states that responded to the questionnaire, speed limits have been decreased based on complaints received from the public. Half of them said that reducing speed limits did not solve the problems.

8.4 NDOT Traffic Engineer Interviews

The major findings of the interview with NDOT traffic engineers are as follows.

- The majority of the traffic engineers stated that the guideline will assist in setting up speed zones in towns along rural highways.
- The interview results showed that the major factor to determine the speed limit of a speed zone is the 85^{th} percentile speed of vehicles.
- All the interviewees agreed that the approval process for speed zones that is now in place is very effective.
- The majority of the interviewees agreed that it will be helpful to have guidance for designing the high-speed to low-speed transition zone.
- All the interviewees agreed that the design of low-speed to high-speed transition zones in rural highways is not critical.

A speed-zone guideline is a very important tool to ensure a uniform process in setting up speed zones in towns along rural highways throughout Nevada. The findings and the recommendations provided in this report can be used as a starting point to develop a proper speed-zone guideline. Once the guideline is prepared, it should be updated regularly. Lessons learned, development of latest technologies, and related research are some of the aspects to be considered when updating the guideline.

9 References

Agent, K. R., Pigman, J. G., & Weber, J. M. (1998). Evaluation of speed limits in Kentucky. *Transportation Research Record: Journal of the Transportation Research Board, 1640*, 57-64.

Alaska Department of Transportation and Public Facilities. (2000). *Policy and procedure: Establishment of speed limits and zones.*

American Association of State Highway and Transportation Officials. (1994). *A policy on geometric design of highways and streets*. Washington, DC.

Arizona Department of Transportation. (2000). *Traffic studies: ADOT traffic engineering policies, guidelines, and procedures*.

Armour, M. (1986). The effect of police presence on urban driving speeds. *Institute of Transportation Engineers Journal, 56* (HS-039 925), 40-45.

Arnold, E., & Lantz, K. (2007). *Evaluation of best practices in traffic operations and safety: Phase I: Flashing LED stop sign and optical speed bars.* (No. VTRC 07-R34). Charlottesville, VA: Virginia Transportation Research Council.

Benekohal, R. F., Resende, P. T. V., & Orloski, R. L. (1992). *Effects of police presence on speed in a highway work zone: Circulating marked police car experiment.* (No. FHWA/IL/UI-240). Federal Highway Administration. Washington, DC.

Blackburn, R. R., Moran, R., & Glauz, W. D. (1989). *Update of enforcement technology and speed measurement devices.* (No. DOT HS 807 584). National Highway Traffic Safety Administration. Washington, DC, USA.

Bloch, S. A. (1998). Comparative study of speed reduction effects of photo-radar and speed display boards. *Transportation Research Record: Journal of the Transportation Research Board, 1640*, 27-36.

California Department of Transportation. (2012). *California manual on uniform traffic control devices*

Chen, H., Cao, L., & Logan, D. B. (2012). Analysis of risk factors affecting the severity of intersection crashes by logistic regression. *Traffic Injury Prevention, 13*(3), 300-307.

CloudMade. (2013). CloudMade - the location platform serving OEMs, enterprises & developers. Retrieved 3/013, 2013, from http://cloudmade.com/

Connecticut Department of Transportation. (2012). Speed limit?, Retrieved 12/18, 2012, from http://www.ct.gov/dot/cwp/view.asp?Q=259744

Cooper, D. R. C., Jordan, P. G., & Young, J. C. (1980). The effect on traffic speeds of resurfacing a road.*SR 571 Monograph*, 22.

Cruzado, I., & Donnell, E. T. (2009). Evaluating effectiveness of dynamic speed display signs in transition zones of two-lane, rural highways in Pennsylvania. *Transportation Research Record: Journal of the Transportation Research Board, 2122*, 1-8.

Cruzado, I., & Donnell, E. T. (2010). Factors affecting driver speed choice along two-lane rural highway transition zones. *Journal of Transportation Engineering, 136*(8), 755-764.

Downward speed zoning, California Vehicle Code 22358.5 (2011).

Dudek, C. L., & Ullman, G. L. (1987). *Speed zoning and control.* (No. 334-2F). College Station, Texas: Texas State Department of Highways and Public Transportation.

Elvik, R. (1997). Effects on accidents of automatic speed enforcement in Norway. *Transportation Research Record: Journal of the Transportation Research Board, 1595*, 14-19.

Elvik, R. (2002). Optimal speed limits: Limits of optimality models. *Transportation Research Record: Journal of the Transportation Research Board, 1818*, 32-38.

Elvik, R. (2012). Speed limits, enforcement, and health consequences. *Annual Review of Public Health, 33*, 225-238. doi: 10.1146/annurev-publhealth-031811-124634

Esposito, T., Mauro, R., Russo, F., & Dell'Acqua, G. (2011). Operating speed prediction models for sustainable road safety management. *The International Conference on Sustainable Design and Construction 2011: ICSDC 2011: Integrating Sustainability Practices in the Construction Industry,* Kansas City, Missouri, *426*(41204) 712-721.

European Transport Safety Council. (1995). *Reducing traffic injuries resulting from excess and inappropriate speed.* Brussels, Belgium.

Evans, L., & Wasielewski, P. (1983). Risky driving related to driver and vehicle characteristics. *Accident Analysis & Prevention, 15*(2), 121-136.

Federal Highway Administration. (2012). *Manual on uniform traffic control devices for streets and highways* (2009th ed.). USA.

Federal Highway Administration. (2011). *Highway statistics 2009* (2011). USA.

Federal Highway Safety Administration. (2000). *Speeding in rural areas.* USA.

Fildes, B. N., Rumbold, G., & Leening, A. (1991). *Speed behaviour and drivers' attitude to speeding.* (No. 16).Monash University Accident Research Centre.

Fitzpatrick, K., Carlson, P., Brewer, M., & Wooldridge, M. (2001). Design factors that affect driver speed on suburban streets. *Transportation Research Record: Journal of the Transportation Research Board, 1751*, 18-25.

Florida Department of Transportation. (2010). *Speed zoning for highways, roads & streets*. Tallahassee, FL.

Forbes, G. J. (2011). *Speed reduction techniques for rural high-to-low speed transitions.* (No. 412). Washington, DC: Transportation Research Board.

Garber, N. J., Miller, J. S., Yuan, B., & Sun, X. (2003). Safety effects of differential speed limits on rural interstate highways. *Transportation Research Record: Journal of the Transportation Research Board, 1830*, 56-62.

Georgia Department of Transportation. (2012). *Traffic control - speed limits: Establishment of speed zones*.

Hajbabaie, A., Benekohal, R. F., Chitturi, M., Wang, M., & Medina, J. C. (2009). Comparison of effects of automated speed enforcement and police presence on speeding in work zones. *Transportation Research Board 2009 Annual Meeting.*

Haselton, C. B., Gibby, A. R., & Ferrara, T. C. (2002). Methodologies used to analyze collision experience associated with speed limit changes on selected California highways. *Transportation Research Record: Journal of the Transportation Research Board, 1784*, 65-72.

Hassan, H. M., & Abdel-Aty, M. A. (2012). Exploring the safety implications of young drivers' behavior, attitudes and perceptions. *Accident Analysis & Prevention,* doi: http://dx.doi.org/10.1016/j.aap.2012.05.003

Hauer, E., Ahlin, F. J., & Bowser, J. S. (1982). Speed enforcement and speed choice. *Accident Analysis & Prevention, 14*(4), 267-278.

Herrstedt, L., Kjemtrup, K., Borges, P., & Andersen, P. (1993). *An improved traffic environment-a catalogue of ideas.* (No. 106).Road Data Laboratory, Road Standards Divison, Road Directorate, Denmark Ministry of Transport.

Highway safety program guideline no. 19: Speed management. (2006). *Uniform guidelines for state highway safety programs*. National Highway Traffic Safety Administration, USA.

Idaho Transportation Department. (1997). *Speed limit and speed zones: A guide to establishing speed zones in idaho*.

Institute of Transportation Engineers. (1993). Technical council report summary: A proposed recommended practice: Speed zone guidelines by ITE technical council committee 4M - 25. *Institute of Transportation Engineers Journal,* , 45.

Institute of Transportation Engineers. (1993). A proposed recommended practice: Guidelines for determining where the 55-mph speed limit could be raised. *Institute of Transportation Engineers Journal, 1987*, 21-25.

Jarvis, J. R., & Hoban, C. J. (1989). The development of a speed zoning knowledge-based system. *Civil Engineering Systems, 6*(1-2), 71-79. doi: http://dx.doi.org/10.1080/02630258908970546

Jonah, B. A. (1986). Accident risk and risk-taking behaviour among young drivers. *Accident Analysis & Prevention, 18*(4), 255-271.

Jordan, G. (1998). Child pedestrian-car crashes near schools are a small percentage of total child pedestrian crashes in philadelphia. *Transportation Research Record: Journal of the Transportation Research Board, 1636*(1), 132-137.

Kallberg, V., Allsop, R., Ward, H., van der Horst, R., & Varhelyi, A. (1999). Recommendations for speed management on European roads. *78th Annual Meeting of the Transportation Research Board, TRB, National Research Council,* Washington, DC. 1-12.

Kamyab, A., Andrle, S., Kroeger, D., & Heyer, D. S. (2003). Methods to reduce traffic speed in high-pedestrian rural areas. *Transportation Research Record: Journal of the Transportation Research Board, 1828*, 31-37.

Kockelman, K., Bottom, J., Kweon, Y., Ma, J., & Wang, X. (2006). *Safety impacts and other implications of raised speed limits on high-speed roads.* Transportation Research Board.

Kraft, W. H., Homburger, W. S., & Pline, J. L. (2009). *Traffic engineering handbook,* Institute of Transportation Engineers.

Lamberti, R., Abate, D., De Guglielmo, M. L., Dell'Acqua, G., Esposito, T., Galante, F, Pernetti, M. (2009). Perceptual measures and physical devices for traffic calming along a rural highway crossing a small urban community: Speed behavior evaluation in a driving simulator. *Transportation Research Board 88th Annual Meeting,* Washington, DC. (09-3233)

Lee, C., Hellinga, B., & Saccomanno, F. (2004). Assessing safety benefits of variable speed limits. *Transportation Research Record: Journal of the Transportation Research Board, 1897*, 183-190.

Lee, J., & Mannering, F. (2002). Impact of roadside features on the frequency and severity of run-off-roadway accidents: An empirical analysis. *Accident Analysis & Prevention, 34*(2), 149-161.

Louisiana Department of Transportation and Development. (1981). *Warrants for the establishment of speed zones, engineering directives and standards manual*.

Malyshkina, N. V., & Mannering, F. (2008). Effect of increases in speed limits on severities of injuries in accidents. *Transportation Research Record: Journal of the Transportation Research Board, 2083*, 122-127.

Massachusetts Highway Department. (2005). *Procedures for speed zoning on state and municipal roadways*.

Michigan Deparment of Transportation. (2004). *Establishing realistic speed limits.*

Milstead, R., Qin, X., Katz, B., Bonneson, J., Pratt, M., Miles, J., & and Carlson, P. (2011). *Procedures for setting advisory speeds on curves*. Washington, DC: Federal Highway Administration.

Missouri Department of Transportation. (2010). Speed limit guidelines - engineering policy guide. Retrieved 3/12, 2013, from http://epg.modot.mo.gov/index.php?title=949.2_Speed_Limit_Guidelines

Montana Department of Transportation. (2007). *Speed studies: Montana traffic engineering manual*.

Najjar, Y. M., Stokes, R. W., & Russell, E. R. (2000). Setting speed limits on Kansas two-lane highways: Neuronet approach. *Transportation Research Record: Journal of the Transportation Research Board, 1708*, 20-27.

National Highway Traffic Safety Administration. (1994). *Research agenda for an improved novice driver education program.* (No. DOT-HS-808-161). Washington, DC, USA.

National Highway Traffic Safety Administration. (2012). *2010 motor vehicle crashes: Overview.* (No. DOT HS 811 552). Washington, DC, USA.

Nevada Department of Transportation. (2012). *Nevada traffic crashes 2010*. Carson City, Nevada.

North Carolina Department of Transportation. (1995). *Guidelines for the establishment of restrictive speed limits*.

Oei, H. (1996). Automatic speed management in the Netherlands. *Transportation Research Record: Journal of the Transportation Research Board, 1560*, 57-64.

Open Street Map. (2013). Open street map of Nevada. Retrieved 3/013, 2013, from http://www.openstreetmap.org/

Oregon Department of Transportation. (2011). *Speed zone manual.*

Parham, A. H., & Fitzpatrick, K. (1998). (No. FHWA/TX-99/1770-2). College Station, Texas: Texas Transportation Institute, The Texas A&M University System.

Pyne, H. C., Dougherty, M. S., Carsten, O. M. J., & Tight, M. R. (1995). A simulator based evaluation of speed reduction measures for rural arterial roads.

Raju, S., Souleyrette, R., & Maze, T. H. (1998). Impact of 65-mph speed limit on Iowa's rural interstate highways: Integrated Bayesian forecasting and dynamic modeling approach. *Transportation Research Record: Journal of the Transportation Research Board, 1640*, 47-56.

Rämä, P. (1999). Effects of weather-controlled variable speed limits and warning signs on driver behavior. *Transportation Research Record: Journal of the Transportation Research Board, 1689*, 53-59.

Raub, R. A. (1985). Removal of roof-mounted emergency lighting from police patrol vehicles: An evaluation. *Transportation Research Record, 1047*, 83-88.

Renski, H., Khattak, A. J., & Council, F. M. (1999). Effect of speed limit increases on crash injury severity: Analysis of single-vehicle crashes on North Carolina interstate highways. *Transportation Research Record: Journal of the Transportation Research Board, 1665*, 100-108.

Rogerson, P. A., Newstead, S. V., & Cameron, M. H. (1994). *Evaluation of the speed camera program in Victoria, 1990-1991: Phase 3, localised effects on casualty crashes and crash severity, phase 4, general effects on speed.* (No. 54). Melbourne: Monash University, Accident Research Centre.

Rules of the road, NRS 484B (2013). Nevada Revised Statutes.

Russell, E. R., & Godavarthy, R. P. (2010). *Mitigating crashes at high-risk rural intersections with two-way stop control.* (No. K-TRAN: KSU-06-4). Manhattan, Kansas: Kansas Department of Transportation.

Sandberg, W., Schoenecker, T., Sebastian, K., & Soler, D. (2006). Long-term effectiveness of dynamic speed monitoring displays (DSMD) for speed management at speed limit transitions. *Compendium of Technical Papers of the Institute of Transportation Engineers Annual Meeting and Exhibit Compendium of Technical Papers,* Jackson, Mississippi.

Sarkar, S., Jan Nederveen, A. A., & Pols, A. (1997). Renewed commitment to traffic calming for pedestrian safety. *Transportation Research Record: Journal of the Transportation Research Board, 1578*, 11-19.

Shinar, D., & Stiebel, J. (1986). The effectiveness of stationary versus moving police vehicles on compliance with speed limit. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 28*(3), 365-371.

Sperling. (2013). People in Luning (zip 89420), Nevada. Retrieved 3/24, 2013, from http://www.bestplaces.net/people/zip-code/nevada/luning/89420

Srinivasan, R., Parker, M., Harkey, D., Tharpe, D., & Sumner, R. (2006). *Expert system for recommending speed limits in speed zones.* U.S. National Cooperative Highway Research Program.

Wisconsin Department of Transportation. (2009). *Statewide speed management guidelines*. Madison, WI.

Streff, F. M., Kostyniuk, L. P., & Christoff, C. (1995). *Effects of drone radar and police enforcement on travel speeds: Test on a 65 mph freeway and 55 mph construction* *zone.* (No. UMTRI-95-22).University of Michigan, Transportation Research Institute.

Stuster, J. W. (1995). *Experimental evaluation of municipal speed enforcement programs.* (No. DOT HS 808 325). National Highway Traffic Safety Administration, Washington, DC, USA.

Stuster, J., Coffman, Z., & Warren, D. (1998). *Synthesis of safety research related to speed and speed management.* (No. FHWA-RD-98-154). McLean, VA: U.S. Federal Highway Administraton.

Teed, N., & Lund, A. K. (1993). The effect of laser speed-measuring devices on speed limit law enforcement in Charleston, South Carolina. *Accident Analysis & Prevention, 25*(4), 459-463.

Texas Department of Transportation. (2011). *Procedures for establishing speed zones*.

Thornton, M., & Lyles, R. W. (1996). Freeway speed zones: Safety and compliance issues. *Transportation Research Record: Journal of the Transportation Research Board, 1560*, 65-72.

Tignor, S. C., & Warren, D. (1990). Driver speed behavior on U.S. streets and highways. *Compendium of Technical Papers, Institute of Transportation Engineers,* Washington, DC.

Torbic, D. J., Gilmore, D. K., Bauer, K. M., Bokenkroger, C. D., Harwood, D. W., Lucas, L. M., . . . Forsberg, M. D. (2012). *Design guidance for high-speed to low-speed transition zones for rural highways.* (No. 737).U.S. National Cooperative Highway Research Program.

Toyota Motor Corporation. (2013). Avoid dangerous situations and prevent accidents with Toyota's active safety technology. Retrieved 2/21, 2013, from http://www.toyota-global.com/innovation/safety_technology/safety_technology/active_safety/

Toyota Motor Sales, U.S.A., Inc. (2013). Toyota | Toyota's collaborative safety research center announces four new safety research projects. Retrieved 03/22, 2013, from http://pressroom.toyota.com/releases/toyota+collaborative+safety+research+center+four+new+partners+december+2011.htm

Traffic law generally, NRS 484A (2013). Nevada Revised Statutes.

Traffic laws, NRS 484 (2011). Nevada Revised Statutes.

Kentucky Transportation Cabinet. (2012). *Traffic operations guidance manual*. Commonwealth of Kentucky.

Transportation Research Board. (1998). *Managing speed: Review of current practice for setting and enforcing speed limits.* (No. 254).

Transportation Research Board. (1984). *A decade of experience.* (No. 204). Washington, DC.

UK Department of Transport. (2005). *Traffic advisory leaflet 1/05: Rumblewave surfacing*. London, UK.

U.S. Census Bureau. (2012). *Nevada: 2010: Population and housing unit counts: 2010 census of population and housing.* (No. CPH-2-30).

USLIMITS2: A tool to aid practitioners in determining appropriate speed limit recommendations. Retrieved 03/12, 2013, from http://safety.fhwa.dot.gov/uslimits/

Vaa, T. (1997). Increased police enforcement: Effects on speed. *Accident Analysis & Prevention, 29*(3), 373-385.

van der Horst, R., & de Ridder, S. (2007). Influence of roadside infrastructure on driving behavior: Driving simulator study. *Transportation Research Record: Journal of the Transportation Research Board, 2018*, 36-44.

Van Houten, R., & Van Huten, F. (1987). The effects of a specific prompting sign on speed reduction. *Accident Analysis & Prevention, 19*(2), 115-117.

Warren, D. L. (1982). *Synthesis of safety research related to traffic control and roadway elements vol.2.* (No. FHWA-TS-82-233). Federal Highway Administration. Washington, DC.

Winnett, M. A., & Wheeler, A. H. (2002). *Vehicle-activated signs – a large scale evaluation.* (No. 548).Transport Research Laboratory.

Wisconsin Transportation Information Center. (1999). *Setting speed limits on local roads.* (No. 21). Madison, WI.

Wyoming Department of Transportation. (2011). *WYDOT traffic studies manual*.

Xie, Y., Zhao, K., & Huynh, N. (2012). Analysis of driver injury severity in rural single-vehicle crashes. *Accident Analysis & Prevention, 47*, 36-44.

Zahabi, S. A. H., Strauss, J., Manaugh, K., & Miranda-Moreno, L. F. (2011). Estimating potential effect of speed limits, built environment, and other factors on severity of pedestrian and cyclist injuries in crashes. *Transportation Research Record: Journal of the Transportation Research Board, 2247*, 81-90. doi: 10.3141/2247-10

Appendix A Crash Statistics by Town

Table 9-1 Total Crashes per Year by Town

Town	No. of crashes	Average crashes per year
Fernley	90	10
Searchlight	41	5
Beatty	35	4
Goldfield	35	4
Austin	30	3
Schurz	26	3
Tonopah	25	3
McGill	22	2
Panaca	15	2
Alamo	13	1
Luning	5	1
Total	**337**	**37**
Average (per town)	**31**	**3**

Table 9-2 Non-fatal Injury-Causing Crashes per Year by Town

Town	No. of non-fatal injury-causing crashes	No. of non-fatal injury-causing crashes per year
Fernley	22	2
Searchlight	13	1
Goldfield	13	1
Tonopah	9	1
Schurz	9	1
Beatty	8	1
McGill	8	1
Austin	8	1
Alamo	3	0
Panaca	3	0
Luning	0	0
Total	**96**	**11**
Average (per town)	**9**	**1**

Table 9-3 No. of PDO Crashes per Year by Town

Town	No. of PDO crashes	No. of PDO crashes per year
Fernley	66	7
Searchlight	28	3
Beatty	27	3
Austin	22	2
Goldfield	21	2
Schurz	17	2
Tonopah	16	2
McGill	14	2
Panaca	12	1
Alamo	10	1
Luning	5	1
Total	**238**	**26**
Average (per town)	**22**	**2**

Table 9-4 Non-fatal Injuries per Year by Town

Town	No. of injuries	No. of injuries per year
Fernley	34	4
Searchlight	17	2
Tonopah	15	2
Goldfield	14	2
Schurz	12	1
Beatty	11	1
Austin	10	1
McGill	9	1
Alamo	9	1
Panaca	3	0
Luning	0	0
Total	**134**	**15**
Average (per town)	**12**	**1**

Table 9-5 Average Injuries per Non-fatal Injury-Causing Crashes by Town

Town	No. of non-fatal injury-causing crashes	No. of injuries	Average injuries per non-fatal injury-causing crashes
Alamo	3	9	3
Tonopah	9	15	2
Fernley	22	34	2
Beatty	8	11	1
Schurz	9	12	1
Searchlight	13	17	1
Austin	8	10	1
McGill	8	9	1
Goldfield	13	14	1
Panaca	3	3	1
Luning	0	0	-
Total	**96**	**134**	**1**
Average (per town)	**9**	**12**	**1**

Table 9-6 PDO Crashes Vs. Non-fatal Injury-Causing Crashes

Town	No. of non-fatal injury-causing crashes	No. of PDO crashes	PDO crashes per non-fatal injury-causing crashes	No. of total crashes
Panaca	3	12	4	15
Beatty	8	27	3	35
Alamo	3	10	3	13
Fernley	22	66	3	90
Austin	8	22	3	30
Searchlight	13	28	2	41
Schurz	9	17	2	26
Tonopah	9	16	2	25
McGill	8	14	2	22
Goldfield	13	21	2	35
Luning	0	5	-	5
Total	**96**	**238**	**2**	**337**
Average (per town)	**9**	**22**	**3**	**31**

Appendix B Time Factors Associated with Crashes

Table 9-7 Crash Distribution by Hour

Time	Crash count	Percentage
12:00AM - 1:00AM	9	3%
1:00AM - 2:00AM	7	2%
2:00AM - 3:00AM	5	1%
3:00AM - 4:00AM	3	1%
4:00AM - 5:00AM	8	2%
5:00AM - 6:00 AM	14	4%
6:00AM - 7:00AM	6	2%
7:00AM - 8:00AM	22	7%
8:00AM - 9:00AM	12	4%
9:00AM - 10:00AM	10	3%
10:00AM - 11:00AM	17	5%
11:00AM - 12:00PM	17	5%
12:00PM - 1:00PM	16	5%
1:00PM - 2:00PM	19	6%
2:00PM - 3:00PM	27	8%
3:00PM - 4:00PM	20	6%
4:00PM - 5:00PM	27	8%
5:00PM - 6:00PM	26	8%
6:00PM - 7:00PM	12	4%
7:00PM - 8:00PM	16	5%
8:00PM - 9:00PM	16	5%
9:00PM - 10:00PM	10	3%
10:00PM - 11:00PM	11	3%
11:00PM - 12:00PM	7	2%
Total	**337**	**100%**

Table 9-8 Crash Distribution by Day

Day	Crash count	Percentage
Sunday	44	13%
Monday	49	15%
Tuesday	46	14%
Wednesday	62	18%
Thursday	51	15%
Friday	48	14%
Saturday	37	11%
Total	**337**	**100%**

Table 9-9 Crash Distribution by Month

Month	Crash count	Percentage
January	31	9%
February	13	4%
March	35	10%
April	25	7%
May	26	8%
June	37	11%
July	21	6%
August	21	6%
September	37	11%
October	39	12%
November	21	6%
December	31	9%
Total	**337**	**100%**

Appendix C Site Data Collection Forms

Preparing Guidelines for Speed Reduction in Towns along Nevada Rural Highways

SITE DATA COLLECTION SHEET

Name of the city: ____

District No: ____

Name of highway: ____

Milepost number: ____

Site description: ____

Name of data collector:____

Date: ____

1. Existing speed zones on road section under review

	Upstream	Speed zone	Downstream
Length	ft	ft	ft
Current posted speed limits	mph	mph	mph

2. Overall environment (Select one)

☐ Urban or suburban

☐ Rural or open space

☐ In between

3. Total number of accesses (in transition zones): __________No. ☐ None

Side 1: (Right side)

Side roads	Type of side roads	Distance from start of transition zone (ft)
Side road # 1	☐ State highway ☐ Village road ☐ Other access road types_________	
Side road # 2	☐ State highway ☐ Village road ☐ Other access road types_________	
Side road # 3	☐ State highway ☐ Village road ☐ Other access road types_________	
Side road # 4	☐ State highway ☐ Village road ☐ Other access road types_________	
Side road # 5	☐ State highway ☐ Village road ☐ Other access road types_________	

Side 2: (Left side)

Side roads	Type of side roads	Distance from start of transition zone (ft)
Side road # 1	☐ State highway ☐ Village road ☐ Other access road types __________	
Side road # 2	☐ State highway ☐ Village road ☐ Other access road types __________	
Side road # 3	☐ State highway ☐ Village road ☐ Other access road types__________	
Side road # 4	☐ State highway ☐ Village road ☐ Other access road types__________	
Side road # 5	☐ State highway ☐ Village road ☐ Other access road types__________	

4. Detailed description of abutting properties: ___________ No. ☐ None

Side 1: (Right side)

Abutting properties	Number of properties	Minimum distance from the road shoulder (ft)
Presence of buildings		
Presence of schools		
Presence of bicycle lanes	NA	
Presence of bus stops		
Presence of pedestrian facilities		
Presence of parking areas		
Any other properties (mention) ___________________________		

Side 2: (Left side)

Abutting properties	Number of properties	Minimum distance from the road shoulder (ft)
Presence of buildings		
Presence of schools		
Presence of bicycle lanes	NA	
Presence of bus stops		
Presence of pedestrian facilities		
Presence of parking areas		
Any other properties (mention) ___________________________		

5. Total number of lanes - both directions combined __________________________

_________________ bound _____________________ lanes

_________________ bound _____________________ lanes

6. Divided or undivided highway: ☐ undivided ☐ divided

(If divided)

7. Median width - ____________________ft

(If undivided)

Type of median separator

☐ Concrete barrier

☐ Painting with rumble strips

☐ Just painting

☐ Any other (Mention) ___________________________

8. Special roadside activities (select one or more)

☐ Schools or numerous pedestrians and/or cyclists

☐ Bus stops

☐ Frequent parking and un-parking movements

☐ Substantial crossing and turning traffic

☐ Recreational or tourist activities

☐ Train crossings

☐ Other, please specify: ____

☐ None of the above

9. Pedestrian and cycle interactions with traffic

☐ Mostly at controlled or supervised crossings

☐ Mostly uncontrolled

10. Presence of pedestrian crossings in speed zone: ☐ Yes ☐ No

(If bus stops present)

11. Clearance from bus stops

☐ Through traffic is frequently disturbed and disrupted

☐ Mainly clear of through traffic, or infrequent

☐ Any other, specify ____

(If parking)

12. Setback

☐ Some space available for maneuvering

☐ No clearance at all from moving traffic

☐ Any other, specify ____

(If frequent crossing and turning)

13. Control of crossing and turning traffic movements:

☐ mostly controlled or protected by turn lanes

☐ Uncontrolled and unprotected

☐ Any other, specify ____

14. Highway geometrics data

a. Presence of horizontal curves ☐ Yes ☐ No

i. Radius of horizontal curve = ____________(To be collected from NDOT)

ii. Degree of curvature: ☐ Very sharp

☐ Sharp

☐ Smooth

☐ Almost straight

iii. Horizontal sight distance: ________ ft

☐ Enough

☐ Not enough

b. Presence of vertical curves ☐ Yes ☐ No

i. Radius of vertical curve ______________(To be collected from NDOT)

ii. Degree of curvature: ☐ Very sharp

☐ Sharp

☐ Smooth

☐ Almost straight

iii. Vertical sight distance: ________ ft

☐ Enough

☐ Not enough

c. Lane width _____________

d. Shoulder width ______________

15. Presence of road intersection in the city ☐ Yes ☐ No

a. If yes, then type of road intersection

☐ Four way stop

☐ Stop signs in access roads

☐ Signalized intersection

☐ If any other type, mention

____

16. Speed reduction techniques used in transition zones

    a. Use of traffic signs (Mention type of traffic signs)

    ____
    ____
    ____
    ____
    ____

    b. Presence of Speed Hump ☐ Yes ☐ No

    c. Use of any other speed reduction techniques (Mention)

    ____
    ____

17. Any other traffic safety techniques used in transition zones

    ____
    ____
    ____
    ____

Preparing Guidelines for Speed Reduction in Towns along Nevada Rural Highways

SPOT SPEED SURVEY

City: ____

District:____

Route: ____

Hwy #:____

Mile Post:____

Date: ________________ Day: __________________ Time: __________________

Weather: ____

Posted Speed Sign: ____________________________________

Data Collector: _______________________________________

Location Description: __________________________________

Remarks: ____

Bicycles Lane Width: _______________ft

Pavement Width: _______________ft

Shoulder Width: _______________ ft

Pedestrians Side Walk Width: ____________________ ft

MPH	Passenger cars						Trucks						Bus	
	Bound	Tot.	%	Bound	Tot.	%	Bound	Tot.	%	Bound	Tot.	%	Bd	Bd
70+														
69														
68														
67														
66														
65														
64														
63														
62														
61														
60														
59														
58														
57														
56														
55														
54														
53														

MPH	Passenger cars						Trucks						Bus	
	Bound	Tot.	%	Bound	Tot.	%	Bound	Tot.	%	Bound	Tot.	%	Bd	Bd
52														
51														
50														
49														
48														
47														
46														
45														
44														
43														
42														
41														
40														
39														
38														
37														
36														
35														

MPH	Passenger cars						Trucks						Bus	
	Bound	Tot.	%	Bound	Tot.	%	Bound	Tot.	%	Bound	Tot.	%	Bd	Bd
34														
33														
32														
31														
30														
29														
28														
27														
26														
25														
24														
23														
22														
21														
20														

Appendix D Site Maps of Towns Under Study

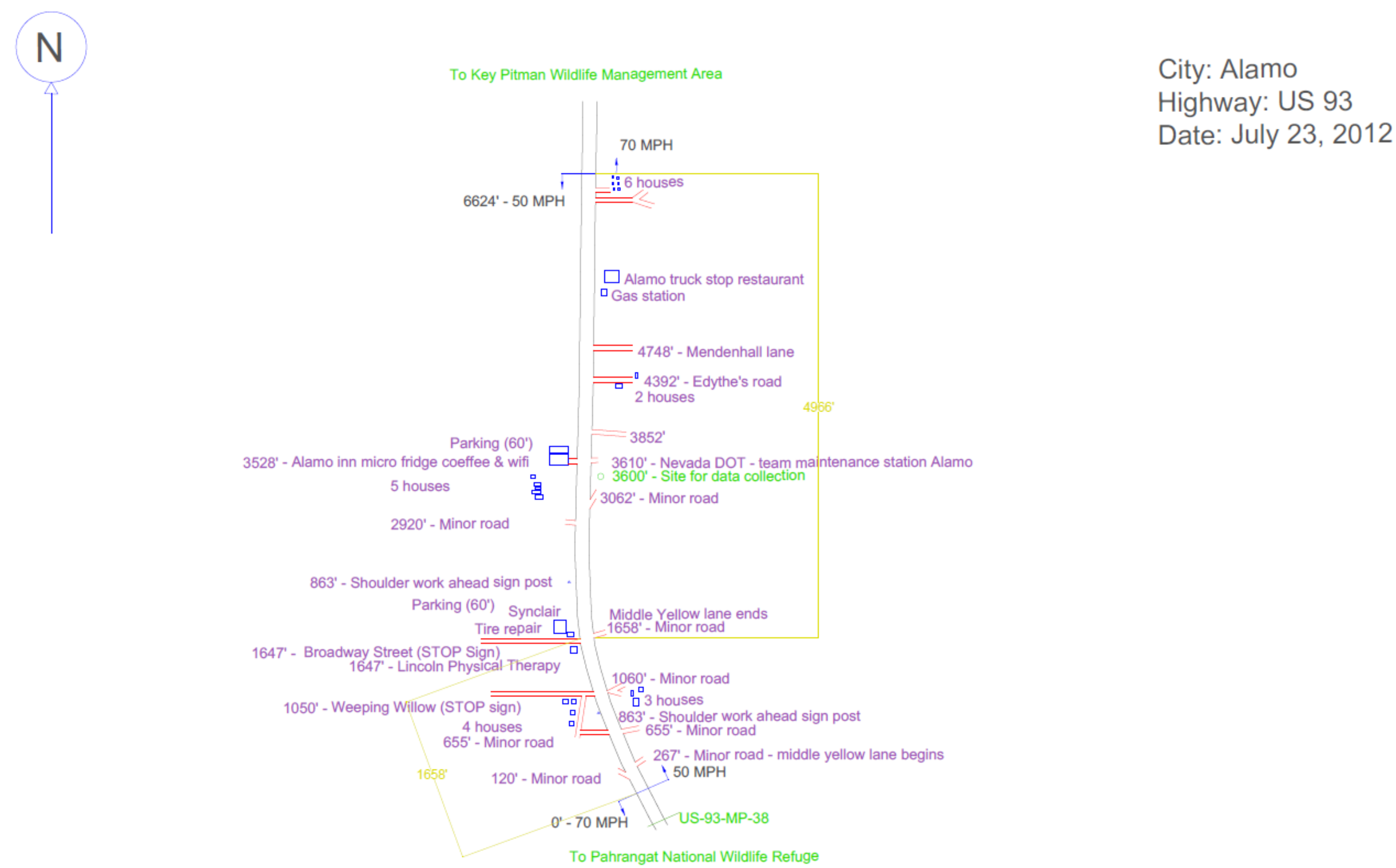

Figure 9-1 Alamo Speed-Zone Map

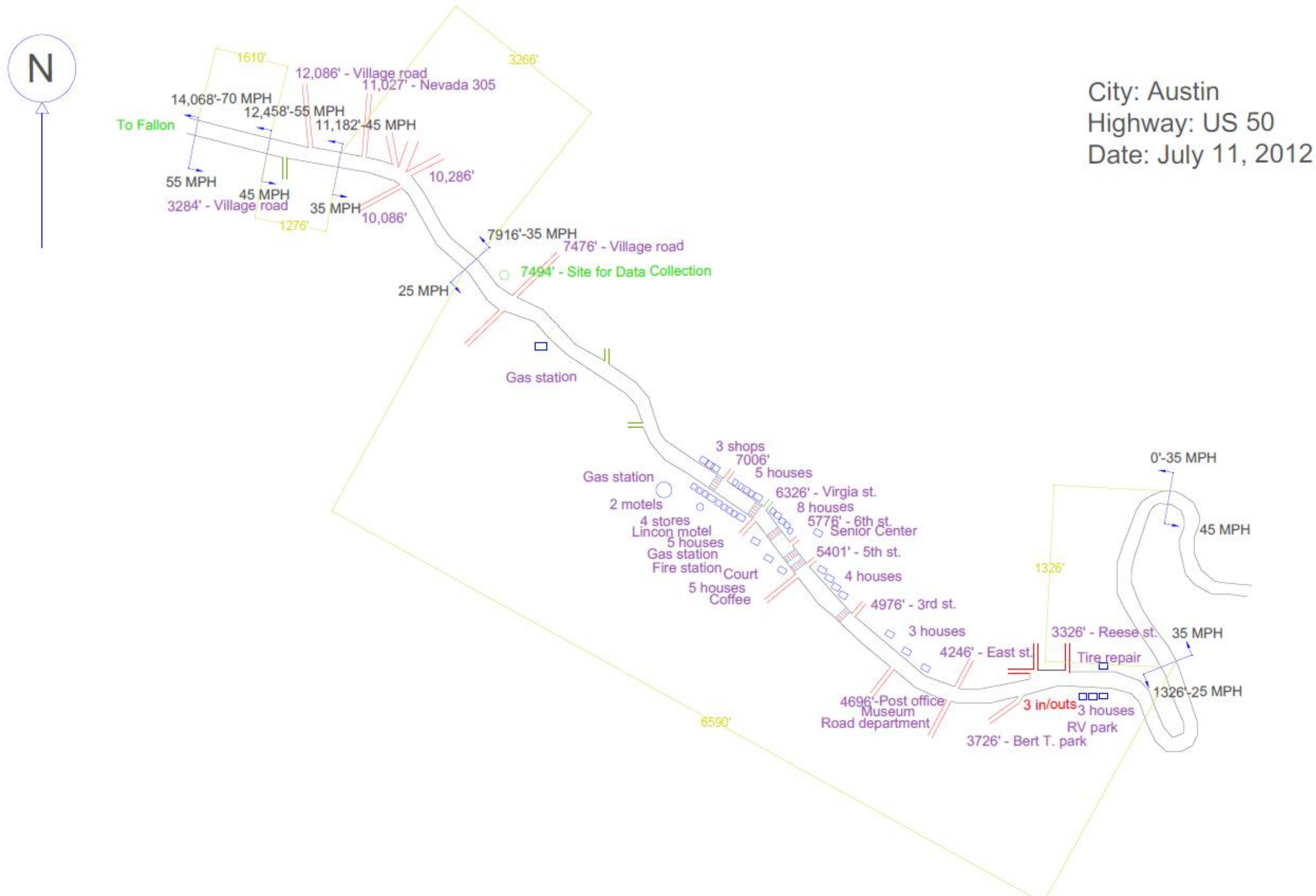

Figure 9-2 Austin Speed-Zone Map

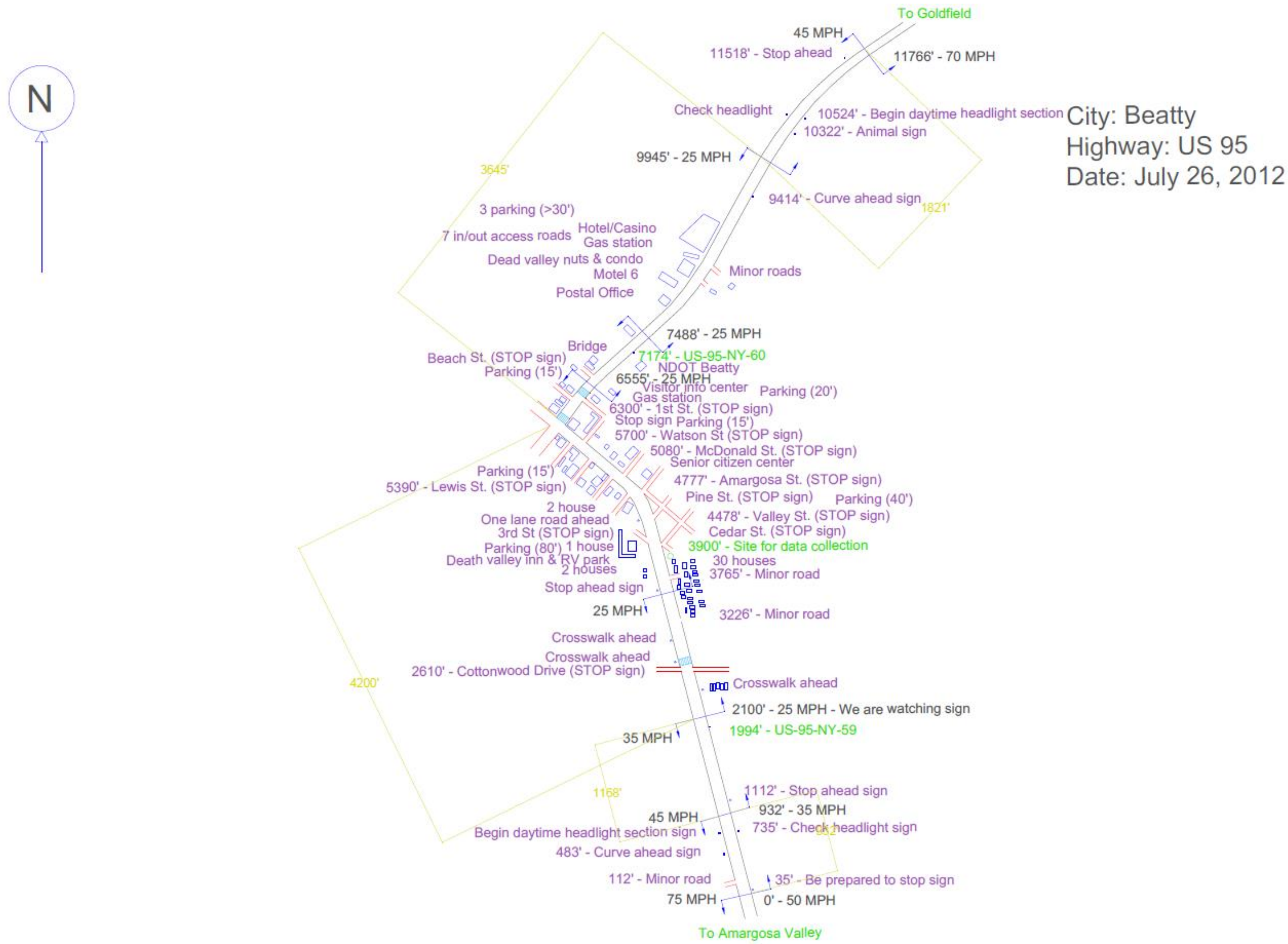

Figure 9-3 Beatty Speed-Zone Map

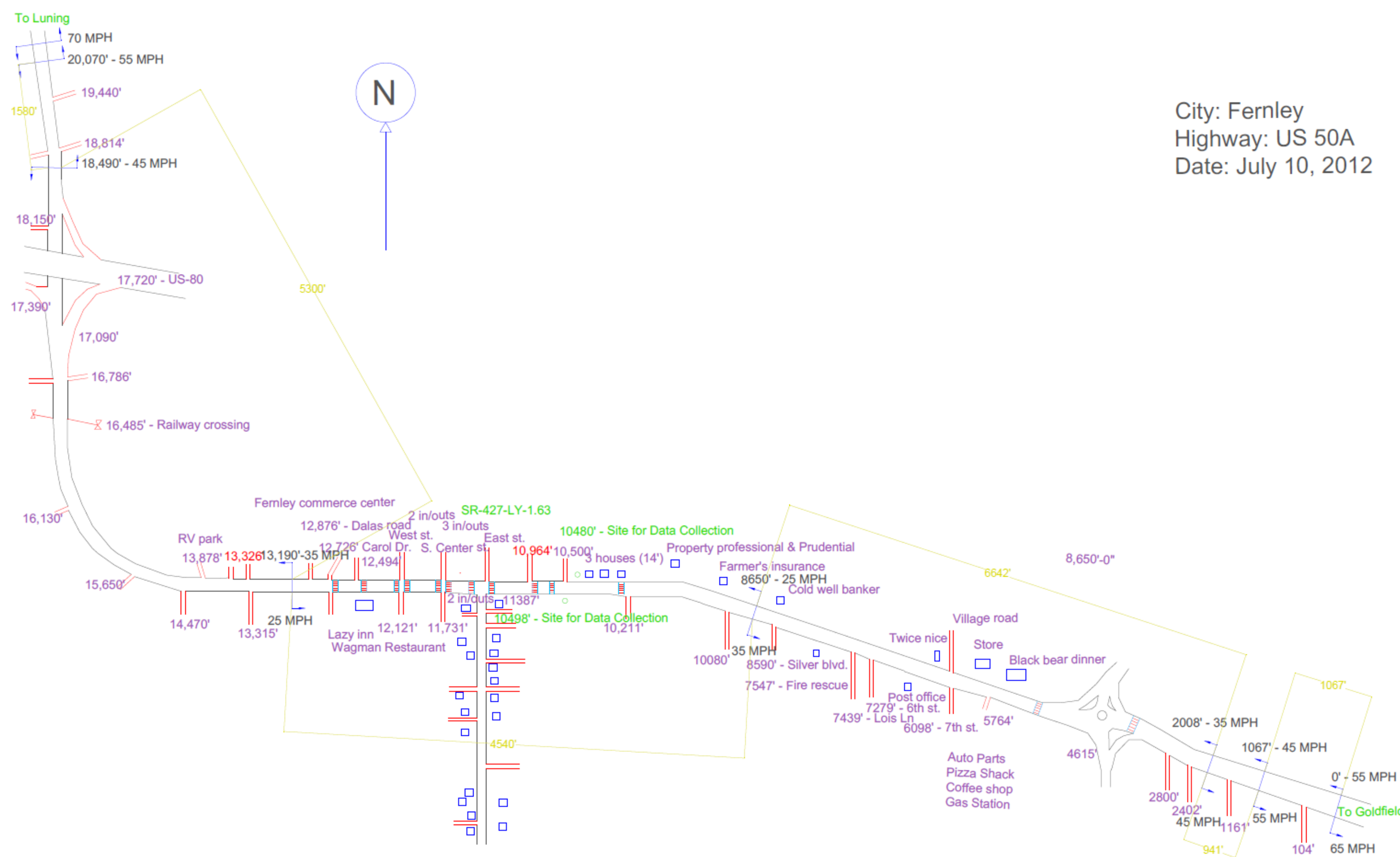

Figure 9-4 Fernley Speed-Zone Map

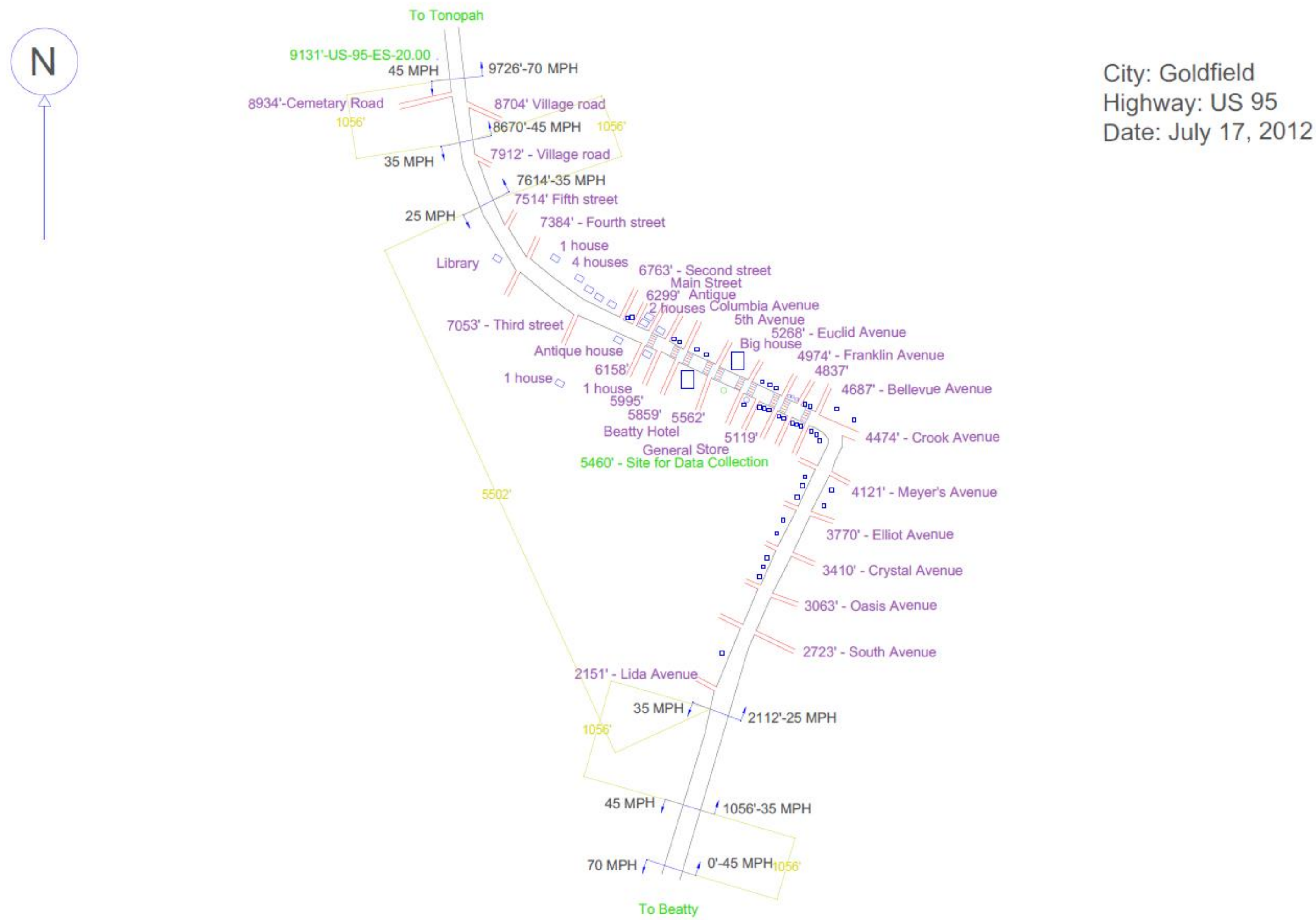

Figure 9-5 Goldfield Speed-Zone Map

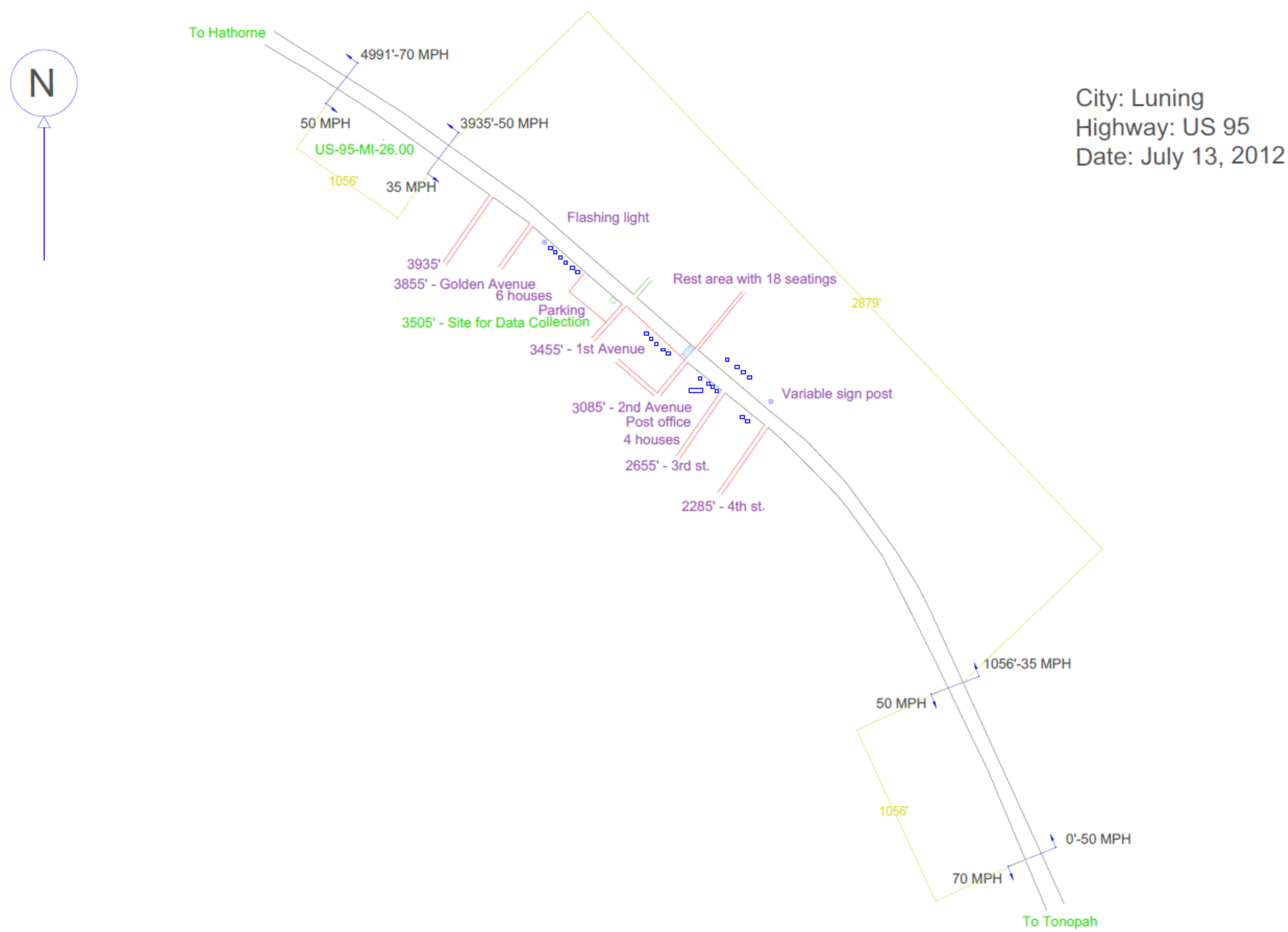

Figure 9-6 Luning Speed-Zone Map

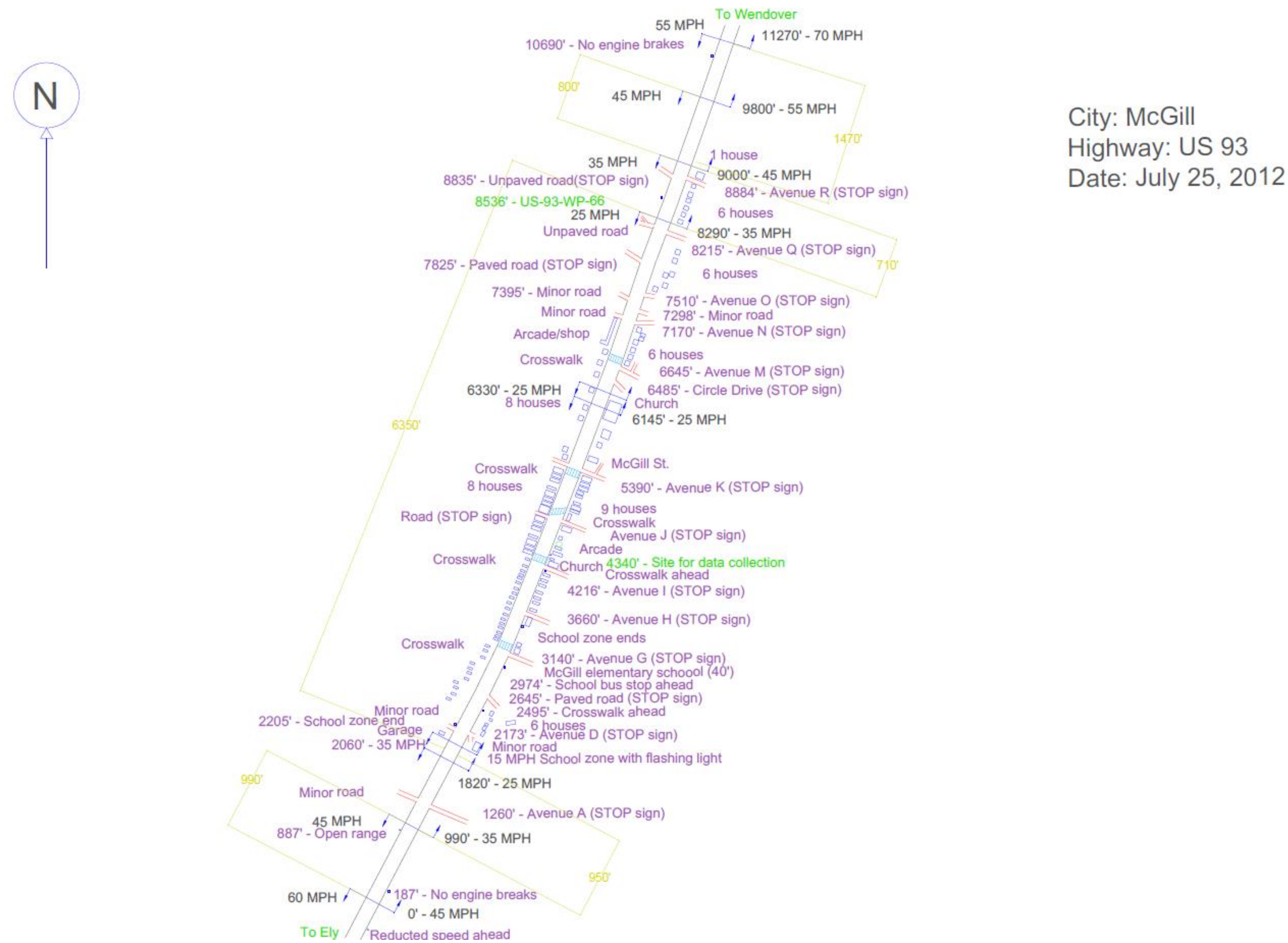

Figure 9-7 McGill Speed-Zone Map

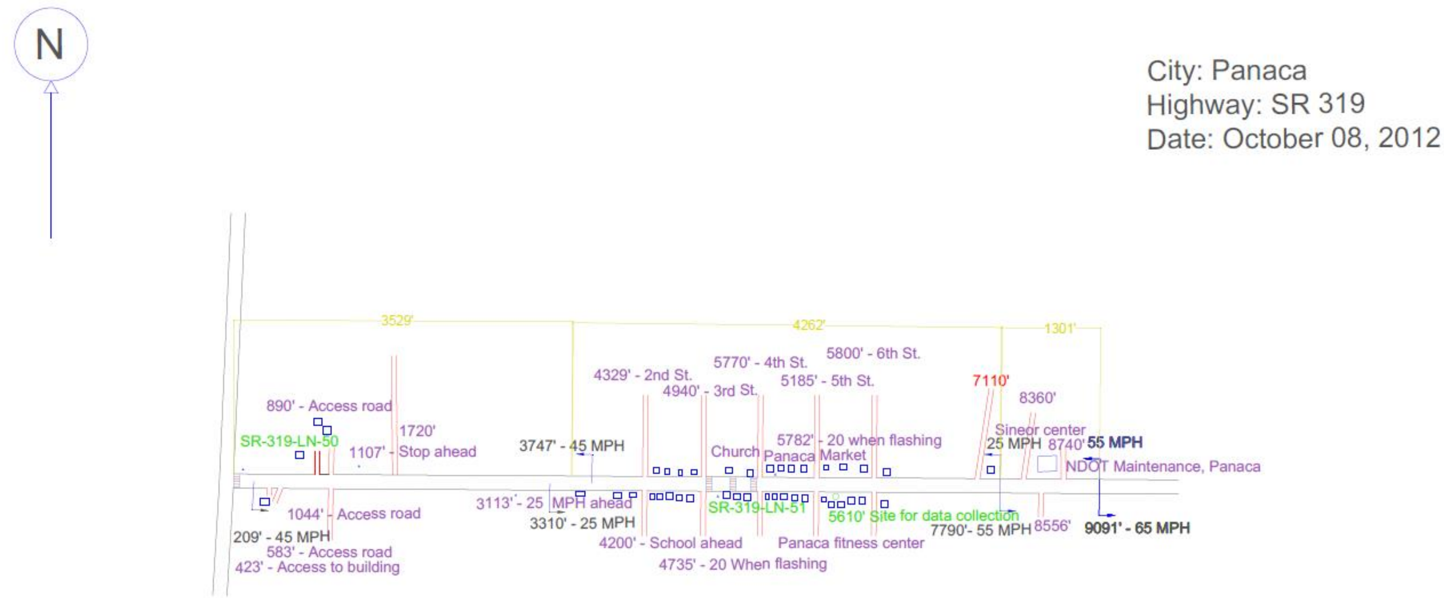

Figure 9-8 Panaca Speed-Zone Map

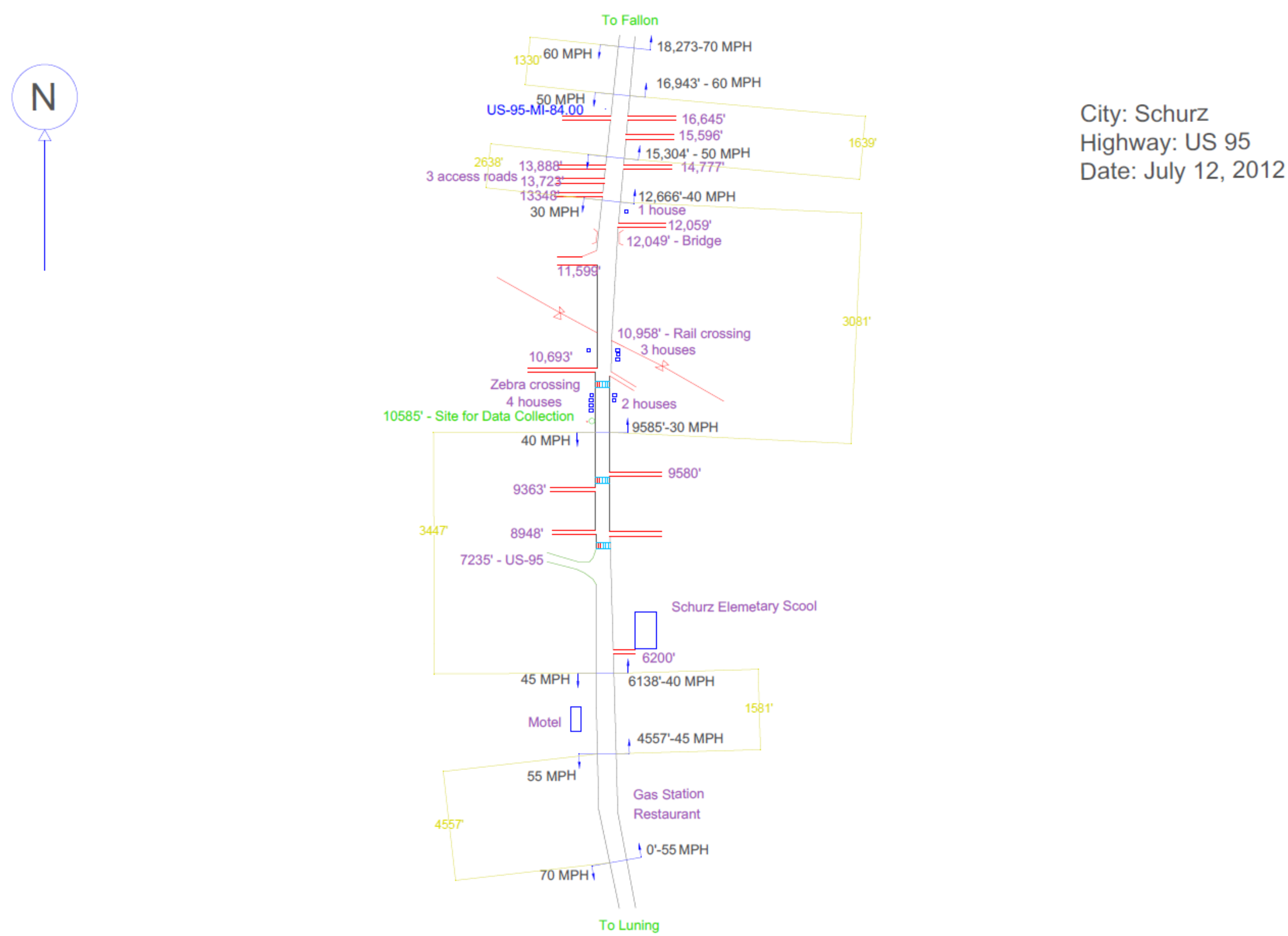

Figure 9-9 Schurz Speed-Zone Map

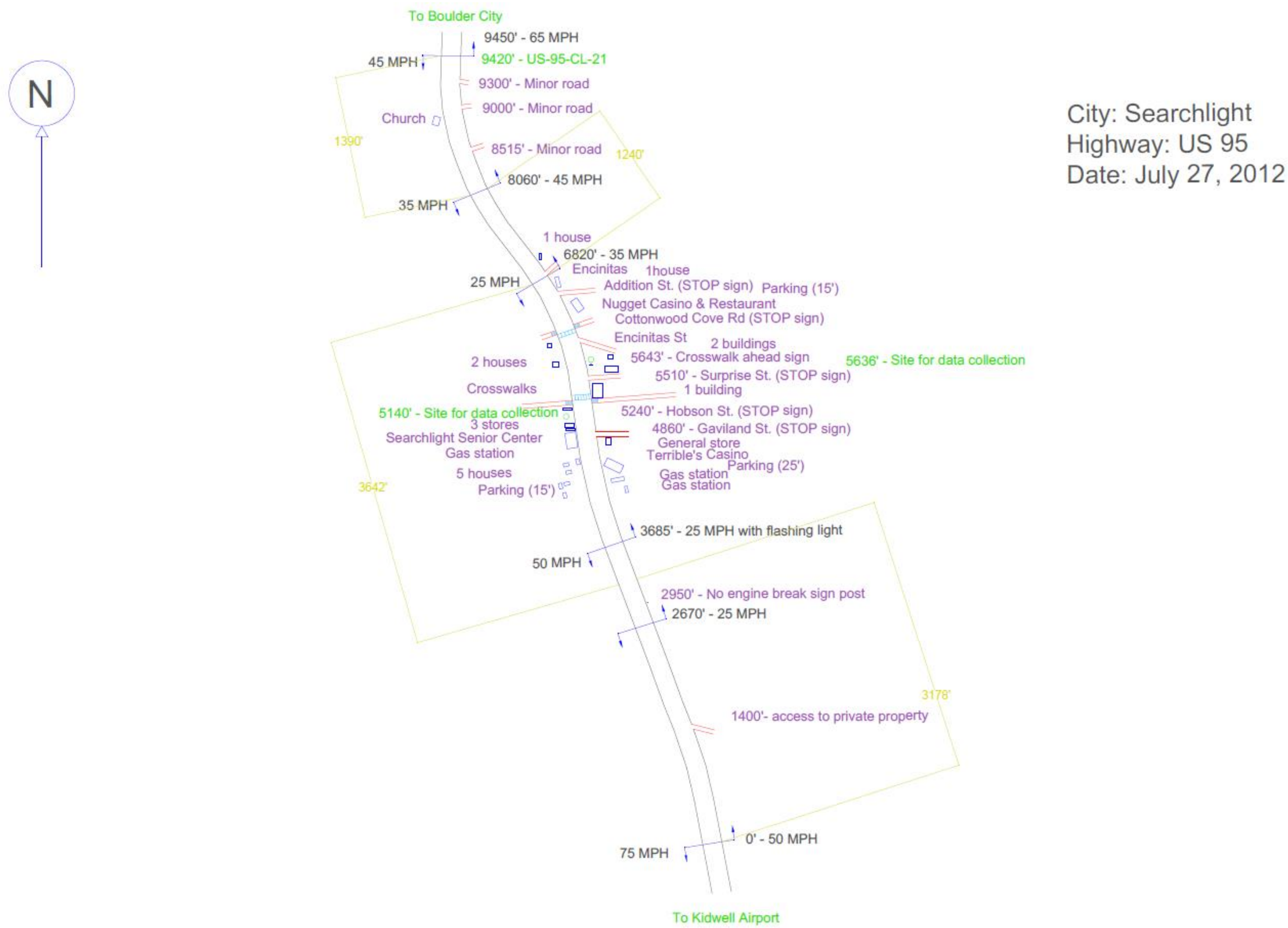

Figure 9-10 Searchlight Speed-Zone Map

Figure 9-11 Tonopah Speed-Zone Map

Appendix E Cumlative Spot Speeds and 85th Percentile Speeds

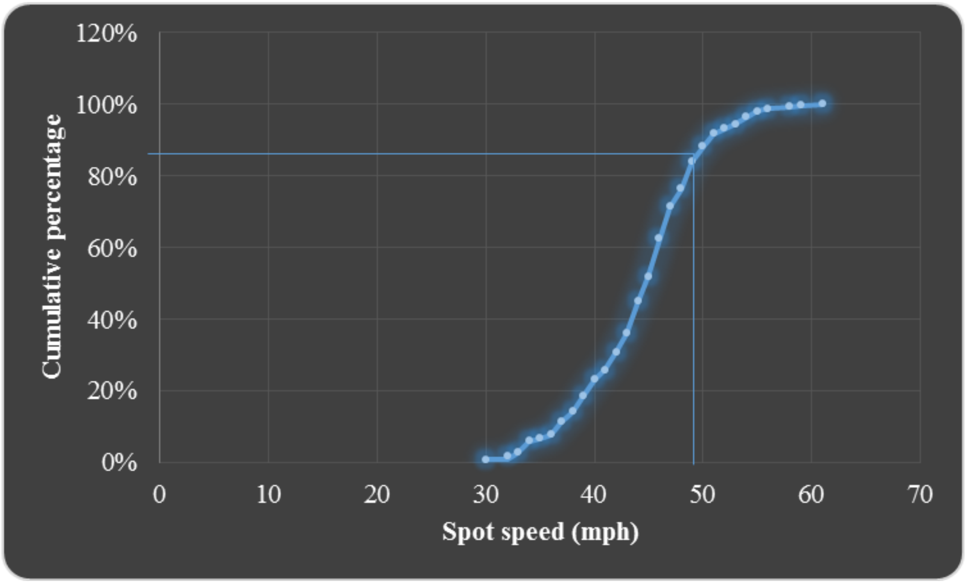

Figure 9-12 Cumulative Spot Speed – Alamo

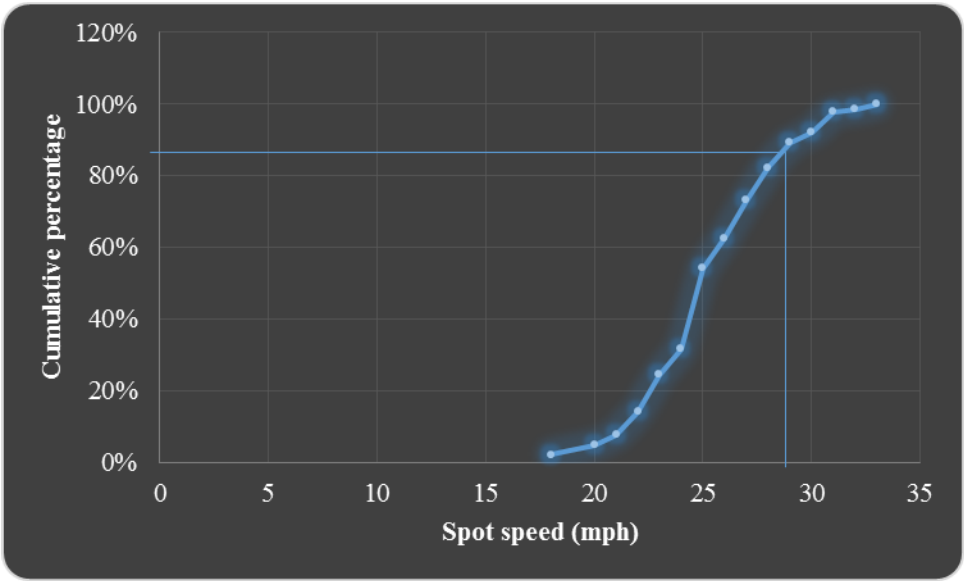

Figure 9-13 Cumulative Spot Speed – Austin

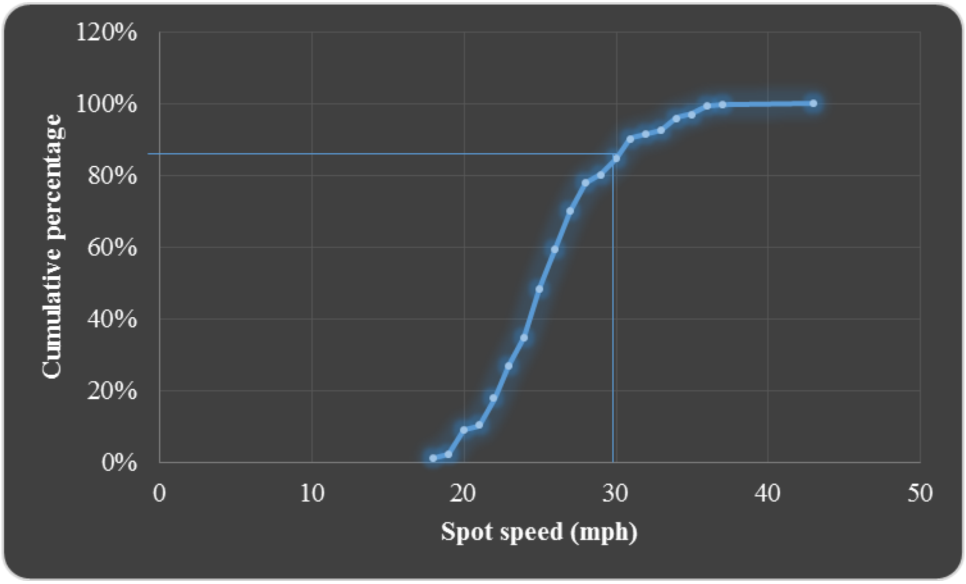

Figure 9-14 Cumulative Spot Speed – Beatty

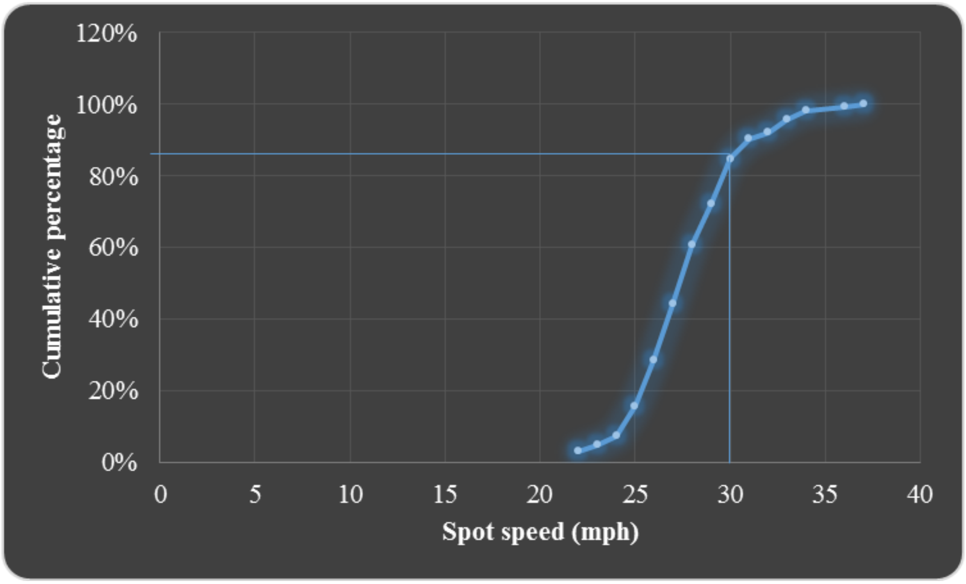

Figure 9-15 Cumulative Spot Speed – Fernley

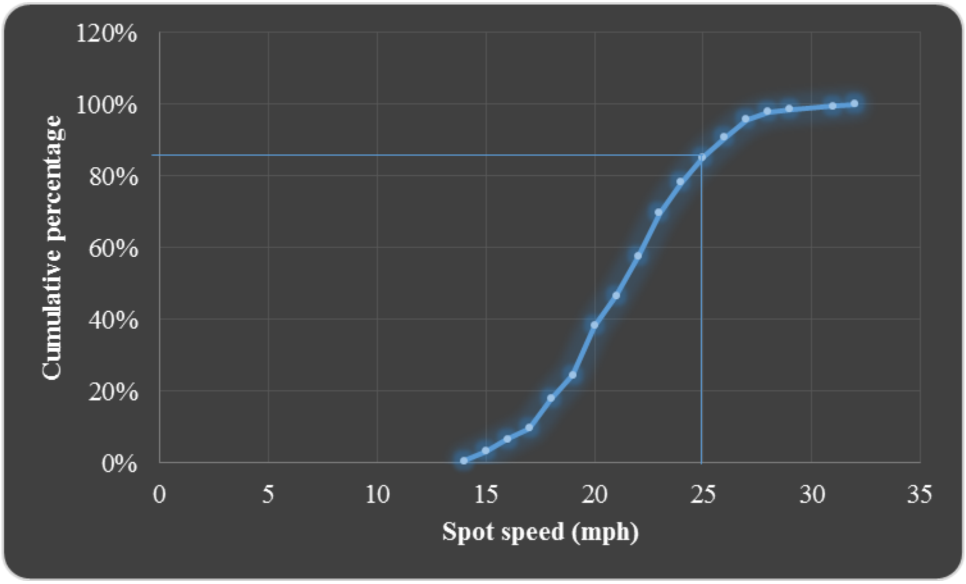

Figure 9-16 Cumulative Spot Speed – Goldfield

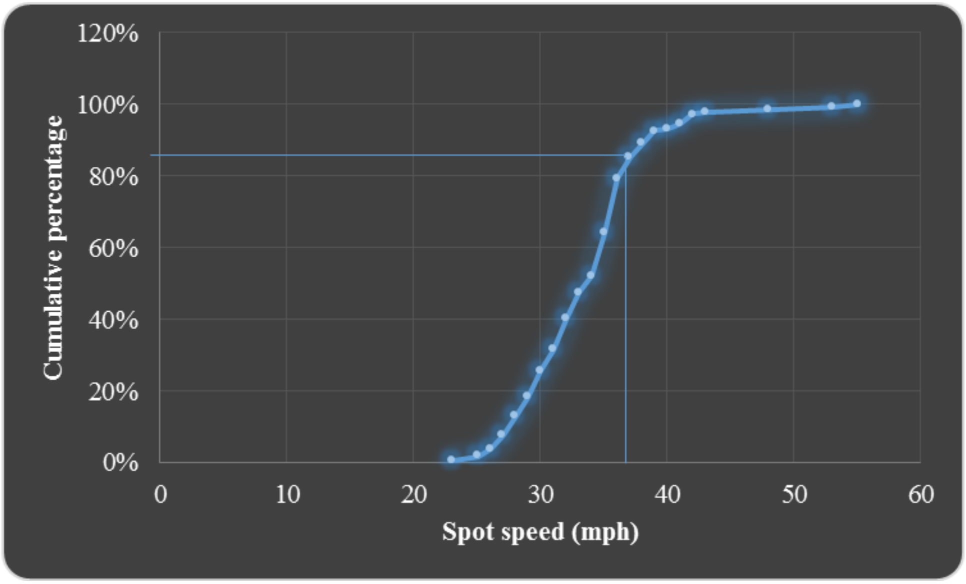

Figure 9-17 Cumulative Spot Speed – Luning

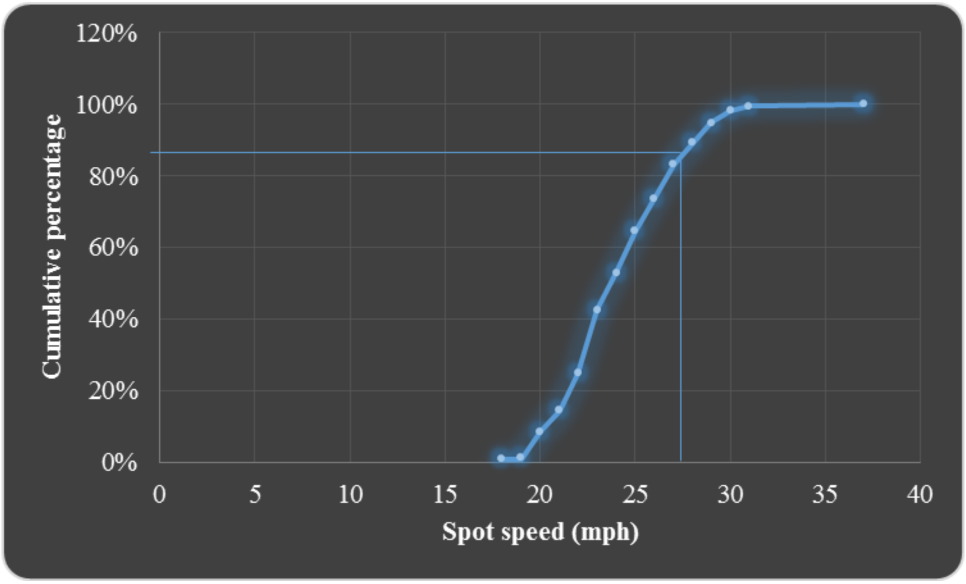

Figure 9-18 Cumulative Spot Speed – McGill

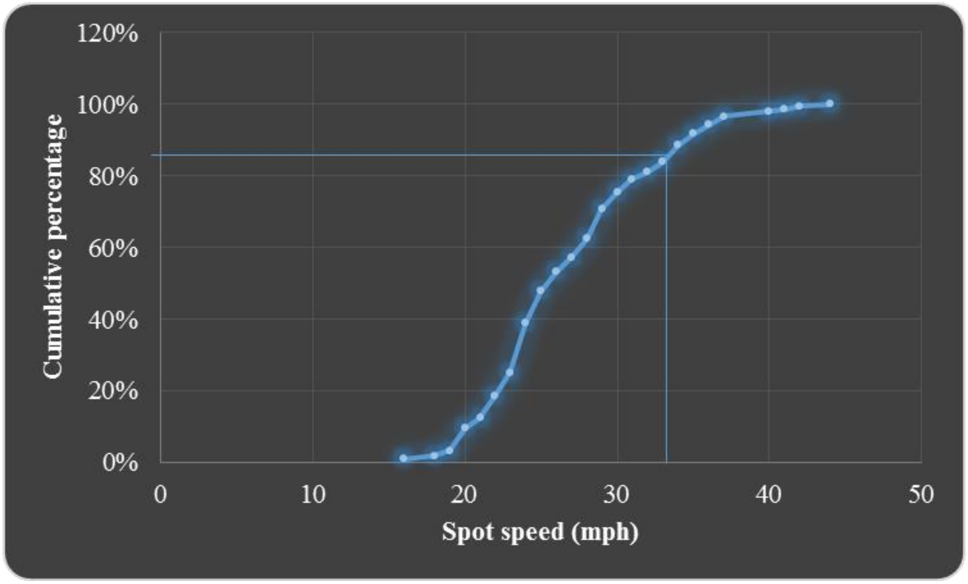

Figure 9-19 Cumulative Spot Speed – Panaca

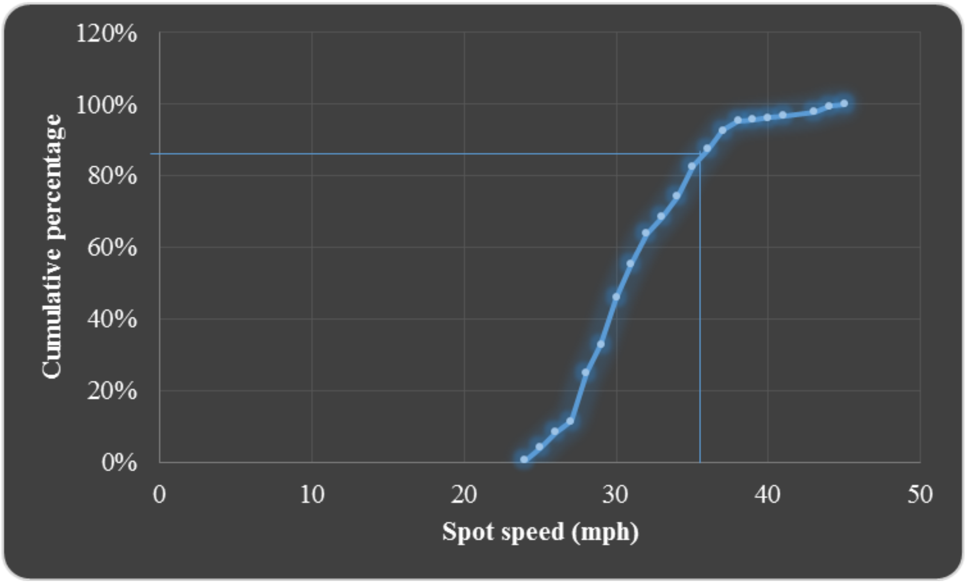

Figure 9-20 Cumulative Spot Speed – Schurz

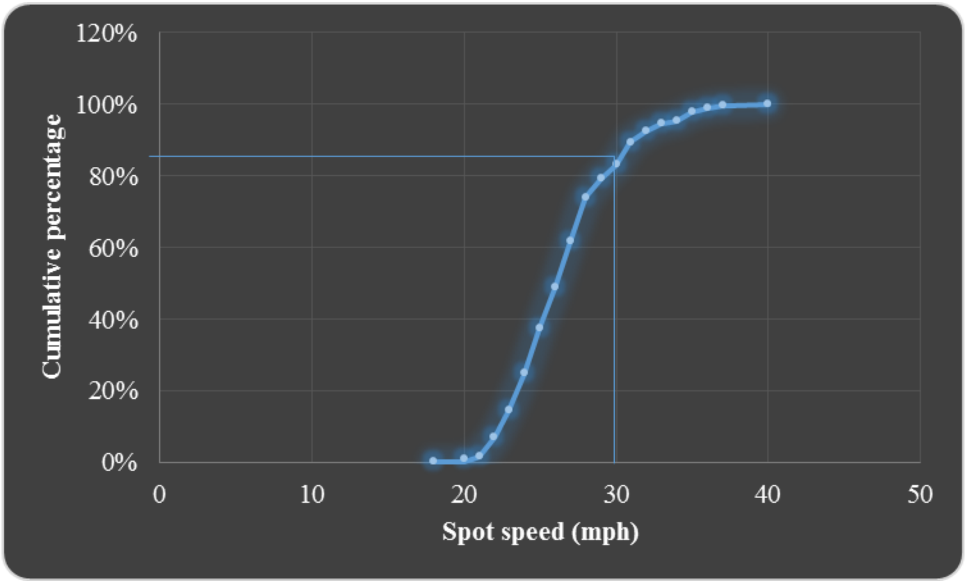

Figure 9-21 Cumulative Spot Speed – Searchlight

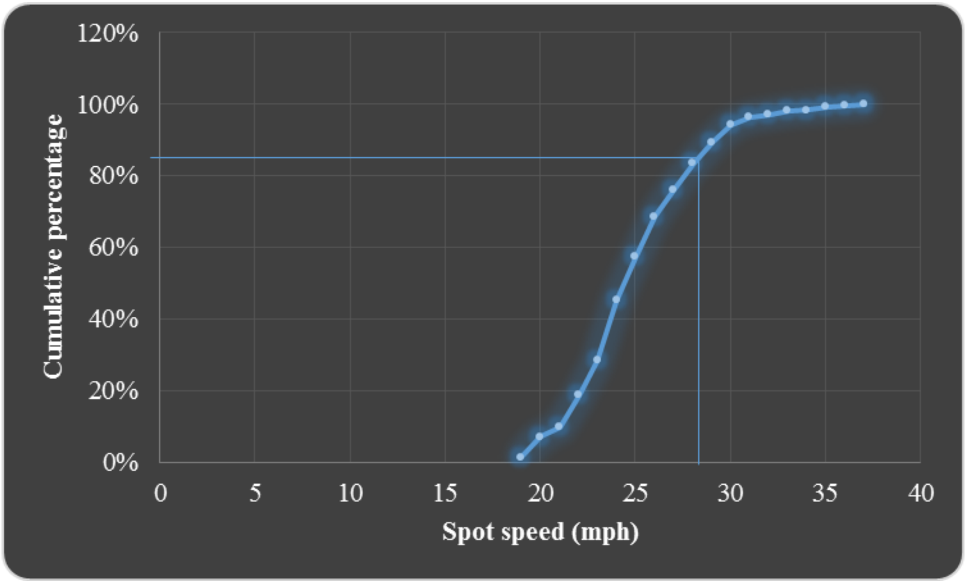

Figure 9-22 Cumulative Spot Speed – Tonopah

Appendix F Correlation Coefficients Between Crashes and Speed Values

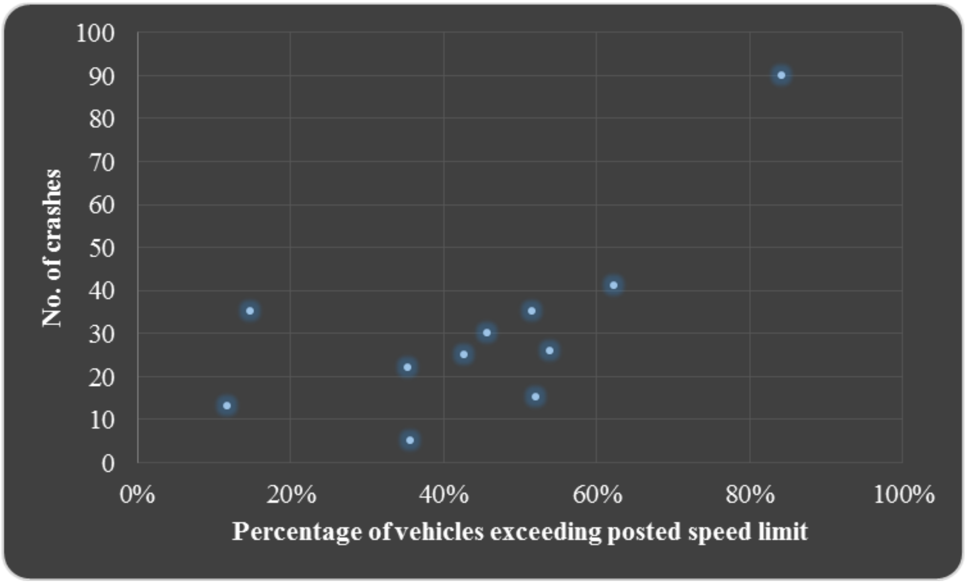

Figure 9-23 Correlation between Number of Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

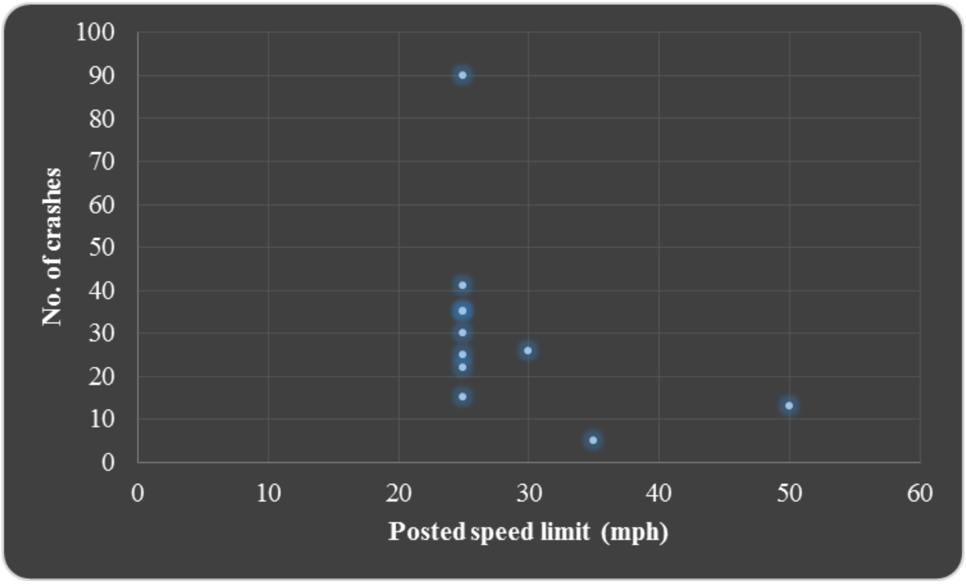

Figure 9-24 Correlation between Number of Crashes and Posted Speed Limit

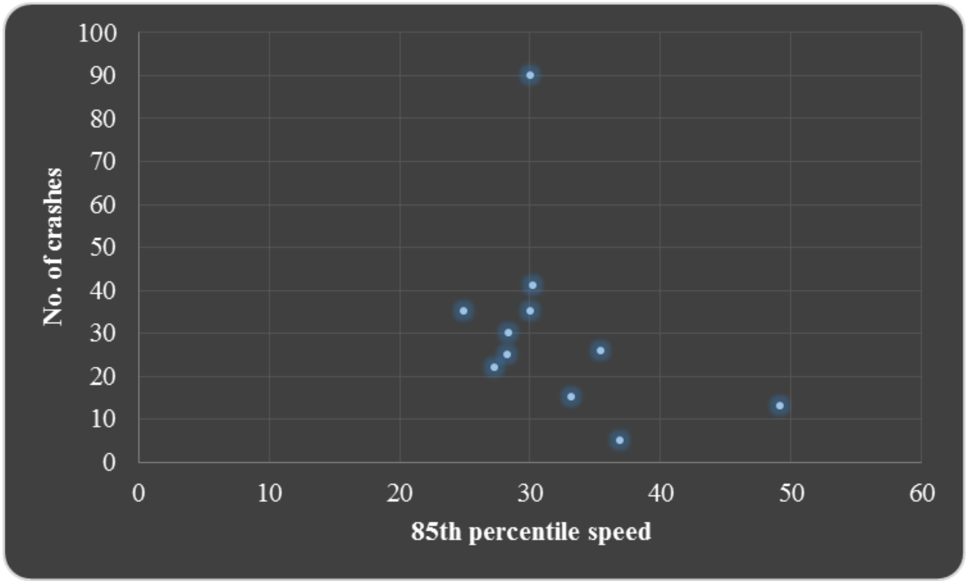

Figure 9-25 Correlation between Number of Crashes and 85th Percentile Speed

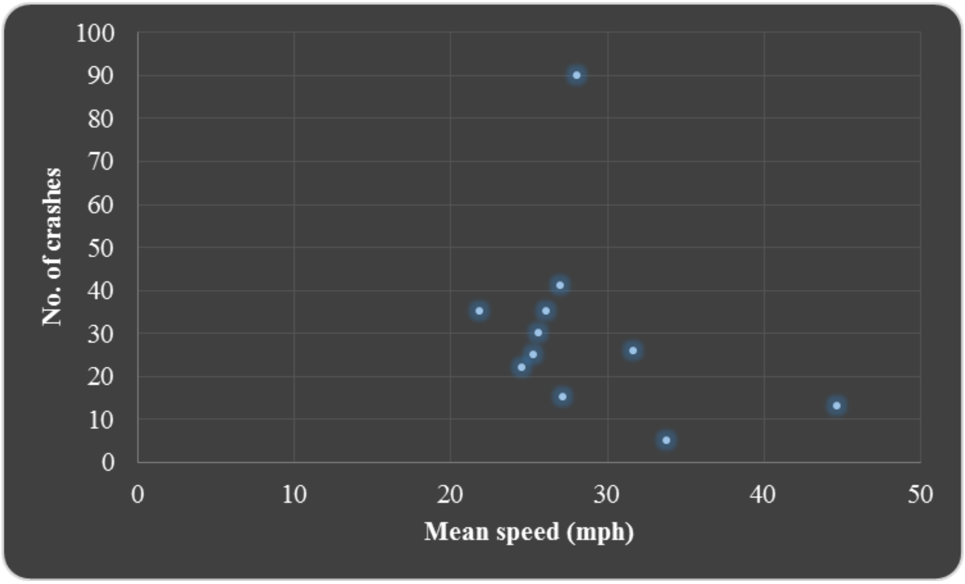

Figure 9-26 Correlation between Number of Crashes and Mean Speed

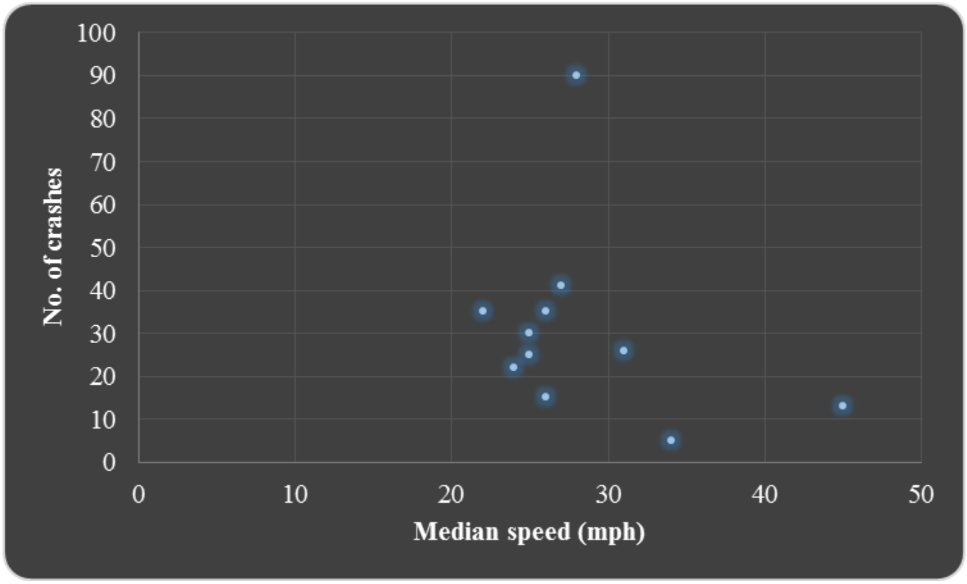

Figure 9-27 Correlation between Number of Crashes and Median Speed

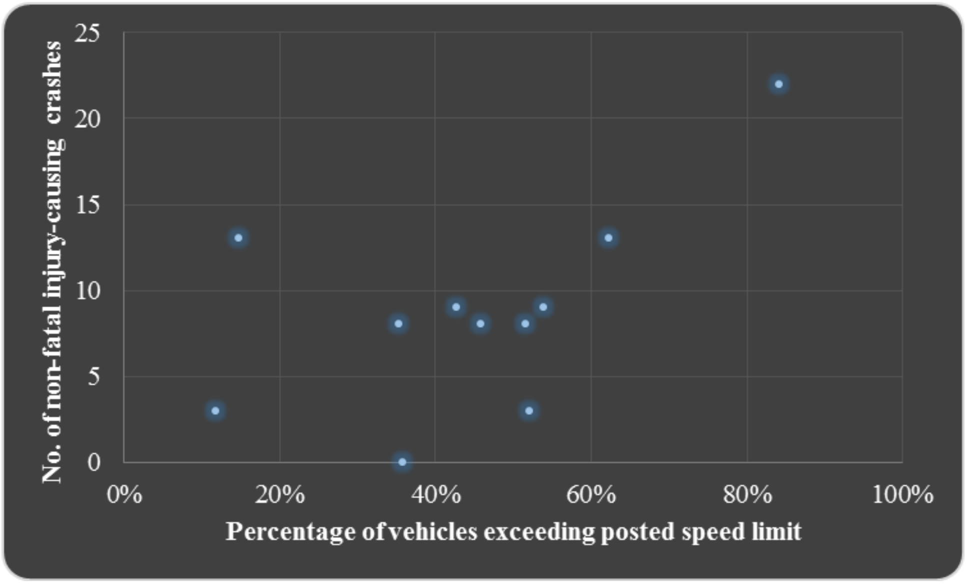

Figure 9-28 Correlation between Number of Non-fatal Injury-Causing Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

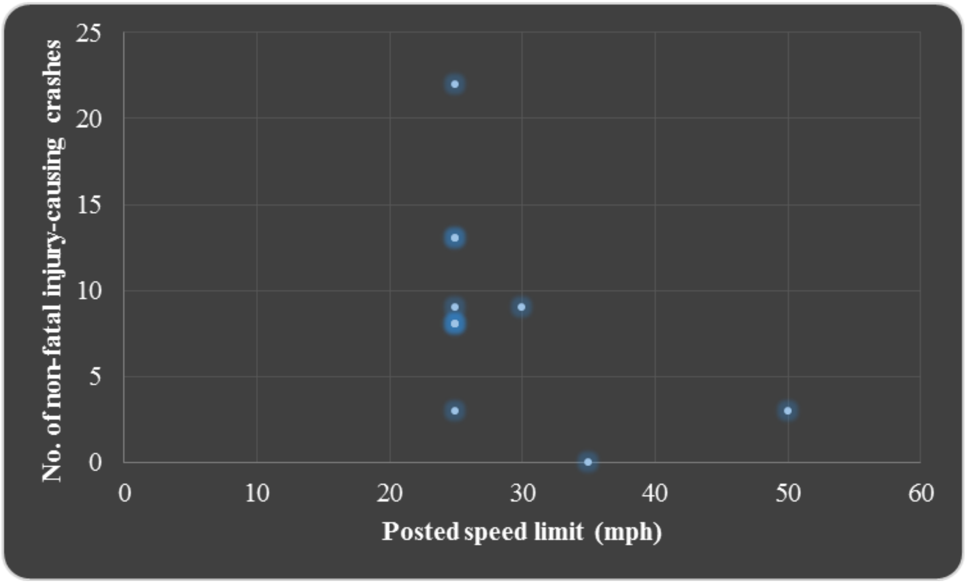

Figure 9-29 Correlation between Number of Non-fatal Injury-Causing Crashes and Posted Speed Limit

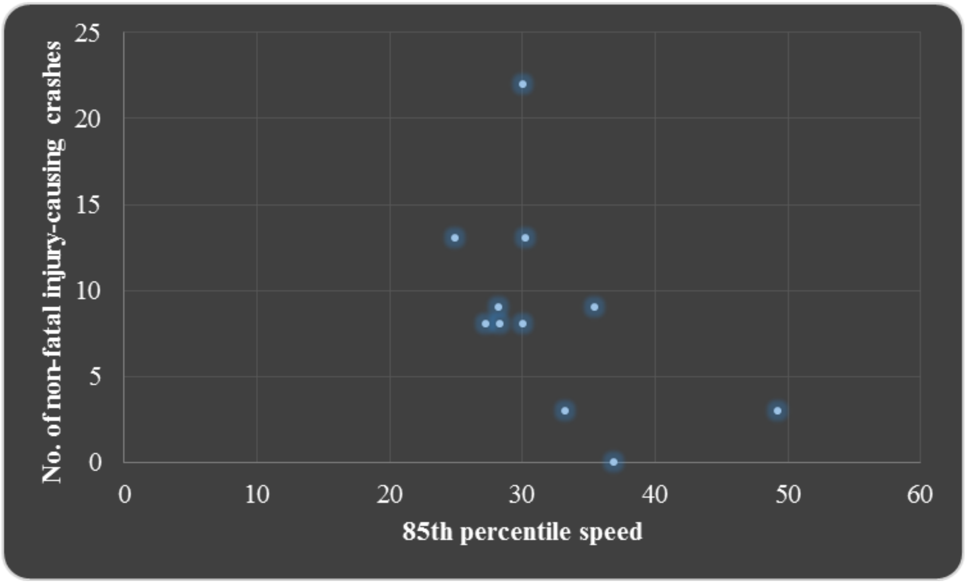

Figure 9-30 Correlation between Number of Non-fatal Injury-Causing Crashes and 85th Percentile Speed

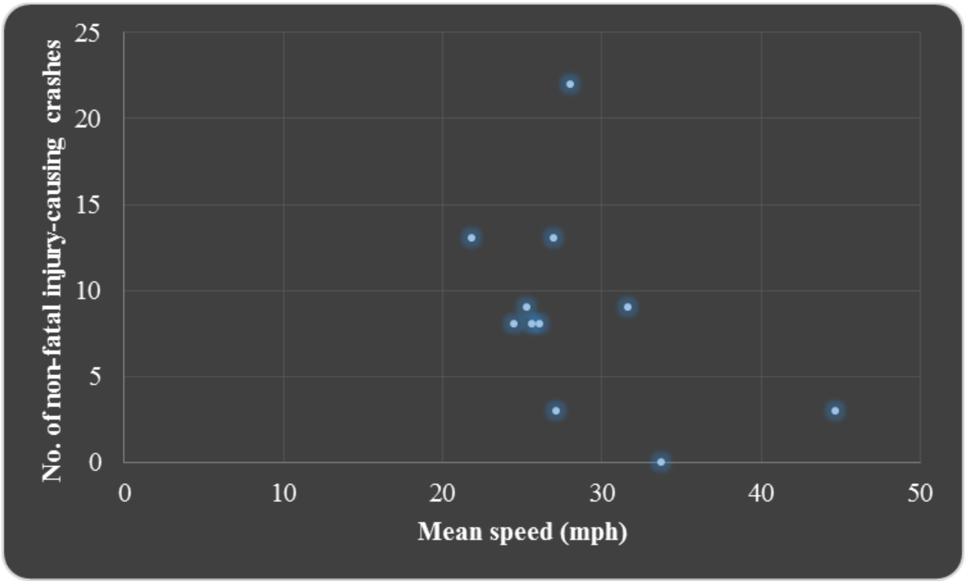

Figure 9-31 Correlation between Number of Non-fatal Injury-Causing Crashes and Mean Speed

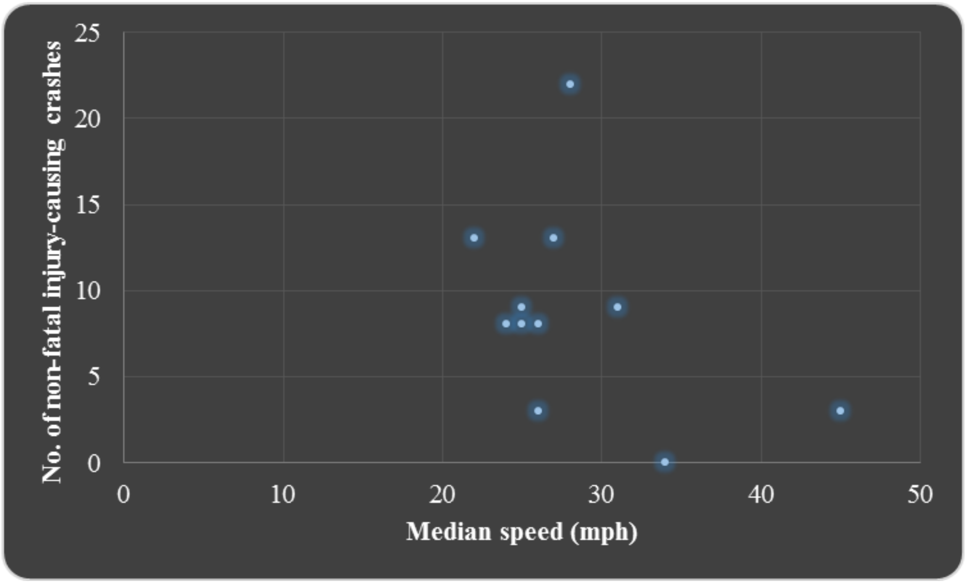

Figure 9-32 Correlation between Number of Non-fatal Injury-Causing Crashes and Median Speed

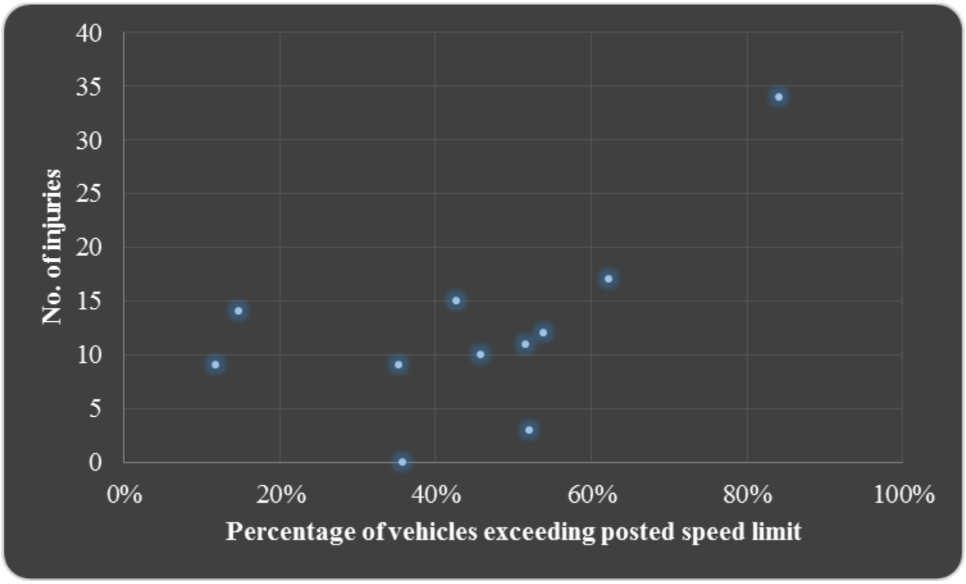

Figure 9-33 Correlation between Number of Injuries and Percentage of Vehicles Exceeding Posted Speed Limit

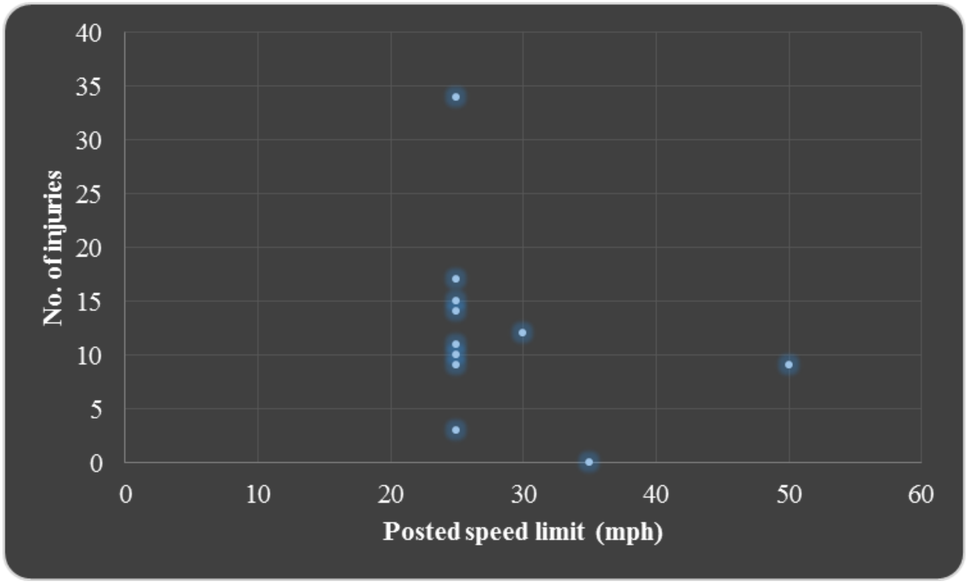

Figure 9-34 Correlation between Number of Injuries and Posted Speed Limit

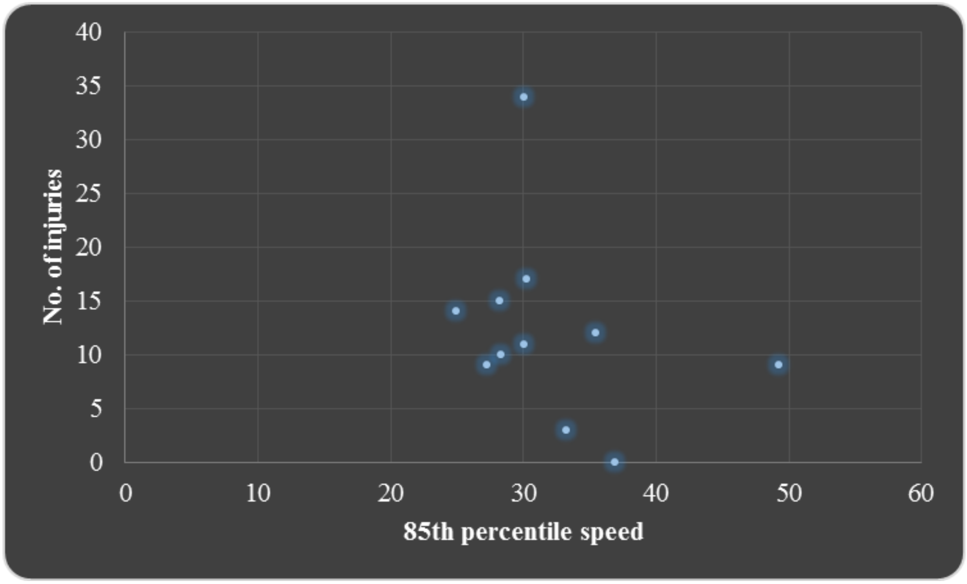

Figure 9-35 Correlation between Number of Injuries and 85th Percentile Speed

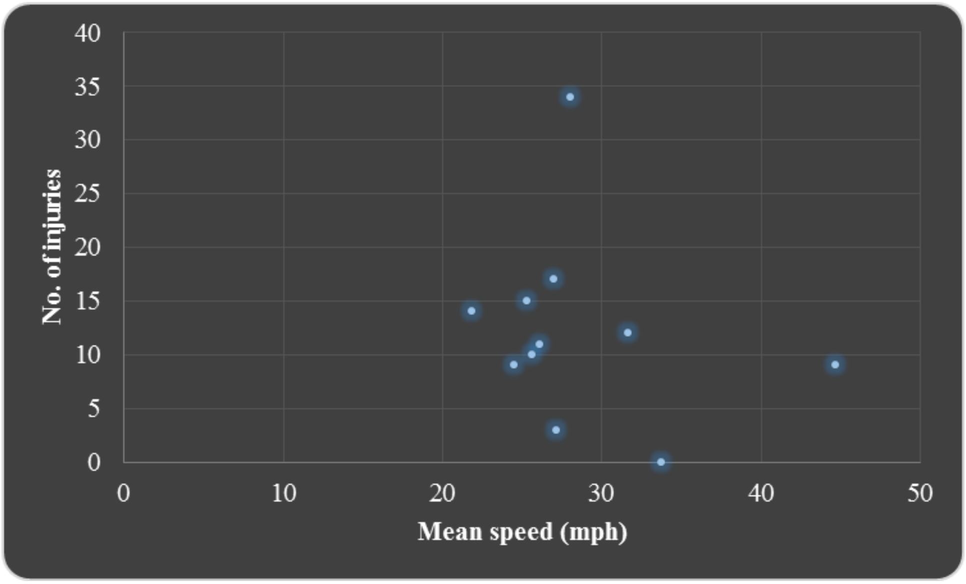

Figure 9-36 Correlation between Number of Injuries and Mean Speed

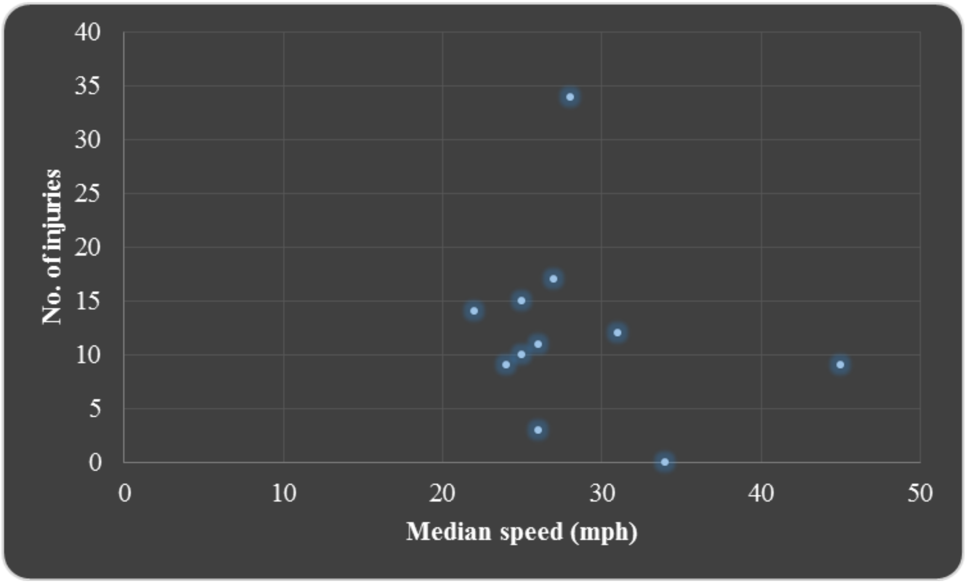

Figure 9-37 Correlation between Number of Injuries and Median Speed

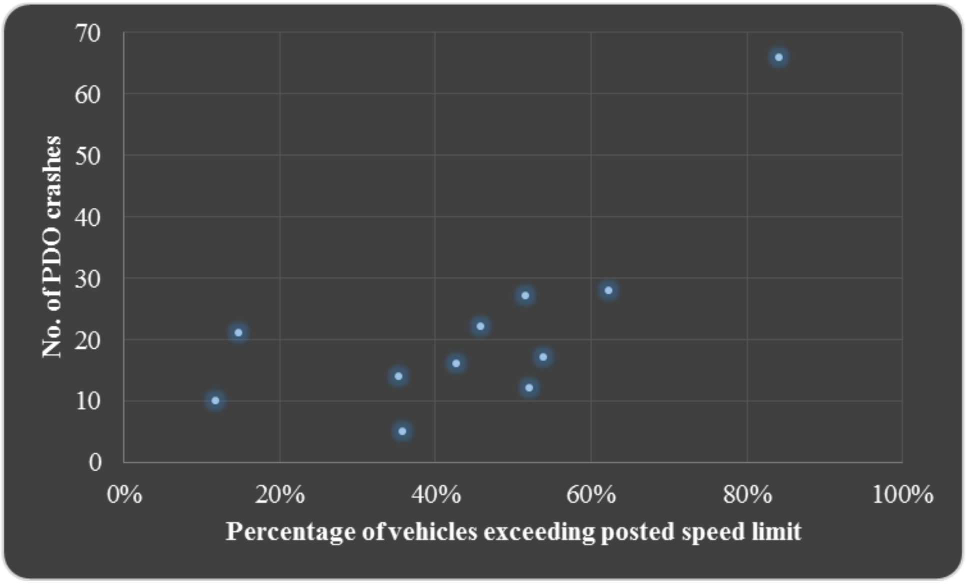

Figure 9-38 Correlation between Number of PDO Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

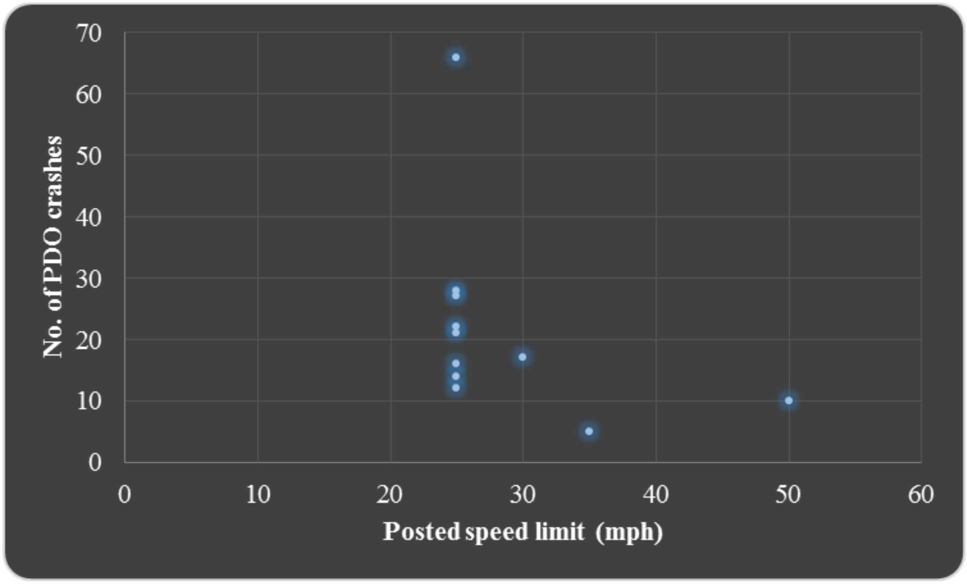

Figure 9-39 Correlation between Number of PDO Crashes and Posted Speed Limit

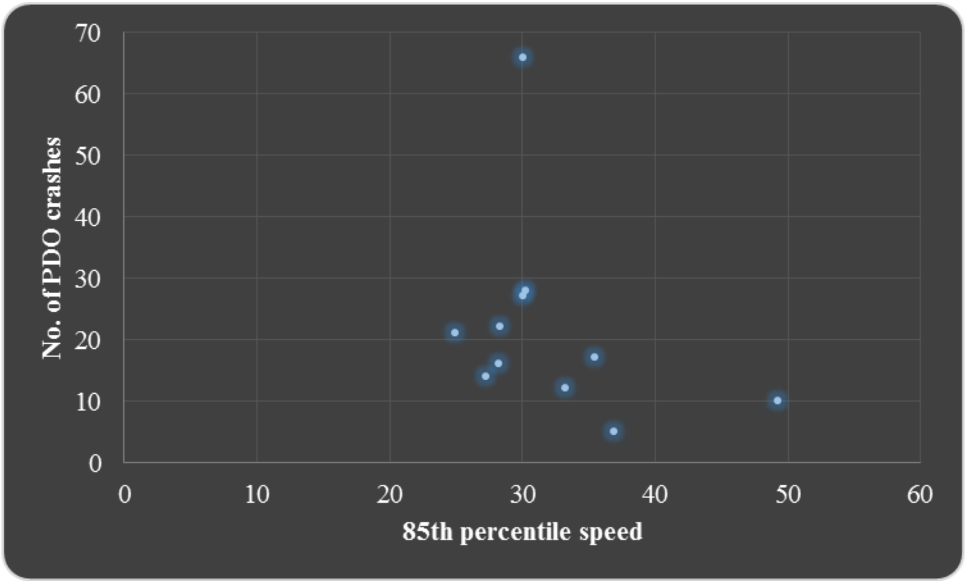

Figure 9-40 Correlation between Number of PDO Crashes and 85th Percentile Speed

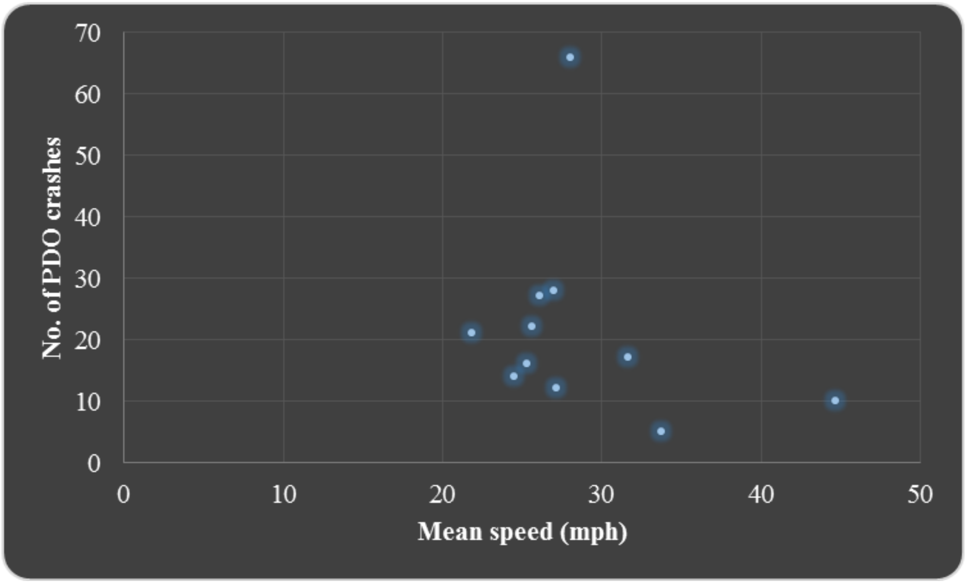

Figure 9-41 Correlation between Number of PDO Crashes and Mean Speed

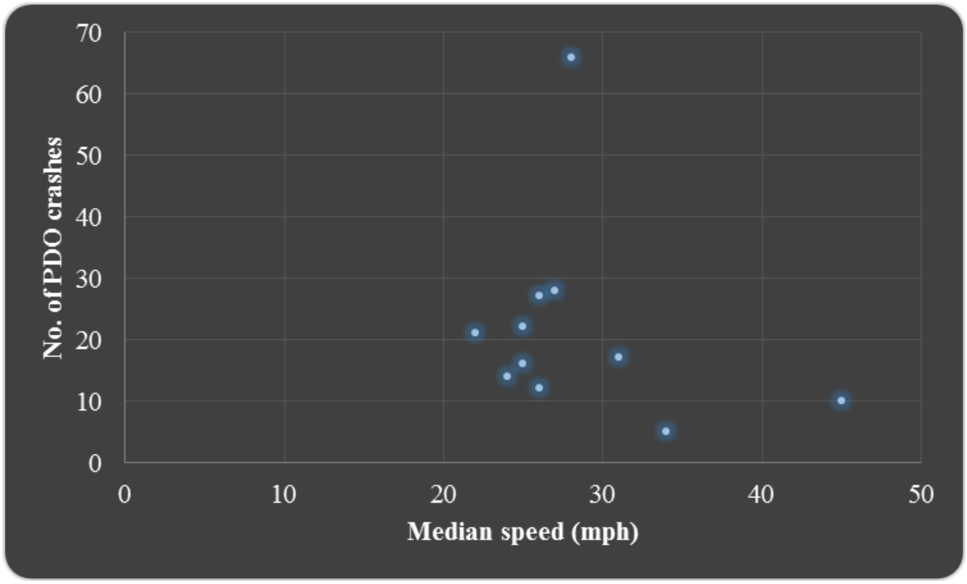

Figure 9-42 Correlation between Number of PDO Crashes and Median Speed

Appendix G Questionnaire Survey Form

Survey of Current Practices in Establishing Speed Limits in Towns along Rural State Highways

We would like to thank you in advance for the time and effort involved in your agency's participation in this research.

This questionnaire is divided into six sections:

- Project General Information
- Rural State Highways and Crash Data
- State Speed-Zone Legislature
- Speed-Zone Guideline or Manual
- Traffic Engineer's Personal View
- Issues of the Local Community.

If not enough space is provided for the brief questions, please feel free to attach extra sheets to the document.

In the questions, we ask for detailed information about the current practices in speed zones. Please do what you can to provide this information as fully as possible. Your detailed responses will allow us to develop new guidelines for speed zone in towns along rural state highways in Nevada.

The confidentiality of this questionnaire will be maintained. The questionnaire data will not be placed in any permanent record, and will be destroyed when no longer needed by the researchers. The identity of person who provided all this information will remain anonymous. The data obtained during this interview will not be linked in any way to the participants' names.

The results of the current survey will be published in the form of "Guidelines for Speed Limit in Towns along Rural State Highway" report that will be available on Nevada Department of Transportation website for the public. We appreciate your cooperation and hope that with your help we can improve the safety on rural highways in Nevada. Please return this questionnaire by email, fax, or mail to the following address:

Dr. Pramen P. Shrestha

Assistant Professor

Department of Civil and Environmental Engineering and Construction

University of Nevada, Las Vegas

4505 S. Maryland Pkwy.

Las Vegas, NV 89154

Phone: 702-895-3841 Fax Number: 702-895-4966

Email: pramen.shrestha@unlv.edu

1. General Information

1.1. Name of the Department of Transportation (DOT): ______________________

1.2. State: ______________________

1.3. Name of the traffic engineer (respondent): ______________________

1.4. Contact person's phone number: ______________________

1.5. Contact person's E-mail address: ______________________

2. Rural State Highways and Crash Data

2.1. How many miles of rural state highways are under your state's jurisdiction?

____

2.2. What is the average annual number of crashes that have occurred on highways in your state in the last five years?

____

2.3. What is the average annual number of crashes that have occurred on the rural state highways in your state?

____

2.4. What is the average annual number of fatalities that have occurred on highways of your state in the last five years?

____

2.5. What is the average number of fatalities that have occurred on your rural state highways from the last five years?

____

2.6. Estimate the amount of crashes that have occurred in towns along rural state highways (the percentage of total crashes occurring in rural state highways).

_______________________ (% of total crashes)

2.7. Please list top five major reasons of the crashes occurring in the towns of rural state highways. List according to its importance. The most important reason should be listed in the first

2.7.1. __________________________________

2.7.2. __________________________________

2.7.3. __________________________________

2.7.4. __________________________________

2.7.5. __________________________________

3. State Speed-Zone Legislature

3.1. Does the state have statutes that mandate the speed zone in the towns of rural state highways?

☐ Yes ☐ No

3.2. If yes, would you provide the link to the statute?

____

3.3. Is it required that an engineering and traffic investigation be conducted for any alteration of speed zones, mandated by your state statutes?

☐ Yes ☐ No

3.4. If yes, what basic investigations will be carried out before deciding the speed zone for particular towns along the rural state highway?

____

____

4. Speed-Zone Guideline or Manual

4.1. Do you have speed-zone guideline or manual in your state?

☐ Yes (Go to Q. No. 4.2) ☐ No (Go to Q. No. 4.4)

4.2. If yes, is there any difference between speed-zone legislature and speed-zone guideline or manual?

☐ Yes (Go to Q. No. 4.3) ☐ No (Go to Q. No. 4.4)

If yes,

4.3. How frequently does the traffic engineer use the guidelines or manual to determine the speed zone of towns in rural highways?

☐ Always
☐ Most frequently
☐ Frequently
☐ Seldom
☐ Never

Please provide a copy of the guidelines (manual), sent to the address provided in cover page; if you have a web link, please type your web address here.

4.4. Do you enforce speed limits in the towns along rural state highways?

☐ Yes (Go to Q. No. 4.5) ☐ No (Go to Q. No. 4.6)

4.5. If yes, then is the speed limit uniform in all the towns along the rural state highways?

☐ Yes (Go to Q. No. 5.1)   ☐ No (Go to Q. No. 4.6)

4.6. If no, what are the criteria for establishing the speed limits in the towns along rural state highways?

____

____

____

4.7. What are the current practices in your DOT for speed limit in towns along rural highways?

____

____

____

5. Traffic Engineer's Personal View

5.1. Mention top five factors that influence a decision in setting a speed zone in a town along a rural state highway.

5.1.1. ______________________

5.1.2. ______________________

5.1.3. ______________________

5.1.4. ______________________

5.1.5 ______________________

5.2. In your opinion, what should be the best practices in determining the speed zone in towns along rural state highways?

____

5.3. Do you observe that speeding traffic in rural highway is a problem in your state?

☐ Yes (Go to Q. No. 5.4) ☐ No (Go to Q. No. 5.5)

5.4. How serious is that problem?

☐ Very Serious

☐ Moderately Serious

☐ Not Serious

☐ No Problem.

5.5. On the scale of 1 to 5 (1 being not important and 5 being highly important), rate the following factors that influence a speed zone of rural state highway. Please feel free to add any other factors, you think relevant.

Contributors	**1**	**2**	**3**	**4**	**5**
Road characteristics (lane width, divided or undivided highway, pavement conditions, horizontal and vertical alignment etc.)					
Traffic volume					
Driver's behavior					
Roadside developments					
School areas					
Number of left turns					
Access points					
Differential speed					
Population of the towns					
Presence of pedestrians, especially children					
Weather conditions					
85^{th} percentile speed of the vehicles					
Number of crashes					

5.6. On the scale of 1 to 5 (1 being not important and 5 being highly important), rate the factors that are important for your DOT to control speeding traffic in rural highway? Please feel free to add other factors, you think relevant.

Contributors	1	2	3	4	5
Changing road characteristics (lane width, divided or undivided highway, pavement conditions, vertical and horizontal alignment, etc.)					
Presence of traffic-calming devices					
Driver education					
Improving roadside developments					
Decreasing access points					
Reducing differential speeds					
Improving speed limit reduction techniques in transition zones					
Installing proper speed-zone signs					
Installing variable speed limit signs					
Increased police enforcement					

5.7. Do you think that increasing the speed limit increases the frequency of crashes?

☐ Yes ☐ No

6. Issues of the Local Communities

6.1. Are there any speed limit complaints from the communities of the towns along rural highways?

☐ Yes (Go to Q. No. 6.2) ☐ No (Go to Q. No. 6.3)

6.2. On average, how many complaints are there in a year?

6.3. Do communities in your state have an interest to decrease the speed limit in towns along their neighboring highways?

☐ Yes ☐ No

6.4. Has your state Department of Transportation decreased the speed limit in towns along rural highways based on the complaints from communities?

☐ Yes (Go to Q. No. 6.5) ☐ No (End of the Questionnaire)

6.5. If yes, did decreasing the speed limit solve the problems in the towns along rural highways?

Explain.

6.6. Please describe the current practices to reduce the speed limit in those towns.

Appendix H Interview Guide Regarding Establishing Speed Limits in Towns along Rural Highways of Nevada

Current Practices

1. Please provide the NDOT practices regarding speed limit on highways. Why, when, how, is speed reduction on rural highways are considered/conducted?
2. What is the current practice in addressing a community's request regarding speed reduction in towns along rural highways?
3. What are the most important factors that NDOT consider while reducing the speed in towns along rural highways? (please list in order of importance)
4. What site data are collected before the speed limit zone is adjusted?
5. How many locations are chosen for spot speed data collection? During the spot speed check, how many spot speed data are taken in a site?
6. Is there any process in place to address the length of speed zone in towns?
7. How does NDOT design transition zones for speed reduction zones in towns?
8. Does NDOT conduct any studies before and after the speed limit is set to determine the impact of the new speed zone?

Suggestions for New Guidelines

Speed Zone Identification Phase

1. Do you think the speed zone should be revised in a recurring fashion? If yes, then after how many years do you think it should be done?
2. In your opinion, how a speed zone re-evaluation should be started, either by local complaint or change of environment in the vicinity of the road (for example but not limited to new school addition, new sport facility addition, new community service facility addition, change in usage of a building, or any other situation that may result in change in community usage of roadside buildings)?
3. Do you have any suggestion about the chain of command of approving the speed zone study after the local complaint is received by NDOT?

Speed Determination Phase

1. What are the most important factors to determine the speed limit? (85th percentile only or any other factors, such as crash history).
2. Mention the steps and precautions taken for spot speed study.
3. Besides spot speed, what other data should be collected to make decision on speed limit of the towns?

Transition Zone Determination

1. How important is transition zone setting up in speed zone?
2. How is length of the transition zone determined?
3. How important are traffic signs of step down and step up speed in speed zone?
4. Should NDOT follow National Cooperative Highway Program (NCHRP) manual for transition zone determination?

Speed Zone Approval Process

1. Is the existing chain of command of approving speed zone change acceptable? If any change is needed, please suggest.

Speed Enforcement

1. Do you think more police is needed to enforce the speed limit in towns?

Follow up studies

1. Do you think before-and after-study is necessary to determine the effectiveness of speed limit zone in towns?

Other Questions

1. In your opinion, how often the guidelines should be revised?
2. Any other comments?

Appendix I Summary of Speed Limit Guidelines of Other DOTs

Data Collection

Identification Phase

- Oregon
  - Before a speed zone investigation can begin there must be a written request from all road jurisdictions involved in ownership, maintenance and enforcement in the section of road to be investigated. This is the authorization to perform the work on that road. If a city or county is investigating a road under its own jurisdiction, concurrence is needed from any other agency that shares jurisdiction of the section of road investigated.
- Wisconsin
  - Speed zone reviews are typically initiated as a result of concerns expressed by interested citizens who live nearby or drive along the roads in question, or may be triggered by a severe crash that has occurred.
  - Requests for speed zone reviews originating outside the Wisconsin Department of Transportation for STHs should come through a mayor or other elected executive, appointed official, government body, or Traffic Safety Commission and be submitted in writing.

Location for data collection

- Spot speed studies should be made as close to the center of the proposed zone as is practical. If the zone is lengthier than one mile, studies should be made at a minimum of two locations. If the difference in data between the two locations is minor, the higher value should be used. If the difference in data is over 5 mph, consideration should be given to designating separate zones. (Missouri)
- Conduct spot speed studies on each road segment where travel speeds differ significantly from other segments due to changes in road character. If practical, do at least three studies for each zone (one at each end and one in the center). (Alaska)
- It would be ideal to have speed checks at an infinite number of locations so that the 85th percentile speed could be computed at all points. Since this is not practical, the speed check stations must 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. (Massachusetts)
- Speed studies for signalized intersection approaches should be taken outside the influence area of the traffic control signal, which is generally considered to be approximately 1/2 mile, to avoid obtaining skewed results for the 85th-percentile speed. (MUTDC - FHWA)

- Speed checks should be taken at the 1/3 points (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. (Ohio)

Oregon

- Every 1/2 mile with a minimum of two spot speed checks per mile. When driving conditions remain virtually unchanged, the interval can be lengthened to 1 mile, or longer for a very long (>3 miles) investigated portion.
- When there is a definite change over 1/4 mile in roadside culture or roadway cross section suggesting a change in driving speed.
- For each existing speed zone in the investigated section. If you are considering splitting an existing speed zone, take a spot speed check in each section of the split.
- An existing designated speed zone may, at the discretion of the State Traffic Engineer, be extended or shortened up to 500 feet without obtaining a spot speed check within that section.
- Tangent sections away from controlled intersections are preferable.
- Do not take spot speeds on curves or near stopped or signalized intersections.
- If the section is mostly curves, take spot speeds from a representative location.
- If the section has closely spaced controlled intersections, try to gain a mid-block location, or split the directions into separate locations for optimum free flow data.
- Locations should be chosen with the request information in mind. They should be designed to answer the road authority's concerns. This may mean checking:
    - lose to speed zone changes,
    - near a particular development or
    - taking more checks than the minimum requirement.
- Attention paid to good judgment in the choice of spot speed checks will eliminate most additional field trips needed to collect appropriate data.
- Speed checks are to be taken every 1/2 mile through the investigated section(s). Speed checks may be spaced up to 1 mile or further if there is no change in the roadway or roadside culture.

Texas:

- In rural areas, speed check stations:
- may be at intervals greater than 0.25 mile, as long as the general speed pattern is followed
- 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.

Conditions/Criteria required for studies

- Exercise care to collect the data in a manner and at times that indicate normal conditions. Normal conditions will be assumed to prevail under good weather conditions on dry pavement, following morning rush hours and prior to the evening rush hours, on any day of the week except Saturdays, Sundays or holidays. Observations should not be made immediately following a significant event or during a period of greater than normal police enforcement. Every effort should be made to disguise or conceal the fact that speeds are being reported. (Missouri)
- Speed checks should be made on a weekday at off-peak hours and under ideal weather conditions. (Massachusetts)
- Speed studies are taken during light to medium traffic conditions on a weekday. Rush hours and adverse weather conditions are avoided because they do not represent normal, freeflow traffic. Areas such as intersections, railroad tracks, or other factors that will influence speed are avoided. Since modified speed limits are the maximum allowable speeds, the conditions under which speed studies are taken must be close to ideal. (Michigan)
- A speed survey should be made at times of the day when it is possible to measure free-flowing traffic. Free-flowing traffic is defined as a condition when drivers have relative freedom to choose a speed without interference from other traffic. Usually, these conditions do not occur during peak traffic hours. An exception would be low-volume facilities. The first vehicle in a platoon should be monitored unless all are free-flowing. (Arizona)
- Off peak hours are normally used in conducting a spot speed study with the speed of approximately 50 free flowing vehicles in each direction obtained. On low volume roads where it would be difficult to obtain a sample of 100 vehicles, the study may be terminated after a study period of one hour. (Kansas)
- 85th-Percentile Speed is determined by taking spot speed observations during weekday off-peak periods. Spot speed checks should be taken to reflect only free flowing vehicles. A vehicle is considered free flow if there is a minimum of five seconds gap (headway) from the other vehicle ahead of it, and it is not accelerating or decelerating for other reasons. If it is not possible to observe free-flow conditions, then the 85th-percentile speed of all vehicles should be increased 5 to 10 miles per hour to approximate the free-flow 85th-percentile speed. If the 85th-percentile speed of several speed checks varies considerably

and is in more than one range in the warrant analysis, average the speed or select the most representative speed. (Ohio)

Texas:

- be made on average week days at off-peak hours
- be made under favorable weather conditions
- include only “free floating” vehicles (see following paragraph)

Wisconsin

- Taken during light to medium traffic conditions on a weekday. Rush hours and adverse weather conditions are typically avoided because they do not represent normal, free-flow traffic.
- Areas such as intersections, railroad tracks, or other factors that will influence speed are avoided. Since modified speed limits are the maximum allowable speeds, the conditions under which speed studies are taken must be close to ideal.
- The speed data are collected by recording the speeds of free flowing motor vehicles using radar, laser or other speed-measuring devices. A representative sample of vehicular speeds is recorded and these speeds would include local residents who drive through the zone. To assist in obtaining representative data, the data collection process should be low key so as to limit any affect on driver behavior.
- Utilize a minimum 6-second headway, i.e. the gap between vehicles should be 6 seconds in order to provide for a good free flow.

Data Collection Criteria

- Number of vehicles:
  - Speeds should be observed for at least 100 passenger cars and pick-up trucks. Trucks over 4 tons will not be included in the data for determining a revised limit. (Missouri)
  - Record the speed of 100 vehicles (the sum of both directions) or, if there are less than 100 vehicles per hour, the greater of the vehicles per hour or 30 vehicles. If these recommended minimums are not met, document the reasons in writing. (Alaska)
  - The speeds of 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. (Massachusetts)
  - 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). (Ohio)

    - At least 75 vehicles each way are necessary for a statistically valid speed check. However, 3 hours is the maximum time you should spend in one location. Lower counts can be used on some low volume roads. For approval to do this, call the Traffic-Roadway Sections' Traffic Engineering Services Unit. Low volume cutoff is 25 vehicles in three hours or 8 total vehicles in one hour. (Oregon)
    - Trucks/Commercial vehicle counts are not included in the report unless those vehicles constitute a significant traffic source (>=20% of traffic), are specifically named in the request for investigation, or are disproportionately represented in the crash data. (Oregon)
    - Texas:
        - include a minimum of 125 cars in each direction at each station
        - be discontinued 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.
        - Trucks and busses should be recorded separately and should not be included as part of the 125-car total.
    - Wisconsin
        - As a general rule, the minimum sample size should never be less than 30 measured spot speeds (for example, 15 vehicles per direction). On higher volume roads the study should include about 100 vehicles per lane per direction (e.g., a total of 200 vehicles for a roadway with one lane in each direction, or 400 vehicles total for a roadway with two lanes in each direction). Accurate spot speed measurements are important for setting limits. Spot speed is the instantaneous speed at one location. Data can be collected over multiple weekdays.
        - A one hour time period is the minimum time period used to conduct a study.
- Other Precautions
    - Record only vehicles that are free flowing, whose speed is not appreciably affected by other traffic. Conduct studies during daylight hours, on dry pavement, and on tangent roadway sections, inasmuch as the limit to be posted represents the maximum safe speed under good conditions. (Alaska)
    - When speed checks are taken near a traffic signal, record only those vehicles that move through the intersection on a green light without slowing or stopping. Do not record vehicles that are impeded by stop signs or other traffic control devices. (Alaska)

- On roads with traffic volumes of less than 30 vehicles during the peak hour, an analytical procedure based on road characteristics and comfortable driving speed may be used to estimate the 85th percentile speed. (Alaska)
- Vehicles should be checked as quickly as possible, but it is not necessary to check the speed of every vehicle. The vehicles checked, insofar as possible, should be the ones in which the driver is choosing his/her own speed. When a platoon of vehicles closely spaced passes a speed check station, only the speed of the first vehicle should be recorded since the other drivers may not be selecting their own speeds. Vehicles involved in short passing or turning maneuvers should not be recorded since they are usually traveling at an abnormal rate of speed. Speeds of vehicles other than passenger cars, such as trucks and buses, shall be recorded as: T, B, S, etc. (Massachusetts)
- In most cases, speed data collection is typically conducted in a passenger car or light truck. It is important that the aforementioned vehicles are unmarked so that motorists do not perceive the recorder's presence as an enforcement activity and adjust their speeds accordingly. (Massachusetts)
- Every effort should be made to disguise or conceal the fact that speeds are being recorded, otherwise distorted data may be collected, the analysis of which may lead to unrealistically low speed limits. (Arizona)
- Only free flow vehicles are counted as making independent choices. This means only one vehicle in a queue is recorded. A queue is when there is less than a 4 second gap between vehicles. (Oregon)
- Oregon
    - Take checks
        - in normal weather,
        - during regular daylight hours and
        - at free flow rather than peak traffic periods.
    - Do not record speeds of passing vehicles.
        - Record trucks or other commercial vehicle speeds separately.
    - Count at least 75 vehicles in each direction.
    - Spend no longer than 3 hours on a spot speed check even if less than 75 vehicles per direction are counted in that time.
        - Observation time on low volume roads (less than 400 Average Daily Traffic) may be limited to one hour

providing less than 8 total countable vehicles are counted in one hour.

- Tally pedestrians and bicycles traveling along the roadside.
  - Count separately for each direction.
  - Do not include pedestrian or bicycle cross-traffic.
  - If the pedestrians and cyclists are predominantly children or youth, note that in the report.
- Once the analysis is done for the initial field work it may indicate that an appropriate speed zone recommendation needs additional spot speed data to meet the above spot speed check requirements.
- Additional spot speed checks must then be taken to complete the work. Experience with speed zone investigations will minimize this additional field work.
- Plan your parking places and radar cone direction from the drive-through data. Try to park in an inconspicuous area, and avoid signalized and stopped intersection vicinities.
- Record speeds on free flow vehicles only; single vehicles, the first vehicle in a pod, etc. Do not record speeds of passing vehicles -- the radar reading is not reliable. Also record the number of pedestrians and bicycles. Commercial vehicle speeds should be recorded separately, and included in the report only if a significant (>=20%) traffic source, specifically named in complaint or disproportionately represented in the crash data.
- Checks should normally be taken every 1/2 mile. Take them closer together if there is a definite change for over 1/4 mile in driving conditions such as roadside culture, road cross section, etc., such that speeds could be expected to change. Checks can be taken farther apart if driving conditions remain virtually the same.
- Curves are not speed checked. It is safest to allow the curves themselves to be the deciding factor for the driver. Curves should be signed if the safe speed around the curve is 10 or more mph less than the posted speed (55 mph statutory if not posted).
- When the road alignment is all curves and a speed can be maintained which is the safe driving speed through the curves, it can be recommended. Caution should be observed in deciding this recommendation. If there are curves with safe

speeds below the recommendation, particularly if they are without warning signing, it is better not to post a speed which drivers then may expect to be able to maintain.
    - To get reliable data, spot speed checks should be taken in normal weather, at free flow periods rather than "rush hours". Be sure to record the weather conditions and beginning/ending times for each speed check.
  - The vehicles checked should be only those in which drivers are choosing their own speed ("free floating"). When a line of vehicles moving closely behind each other passes the speed check station, only the speed of the first vehicle should be checked, since the other drivers may not be choosing their own speed. Cars involved in passing or turning maneuvers should not be checked, because they are probably driving at an abnormal rate of speed. (Texas)

Choice of equipment:

- Arizona
  - If hoses or other electrical and/or mechanical devices are selected to collect speed data, procure a sample of vehicles during a 24-hour period for each travel direction.
  - If radar is selected to collect speed data, and
    - If the average daily traffic (ADT) is under 2000, procure a minimum sample size of 50 vehicles per direction within a maximum time limit of two hours.
    - If the ADT is 2000 and over, procure a minimum sample size of 100 vehicles per direction within a maximum time limit of two hours.
- Speeds are measured by a radar gun or laser gun. Both instruments are extremely accurate and provide the engineer with invaluable data when used properly. Caution should be taken that the manufacturer's instructions are followed stringently in order to insure that collected data is correct and accurate for speed zoning purposes. (Massachusetts)
- Radar
- Pneumatic tube
- Precautions to be taken while using those equipment

Safety precautions for site data collection

- Hat
- Vest

Calculation for speed zone

Use USLimits online tool to determine speed? (http://safety.fhwa.dot.gov/USLIMITS/)

Generally, no reduced speed zone will be necessary through an area that does not meet the statutory requirements for a business or residential district. Speed zones are related to roadside development and have no relation to city limits. (Kentucky)

Appropriate speed limit

- One or more of 85th percentile, upper limit of the 10 MPH pace, and average test run speed (Missouri)
- The selected speed limit (in 5 mph increments) should not exceed the established prevailing speed by more than 3 mph.(Missouri)
- The prevailing speed shall not be reduced below the 50th percentile (average) speed using these factors. (Missouri)
- Speed zones are established where regulatory maximums do not fit specific road or traffic conditions. They should only be established where the regulatory maximum deviates more than 3 MPH from the (calculated prevailing) speed… (Alaska)
- Determine the 5-MPH increment nearest the 85th percentile speed. (Alaska)
- The proposed speed limit for any location should not be higher than the critical approach speed ……. critical approach speed can be considered equal to the 95th percentile speed in the absence of geometric restrictions …… the estimated safe speed shall not be more than 7 m.p.h. below the 85th percentile speed (Massachusetts)
- The value of the speed limit for each zone should generally be equal to or slightly less than the average of the values of the safe speeds for speed observation locations within the zone. (Massachusetts)
- Representative field checks of existing speeds to calculate the 85th percentile speed, and the pace speed Roadside development (Georgia)
- North Carolina Approach (Consideration of speed limit based on roadside development but it is not deciding factor)
    - 35 MPH or lower speed limits should be considered when the overall amount of roadside development is or exceeds 75% for a given roadway length of 0.25 mile.
    - Speed limits of less than 20 MPH should not normally be enacted.
    - Restrictive 40, 45, or 50 MPH speed limits should be considered when the overall amount of roadside development is less than 75% for a given roadway length of 0.25 mile.
- Transition speed zones may be used to guide motorists from a higher rural speed limit to a lower urban speed limit. The normal speed transitions are from 55 mph to 45 mph and 35 mph to 25 mph. (Kentucky)

- The roadway design speed has been cited by some transportation professionals as a basis for limiting the maximum speed limit. The determination of design and realistic speed zones are two separate and distinct activities that should not be combined to establish speed zones that are unreasonable to motorists. (Idaho)
- Idaho Approach
    - The upper limit of the pace speed has been used as a criterion for establishing the maximum speed limit.
    - The top of the pace speed is used when there is a high percentage of vehicles within the pace speed and the 85th percentile speed appears inappropriately high. Speed limits are set at uniform 5 mph increments and are adjusted up or down to the next increment to increase the percentage of vehicles in the pace. For example, in a positive skewed speed distribution, the 85th percentile speed may be at 58 mph, but the pace may range from 46 to 56 mph. In this case, a 55 mph speed limit would be appropriate. However, with a negative skewed speed distribution, an 85th percentile speed of 58 mph may be associated with a pace ranging from 51 to 61 mph. In this case, a 60 mph speed limit would be appropriate.
- Idaho Approach (Detailed)
    - Average of
        - 85th percentile speed - factor 3
        - Upper limit of 10 mph pace - factor 3
        - Average test run speed - factor 4
- Maine
    - A properly set speed limit will be within 3 miles per hour (±) of this observed speed. The posted speed limit will then be rounded to the nearest 5 miles per hour.
- Louisiana
    - Numerical value of the speed limit should not be set below the upper limit of the 10 mile per hour pace, that is the 10 mile per hour speed range containing the largest percentage of vehicles in the sample of spot speeds.
- Oregon
    - The speed limit within a speed zone should be set at the nearest 5 MPH increment to the 85th percentile speed.
- Texas
    - Speed limits on all roadways should be set based on spot speed studies and the 85th percentile operating speed (see Chapter 3, "Speed Zone Studies," of this manual). Legal minimum and maximum speeds

should establish the boundaries of the speed limits. If an existing roadway section's posted speed limit is to be raised, the roadway's roadside features should be examined to determine if modifications may be necessary to maintain roadside safety.

  - *It is appropriate for posted speed limits to be based on the 85th percentile speed, even for those sections of roadway that have an inferred design speed lower than the 85th percentile speed. Posting a roadway's speed limit based on its 85th percentile speed is considered good and typical engineering practice. This practice remains valid, even where the inferred design speed is lower than the resulting posted speed limit. In such situations, the posted speed limit would not be considered excessive or unsafe.*
  - Arbitrarily setting lower speed limits at point locations due to a perceived shorter than desirable stopping sight distance is neither effective nor good engineering practice.
  - In no case shall the 85th percentile speed be interpolated between two speeds in the M.P.H. column.
  - Different Results at Adjacent Speed Check Stations. If the 85th percentile speeds for adjacent speed check stations are approximately the same, they may be averaged to determine the zone speed. Any 85th percentile speed should not be included in such averages if it varies more than 7 miles per hour from the speed derived from the average.
- Wisconsin
  - The 85^{th} percentile is used as the primary bases of establishing posted speed limits and, by extension, design speeds. Motorist's behavior will account for road characteristics such as shoulder condition, grade, development and sight distance.
  - Posted speeds may be higher than the design speed for a section of highway.
    - Individual design features such as isolated horizontal and vertical curves and shoulder width narrowing should not dictate posted speed; rather, overall design features should determine the appropriate posted speed.
    - Drivers perceive the overall design features to determine a safe operating speed.

Test run/Trial run

- Average test run speeds shall be determined on the basis of at least two runs in each direction over the length of the proposed zone. The prime consideration in these test runs is to determine a maximum permissible speed. Speeds are to be recorded at 0.1 mile intervals. While making the test run, the driver will try to “float” in the traffic stream, passing as many vehicles as pass the test car. (Missouri)

- Trial runs should be made over the entire roadway by engineers, enforcement officers and municipal officials using at least three different drivers. An observer seated directly behind the driver should take and record readings of the speedometer and odometer for every tenth of a mile. The drivers should operate at the safe maximum comfortable speed. The actual speed is observed for each point and plotted on the Trial Run Sheet. (Note: Use a different color pencil for each driver.) The high and low speeds are discounted and the remaining speeds are averaged, thereby developing a speed curve. The speeds at each tenth of a mile are then recorded on the Speed Control Summary Sheet. (Massachusetts)
- After the proposed speed limits and zone lengths have been determined, repeat the trial speed runs, driving in each direction over each part of the zone at the recommended speed for that direction. Make notes on whether the limits and the lengths of the separate zones appear to be satisfactory. Note also the readings of the Ball-bank indicator when negotiating horizontal curves. If some revision in the zone appears to be necessary, make the required adjustments and recheck with test runs accordingly.(Massachusetts)
- Test drive - to confirm driving conditions (Georgia)
- Ohio
    - Test runs should be made; however, these will also be conducted by the District personnel reviewing requests submitted to ODOT.
        - Test runs should be made by driving as fast as it is comfortably safe.
        - Test runs should be made in such a way that other traffic will not delay the test car.
        - The speed should be recorded at a range of 0.10 to 0.25 mile interval or more.
        - The average speed of three test runs should be determined in each direction.
- After the 85th percentile speeds and zone lengths have been selected, several trial runs should be made through the area in both directions driving at the selected speeds. This should show any irregularities in the zoning which need correction. (Texas)

Other factors to be considered for reduction (or change) of speed limit

- Missouri Approach – reduction of prevailing speed (5% or 10%)) based on crash statistics, pedestrian, parking, adjacent development

    - Fatality and disabling Injury crash rate, total crash rate, pedestrian traffic, parking, adjacent development, physical roadway conditions
    - 5% or 10% reduction of prevailing speed limit if fatal or disabling injury crash rate, or total crash rate is more 1.5 or 2.0 times statewide average for same type of road
    - 5% speed reduction of prevailing speed limit if no sidewalk and total pedestrian exceeds 10/hour for 3 hours of any 8-hour period
    - 5% reduction of prevailing speed if parking allowed in adjacent traffic lane
    - 5% if driveway conflict number exceeds a rate of 40 per mile, 10% if it exceeds 60 per mile
- Alaska Approach - Reduce the speed limit, but not below the median speed of the pace, where *police enforce speed limits frequently* and either of the following conditions exist:
    - The road runs through a residential area or business district
    - Accident experience indicates a need for a reduced limit, in the judgment of the Regional Traffic Engineer.
- Massachusetts –
    - If the 85th percentile speeds for adjacent speed check stations are approximately the same, they may be statistically averaged to determine one speed zone. No 85th percentile speed should be included in such averages, however, if it varies more than 7 miles per hour from the speed derived from the average. Posted limits are rounded off to the nearest 5 mile per hour increment.
    - On sections of highways having a high accident experience, the zone speed may be lower than the 85th percentile speed, but in no case more than 7 miles per hour lower. This should be considered more as an exception than the rule, and should be done only where enforcement agencies will ensure consistent enforcement which will increase the effectiveness of the zone to an acceptable level of conformance.
    - At locations where traffic volumes are low and one hundred cars cannot be recorded in the two hours that the speed check station is operated, the 85th percentile speed may not be reliable. In many cases such as this, speed zoning will probably not be required. However, if conditions such as roadside development and high accident experience indicate that speeds lower than the prima facie limits are required, it would be beneficial to make a number of trial runs through the area. From the data obtained from the trial runs and from the speed check data, it should be possible to arrive at a reasonable and proper speed

zone. Posted limits are rounded off to the nearest 5 mile per hour increment.

- Massachusetts –
  - Accident Rating - When the accident rate for a section is much higher than the average for other highways of similar classification, the estimated maximum safe speed should approach the lower limit of this speed range. When the accident rating is average or below, the estimated safe speed should be closer to the upper limit of the speed range.
  - Probable value of the speed limit – When the speed limit is likely to be 40 m.p.h. or above, the value of the estimated speed limit should generally approach the upper limit of the speed range.
  - Physical Conditions - When the strip map on the Speed Control Summary Sheet reveals narrow shoulders and lack of sufficient space for maneuvering in the event of emergency, or any other conditions or traffic impediments present that may require additional caution on the part of motorists using the roadway, it may be desirable to use slightly lower values to provide some additional margin of safety (such as the presence of schools, elderly housing, etc.). However, the proposed speed limit should never be lower than the lower limit of the safe speed range.
- MUTDC – FHWA Approach
  - Road characteristics, shoulder condition, grade, alignment, and sight distance;
  - The pace;
  - Roadside development and environment;
  - Parking practices and pedestrian activity; and
  - Reported crash experience for at least a 12-month period
- North Carolina – Approach
  - The 85th percentile speed of prevailing traffic in the area under study.
  - Condition and type of roadway surface.
  - Roadway type, width, and number of traffic lanes.
  - Shoulder width, condition and type.
  - Horizontal and vertical alignment of the roadway.
  - Roadside development: amount, type, and proximity to the travel way.
  - Composition of the traffic using the roadway.
  - Numbers and types of intersections, including private driveways and roads.
- Georgia

- Road geometrics and design - width, clearances, shoulders, sight distances, stopping sight distances Other conditions of the roadway - parking, presence of pedestrians and trucks
    - Accident history - for recent 12 month period
- Michigan
    - The traffic survey team makes a personal inspection of the roadway to verify the accuracy of their data. They drive the roadway to determine if there are any hazards not readily apparent to the motoring public. Sometimes consideration is given to reduce a speed limit due to a certain condition. If a hazardous condition is found, an attempt should be made to correct it. If it cannot be corrected, consideration should be given to posting an advisory speed control sign or, if several conditions are present, then the speed limit may be reduced. Of particular concern are hills and curves where vision is restricted. On long stretches of roadway, one or two hills or curves should not dictate the speed for the entire roadway. Motorists are warned of the reduced sight distance through the use of warning signs with advisory speed controls.
- Idaho Approach
    - Roadway – hidden intersections, lane-drops etc.
    - Roadside – significant number of commercial access or other sources of entering and exiting vehicles within the speed zone
    - Parking – if there is an unusually high parking turnover rate, parking stalls or lanes are unusually narrow, or other conditions exist such that parking ingress and egress, or persons entering and exiting from vehicles creates a hazard that is not readily apparent to the motorist
    - Pedestrian and Bicyclist - The effect of pedestrians and bicyclists on the speed of the traffic being studied should be observed and documented. Also document the level of bicycle and/or pedestrian activity relative to what normally might be expected for a similar roadway type and area, and note the apparent age of bicyclists/pedestrians. Special consideration may be required if a large percentage of the bicyclists/pedestrians are under age 14 or over age 65.
    - Accident experience - Reported accident experience for at least the last 12-month period indicating number and type of accidents by location or accident rate compared to rates for other similar roadways…. Accidents should be reviewed to determine which can be attributed primarily to speed. The types of accidents occurring may indicate whether a lower, or higher, speed limit is needed.

- Washington
    - Roadway characteristics, shoulder condition, grade, alignment and sight distance
    - Roadside development and lighting
    - Parking practices, e.g., angle parking, and pedestrian and bicycle activity
    - Collision rates and traffic volume trends
    - Right lane/entering traffic conflicts (for freeways)
- Virginia DOT
    - Engineering Investigation: review of
        - Lane width
        - Pavement type and condition
        - Terrain
        - Parking conditions
        - Commercial and residential development along the road
        - The number, width and type of entrances and intersecting streets
    - Traffic investigation
        - Prevailing vehicle speeds
        - Average test runs
        - Traffic volumes
        - Accident experience
        - Traffic control devices that affect or are affected by vehicle speeds
- Arizona
    - Length of section
    - Alignment
    - Roadway width and shoulders
    - Surface condition
    - Sight distance
    - Traffic volume
    - Accident experience
    - Maximum comfortable speed on curves
    - Side friction (roadside development)
    - Parking practices and pedestrian activity
    - Signal progression.
- Minnesota
    - Roadway type and condition
    - Location and type of access points (intersections, entrances, etc.)
    - Sufficient length of roadway (1/4 mile minimum)

    - Existing traffic control devices (signs, signals, etc.)
    - Crash history
    - Traffic volume
    - Sight distances (curve, hill, etc.)
    - Test drive results
    - Speed study
- Maryland
    - Atypical traffic characteristics because of particular land use or other conditions.
    - Road design elements substantially above or below what are typical.
    - Prevailing speeds consistently higher or lower than the statutory speed limit.
    - Transition between rural and urban areas on major highways.
    - Schools or other significant pedestrian traffic areas.
    - Road construction activity.
    - Frequent collisions in which speed is a contributing cause.
    - Unusual or unanticipated conditions.
- Maine
    - geometric design of the road,
    - public and private access points,
    - the number of intersections,
    - the number of roadside businesses,
    - observed travel speeds of traffic,
    - the 85th percentile of the observed speed ranges,
    - total accidents in a 3 year time frame,
    - accidents just from driveways and intersections within a 3 year period,
    - a series of test runs on that section of road driving a certain speed evaluating safety and drivability.
- Louisiana
    - Roadway characteristics and shoulder conditions, such as curves, striping and surface width and type; grade alignment and visibility.
    - Roadside development factors, such as sites along the location which generate traffic.
    - Safe speed for curves or hazardous locations
    - Parking practices and pedestrian activity
    - Traffic volume
    - Crash history
    - Traffic signals
    - Speed study
- Kansas

- This speed is subject to revision based upon such factors as:
    - crash experience,
    - roadway geometries,
    - parking,
    - pedestrians,
    - curves,
    - adjacent development, and
    - engineering judgment.
- Connecticut
  - Principal factors considered are:
    - road type and surface (curve, hill, etc.)
    - location and type of access points (intersections, entrances, etc.)
    - existing traffic control devices (signs, signals, etc.)
    - accident history
    - traffic volume
    - sight distances
    - test drive results
    - radar observations
- Colorado
  - Each Investigation to determine an appropriate speed limit should consider the following factors applicable to the portion of road being studied.
    - Prevailing speed data (85th percentile)
    - Roadside development
    - Accident experience
    - Road characteristics
    - Pace speed
    - Parking practices/pedestrian activity
- Missouri
  - Road type and surface (i.e. curve or hill)
  - Location and type of access points (i.e. intersections, entrances)
  - Roadway length
  - Existing traffic-control devices
  - Crash history
  - Traffic volume
  - Sight distances
- Ohio
  - Field review should consider
    - Roadway width

  - Width of lanes
  - Width of berms
  - Setback of the buildings
  - Distances to any fixed objects within 10 feet of the pavement edge
  - Type and condition of the pavement surface
- The review should consider features 500 feet beyond each end of the proposed zone.
- Pavement marking or restricted sight distances less than 600 feet, signals and flashers, and Warning and Regulatory Signs.
- The number of, and point at which, more than five pedestrians per hour cross or walk on the pavement.
- The number and type of crashes that occurred in the last three years.
- Crashes/MVM - intersection crashes not on the approach to the section under study should not be included in the evaluation. Crashes at horizontal curves should be considered only after all appropriate Warning and Advisory Speed signs are in place. Caution needs to be exercised in applying the crash experience if there is an over representation of crashes caused by animals, the environment (such as ice), impaired drivers, vehicle defects, construction, etc. It is desirable to consider a review of crashes over a three-year period; however, crash data for one year is acceptable if more is not available. Copies of the crash reports, or a list documenting the location and type of each crash, shall be submitted with the request.
- A study area near or adjacent to an incorporated area or other warranted speed reduction(s).
- Maintaining uniformity of speed limits within a contiguous section of highway.
- Truck volumes along with the lane width should be considered, i.e., Volumes:

< 5%	Low impact/consideration
5% to 10%	Moderate impact/consideration
> 10%	High impact/consideration

An effective width of 20 feet is considered adequate only for low-volume roads where meeting and passing are infrequent and the truck volumes are low.

- Land along the study area is generally fully developed based on local zoning and/or local subdivision regulations.
- Other conditions:
  - A large number of driveways with limited visibility.

        - The results of the test runs are not representative of the 85th-percentile or calculated speed.
        - Abnormal traffic volume flows.
        - A large number of horizontal and vertical curves requiring speed reductions.
        - The use of the road as related to access vs. mobility (e.g., functional classification).
        - An unincorporated area that looks to the driver the same as an incorporated area.
        - Large number of items that affect the assured clear stopping distance of the driver.
        - Volume of pedestrian traffic and/or official signed bike routes.
        - Proximity to a school.
        - Geometric or other work zone features that cannot be modified and are not otherwise taken into consideration elsewhere in the process (for Work Zone Speed Zones that are on facilities other than high-speed, ≥55 mph, multi-lane highways).
        - Photographs may also be helpful in describing features of particular concern.
- Oregon
    - Geometric features
        - Geometric features include vertical and horizontal alignments and available sight distance. The appropriate warning sign with speed advisory plaques should be used rather than lower speed limits to indicate appropriate speeds for curves and hills.
    - Pedestrian and bicycle movements
        - When determining the appropriate speed, pedestrian and bicycle movements should be taken in to consideration. The type of accommodations for non-motor traffic, such as sidewalks and separated cycling paths versus shoulder use, should be considered if there is consistent pedestrian or cyclist traffic.
    - Type and density of adjacent land use
        - It is desirable that features such as roadside development (business, residential, rural, etc.) within each speed zone be consistent, as comparable sections tend to encourage similar operating speeds. It is not always practical to subdivide a roadway section into homogenous speed zones because it could result in a number of short sections with various speed limits. The section length used for speed zoning should be at least ¼

of a mile in length, except transition speed zones may be a minimum of 1000 feet in length.

- Enforcement
    - Signing alone is of little benefit accomplishing a change in travel speeds. Even if most drivers believe the limits are reasonable and comply with them, enforcement is essential to ensure conformity of the remaining drivers. *Setting speed zones too low makes enforcement difficult and expensive.* The deterrence effects of enforcement are temporary and must be reinforced often.
- Crash history
    - A crash analysis should be conducted as a routine part of speed zone investigations. *Speed zoning is not usually an appropriate counter measure to address high crash situations.* The analysis should identify high crash characteristics and problem locations. The crash history is relevant to the speed zone if the crashes are spread out along a section, rather than concentrated around a single feature such as a severe curve or intersection. The road authority should conduct a separate field review to identify possible causes and develop recommendations for improvements for singular crash locations.
- Public testimony
    - The road authority may consider public testimony before establishing a speed zone. Extenuating circumstances or other issues may be revealed beyond the speed zone investigation.
- Accesses
    - Numerous accesses which are typically found in urban or community settings can increase the potential of vehicle conflicts.
- Oregon
- Before field investigation
    - Established speed zones
    - The most recent investigation
    - Correct mileposts (if on State highway)
    - Current map
    - Crash data
    - Average Daily Traffic (ADT)
- Before field investigation (in other words)
    - All relevant established speed zones on the road being investigated.

        - Previous investigations of the requested area.
        - Up-to-date map showing all road connections and jurisdiction changes.
        - Crash history if possible (3 year minimum). Identify types of crashes, locations, problem areas, severity.
    - During field investigation
        - Roadway Data
        - Photographs
        - Spot Speed Data
    - During field investigation (in other words)
        - Field Review:
        - Calibrate the distance meter, preferably for 1 mile, in feet. Be sure to use a surveyed set of marks.
        - Drive through:
            - Note topography, culture, high crash areas, traffic flow, and comfortable speeds.
            - Document the following
            - Number of horizontal curves: on state highways, ball bank if not signed or advisory speed is questionable
            - Vertical alignment
            - Sight distances less than adequate if no advance signing
            - Other areas where driving requirements are different than majority of the roadway
            - Parking prohibitions
            - Bicycle/Pedestrian facilities
        - Milepoint log: Milepost and describe all accesses, traffic control and driver information:
            - Use centerline of intersections noting intersection type and alignment (lt./rt.), type of stop or signal, surface type of intersecting street.
            - Use centerline of driveways. If there are too many to note practically, note 'avg. 100 feet left" or "numerous" if at very irregular intervals, with begin/end milepoints.
            - Log all traffic signs: location, logo, condition and sizing (if nonstandard or oversize).
        - NOTE: The point is to document driving conditions, conflicts, instructions and information.
        - Typical Sections:
            - Take shoulder-to-shoulder sections along the length of the investigation.

            - Determine where the roadway/shoulder width extremes are in each investigated portion and take the sections at these locations.
            - Record the widths, at right angles to centerline, of each: shoulder (including gutters), bike lane, travel lane median, island, etc.
        - Photos:
            - Take both road ahead and road back at reasonable intervals to establish the character of the road and roadside culture, and to pick up any signing or features to be noted in the report text. Intervals should generally be 1/4 mile minimum. Photos should be taken on both sides of a speed zone boundary and show the speed signs in the shots. Photos should be taken from centerline, if safe to do so, or from the outside of a curve. It's helpful to show the existing posted speed and warning signs in the photos. If one of the pair of photos shows the back side of signs or one side of an intersection, it is a good idea to move to the other side of the sign or intersection for the second shot in order to show the message on the sign and the details of the intersection.
            - If sight distance is restricted where public roadways intersect the investigated roadway, take photos at those intersections to show the sight distance.
            - Keep a log listing each photo by film strip number and photo location (distance from nearest cross street and/or milepoint).
            - Keep numbering of photos in the report consistent for ease of understanding. For instance, all odd numbered photos face north and even numbered photos face south.
            - Photos should be numbered and listed on the map and photo pages in the same direction as you list the speed zones.
- Oregon
    - If an electronic counter is used, the report from the automated analysis must include all of the following, or analysis will have to be completed manually for submittal:
        - 85th percentile speed

- 10 mile per hour pace limits
- Percent of traffic in the 10 mile per hour pace
- Posted speed
- Percent of traffic exceeding the posted speed
- Maximum speed, per direction and combined

- Line or data point chart showing total vehicles tallied per speed (MPH) in 1 mile increments vs. percentage of total vehicles counted (percentile). The chart must be scaled to read percentile accurately for any speed.Texas
    - If a section of roadway has (or is expected to have) a posted speed in excess of the roadway's inferred design speed and a safety concern exists at the location, then appropriate warning or informational signs should be installed to warn or inform drivers of the condition. Slightly shorter than desirable stopping sight distances do not present an unsafe operating condition, because of the conservative assumptions made in establishing desirable stopping sight distances. It is important to remember that any sign is a roadside object and that it should be installed only when its need is clearly demonstrated.
    - New or reconstructed roadways (and roadway sections) should be designed to accommodate operating speeds consistent with the roadway's highest anticipated posted speed limit based on the roadway's initial or ultimate function.
    - Factors Affecting Safe Speed
        - Design and Physical Factors of the Roadway
        - horizontal and vertical curves
        - hidden driveways and other roadside developments
        - high driveway density
        - rural residential or developed areas
        - lack of striped, improved shoulders.

        The effects of such factors as lane width, condition of surface, type and width of shoulders, frequency of intersections, and roadside development are not so easily measured. As a general rule, especially on tangents, these factors will be measured on the basis of prevailing speeds as determined by speed checks.

        - The Vehicle
        - The Driver
        - Traffic (including pedestrians)
        - Weather and Visibility
        - Accident Reconstruction Speed Limits
    - The traffic and engineering investigation will include a review of:
        - the statuatory prima facie speed applicable to the highway

        - the design speed applicable to the highway
        - a trial run speed study for the highway.
- To set an interim speed limit at a speed that is less than the prima facie speed applicable to the highway, a commission minute order or a city ordinance setting the interim speed limit is required.
- Scope of Study
- A speed zone study consists of the following principle areas:
    - determining the 85th percentile speed
    - crash study
    - developing of strip maps
    - speed zone design
    - rechecks of speed zones.
- Crash Rate Greater Than Average. On a section of highway having a crash rate greater than the statewide average crash rate for the same type roadway section, the zone speed may be as much as 7 miles per hour lower than the 85th percentile speed. NOTE: This should be considered more as an exception than as a rule, and should be done only where enforcement agencies will assure a degree of enforcement that will make the speed zone effective.
- Light Traffic Volumes. At locations where traffic volumes are light and 125 cars cannot be checked in the two or four hours that the speed check station is operated, the 85th percentile speed may not be reliable. Trial runs need to be made and documented in the study. (“Trial runs” are defined and explained later in this section.) Trial runs may be documented using the Summary of Trial Run for Speed Zones (TxDOT Form 1929), to supplement a strip map. (The form is available via hyperlink — click on the form number above — or from the Traffic Operations Division.) Figure 3-10, “Example of completed Summary of Trial Run for Speed Zones,” shows an example of a completed Summary of Trial Run for Speed Zones.
- Legislative or Congressional Action. Notwithstanding the volume of traffic, if legislative or congressional action results in the immediate increase in statewide maximum legal speed limits, then reasonable and prudent speed zones may be established by trial runs and engineering judgment in lieu of other speed check procedures provided in this manual. (“Trial runs” are defined and explained later in this section.) Trial runs may be documented using the Summary of Trial Run for Speed Zones (TxDOT Form 1929) instead of a strip map. (The form is available via hyperlink — click on the form number above — or from the Traffic Operations Division.) Figure 3-10,“Example of completed

Summary of Trial Run for Speed Zones," shows an example of a completed Summary of Trial Run for Speed Zones. Speed zones established through this process should be rechecked in accordance with the procedure in Section 5 of this chapter.

  - Additional Roadway Factors. The posted speed limit may be reduced by as much as 10 miles per hour (12 miles per hour for locations with crash rates higher than the statewide average) below the 85th percentile speed or trial-run speed (if 125 cars cannot be checked during the two- or four-hour speed check), based on sound and generally accepted engineering judgment that includes consideration of the following factors:
    - narrow roadway pavement widths (20 feet or less, for example)
    - horizontal and vertical curves (possible limited sight distance)
    - hidden driveways 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)
    - crash history along the location
    - rural residential or developed areas (higher potential for pedestrian and bicycle traffic)
    - lack of striped, improved shoulders (constricted lateral movement).
  - Local public opinion may also be considered on farm-to-market and ranch-to-market roads without improved shoulders (Transportation Code, Section 545.3535(b)).
  - Speed limits should not be posted more than 10 miles per hour (12 miles per hour for locations with crash rates higher than the statewide average) below the 85th percentile or trial-run speed (if 125 cars cannot be checked during the two- or four-hour speed check), since unreasonably low speed limits have not been shown to be an effective way to control speeding. Allowing too great a variation would risk losing motorist respect for speed limits and traffic control devices.
- Wisconsin
  - The design, physical condition, and classifications of a roadway have an-effect on vehicle speeds because motorists vary their speeds depending on the driving environment. The traffic engineer considers significant items in the driving environment. These items may include:
    - Traffic volumes
    - Roadside development (type, density and lateral offset)

        - Roadway and shoulder widths
        - Condition of the roadway
        - The number of lanes
        - Intersections
        - Driveways
        - Hills, curves
        - Urban Roadway cross-section (presence of curb and gutter rather than ditches
        - Parking
        - Pedestrian and bicyclists – frequent presence 10% of time
        - Any other factors recorded by the study team
    - The number of changes in the speed limit along a given route should be minimized. With this in mind, the length of the speed zone should be at least 0.3 miles. Speed limits are not a spot issue. The traffic engineer bases the recommendation on the conditions that exists at the time of their evaluation and should not attempt to consider such things as future growth, anticipated enforcement, or concerns for something that has not happened.

Factors not to be considered

- All factors that are readily apparent to the drivers
- Normally, isolated curves and turns, areas of restricted sight distance, no passing zones, etc. will not be considered as areas for lowering speed limits. (Missouri)
- Physical conditions such as width, curvature, grade, and surface conditions, or other conditions readily apparent to a driver in the absence of other factors, would not require special downward speed zoning (California Vehicle Code 22358.5)
- Except for traffic control zones, speed zones shall not be established where intermittent physical conditions such as width, curvature, grade and surface conditions or any other physical condition readily apparent to the driver are the only reasons for a reduced speed. (Alaska)

Appropriate speed zone length

- Additionally, speed limits in *unincorporated or "non-community"* areas should stay consistent for a *minimum of 2 miles*. (Missouri)
- Except for traffic control zones and school zones, short speed zones should be avoided. They are ineffective and difficult to enforce. As a general rule, no speed zone should be shorter than the distance traveled in 25 seconds at the posted limit. (Alaska)

- All zones are to be computed to the nearest tenth of a mile. With a few exceptions, zones ideally should be at least 0.5 miles in length. However, exceptions to this guide do exist. For example, on an approach to a section of roadway where it is determined that it is necessary to reduce the speed limit due to an adverse or dangerous situation, a minimum zone length of 0.5 miles is not needed to adequately advise motorists of the proper operating speed through such a condition. (Massachusetts)
- Each speed zone should be as long as possible…………..) In rural areas, the length of a zone generally should be at least one-half mile when possible. Each zone in a series of graduated speed zones should be at least two tenths of a mile in length (Massachusetts)
- Speed limit changes should not be closer than 0.20 mile to any major (i.e., signalized) at-grade intersecting roadway or 0.02 mile to any at-grade intersecting roadway. (Georgia)
- Loop and dead end roads 0.5 mile or less in length should not generally be speed zoned because of the local traffic characteristics. (North Carolina)
- The number of changes in the speed limit along a given route should be minimized. With this in mind, the length of the speed zone should be at least one-half mile. Survey team members base their recommendation on the conditions that exist at the time of their evaluation and should not attempt to consider such things as future growth, anticipated enforcement, or concerns for something that hasn't happened. (Michigan)
- After the engineer has determined that a speed limit is needed, he will determine the length of the zone and the speed limit that is to be established. Unreasonably short zones or short transition zones should be avoided. It is desirable to transition at a rate which can be achieved by the driver removing his foot from the speed changes per mile be made with no change to exceed 10 miles per hour. Minimum lengths of individual zones should range from 1,000 feet for 25 and 30 miles per hour to 2,500 feet for 50 miles per hour zones. (Louisiana)
- Roads of insufficient length (usually 500' or less) do not warrant or need a speed limit. (Connecticut)
- An existing designated speed zone may, at the discretion of the State Traffic Engineer, be extended or shortened up to 500 feet without obtaining a spot speed check within that section. (Oregon)
- Texas:
    - The length of any section of zone set for a particular speed should be as long as possible and still be consistent with the 85th percentile speeds. These zone lengths should be shown on the strip map in miles to three decimal places. Where graduated zones on the approach to the

city or town are at locations where speeds fluctuate, the speed zone should generally be 0.200 mile or more.
    - School zones are the exception to this rule and may be as short as reasonable in urban areas, depending on approach speeds. School zones in urban areas where speeds are 30 miles per hour or less may have school zones as short as 200 to 300 feet.
    - If adjacent 85th percentile speeds show an abrupt change of more than 15 miles per hour, a transition zone of approximately 0.200 mile or more in length should be used.
- Wisconsin
    - Length/Transitions: A speed limit should generally not be recommended when the length of the total zone would be less than 0.3 miles of a mile in length. A shorter distance may be considered or even necessary in urban settings where transitional speed limits are enacted as a buffer between high and low speed limits. The 85th percentile should support these transitional zones. Avoid unwarranted step down speed limits; rather base it on the character of the roadway.
    - Generally, it is not recommended to have transition/step down speed zones. Transitional speed zones are typically less than 0.3 miles in length and provide a means to allow drivers to step down their speed when approaching zones that are reduced due to constraints such as urban areas or construction. Research suggests that drivers may not reduce their speed to the posted speed limit on the basis of signage alone. Speed is more dependent on other factors, such as the physical characteristics of a highway.
    - Transition zone should be considered, if the physical characteristics of the roadway change, such as a rural section that transitions to a curb and gutter section with minimal driveways, and then to a curb and gutter section with a significant number of driveways.
    - Consider no more than 2 step-downs and only if within the 85th percentile speeds. Where there is development in an outlying area, a step down/transitional zone may be appropriate. However, where the highway is rural and transitions directly into a community without an outlying business area, the step down/transition zone is probably not appropriate.

Location of Speed Zone

- Speed limits shall begin at a point on or as near in advanced of the point as possible where the speed limit is warranted and shall end at the point or as near the point as possible where the speed limit is not warranted. (Missouri)

- Soil or gravel roads should not generally be speed zoned because of the unstable conditions affecting vehicular speed on roads of this type. Special hazards requiring speed reductions should be marked with warning signs and, if necessary, advisory speed plates. Under certain conditions with a high percentage of roadside development, restrictive speed limits may be established, not to exceed 35 MPH. (North Carolina)

Avoiding speed transition zone or not

- In many rural areas where urban sprawl is not present, an abrupt change occurs in the driving environment when entering or leaving an urban area and a transition speed will not be supported by the 85th percentile speed. Unless the driver perceives a reason to slow down, transitional zones are almost completely ineffective. In these cases, advance signing advising the driver of a drop in the speed limit is the preferred method. (Wisconsin)
- If roadside development > 0.75 for 0.25 mile of roadway then 35 MPH or less

Additional Notes

- Except on divided highways, different speeds for traffic in opposite directions cannot be justified. (Missouri)
- Physical conditions that require reduced speeds are best handled with standard warning signs accompanied by advisory speed plates. (Alaska)
- Speed limit changes may be made in increments of 5, 10, or 15 miles-per-hour. 10 or 15-mile-per-hour changes with relatively long zones are preferable to multiple short zones with 5-mile-per-hour increments. (Alaska)
- When multiple speed studies made on one segment of road result in 85th percentile speeds within 5 MPH of each other, the results should be averaged to minimize the number of speed limit changes. (Alaska)
- Speed zones are established in both directions, for all lanes of traffic, vehicles, times and conditions unless otherwise noted. (Georgia)
- There is no question, however, that speed plays a role in accident severity. Once an accident has begun to occur the degree of damage to a vehicle and its occupants is directly related to the speed the vehicle is going. (Colorado)
- ITE
    - Speed zoning is based on several fundamental concepts deeply rooted within the American system of 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 consistently favorable driving records;
        - The normally careful and competent actions of a reasonable person should be considered appropriate;

        - Laws are established for the protection of the public and the regulation of unreasonable behavior on the part of individuals; and
        - Laws cannot be effectively enforced without the consent and voluntary compliance of the public majority.
    - COMMON MISCONCEPTIONS: The public normally accepts the concepts noted above. However, when emotionally aroused in a specific instance, the same public will often reject these fundamentals and rely instead on more comfortable and widely-held misconceptions such as:
        - Reducing the speed limit will slow the speed of traffic;
        - Reducing speed limits will decrease the number of crashes and increase safety;
        - Raising the posted speed limit will cause an increase in the speed of traffic;
        - Any posted speed limit must be safer than an unposted speed limit; and
        - Drivers will always go 5 mph over the posted speed limit.
    - The most widely accepted method by state and local agencies is to set the limit at or below the speed at which 85 percent of the traffic is moving. The 85th percentile speed is how drivers "vote with their feet.
- *Speed zones are not a tool to warn motorists of hazardous conditions.* If a hazardous condition is found to exist within a road segment under study, this condition should be corrected or an appropriate warning sign with an advisory speed rider should be posted. (Oregon)
- Wisconsin
    - Increments: Speed limit recommendations between adjacent sections of highway outside incorporated cities/villages should generally be made in increments of ten MPH, but increments of five MPH are permissible when justified. Inside the incorporated cities/villages these speed limits should be in increments of five MPH. The number of such changes should be held to a minimum when speed limits are being applied to several adjacent sections of highway.

School Zone

- Highways designated as part of the Interstate System or other controlled access highways shall not have school speed zones posted. (North Carolina)
- Restrictive school speed limits should not normally be established along highways without abutting school property. (North Carolina)

- The restrictive school speed limit should not normally extend along any highway, for a distance more than five hundred (500) feet on either side of such school property lines. (North Carolina)
- The speed limit so established should normally be effective for thirty (30) minutes prior to and thirty (30) minutes following the time of each beginning and each ending schedule. (North Carolina)
- The speed limit so established should not be ordinance less than 10 MPH below the 85th percentile speed of prevailing traffic in the area or the posted non-school speed limit. In no case shall the school speed limit be less than 25 MPH. (North Carolina)
- Kentucky Approach
    - School speed limits may be established according to KRS 189.390 and 189.336 for public or private schools if both of the following criteria are satisfied:
        - The school property is adjacent to a state-maintained facility.
        - The student enrollment is equal to or greater than 100 in kindergarten through 12th grade.
        - Preschools, day cares, head starts, and postsecondary facilities are not eligible.
    - The school speed limit should normally be 10 mph lower than the normal posted speed limit, not less than 25 mph and not more than 45 mph. Unusual sight distance restrictions, roadway conditions, or crash history may justify reductions greater than those listed above.
- Loisiana
    - Speed Limit Reductions for a School Zone:

SPEED LIMIT REDUCTIONS	
EXISTING SPEED LIMIT (MPH)	REDUCTION (MPH)
25 OR LESS	0
30	5
35-45	10
50 OR ABOVE	15

- Texas
    - Speed checks provide a sound basis for selecting the proper speed limits for school zones. While it is not common practice to set speed limits significantly lower than the 85th percentile speed for regulatory speed zones, exceptions to this practice are often found at school zones.
    - Factual studies, reason, and sound engineering judgment, rather than emotion, should govern the final decision on the maximum deviation

from the 85th percentile speed which will provide a reasonable and prudent speed limit.
  - It is not advisable to set a school speed limit above 35 miles per hour in either rural or urban areas. Lower school speed limits should be considered when the 85th percentile speed is below 50 miles per hour.
  - When the results of a speed study indicate an 85th percentile speed at or below 50 miles per hour, the reduced school speed limit should not be more than 15 miles per hour below the 85th percentile speed or normal posted speed limits. If the 85th percentile speed is 55 miles per hour, the reduced school speed limit should be 20 miles per hour below the 85th percentile speed. Any roadway with an 85th percentile speed greater than 55 miles per hour requires a buffer zone to transition down to a 35-mph speed limit.

Minimum Speed Limit

- Idaho Code establishes provisions for setting minimum speed limits on the state highway system although these provisions normally have not been used as a means of raising the speed of slower vehicles. If minimum speeds are considered, the engineering study should take into account the 15th percentile speed or lower limit of the pace speed in selecting the minimum speed limit. (Idaho)
- The lower limit of the 10 mile per hour pace should generally be used as a guide in establishing minimum speed limits. Usually minimum speeds should not be lower than 35 miles per hour.(Louisiana)

Variable Speed Limit

- Oregon
  - Variable Speed Zone System Criteria and Process:
    - The safety and operational problems that prompt the need for a variable speed zone system.
    - The system employed to enact the variable speeds must be fully described and approved by the State Traffic Engineer prior to the design and implementation of the variable speed zone.
    - The system that will trigger the change in posted speed will use current traffic volumes, current 85th percentile speeds, incident detection and/or adverse condition detection.
    - The traffic volumes and 85th percentile speed data will be obtained from detectors in real-time and will be based on small time periods (typically 15 minutes or less).

    - The variable speed control software will be configured to comply with requirements for each
    - Individual location and identified applicable standards and procedures for the increase or decrease of posted speeds.
    - Posted speed should not be modified more than once within 15 minutes.
    - Speed signs shall display speeds only in increments of 5 mph.
    - Volume and speed should be selected from the detector with the highest volume and lowest speed.
    - Unless the highway has more than two lanes in each direction and is separated by a wide median or positive barrier, variable speed signs shall display the same speed for all lanes of traffic at the same location.
    - The variable speed zone order will not exceed the maximum speed determined by the standard speed zoning investigation criteria described in OAR 734-020-0015 or, for interstate highways, OARs 734-020-0010 and 734-020-0011.
    - The variable speed zone becomes enforceable when appropriate signs are posted and operational on the portion of the highway where the variable speed zone is imposed.

Horizontal Curves – Advisory speeds

- If the safe speed determined by a Ball- Bank Indicator through a particular curved section of a roadway differs from the preceding speed zone by 10 miles per hour or less, and the curved section of roadway is less than 0.20 miles, or if engineering judgment determines that it is appropriate, a warning sign used in conjunction with an advisory speed plate indicating the safe speed can be used in lieu of establishing a separate speed zone for an isolated condition. (Massachusetts)
- If there are numerous locations within the speed zone that would require advisory speed warning signs (such as sharp curves, sections with restricted stopping sight distance, etc.), it may be practical to reduce the posted speed limit below the 85th percentile speed. In situations where traffic is constantly accelerating and decelerating between continuous curves, a spot speed study conducted at a single location may not present a true picture of the appropriate speed limit. The test run method discussed later would give a better indication. Isolated slow-speed curves should not influence the speed limit selection. … Advisory speed signs supplementing the curve warning signs are more effective. (Idaho)
- Idaho Approach

- The advisory safe speed for any particular curve is that speed at which the following ball-bank reading is indicated:
  - 10 degrees (for speeds 35 mph and higher)
  - 12-1/2 degrees (for speeds of 25 mph and 30 mph)
  - 15 degrees (for speeds 20 mph and below)
- Some suggestions for field determination of advisory safe curve speeds are:
  - Keep car in balance by evenly distributing load and occupants, checking tire pressure, etc.
  - Calibrate the accuracy of the vehicle speedometer reading by making three time-and-distance determinations over a range of speeds.
  - Run the curves as smoothly as possible at any selected speed. Maintain a distance of approximately 2 feet between the roadway centerline (or lane line if multi-lane highway) and the left vehicle wheels throughout the length of the curve.
  - Determine the advisory safe-speed readings for each direction of travel on all curves.
  - Read the ball-bank indicator and speedometer directly from the front since side-view readings are incorrect.
  - Record ball-bank readings in 2-1/2 degree increments. (A 2-1/2 degree increment is approximately equal to a 5 mph speed differential.)
  - When determining advisory safe speeds for curves on multilane roadways, record the advisory speed for each lane in both directions, and use the safe speed for the most restrictive lane.
  - The pace can usually be determined by visual inspection of the Speed Distribution Chart.

- Arizona
  - To achieve a comfortable operating speed, a specific location may justify a speed that is lower than the lawful posted speed for a given section of highway, such as an isolated horizontal curve on an otherwise straight section. Such locations may be treated by the application of special warning signs such as Curve and Turn signs with advisory speed signs.
- Louisiana
  - The ball bank indicator is used to measure the overturning force (side friction), measured in degrees, on a vehicle negotiating a horizontal curve. The ball bank should be mounted in such a position as to allow the ball to rest freely at the zero degree position when the vehicle is

standing level. The movement of a car around a curve to the left, for example, causes the ball to swing to the right of the zero degree position. The faster the car moves around the curve or the sharper the curve, the greater degree indication from the zero degree position.

- Beginning well in advance of the curve being checked during free flow conditions, the driver should enter the curve at a predetermined speed (mph as stated in the paragraph below), drive the car parallel with the centerline of that travel lane, and maintain uniform speed throughout the curve. The curve should be driven a number of times until at least two identical ball bank readings (degrees) for each direction of travel are obtained. Each direction of travel shall be considered separately. See Table 20.2.1 for criteria in determining the curve advisory speed.
- Criteria for Curve Advisory Speed Determination

Speeds (mph)	**Ball Bank Reading (degrees)**
≤ 20	16
25-30	14
≥ 35	12
50 OR ABOVE	15

- The first trial run is made at a speed below the anticipated maximum speed.
- Subsequent trial runs are conducted at 5 mph speed increments. Readings of 16 degrees for speeds of 20 mph or less, 14 degrees for speeds of 25 mph through 30 mph and 12 degrees for speeds of 35 mph or greater are the usually accepted limits beyond which riding discomfort will be excessive and loss of vehicle control may occur.
- The recommended advisory speed should be to the nearest 5 mph less than the maximum negotiable speed determined separately for each direction of travel.
- Considerations of sight distance, intersections, crash records, and other conditions may result in a recommended speed lower than that derived by the ball bank indicator method.
- Advisory speed plates (mph) should be used in conjunction with curve and turn signs when the operating speed is below the posted or prevailing speed on the roadway. When plates are used with curve and turn signs, the miles-per-hour value shown on each plate should be determined by the use of the ball-bank indicator. The lowest speed (to the nearest 5 mph) obtained during trial runs that create a reading equal to or more than the degrees stated in Table 20.2.1 with the

corresponding mph should be posted. Each direction should be checked independently and may be posted with different speeds.

- A horizontal alignment sign with advisory speed plates shall be required for speed advisories differing more than 9 mph from the posted speed. A horizontal alignment sign may be installed for alignments differing less than 9 mph. To decide if the horizontal alignment sign should be a turn or a curve sign, the driver should make test runs at 30 mph (or less, for safety). If the ball bank indicator exceeds 12 degrees or more, a turn sign will be required. If the indicator reading is less than 12 degrees at test run speeds of 30 mph, then test runs should be made at greater speeds. If the indicator exceeds 12 degrees at speeds between 31 and 65 mph, then a curve sign is required. See Table 20.2.2 below and Table 2C-5 in the MUTCD for further guidance.
- Turn Sign vs. Curve Sign

Number of Alignment Changes	**Advisory Speed Sign**	
	≤ 30 mph	**> 30 mph**
1	Turn (W1-1)	Curve (W1-2)
2	Reverse Turn (W1-3)	Reverse Curve (W1-4)
3 or more	Winding Road (W1-5)	

- Safe speeds on horizontal curves must also be related to the safe-stopping sight distance and various other factors which cannot be determined by using either the Ball Bank Indicator or the calculation method for determining curve advisory speed signing (Section 1213-3) (Ohio).
- OMUTCD Section 2C.46 indicates that the advisory speed "may be the 85th-percentile speed of free-flowing traffic, the speed corresponding to a 16-degreee ball bank indicator reading, or the speed otherwise determined by an engineering study because of unusual circumstances." (Ohio)
- Texas:
  - Methods to Establish Curve Warning Advisory Speeds
    - Direct Method,
    - Global Positioning System (GPS) Method, and
    - Design Method.
  - Issues with Ball-Bank Indicator.
    - Historically, the ball-bank indicator has been used to establish the curve advisory speed. However, this device is susceptible to forces that are not a result of road curvature (e.g., bounce due

to rough pavement, jerk due to steering corrections, slip due to variation in pavement friction supply, etc.).

- The Direct Method is based on the field measurement of curve speed. The GPS Method is based on a single-pass survey using a GPS receiver and software to compute the curve radius and deflection angle. The Design Method is useful when the radius and deflection angle are available from as-built plans.
- Direct Method
  - The Direct Method is based on the field measurement of vehicle speeds on the subject curve. The procedure for implementing the Direct Method consists of three steps. During the first step, speed measurements are taken in the field. During the second step, the measurements are used to compute the advisory speed. During the last step, the recommended advisory speed is confirmed through a field trial run. Each of these steps is described in the remainder of this subsection.
- GPS Method
  - The GPS Method is based on the field measurement of curve geometry. The geometric data are then used with a speed prediction model to compute the average speed of trucks. This speed then becomes the basis for establishing the advisory speed.
- Design Method
  - The Design Method is based on the use of curve geometry data obtained from files or as-built plans. This method is suitable for evaluating newly constructed or reconstructed curves because the data are available from construction plans.
- The procedure for implementing the Design Method consists of three steps. During the first step, curve geometry data are obtained from files or plans. During the second step, the measurements are used to compute the advisory speed. During the last step, the recommended advisory speed is confirmed through a field trial run, if or when the curve exists. Each of these steps is described in the remainder of this subsection.

Speed Limit Enforcement

Enforcement of speed limits within speed zones should be uniform. Efforts should be made to coordinate the implementation of speed zones with the enforcement policies of the governing enforcement agency. (Oregon)

Traffic Signs and Signal in Transition Zones

Refer to Section 2B.13, 2B.14, 2B.15, 2B.16, 2C.38, 4L.04, 5B.03, 7B.15, and 7B.16 of MUTDC - FHWA for guidelines related to Speed Limit Sign.

Two types of Speed Limit signs may be used: one to designate passenger car speeds, including any nighttime information or minimum speed limit that might apply; and the other to show any special speed limits for trucks and other vehicles. (MUTDC-FHWA)

A changeable message sign that changes the speed limit for traffic and ambient conditions may be installed provided that the appropriate speed limit is displayed at the proper times. (MUTDC - FHWA)

A changeable message sign that displays to approaching drivers the speed at which they are traveling may be installed in conjunction with a Speed Limit sign. (MUTCDC - FHWA)

Speed limit signs (R2-1) shall be placed at the beginning of each speed zone, and should be placed after major intersections, and at other locations within the zone as necessary to advise the motorist of the posted limit. On urban roads, intermediate signs should be placed at least once every two minutes of travel time. Intermediate signs should be spaced no further than ten minutes apart on rural roads with the following exception: Where approved by the Regional Traffic Engineer, intermediate signs on rural roads with low volumes and no speed limit changes may be spaced up to 30 minutes apart. All intervals assume travel at the posted speed limit. (Alaska)

....if the speed limit is reduced from one zone to the next by 15 mph or greater, a W3-5, "REDUCED SPEED LIMIT AHEAD" sign shall be erected in advance of the lower limit in order to inform motorists to adjust their speeds accordingly. The point where the highway enters or leaves a residential district should be used, when feasible, as points of change in numerical limits for a graduated speed zone. (Massachusetts)

When posting restrictive speed zones on arterial and major collector streets, restrictive speed limit signs should be posted so that the motorist has at least one speed limit sign in view at all times. Inside municipal limits of an incorporated town or city where the statutory limit is 35 MPH and the beginning point of the zone is properly marked, it is not necessary to retain a 35 MPH sign in view at all times. (North Carolina)

At the end of the section to which a speed limit applies, a Speed Limit sign showing the next speed limit shall be erected. All existing “Resume Safe Speed” signs should be replaced with the proper speed limit sign. (North Carolina)

A “Reduced Speed Ahead” sign shall be posted 600 feet minimum in advance of the point where a speed zone restriction begins when such restriction imposes any lower speed limit. The “Begin XX 1000 Feet Ahead” sign shall be used when the speed reduction is 15 MPH or more. The “Reduced Speed Ahead” sign should be erected 500 feet in advance of the “Begin XX 1000 Feet Ahead” sign. (North Carolina)

10. For traffic entering an incorporated Town or City over 5,000 population, there shall be erected at or near the corporate limit a sign indicating "Citywide Speed Limit 35 MPH Unless Otherwise Posted." This sign shall not be erected on controlled access highways. (North Carolina)

Advance warning of speed transitions from rural to urban conditions shall be signed using the SPEED REDUCTION sign (W3-5, shown below). In situations where the transition in speed limits is greater than 10 mph, the SPEED REDUCTION signs and SPEED LIMIT signs should be dual-mounted. (Kentucky)

Signs should be installed at the start of a zone, beyond major intersections and at approximately one-half mile intervals. The speed limit is established in increments of 5 mph, as close as possible to the 85th percentile speed. "REDUCED SPEED AHEAD" signs may be posted to advise motorists of speed limit reductions. These signs are not normally required in urban areas where speeds are relatively low. (Michigan)

Posting reduced ahead sign at particular distance

- If speed reduction is more than 10
- If there are some factors of reducing speed limit that are readily not apparent to the drivers

Louisiana

- Since warning signs are primarily for the benefit of the driver who is unfamiliar with the road, it is very important that care be given to the placement of such signs. Warning signs should provide adequate time for the driver to perceive, identify, decide, and perform any necessary maneuver to safely negotiate the curve. This total time to perceive and complete a reaction to a sign is the sum of the times necessary for perception, identification/understanding, emotion/decision-making, and execution of decision. This time may vary from approximately 3-seconds for general warning signs to as much as 10-seconds for high driver judgment condition warning signs. The advance distance for the placement of warning signs is determined by the posted speed or the 85th percentile speed as calculated from speed study data and conditions that exist on the section of roadway being studied. Once the type of warning signs has been selected, the proper sign location can be determined. The advance warning sign placement shall be in accordance with Table 2C-4 Guidelines for Advance Placement of Warning Signs in the current adopted edition of the MUTCD.

Since speed zones are legally described to the nearest thousandth of a mile (5 feet), regulatory speed limit signs should be located within approximately 5 feet of the actual reference marker or milepoint defined in the minute order or city ordinance. Therefore the locations of regulatory speed zones tied to speed changes should be examined carefully to ensure that signs can be erected within the 5 feet variation. (Texas)

Refer to MUTDC would be better

Documenting the new speed limit for approval

- Oregon
  - A Speed Zone Report includes the investigation data summary and resulting recommendation. One is written for every speed zone request and submitted to the State Traffic Engineer. All of the following is submitted with the Speed Zone Report to complete the report of investigation:
    - 1 copy of the transmittal letter
    - 1 copy of all correspondence
    - 1 copy of the supporting data from the field investigation:
    - 1 copy of the unmarked map if the map was not created electronically.
    - Completed Speed Zone Reports: one copy for each jurisdiction, one for Region files and one for Traffic-Roadway Section files.
  - Each Speed Zone Report must closely adhere to the criteria as described in this manual. The report includes in the order of presentation:
    - Report Outline,
    - Map,
    - Photograph page(s),
    - Crash Summary(s) and
    - Spot Speed Summary(s).
  - Have before starting field investigation:
    - Request:
      - from local jurisdiction
      - from local agency or private citizen (on rural state highways)
    - Approval: - from State Traffic Engineer or Region Traffic Supervisor
  - For "Location" information, always give a measured distance from the nearest cross street or permanent feature, such as a creek, that can be located on existing maps of the area. Don't use political boundaries (e.g., city limits), buildings, fences, sign, pullout areas, driveways, etc.
- Wisconsin
  - Engineering studies shall include the following:
    - Measure prevailing speed characteristics and determine the 85th percentile speed;
    - Evaluate reported crash experience for the past three to five years;
    - Check the road’s geometrics including lane widths, curves, roadside hazards and sight distances;
    - Determination of the 10 mile per our pace;

        - Determine average speed;
        - Evaluate density and roadside development in terms of the number of driveways and access points where vehicles can enter the traffic flow.
    - Engineering studies should include the following:
        - Consider conflicts with parking practices, and pedestrian and bicycle activity.
        - Evaluate shoulder widths as well as roadway and shoulder conditions.
        - Determine the current level of enforcement.
    - The following elements are expected to be prepared by the region as part of every speed zone engineering and traffic investigation.
        - Speed checks are taken at appropriate intervals to determine the 85th percentile and mean of the speed distribution at each of the monitored locations. Exceptions are minor adjustments of existing speed zone termini due to changes in highway features, and development or signage that requires the speed limit sign locations to be adjusted. In addition, for all recommendations sent to the Bureau of Highway Operations.
        - A picture or photo of each location where speed readings were taken. Document the capture zone.
        - Crash history when it bears on the recommendation.
        - A map depicting the limits of both the existing and proposed speed zoning.
        - Documentation of any concurrences or protest by local units of government, particularly where existing speeds are to be altered, and discussion of the reason for a recommended change.
- Photographs
- Crash statistics
    - 1 year? 3 year? 5 year?
    - Types of crashes – fatal only, fatal and disabling?
- Documentation of all related data

Approval process

- All speed zones must be documented on a Master State Order or on a Local Ordinance or Resolution to be enforceable. Zones must be defined by road number and/or name (must have name for off-system), beginning and ending points, length of zone, and speed limit. (Georgia)
- Kentucky Approach
    - If the district feels that a speed limit revision is justified based on the results of the study, it shall forward the following information to the division with a recommendation:

- Results of speed studies including 85th percentile speeds
  - Crash history for a three-year period
  - Descriptions with milepoints for all proposed and existing speed zones
  - If the division agrees with the recommendations, the division shall ask the district to obtain local comment. Once this information is received, the division shall forward an Official Order to the Secretary of Transportation for approval. Once approved, the Official Order will be forwarded to the district for posting of signs. After posting Speed Limit signs (R2-1), the district shall send an e-mail to the division indicating the date the signs were installed.
- Ohio
  - Following approval of a regular, "permanent" speed zone on ODOT-maintained highways, the District shall erect the appropriate Speed Limit signs, record the dates of sign erection on Form 1296-6a, and notify the OSHP and other law enforcement agencies as appropriate. A copy of the signed form shall be forwarded to the Office of Traffic Engineering (OTE).
  - Following approval of a regular, "permanent" speed zone for a local jurisdiction, the District shall send the local authority the Speed Limit Revision authorization (Form 1296-6a). After erecting the related Speed Limit signs, the local authorities shall complete the bottom portion of the form, certifying that the signs were erected and when, and return the form to the District. Upon receipt of the completed Form 1296-6a, the District shall notify OSHP and other law enforcement agencies as appropriate. A copy of the signed form shall be forwarded to OTE.
  - As noted in Section 1203-4, withdrawal of an authorized Speed Zone basically follows the same process used to authorize it originally. The District uses Form 1296-7a to approve withdrawal of a Speed Zone, and the jurisdiction involved then uses the bottom portion of the form to certify that the related Speed Limit signs have been removed and when. A copy of the completed form is forwarded to OTE, and the District notifies OSHP and other law enforcement agencies as appropriate.
- Texas:

If the speed zone is...	Then it is established by...
outside a city	Transportation Commission minute order
inside a city	city ordinance or resolution or Transportation Commission minute order

  - Outside an Incorporated City
    - If the strip map contains only zones outside of incorporated city limits (to be set by Transportation Commission minute order), the district should send two prints or an electronic version of the strip map to the Texas Department of Transportation (TxDOT) Traffic Operations

Division (TRF) for review. When TRF and the district have reached agreement on the proposed speed limits, TRF will write the necessary commission minute order. Prints required by the district should be made prior to submitting original tracings, mylars, or computer prints to TRF.

- Within an Incorporated City
  - If the strip map contains only zones within the corporate limits of a city, the district should send two prints or an electronic version of the strip map to TRF for review. When TRF and the district have reached agreement on the proposed zones, the district should then request the city to pass an ordinance establishing the speed zones. After receiving the ordinance from the city, the district should retain the original strip map and ordinance for its use.
- Adjacent Portions Within and Outside an Incorporated City
  - If a strip map submission contains adjacent altered speed zones situated both within and outside the corporate limits of a city, the district should send two prints or an electronic version of the strip map to TRF for review. When TRF and the district have reached agreement on the proposed zones, the district should then request the city to pass an ordinance establishing the zones within the city limits and TRF will write the necessary commission minute order. If there is an immediate need to post the speeds set by ordinance, signs may be installed for these zones prior to receiving a commission minute order on the adjacent section, as long as the city zone and adjacent existing rural zones are compatible.

- Wisconsin
  - The region should prepare the submittal in the prescribed submittal/approval shell.
  - The region's submittal is reviewed by the State Highway Traffic Safety Engineer at the Bureau of Highway Operations Traffic Engineering Section who identified, based on region input and other factors, recommendations that may be expected to generate special attention or controversy and will review those recommendations with the Sate Traffic Engineer. The State Highway Traffic Safety Engineer will make routine approvals. Upon approval, the official records are updated and the region is notified. The Bureau of Highway Operations will respond to region recommendations in writing, including an explanation of the reasons for any denials.
  - Local governments can implement speed limit changes on the local road system without department approval when proposals are within the constraints shown in Figure 1 contained herein.

- The Project Development Group engineers need to obtain approval from the Regional Traffic Unit at the scoping meeting to establish the proper speed limit for the improvement plan.
- Additionally, the Regional Traffic Unit will need to create a speed limit declaration for any speed zone that is an exception to state statute. Traffic Section should issue the speed zone declaration at the PS&E.
- The traffic engineer shall establish the speed limit of a roadway in consultation with projects group.

Follow up studies

- Note the change in driver behaviors
- Studies have shown that speed zoning has very little permanent effect on average vehicular speeds. There are indications, however, that it does have a tendency to group more of the drivers within the Pace since some of the slower drivers speed up and some of the faster drivers slow down after the speed limits are posted. (Massachusetts)

Effect of Speed Zones

- Before and after – comparison of
    - crash rate,
    - severity,
    - change in crash pattern

Miscellaneous

- Review/revision of speed zone
    - 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 five to ten years. In many instances, trial runs may be sufficient.
    - States and local agencies should conduct engineering studies to reevaluate non-statutory speed limits on segments of their roadways 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. (MUTCD - FHWA)

- The establishment or review of speed zones originates for a variety of reasons. These may be road construction, changes in land use, violations, crashes, or poor compliance with an established speed limit. (Michigan)
- If a location has been studied within 2 years of the current date, a new study shall be conducted only if there has been a major traffic generator or traffic volumes added to the area. (Louisiana)

Appendix J Site Photographs of Eleven Towns under Investigations

Austin

Alamo


SUBWAY
Denny's


HBO · ESPN
MINUTES AHEAD
SPEED LIMIT 25
DEATH VALLEY


MOTEL
EXCHANGE CLUB
CASINO · MOTEL
HAPPY BURRO
DEATH VALLEY
NATIONAL PARK

Beatty


BEATTY
GENERAL
STORE
GASOLINE
KEEP
RIGHT

Search light


COOL
DEAL


SPEED
LIMIT
35

Tonopah


Nye
COUNTY LINE
US
6
NY
0
US
6
ES
57.74
COVER
THE
EARTH


SPEED
LIMIT
25
CLOWN
MOTEL


Convention
Center
TONOPAH
HISTORIC MINING
PARK & MUSEUM
WESTERN STORE


H
HOSPITAL
SPEED
LIMIT
25
NYE REGIONAL
MEDICAL CENTER
EMERGENCY ROOM
OPEN 24 HOURS

Fernley


SPEED
LIMIT
25
BIOOMIN
BUSHES

Goldfield


GOLDFIELD
GLORYHOLE
AMSOIL
LAS VEGAS (702) 565-0269
RENO (800) 497-5220
20

Luning


CATTLE
GUARD
AHEAD

McGill City


END
SCHOOL
ZONE


SPEED
LIMIT
35

Panaca City


JCT
319

Schurz


LIMIT
40


PAIUTE ESTATES PKWY

Nevada Department of Transportation
Rudy Malfabon, P.E. Director
Ken Chambers, Research Division Chief
(775) 888-7220
kchambers@dot.nv.gov
1263 South Stewart Street
Carson City, Nevada 89712