5-1-2013

Investigation of Crashes and Identifying the Best Practices for Setting up Speed Zones in Towns Along Rural Highways in Nevada

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INVESTIGATION OF CRASHES AND IDENTIFYING THE BEST PRACTICES FOR SETTING UP SPEED ZONES IN TOWNS ALONG RURAL HIGHWAYS IN NEVADA

By

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Bachelor's Degree in Civil Engineering
Pulchowk Campus, Institute of Engineering
Tribhuvan University, Nepal
2010

A thesis submitted in partial fulfillment of the requirements for the

Master of Science in Engineering - Civil and Environmental Engineering

Department of Civil and Environmental Engineering and Construction
Howard R. Hughes College of Engineering
The Graduate College

University of Nevada, Las Vegas

May 2013

THE GRADUATE COLLEGE

We recommend the thesis prepared under our supervision by

Krishna Prasad Shrestha

entitled

Investigation of Crashes and Identifying the Best Practices for Setting up Speed Zones in Towns Along Rural Highways in Nevada

be accepted in partial fulfillment of the requirements for the degree of

Master of Science in Engineering – Civil Engineering
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May 2013

ABSTRACT

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By

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In 2010, 51,664 crashes occurred in Nevada. Only about 9% of those crashes occurred in rural areas of the state. However, if only fatal crashes are considered, 41% of those fatal crashes occurred in rural areas. 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 setup 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.

Eleven towns along rural highways of Nevada were identified by the Nevada Department of Transportation (NDOT) Technical Advisor Panel (TAP) for crash data analysis. Ten year of crash data for these towns were collected and analyzed. The result showed that the percentage of fatal crashes in these towns was 0.89% for 9 years. For all the rural areas in Nevada, the percentage of fatal crashes in 2010 was 2.00%. 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 the 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. If proper enforcement is ensured, speed zones can be effective to reduce the number of crashes in towns along rural highways.

The study results will assist in formulating a speed-zone guideline for towns along the rural highways of Nevada. Recommendations to prepare the speed-zone guideline are provided as well as the limitations of the study.

Keywords: crash severity analysis, speed limit guideline, speed zone guideline, Nevada Department of Transportation (NDOT), towns of Nevada, rural highways of Nevada

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to Dr. Pramen P. Shrestha, my advisor and the Chair of the Advisory Committee, for introducing me to the world of the academic research. I appreciate the time and effort he has invested to guide me up to this stage of my academic career. It is my great privilege to have such a helpful and understanding professor as my advisor.

Many thanks to the thesis committee members, Dr. Aly Said, Dr. Ying Tian, and Dr. Ozkan Eren for their support and feedback for the thesis. I appreciate the constructive feedbacks received from them which gave me an opportunity to make improvements to this thesis.

I am grateful to the Nevada Department of Transportation (NDOT) for funding this study. The NDOT has played a very important role for this study – from selecting the 11 towns for the study to providing crash data of those towns. The NDOT also provided radar guns and a measuring wheel for the site data collection.

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

I would also like to thank Mr. Kishor Shrestha for helping me with the site data collection for this research.

I cannot forget Ms. Julie Longo, Technical Writer at the College of Engineering, and Ms. Carol Turner, Consultant at Writing Center, for proofreading and copy-editing this thesis.

Finally none of this would have been possible without the help and support from my family, especially my sister Ms. Buddha Laxmi Shrestha. She always encouraged me to believe in myself and guided me in every step of my life. Her unconditional love and support is first reason that I have been up to this point of my life. Also, I cannot forget my brother, Mr. Babu Krishna Shrestha, for doing everything he can, for my better future. Many thanks go to my mother, Ms. Ganga Laxmi Shrestha, and my father, Mr. Hari Krishna Shrestha, for their never-ending love and support.

DEDICATION

To my sister, brother, mother, and father,

thank you all for your love and support in every step of my life.

I love you all.

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CHAPTER 1

INTRODUCTION

Half a century back, the number of traffic fatalities in United States (U.S.) was increasing rapidly (National Highway Traffic Safety Administration [NHTSA], 2012). However, the number of such fatalities has been decreasing since 2005. The Nevada Department of Transportation report shows that the number of fatalities in Nevada had been decreasing from 2006 to 2009 (NDOT, 2012). Nevertheless, the numbers of fatal crashes per 100 million Vehicle Miles Traveled (VMT) in Nevada were higher than the national averages from year 2001 to 2009. Nevada is among the top ten states with the highest crash rates in the U.S. In order to reduce the number of traffic crashes and resulting fatalities, investigation of crashes becomes necessary.

The major reasons for crashes fall 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 is crucial for safer road, especially concerning youth drivers (NHTSA, 1994).

Idaho Transportation Department states that the severity of crashes depends on the vehicle speed (IDT, 1997). However, the probability of crashes depends more on the differential speeds than on the absolute speeds. Various transition zone treatments have been investigated and practiced to reduce the speed of vehicles that are approaching towns along rural highways (Torbic et al., 2012).

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 the 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, NDOT is funding this study 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 Nevada Department of Transportation (NDOT) does not yet have such guideline or manual. A guideline for setting up speed zones in towns along the rural highways is necessary for consistent procedure to setup speed zone throughout the state. The guideline, once prepared, should 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). Crash data of these towns from April 1, 2001 to April 10, 2011 were obtained from the Nevada Citation & 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 and highway characteristics data. These data also were used to determine their association with the crashes.

Figure 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 to prepare speed-zone guideline as well as a discussion of the limitations of the study are provided.

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 determine the factors associated with crashes;
2) To determine the factors that affect a speed limit;
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 provide recommendations for preparing a speed-zone guideline for towns along the rural highways in Nevada.

CHAPTER 2

LITERATURE REVIEW

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

The FHWA (2012, p. 21)'s Manual on Uniform Traffic Control Devices (MUTCD) defined a design speed as "a selected speed used to determine the various geometric design features of a roadway." Some transportation professions have cited the design speed as a limiting factor for determining a maximum speed limit (Idaho Transportation Department [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 while 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 will result 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 depending upon the roadway conditions rather than the speed limit. Hence, setting an unrealistically low speed limit is likely to result in more variation 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 realistic speed limit; various speed reduction techniques; and various state DOT guidelines for establishing speed zones. These studies are summarized in following sections.

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 depends 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 depend upon road and roadside characteristics. The findings of those studies are presented in following sections.

Road Characteristics

The literature related to relationship between road characteristics and operating speed are summarized in Table 1.

Table 1 Summary of Literature Related to the Effect 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, 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 sign.
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 (1999)	USA	The speed limits depend upon land use, including cross streets, traffic volume, 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 section of roadway.
6	Fildes et al. (1991)		The road width and the number of lanes were the most important factors in choosing speed in particular section of roadway.
7	Cooper et al. (1980)		The speed depends upon the surface conditions of the road.
8	Warren (1982)		The road curvature, grade, length of grade, number of lanes, surface condition, sight distance, lateral clearance, number of intersections, and built-up areas near the road as the most significant factors affecting the speed of the drivers.

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. 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 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 nearby commercial development were the most important factors in determining the speed of the drivers.

Human Factors

Two literature related to the association between human factors and the operating speed were reviewed. Hassan and Abdel-Aty (2012) used questionnaire survey to measure aberrant driving behavior of young drivers. The study found that young drivers are 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, road user, taxpayer, and residential.

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 take more risks while driving and hence are more likely to get involved in the injury crashes. Lee and Mannering (2002) found that roadside features such 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 after they returned home than in school premises.

Statistical Models to Determine Factors Affecting Crash Severities

Some studies had used various modeling approaches such as, binary logistic regression, multinomial logit model, support vector machine model, non-parametric classification tree technique, Bayesian multivariate Poisson lognormal model, and mixed logit model to determine the factors that have association with severities of crashes. These study findings are summarized below.

Binary logistic regression.

Chen et al. (2012) determined the factors that had 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 month and day of 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.

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 multinomial logit (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 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 significant correlation with the severity level of the driver's injury.

The authors also 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%.

Support vector machine model.

Li et al. (2012) estimated the effect of various factors on crash injury severity by the use of Support Vector Mechanics (SVM). The authors also compared the results of the SVM model with the traditional Ordered Probit (OP) method. For this analysis, a total of 5,538 crash records in the State of Florida were used from 326 freeway segments that had a deceleration lane and an exit ramp. An influence area up to 1,500 feet (458 m) upstream and 1,000 feet (305 m) downstream of the painted nose at the exit ramp was considered. Five levels of injury severity – no-injury, possible injury, non-incapacitating injury, incapacitating injury, and fatal injury – were categorized for the purposes of analysis.

This study also considered 37 explanatory variables related to ramp type, number of main lanes, the number of ramp lanes, the length of the deceleration lane, exit ramp, surface type, shoulder type, width, speed light condition, weather, road surface, crash type, and use of drugs.

The first set of SVM analysis was done by dividing data in a 4:1 ratio into training data and testing data. The model predicted five levels of injury severity with an accuracy of 79.6% for training data and 48.8% for testing data. In order to improve the accuracy of the predictions, the level of injury was reduced to two classes. The model developed after that change showed an improved accuracy of 83.8% for training data and 57.6% for testing data. Similarly, the OP model was developed using the same set of training and testing data. The results showed that the SVM model had a higher prediction accuracy compared to the OP model, with 48.8% versus 44.0%, respectively, for testing data.

The authors also conducted a sensitivity analysis, using the OP model, to determine the relationship between the explanatory variables and the crash injury severity. The results showed that the number of main lanes on a freeway, the type of land use in surrounding area, the length of the entire exit ramp, the shoulder width of the freeway main lane, freeway pavement surface conditions, lighting conditions, weather conditions, alcohol/drug involvement, and rear-end and sideswipe collision types all were significantly correlated to the injury severity in crashes. The authors also compared the relationship between the explanatory variables and crash injury levels of the SVM and OP models. They concluded that there were inconsistent results for two variables: the length of the exit ramp and the shoulder width of freeway main lanes. Researchers concluded that the results provided by SVM model were more reasonable in compared to OP model.

Non-parametric classification tree technique.

Chang and Wang (2006) applied the Classification and Regression Tree (CART), a non-parametric model, to analyze the relationship of traffic injury severity with 20 predictor variables related to:

1. Temporal characteristics (e.g., time of crash),
2. Highway/environmental characteristics (e.g., lighting condition or speed limit),
3. Driver/vehicle characteristics (e.g., driver age, vehicle type), and
4. Accident variables (e.g., collision type or contributing circumstances).

A total of 12,604 crash records involving 29,673 vehicles in Taipei, Taiwan in 2001 were divided into training and testing data. The data from first eight months were used for the training model, and rest of the data was used for testing of the model.

The overall accuracy of the model prediction was about 90.3% for training data and 91.7% for testing data. The study showed that vehicle type was the single most influential variable for classifying injury severity in a traffic crash. It also showed that pedestrians, motorcycles, and bicycle riders were the most vulnerable to severe injuries. Also collision type, contributing circumstances, and actions of the driver or vehicle were found to be important factors in determining the severity of crash injuries. The study concluded that the CART was a good technique for the analysis of crash injury severity.

Bayesian multivariate Poisson lognormal model.

Aguero-Valverde and Jovanis (2009) used a full Bayes multivariate Poisson-lognormal model to predict the crash frequency of different severity levels. The crash frequency prediction was combined with expected cost data in order to rank road segments for safety improvements. In addition, they compared the results of the multivariate model with those obtained from the independent or univariate Poisson-lognormal model.

Crash data from District 2-0 of the Pennsylvania Department of Transportation (PennDOT) was used to develop the models. For each crash record, the data included five severity levels: deaths, major injuries, moderate injuries, minor injuries, and PDO crashes.

The study results showed that using the multivariate model instead of the univariate model significantly improved the accuracy of crash frequency estimates for each level of severity. By using the multivariate model, the average standard deviation of crash frequency estimates was reduced by 20%. Similarly, standard deviations of crash frequency estimates for fatal and major injuries were reduced by 41% and 48% respectively.

Mixed logit model.

Milton et al. (2008) developed a model to estimate the proportion of various injury-severity levels, based on the reported accident frequencies on specific roadway segments. This model allowed the prediction of a severity distribution of accidents on a given roadway segment as a function of roadway, traffic, and weather-related variables. A mixed logit model was used for the analysis. The data of 274 roadway segments of Washington State's multi-lane divided highways were used. The crash data was collected for 1990 to 1994.

Crash data of 22,568 crashes were used for the study. Due to a limited number of fatal and disabling injury crashes, only three categories of crashes were used: PDO; possible injury; and injury, which included evident injury, disabling injury, and fatality.

The factors found to be random included average daily traffic per lane, average annual snowfall for PDO, the percentage of trucks for possible injury, average daily truck traffic, and number of interchanges per mile. Other factors, for example, horizontal curves, number of grade brakes per mile, and pavement frictions were found to be fixed in nature.

The study concluded that the mixed logit model was able to account for the segment-specific heterogeneity arising from a number of factors relating to roadway characteristics. Environmental factors, driver behavior, vehicle type, and interactions were among these factors.

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.

Table 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, likelihood of injury, fatality, or both increase 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 probability of sustaining class B, C, or A injuries.
3	Zahabi et al. (2011)	USA	The study found that there is significant relation between the speed limit and the severity of injury.
4	Agent et al. (1998)	Kentucky, USA	The study found no significant changes in the number of crashes as a result of speed limit increase.
5	Haselton et al. (2002)	California, USA	The study found that the increase in speed limit significantly increases the total crashes.
6	Raju et al. (1998)	Iowa, USA	The 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 speed limit increase.
8	Kockelman et al. (2006)	USA	There is no broad consensus on the effects of the speed changes on crashes.
9	Thornton and Lyles (1996)	USA	The higher speed limit does not necessarily leads to more crashes, but it is clear that some crashes will be more sever at higher speed.
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	The study determined no significant difference in the crash rates occurred in rural Interstate highways that uses 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 while using dynamic display system.

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 zone.

A project called “Managing Speeds of Traffic on European Roads” determined three key issues related to speed of traffic in that continent (Kallberg et al., 1999). The study determined the acceptable ranges of speeds for drivers on various types of roads and under various traffic conditions and also 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. The 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 are intervening measures, and include conventional speed enforcement, automated speed enforcement, adaptive cruise control, and in-vehicle speed limiters.

This study prepared recommendations for speed management on different kinds of roads. The recommendations outlined the process for determining the 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.

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 3.

Table 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	The study showed that 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 study results showed that 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 reduced significantly.
4	Raub (1985)	Illinois, USA	The police using patrol vehicles without 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. The study showed that 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.

Effect of Radar Technology on Speed and Crash Reduction

Study findings related to the use of various radar technologies to reduce the vehicle speeds and crashes are summarized in Table 4.

Table 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 the crashes. The results showed that crashes were reduced by 20%, which is significant at alpha level 0.05.
4	Hajbabaie (2009)	Illinois	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 trailer plus a police car with lights off in work zones and extensive speeding zones. The results showed that 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	Display board without police presence was the most cost effective solution to reduce vehicle speeds, followed by display board with police presence and, finally, the photo-radar.

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. It also was found that there was no significant change in the crash frequency at the test sites.

Teed and Lund (1993) found more speed limit violations where new laser device were 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.

Effect of Dynamic Speed Display on Speed Reduction

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

Table 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 permanent sign and the continuous sign.
3	Sandberg et al. (2006)	Minnesota, USA	This study showed that 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	This study showed that 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	The study results showed that dynamic speed display signs significantly reduced the mean speed of vehicles on rural two-lane highway by 6 mph.

Traffic Calming

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

Table 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	This study determined that the 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	The result of a driving simulator showed that a combination of treatments provided in transition zones of rural highway approaching a village can significantly reduce the mean speed and 85^{th} 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 increases 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	The study found that 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 85^{th} percentile of traffic speed by 1% to 6%.
12	Russell and Godavarthy (2010)	Kansas, USA	The study was conducted to determine the effectiveness of four different speed management techniques on rural roads. The measures used were colored pavement, solar speed displays, a mobile speed trailer, and optical speed bars. The study results showed that the mobile speed trailer was the most effective measure to reduce the mean speed and 85^{th} percentile speed of the vehicles.

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." According to a survey by the Institute of Transportation Engineering (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 85th percentile speed. Each speed zone should be restudied within five years to determine the appropriate speed limit. While establishing the speed limit, it is recommended that the nearest 5-mph increment to the 85th 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.

The Federal Highway Administration (FHWA) has developed 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 guideline or manuals to setup speed zones in particular stretch 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.

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.

Florida DOT Speed-Zone Manual

In 2010, Florida Department of Transportation (FDOT) prepared a manual for *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 85^{th} percentile speed, upper limit of 10 mph pace, and 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 85^{th} 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.

Oregon DOT Speed-Zone Manual

The *Speed-Zone Manual* prepared by 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 the 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 to be conducted are statistical analyses of

- 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.

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 "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.

Texas DOT Speed-Zone Manual

The Texas Department of Transportation (TXDOT) also has developed a manual for establishing speed zones (TXDOT, 2011) titled *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 deciding on 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 85th percentile of the speed.
- The posted speed limit should be based on the 85th 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.

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.

Wisconsin DOT Speed-Zone Manual

Wisconsin DOT's *Traffic Guidelines Manual* (2009) provides detailed information regarding setting up speed zones. The manual defines 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: 85th percentile speed, 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 where vehicles
- Shoulder widths and 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 at minimum of a 0.3-miles-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 85th 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.

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:

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

The manual recommended providing the speed limit of 35 mph or less in a road if the roadside development is at least 75%. The manual also recommended providing the 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 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 85th percentile speed. However, it should not be less than 25 mph in any case.

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 speed limit: 85th percentile speed, pace, speed profile, and Montana. Factors such 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 detailed explanation for conducting traffic studies. The manual recommended collecting spot speed data of at least 100 vehicles in each direction during traffic study.

Missouri DOT Speed-Zone Guideline

The Missouri *Speed Limit Guidelines* (2010) recommended setting up at least 2-mile long speed zones for unincorporated or “non-community” areas. The guidelines consist of a procedure for conducting traffic study. During traffic study, the 85th percentile speed, upper limit of the 10 mph pace, or average test run speed data is collected to determine the speed limits of speed zones. The guidelines recommended selecting speed limits in 5 mph increment; 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 discretion to reduce the speed limits derived from the traffic study in any speed zones based on some factors. Table 7 lists those factors, 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 minimum value should be selected or two speed zones with two different speed limits can be provided.

Table 7. Prevailing Speed Reduction (Adapted From Missouri Department of Transportation (MoDOT, 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.

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. The 85th percentile speed of the traffic will be determined by conducting speed study. During 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 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 location and existing site condition, including speed study data are required for setting a new speed zone.

The manual recommended in providing minimum length of a speed zone as 1,000 ft for 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.

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 setup 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 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.

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 it 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 does not need to be considered unless the conditions are unusual and not readily apparent to the drivers. And those factors 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 given ball-bank reading is provided in Table 8.

Table 8 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 9.

Table 9 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 85^{th} 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.

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.

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 must 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.

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:

- Speed study
- Crash records
- 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 hour on weekend.
- Weather should be fair and usual.
- Speed data of minimum of 50 vehicles is required.
- Speed zone should be at least 0.5 miles except in transition areas.

Speed zoning should be in 10 mph increment for rural area. For urban area 5 mph increment are preferable.

FHWA Manual on Uniform Traffic Control Devices (MUTCD)

The FHWA (2012) has prepared the MUTCD, which is approved as the National Standard. It has a section (Section 2B.13) for 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 85^{th} 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.

Recommended Practices of the Institute of Transportation Engineers (ITE)

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, allowed more time to understand and react to situations, and provided a long breaking distance.

Nevada Statutes Related to the Speed Limit

Nevada Revised Statutes includes three chapters, NRS-484 – Traffic laws (2011), NRS-484A – Traffic laws generally (2013), and NRS-484B Rules of the road (2013), related to traffic speed limits. However, all the contents in NRS 484 have been replaced by NRS 484A and 484B. The purposes 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". The statute allows the Nevada Department of Transportation to prescribe and eliminate speed zones after necessary studies have been made. It gives the Department of Transportation a right to "establish the speed limits for motor vehicles on highways which are constructed and maintained by the Department of Transportation." The maximum speed allowed by statute is 75 mph. The speed limit for school zone, as set by state statute, is 15 mph. For the school crossing zone, the speed limit, as set by the statute, is 25 mph.

CHAPTER 3

RESEARCH METHODOLOGY

The study was divided into six phases as shown in Figure 2. During the first phase, the scope and the objectives of the study were defined. In the second phase, various literature were reviewed related to factors affecting speeds and crashes, crash data analysis techniques, speed-zone guidelines, and speed reduction techniques. In the third phase, crash data were collected from the NDOT. The research team visited the 11 towns under study to collect the spot speed and road characteristics data 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. In the next phase, the crash data, site data, and survey data that had been collected were analyzed. Then the best practices for setting up speed zones were identified. Finally, conclusions and recommendations were made for preparing the speed-zone guideline for towns along rural highways of Nevada.

The crash data of towns obtained from the NDOT were analyzed to compare the towns based on a number of factors, including injury crashes, injuries, average injuries per non-fatal injury-causing crashes, and PDO crashes per year. Descriptive statistics were used to analyze these crash data of the past nine years. The site spot speed data collected were used to anlyze their correlations with the number of crashes occurred in these towns. The Pearson correlation test was used to determine the correlations between the spot speed parameters and the number of crashes. Ordinary least squares models were developed to determine the percentage variations of crashes explained by these parameters. Two statistical modeling techniques namely binary logit model, and multinomial logit were used to determine the factors affecting the injury and non-injury crashes. Finally, the survey questionnaire data were analyzed using descriptive statistics to determine the factors affecting the speed zones.

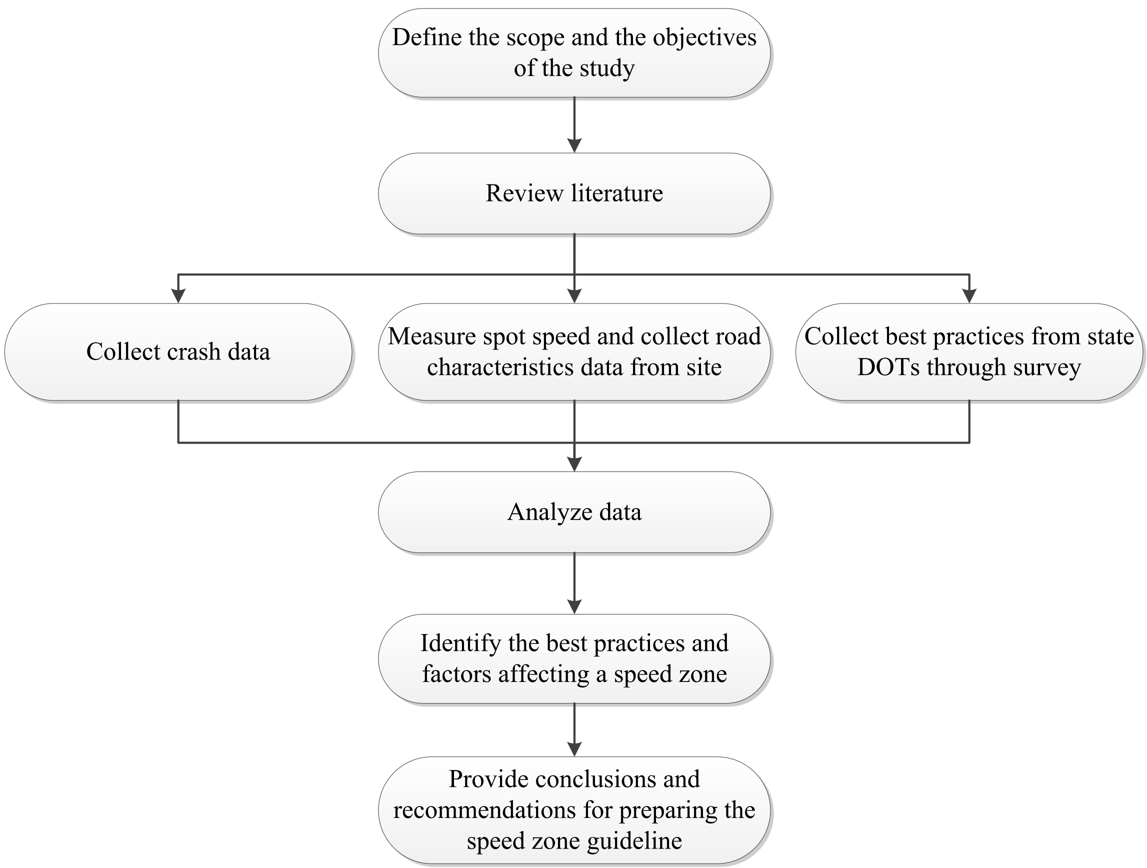

Figure 2 Overview of the Research Methodology

Statistical Models

Rrdinary least squares models, binary logit models, and multinomial logit models were developed for the study.

Ordinary Least Squares Model

The models based on the Ordinary Least Squares (OLS) regression were used to find the correlations between speed variables and crash variables. Various speed parameters – mean speed, median speed, and percentage of vehicles exceeding posted the speed limits – were calculated from the spot-speed data collected in each town. Coefficients of correlation (Pearson's r) between the speed parameters and crash statistics were calculated to measure the correlation among those variables. Pseudo R^2 values also were calculated to quantify the percentages of crash statistics as explained by each of those speed parameters.

Binary Logit Model

For the binary logit models, response variable was the injury i.e. whether or not the crash was injury crash. The predictor variables included factors such as, road conditions, weather conditions, and road lighting. The models were used to find out the factors that significantly affected the possibility of the crashes being injury crashes.

Multinomial Logit Model

For the models based on the multinomial logit model (MNL), the response variable was crash severity with five outcomes: PDO, claimed, non-incapacitating, incapacitating, and fatal. The models were developed to identify the factors that significantly affected the crash severities.

Research Hypotheses

The research hypothesis related to Pearson correlations is the correlation coefficients of the number of crashes to other speed variables are significantly different from zero. For ordinary least squares models, the research hypothesis is that the coefficients of predictor variables (speed parameters) are significantly different from zero. The research hypothesis related to binary logit models and multinomial logit models is that the coefficients of all the predictor variables (road conditions, weather, etc.) in the model are significantly different from zero.

Null Hypotheses

For ordinary least squares models, the null hypothesis states that the coefficients of independent variables (speed parameters) are equal to zero. Similarly for binary and multinomial logit models, the null hypothesis states that all the coefficients of predictor variables are equal to zero. Mathematically they can be expressed as

$$\beta_1 = \beta_2 = \beta_2 = \beta_2 \ldots\ldots\ldots\ldots\ldots = \beta_n = 0$$

Where $\beta_1, \beta_2, \ldots\ldots\ldots\ldots\ldots, \beta_n$ are the coefficients of the independent predictor variables.

Limitations

The towns were selected based on the complaints about the higher number of crashes. Thus the results of the analysis are applicable only to the towns under study and cannot be generalized.

While developing ordinary least squares models, the spot speed data collected in 2012 was 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' behavior of the vehicles passing through the towns under study has not changed significantly nor have the roadways and roadside characteristics. The crash data of Schurz were obtained from US 95 and US 95A while the speed data were collected only from US 95. Also, for Tonopah, the crash data were obtained from US 95 and US 6 while the speed data were collected only from US 6. The sample sizes of the data was very small (11), which could result in a poor statistical analysis. The pseudo R^2 parameter was used instead of R^2 to account for the error that can be caused by a very small sample size. Use of data from more towns would produce more accurate statistical analysis and results. All the predictor variables considered for developing binary logit and MNL regressions may not have 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.

CHAPTER 4

DATA COLLECTION

Three sets of data were collected for the analysis: the historical crash data were obtained from the NDOT; spot speed and site characteristics data were collected from field visit; and questionnaire data were collected from the survey. The details of data collection processes for each set of data are described below.

Crash Data

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. The residents of these towns complained to NDOT that high number of crashes occurred in these towns. Crash data from April 1, 2001 to April 10, 2011 were obtained from the NCATS, a system used by NDOT. However, data from only 9 calendar years from 2002 to 2010 were analyzed to identify the factors associated with the crashes.

The data obtained from NDOT contained a total of 38 variables, out of which 16 variables 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 the 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 very limited data set were not used in the analysis.

Site Data

For all the 11 towns under the study, spot speeds, road-surface characteristics, and roadside characteristics for the section of highways were collected. A guideline provided by NDOT was followed for spot speed data collection. A radar gun was used to collect speed data. A simple measuring wheel was used to measure distances of various points along the highways. 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 remaining towns, only one location was chosen for each town. Multiple locations were chosen so that the angle between line of sight of the radar and travel direction of the vehicles is less than 15°. Those spot speed data were combined for analysis. Different statistical parameters – 85^{th} percentile speed, mean speed, median speed, and percentage exceeding posted speed – were calculated from the speed data.

Location of Data Collection

For each town, various roadway and roadside characteristics were collected. 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 appendix: SITE DATA COLLECTION FORMS. Speed-zone maps were drawn for all the sites using the collected data and Google Maps. The details of the location of each towns are presented in Table 10.

Table 10 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/ US 95A	District II	Researchers
Searchlight	US 95	District I	Researchers
Tonopah	US 95/ US 6	District I	Researchers

Most of the data were collected in July 2012 (Table 11). 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. The location of the spot data collection in Panaca was 190 ft from an intersection. Thus, the speeds of the vehicles slowing down for turning were not recorded.

Table 11 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

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.

Questionnaire Survey Data

Speed-zone guidelines and/or speed-zone manuals of various states were reviewed in order to collect various approaches used by the state DOTs. To determine the recent best practices for providing speed zones, a questionnaire was prepared and sent to NDOT for feedback. After the feedback the questionnaire was 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 focused on collecting 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 that might be different from those stated in their manuals. The last section contained questions about the current scenario of the community complaints regarding speed zones in their states.

The questionnaire was prepared and sent as a document file. The reason for using a document attachment instead of a standard online survey system was to allow multiple persons in each DOT to fill in different sections of the questionnaire. Also, this allowed each DOT to stop and continue the questionnaire at any time, as compared to online surveys. The full questionnaire can be found in the appendix: QUESTIONNAIRE SURVEY FORM.

All the state DOTs of the U.S., except Nevada, were contacted for collecting responses to the survey questionnaire. E-mail and phone calls were used for communicating with state DOT representatives starting from first week of May to second week of October, 2012. After continuous follow-ups, survey questionnaire responses were received from 37 states.

CHAPTER 5

RESULTS

The results of the study are subdivided into three categories: crash data results, site data results, and survey questionnaire results.

In crash data results, the descriptive statistics as well as results of the crash severity analysis models are presented. Descriptive statistics include the distributions of crashes by town and based on different factors associated with the crashes. Crash data of 11 towns combined were compared with that of all rural areas of Nevada. In crash severity prediction models, severity of crashes as well as odds that crashes would involve injury were calculated.

In site data results, the correlations of the crash data and speed data are presented. It also include the characteristics of the speed zones, roadway, and roadside environment of the highways of the 11 towns under study.

Finally, in the survey questionnaire results, the descriptive statistics of the responses are presented. Average ratings as well as response counts for different factors related to the crashes, speed zones, enforcements etc. have been calculated and presented.

Crash Data Results

Crash records of 11 towns from 2002 to 2010 were collected and analyzed. Overall statistics of the study are shown in Table 12. This table indicates that there were a total of 3 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 4 fatality in these towns that 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 12 Overall Crash Statistics of the 11 Towns Under Study

Detail	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	0.33	10.67	26.44	37.44	0.44	14.89	15.33

Crash Data by Town

The crash data of the 11 towns under study has been compared and presented in following sections. Comparisons were made 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 in appendix: CRASH STATISTICS BY TOWN.

Total crashes per year.

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

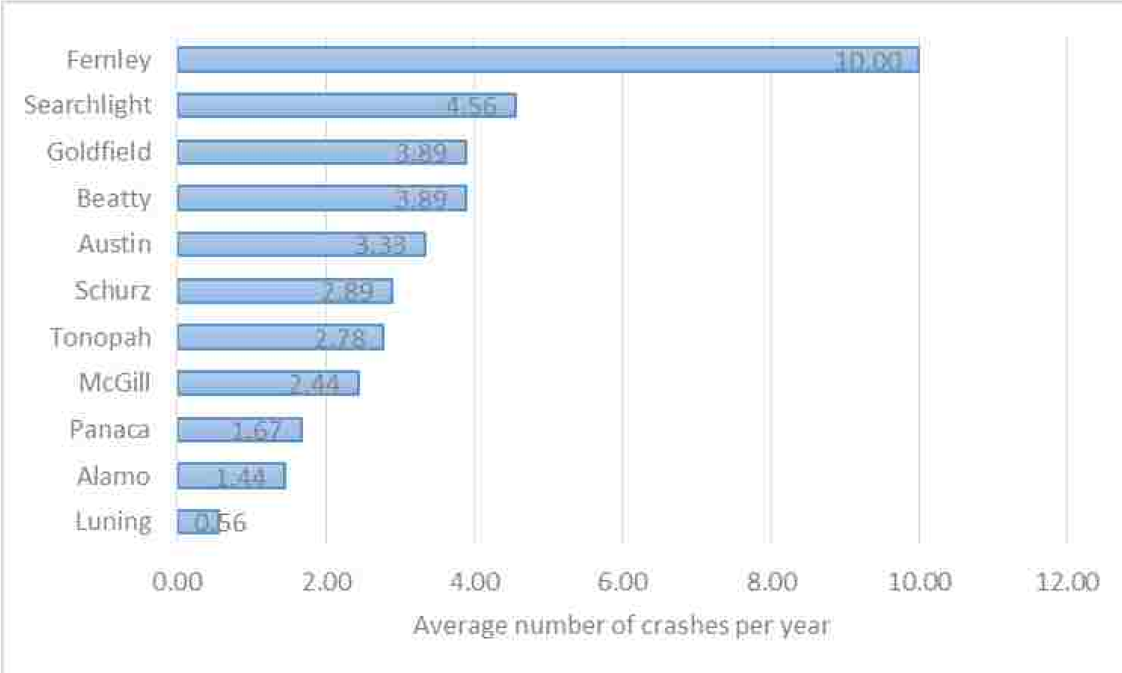

Figure 3 Average Number of Crashes per Year by Town

Total fatal crashes.

Table 13 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 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 13 Fatal Crashes and Fatalities by Towns

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

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 4 shows the average number of PDO crashes and non-fatal injury-causing crashes per year respectively that occurred in these towns. The data showed that Fernley has 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 for the towns under study. 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 was zero non-fatal injury-causing crash that occurred in Luning. Other towns had non-fatal injury-causing crashes in between 3 to 13.

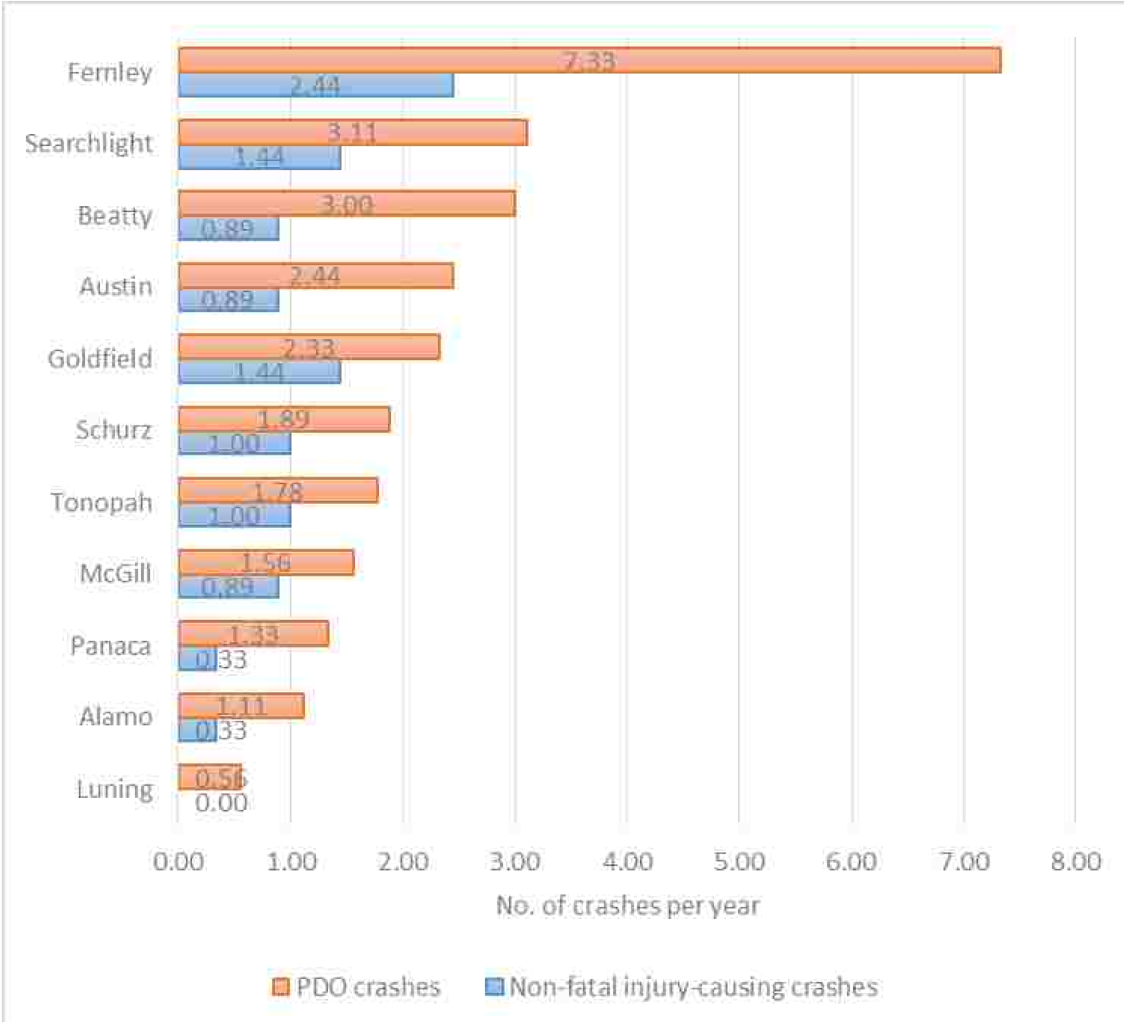

Figure 4 PDO Crashes and Non-fatal Injury-Causing Crashes per Year by Town

Figure 5 shows the total number of injuries per year sustained due to the crashes. Fernley had the highest number of injuries per year (3.78/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.

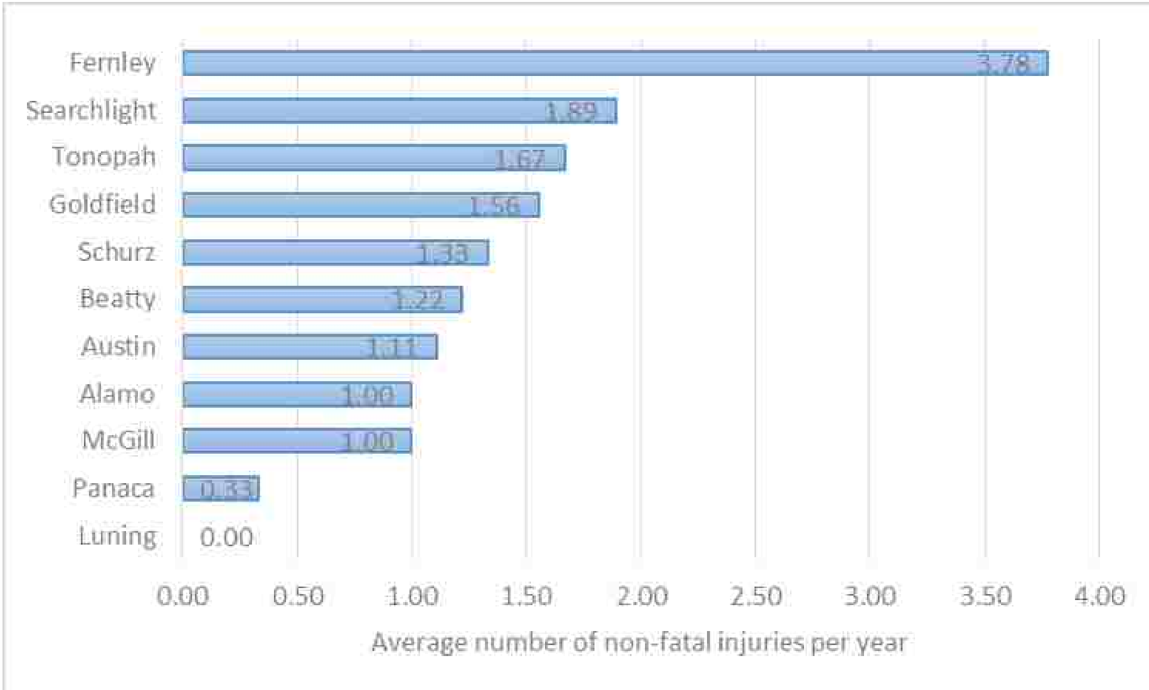

Figure 5 No. of Non-fatal Injuries per Year by Town

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 are 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, in 'road conditions' factor, 13 unique values in the original crash data were combined together to create only five larger values. For instance, 'Wet' and 'Other: Wet' were combined together in the 'Wet' value to cover more conditions.

Road conditions.

The various road conditions during the crashes are presented in Table 14. 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 14 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%**

Weather conditions.

More than two thirds of the crashes occurred during clear weather (Table 15). All total, there were only 14% of crashes that occurred in any other weather conditions besides clear and cloudy. The crashes that occurred during ‘snow/silt/hail’, rain, and severe crosswind are 4%, 2%, and 2% respectively.

Table 15 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%**

Road lighting.

Table 16 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 16 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%**

Primary vehicle's most harmful events.

Table 17 shows that 29% of total crashes occurred when primary motor vehicle was in transport (i.e., in motion). Overturn and rollover together contributes to 14% of the total crashes. Crashes with slow and stopped vehicles accounts for 12% of the total crashes. Crashes because of animals (i.e., burro, cattle and deer all combined) accounted for 8% of total crashes.

Table 17 Distribution of Crashes Based on Primary Vehicle 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%**

Collision types.

More than half of the crashes were of the non-collision type. Seventeen percent of the crashes were rear-end collision crashes followed by angle and sideswipe (Table 18). Head-on collision crashes constitute just 2% of total crashes.

Table 18 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%**

Primary driver factor.

Sixty-three percent of total crashes occurred when the primary vehicle driver was in a normal condition (Table 19). Eleven percent of crashes occurred because of the inattention of the primary vehicle driver. 'Falling asleep' accounts for the about 4% of crashes.

Table 19 Distribution of Crashes Based on 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%**

Primary vehicle actions.

Fourteen types of primary vehicle actions that cause crashes have been categorized into seven larger categories. As shown in Table 20, about three-quarter of the crashes occurred while the primary vehicle was going straight. The second largest portion, 9%, involved turning left.

Table 20 Distribution of Crashes Based on Primary Vehicle 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%**

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 21). Vans account for the least number of crashes.

Table 21 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%**

Total vehicles involved.

Almost all of the crashes involved either one or two vehicles as shown in Table 22. 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 22 Distribution of Crashes Based on Number of Vehicles Involved

No. of vehicles involved	Crash count	Percentage
One	174	52%
Two	152	45%
Three	10	3%
Four	1	0%
Total	**337**	**100%**

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 appendix: TIME FACTORS ASSOCIATED WITH CRASHES. Figure 6 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 towns and is 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 is also higher than other time interval.

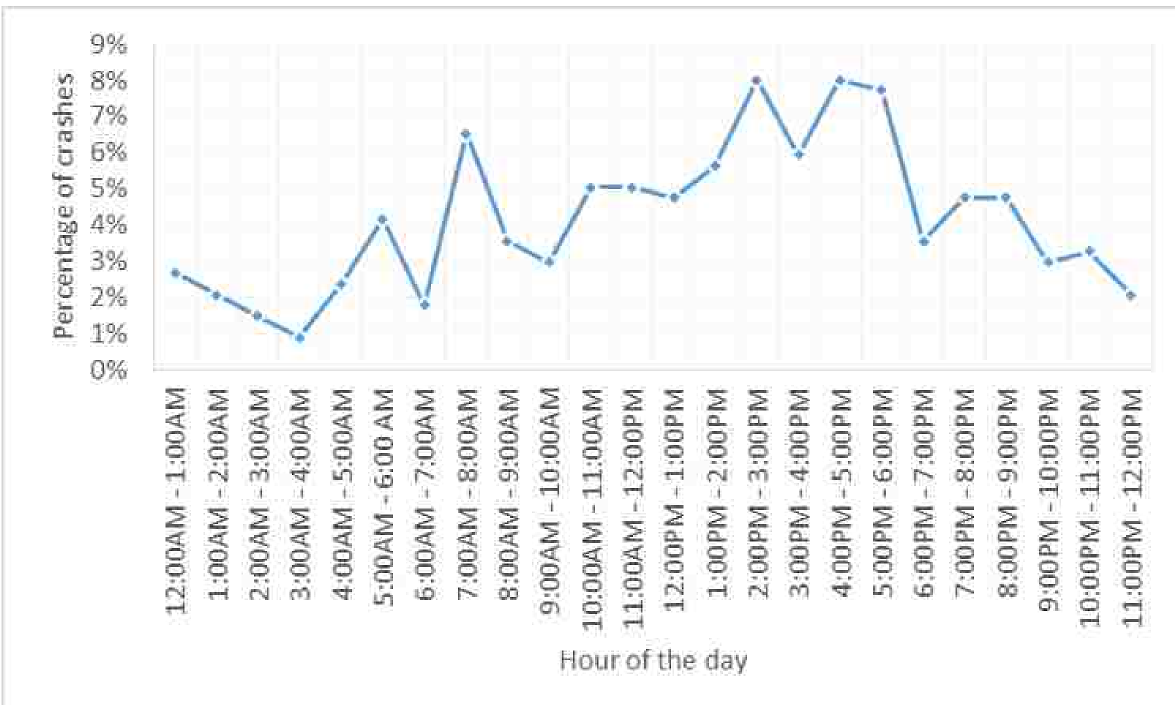

Figure 6 Distribution of Crashes by Hour

When the crash data were analyzed based on the days of the week, the highest number of crashes (18%) occurred on Wednesday (Figure 7). The minimum number of crashes can be observed on Saturday followed by Sunday with 11% and 13% of the total crashes respectively.

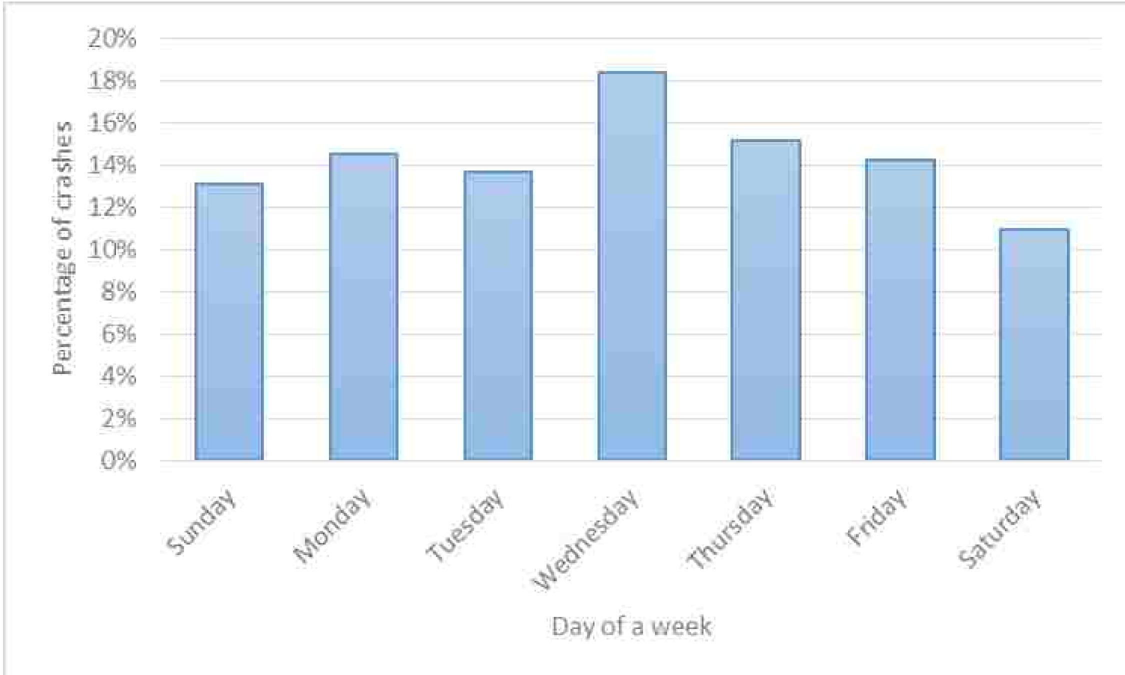

Figure 7 Distribution of Crashes by Day

The crash data were also analyzed based on the month on which the crashes occurred. Figure 8 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.

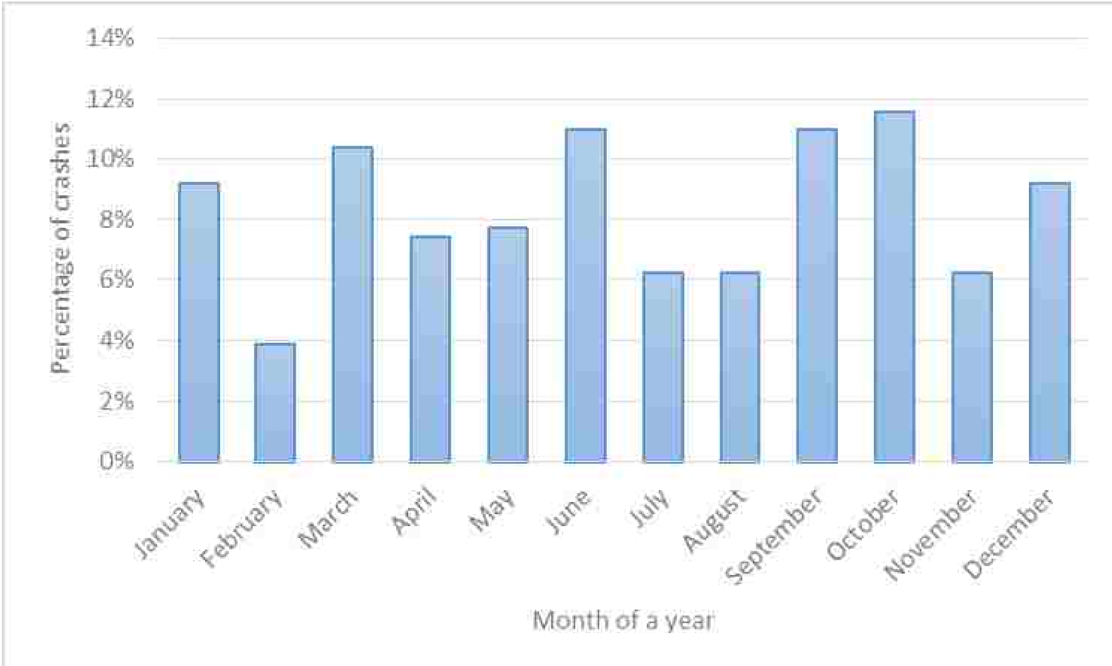

Figure 8 Distribution of Crashes by Month

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.

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. To obtain the total lane mileage, the number of lanes was multiplied with length of the each town. It should be noted that some towns had more than two lanes for limited length; however it was assumed that an equal number of lanes existed throughout the mileage under consideration. Table 23 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 23 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**

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 24. 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, this does not give a fair comparison of crashes. It should be noted that data from different years were used, i.e., the total rural crash count was for year 2010 while the rural lane mileage was for year 2009.

Table 24 Compaisons 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)

Populations and crashes

The number of crasher per 1,000 population for nine-year period was calculated for each town and is presented in Table 25. The data showed that Austin had highest number of crashes per 1,000 population. Fernley had the lowest number of crashes per 1,000 population, while the same town had highest number of total crashes during this nine-year period.

Table 25 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 is of 2012

Table 26 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 rural areas of Nevada, there was 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 from limited mileages in these towns. Also for all rural areas of Nevada, the crash data were not limited to highways.

Table 26 Compaisons 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)

Percentage of fatalities

Table 27 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 27 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)

Crash Severity Prediction Models Using MNL Model and Binary Logit Model

Two statistical models were developed to analyze the crash data: 1) multinomial logit (MNL) model to predict the 5 different levels of severity of crashes and 2) binary logit model to predict the injury 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 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 28.

Table 28 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

Multinomial logit model (MNL).

Null hypothesis of the MNL model developed is that all of the regression coefficients are equal to zero. The test results showed that the null hypothesis was rejected because the probability of null hypothesis being true is 0.0031 which means, null hypothesis can be rejected at 95% confidence interval.

Number of observations used = 337

LR $chi^2(236) = 299.78$

Prob>$chi^2 = 0.0031$

Log likelihood = -160.91468

Pseudo $R^2 = 0.4823$

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 predictor variables.

Table 29 lists the predictor variables and corresponding Relative Risk Ratio (RRR) of the factors that significantly affect the crash severity.

The relative risk of crashes on June being claimed rather than PDO, relative to crash on January, is 0.111 when other variables in the model are kept constant. Thus crashes on January were 9 times (=1/0.111) more likely to be claimed as compared to crashes on June. In comparison to crashes on October, crashes on January were 8(=1/0.123) times more likely to be claimed than PDO.

Table 29 shows that the crashes being claimed were very high for motorcycle as compared to crashes involving car, pickup/van, or heavy vehicle. Also, the crashes caused by speeding were 18 (=1/0.056) 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 7 times more likely to be involved in the non-incapacitating crashes than the drivers in normal conditions. An interesting observation is that speeding was less likely to cause non-incapacitating crashes as compared to inattention. In other words, inattention is likely to result into more severe crashes than speeding.

It may be noted that the lighting factors were not found to have significant effects on the MNL models discussed here (i.e., models in which days were categorized into weekends and weekdays). However, when another models were developed by categorizing days into 7 days of the week, lighting condition – dark with unknown lighting – was found to have significant effect on causing claimed injuries.

Table 29 Relative Risk Ratios for Significant Factors (Multinominal Logit Model)

Severity	Category	Value	RRR	P>|z|	95% Con. Interval
Claimed					
	month	January			
		June	0.111	0.023	0.017 – 0.740
		October	0.123	0.037	0.017 – 0.882
	v1type	Motorcycle			
		Car	0.052	0.013	0.005 – 0.538
		Pickup/Van	0.065	0.023	0.006 – 0.690
		Heavy	0.076	0.030	0.007 – 0.783
	v1vehiclef	Speeding			
		Inattention	0.056	0.023	0.005 – 0.669
		Unknown/Other	0.112	0.002	0.028 – 0.449
Non-incapacitating					
	action	Going straight			
		Passing other vehicle	46.169	0.010	2.483 – 858.446
	tgroup	12:00 AM to 3:59 AM			
		8:00 AM to 11:59 AM	0.012	0.008	0.000 – 0.324
		8:00 PM to 11:59 PM	0.080	0.042	0.007 – 0.910
	day	Weekdays (base Weekends)	35.539	0.001	4.535 – 278.475
	v1type	Motorcycle			
		Carry-all/Utility	0.008	0.008	0.000 – 0.285
		Car	0.017	0.011	0.001 – 0.395
		Pickup/Van	0.035	0.035	0.002 – 0.793
		Heavy	0.014	0.016	0.000 – 0.453
	v1driverf	Apparently Normal			
		Drink/Drugs	6.872	0.035	1.144 – 41.283
	v1vehiclef	Speeding			
		Inattention	49.061	0.012	2.393 – 1005.812

The overall effect of different predictor variables are listed on Table 30. The only factor that had significant effect on the crash severity was day.

Table 30 The Overall Effect of Different Predictor Variables on Crash Injuries (MNL Model)

Category	chi2	Prob > chi2
weather	5.25	1.000
ctype	5.47	0.993
action	9.99	0.867
lighting	10.21	0.964
vcount	3.00	0.557
tgroup	13.41	0.859
day	13.58	0.009*
month	23.02	0.996
v1type	13.28	0.865
v1driverf	15.53	0.745
v1harmful	17.23	0.944
v1vehiclef	26.84	0.312

*p < 0.05

Binary logistic model.

For binary logistic regression, all 5 crashes with ‘Other’ type of primary vehicles resulted into PDO crashes. That means, failure was predicted perfectly in those cases and hence those crash records were dropped by STATA®. The total number of records used for the binary logistic model was 329. The model developed fits significantly better than an empty model (i.e., a model without any predictor).

Number of observations used = 329

LR $chi^2(58) = 98.64$

Prob > $chi^2 = 0.0007$

Pseudo $R^2 = 0.2472$

Log likelihood = -150.195

The factors and corresponding odd ratios that were found to be significant for causing non-fatal injury crashes as compared to PDO crashes are listed in Table 31. The crashes that occurred from midnight until 4 in the morning, as compared to crashes that occurred in other time intervals listed in Table 31, were likely to be injury crashes than PDO crashes. Interestingly, crashes that occurred on weekdays were 3 times more likely to be injury crash than crashes that occurred on weekends. Also, the crashes that occurred on January were 5 (=1/0.209) times more likely to be injury crashes than the crashes that occurred on June. Motorcycle was found to be significantly more prone to injury crashes as compared to other types of vehicles listed in Table 31. Speeding was found to be 17 (=1/0.060) times more responsible for the injury crashes than mechanical defect of the vehicle.

Table 31 Odds Ratios for Significant Factors (Binary Logit Model)

Category	Value	Odds Ratio	P>|z|	95% Con. Interval
tgroup	12:00 AM to 3:59 AM			
	8:00 AM to 11:59 AM	0.110	0.012	0.019 – 0.617
	12:00 PM to 3:59 PM	0.105	0.010	0.019 – 0.587
	8:00 PM to 11:59 PM	0.211	0.041	0.047 – 0.938
day	Weekdays (base Weekends)	3.119	0.006	1.375 – 7.074
month	January			
	June	0.209	0.032	0.05 – 0.875
v1type	Motorcycle			
	Carry-all/Utility	0.067	0.008	0.009 – 0.49
	Car	0.051	0.001	0.008 – 0.318
	Pickup/Van	0.094	0.010	0.015 – 0.574
	Heavy	0.046	0.001	0.007 – 0.299
v1vehiclef	Speeding			
	Mechanical defect	0.060	0.034	0.004 – 0.805
	Unknown/Other	0.224	0.005	0.079 – 0.638

The overall effects of the predictor factors are shown in Table 32. Considering only the overall effects, only variables that are significant were day of the week, primary vehicle type, and primary vehicle most harmful event.

Table 32 The Overall Effect of Different Predictor Variables on Crash Injuries (Binary Logistic Model)

Category	**chi2**	**Prob > chi2**
weather	3.85	0.572
ctype	3.03	0.552
action	4.06	0.398
lighting	3.32	0.650
vcount	0.48	0.488
tgroup	9.97	0.076
day	7.41	0.007*
month	8.76	0.644
v1type	12.73	0.013*
v1driverf	5.71	0.335
v1harmful	15.94	0.026*
v1vehiclef	11.01	0.088

*$p < 0.05$

Margins were calculated for the binary logit model developed in for this study. The factors that had the highest probability of causing injury crashes, when other factors are kept at their mean values, are provided in Table 33 shows that the crashes involving motorcycle had 80.2% probability of being injury crashes when other factors were kept at their mean value. It also can be seen that crashes that occurred from midnight until 4 in the morning have 58.3% chances of being injury crashes. Severe crosswinds, passing other vehicle, and fatigue were also likely to result into severe crashes as compared to other values in their category.

Table 33 Margins of the Factors That are Likely to Result in Injury Crashes

Category	Value	Margin	P>|z|	95% Con. Interval
weather	Severe Crosswinds	0.505	0.039	0.026 – 0.984
ctype	Others/Unknown	0.484	0.025	0.062 – 0.907
action	Passing other vehicle	0.454	0.015	0.09 – 0.819
lighting	Dawn/Dusk	0.386	0.018	0.067 – 0.705
vcount	Multiple	0.270	0.002	0.096 – 0.443
tgroup	12:00 AM to 3:59 AM	0.583	0.000	0.266 – 0.899
day	Weekdays	0.267	0.000	0.195 – 0.339
month	November	0.360	0.020	0.056 – 0.664
v1type	Motorcycle	0.802	0.000	0.533 – 1.07
driverf	Fatigue/Asleep	0.435	0.023	0.06 – 0.809
v1harmful	Others	0.784	0.000	0.522 – 1.047
v1vehiclef	Speeding	0.399	0.000	0.241 – 0.558

The marginal effects of switching values of variables from the base value to another values were calculated. The marginal effects that were found to be significant are listed in Table 34.

Assuming a hypothetic situation, in which all the crashes that occurred in a clear weather occurred in a mixed unfavorable weather, the probability of those crashes being injury crashes would decrease by 0.209. In other words, 1 out of 5 (= 1/0.209) such crashes would be a PDO crash instead of a non-fatal injury-causing crash. Similarly, if the time of crashes that occurred in time interval '12:00 AM to 3:59 AM' were switched to other time intervals listed in the table, the probability of such crashes being injury crashes would decrease by 0.242 to 0.358 depending upon the time intervals. If the day of the crashes that occurred in weekends were weekdays, the probability of those crashes being injury would increase by 0.157. The table also shows that, if the vehicle type were switched from motorcycle to other vehicle types listed in the table, the probability of those crashes being non-fatal injury-causing crashes would decrease. Finally, if all the crashes related to speeding were caused by mechanical defect, the probability of those crashes being non-fatal injury-causing crashes would decrease by 0.343.

Table 34 Marginal Effects on Probablility of Injury by Changing Variables From Base Value

Category	Value	dy/dx	P>|z|	95% Con. Interval
weather	Clear			
	Mixed Unfavorable	-0.209	0.033	-0.402 – -0.016
tgroup	12:00 AM to 3:59 AM			
	8:00 AM to 11:59 AM	-0.353	0.007	-0.608 – -0.097
	12:00 PM to 3:59 PM	-0.358	0.006	-0.613 – -0.102
	4:00 PM to 7:59 PM	-0.242	0.043	-0.476 – -0.008
	8:00 PM to 11:59 PM	-0.260	0.031	-0.497 – -0.023
day	Weekdays (base Weekends)	0.157	0.002	0.059 – 0.255
month	January			
	June	-0.222	0.027	-0.419 – -0.026
v1type	Motorcycle			
	Carry-all/Utility	-0.448	0.002	-0.727 – -0.17
	Car	-0.488	0.000	-0.732 – -0.243
	Pickup/Van	-0.393	0.002	-0.642 – -0.145
	Heavy	-0.502	0.000	-0.751 – -0.253
v1vehiclef	Speeding			
	Mechanical defect	-0.343	0.000	-0.522 – -0.163
	Unknown/Other	-0.228	0.003	-0.379 – -0.076

Site Data Results

Previous studies showed that prevailing speed, roadway characteristics, and roadside characteristics are the most important factors that affect the speed of the vehicles.

Therefore, these factors are considered in most of the speed-zone guidelines and manuals of state DOTs.

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 appendix: SITE MAPS OF TOWNS UNDER STUDY.

Descriptive Statistics of Spot Speed Data

Table 35 shows that the 85^{th} percentile speeds of these towns were higher than the posted speed limit in all the towns. The data also showed that mean speed was higher than the posted speed limit in five towns, namely, Austin, Beatty, Fernley, Searchlight, and Schurz. Also, the median speed was higher than the posted speed limit in Beatty, Fernley, 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 are presented in appendix: CUMULATIVE SPOT SPEEDS AND 85^{TH} PERCENTILE SPEEDS .

Table 35 Descriptive Statistics of Spot Speed Analysis

Town	Highway number	Posted speed (mph)	85th percentile (mph)	Mean speed (mph)	Median speed (mph)	Percent 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%

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 36 through Table 42.

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 36 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 37. The widths of the shoulders vary at different locations of each highway.

Table 37 Sectional Properties of the Highways Under Study

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

The number of access points in Table 38 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 38 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

None of the transition and speed zones under study had speed humps. There was an electronic speed display system at Searchlight, displaying the speeds of travelling vehicles. Different towns had different step down speed limits, as shown in Table 39.

Table 39 Traffic Control Devices on the Highways

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

All the highways under study had undivided painted medians with the number of lanes varying from 2 to 4 lanes (Table 40). 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 40 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 41.

Table 41 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 42 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 42 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

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. However, it may be noted that current speed data (2012) was analyzed for correlation with historical crash records (2002-2010). The assumption was that the trend of speeding has remained the same over time in each of those towns.

The higher the value of a coefficient of correlation – hence the higher value of R^2 – indicates a stronger relationship between those two variables. The value of R^2 represents the percentage of the change in value of dependent variable, as explained by that particular independent variable.

Overview of all coefficients of correlations.

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. Table 43 shows that all the crash parameters under study have a negative correlation with all the speed parameters under study except the percentage exceeding the posted speed. 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 appendix: CORRELATION COEFFICIENTS BETWEEN CRASHES AND SPEED VALUES.

Table 43 Overview of All Coefficients of Correlation

Coefficient of correlation between two parameters	Percentage exceeding posted speed	Posted speed (mph)	85^{th} 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

Overview of all pseudo R^2 values.

Table 44 summarizes the strength of the relationship between the speed variables and crash variables. The pseudo R^2 values for these correlations are shown in Table 44. The table shows that crash statistics are best described by the percentage of vehicles exceeding the posted speed limit than by any other speed factor under consideration. It also shows that about half of the crashes and half of the PDO crashes are explained by the percentage of vehicles exceeding the posted speed limit. In addition, about one fourth of non-fatal injury-causing crashes and injuries can be described by the percentage of vehicles exceeding the posted speed limit.

Table 44 Overview of All Pseudo R^2 Values

Items	Percentage exceeding posted speed	Posted speed (mph)	85^{th} percentile speed (mph)	Mean speed (mph)	Median speed (mph)
No. of crashes	0.42	0.08	0.05	0.00	-0.01
No. of non-fatal injury-causing crashes	0.25	0.16	0.18	0.11	0.09
No. of injuries	0.27	-0.01	-0.01	-0.06	-0.07
No. of PDO crashes	0.47	0.05	0.01	-0.03	-0.04

Survey Questionnaire Results

All 49 state Departments of transportation (except NDOT) were contacted for the questionnaire by email. 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 45, a total of 37 questionnaire responses were received; two states refused to fill out the questionnaire because of a limitation of time and resources. The remaining ten states did not provide any response, even after multiple follow ups.

Table 45 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%**

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. Also, few DOTs provided data based on fewer than 5 years duration. Table 46 lists the statistics provided by the DOTs. North Carolina had 73,000 miles of rural state highways, which is more than any other state's rural state highway mileage. Rhode Island had only 400 miles of rural state highways, which is the least of all.

A general overview of crash statistics is presented in Table 47. 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 highway, 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 occurred in rural highways in Montana which is the highest among all. Massachusetts had only 4% of the total crashes that occurred on rural state highways which is the least among all.

Table 46 Highway and Crash Statistics

State	Rural state highways (mile)	Average annual crashes		Average annual fatalities	
		All highways	Rural state highways	All highways	Rural state highways
North Carolina	73,000	212,000	91,000	1,290	895
Texas	64,557	222,364	46,033	2,395	1,287
Virginia	47,485	126,872	30,567	821	523
Pennsylvania	41,000	125,244	33,733	1,365	229
West Virginia	33,000	43,025	32,269	364	257
Missouri	30,900	77,700	25,900	887	467
South Carolina	30,291	108,000	65,000	900	550
Kentucky	25,203	125,805	46,214	831	486
Georgia	14,055	309,431	35,019	1,377	476
Maryland	13,953	43,874	8,154	396	127
Louisiana	13,142	94,590	18,214	643	334
New Mexico	11,951	46,156	8,135	-	369
Montana	11,375	10,380	7,020	170	151
Arkansas	11,183	39,952	8,550	478	194
Kansas	9,806	23,680	11,899	219	158
Mississippi	9,540	71,820	19,299	728	415
Nebraska	9,539	12,633	6,243	124	106
Indiana	8,826	61,440	28,605	401	253
Iowa	7,872	55,458	11,128	396	162
Maine	7,780	29,673	2,221	157	18
Colorado	7,720	47,784	18,519	312	209
Wisconsin	7,344	63,564	27,764	382	207
Alabama	7,229	126,954	12,424	848	371
Michigan	7,069	299,928	34,322	953	165
Oregon	6,640	16,900	6,780	223	170
Wyoming	6,600	16,409	6,892	150	110
Arizona	5,778	115,819	22,754	880	483
Ohio	4,620	9,011	5,246	133	111
Delaware	2,878	20,000	4,600	113	-
Connecticut	1,278	90,047	-	277	-
Massachusetts	756	132,890	1,508	351	14
Hawaii	590	4,604	1,150	82	28
Rhode Island	400	47,500	1,500	70	13
Illinois	-	364,000	53,000	1,075	475
California	-	463,285	-	3,476	-
Total	**509,908**	**2,611,740**	**638,163**	**17,944**	**8,762**

Table 47 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%
All combined	**1,252**	**17**	**24%**	**49%**

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 to 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’ in some form as one of the top five reasons for crashes (Table 48). ‘Fatigue and inattention’ was also mentioned as one of the top five reasons for crashes by the same number of representatives. ‘Failure to yield’ was seen as one of the top five reasons, almost as important as ‘speeding’ and ‘fatigue and attention.’ ‘Run off lane/road’, ‘DUI’, and ‘following too close’ were listed as important reasons for crash by many DOT representatives.

Table 48 Top Reasons for Crashes (Sorted According to the Count)

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%
DUI	10	27%
Following too close	10	27%
Animal/object in roadway	8	22%
Turning related	5	14%

* The percent of responses that were categorized into each of those categories. The sum of those percent is not 100%.

Average ratings were calculated for each category of top reasons for crashes based on how each DOT representative ranked the top 5 reasons. 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 reasons 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 9). Speeding is ranked sixth in the list followed by DUI and ‘following too close.’

Figure 9 Average Ratings of Reasons for Crashes

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 10). That means more than half of the states that responded the survey had the speed-zone statutes.

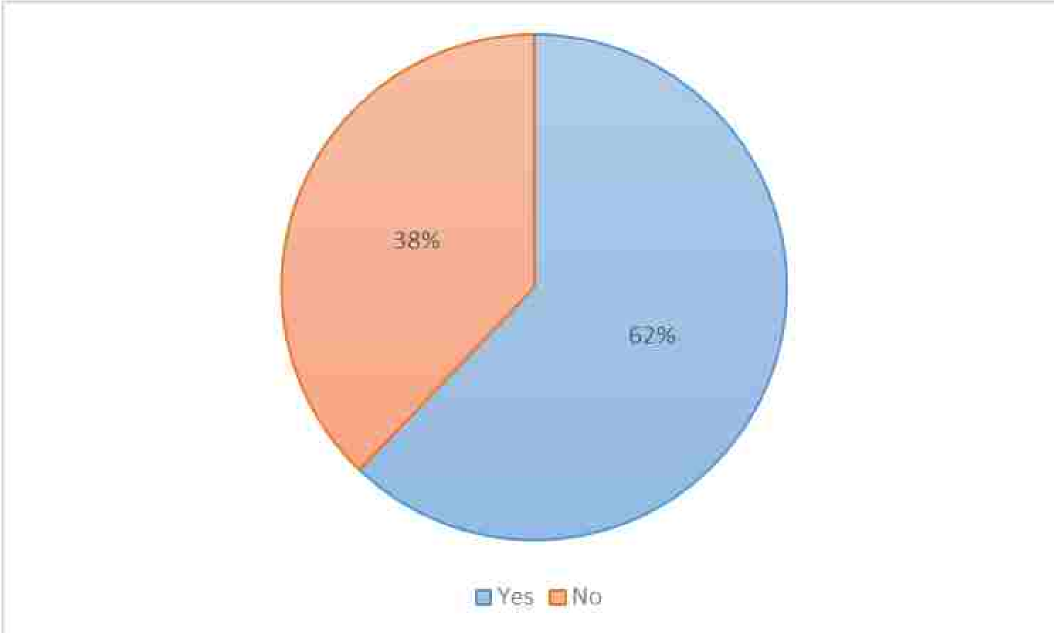

Figure 10 Presence of State Statutes That Mandates the Speed Zone in the Towns on Rural State Highways

Three out of 37 DOTs did not require any engineering and traffic investigation to be conducted to alter speed zones. Almost all of the DOTs (92%) were required to conduct some sort of an engineering and traffic investigation before the alteration (Figure 11).

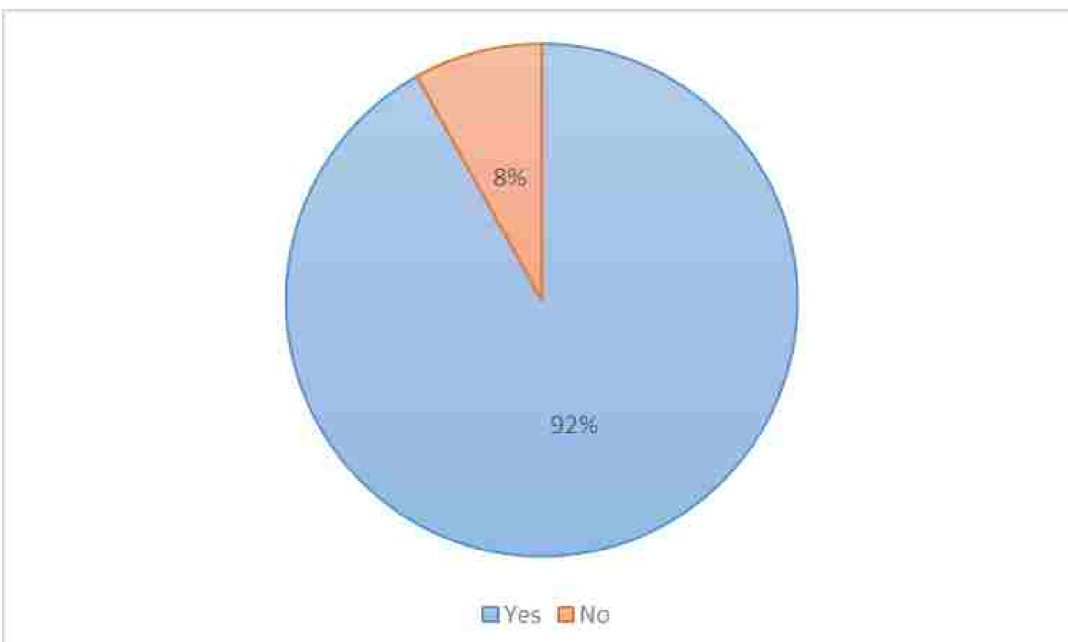

Figure 11 Engineering and Traffic Investigation Required for Alteration of a Speed Zone

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 12).

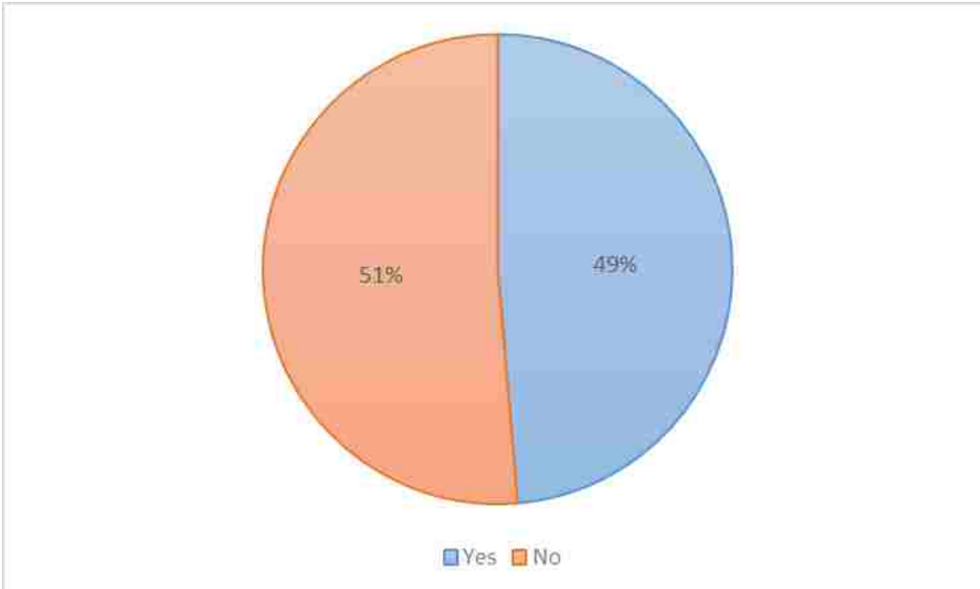

Figure 12 Presence of a Speed-Zone Guideline or Manual

Among the 18 DOTs that had some form of a speed guideline or a manual, 11 DOTs had some differences between speed-zone legislature and the speed-zone guideline or manual (Figure 13).

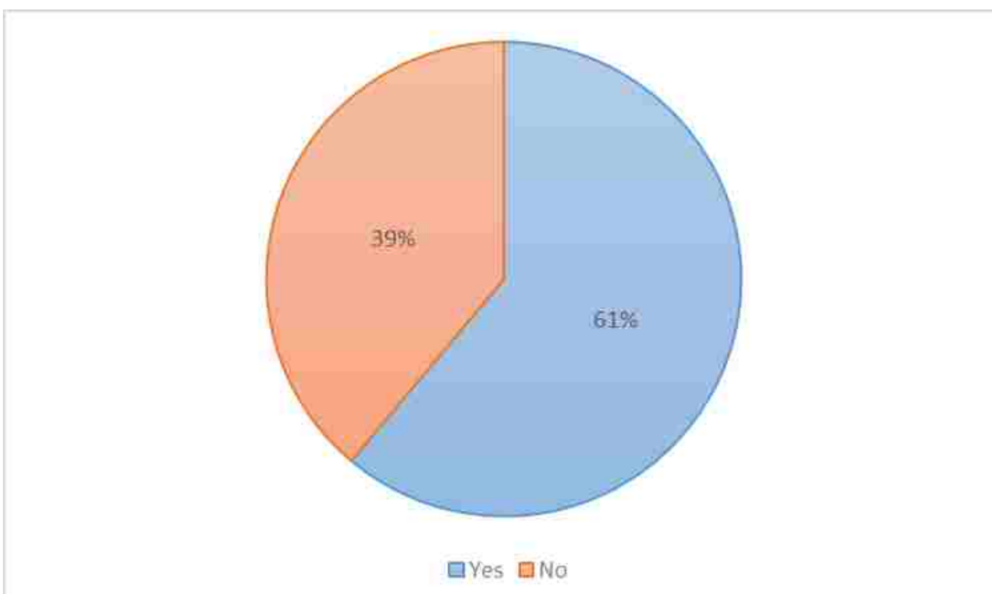

Figure 13 Difference between a Speed-Zone Legislation and a Speed-Zone Guideline or Manual

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 14). 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.

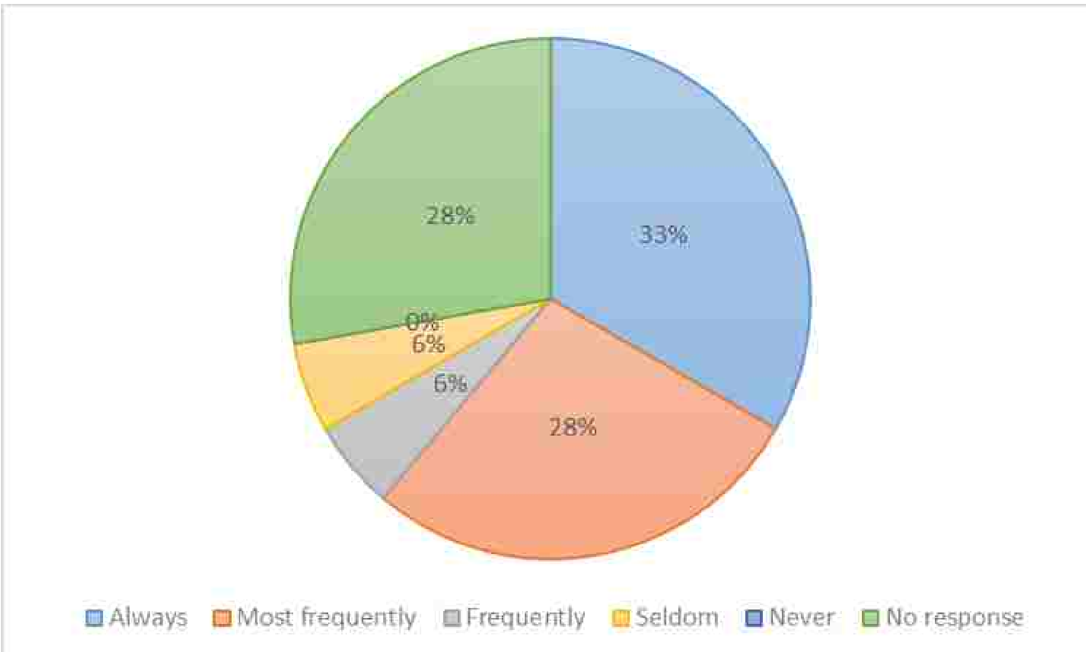

Figure 14 Use of a Speed-Zone Guideline or Manual (DOTs That Had a Speed-Zone Guideline or Manual)

Considering all the DOTs that responded to the questionnaire – unlike previous cases in which the only DOTs that had some form of speed-zone manual or guideline were considered – 16% said that they always used the guideline or manual (Figure 15). Thirteen percent of state DOT representatives said they used the guideline or manual most frequently, 3% said they frequently used the guideline and manual, and another 3% said they seldom use the guidelines or manual to set up the speed zone. Sixty-five percent of state DOT representatives did not provide a response, mostly because the question was not applicable to them.

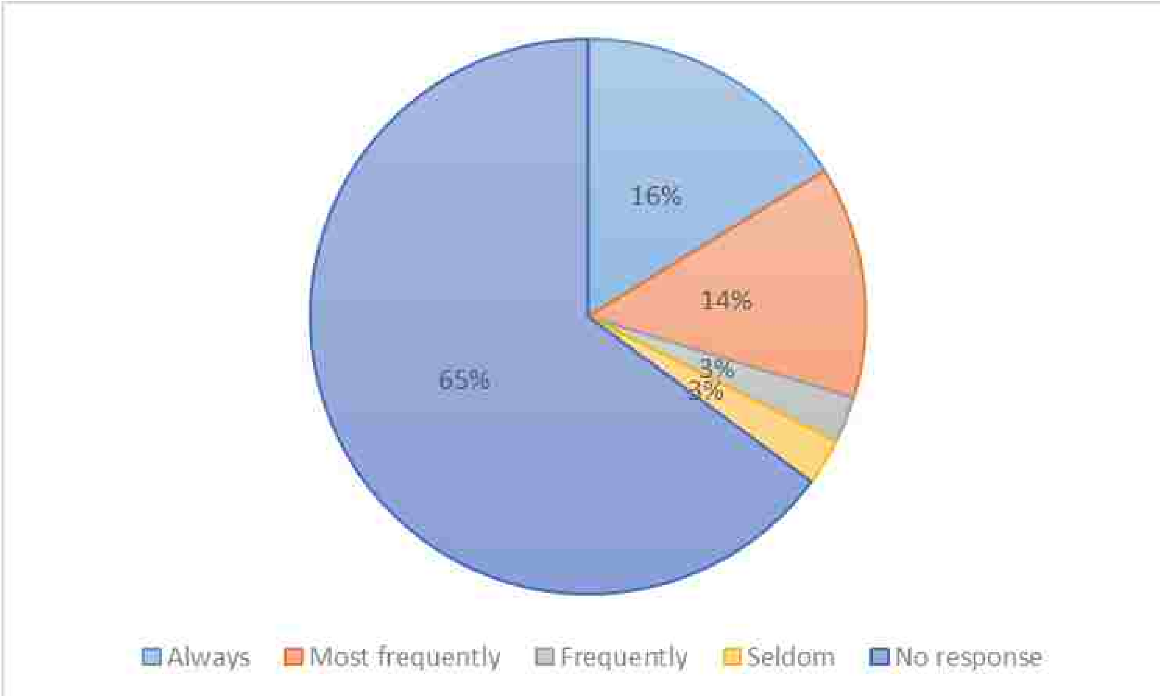

Figure 15 Use of a Speed-Zone Guideline or Manual (Considering All the DOTs That Responded to the Questionnaire)

Fifty-seven percent of DOTs that provided a response to the questionnaire said they enforced speed limits in the towns (Figure 16). The wording of the question seemed confusing to most of the DOT representatives that whether the questions asked about the police enforcement or their office setting up the speed zone. Therefore, there is high number of negative answers in this question.

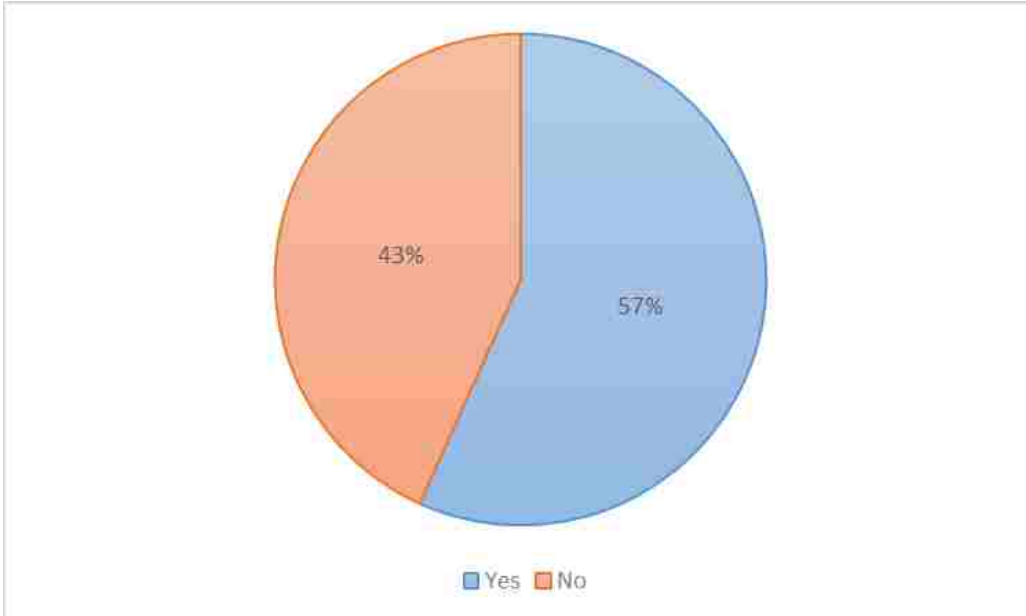

Figure 16 Speed Limit Enforcement

Ninety-five percent of the DOTs that enforced speed limits in towns along rural state highways said they did not have a uniform speed limit in different towns along the rural state highways (Figure 17). Only one DOT said it had a uniform speed limit along all the towns along the rural state highways.

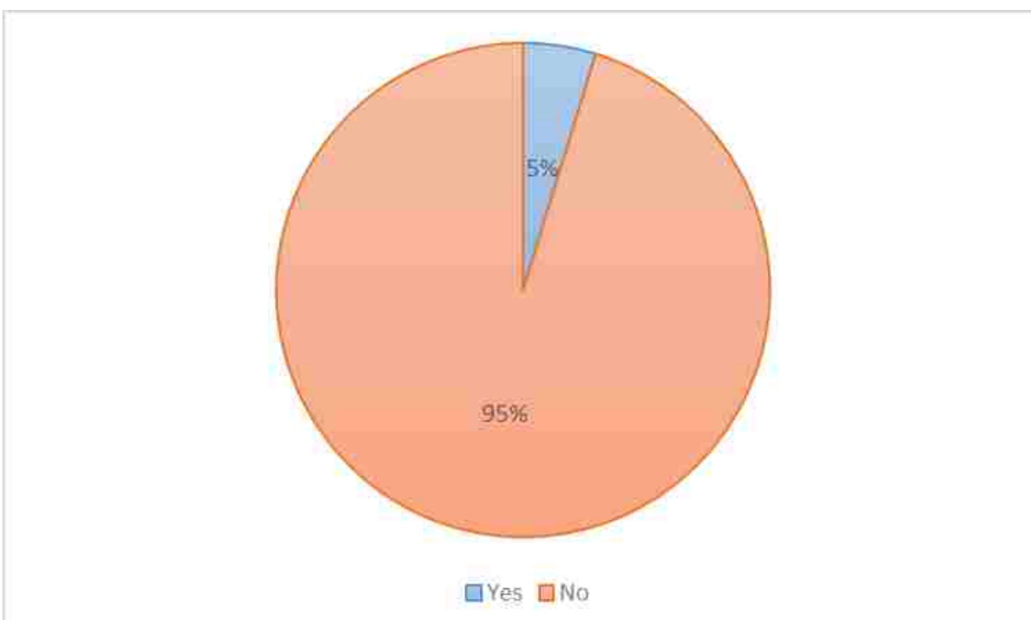

Figure 17 Uniformity of a Procedure to Setup Speed Limits in all the Towns along Rural State Highways

Traffic Engineer's Personal View

Out of 167 factors mentioned by different state DOTs' traffic engineers, 143 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. The most important factor, as shown by the survey, was 'prevalent traffic speed' Table 49. 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 towns along a rural state highway – according to the views of DOT representatives.

Table 49 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 percentage of DOT traffic engineers mentioned that they did perceive speeding as a problem in their state (Figure 18). 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.

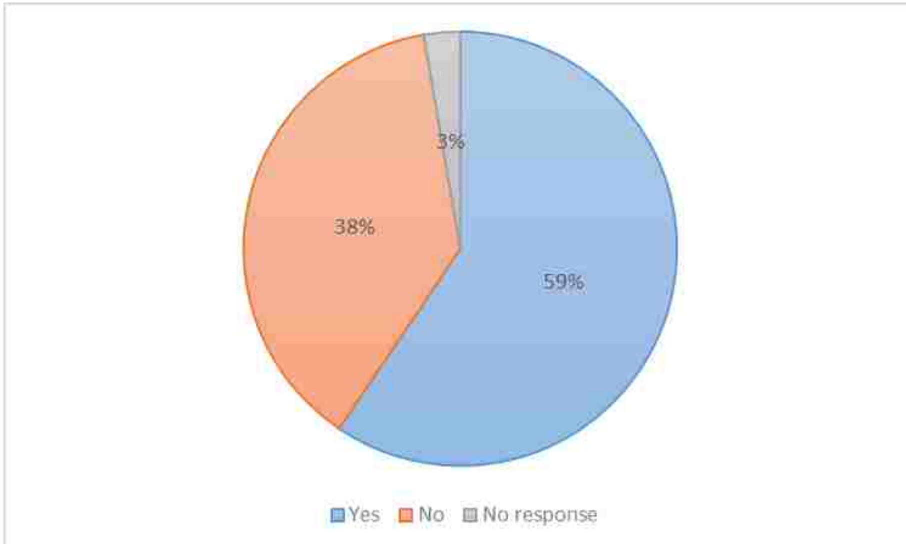

Figure 18 Speeding Traffic as a Problem in Rural Highways

About three-quarters of the DOTs that considered speeding as a problem mentioned that the problem was only moderately serious (Figure 19). Half of the remaining DOTs considered the problem as not serious and the other half considered it a very serious problem.

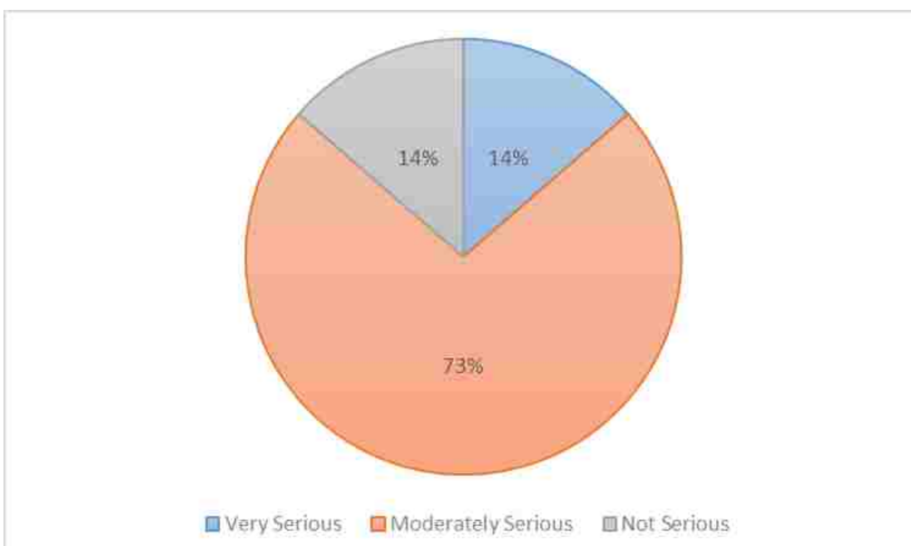

Figure 19 Seriousness of the Speeding Problem (Considering DOTs that Mentioned Speeding as a Problem)

Considering all the DOTs that responded to the questionnaire, 43% of them considered speeding as a moderately serious problem (Figure 20). Eight percent of them considered it not to be serious and another 8% of them said it is very serious.

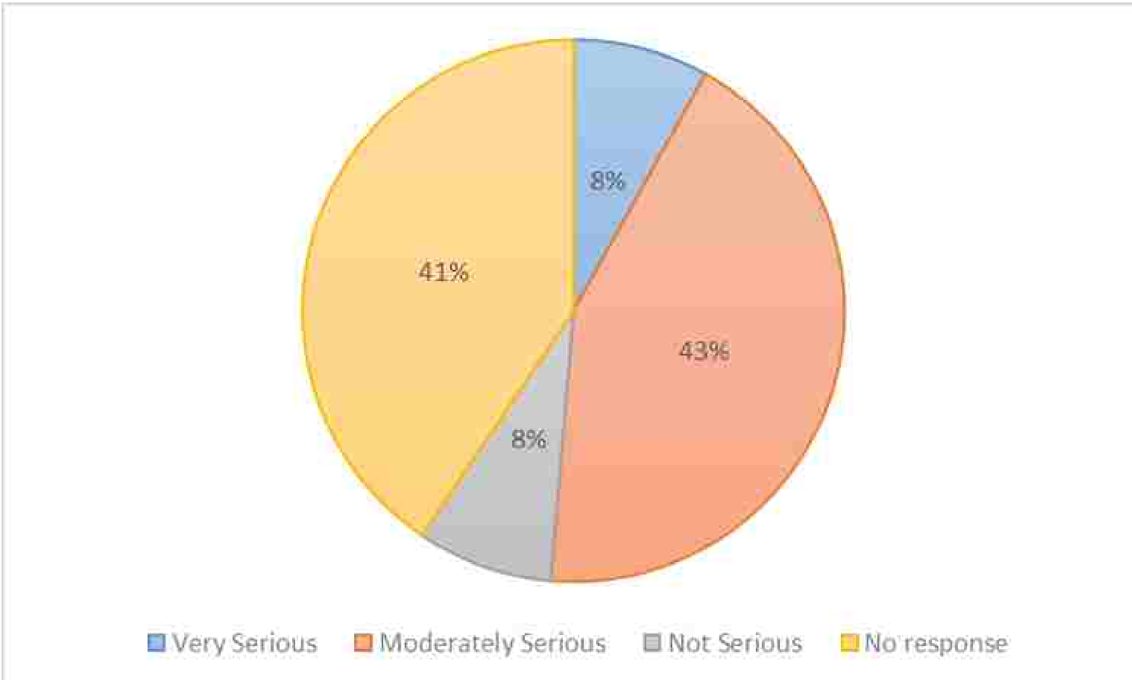

Figure 20 Seriousness of the Speeding Problem (Considering all the DOTs that responded)

Thirteen factors that were considered to have an important influence in setting up the speed zone were listed and state DOT representatives were asked to rate the importance of each of these factors. The scale of rating ranged from 1 to 5 - 5 being most important and 1 being least. Average rankings were calculated as weighted average of the rankings. Figure 21 lists the factors and the calculated average ratings. The 85th percentile speed was considered as the most important factor for setting up a speed limit, followed by road characteristics and the number of crashes. 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.

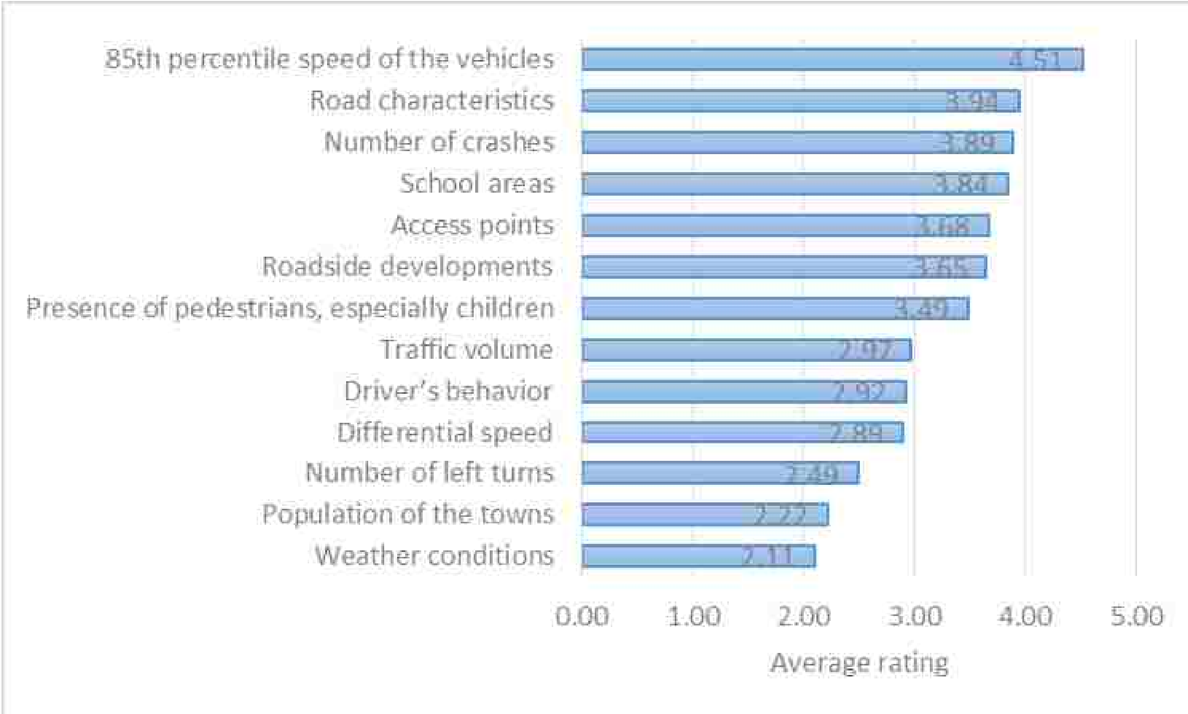

Figure 21 Average Ratings of the Factors Influencing the Speed Zone of Rural State Highway

State DOT representatives were asked to rate ten factors that were considered important to control speeding traffic on rural highways. The average ratings of those factors are shown in Figure 22. Increased police enforcement had the highest rating of 4.2. Installing proper speed-zone signs and changing road characteristics were also 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.

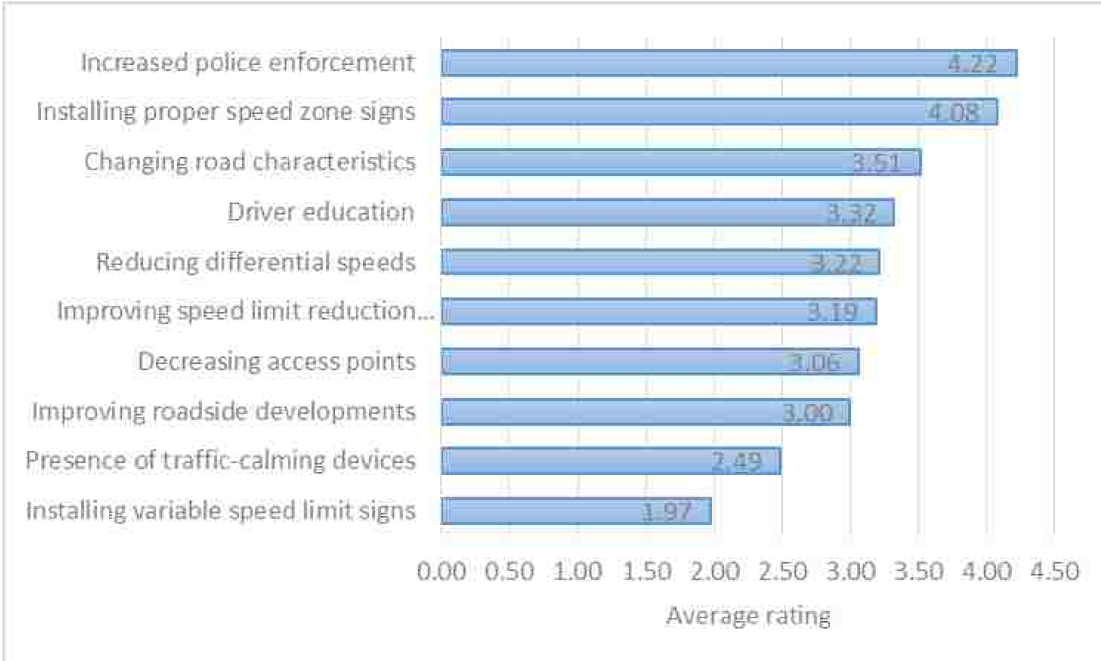

Figure 22 Average Ratings of the Factors to Control Speeding Traffic on Rural Highway

Almost all of the DOT representatives (92%) agreed that increasing the speed limit did not increase the frequency of crashes (Figure 23). Only two of them disagreed and one did not respond to the question.

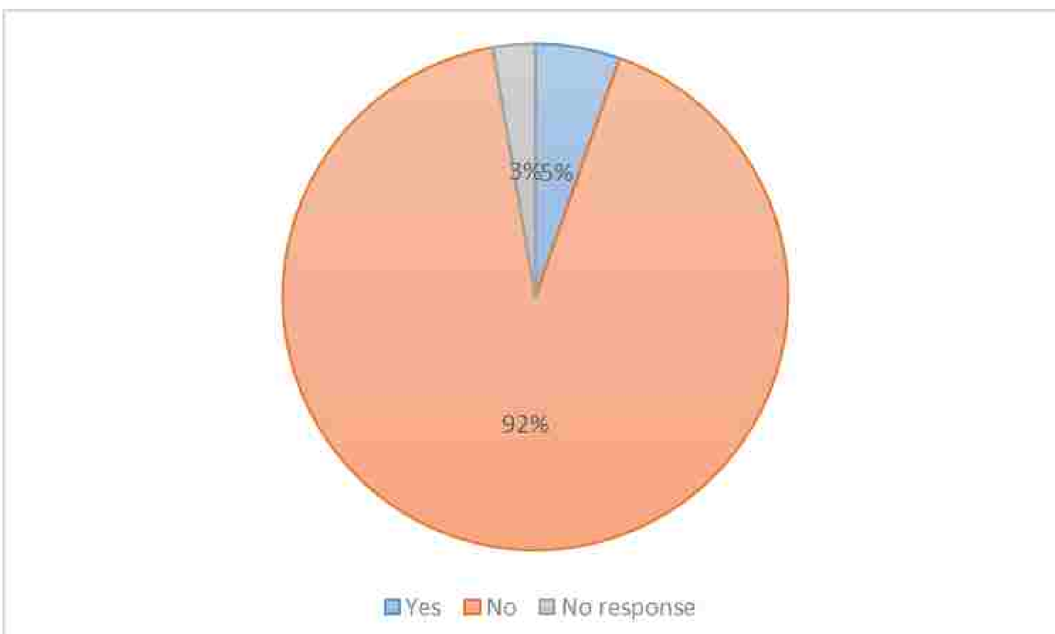

Figure 23 The Relationship between Increase in Speed Limits and Increase in the Frequency of Crashes

Issues of the Local Communities

All of the states that responded to the questionnaire, received speed limit complaints from the communities of towns along rural highways, except one state (Figure 24). The one state did not respond to the question.

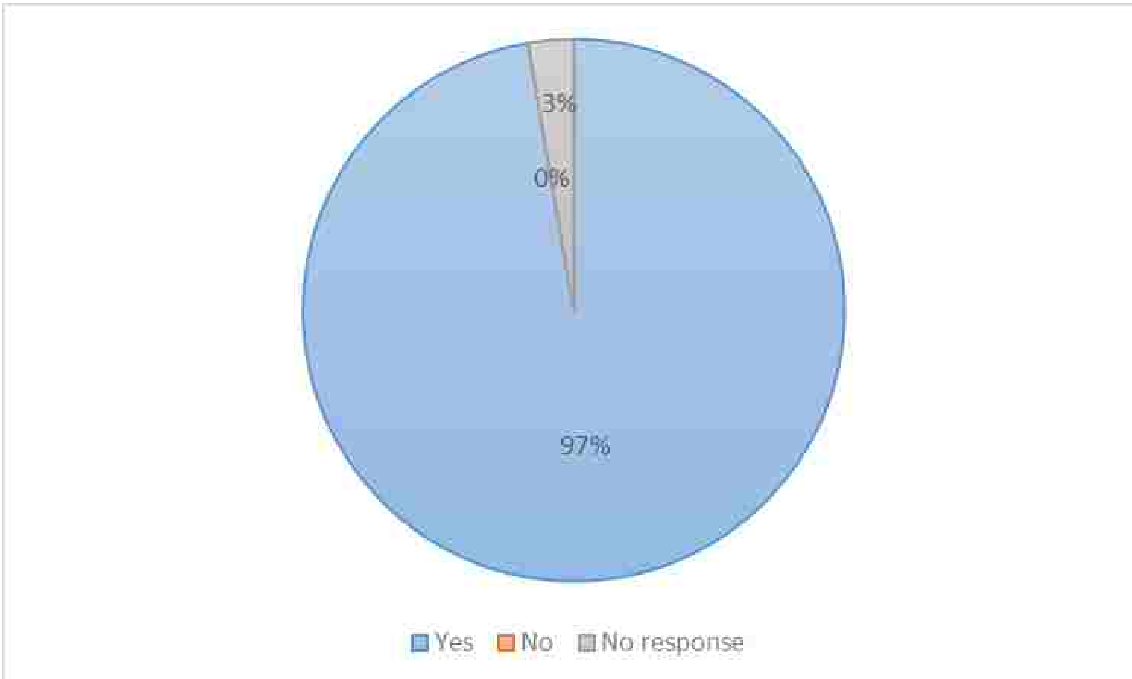

Figure 24 Receipt of Speed Limit Complaints from the Communities of the Towns along Rural Highways

The DOT representatives were asked to give the estimated number of complaints they received every year regarding the speed zone. Fourteen DOT representatives mentioned that they received less than 50 complaints a year while 8 DOTs said they received more than 50 complains in a year (Table 50). Fifteen DOTs did not provide any quantifiable answers to the question.

Table 50 Number of Complaints from Communities of Towns Along Rural Highways

Complaint count	DOT count	Percentage
50 or less	14	38%
51 to 100	4	11%
More than 100	4	11%
No response	15	41%
Total	**37**	**100%**

Communities from 33 out of 37 states were interested in decreasing the speed limits in towns along their neighboring highways (Figure 25). Communities from another two states did not have any interest to decrease the speed limit according to responses received from DOTs. Two DOT representatives did not respond to this question.

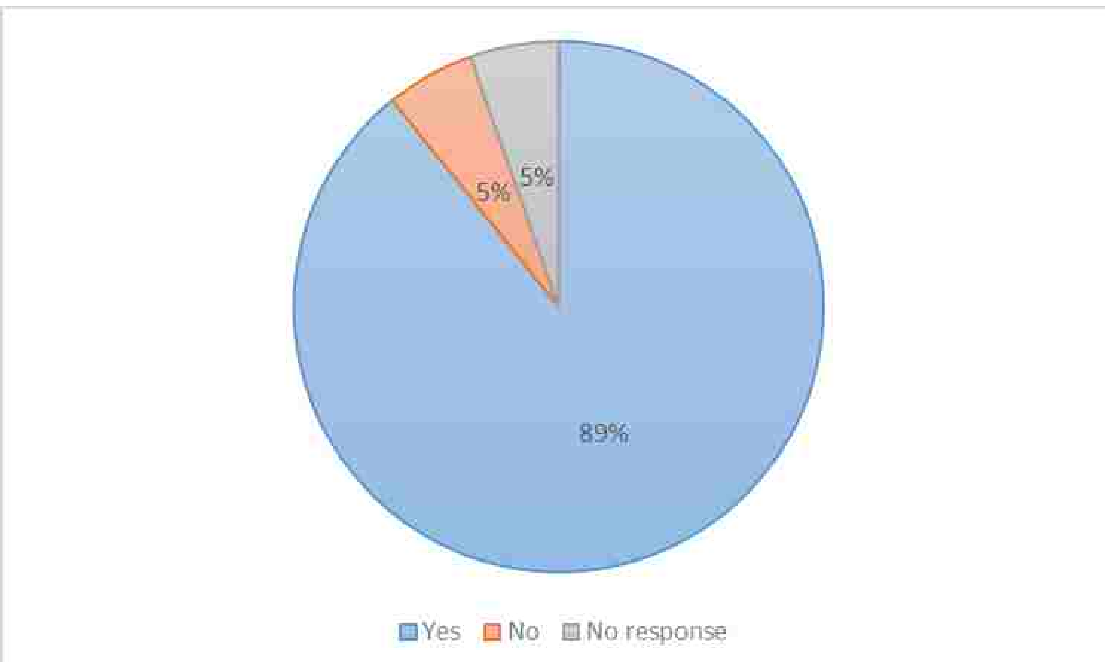

Figure 25 Community Interest to Decrease the Speed Limits in Towns along Their Neighboring Highways

More than half the DOTs reduced the speed limit in towns along rural highways based on complaints from communities (Figure 26). Ten DOT representatives said they did not decrease the speed limit. Four DOTs did not respond to the question.

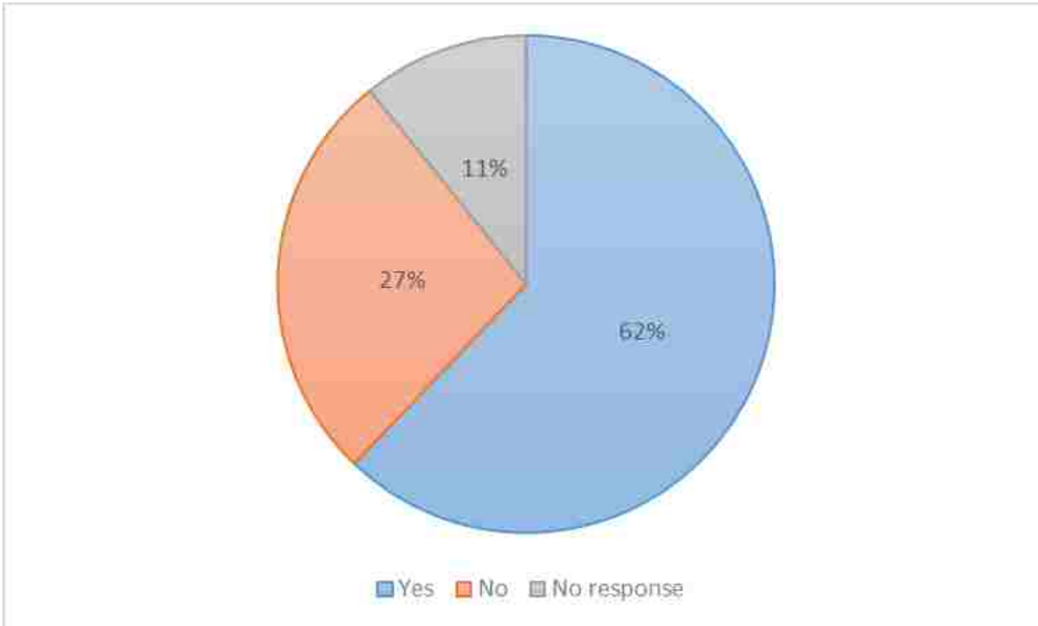

Figure 26 Decrease of Speed Limits Based on Complaints from Communities

Out of 23 states that decreased the speed limit in towns along rural highways, 13 states said decreasing speed limits did not solve the problems (Figure 27). Half of the remaining DOTs said it did solve the problem, and the remaining half did not provide any definite response.

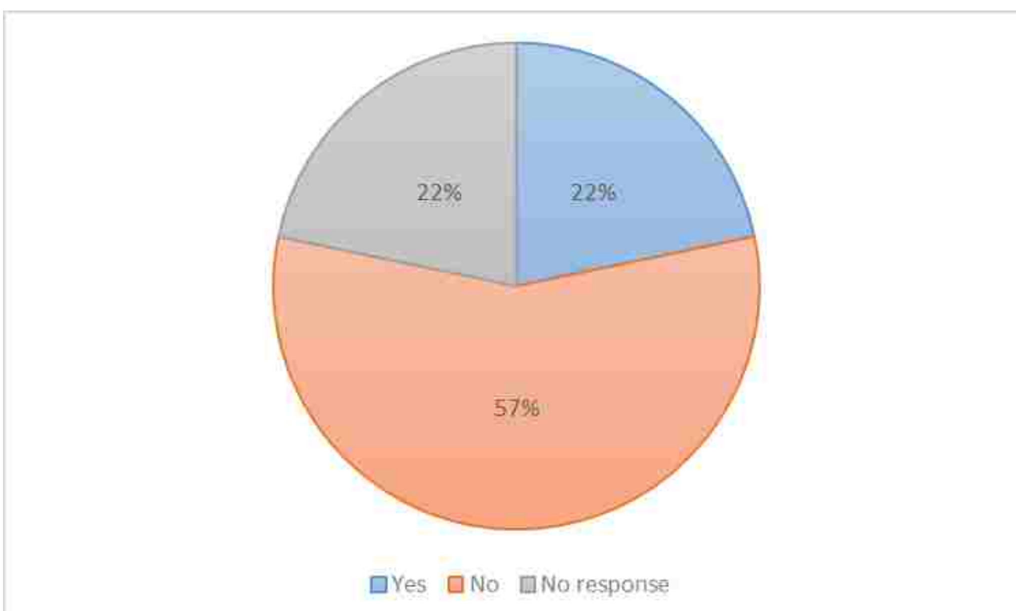

Figure 27 Whether Decreasing the Speed Limit Solved the Problem

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; however, 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, results 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."

Factors That Affect in Setting up a Speed Limit

The representatives of state DOTs who reported that engineering and traffic investigation is required for alteration of speed zones answered that they follow the process mentioned in their traffic manual to set up speed limits in highways. Some factors mentioned by DOT representatives that affect the process of setting up a speed zone are:

- Spot speed studies,
  - Calculation of 85th percentile,
  - Upper limit of 10 mph pace,
  - Trial runs
- Crash history,
- Study of the top factors affecting the speed limit,
  - Roadway characteristics (design, pavement, width, geometry, traffic control device conditions)
  - Roadside environment
  - Volume of pedestrians
  - Presence of parking
  - Number of access point
- Anticipated speed limit violation rate
- Emphasizing law enforcement along with their study recommendation

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 are basic speed laws, roadway functional classifications, and the upper limit of the 5- or 10- mph pace. One DOT representative mentioned that that state was "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 are considering their current legislations and guidelines or manuals as a basis of setting up speed limits. Some mentioned that they perform 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. Also, this DOT was in the process of examining the speed limits to figure out the answer.

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

- Consideration of statutory speed limits;
- Consideration of existing speed-zone guidelines;
- Determining reasonable, realistic, self-regulating, and defendable speed by:
    - Conducting of an engineering study to find out the 85th 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;"
    - Balancing the community desire and the speed the traffic wishes to go;
- Use of proper warning signs;
- Conducting before and after studies;
- Consistency in setting up speed-zone determination process.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of the study have been categorized into three parts. The first part includes the conclusions and recommendations obtained from analyses of crash statistics. The second part includes the conclusions and recommendations related to the speed-zone guideline. The third part continues the conclusions and recommendations of second part by providing the best practices found from review of literature as well as from the results of survey questionnaires.

Crash Statistics

The crash record analyzed in this study shows that most of crashes in the rural towns occurred in favorable conditions. For example, 87% of total crashes occurred when road was in dry condition, 70% of crashes occurred in clear weather, 60% of crashes occurred in daylight, and 63% of crashes occurred when driver was in normal condition. Similarly, 74% of crashes occurred while primary vehicle was going straight. It shows that lesser crashes have occurred in unfavorable conditions like snow, dark, rain etc. - possibly because drivers are more alert in unfavorable driving conditions. However, the reason behind fewer crashes during favorable driving conditions might also be the fact that the weather in most of the towns in Nevada is favorable throughout the year and lesser people drives at night. Those factors were not considered in detail in this study. More detailed study can be conducted with emphasis on those factors for more definite answer to those uncertainties.

Regression analyses shows that no. of crashes, no. of injuries and no. of PDO crashes were significantly correlated with percentage of vehicles exceeding posted speed limits. The pseudo R^2 value shows that 42% of total crash count, 27% injury count and 47% of PDO crash count can be explained by percentage of vehicles exceeding posted speed limits only. Thus speed enforcement is very important factor in order to reduce the number of crashes.

The multinomial logit model shows that the claimed injury crashes were significantly correlated with the month when the crashes occurred, vehicle types and vehicle factors associated with the crashes. The 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. The binary logit model shows that injury crashes were significantly correlated with time of the day, days of the week (weekend and weekdays), month, vehicle types, and vehicle factors associated with the crashes.

Speed-Zone Guideline

Speed-zone guideline is very important tool to ensure 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 proper speed-zone guideline. Once the guideline is prepared, it should be updated regularly. Lessons learned, development of latest technologies, and related researches are some of the aspects to be considered while updating the guideline. Preparing, publishing, and distributing "A Rule of Majority" pamphlet – providing concise information on how speed zones are setup in layman terms - can be an effective tool to increase the public awareness about the process to setup speed zone. Such information is likely to decrease the community complaints related to speed zones, especially community requests to reduce a speed limit.

Best Practices

As per the responses from state DOTs, ‘speeding’ and ‘fatigue & inattention’ are two top reasons for crashes. ‘Failure to yield’, ‘run off lane/road’ are other important reasons for crashes followed by ‘DUI’ which is ranked fifth in the list of the important reasons. Only half of the DOT representatives that responded to the questionnaire have a speed-zone guideline or manual. Many DOTs did not have uniform process in setting up speed zones in their towns along rural highways.

‘Prevailing speed’ (usually represented by 85th percentile) is the most important factor deciding features of speed zones as per the traffic engineer’s personal view. ‘Crash history’, ‘road geometry’, ‘roadside environment’, and ‘political and public influence’ are other four important factors deciding features of speed zones.

Fifty-nine percent of DOT representatives responded that speeding in rural highways is a problem in their state. About three fourth of them mentioned that the problem is moderately serious. Half the remaining DOT representatives said it is not a serious problem while other half mentioned it is a very serious problem.

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 frequency of crashes. Communities in most of the states have an interest to decrease 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 complains received from the public. Half of them said that reducing speed limits did not solve the problems.

APPENDIX A CRASH STATISTICS BY TOWN

Table 51 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 52 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 53 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 54 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 55 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 56 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 57 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 58 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 59 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														
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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														
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APPENDIX D SITE MAPS OF TOWNS UNDER STUDY

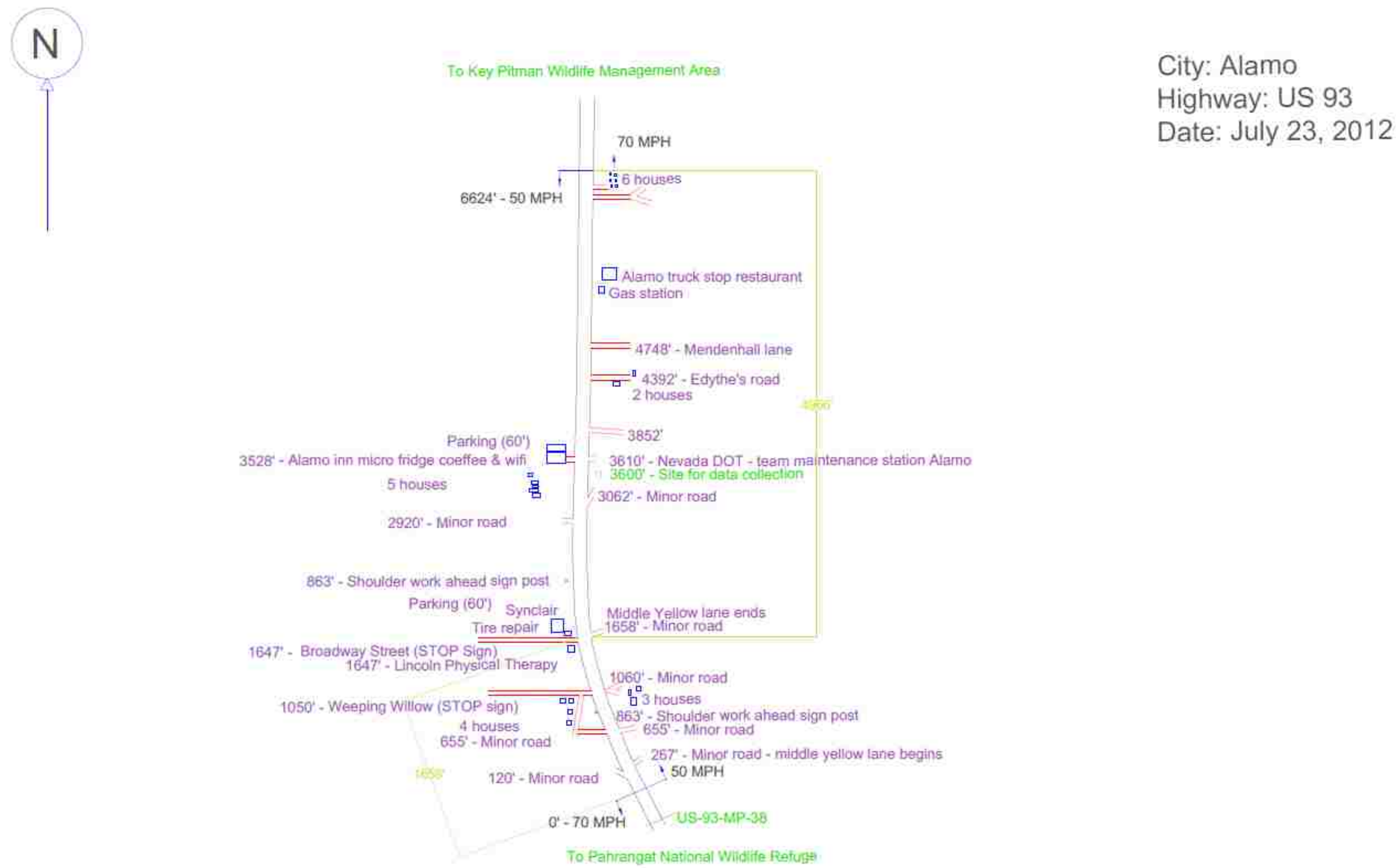

Figure 28 Alamo Speed-Zone Map

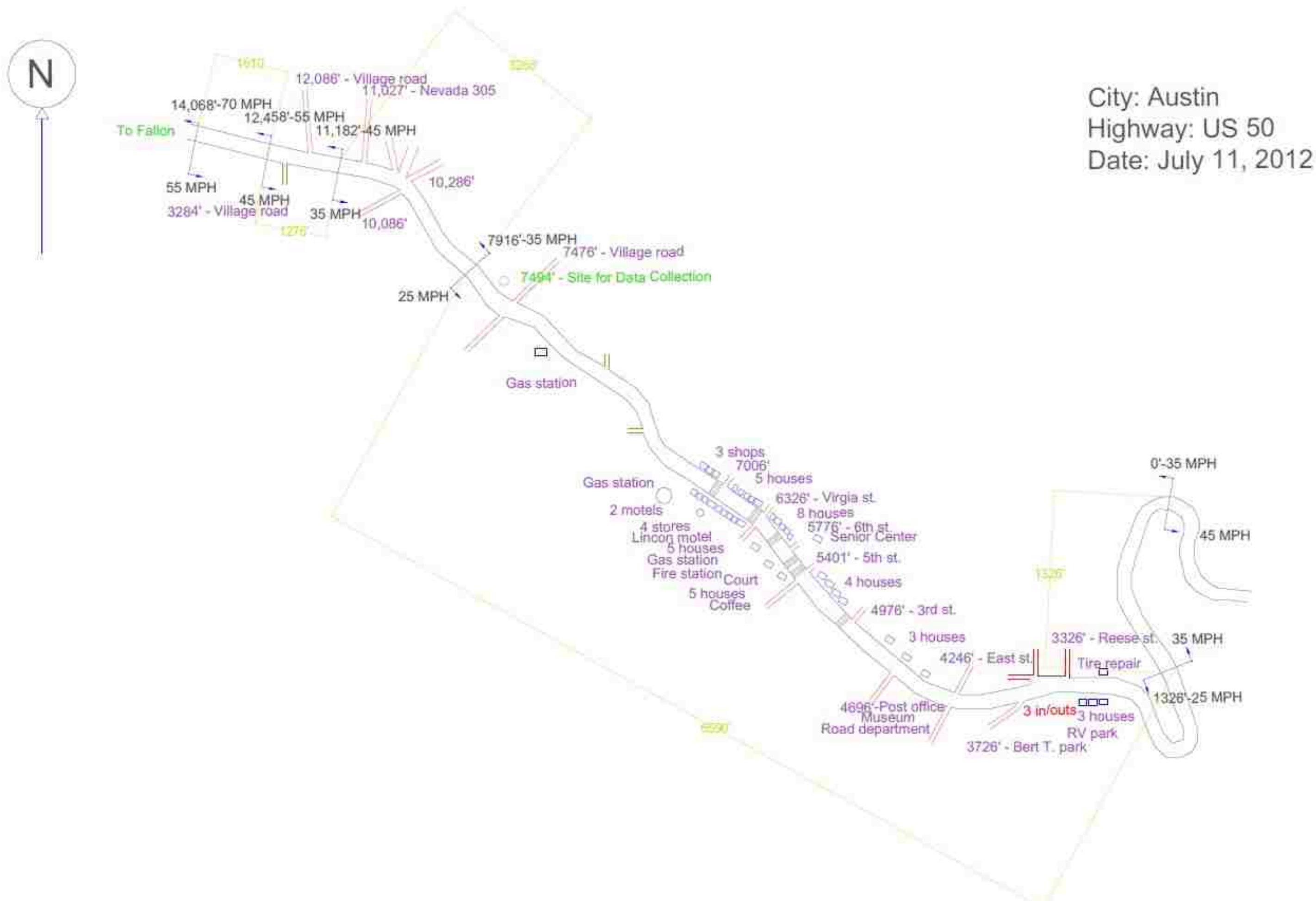

Figure 29 Austin Speed-Zone Map

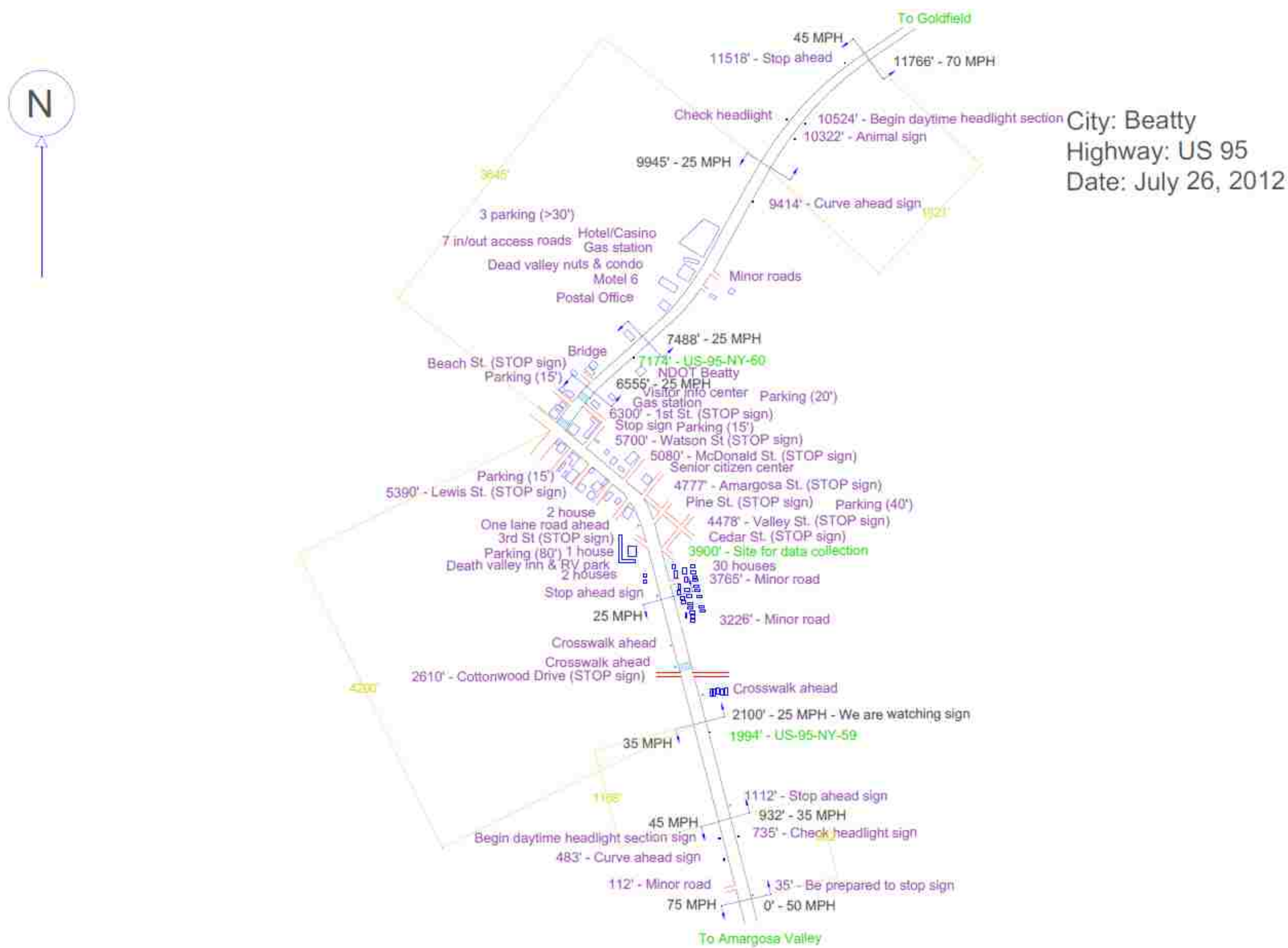

Figure 30 Beatty Speed-Zone Map

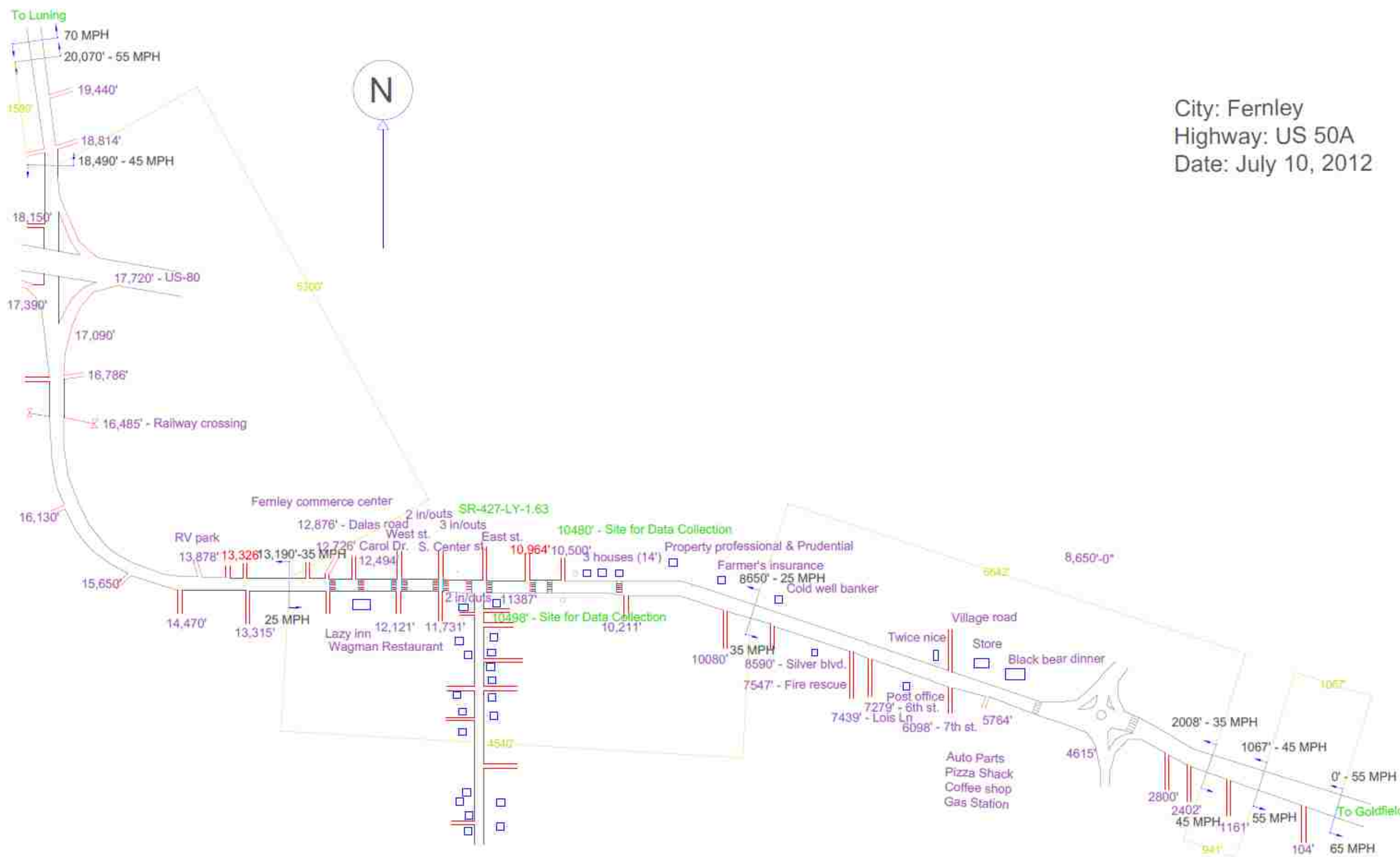

Figure 31 Fernley Speed-Zone Map

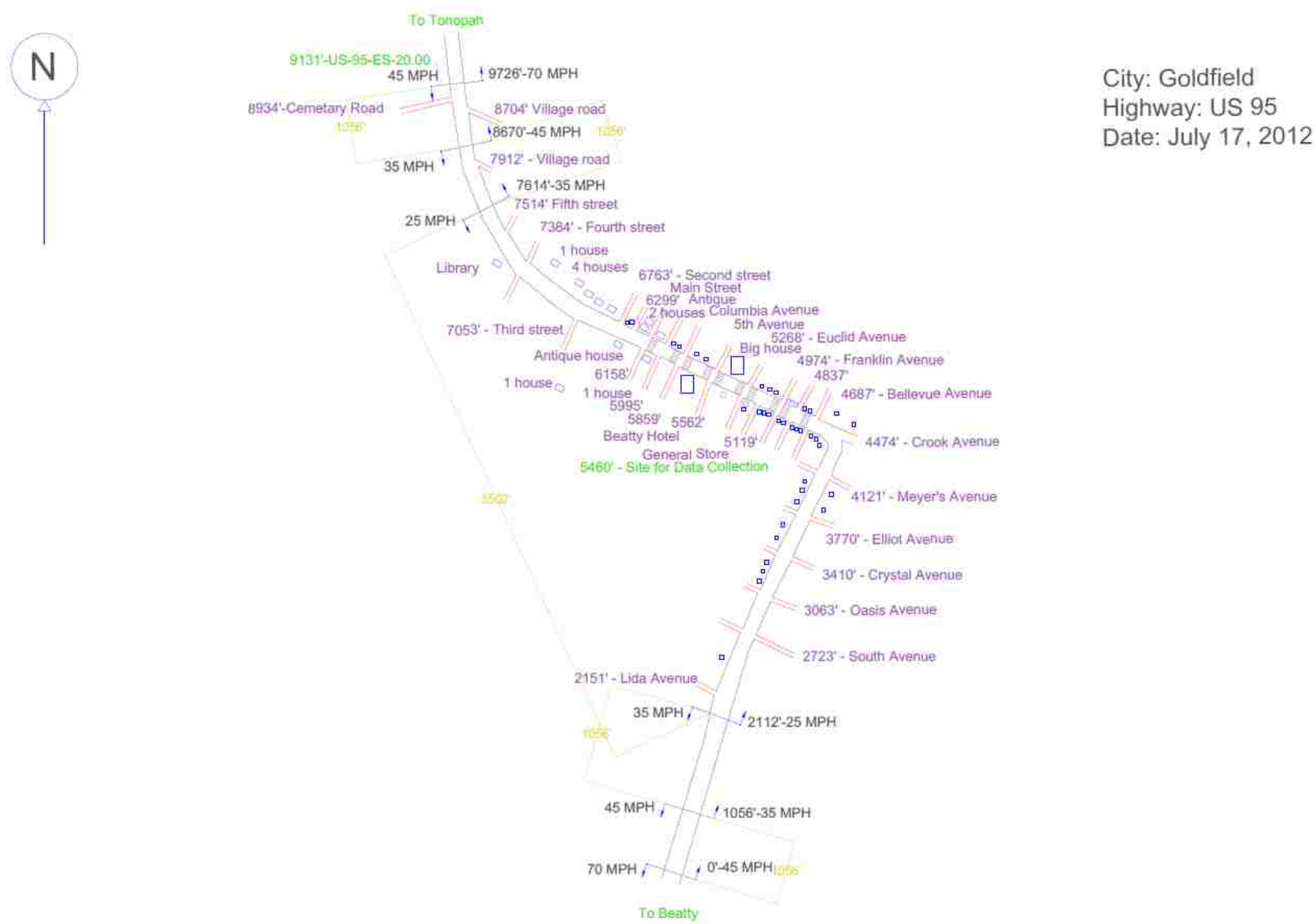

Figure 32 Goldfield Speed-Zone Map

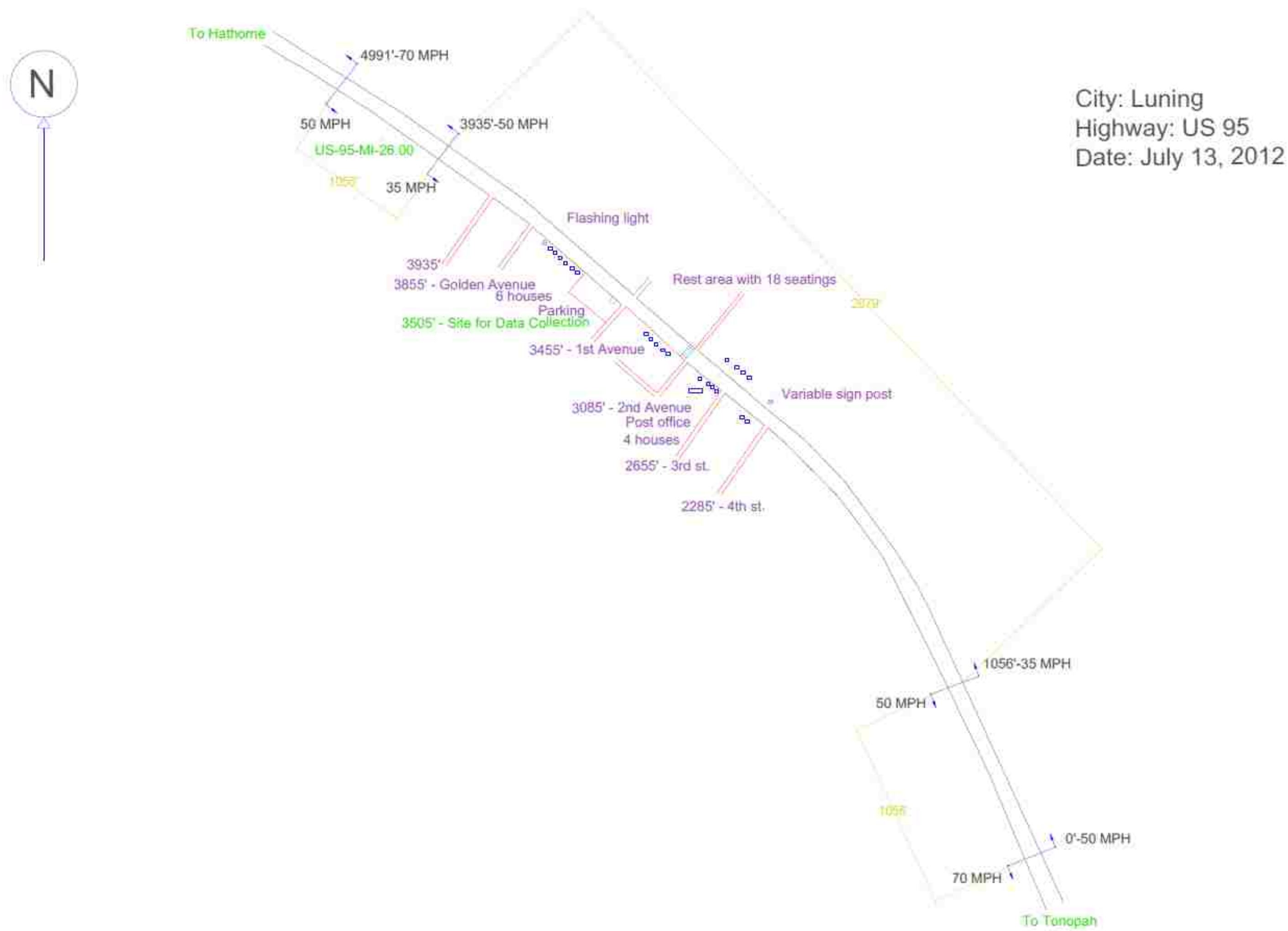

Figure 33 Luning Speed-Zone Map

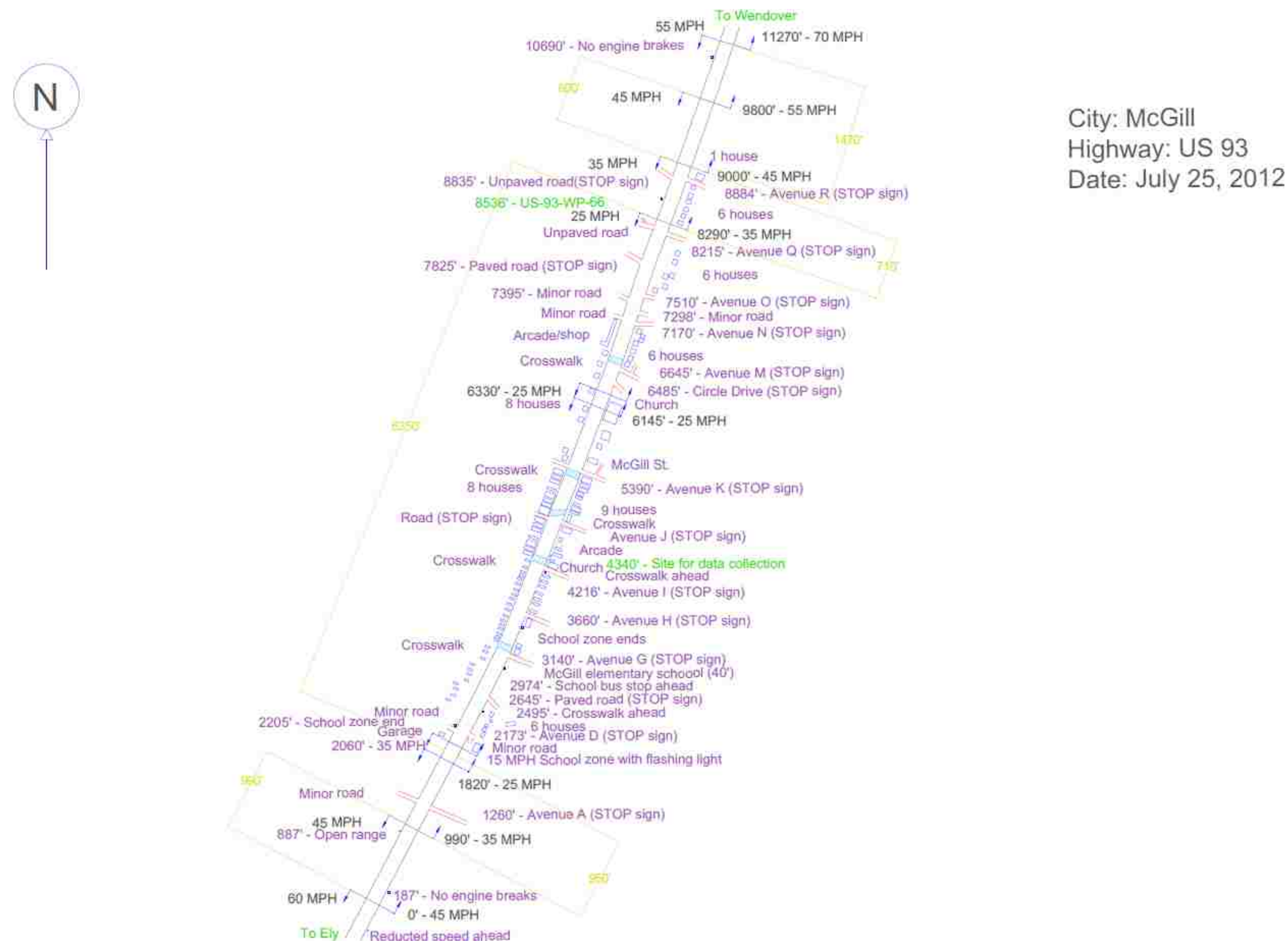

Figure 34 McGill Speed-Zone Map

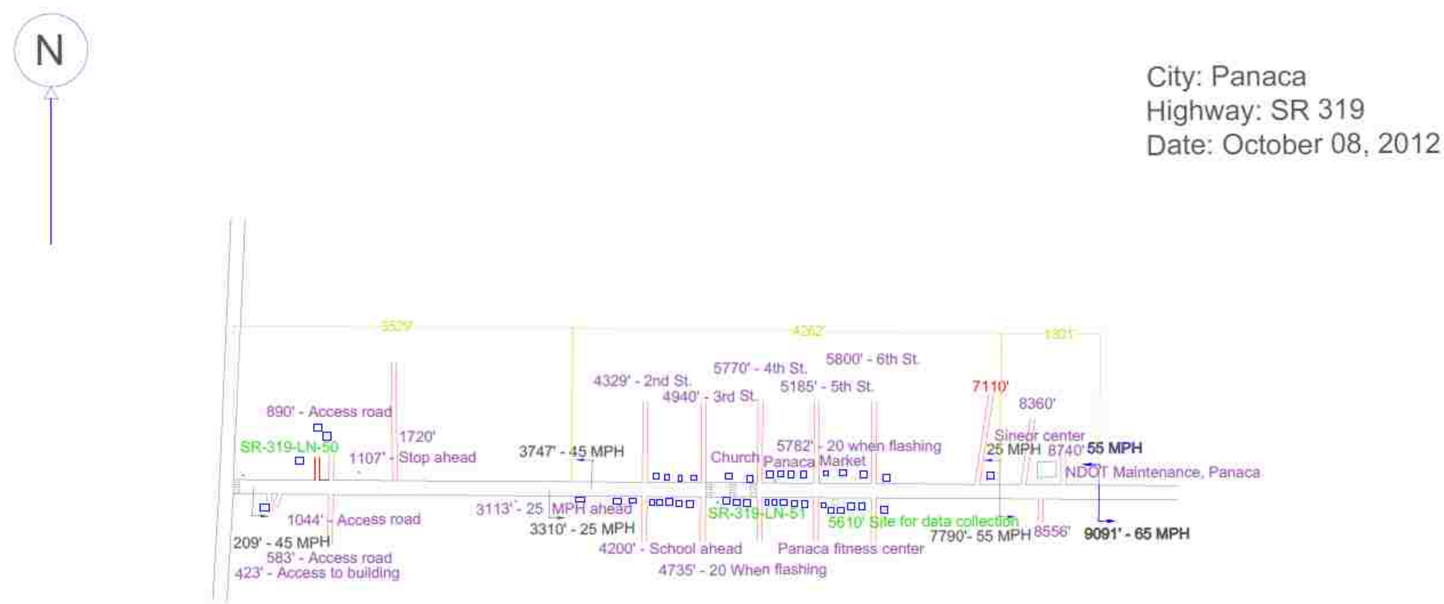

Figure 35 Panaca Speed-Zone Map

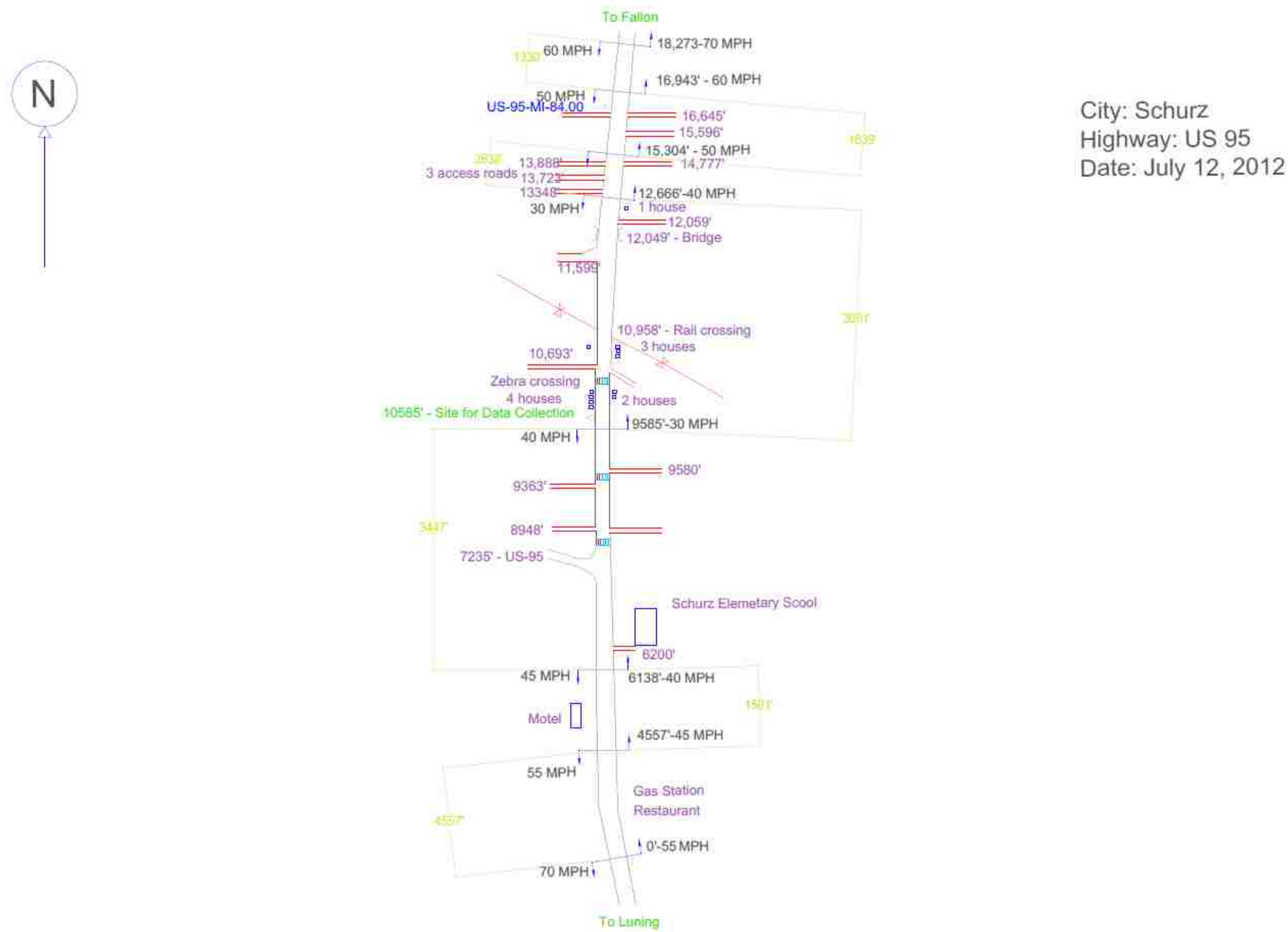

Figure 36 Schurz Speed-Zone Map

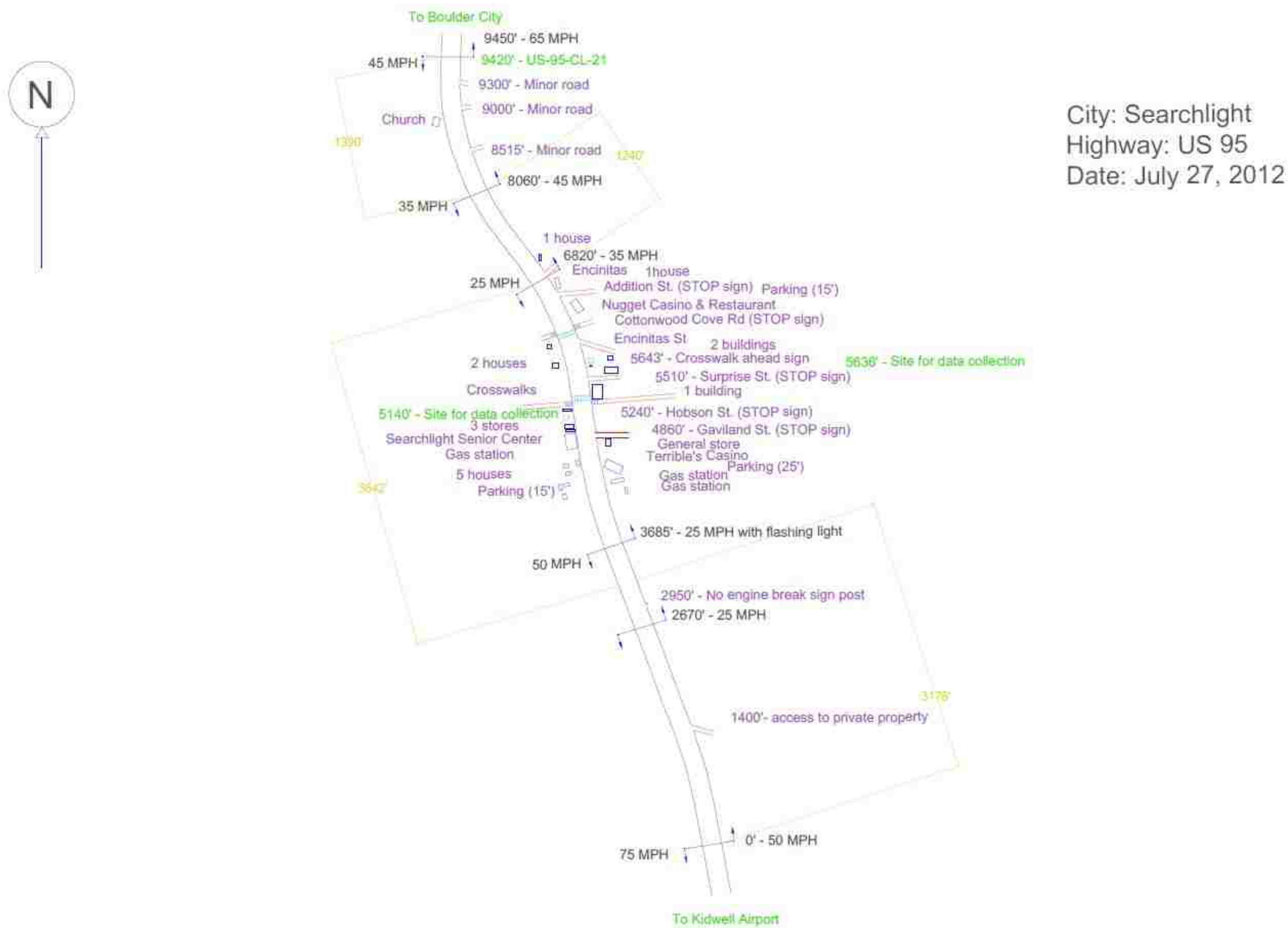

Figure 37 Searchlight Speed-Zone Map

Figure 38 Tonopah Speed-Zone Map

APPENDIX E CUMULATIVE SPOT SPEEDS AND 85TH PERCENTILE SPEEDS

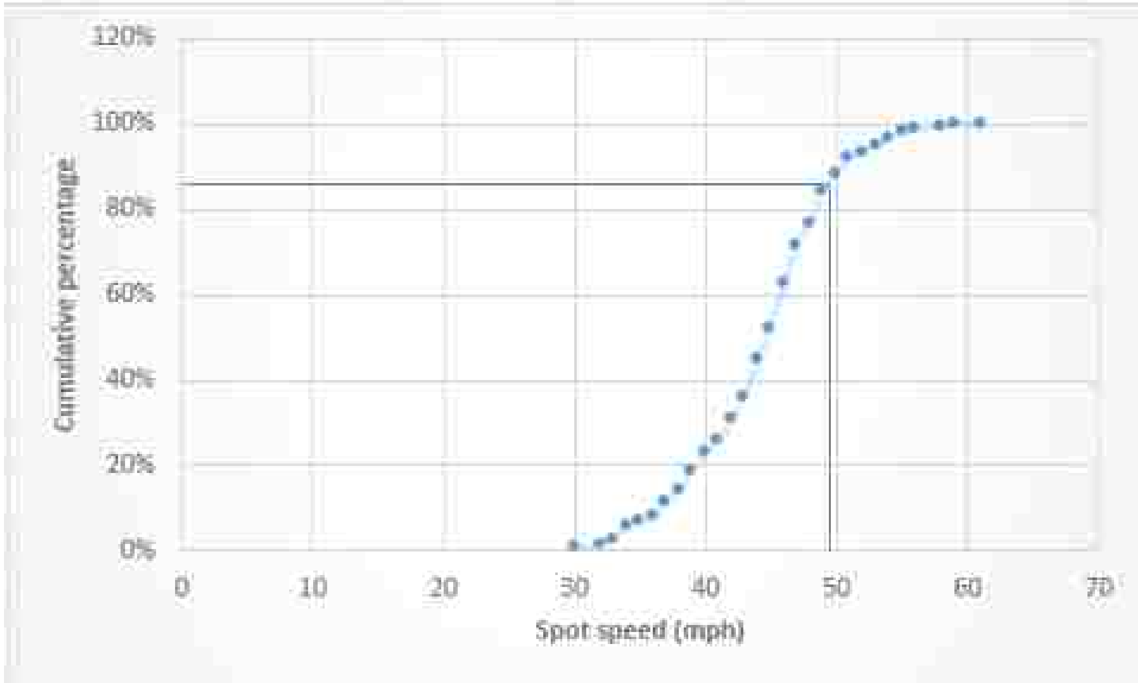

Figure 39 Cumulative Spot Speed – Alamo

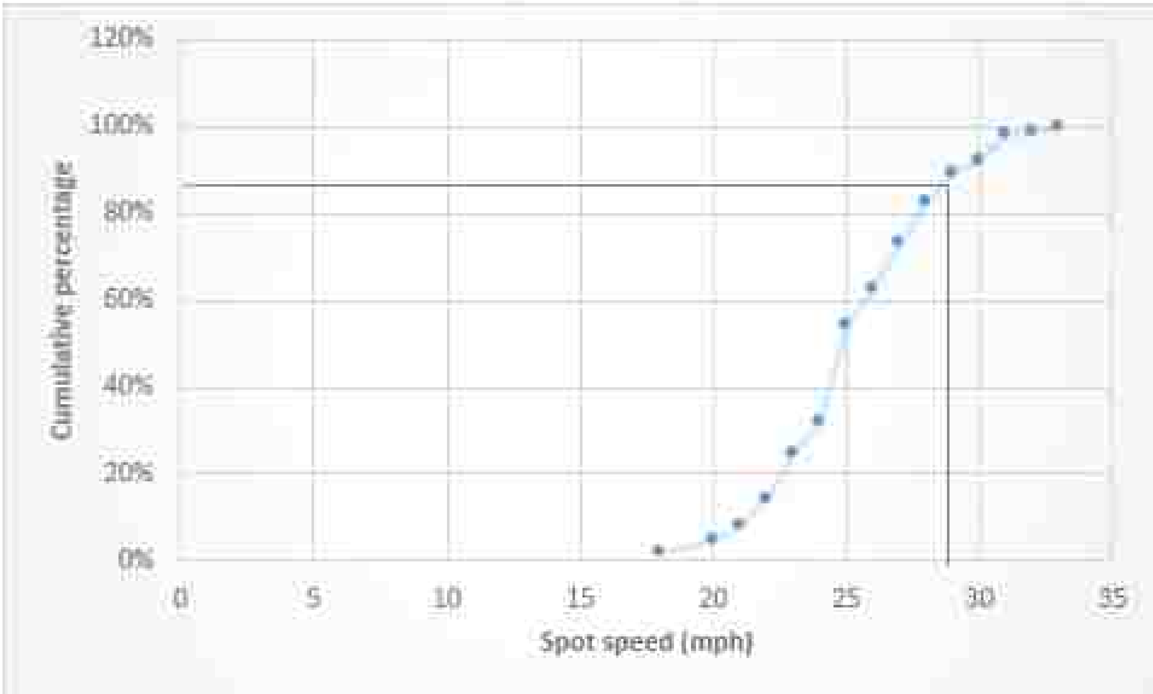

Figure 40 Cumulative Spot Speed – Austin

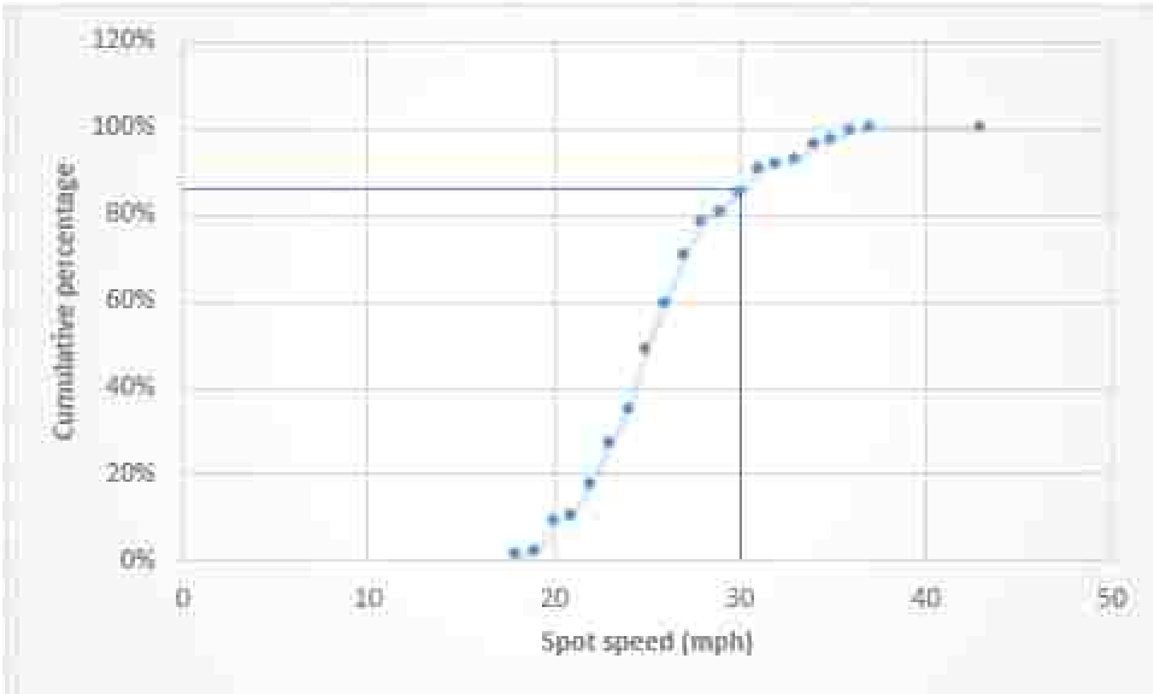

Figure 41 Cumulative Spot Speed – Beatty

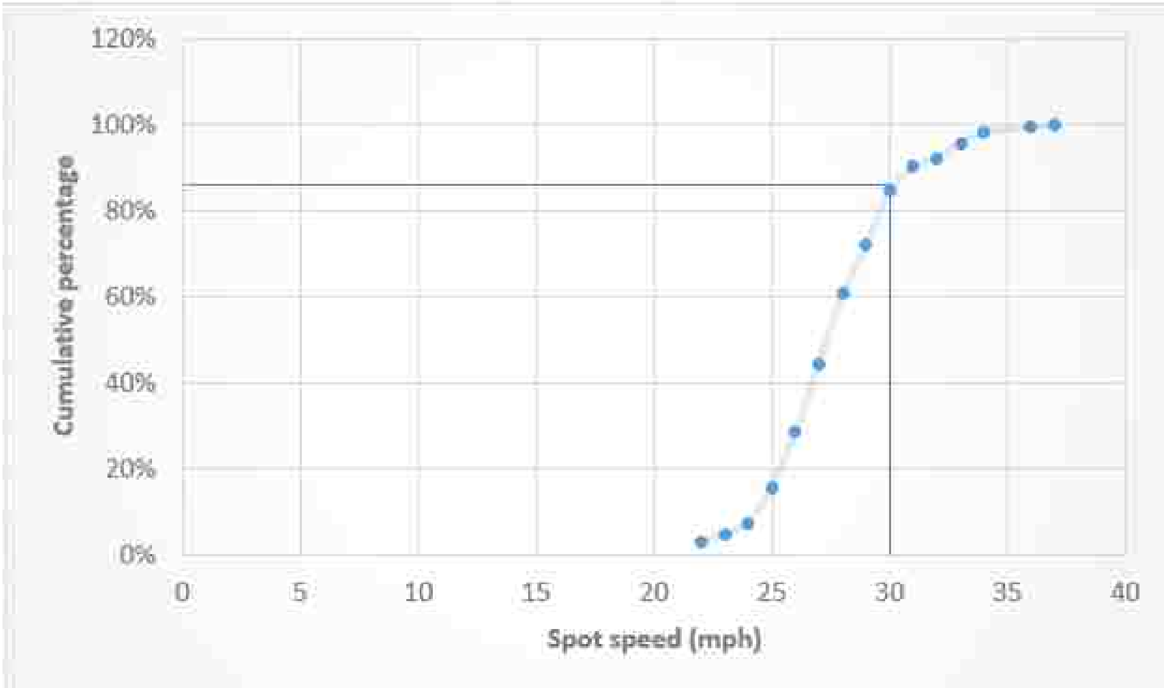

Figure 42 Cumulative Spot Speed – Fernley

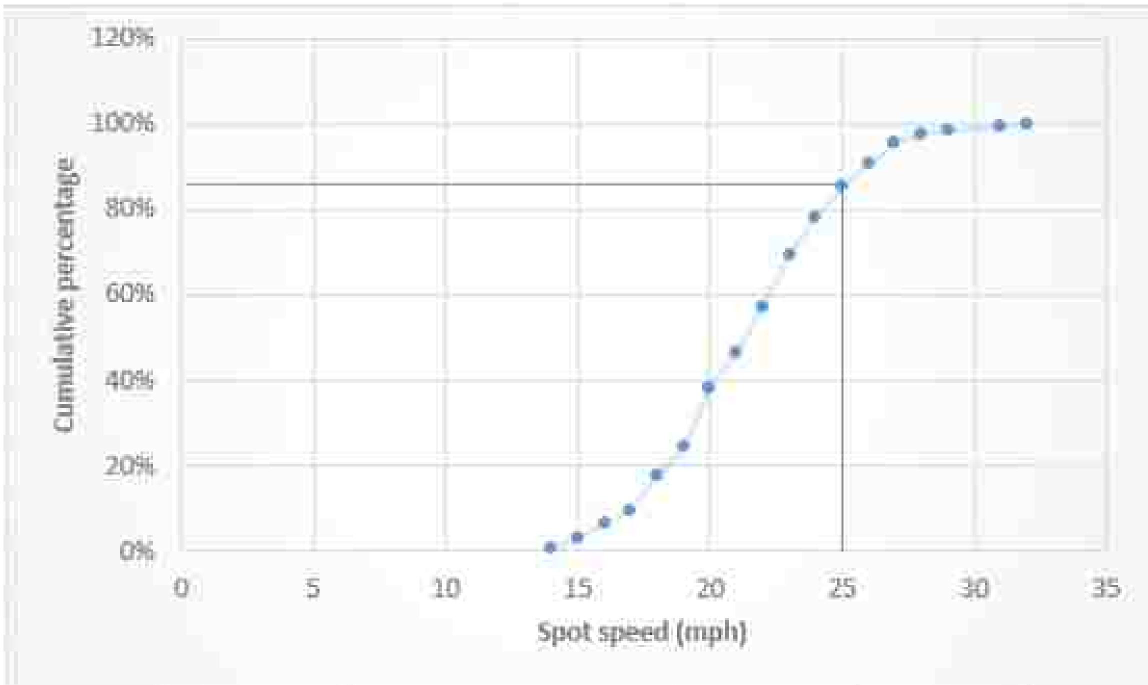

Figure 43 Cumulative Spot Speed – Goldfield

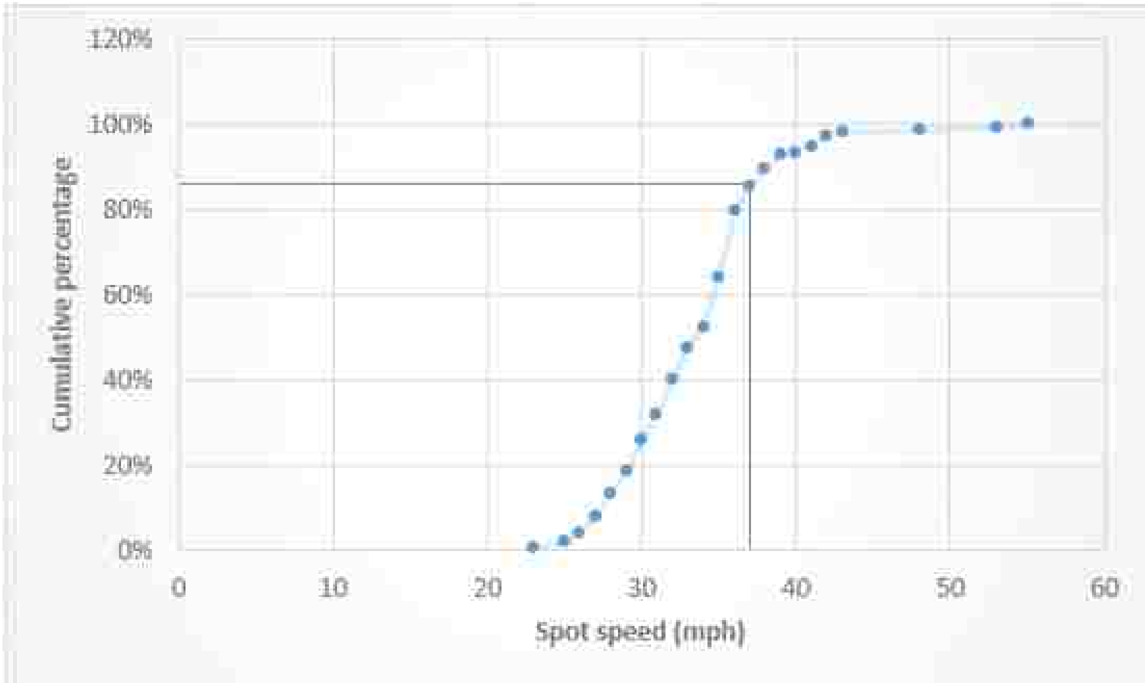

Figure 44 Cumulative Spot Speed – Luning

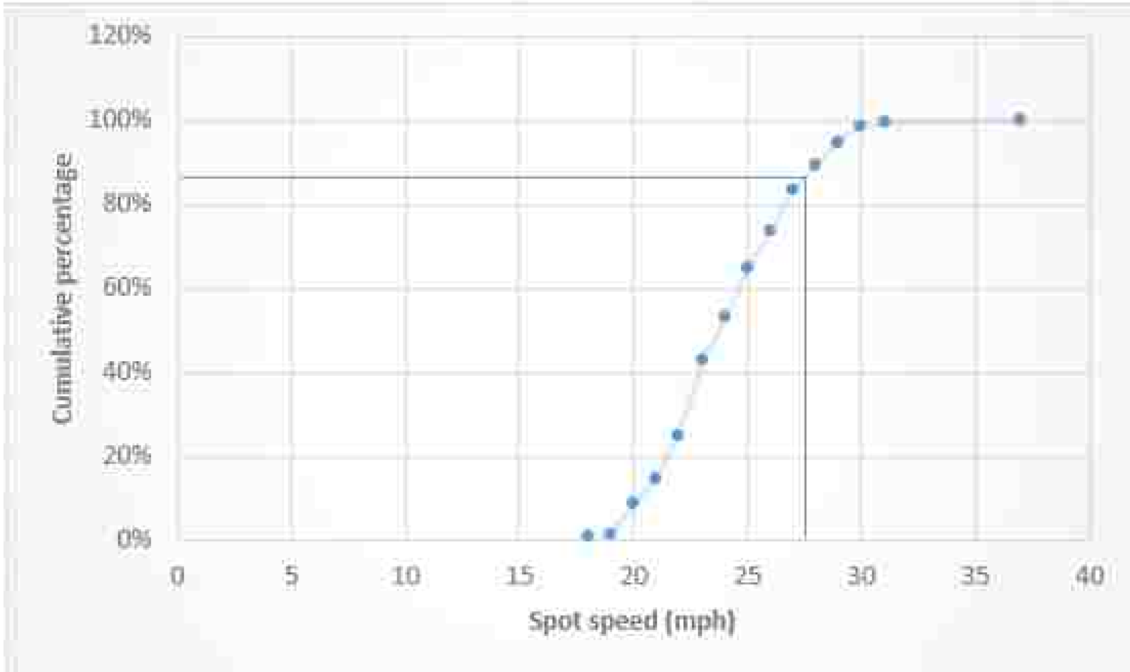

Figure 45 Cumulative Spot Speed – McGill

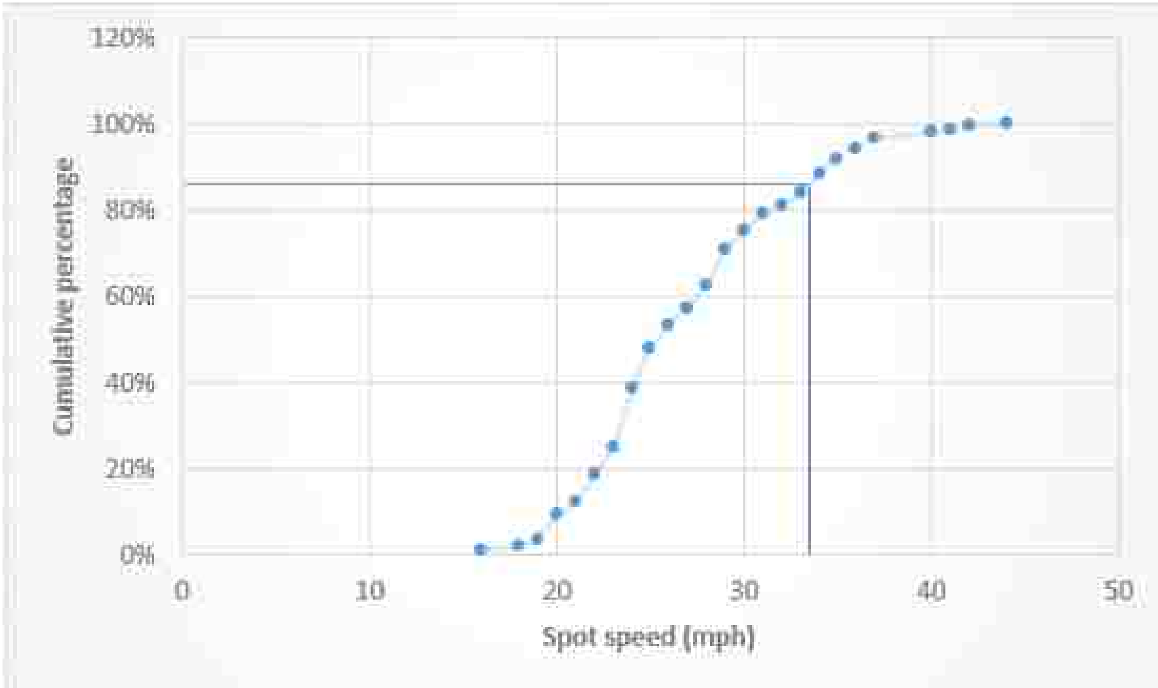

Figure 46 Cumulative Spot Speed – Panaca

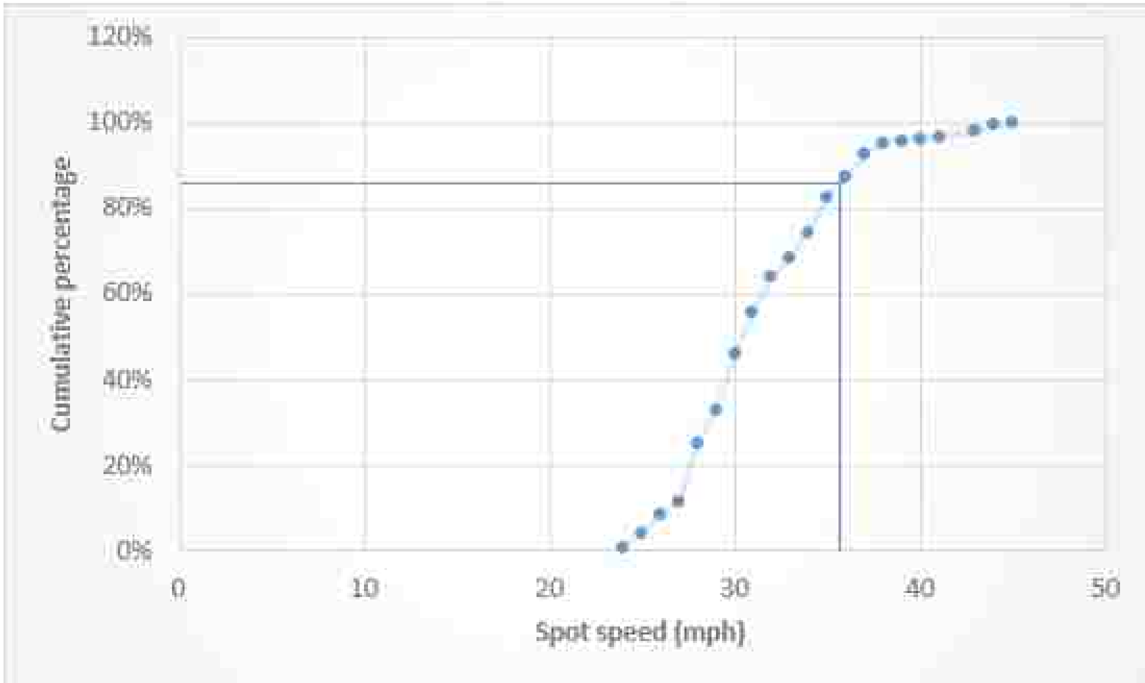

Figure 47 Cumulative Spot Speed – Schurz

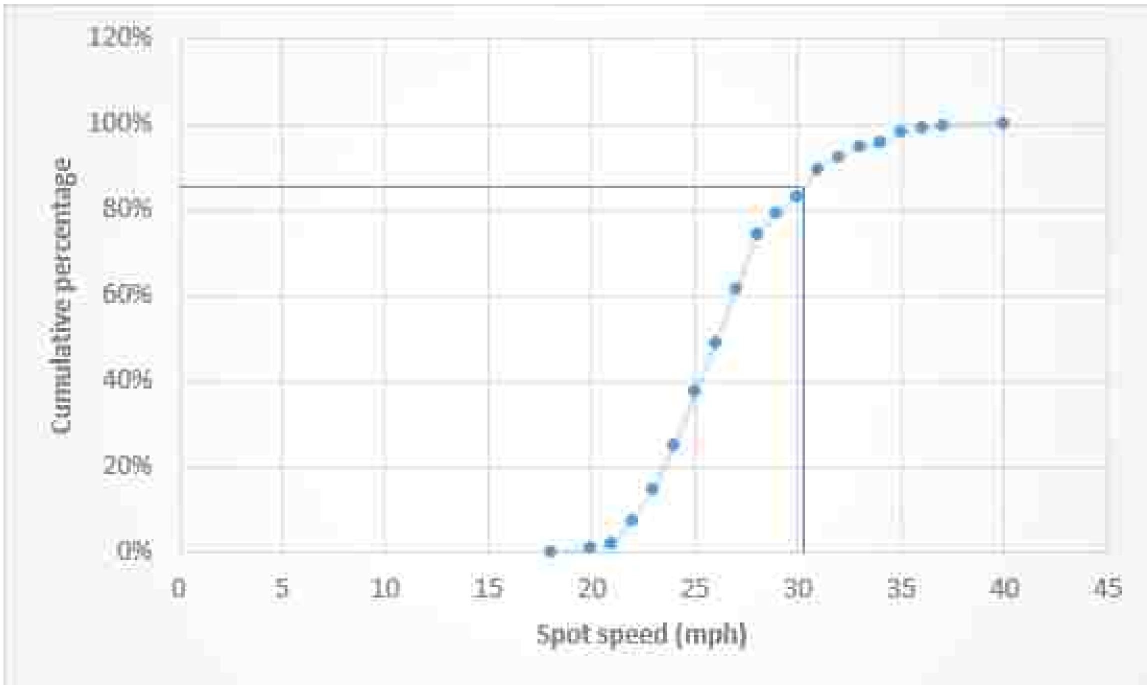

Figure 48 Cumulative Spot Speed – Searchlight

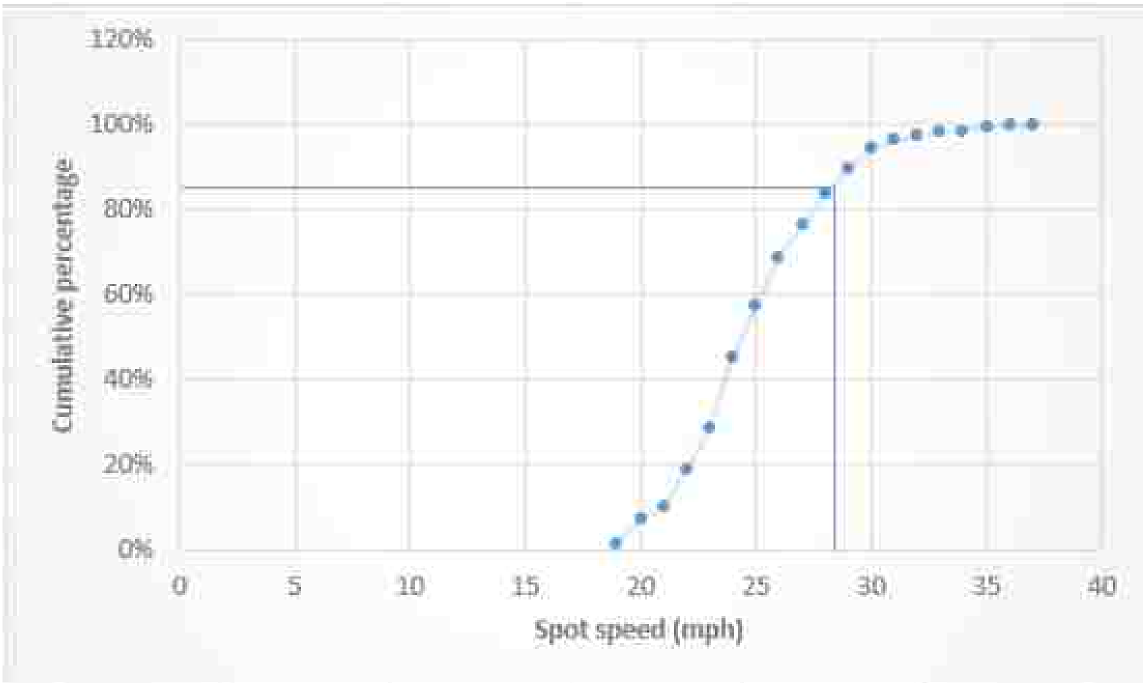

Figure 49 Cumulative Spot Speed – Tonopah

APPENDIX F CORRELATION COEFFICIENTS BETWEEN CRASHES AND SPEED VALUES

Table 60 Correlation between Number of Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

Town	Percentage exceeding posted speed	No. of crashes
Alamo	12%	13
Goldfield	15%	35
McGill	35%	22
Luning	36%	5
Tonopah	43%	25
Austin	46%	30
Beatty	52%	35
Panaca	52%	15
Schurz	54%	26
Searchlight	62%	41
Fernley	84%	90

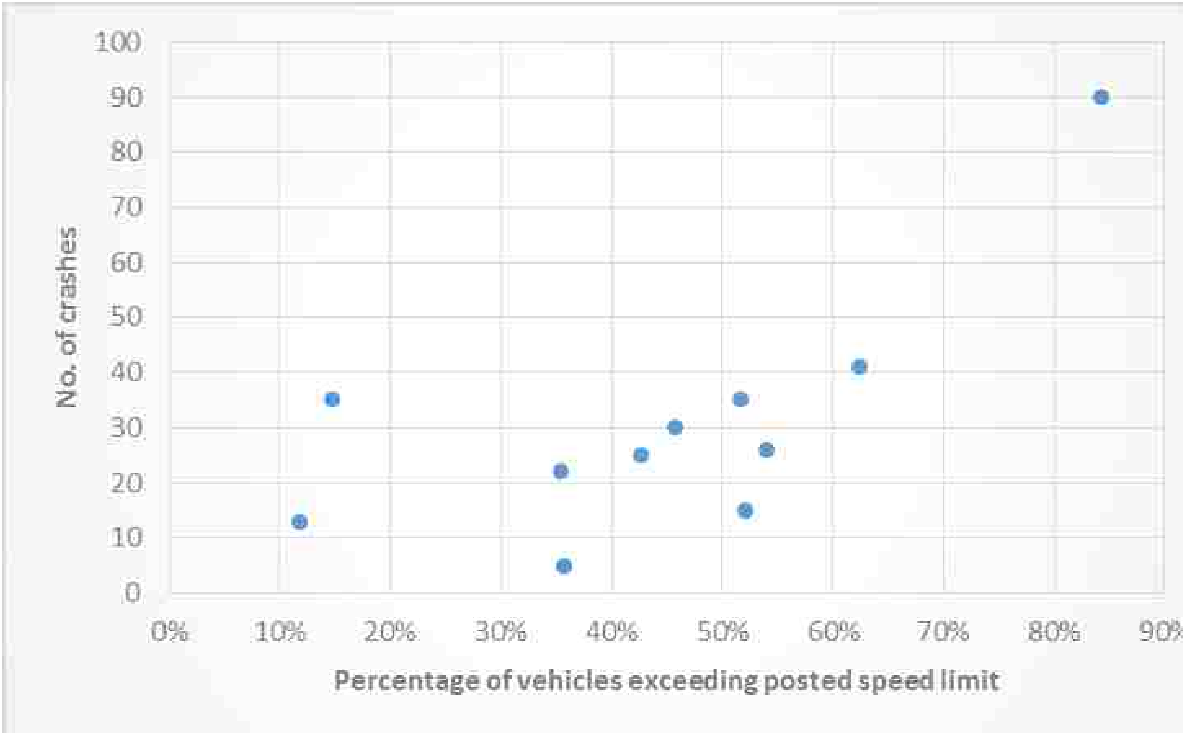

Figure 50 Correlation between Number of Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

Table 61 Correlation between Number of Crashes and Posted Speed Limit

Town	Posted speed (mph)	No. of crashes
Austin	25	30
Beatty	25	35
Fernley	25	90
Goldfield	25	35
McGill	25	22
Panaca	25	15
Searchlight	25	41
Tonopah	25	25
Schurz	30	26
Luning	35	5
Alamo	50	13

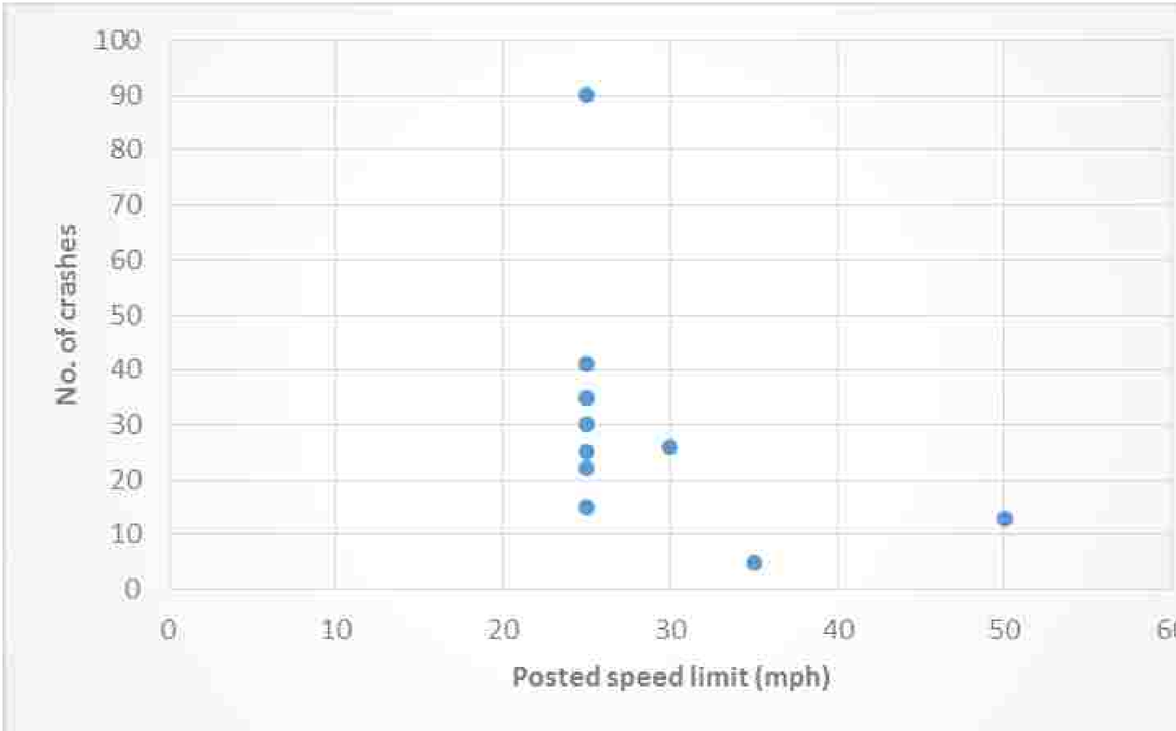

Figure 51 Correlation between Number of Crashes and Posted Speed Limit

Table 62 Correlation between Number of Crashes and 85th Percentile Speed

Town	85th percentile speed (mph)	No. of crashes
Goldfield	25	35
McGill	27	22
Austin	28	30
Tonopah	28	25
Beatty	30	35
Fernley	30	90
Searchlight	30	41
Schurz	35	26
Luning	37	5
Panaca	47	15
Alamo	49	13

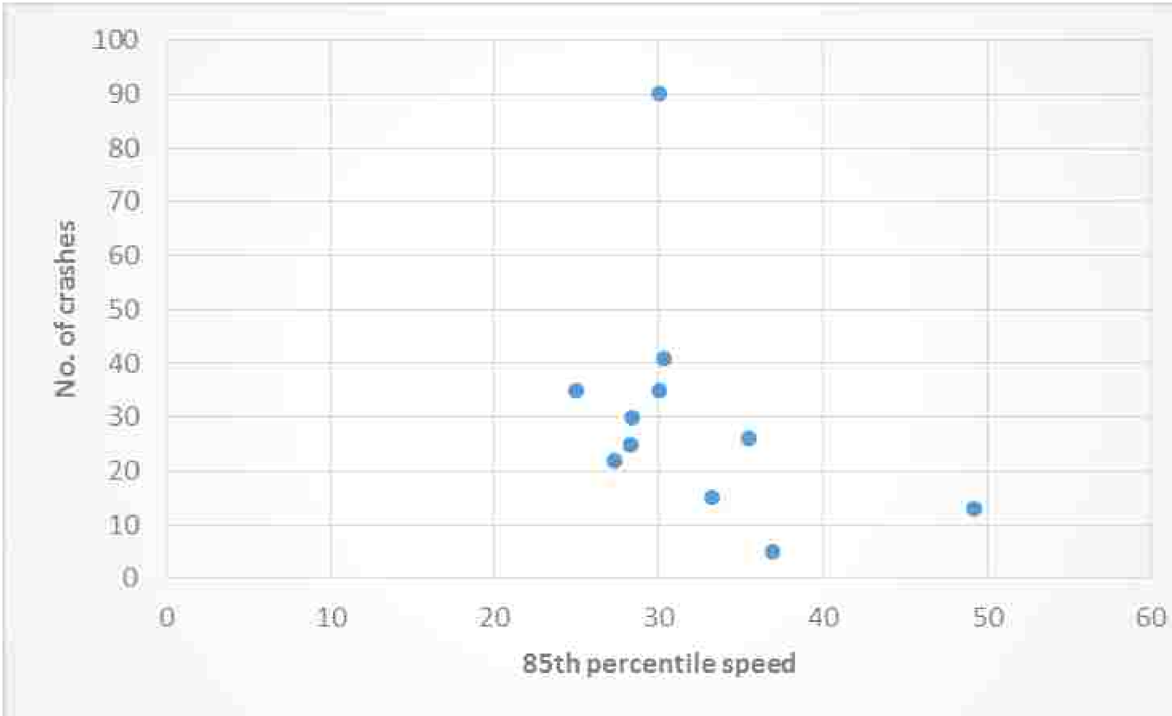

Figure 52 Correlation between Number of Crashes and 85th Percentile Speed

Table 63 Correlation between Number of Crashes and Mean Speed

Town	Mean speed (mph)	No. of crashes
Goldfield	22	35
Tonopah	25	25
McGill	25	22
Beatty	26	35
Austin	26	30
Searchlight	27	41
Fernley	28	90
Schurz	32	26
Luning	34	5
Panaca	44	15
Alamo	45	13

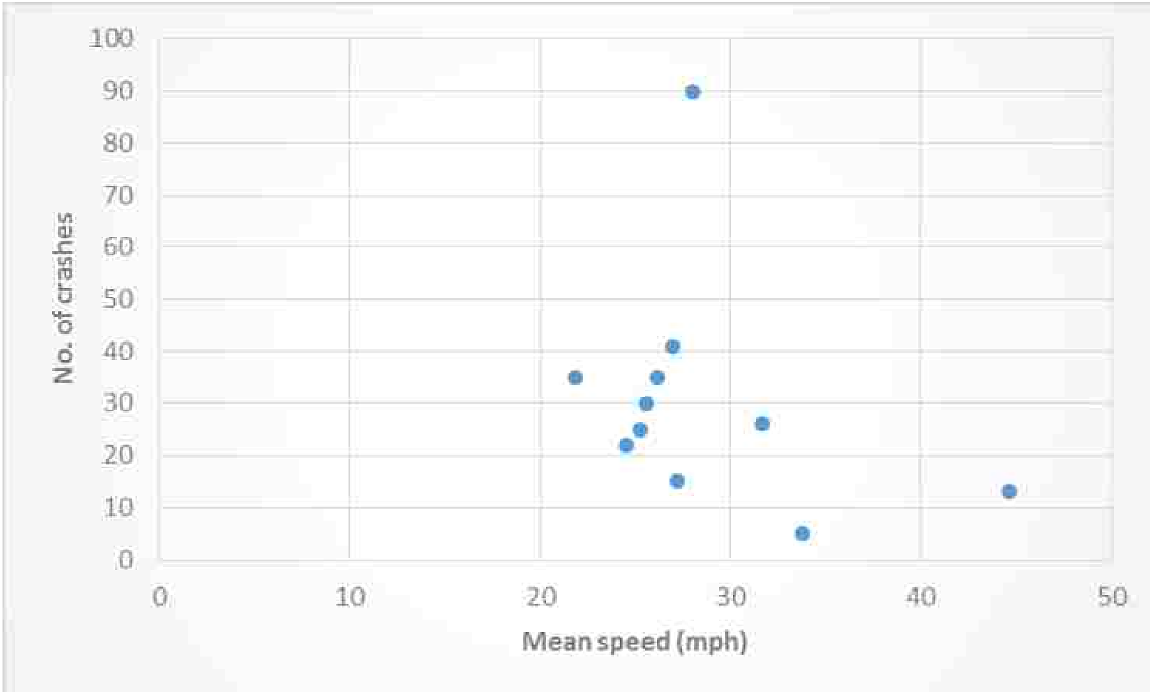

Figure 53 Correlation between Number of Crashes and Mean Speed

Table 64 Correlation between Number of Crashes and Median Speed

Town	Median speed (mph)	No. of crashes
Goldfield	22	35
McGill	24	22
Austin	25	30
Tonopah	25	25
Beatty	26	35
Searchlight	27	41
Fernley	28	90
Schurz	31	26
Luning	34	5
Panaca	43	15
Alamo	45	13

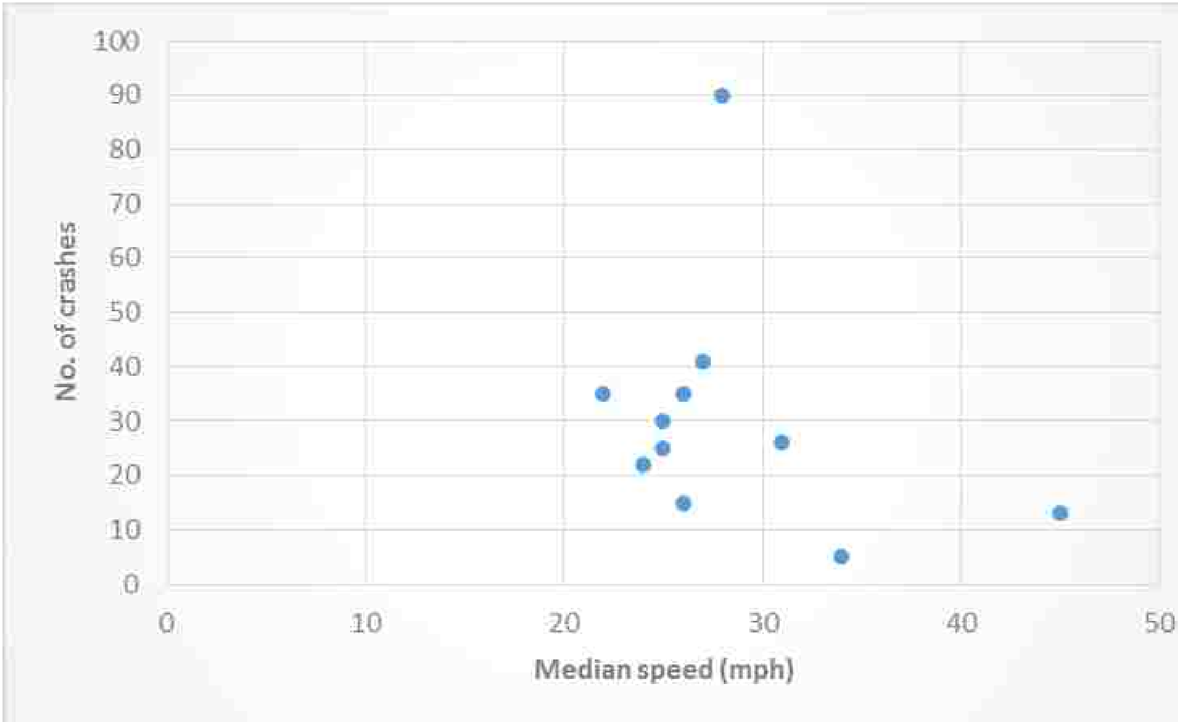

Figure 54 Correlation between Number of Crashes and Median Speed

Table 65 Correlation between Number of Non-fatal Injury-Causing Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

Town	**Percentage exceeding posted speed**	**No. of non-fatal injury-causing crashes**
Alamo	12%	3
Goldfield	15%	13
McGill	35%	8
Luning	36%	0
Tonopah	43%	9
Austin	46%	8
Beatty	52%	8
Panaca	52%	3
Schurz	54%	9
Searchlight	62%	13
Fernley	84%	22

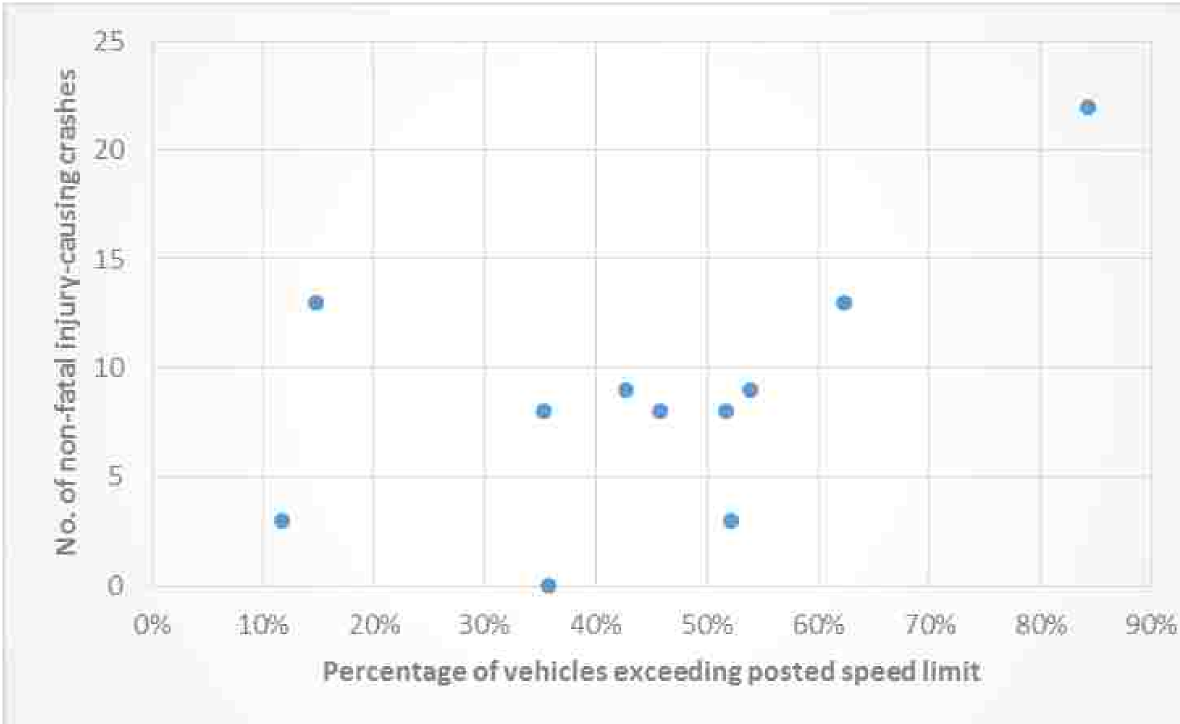

Figure 55 Correlation between Number of Non-fatal Injury-Causing Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

Table 66 Correlation between Number of Non-fatal Injury-Causing Crashes and Posted Speed Limit

Town	Posted speed (mph)	No. of non-fatal injury-causing crashes
Austin	25	8
Beatty	25	8
Fernley	25	22
Goldfield	25	13
McGill	25	8
Panaca	25	3
Searchlight	25	13
Tonopah	25	9
Schurz	30	9
Luning	35	0
Alamo	50	3

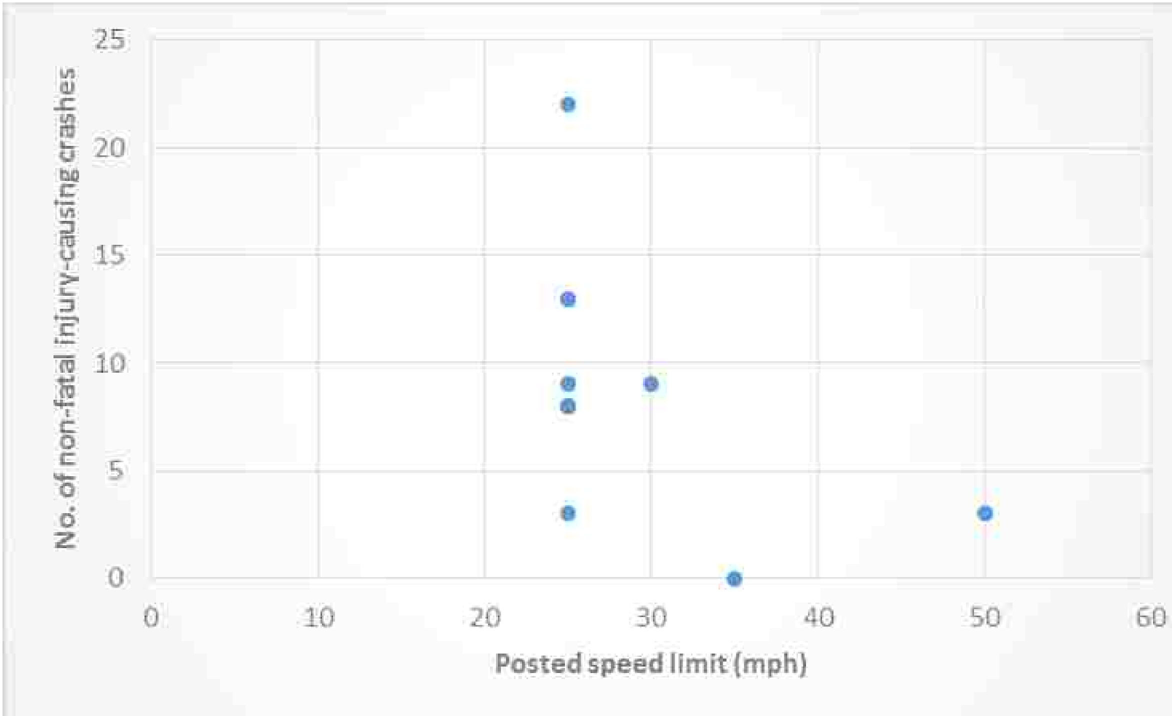

Figure 56 Correlation between Number of Non-fatal Injury-Causing Crashes and Posted Speed Limit

Table 67 Correlation between Number of Non-fatal Injury-Causing Crashes and 85th Percentile Speed

Town	85th percentile speed (mph)	No. of non-fatal injury-causing crashes
Goldfield	25	13
McGill	27	8
Tonopah	28	9
Austin	28	8
Fernley	30	22
Beatty	30	8
Searchlight	30	13
Panaca	33	3
Schurz	35	9
Luning	37	0
Alamo	49	3

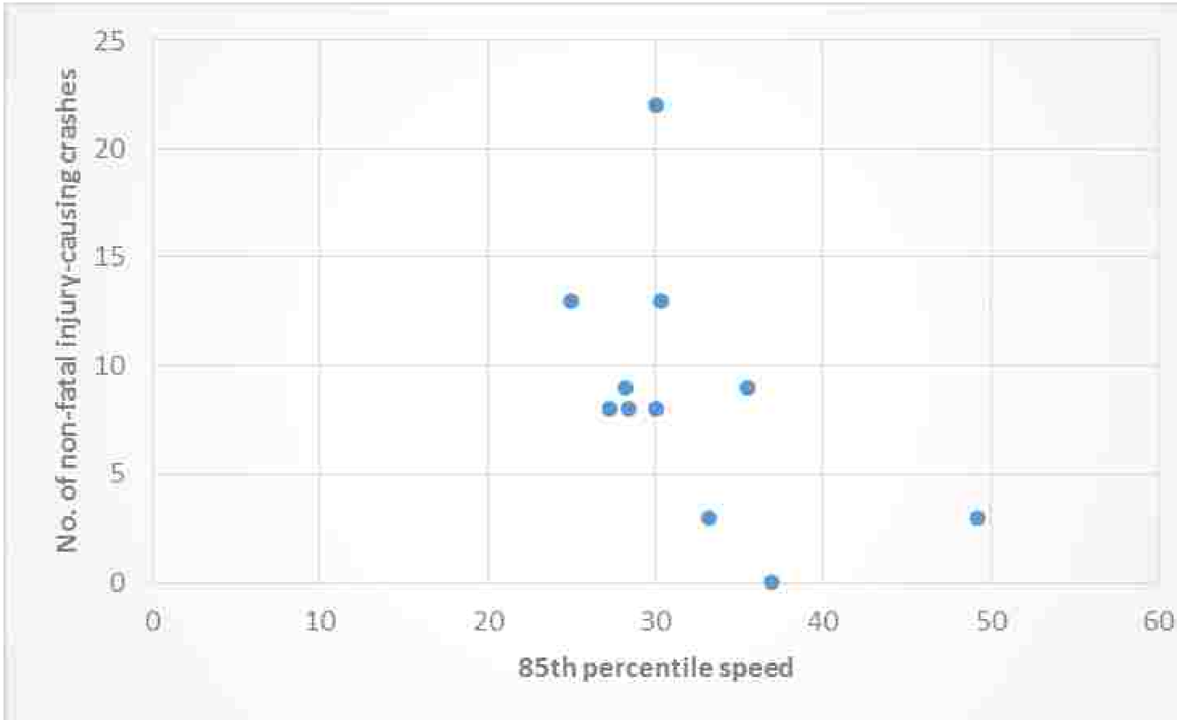

Figure 57 Correlation between Number of Non-fatal Injury-Causing Crashes and 85th Percentile Speed

Table 68 Correlation between Number of Non-fatal Injury-Causing Crashes and Mean Speed

Town	Mean speed (mph)	No. of non-fatal injury-causing crashes
Goldfield	22	13
McGill	25	8
Tonopah	25	9
Austin	26	8
Beatty	26	8
Searchlight	27	13
Panaca	27	3
Fernley	28	22
Schurz	32	9
Luning	34	0
Alamo	45	3

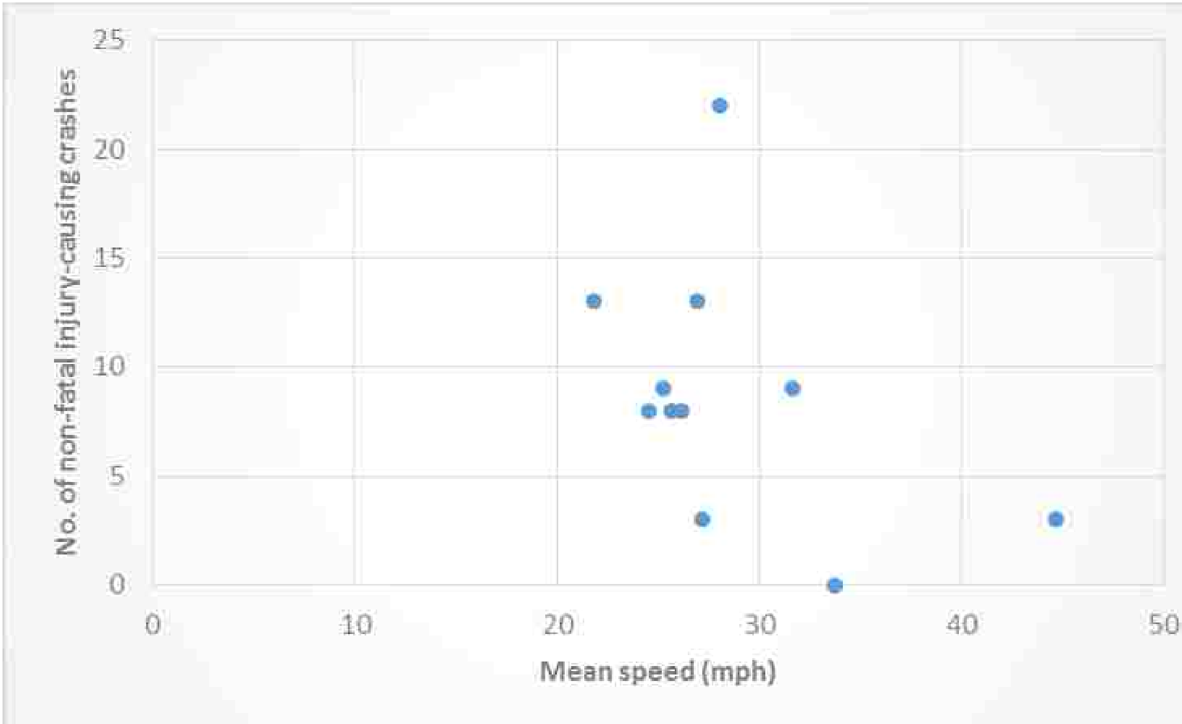

Figure 58 Correlation between Number of Non-fatal Injury-Causing Crashes and Mean Speed

Table 69 Correlation between Number of Non-fatal Injury-Causing Crashes and Median Speed

Town	Median speed (mph)	No. of non-fatal injury-causing crashes
Goldfield	22	13
McGill	24	8
Austin	25	8
Tonopah	25	9
Beatty	26	8
Panaca	26	3
Searchlight	27	13
Fernley	28	22
Schurz	31	9
Luning	34	0
Alamo	45	3

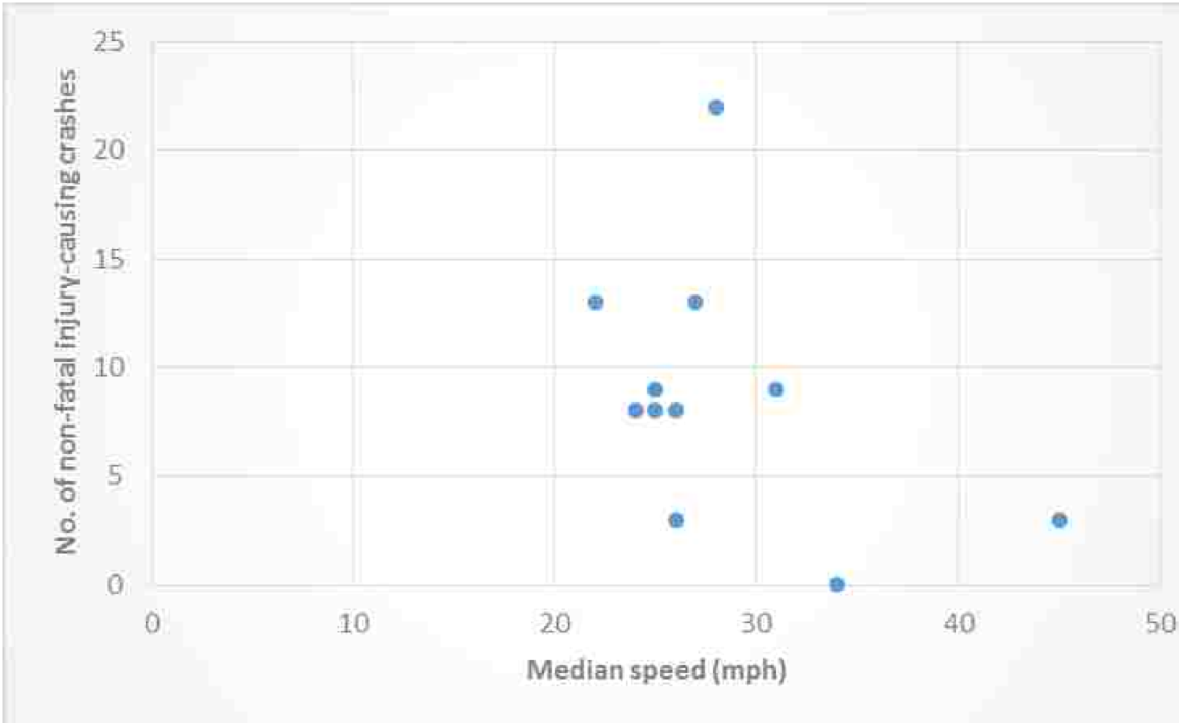

Figure 59 Correlation between Number of Non-fatal Injury-Causing Crashes and Median Speed

Table 70 Correlation between Number of Injuries and Percentage of Vehicles Exceeding Posted Speed Limit

Town	Percentage exceeding posted speed	No. of injuries
Alamo	12%	9
Goldfield	15%	14
McGill	35%	9
Luning	36%	0
Tonopah	43%	15
Austin	46%	10
Beatty	52%	11
Panaca	52%	3
Schurz	54%	12
Searchlight	62%	17
Fernley	84%	34

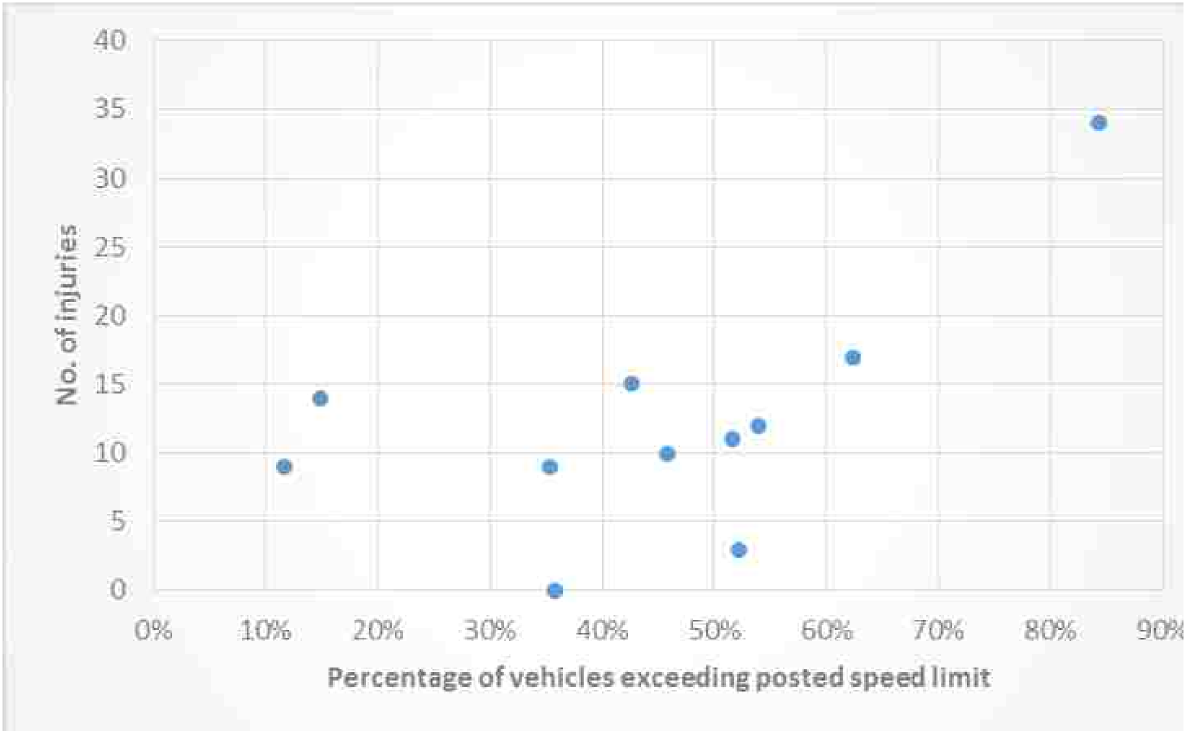

Figure 60 Correlation between Number of Injuries and Percentage of Vehicles Exceeding Posted Speed Limit

Table 71 Correlation between Number of Injuries and Posted Speed Limit

Town	Posted speed (mph)	No. of injuries
Austin	25	10
Beatty	25	11
Fernley	25	34
Goldfield	25	14
McGill	25	9
Panaca	25	3
Searchlight	25	17
Tonopah	25	15
Schurz	30	12
Luning	35	0
Alamo	50	9

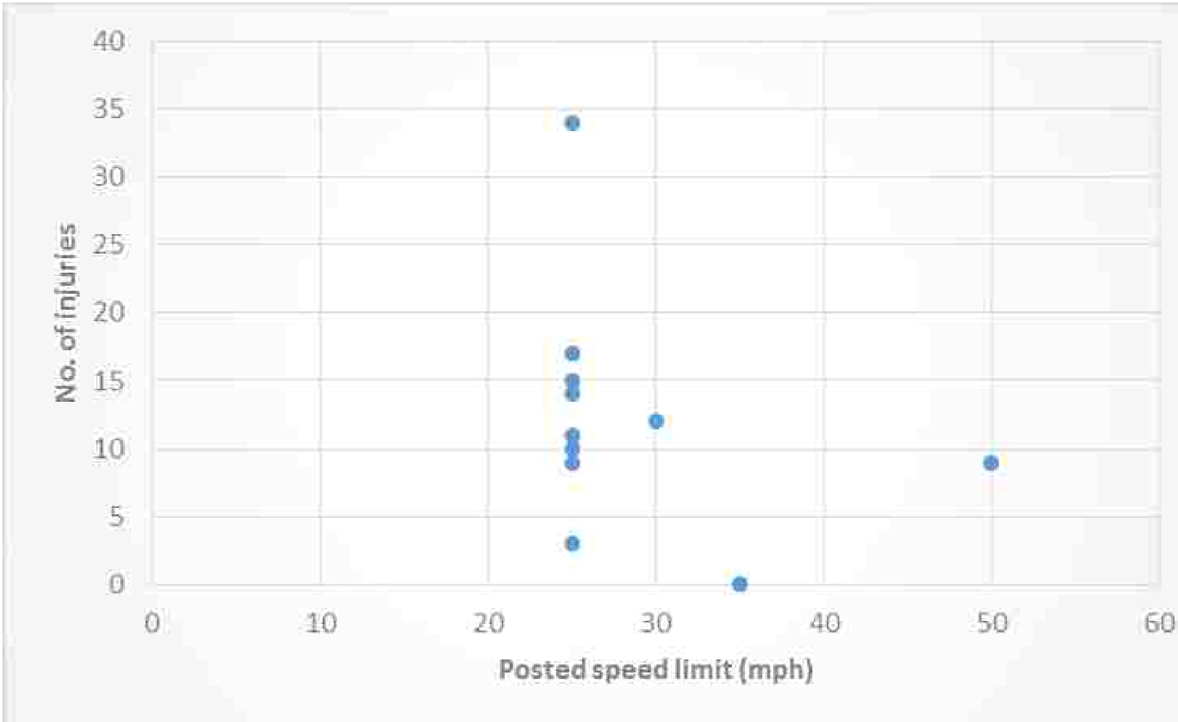

Figure 61 Correlation between Number of Injuries and Posted Speed Limit

Table 72 Correlation between Number of Injuries and 85th Percentile Speed

Town	85^{th} percentile speed (mph)	No. of injuries
Goldfield	25	14
McGill	27	9
Tonopah	28	15
Austin	28	10
Fernley	30	34
Beatty	30	11
Searchlight	30	17
Panaca	33	3
Schurz	35	12
Luning	37	0
Alamo	49	9

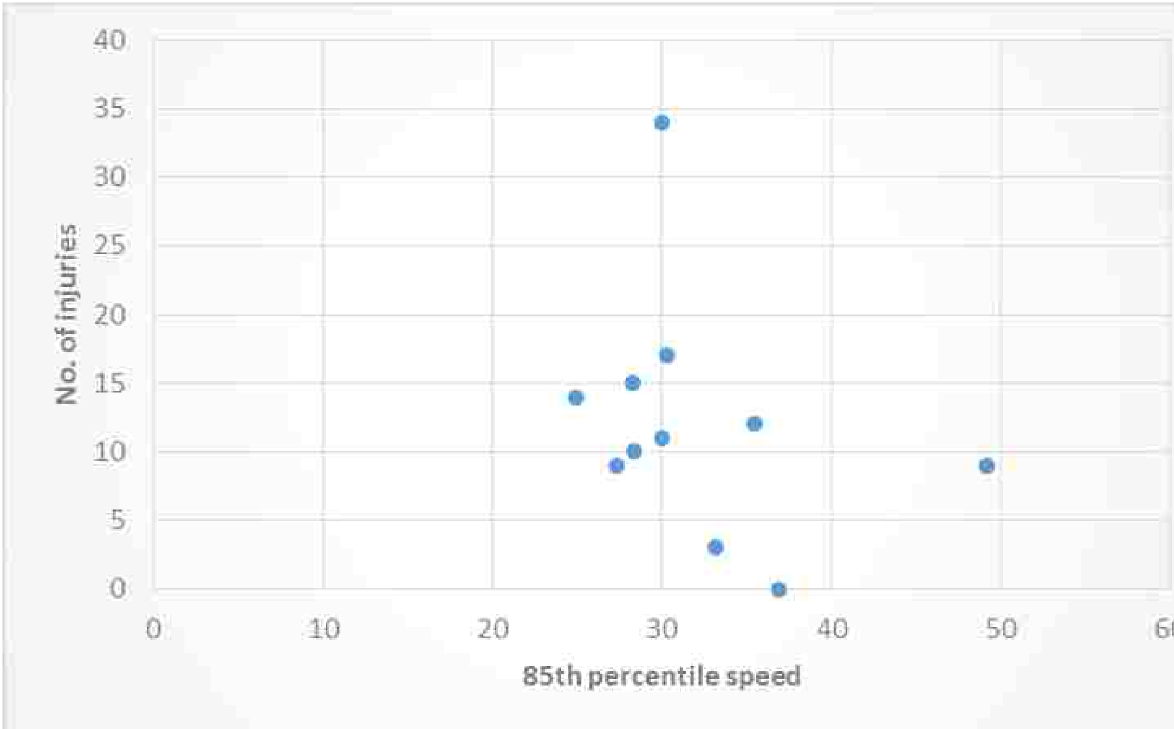

Figure 62 Correlation between Number of Injuries and 85th Percentile Speed

Table 73 Correlation between Number of Injuries and Mean Speed

Town	Mean speed (mph)	No. of injuries
Goldfield	22	14
McGill	25	9
Tonopah	25	15
Austin	26	10
Beatty	26	11
Searchlight	27	17
Panaca	27	3
Fernley	28	34
Schurz	32	12
Luning	34	0
Alamo	45	9

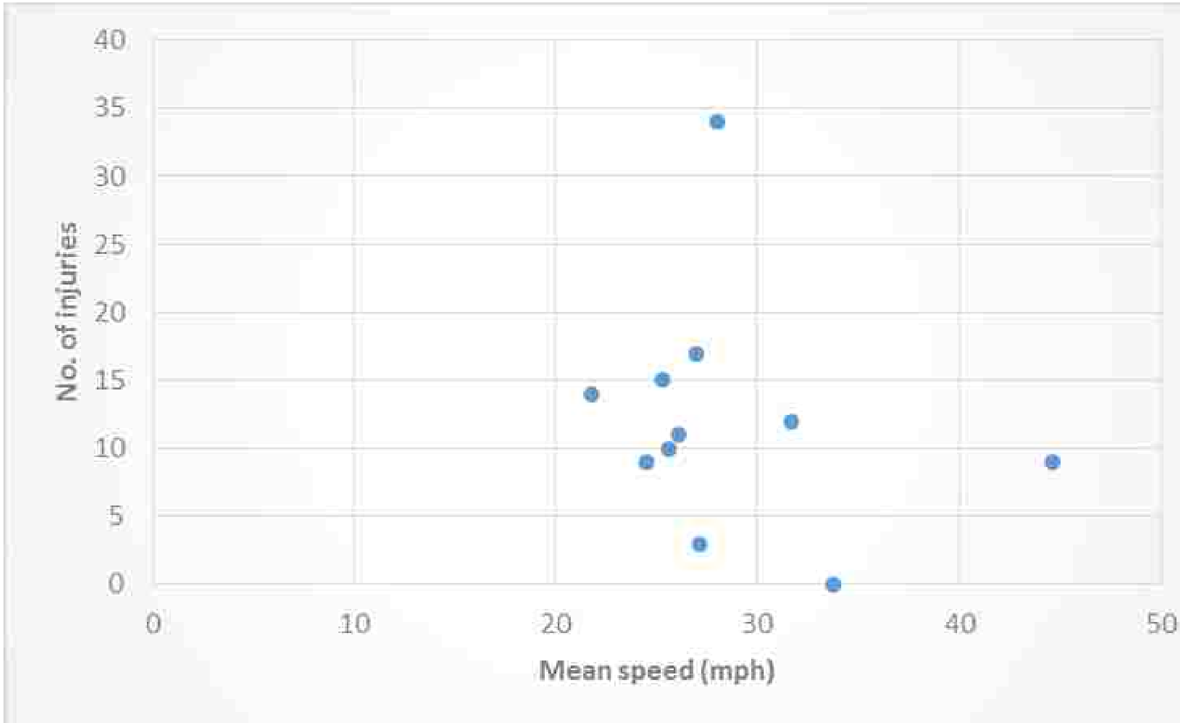

Figure 63 Correlation between Number of Injuries and Mean Speed

Table 74 Correlation between Number of Injuries and Median Speed

Town	Median speed (mph)	No. of Injuries
Goldfield	22	14
McGill	24	9
Austin	25	10
Tonopah	25	15
Beatty	26	11
Panaca	26	3
Searchlight	27	17
Fernley	28	34
Schurz	31	12
Luning	34	0
Alamo	45	9

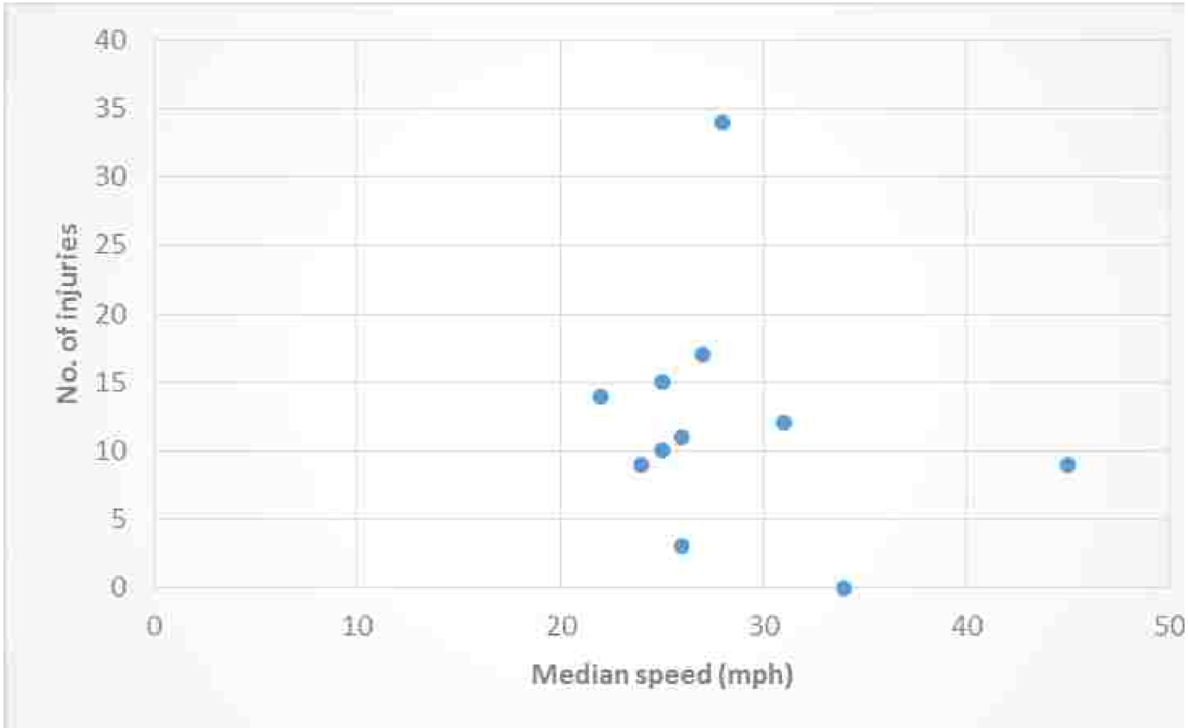

Figure 64 Correlation between Number of Injuries and Median Speed

Table 75 Correlation between Number of PDO Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

Town	Percentage exceeding posted speed	PDO crashes
Alamo	12%	10
Goldfield	15%	21
McGill	35%	14
Luning	36%	5
Tonopah	43%	16
Austin	46%	22
Beatty	52%	27
Panaca	52%	12
Schurz	54%	17
Searchlight	62%	28
Fernley	84%	66

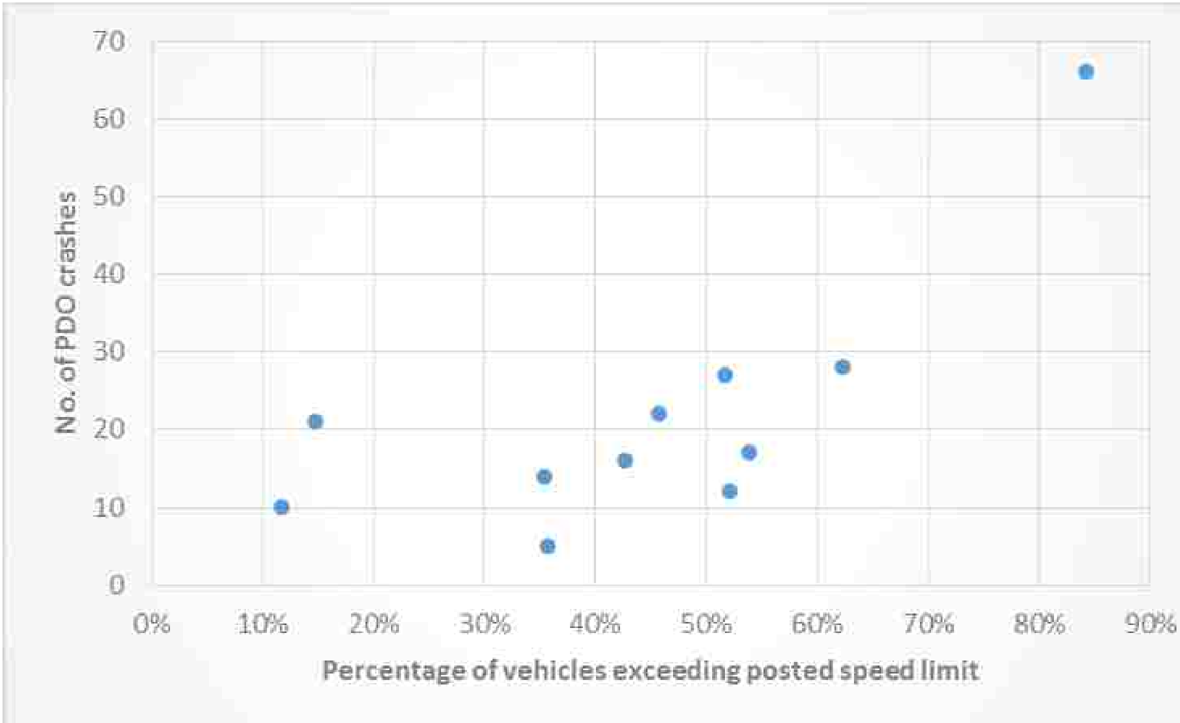

Figure 65 Correlation between Number of PDO Crashes and Percentage of Vehicles Exceeding Posted Speed Limit

Table 76 Correlation between Number of PDO Crashes and Posted Speed Limit

Town	Posted speed (mph)	PDO crashes
Austin	25	22
Beatty	25	27
Fernley	25	66
Goldfield	25	21
McGill	25	14
Panaca	25	12
Searchlight	25	28
Tonopah	25	16
Schurz	30	17
Luning	35	5
Alamo	50	10

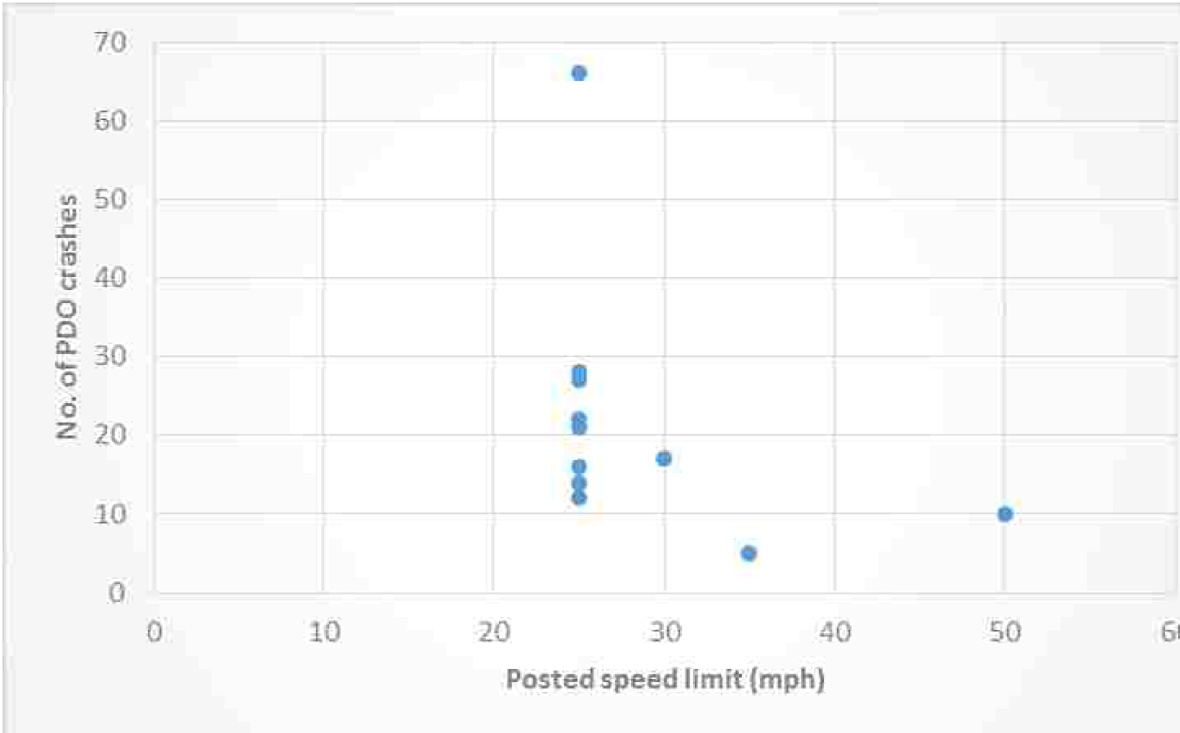

Figure 66 Correlation between Number of PDO Crashes and Posted Speed Limit

Table 77 Correlation between Number of PDO Crashes and 85th Percentile Speed

Town	85^{th} percentile speed (mph)	PDO crashes
Goldfield	25	21
McGill	27	14
Tonopah	28	16
Austin	28	22
Fernley	30	66
Beatty	30	27
Searchlight	30	28
Panaca	33	12
Schurz	35	17
Luning	37	5
Alamo	49	10

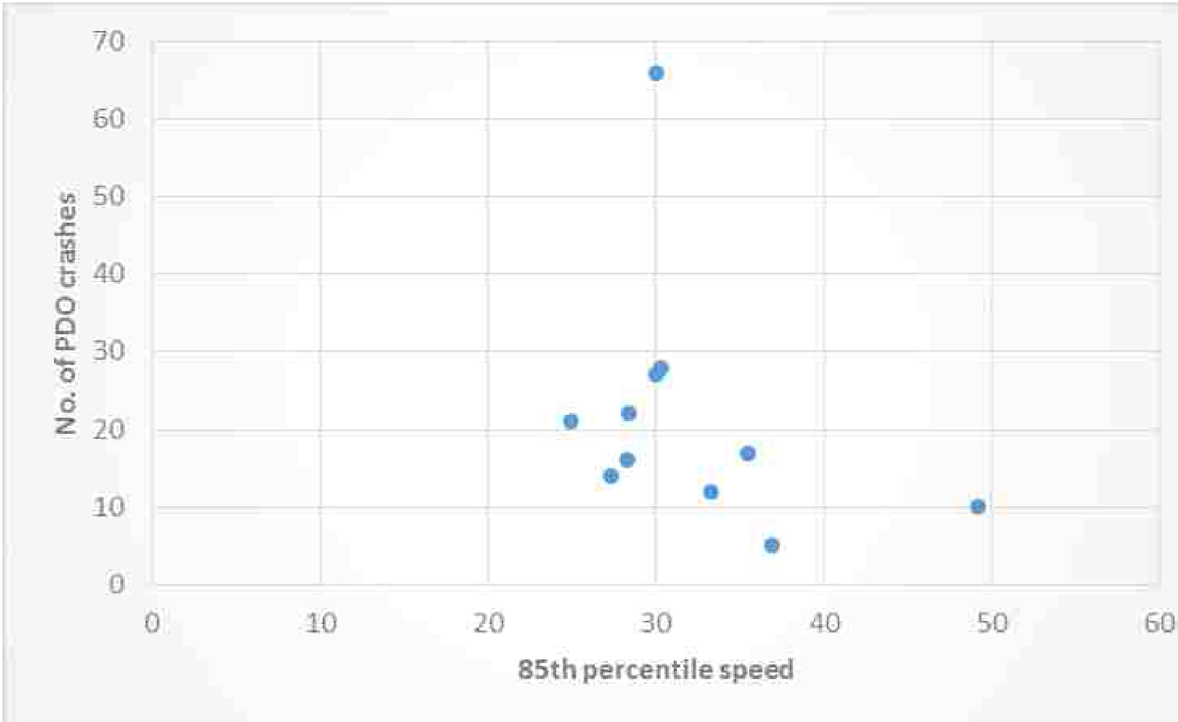

Figure 67 Correlation between Number of PDO Crashes and 85th Percentile Speed

Table 78 Correlation between Number of PDO Crashes and Mean Speed

Town	Mean speed (mph)	PDO crashes
Goldfield	22	21
McGill	25	14
Tonopah	25	16
Austin	26	22
Beatty	26	27
Searchlight	27	28
Panaca	27	12
Fernley	28	66
Schurz	32	17
Luning	34	5
Alamo	45	10

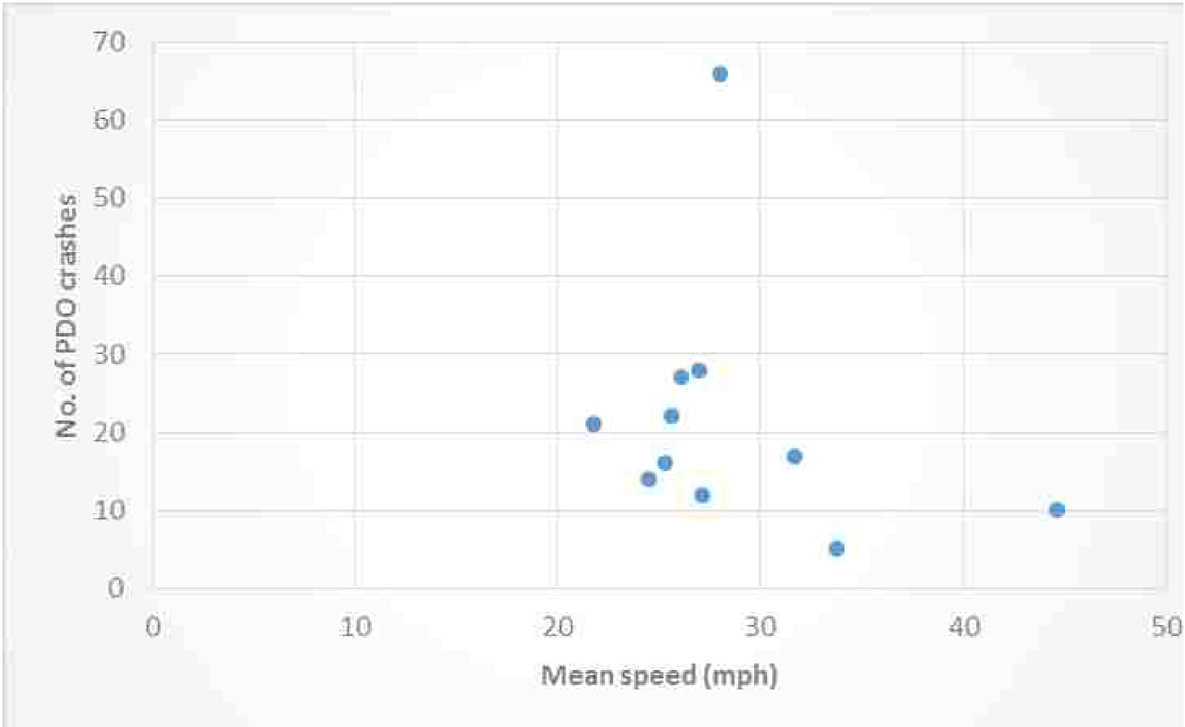

Figure 68 Correlation between Number of PDO Crashes and Mean Speed

Table 79 Correlation between Number of PDO Crashes and Median Speed

Town	Median speed (mph)	PDO crashes
Goldfield	22	21
McGill	24	14
Austin	25	22
Tonopah	25	16
Beatty	26	27
Panaca	26	12
Searchlight	27	28
Fernley	28	66
Schurz	31	17
Luning	34	5
Alamo	45	10

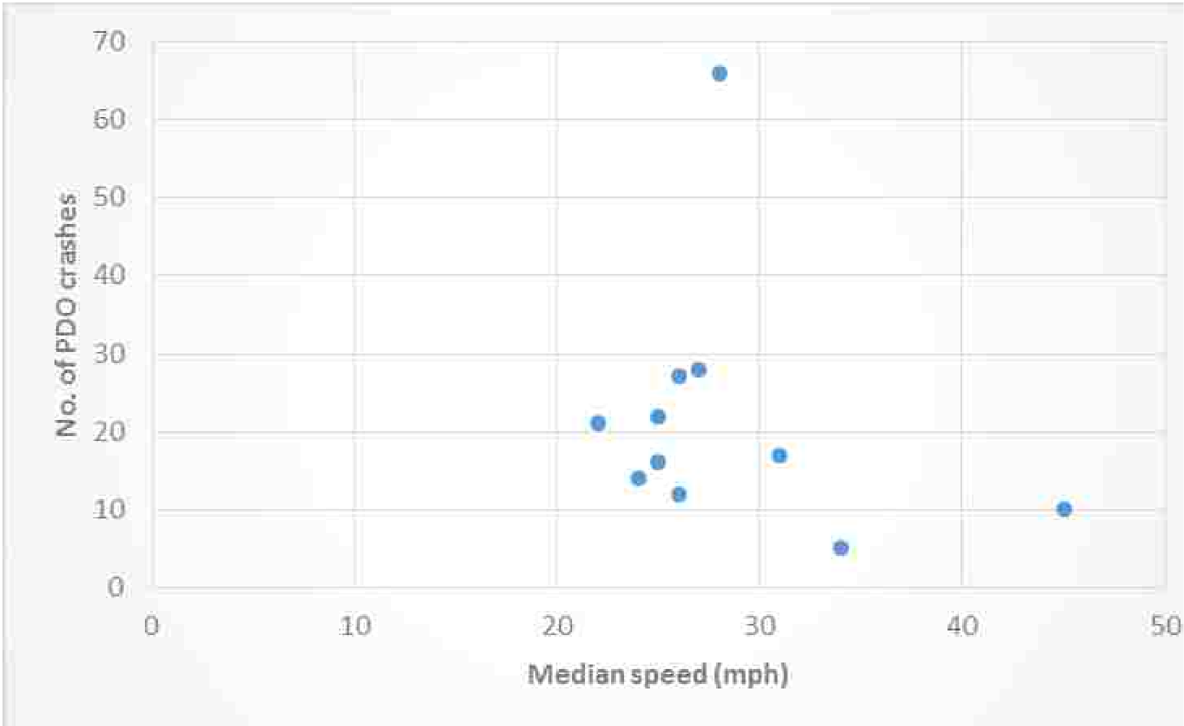

Figure 69 Correlation between Number of PDO Crashes and Median Speed

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:

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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

Email: pramen.shrestha@unlv.edu

Fax Number: 702-895-4966

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.

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