MODELING OF 85^{TH} PERCENTILE SPEED FOR RURAL HIGHWAYS FOR ENHANCED TRAFFIC SAFETY

FINAL REPORT - FHWA-OK-11-07

ODOT SPR ITEM NUMBER 2211

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March 2011

TECHNICAL REPORT DOCUMENTATION PAGE

1. REPORT NO. FHWA-OK-11-07	2. GOVERNMENT EVALUATEION NO.	3. RECIPIENTS CATALOG NO.
4. TITLE AND SUBTITLE **Modeling of 85th Percentile Speed for Rural Highways for Enhanced Traffic Safety**		5. REPORT DATE March 2011 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Dharamveer Singh, Musharraf M. Zaman, and Luther White		8. PERFORMING ORGANIZATION REPORT
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Civil Engineering and Environmental Science University of Oklahoma Norman, OK 73019		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. ODOT SPR Item Number 2211
12. SPONSORING AGENCY NAME AND ADDRESS Oklahoma Department of Transportation Planning and Research Division 200 N.E. 21st Street, Room 3A7 Oklahoma City, OK 73105		13. TYPE OF REPORT AND PERIOD COVERED Final Report October 2008 – December 2010 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Traffic operation on two-lane rural highways and setting posted speed limits are some of the difficult tasks faced by the Oklahoma Department of Transportation (ODOT) and other transportation agencies. The present study was undertaken to develop artificial neural network (ANN) models to predict 85th percentile speed (V_{85}) of two-lane rural highways in Oklahoma. Several input parameters, namely, roadway characteristics, traffic conditions, and accident experience were considered in developing the ANN models. Physical characteristics of road include, surface width (SW), shoulder type (ST), and shoulder width (SHW). Traffic parameters cover average daily traffic (ADT), posted speed (PS), and V_{85}. Pavement condition includes skid number (SN), and international roughness index (IRI). The location collision rate, statewide collision rate (overall, fatal, and injury), and percentage unsafe speed drivers (USD) were covered in the accident data.

Data from a total of 241 two-lane rural highway sites were collected and used in developing the ANN models. The following four different ANN models were developed: Model 1 includes Posted Speed but does not include Accident Data; Model 2 includes neither Posted Speed nor Accident Data; Model 3 includes both Posted Speed and Accident Data; and Model 4 does not include Posted Speed but includes Accident Data. Model 1 included physical characteristics of road, and traffic parameters including PS, while Model 2 covered all the parameters included in Model 1 except PS. Similarly, Model 3 considered accident data with all the parameters included in Model 1. Model 4 used all the parameters included in Model 3 excluding PS. The developed models provided an overall accuracy of more than 90%. For example, Model 1 and Model 2 developed without accident data gave an overall accuracy of 97%, and 91.5%, respectively. Similarly, Model 3 and Model 4 developed using accident data resulted in an overall accuracy of 97.5%, and 94.1%, respectively. It was found that inclusion of accident data improves the performance of the model only marginally.

The present study was pursued with the goal that ANN models for V_{85} would provide a cost effective alternative for estimating site-specific V_{85} of two-lane rural highways in Oklahoma. Also, the developed models are expected to be useful for prediction of V_{85} when roadway characteristics and/or traffic operational factors change.

17. KEY WORDS	18. DISTRIBUTION STATEMENT		
85th percentile speed, posted speed, neural network model, two-lane rural highways	No restrictions. This publication is available from the Planning & Research Division, Oklahoma Department of Transportation.		
19. SECURITY CLASSIF. (OF THIS REPORT) Unclassified	20. SECURITY CLASSIF. (OF THIS PAGE) Unclassified	21. NO. OF PAGES 109	22. PRICE N/A

SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units					Approximate Conversions from SI Units				
Symbol	When you know	Multiply by	To Find	Symbol	Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.40	millimeters	mm	mm	millimeters	0.0394	inches	in
ft	feet	0.3048	meters	m	m	meters	3.281	feet	ft
yd	yards	0.9144	meters	m	m	meters	1.094	yards	yd
mi	miles	1.609	kilometers	km	km	kilometers	0.6214	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm	mm^2	square millimeters	0.00155	square inches	in^2
ft^2	square feet	0.0929	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.8361	square meters	m^2	m^2	square meters	1.196	square yards	yd^2
ac	acres	0.4047	hectares	ha	ha	hectares	2.471	acres	ac
mi^2	square miles	2.590	square kilometers	km^2	km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.0338	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.2642	gallons	gal
ft^3	cubic feet	0.0283	cubic meters	m^3	m^3	cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.7645	cubic meters	m^3	m^3	cubic meters	1.308	cubic yards	yd^3
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.0353	ounces	oz
lb	pounds	0.4536	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
ºF	degrees Fahrenheit	(ºF-32)/1.8	degrees Celsius	ºC	ºC	degrees Celsius	9/5+32	degrees Fahrenheit	ºF
		FORCE and PRESSURE or STRESS					**FORCE and PRESSURE or STRESS**		
lbf	poundforce	4.448	Newtons	N	N	Newtons	0.2248	poundforce	lbf
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa	kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

ACKNOWLEDGEMENT

The authors would like to gratefully acknowledge the financial support provided by the Oklahoma Department of Transportation (ODOT) for this project. Also, the authors would like to express their sincere appreciation to Harold Smart, Chris Westlund, and Ginger McGovern all from ODOT for their technical assistance provided during the course of this study. The authors are especially thankful to David Glabas and Matt Warren, both from the Traffic Division at ODOT, for generating the data that were used in developing the neural network models. The authors are especially thankful to Dr. Zahid Hossain from the University of Oklahoma and Mr. Bryan Hurst for their assistance in making this report ADA compliant. Finally, the authors gratefully acknowledge the assistance of Ginger Miller from ODOT Traffic Division for providing access to the accident database.

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

One of the primary purposes of our highway system is to provide a safe, convenient and efficient mode of transportation. An increase in traffic volume causes serious congestion problems that affect work force productivity and contribute to air pollution. Traffic congestion results in excessive vehicle-hour of delays and fuel consumption (Verhoef, 2003; Stathopoulos et al., 2000; Verhoef, 1999; Lindley, 1989). Also, the continuously increasing rate of accidents is causing many traffic-related fatalities and significant damage to properties (FHWA, 2010). Both congestion and accident problems are correlated to a great extent with traffic speed. Traffic speed is an important parameter because it relates to safety, time, comfort, convenience, and economics (Agent et al., 1998).

A driver's speed on a highway varies due to many factors including roadway conditions, roadside characteristics, traffic volume, and environmental situations. Since these factors can vary substantially from one state to another, the U.S. Congress approved the National Highway System Designation Act, which allows states to set their own posted speed (PS) limits (Carney, 1996).

Traffic operation on two-lane rural highways and setting PS limits are some of the difficult tasks faced by the Oklahoma Department of Transportation (ODOT). For such highways, overtaking slower vehicles is possible only by using the opposing lane where sight distance and gap in the opposing traffic stream play a key role. While many states, including Oklahoma, uses the 85th percentile speed (V_{85}) as a major factor in determining PS for rural highways, other factors such as pavement width, shoulder type, shoulder width, topography, weather, roadside development, and accident experience also play an important role in determining PS limits.

Speed characteristics determined from a spot speed study are used to estimate V_{85} (Garber, 2002). However, conducting such spot studies can be expensive and time consuming. State and local transportation agencies do not have the resources to conduct the large number of engineering studies required to respond to all of the speed requests in a timely fashion. Moreover, after collecting the field speed data needed to determine V_{85} on a given roadway, engineers must then rely upon professional judgment to determine whether any other factors (e.g., accident experience, roadway geometry, adjacent development) warrant the establishment of speed limits lower than the observed V_{85}. Therefore, characterizing the relationship between V_{85} and the roadway characteristics is important in selecting PS limits on highway sections where field surveying is difficult due to resource limitations (Najjar et al., 2000).

Researchers have developed both regression and artificial neural network (ANN)-based models for predicting speed. Regression models assume that some relationship (usually linear) exists in the data and then tests to see if the data satisfy the assumption. Comparatively, a neural network model learns to recognize patterns that exist in a dataset. In recent years, artificial neural network (ANN)-based models have been used successfully for many engineering problems, including modeling of V_{85} for rural highways in Oklahoma, Kansas, and other states (Zaman et al., 2010; Tarefder et al., 2005; Najjar et al., 2002; McFadden et al., 2001; Najjar et al., 2000; Zaman et al., 2000; Najjar et al., 1999; Issa et al., 1998; Basheer et al., 1996; Najjar et al., 1996a; Najjar et al., 1996b; Zupan et al., 1993; Simpson, 1990). Developing an ANN model based on appropriate pavement, traffic, and environmental data can be an effective tool for ODOT to enhance traffic safety in the state, which is one of the objectives of this study.

The present study is a continuation of a previous ODOT study conducted by Issa et al., (1998), where an ANN-based model was developed for predicting V_{85} for two-lane rural highways in Oklahoma. Data from 121 sites, distributed throughout Oklahoma, were used in that study (Issa et al., 1998). The following parameters were included in developing ANN models: average daily traffic (ADT), international roughness index (IRI), present serviceability index (PSI), surface width, shoulder type, shoulder width, % passing, and crash data. Shoulder type and crash data were not used in development of ANN models in that study. Results from that project indicated that the developed ANN model might have suffered from over fitting. This phenomenon sometimes occurs as a result of small data sets and lack of sufficient distribution of data for the entire range of a model parameter. Also, over fitting can occur when an ANN model fits the training dataset well, but does a poor job in fitting data not used in the training process (Tarefder et al., 2005). Nonetheless, the previous model developed by the University of Oklahoma was an important first step towards realizing the objective of developing ANN-based models for the setting of V_{85} for two-lane rural highways in Oklahoma.

A careful review of the previous ANN models developed by the OU research team about a decade ago suggested that additional data would be needed to increase model robustness in capturing the parameters that influence V_{85} in rural two-lane highways (Issa et al., 1998). Also, it was evident that a better distribution of the dataset was needed. Since the data from the 121 sites used in developing the previous model have changed significantly over the past ten years, it was important to update them. To this end, the present study was undertaken to develop improved ANN models that would overcome the aforementioned limitations and cover a larger range of sites than before.

1.2 OBJECTIVES

The main objective of the present study was to develop artificial neural network (ANN) models to predict V_{85} of two-lane rural highways in Oklahoma. The ANN approach takes into consideration a variety of factors such as roadway characteristics, traffic conditions, and accident experience in developing the models. The present study was pursued with a goal that ANN model for V_{85} would provide a cost effective alternative for estimating site specific V_{85} for two-lane rural highways in Oklahoma. Also, it is expected that the developed model would be useful for future prediction of V_{85} when roadway characteristics and/or traffic operational factors change.

1.3 METHODOLOGY

In developing ANN models, it is important to include important model parameters pertaining to roadway characteristics, traffic conditions, and accident experience. An understanding and quantification of these factors is expected to improve traffic engineers' ability to determine the most appropriate posted speed (PS) on two-lane rural highways, where spot study is not feasible due to time and resource limitations. With this scope in mind, the present study addresses the following basic elements: selection of model parameters, data collection and database development, data analysis, and development of ANN models.

1.4 ORGANIZATION OF THE REPORT

This report is composed of five chapters. Chapter 1 provides a brief background of the study, objectives, and methodology. Chapter 2 is focused on the literature review. The data collection process is discussed in Chapter 3. Chapter 4 describes the development of the ANN models along with a User's Manual to estimate V_{85}. Finally, summary, conclusions, and recommendations of this study are presented in Chapter 5.

2.1 INTRODUCTION

Speed is used as a performance measure to evaluate highway and street designs (Fitzpatrick et al., 2003). Speed limit is used in most countries to regulate vehicle speed. Most traffic engineers believe that speed limits should be posted to reflect the maximum speed considered to be safe and reasonable by a majority of drivers using the roadway under favorable conditions (Donald, 1994). Procedures used to set speed limits have evolved through years of experience and research. Most states and localities set speed limits for streets and highways based on the results of an engineering and traffic investigation (Taylor et al., 2007; McFadden et al., 2001; Najjar et al., 2000; Agent et al., 1998; Issa et al., 1998). For example, a spot speed study is conducted to estimate the distribution of vehicle speeds in a stream of traffic at a particular location of highway (Garber, 2002).

Speed percentiles are the tools used to determine effective and adequate speed limits. In the United States, speed zoning is generally based on the principle of setting speed limits as near as practicable to the speed at or below which 85 percent of drivers are traveling. The 85th percentile of speed (V_{85}) is normally assumed to be the highest safe speed for a roadway section (Agent et al., 1998; Homburger et al., 1996). In this case, setting the speed limits at V_{85} appears to be the safest method because it reduces speed differentials (Najjar et al., 2000; Agent et al., 1998). When the posted speed (PS) limit is below V_{85}, few drivers will obey the PS limits. Such speed differentials may result in increased accidents (Najjar et al., 2000). The basic speed rule according to the Uniform Vehicle Code states, “No person shall drive a vehicle on a highway at a speed greater than is reasonable and prudent under the conditions and without having regard to the actual and potential hazards then existing” (Uniform Vehicle Code, 1992).

2.2 FACTORS AFFECTING TRAFFIC SPEED

A literature survey was conducted in this study to examine and identify roadway and traffic-related variables that affect the setting of speed limits. Each state in the U.S. has a basic speed statute requiring drivers to operate their vehicles at a speed that is reasonable and prudent under existing conditions (Carney, 1996). This law recognizes that the maximum safe speed varies due to traffic, roadway, weather, and other conditions. A majority of motorists select a driving speed so as to reach their destinations in the shortest time possible without endangering themselves and others, as well as their property. The following four groups of factors are believed to affect the traffic speed:

a. Geometric features,
b. Traffic characteristics and control,
c. Environmental features and weather conditions,
d. Driver's experience and knowledge of traveling path.

2.2.1 Geometric Features

Geometric features of a roadway and roadside are important factors that influence traffic flow in two-lane rural highways. Geometric features that are considered important in affecting two-lane traffic speed are listed below (Fitzpatrick et al., 2003; Najjar et al., 2000; Gattis et al., 1999; Polus et al., 1991):

a. Lane width and paving conditions,
b. Usable shoulder width,
c. Degree of horizontal curvature and length of curve,
d. Median presence and width,
e. Terrain type: Level terrain, rolling terrain, or mountainous terrain,
f. Length of no passing zones.

A survey was conducted in early 1999 under the National Highway Cooperative Research Program (NCHRP) project 15-18 to understand speed definitions and factors affecting speed (Fitzpatrick et al., 2003). Respondents were asked questions divided into four sections relating to definitions, policies and practices, design values, and speed values. Respondents were also asked to provide comments on the topic and information regarding their current position and previous experience. All of the respondents indicated that narrow lane widths cause drivers to drive slower on freeways, and most (89%) believe that narrow lane widths cause drivers to drive slower on local streets. When wide lane widths exist, most of the respondents believe they do not affect drivers' speeds on freeways but do affect local street speeds. 71% of the respondents indicated that shoulder width affects traffic speed. About two-thirds believed narrow shoulders cause drivers to drive slower on both urban and rural freeways. About one-half of the respondents believed that wide paved shoulders cause drivers to drive faster. A large majority (more than 80%) believed that narrow clear zone/lateral clearance widths affect the speed that drivers select on both urban and rural roads. A smaller majority (approximately 60%) believed that wide lateral clearance/clear zone widths cause drivers to drive faster.

Najjar et al. (2000) investigated the effect of two different types of shoulder: pavement/combination (P/C) and turf/gravel (T/G) on V_{85}. It was reported that V_{85} increases for the T/G case where the shoulder width is about 3 ft. After that, it slightly decreases with an increase in shoulder width to 6 ft; beyond that, it stays almost constant. These findings are contradictory to the general belief that V_{85} should increase with an increase in shoulder width. According to Najjar et al. (2002), population density is generally low on roads with narrow shoulders and most drivers are familiar with these roads. The population density and familiarity factors contribute to higher speeds on roads with narrow shoulders.

Polus et al. (1991) measured V_{85} and found it to be 46 mph (74 km/h) and 40.4 mph (65 km/h) for a highway with surface width of 23.6 ft (7.2 m) and 19.7 ft (6 m), respectively. It was reported that traffic speed increases with an increase in lane width. In a similar study, Farouki et al. (1976) observed free-flow speeds on roads varying from 17 to 46 ft (5.2 to 14.0 m) wide. It was found that the mean speed increases linearly with lane width. Similar observations were also reported by several other researchers including Gattis et al. (1999) and Heimbach et al. (1983).

2.2.2 Traffic Characteristics and Control

A vehicle's speed is greatly influenced by traffic characteristics. Average speed decreases, almost linearly, with an increase in traffic volume on two-lane highways (HCM, 2000). Pursula et al. (1991) reported that an increase in two-lane flow rate from 400 to 1600 vehicles/hour decreased the traffic speed from 43.5 mph (70 km/h) to 37.3 mph (60 km/h) and increased the queue length significantly. The highway capacity manual defines ideal traffic conditions based on passengers' cars, directional split of traffic, and no passing zones (HCM, 2000). Under ideal traffic conditions, a roadway will have 2800 passenger cars per hour (pcph), a 50/50 directional split of traffic, and no "no passing zones." The designated speed under these ideal conditions is 60 mph (96 km/h) or greater. In order to design reasonable speed limits on a specific section of a highway, one should consider the following traffic factors:

a. Traffic volume (average annual daily traffic (AADT), average daily traffic (ADT), flow rate),
b. Traffic compositions (% trucks, % cars, % vans, % buses),
c. Traffic signals (speed limits, stop signs, passing/no passing zones),
d. Traffic split in two directions (50/50, 40/60, 30/70, 20/80).

Post mounted delineators and retroreflective raised pavement markers at horizontal curves have a significant influence on traffic flow at nighttime (Taylor et al., 2007; Krammes et al., 1991; Stimpson et al., 1977). The average citizen believes that reducing speed limits will increase roadway safety. However, research indicates that a reasonable and prudent driver will drive at speeds suggested by roadway and traffic conditions rather than rely on the PS limits. Because accidents appear to depend less on absolute speed and more on speed variations in the traffic stream, setting unrealistically low speed limits may actually lead to an increase in accidents. For example, a study conducted by the Florida Department of Transportation concluded that motorists tend to pay little attention to speed regulations which they consider unreasonable unless there is an inordinate degree of enforcement (Florida DOT, 1980). Unreasonablely low speed limits are commonly violated by a majority of motorists, making enforcement difficult, with resulting operating speeds somewhat higher than would exist with proper, realistic speed limits (Najjar et al., 2000; Florida DOT, 1980).

Binkowski et al. (1998) studied speed differences between trucks and cars. It was found that large truck speed was approximately 8 mph slower than passenger car speed. Change in speed limits did not increase the difference in speed between small and large vehicles.

2.2.3 Environmental Features and Weather Conditions

The physical and climatic environment surrounding a transportation vehicle can also be factors in the occurrence of a crash. On two-lane roads, where scenic and recreational areas are spread along the sides and drivers enjoy the vista, speeds below V_{85} may be beneficial to drivers in these rapidly developing areas (Ullman et al., 1987). Tebinka (1995) considered the new developments to be a significant element affecting traffic flow. On the other hand, unfavorable weather conditions like snow, rain, and ice tend to increase the accident potential (Harwood et al., 1988). Traffic speed under these weather conditions decreases because of poor roadway visibility. Environmental features include the following, among others:

a. Number of roadside business,
b. Building setback,
c. Adjacent land use,

d. Recreational facility,

e. Number of intersections,

f. Daytime/or nighttime, Peak/or off peak hour,

g. Weather conditions (sunny, cloudy, windy, foggy, rainy, snowy).

Binkowski et al. (1998) studied effects of increasing speed limits on certain sections of highways in Michigan. It was found that nighttime speeds were slower than daytime speeds by approximately 1.5 mph (2.4 km/h). In addition, V_{85} speeds for weekend traffic were approximately 0.2 mph (0.3 km/h) higher than weekday traffic.

The wet and dry condition of the pavement also affects the traffic speed. A study by Ibrahim et al. (1994) found that light rain affected speed by about 1 mph (1.6 km/h), and heavy rain had an effect of 3 to 6 mph (4.8 to 9.7 km/h). In another study, Lamm et al. (1990) found no statistical difference in operating speeds on wet and dry pavements.

2.2.4 Driver's Experience and Knowledge of Traveling Path

Vehicle travel behavior varies with drivers' aptitude and experience. Sex and age of the drivers also have considerable effect on the driving speed (McKelvey et al., 1998; Polus et al., 1991). Male and young drivers tend to drive faster than female and older drivers for the same roadway conditions. The drivers' prior knowledge of the road may encourage them to drive faster than the posted speed limits (Donald, 1994). A major contributing cause of many crash situations is the performance of the driver of one or both of the vehicles involved. Driver error can occur in many ways. These include attention to the roadway and surrounding traffic, failure to yield the right of way, and/or traffic law (Garber, 2002).

2.3 TRAFFIC SPEED MODELS

The ability to predict accurate vehicular operating speeds is useful for evaluating the planning, design, traffic operations, and safety of roadways (McFadden et al., 2001).

Researchers have developed regression and artificial neural network (ANN)-based models for estimating vehicle speed. For example, Issa et al., (1998) developed an ANN-based model for predicting V_{85} for two-lane rural highways in Oklahoma. The following model parameters were selected: average daily traffic (ADT), international roughness index (IRI), present serviceability index (PSI), surface width, shoulder type, shoulder width, % passing, and crash data. It was noted that inclusion of shoulder types adversely impacted the performance of the ANN model, and as such, shoulder type was excluded from the model. In addition, crash data were also eliminated based on the findings from a similar study conducted by the Kansas Department of Transportation (Stoke et al., 1998). It was noted that V_{85} is dictated by variables that a driver feels and/or sees. A 5-4-1 ANN model was developed with 5 input nodes (ADT, PSI, surface width, shoulder width, % passing), 4 hidden nodes (one layer), and one output node (V_{85}). It was found that the developed ANN model had about a 96% overall average degree of accuracy in predicting V_{85} (i.e., ± 4% average degree of deviation from the actual 85^{th} percentile speed).

In another study Najjar et al. (2000) developed an ANN-based model to predict V_{85} for two-lane rural highways in Kansas. The pattern recognition and function approximation capabilities of back-propagation ANN models were used to develop models that can efficiently predict V_{85} on two-lane, uninterrupted-flow highways in rural Kansas. The following eight input variables were used: surface width, IRI, percent heavy commercial traffic, stopping sight distance, number of accidents (current), percent restricted passing, median width, and ride ability. It was recommended that the input parameters be limited to those variables that drivers perceive and respond to as part of the driving task. As a result, input variables such as accident frequencies were eliminated from the database. The best performance was achieved using a 5-5-1 network with five input nodes (shoulder width, shoulder type, pavement/combination (P/C) and turf/gravel (T/G), ADT, and percentage of no passing zones), five hidden nodes (one layer), and one output node (V_{85}). It was reported that the developed model would predict V_{85} with an average degree of accuracy of about 96 percent (i.e., ±4 percent average deviation from the actual value).

In a recent study, Taylor et al. (2007) developed a speed profile model for construction work zones on highways using the ANN approach. The model inputs include: horizontal and vertical alignment variables, cross-section dimensions, and traffic control features. In a similar study, Donnell et al. (2001) developed an operating speed prediction model for trucks on two-lane rural highways. A series of regression models were developed to predict the 85th percentile truck operating speeds upstream, along, and downstream of a horizontal curve. The correlation coefficient (R^2) of these models ranged from 0.55 to 0.63. These models consider the effect of length and grade of approach tangent, horizontal curve radius, and length and grade of departure gradient. Similarly, McFadden et al. (2001) developed an ANN model for estimating the operating speed for two-lane rural highways. Operating speed profile (OSP) models are used in the geometric design of highways to evaluate design consistency.

CHAPTER 3 DATA COLLECTION

3.1 INTRODUCTION

The University of Oklahoma research team worked closely with the ODOT Traffic Engineering Division’s staff to prepare the database used for the development of the ANN models. Data were collected from the followings sources: Federal Highway Administration (FHWA), highway performance monitoring system (HPMS) reports, need and sufficiency reports, skid number reports, accident reports, and speed study reports. The HPMS is a nationwide inventory system that includes data for all of the nation's public road mileage as certified by the states' Governors on an annual basis (FHWA, 2011). The HPMS reports provide data that reflects the extent, condition, performance, use, and operating characteristics of the nation’s highways. Need and sufficiency report provides the sufficiency rating, which is calculated to determine the physical and operational adequacy of a roadway or bridge (ODOT, 2007a). Information for each roadway subsection covers three areas: (1) Identification and physical measurements; (2) sufficiency rating; (3) design standard, improvement type, and estimated cost of improvement. Skid number reports provide the skid number (SN) for various control sections of each county (ODOT, 2007b). The reports record SN based on county, route, control section, direction of lane, and mileage. Accident reports contain various accident data in terms of number of collisions (overall, fatal, injury, and property damage), collision rates (fatal and injury), and percentage of drivers with unsafe speed (USD). The speed study report provides the 85th percentile speed (V_{85}) and the posted speed (PS) at a particular location on a control section.

3.2 SELECTION OF MODEL PARAMETERS

Selection of model parameters is a critical task to any modeling process. In the present study, selection of model parameters was based on the results of the literature review, the availability of the data from ODOT data files, and on the previous study conducted by Issa et al. (1998).

Various model parameters were selected in the initial stage of modeling to assess their suitability. Model parameters were divided into four different groups, namely physical roadway characteristics, pavement condition, traffic parameter, and accident data. The parameters for each group are listed in Table 3.1. Physical characteristics of road include surface width (SW), shoulder type (ST), and shoulder width (SHW). The traffic parameters category includes average daily traffic (ADT), PS, and V_{85}. The pavement condition group includes skid number (SN) and international roughness index (IRI). The location collision rate, statewide collision rate (overall, fatal, and injury), and percentage unsafe speed drivers (USD) are covered in the accident data.

Table 3.1 Model Parameters

Physical Characteristics of Road	
Surface Width	SW
Shoulder Type	ST
Shoulder Width	SHW
Traffic Parameters	
Average Daily Traffic	ADT
Posted Speed	PS
85^{th} Percentile Speed	V85
Pavement Conditions	
Skid Number	SN
International Roughness Index	IRI
Accident Data	
Location Collision Rate Overall	LCRO
Location Collision Rate Fatal	LCRF
Location Collision Rate Injury	LCRI
Statewide Collision Rate Overall	SCRO
Statewide Collision Rate Fatal	SCRF
Statewide Collision Rate Injury	SCRI
% Unsafe Speed Drivers	USD

3.3 DATA COLLECTION

As noted earlier, site specific data used in this study were collected from different sources. Since the purpose of the present study is to develop ANN-based models for estimating V_{85} for two-lane rural highways, only those sites were chosen where V_{85} speeds were available. First, speed study reports were used to select the site where V_{85} and PS were available. Once the site was selected, its basic information including county number, county name, division number, start point mileage, end point mileage, and primary direction were noted from the need and sufficiency rating report. As noted previously, the other model parameters, namely physical characteristics of road, traffic, road condition, and accident data were collected from the HPMS report, need and sufficiency report, skid report, and accident report, respectively. Based on the data available in these reports, a total of 241 sites were selected that span 46 counties and 8 divisions. Figure 3.1 shows the divisional distribution of these 241 sites. Note that Division 8 had the largest number of sites (67), followed by Division 3 (43 sites).

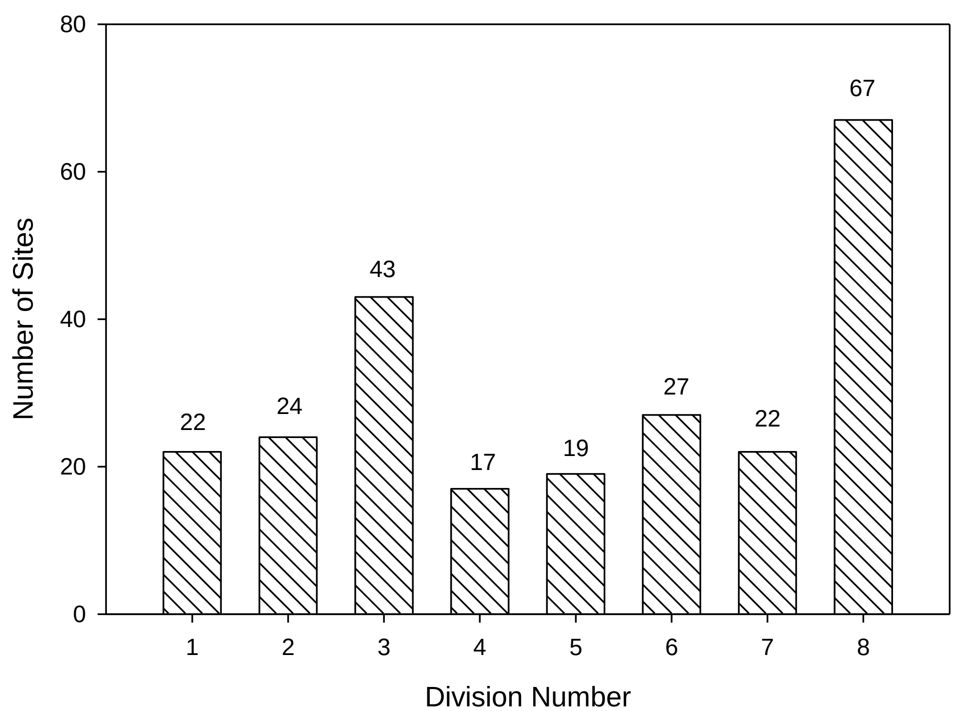

Figure 3.1 Divisional Distribution of Sites

3.3.1 Physical Characteristics of Road

The need and sufficiency report categorizes shoulders in six different groups. Each shoulder is given a particular number, for example: No shoulder – 0, Paved – 1, Gravel – 2, Sod – 3, Curb on both sides – 4, Curb on one side – 5, Combination Paved and Sod – 6.

3.3.2 Traffic Parameters

V_{85} and PS for all 241 sites were recorded from the speed study reports (ODOT, 2007c). The speed study reports were collected from ODOT and two-lane rural highways were shortlisted where V_{85} speed data was available. Furthermore, ADT for each site was taken from the need and sufficiency report.

3.3.3 Pavement Condition Parameters

SN for all 241 sites was collected from the skid number report. Skid report records SN values based on county, route, control section, direction of lane, and mileage. In the skid report, SN for a particular site is available for both directions (e.g., East-West, North-South). Based on discussions with the ODOT project panel members, it was decided to take the SN data for only the primary direction. Primary direction represents the direction along which a site ends (end mileage). The IRI value for each site was recorded from the HPMS report.

3.3.4 Accident Data

The Oklahoma Department of Transportation (ODOT) provided access to the research team to collect the accident data from their online database. Accident data reports were generated by selecting start and end points for each selected site. Location and statewide collision rates were selected as model parameters. At any particular site, the following accident-related data were collected: location collision rate overall (LCRO), location collision rate fatal (LCRF), location collision rate injury (LCRI), statewide collision rate overall (SCRO), statewide collision rate fatal (SCRF), statewide collision rate injury (SCRI), and % unsafe speed drivers (USD).

Table 3.2 summarizes the format used for collecting data for each site. The data was recorded according to the county name, division, and control section. The data collected for all 241 sites are provided in Appendix-A.

Table 3.2 Data Format

Designation	
County Number	CNO
County Name	CN
Division Number	DNO
Control Section Number	CSNO
Site Start Miles	SST
Site End Miles	SEM
Primary Direction	PD
Highway Designation	HD
Number of Lane	NL
Surface Width	SW
Shoulder Type	ST
Shoulder Width	SHW
Average Daily Traffic	ADT
Skid Number	SN
International Roughness Index	IRI
Posted Speed	PS
85^{th} Percentile Speed	V85
Location Collision Rate Overall	LCRO
Location Collision Rate Fatal	LCRF
Location Collision Rate Injury	LCRI
Statewide Collision Rate Overall	SCRO
Statewide Collision Rate Fatal	SCRF
Statewide Collision Rate Injury	SCRI
% Unsafe Speed Drivers	USD

Descriptive statistics of all model parameters are given in Table 3.3. The maximum and minimum surface widths for two-lane rural highways were found to be 20 and 24 feet, respectively. Shoulder types included in the dataset are: Type 1 (Paved), Type 2 (Gravel), Type 3 (Sod), and Type 6 (Combination Paved and Sod). Shoulder width ranges from 1 foot to 10 feet, with an average value of approximately 6 feet. The maximum and minimum values of SN were 62.8 and 25.6, respectively, while the IRI values ranged between 38 and 202 in/mile. The

ADT values of two-lane rural highways ranged between 330 and 9100, with an average of 3180. Maximum and minimum PS values were found to be 65 mph and 35 mph, respectively. Similarly, maximum and minimum V_{85} speeds were estimated to be approximately 70.5 mph and 38.5 mph, respectively. Location collision rate and statewide collision rate were recorded for each site (Table 3.3). The LCRO values ranged from 0 to 762.4 (100 million vehicle miles), while the SCRO values were found to be in the range of 86.29 to 189.05 (100 million vehicle miles). There was little variation observed in the statewide collision rate (SCRO, SCRF, and SCRFI). Percentage USD was observed in the range of 0 to 61.9.

Table 3.3 Descriptive Statistics of Model Parameters

Designation		Maximum	Minimum	Mean
Surface Width (ft)	SW	24	20	23.85
Shoulder Type	ST	6	1	-
Shoulder Width (ft)	SHW	10	1	6.12
Average Daily Traffic	ADT	9100	330	3180
Skid Number	SN	62.8	25.6	42.8
International Roughness Index (in/mile)	IRI	202	38	96.5
Posted Speed (mph)	PS	65	35	55.2
Location Collision Rate Overall	LCRO	762.4	0	125.7
Location Collision Rate Fatal	LCRF	54.6	0	2.99
Location Collision Rate Injury	LCRI	330.4	0	55.42
Statewide Collision Rate Overall	SCRO	189.05	86.29	116.13
Statewide Collision Rate Fatal	SCRF	3.15	1.89	2.78
Statewide Collision Rate Injury	SCRI	65.2	41	48.5
Unsafe Speed Drivers (%)	USD	61.9	0	14.93
85^{th} Percentile Speed (mph)	V85	70.5	38.5	57.07
*Collision rate : 100 million vehicle miles				

3.4 DEVELOPMENT OF HISTOGRAMS

Histogram plots were constructed for each model parameter. These plots provide a visual distribution of each parameter and are found to be useful in identifying the nature of additional sites to be included in the dataset. Figures 3.2 through 3.16 show the histograms for all selected model parameters.

Figure 3.2 shows the histogram for SW. It shows that almost 98% of the sites had a surface width of 24 feet. The histogram plot for ST indicates that the most of the sites had Type

1 shoulder (paved shoulder), followed by shoulder Type 3 (sod), and shoulder Type 6 (combination of paved and sod) (Figure 3.3). The histogram of distribution of shoulder width shows that a majority of sites had a shoulder width of 8 feet or more (Figure 3.4). The histogram plot for ADT covers a rather large range of ADT, with a maximum of 9100 and a minimum of 330 (Figure 3.5). Distributions of SN and IRI are shown in Figures 3.6 and 3.7, respectively. A large number of sites had SN in the range of 35-45, and IRI in the range of 50-150 in/mile.

A total of 179 sites had PS values in the range of 55 to 65 mph (Figure 3.8). The V_{85} speed values were found to be in the range of 45 to 70 mph, with one site having greater than 70 mph (Figure 3.9). The distribution of location and statewide collision rate are shown in Figures 3.10 through 3.16. Statewide collision rate was found to be uniform for all the sites. The histograms for location collision rates show large variations among the selected sites, whereas the histograms for statewide collision rate showed little variation.

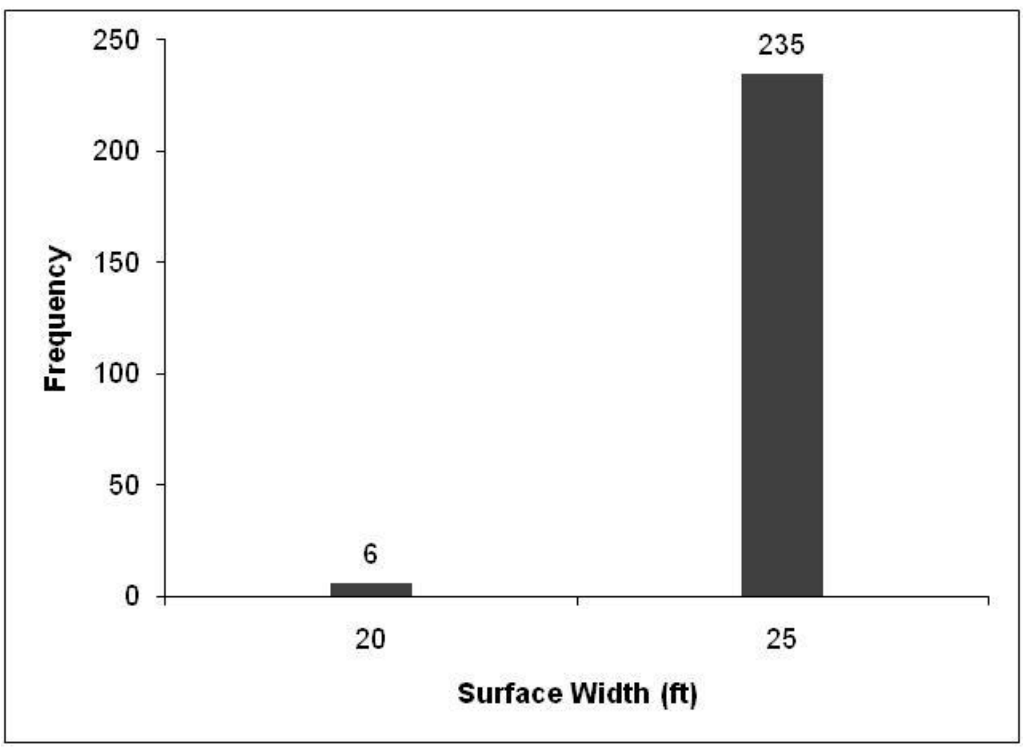

Figure 3.2 Distribution of Surface Width

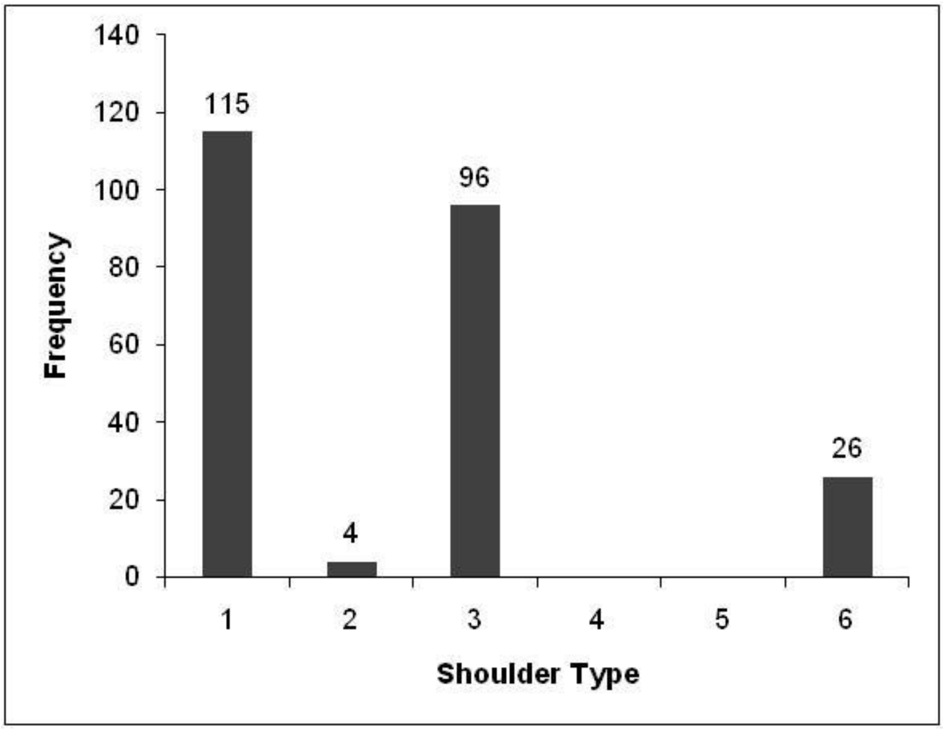

Figure 3.3 Distribution of Shoulder Type

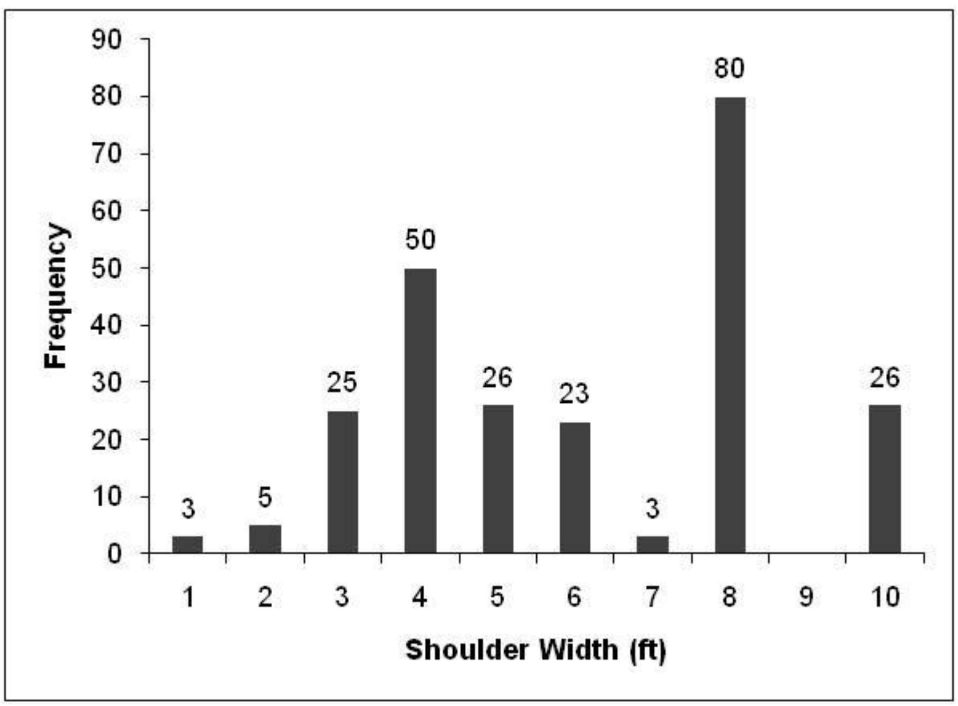

Figure 3.4 Distribution of Shoulder Width

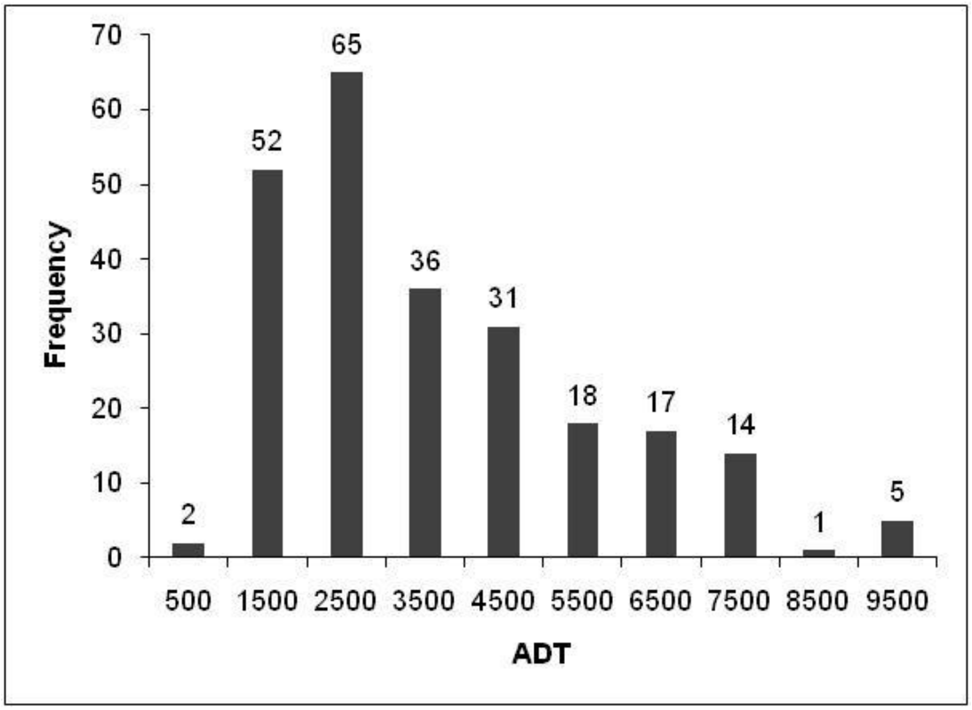

Figure 3.5 Distribution of Average Daily Traffic

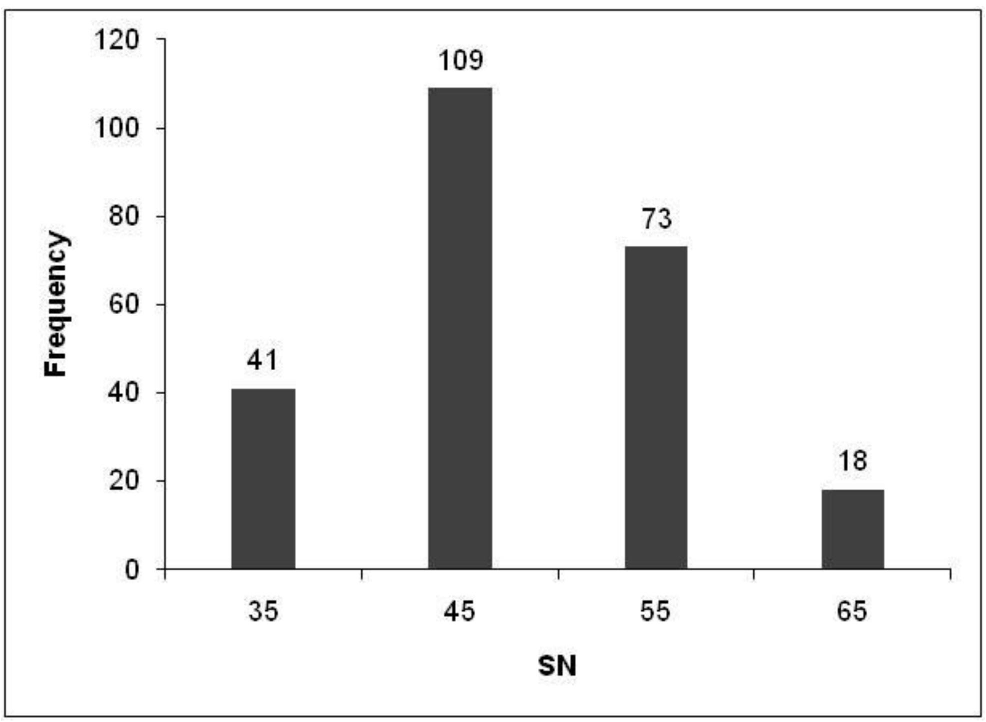

Figure 3.6 Distribution of Skid Number

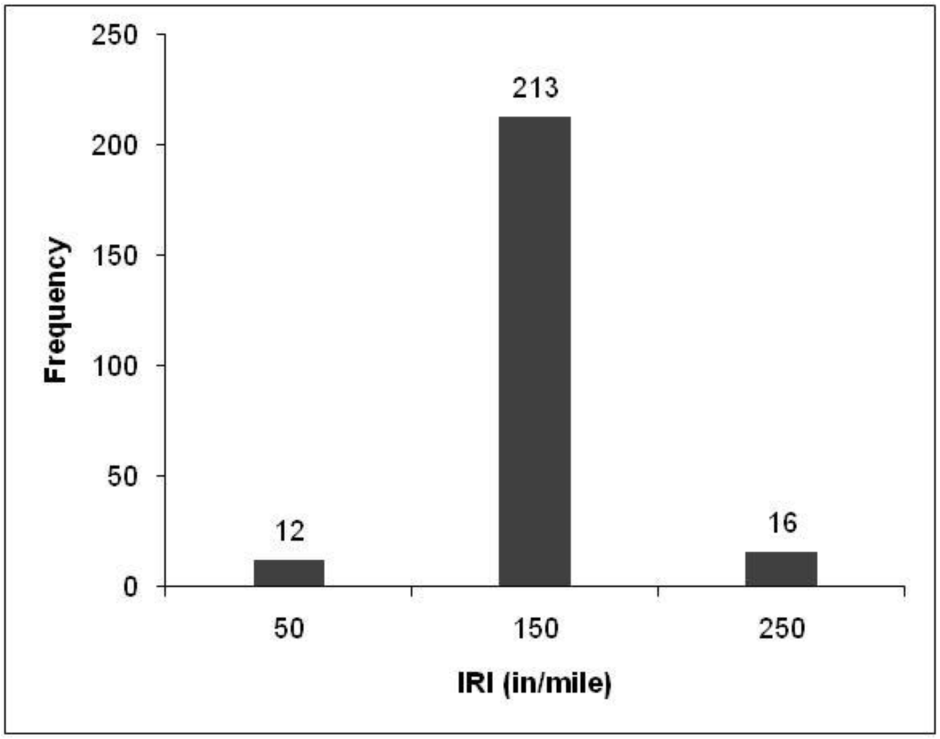

Figure 3.7 Distribution of International Roughness Index

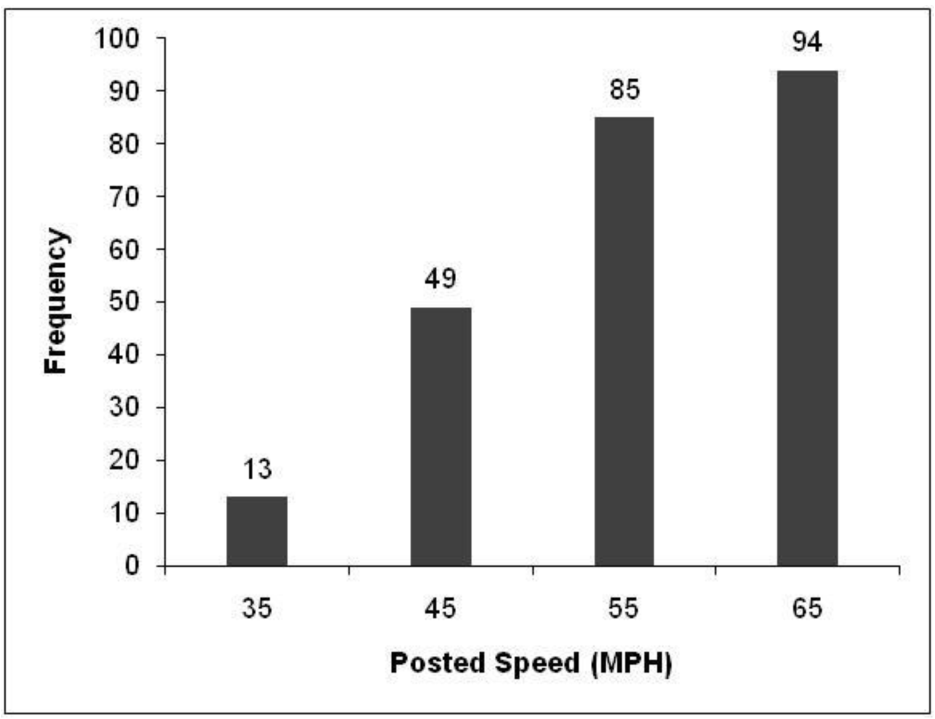

Figure 3.8 Distribution of Posted Speed (MPH)

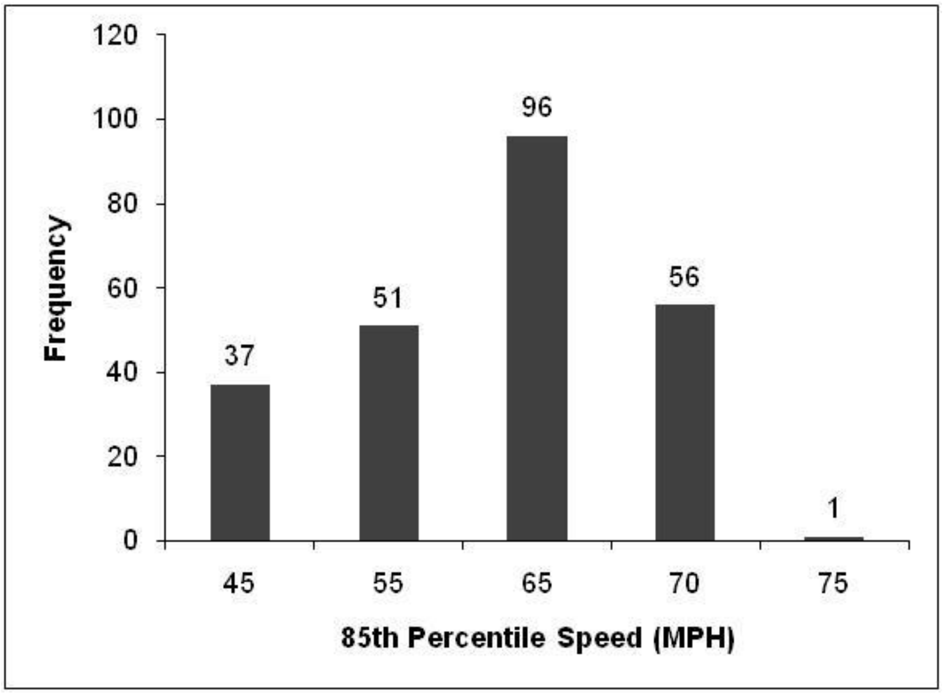

Figure 3.9 Distribution of V_{85} Percentile Speed (MPH)

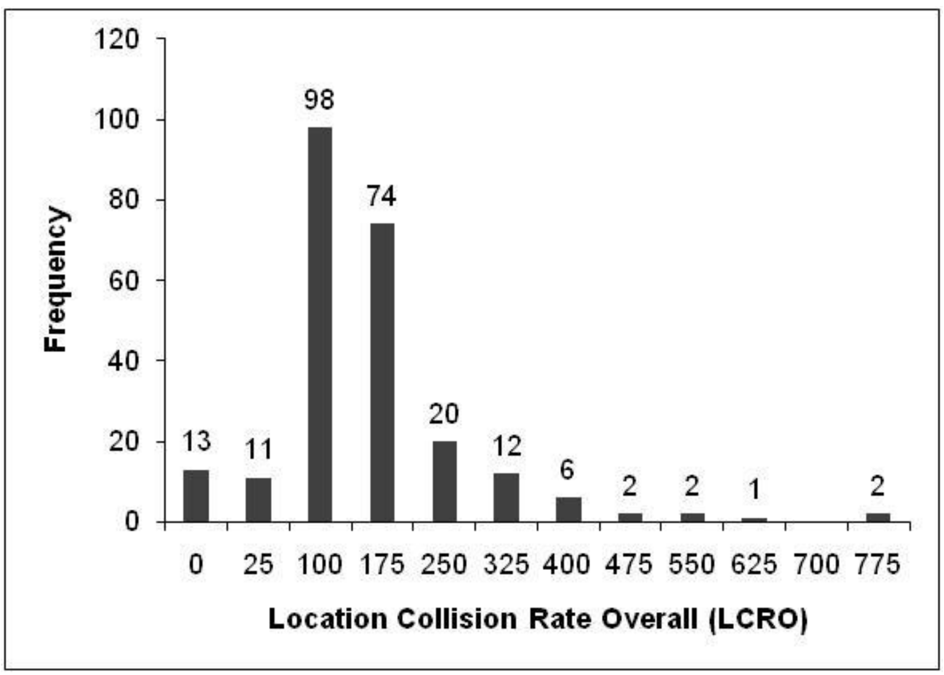

Figure 3.10 Distribution of Location Collision Rate Overall (LCRO)

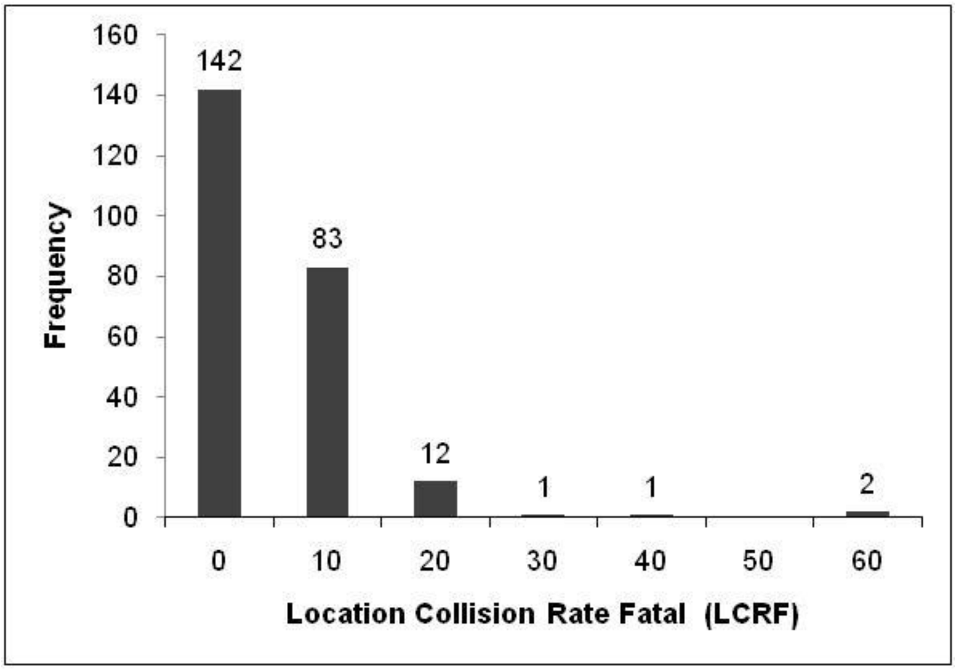

Figure 3.11 Distribution of Location Collision Rate Fatal (LCRI)

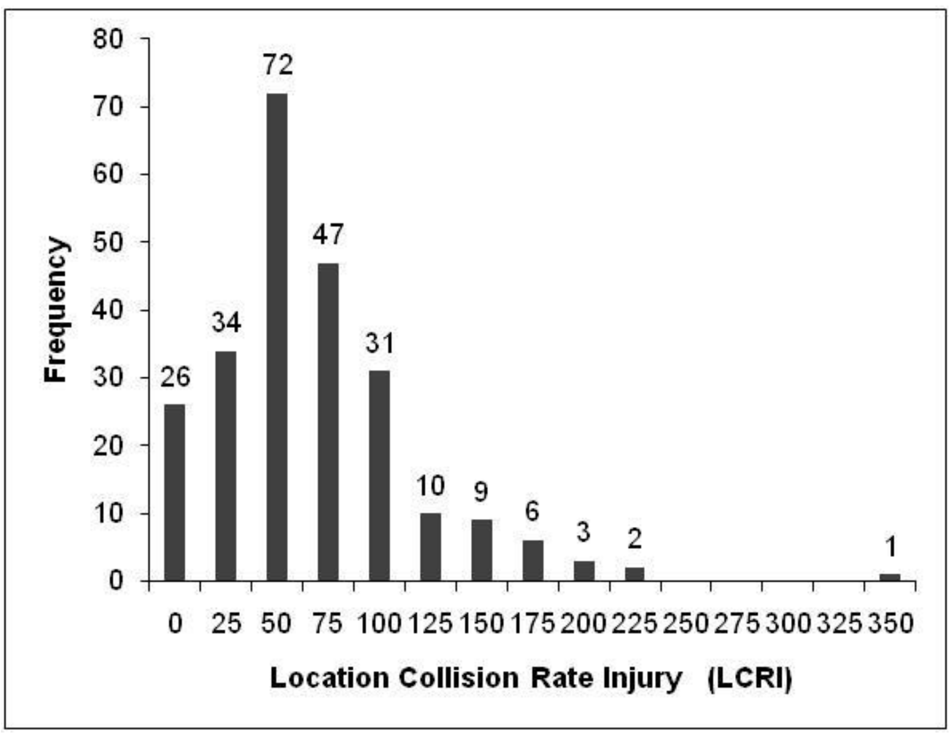

Figure 3.12 Distribution of Location Collision Rate Injury (LCRI)

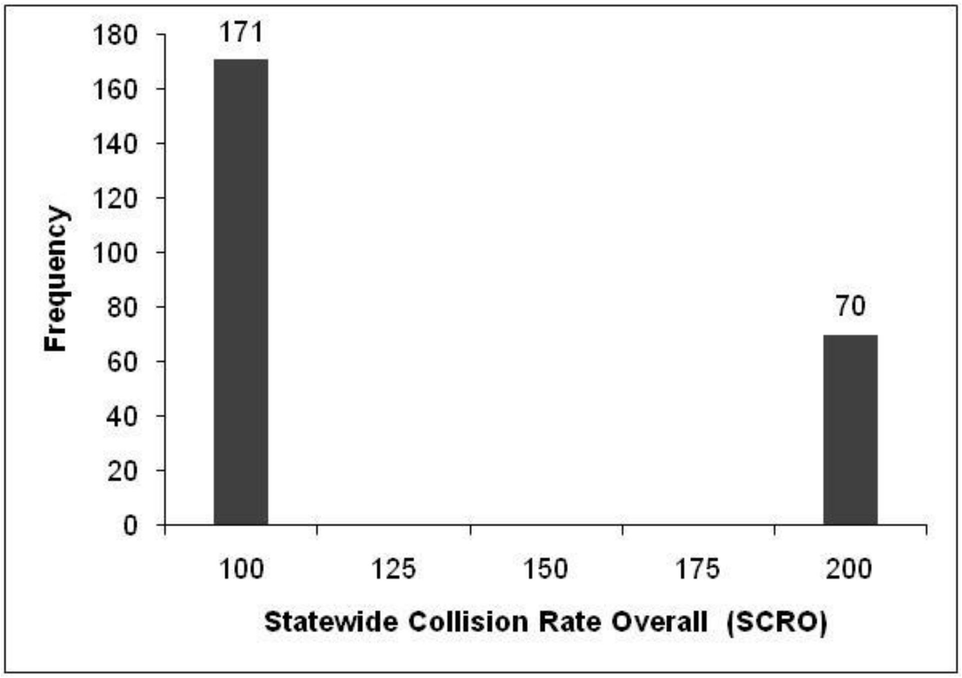

Figure 3.13 Distribution of Statewide Collision Rate Overall (SCRO)

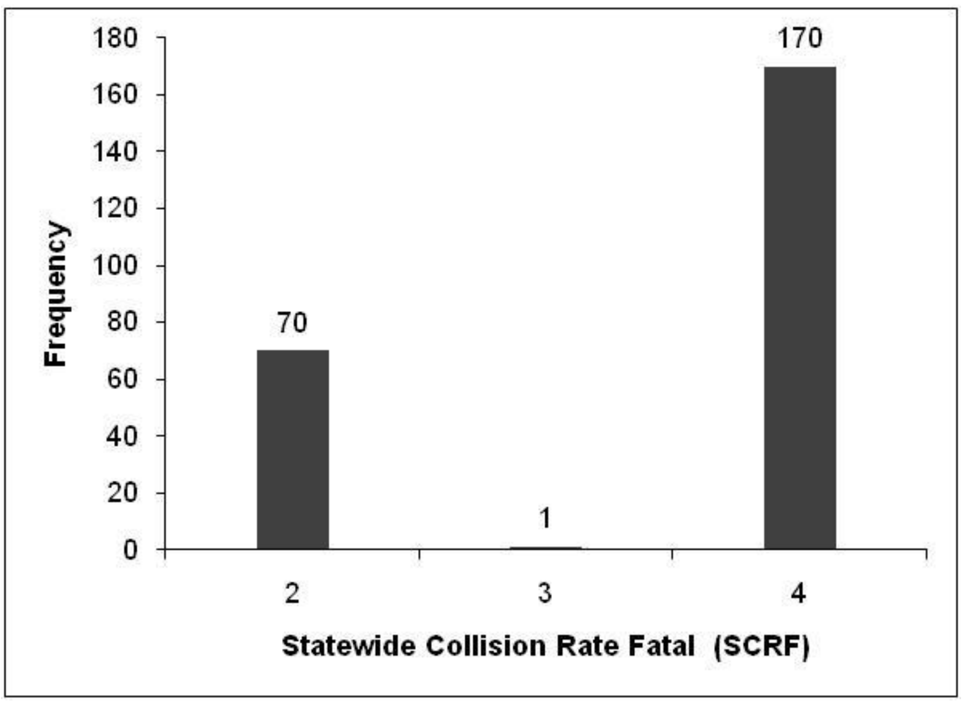

Figure 3.14 Distribution of Statewide Collision Rate Fatal (SCRF)

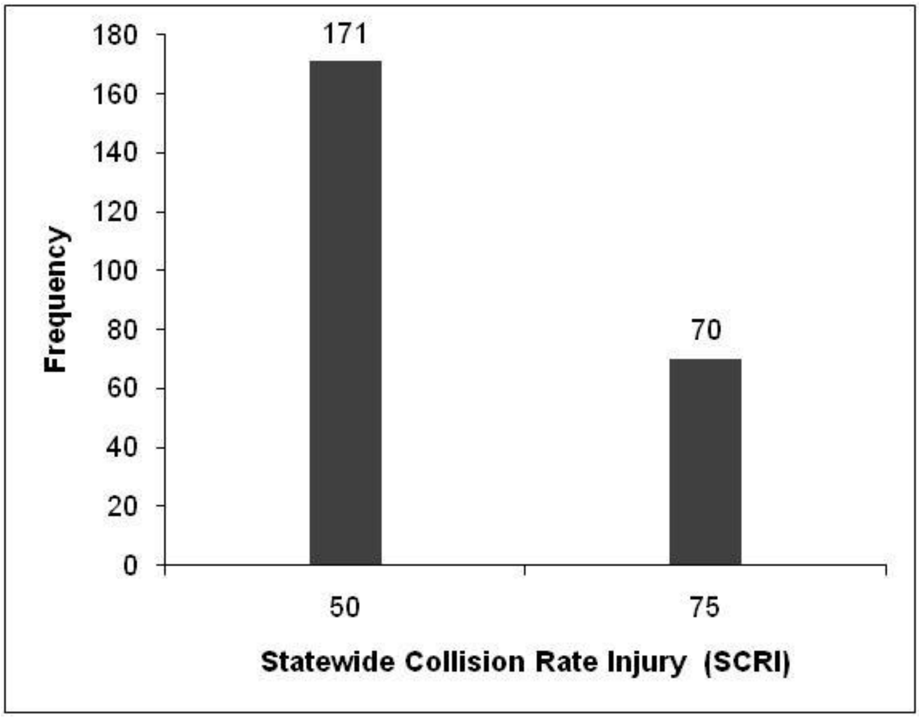

Figure 3.15 Distribution of Statewide Collision Rate Injury (SCRI)

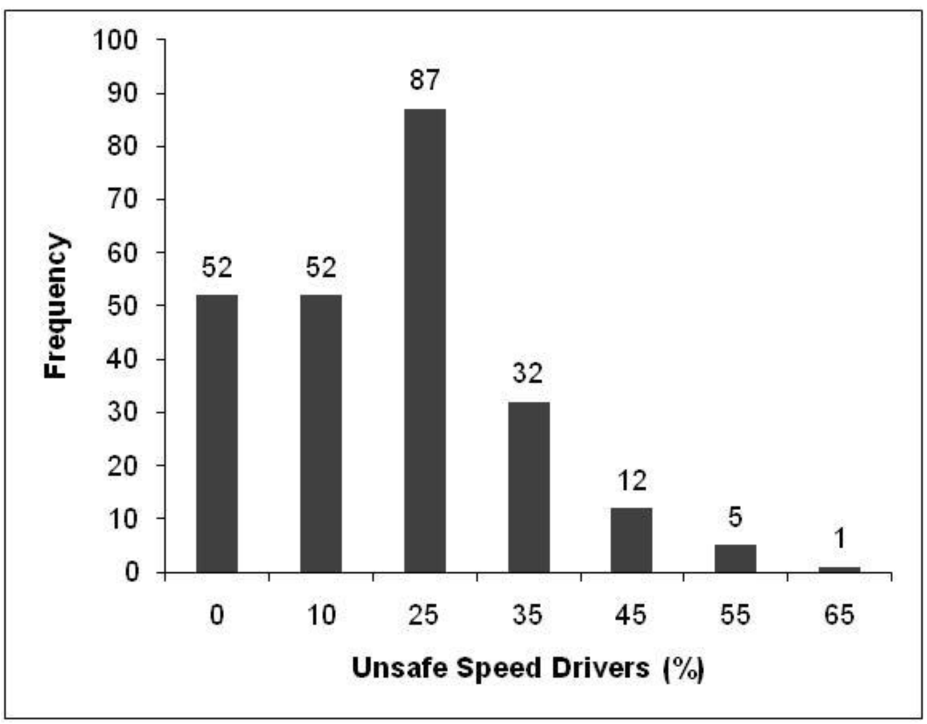

Figure 3.16 Distribution of Unsafe Speed Drivers (USD) (%)

CHAPTER 4 ARTIFICIAL NEURAL NETWORK MODELING

4.1 INTRODUCTION

Artificial Neural Networks (ANNs) represent a class of models designed to perform the mapping of an input vector into an output vector (Zaman et al., 2010; Zaman et al., 2000; Tarefder et al., 2005; Hagan et al., 1996). The architecture and operation of these networks is an over simplification of those of the biological nervous system. Therefore, ANNs are massively parallel systems that adapt according to stimuli induced by an external environment. In other words, ANNs are designed to learn incrementally from examples presented to them (Zaman et al., 2010; Zaman et al., 2000; Tarefder et al., 2005; Hagan et al., 1996).

The architecture of a simple ANN model is a collection of nodes distributed over an input layer, hidden layer(s), and an output layer (Figure 4.1). In the input layer, the input variables of the problems are situated. The output layer contains the output variables of what is being modeled. In statistical terms, the input layer contains the independent variables and the output layer contains the dependent variables. The nodes between successive layers are connected by links each carrying a weight that quantitatively describes the strength of those connections, thus denoting the strength of one node to affect the other node. For the backpropagation paradigm, no connections between nodes of the same layer are permitted and all connections proceed in the forward direction from the input layer to the hidden layer and then to the output layer (i.e., no cyclic or backward connections).

In the backpropagation training algorithm, the first example (input and output vectors) is presented to the network whose connection weights have been initialized before the presentation of the example. For each hidden node, the sum representing the scalar product of impinging nodes and their respective connection weights is computed. The sum is then converted to activation by using a transfer function such as tansigmoidal or sigmoidal. This procedure is repeated for each of the higher level nodes until the output is computed. At this stage, an error function describing the difference between the computed output value and the target value is also calculated. All examples in the dataset are presented to the network in this forward fashion. Next, an average error function for all examples is determined, which is used by the algorithm to adjust the connection weights on all of the links starting from the output layer and continuing down to the input layer. This procedure of forward presentation of examples and backward correction of links is repeated many times until the average error function is minimized.

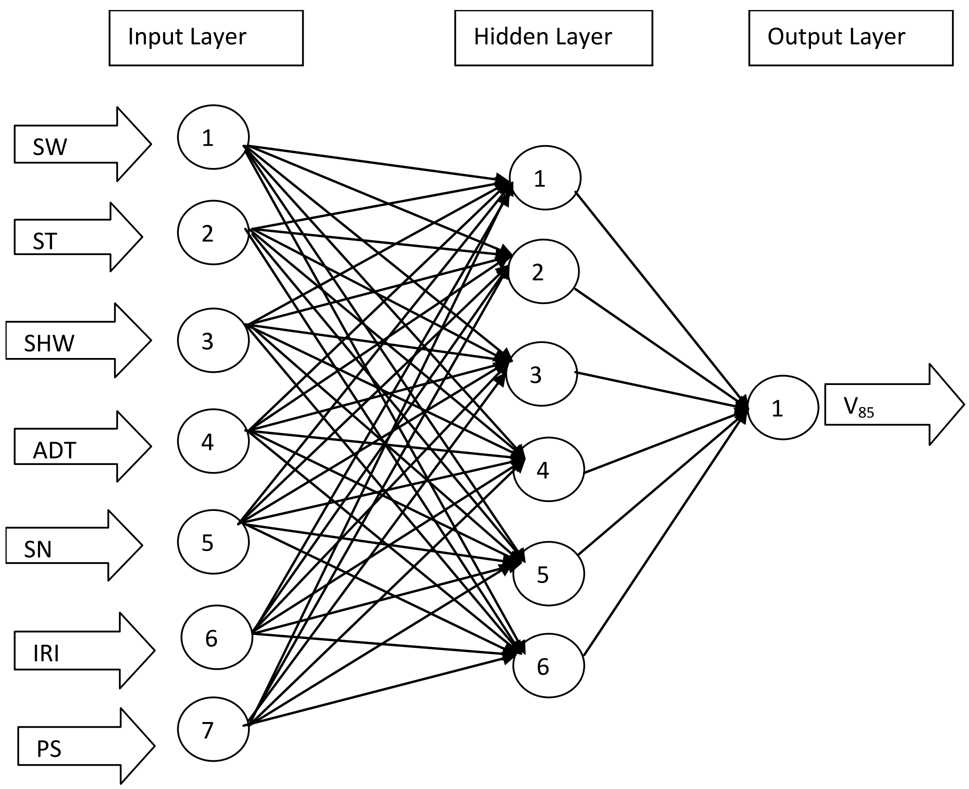

Figure 4.1 Network Architecture of ANN Model

The first step in the formulation of an ANN model is to separate the available dataset into two sets, one for training and another for testing of the developed model. This separation should be done randomly, but it should also be done in a manner such that the training dataset has the range of variables seen in the testing dataset or expected to be seen in further applications of the model. ANNs are similar to regression models in this respect, and they should not be expected to perform well when they are used to extrapolate beyond the data used for training. An optimal network is the one that has minimized a specific average error on the testing database. This procedure is conducted to prevent the network from memorizing the training data through using an excessive and unnecessary number of training cycles or over fitting that arises when large numbers of hidden nodes are attempted. The over fitting phenomenon occurs when a large number of degrees of freedom are used in polynomial fitting by nonlinear regression (Zaman et al., 2010; Zaman et al., 2000; Tarefder et al., 2005; Hagan et al., 1996). The polynomial will be able to produce excellent predictions only on those data points used for the regression but not on other data.

Currently, there are several learning paradigms available in the literature for training ANN models. The interested reader can refer to many books and publications on ANNs such as Zaman et al. (2010); Basheer et al. (1996), Najjar et al. (1996 a, and 1996 b); Tarefder et al. (2005); Zupan et al. (1993), and Simpson (1990).

4.2 DEVELOPMENT OF ANN MODELS

The overall dataset of 241 sites was divided into a training dataset and a testing dataset. This partition was done randomly with roughly 80% of the data used for training and 20% (every fifth data vector with the rest used for training) of the total data used for testing. Thus, 193 sites were used for training and 48 sites were used for testing purposes. Table 4.1 and Table 4.2 show the descriptive statistics for the training and testing datasets, respectively. It can be seen that the range of the testing dataset falls within the range of the training dataset. Four different ANN models, namely Model 1, Model 2, Model 3, and Model 4, as noted earlier, were developed with and without considering posted speed and accident data. For example, Model 1 and Model 2 were developed without considering the accident data, while Model 3 and Model 4 were developed by including the accident data. The only difference between Model 1 and Model 2 was the posted speed. Model 1 includes posted speed, while Model 2 does not. Similarly, Model 3 considered posted speed, while Model 4 did not. The purpose of including accident data in the modeling was to assess if inclusion of the accident data affects the performance of the developed models. In addition, it was found that the posted speed was highly correlated with the V_{85} speed with a correlation coefficient (R^2) = 0.929, hence, it was decided to separate models based on the posted speed. Consequently, the four different ANN models developed here are: Model 1: With Posted Speed but Without Accident Data; Model 2: Without Posted Speed and Without Accident Data; Model 3: With Posted Speed but With Accident Data; and Model 4: Without Posted Speed and With Accident Data. Table 4.3 summarizes the model parameters used for each model. The cross mark (x) indicates the model parameters that are included in the modeling process as an input vector, p. The function output, t, associated with this given input vector is V_{85}. A commercial software MATLAB® tool box was used to develop codes for the ANN models. Several networks with different numbers of hidden layers and neurons were tried. After numerous trial and error processes, the best performance was found with one hidden layer having 6 neurons. The number of nodes in the input layer depends on the number of model parameters. The number of nodes in the output layer in the present study was one (V_{85}). A tansigmoidal function was used in the hidden layer, while a linear function ("purelin") was used in the output layer. The models were trained using the Levenberg Marquardt optimization method (Tarefder et al., 2005; Hagan et al., 1996). The function to be determined can be expressed in terms of a composition of functions shown in Equation (4.1)

$$t = f_2 (W_2 f_1 (W_1 p + b_1) + b_2 \qquad (4.1)$$

The function is determined by specifying the matrices W_1 and W_2 along with the bias vectors b_1 and b_2 and the functions f_1 and f_2. To "train" the neural network means to determine the parameters to match the (input, output) or (p_o, t_o) data pairs. Typically, a dataset is presented as a collection of M data pairs. Normalization of input data has been found to significantly influence the predictive capability of an ANN model. Hence, it is useful to normalize the data so that the mean and variance become zero and unity, respectively. This facilitates the analysis of the sensitivity of outputs to different factors and is an important improvement to the model. In this regard, a principal component analysis is useful to possibly reduce the number of variables, although in the present application the number of variables is sufficiently small so the use of the principal component analysis was not found to be useful. The parameters are determined to minimize the squared error between model output and the observation. The training procedure amounts to a minimization algorithm that iteratively determines W_1, b_1, W_2, and b_2 by means of the backpropagation or the Levenburg-Marquardt algorithms.

The architecture of a particular model can be presented in the form of I-H-O, where I, H, and O indicate the number of nodes in input, hidden, and output layers, respectively. For example, Model 1 has 7-6-1 architecture, where 7 indicates the input parameters, 6 indicates one hidden layer with 6 neurons, and 1 indicates output layer with one neuron (V_{85}). Similarly, Model 2, Model 3, and Model 4 had the following architecture, 6-6-1, 14-6-1, and 13-6-1, respectively. The strength of each training and testing stage was evaluated by calculating the mean absolute relative error (%) (MARE). Generally, for problems of the type considered here, outputs depend on the initialization of the weights in the minimization algorithms. Ideally, the network should give close to the same answer regardless of the initial value of the weight, but in reality that may not be the case. The approach used here involved random generation of starting values of weights to obtain a collection of different estimated weights. This collection is used in a simulation to determine distributions of outputs for a given input. Each model was developed by randomly varying the weight by 500 times, and then the output was calculated as the mean of all 500 values from the histogram. This approach gives a measure of the uncertainty in the predicted output for new data. After the network was trained, then testing of the developed ANN model was conducted using data for sites that were not used in the training.

Table 4.1 Descriptive Statistics of Training Dataset

Designation		Maximum	Minimum	Mean
Surface Width (ft)	SW	24	20	23.87
Shoulder Type	ST	6	1	-
Shoulder Width (ft)	SHW	10	1	6.09
Average Daily Traffic	ADT	9100	330	3123
Skid Number	SN	62.8	25.6	42.5
International Roughness Index (in/mile)	IRI	202	38	97.2
Posted Speed (mph)	PS	65	35	52.26
Location Collision Rate Overall	LCRO	715.9	0	125.3
Location Collision Rate Fatal	LCRF	54.6	0	3.079
Location Collision Rate Injury	LCRI	330.4	0	56.44
Statewide Collision Rate Overall	SCRO	189.05	86.29	117.7
Statewide Collision Rate Fatal	SCRF	3.15	1.89	2.75
Statewide Collision Rate Injury	SCRI	65.19	41.4	48.72
Unsafe Speed Drivers (%)	USD	61.9	0	15.69
85^{th} Percentile Speed (mph)	V_{85}	70.5	38.5	57.08
*Collision rate : 100 million vehicle miles				

Table 4.2 Descriptive Statistics of Testing Dataset

Designation		Maximum	Minimum	Mean
Surface Width (ft)	SW	24	20	23.79
Shoulder Type	ST	6	1	-
Shoulder Width (ft)	SHW	10	2	6.31
Average Daily Traffic	ADT	9100	560	3407
Skid Number	SN	60.6	28.1	43.9
International Roughness Index (in/mile)	IRI	158	39	93.9
Posted Speed (mph)	PS	65	35	54.79
Location Collision Rate Overall	LCRO	762.4	0	127.8
Location Collision Rate Fatal	LCRF	35.3	0	2.64
Location Collision Rate Injury	LCRI	213.2	0	51.2
Statewide Collision Rate Overall	SCRO	189.1	86.29	109.9
Statewide Collision Rate Fatal	SCRF	3.15	1.89	2.85
Statewide Collision Rate Injury	SCRI	65.19	41	46.89
Unsafe Speed Drivers (%)	USD	41.7	0	11.89
85^{th} Percentile Speed (mph)	V_{85}	68.5	38.5	57.05
*Collision rate : 100 million vehicle miles				

Table 4.3 Model Parameters for Different ANN Models

Model Parameters	Designation	Model 1	Model 2	Model 3	Model 4
Surface Width (ft)	SW	x	x	x	x
Shoulder Type	ST	x	x	x	x
Shoulder Width (ft)	SHW	x	x	x	x
Average Daily Traffic	ADT	x	x	x	x
Skid Number	SN	x	x	x	x
International Roughness Index (in/mile)	IRI	x	x	x	x
Posted Speed (mph)	PS	x		x	
Location Collision Rate Overall	LCRO			x	x
Location Collision Rate Fatal	LCRF			x	x
Location Collision Rate Injury	LCRI			x	x
Statewide Collision Rate Overall	SCRO			x	x
Statewide Collision Rate Fatal	SCRF			x	x
Statewide Collision Rate Injury	SCRI			x	x
Unsafe Speed Drivers (%)	USD			x	x

4.3 RESULTS AND DISCUSSION

4.3.1 Model 1: With Posted Speed but without Accident Data

As noted earlier, Model 1 was developed by considering seven input parameters: SW, ST, SHW, ADT, SN, IRI, and PS. Accident data were not included in this model. This model includes the posted speed (PS) as one of the input parameters. This model can be used at the sites where PS is available. The performance indicator MARE for the training dataset was found to be 2.6%, which implies that this model is well trained to calculate V_{85} with 97.4% average degree of accuracy. Figure 4.2 shows the histogram of the training state. It is evident that Model 1 predicted V_{85} with an absolute speed difference (|measured V_{85} –predicted V_{85}|) less than 5 mph for 98% of the sites. This trained model was tested for 48 sites (testing dataset) that were not used in the training process. The performance of this model for the testing dataset was found to be excellent, with a MARE value of 5.1% (94.9 ≈ 95% degree of accuracy). Figure 4.3 shows the histogram of the testing dataset for all 48 sites. It is seen that Model 1 predicted V_{85} with an absolute speed difference of less than 5 mph for almost 90% of the sites.

Then Model 1 was tested for all 241 sites to evaluate its overall accuracy. The MARE value for all datasets was found 3.1% (96.9 ≈ 97% degree of accuracy). Therefore, if this network predicts V_{85} = X mph, then the actual speed may lie within X [1 ± (overall MARE/100)] mph. For example, if this network predicts V_{85} = 60 mph, then the actual speed may lie between 58.1 mph [60(1 – 0.031) = 58.1 mph] and 61.9 mph [60(1 +0.031) = 61.9 mph].

The histogram and scatter plots for all 241 sites are shown in Figure 4.4 and Figure 4.5, respectively. These plots indicate that this model predicted V_{85} with an absolute speed difference of less than 5 mph for almost 97% of the sites. Moreover, the scatter plot shows that the measured and the predicted V_{85} are well located along the line of equality, which indicates that the model has an excellent capability in predicting V_{85}.

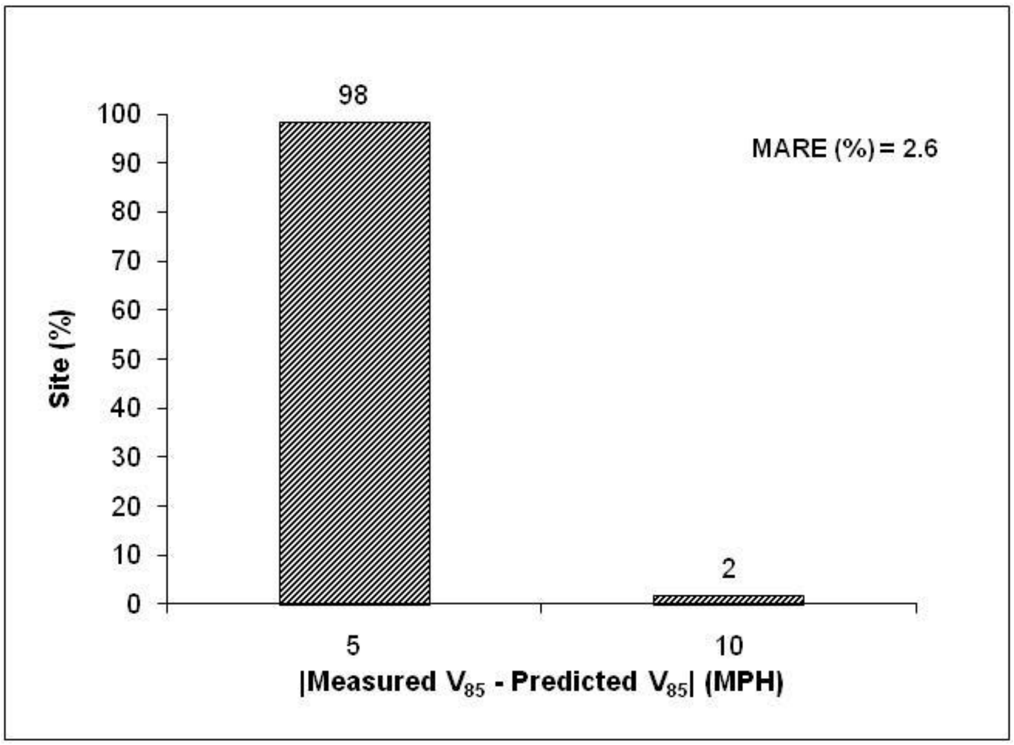

Figure 4.2 Histogram of Training Dataset for Model 1

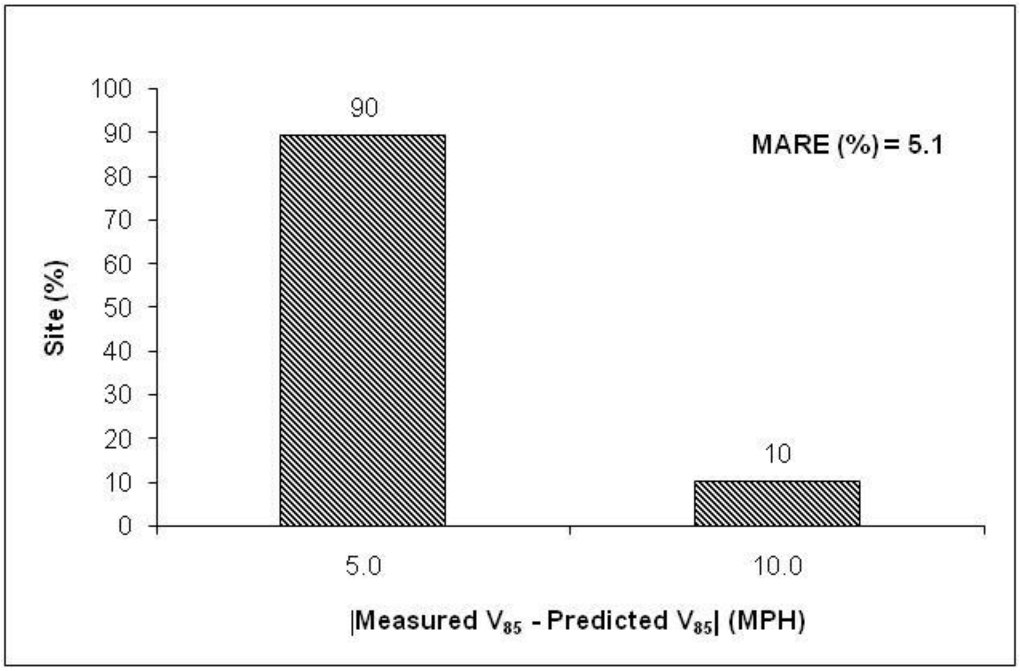

Figure 4.3 Histogram of Testing Dataset for Model 1

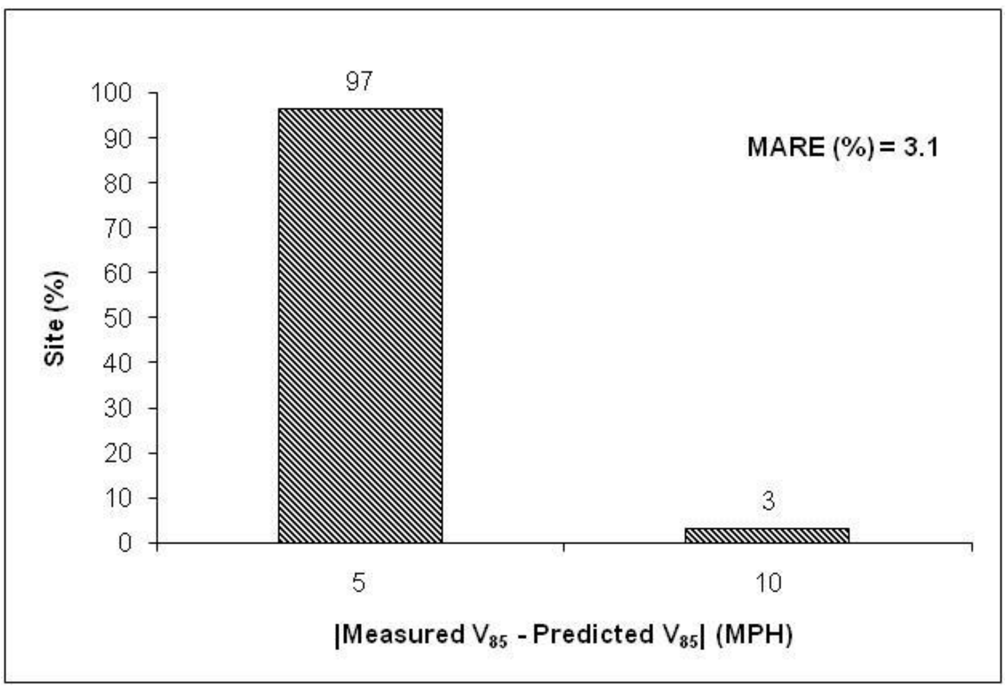

Figure 4.4 Histogram of All Data (Training and Testing Dataset) for Model 1

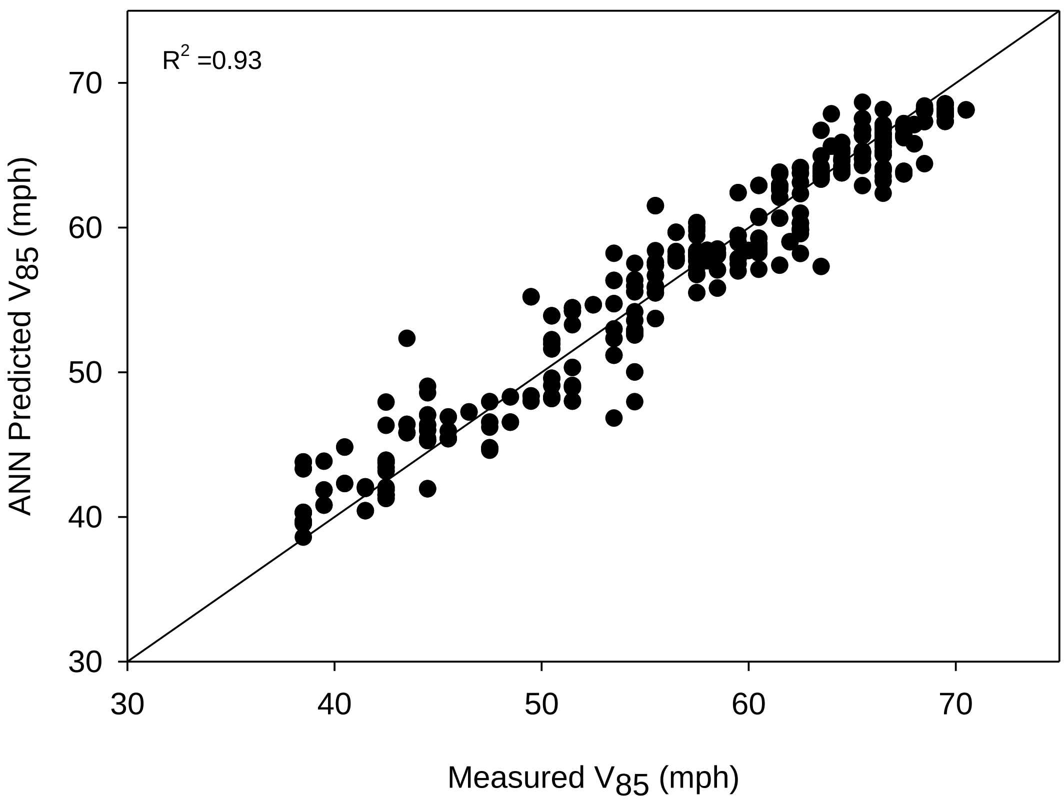

Figure 4.5 Measured and Predicted V_{85} for Model 1

4.3.2 Model 2: Without Posted Speed and without Accident Data

Model 2 was developed by considering six different input parameters: SW, ST, SHW, ADT, SN, and IRI. The MARE value for the training dataset of this model was found to be 7.4%, indicating that this model is trained to calculate V_{85} with 92.6% average degree of accuracy. Figure 4.6 shows the histogram for the training dataset. It is seen that this model predicted V_{85} with an absolute speed difference less than 5 mph for 68% of the sites, and estimated approximately 25% of the sites with an absolute speed difference within a range of 5-10 mph. This trained model was tested for the remaining 48 sites (testing dataset) that were not used in the training process. The performance of Model 2 for the testing dataset was found to be reasonably good (but worse than Model 1) with a MARE value of 13.8% (≈ 86% degree of accuracy). Figure 4.7 shows a histogram of the testing dataset. It is seen that Model 2 predicted V_{85} with an absolute speed difference of less than 5 mph for almost 50% of the sites.

As done in case of Model 1, Model 2 was tested for all 241 sites to evaluate its overall accuracy. The MARE value for the combined dataset was found to be 8.6% (≈ 92% degree of accuracy). Accordingly, if this network predicts V_{85} = 50 mph, then the actual speed may lie between 45.7 mph [50(1 – 0.0860) = 45.7 mph] and 54.3 mph [50(1 +0.0860)]. The histogram and scatter plot for all 241 sites are shown in Figure 4.8 and Figure 4.9, respectively. It is evident that this model predicted V_{85} with an absolute speed difference of less than 10 mph for approximately 88% of the sites. Overall, this model did not perform as well as Model 1.

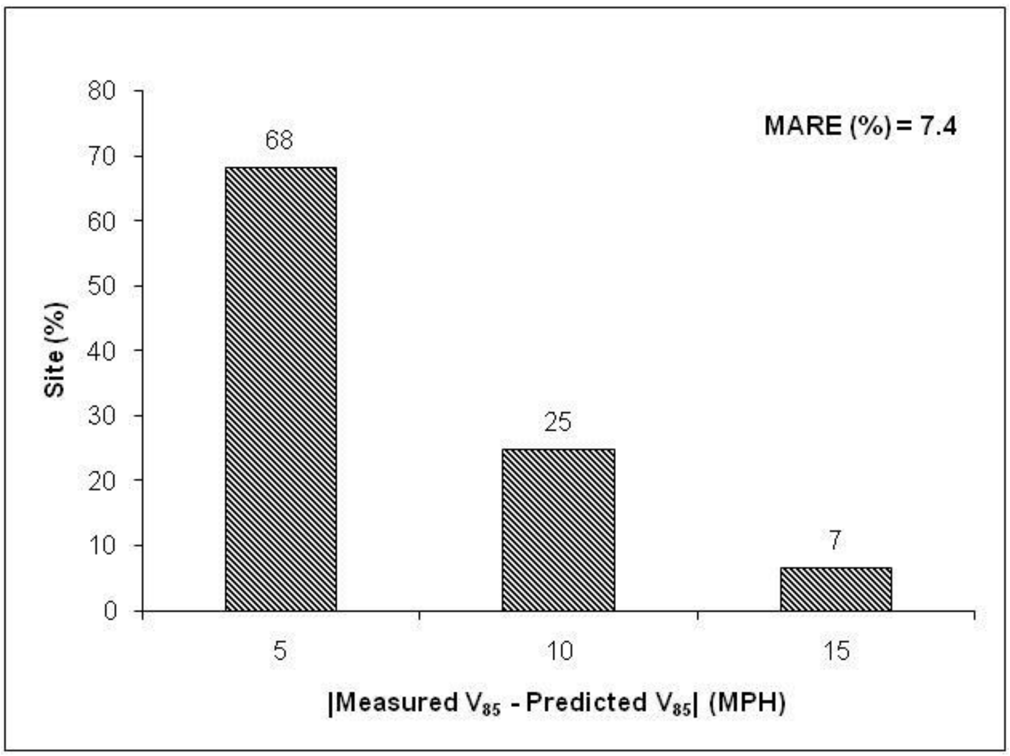

Figure 4.6 Histogram of Training Dataset for Model 2

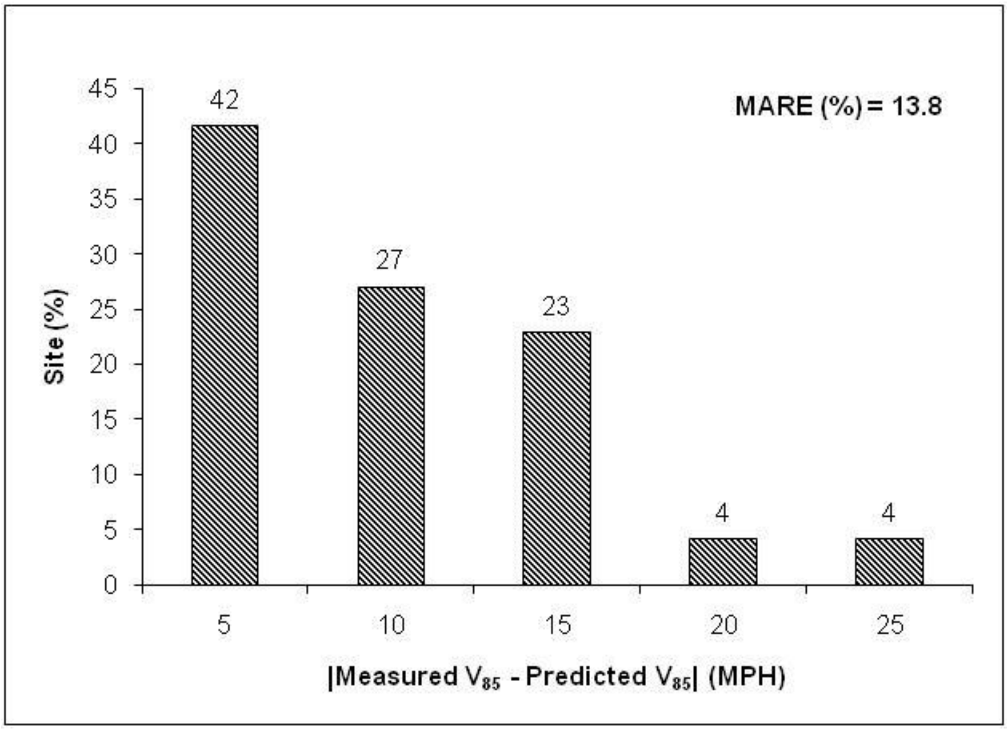

Figure 4.7 Histogram of Testing Dataset for Model 2

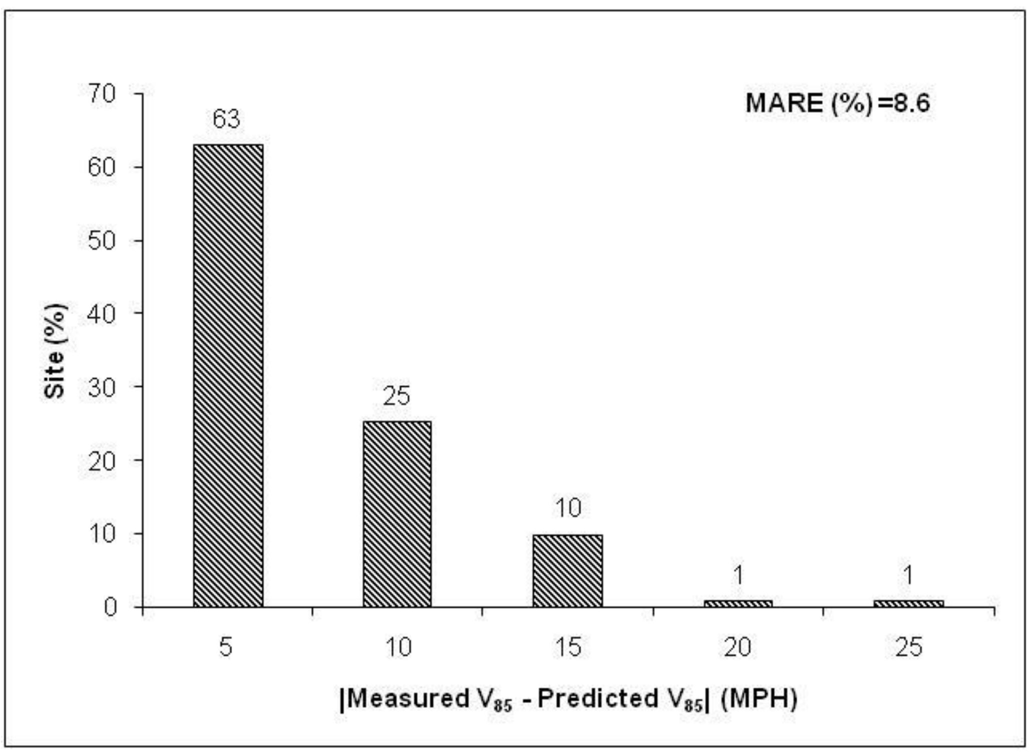

Figure 4.8 Histogram of All Data (Training and Testing Dataset) for Model 2

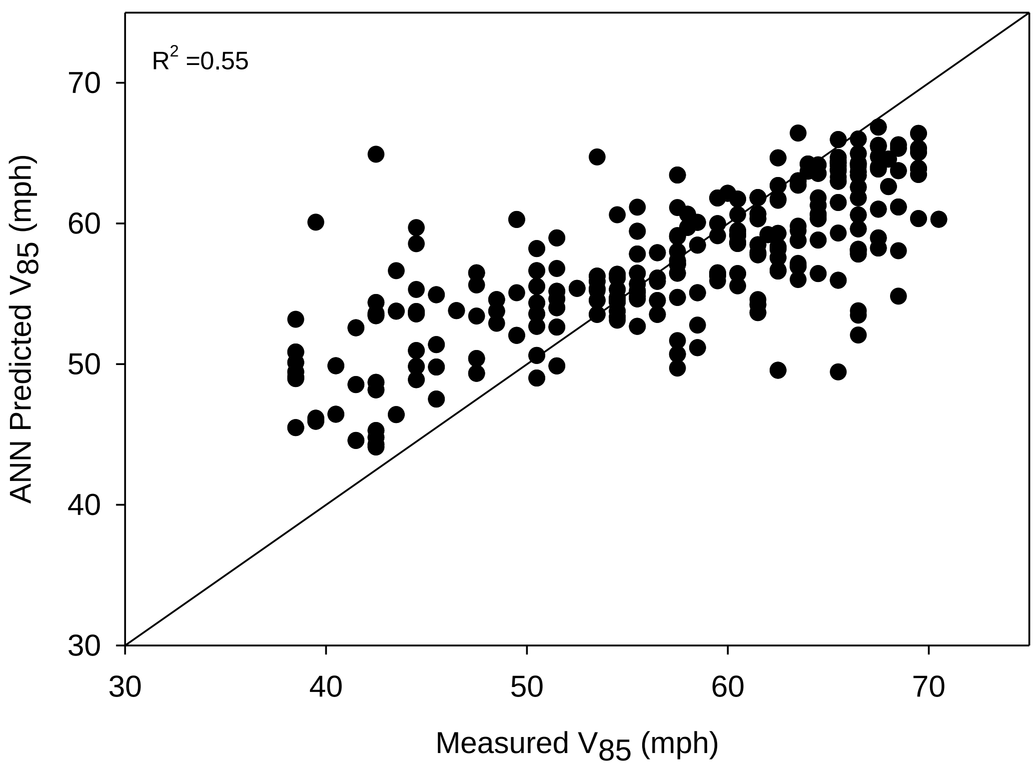

Figure 4.9 Measured and Predicted V_{85} for Model 2

4.3.3 Model 3: With Posted Speed and with Accident Data

Model 3 was developed using accident data. The following 14 independent input parameters were used in developing this model: SW, ST, SHW, ADT, SN, IRI, PS, LCRO, LCRF, LCRI, SCRO, SCRF, SCRI, and USD. The MARE value for the training dataset was found to be 1.8%, which indicates that this model is trained well to estimate V_{85} with a degree of accuracy of ± 98.2%.

Figure 4.10 shows the histogram for the training dataset, which indicates that this model is expected to predict V_{85} with an absolute speed difference of less than 5 mph for 99% of the sites. This trained model was tested for the testing dataset (48 sites) that was not used in the training process. The performance of Model 3 for the testing dataset was found to be excellent, with a MARE value of 5.8 % (≈ 94.2% degree of accuracy). Figure 4.11 shows the histogram of the testing dataset. It shows that the Model 2 predicted V_{85} with an absolute speed difference of less than 5 mph for almost 83% of the sites. The histogram indicates that the trained Model 2 predicted V_{85} fairly well for all the sites considered for testing purposes.

As done for Model 1 and Model 2, Model 3 was tested for all 241 sites to evaluate its overall accuracy. The MARE value for all dataset was found 2.5% (≈ 97.5% degree of accuracy). Accordingly, if this network predicts V_{85} = 65 mph, then the actual speed may lie between 63.4 mph [65(1 – .025)] and 66.6 mph [65(1 +0.025)]. The histogram and scatter plot for all 241 sites are shown in Figure 4.12 and Figure 4.13, respectively. The histogram plots indicate that this model predicted V_{85} with an absolute speed difference of less than 5 mph for almost 96% of the sites used in the present study. The scatter plot shows that predictions of Model 3 are tightly located around the line of equality, which indicates a low bias. Overall, it is evident that the inclusion of accident data slightly improves the performance of Model 3 compared to Model 1. Model 3 is useful when accident data is available for a selected site. However, in absence of accident data Model 1 or Model 2 may be used.

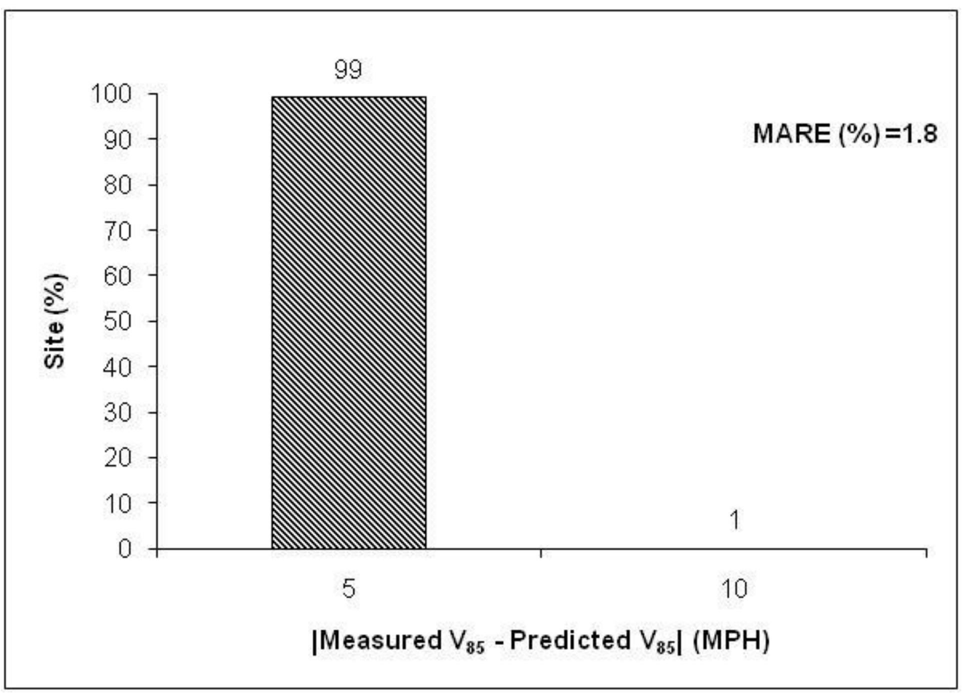

Figure 4.10 Histogram of Training Dataset for Model 3

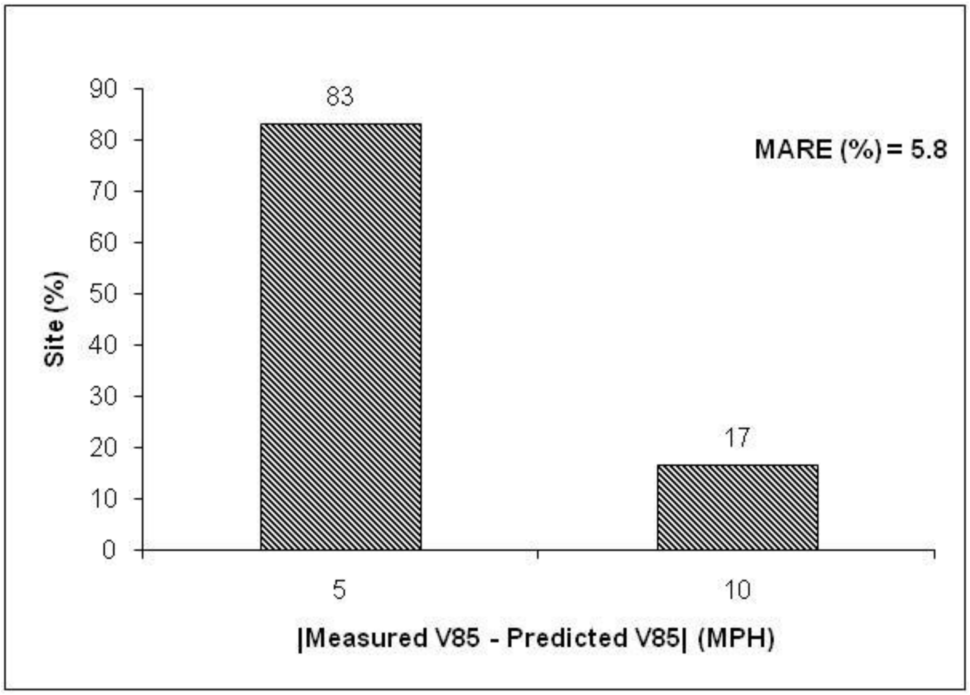

Figure 4.11 Histogram of Testing Dataset for Model 3

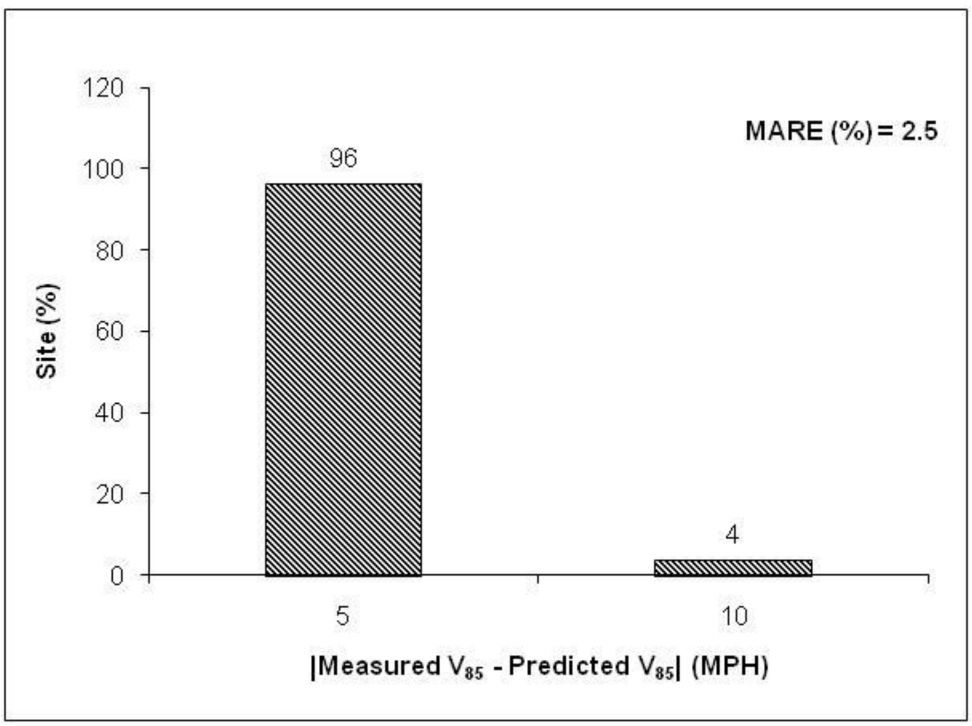

Figure 4.12 Histogram of All Data (Training and Testing Dataset) for Model 3

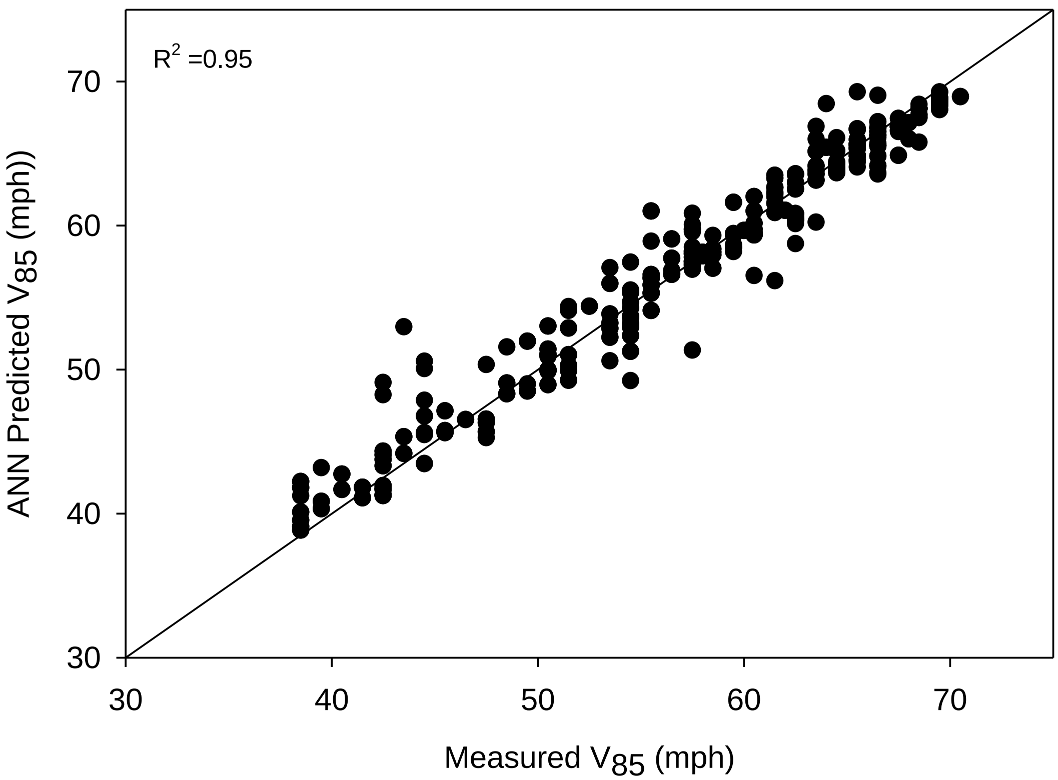

Figure 4.13 Measured and Predicted V_{85} for Model 3

4.4.4 Model 4: Without Posted Speed with Accident Data

Model 4 was developed using accident data. The following 13 independent input parameters were used in developing this model: SW, ST, SHW, ADT, SN, IRI, LCRO, LCRF, LCRI, SCRO, SCRF, SCRI, and USD. The MARE value for the training dataset for Model 4 was 4.4%, indicating that the model is well trained to calculate V_{85} with an accuracy of 95.6%.

Figure 4.14 shows the histogram for the training dataset, which indicates that this model is expected to predict V_{85} with an absolute speed difference of less than 5 mph for approximately 90% of the sites. This trained model was tested for the testing dataset. The performance of this model for the testing dataset was found to be reasonably good with a MARE value of 12.3% (≈ 88% degree of accuracy). Figure 4.15 shows the histogram of the testing dataset. It shows that this model predicted V_{85} with an absolute speed difference less than 5 mph for almost 56% of the sites.

As in the other models, Model 4 was tested for all 241 sites to evaluate its overall accuracy. The MARE value for all datasets was found to be 5.9% (≈ 94% degree of accuracy). Accordingly, if this network predicts V_{85} = 50 mph, then the actual speed may lie between 47.1 mph [50(1 – 0.059)] and 52.9 mph [50(1 +0.059)]. The histogram and scatter plot for all 241 sites are shown in Figure 4.16 and Figure 4.17, respectively. The histogram plot indicates that this model predicted V_{85} with an absolute speed difference of less than 5 mph in almost 83% cases.

The only difference between Model 2 and Model 4 is the accident data. Model 2 includes all the data except the accident data, while Model 4 considers the accident data. The inclusion of accident data only marginally improves the performance of this model when compared with Model 2. Model 4 is useful when the accident data is available for a site. In absence of accident data Model 2 can be used with a reasonable level of accuracy. The inclusion of PS in the model improves the results significantly. Table 4.4 summarized results of all four developed models.

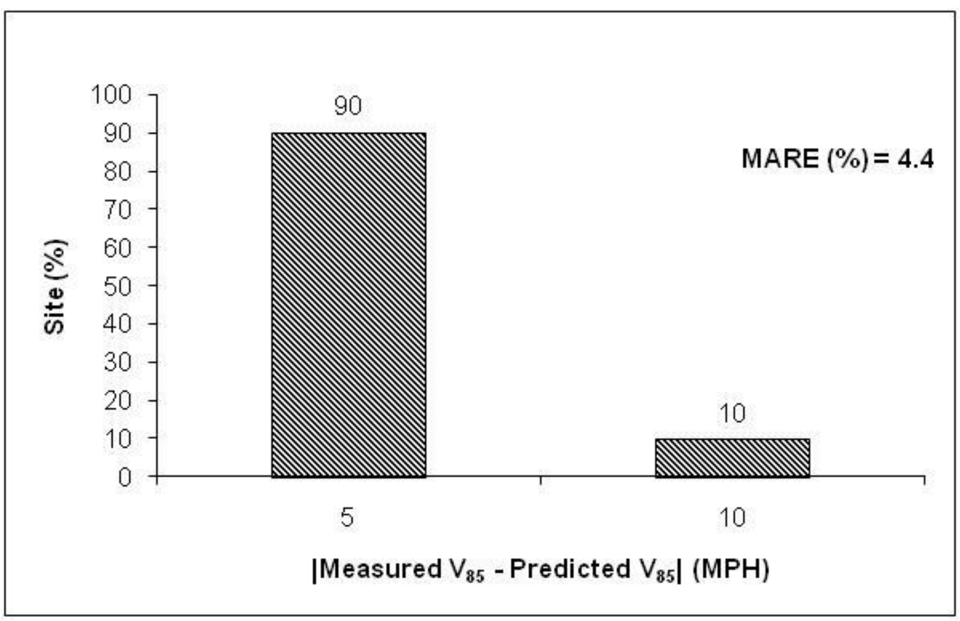

Figure 4.14 Histogram of Training Dataset for Model 4

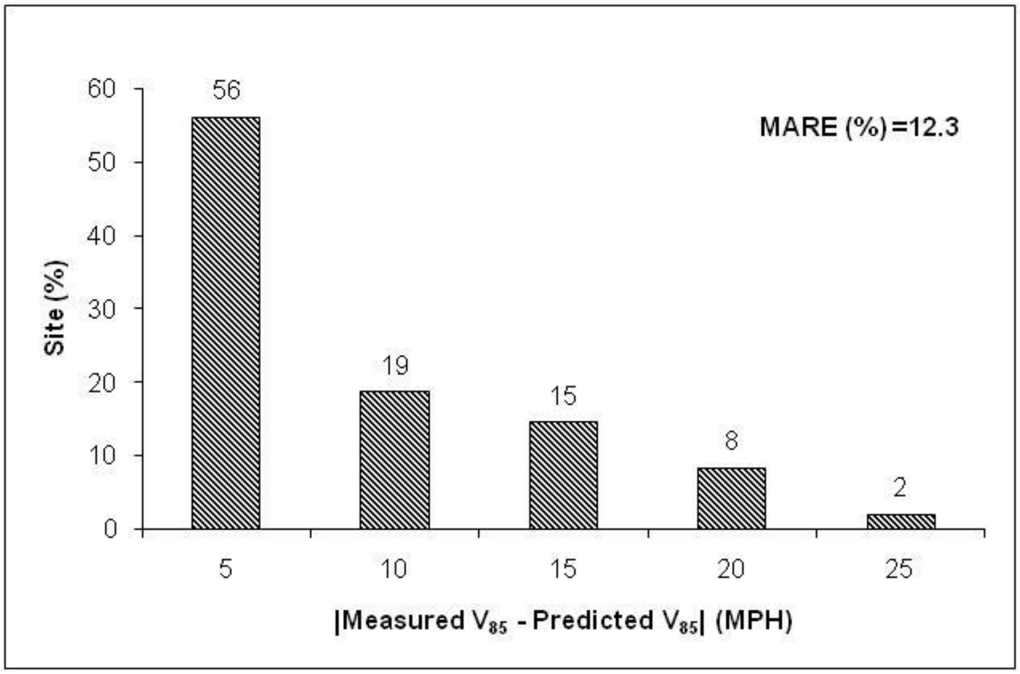

Figure 4.15 Histogram of Testing Dataset for Model 4

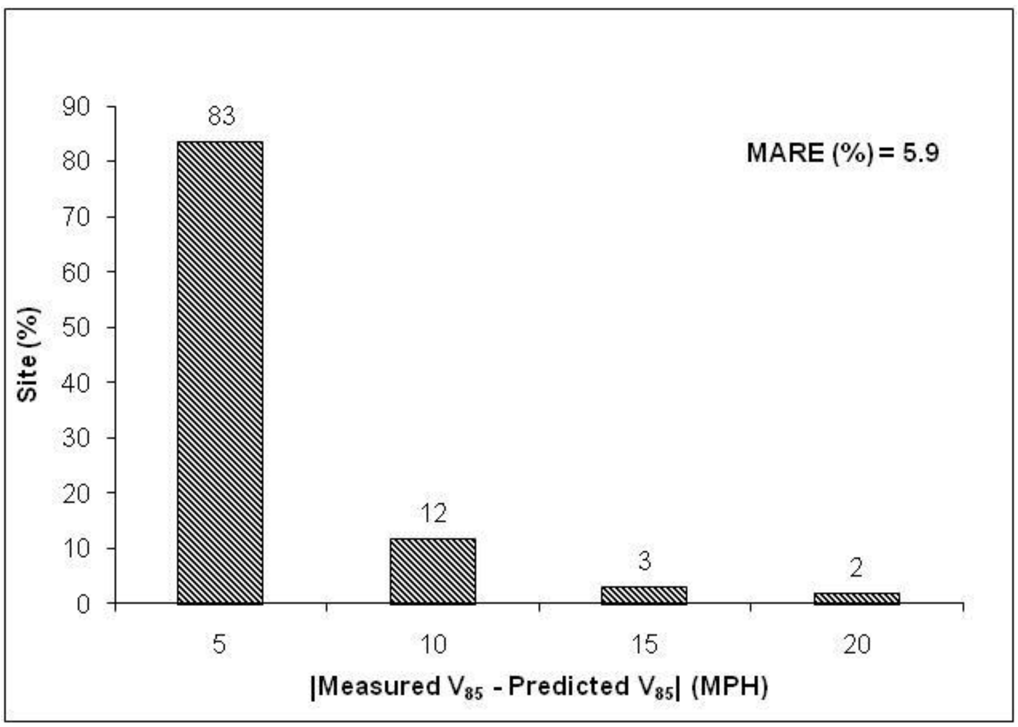

Figure 4.16 Histogram of All Data (Training and Testing Dataset) for Model 4

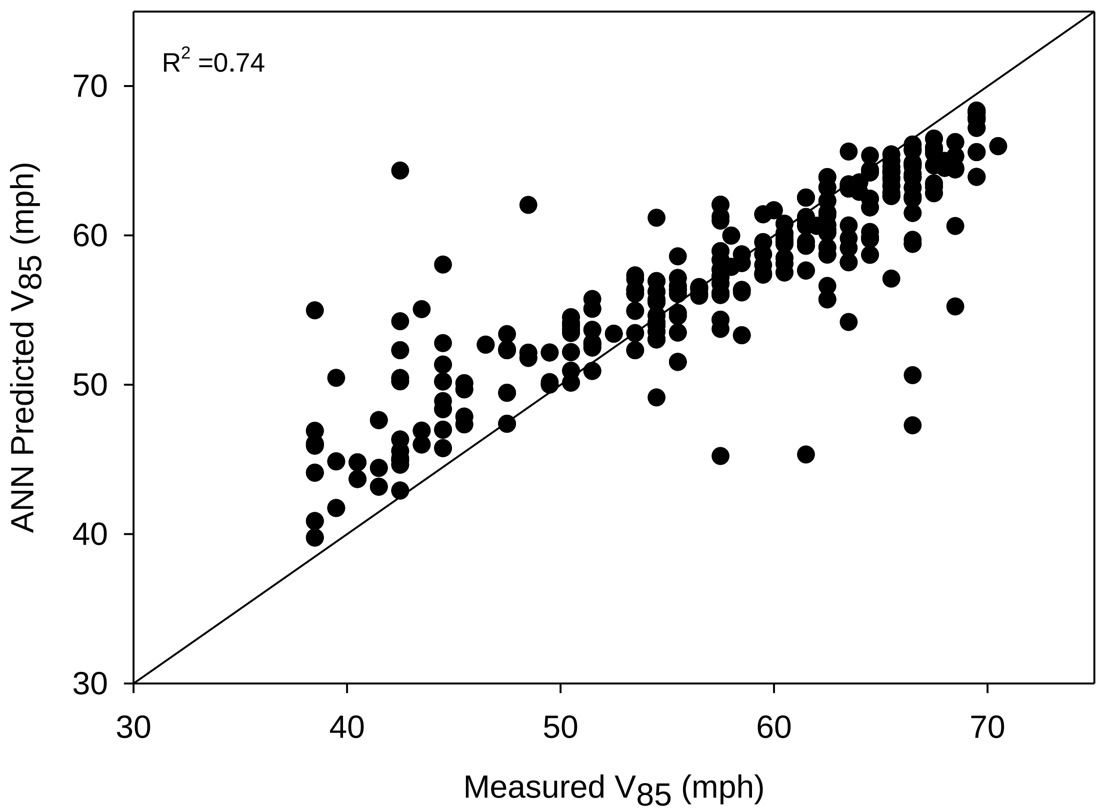

Figure 4.17 Measured and Predicted V85 for Model 4

Table 4.4 Performance Summary for ANN Models

Model No.	Model Architecture	MARE (%)		
		Training	Testing	Overall
Model 1	7-6-1	2.6	5	3.1
Model 2	6-6-1	7.3	13.7	8.6
Model 3	14-6-1	1.8	5.8	2.5
Model 4	13-6-1	4.4	12.3	5.9

4.4. PARAMETRIC STUDY

In order to obtain an understanding of the relationship between V_{85} and other model parameters, namely SW, ST, SHW, ADT, SN, IRI, LCRO, LCRF, LCRI, SCRO, SCRF, SCRI, and USD, a parametric study was conducted. To determine the effect of changes in one input parameter at a time on V_{85}, the average of each model parameter was calculated first. The selected model parameter was varied about its mean, while keeping the other parameters at their average value. Shoulder Type 1 (paved shoulder) was kept constant for all the cases. It is important that the range of selected model parameters fall within the range of training input parameters, otherwise the ANN model is likely to give erroneous results (Tarefder et al., 2005; Hagan et al., 1996).

Figure 4.18 shows the effect of surface width on V_{85}. The V_{85} speed increases with an increase in SW. For example, increasing SW from 21 feet to 24 feet increased V_{85} from 55 mph to 61 mph. On a wider road a driver feels more comfortable and does not perceive any danger, which results in a higher V_{85}, as expected. Similar results were obtained with the other three types of shoulder. The results in the present study are consistent with the results reported by other researchers (see e.g., Gattis et al. (1999); Farouki et al. (1996); Polus et al. (1991), and Heimbach et al. (1993)). Polus et al. (1991) reported that increasing surface width from 19.7 ft. to 23.6 ft. increased the V_{85} from 40.4 mph to 46 mph. Similarly, Farouki et al. (1976) reported that the mean speed increases linearly with lane width.

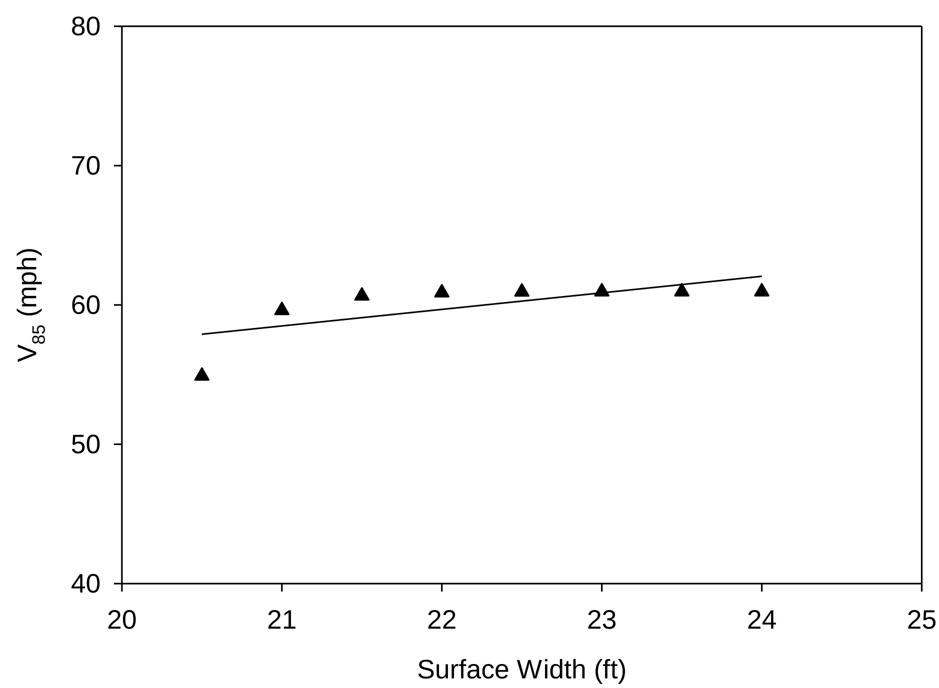

Figure 4.18 Variation of V_{85} with Surface Width

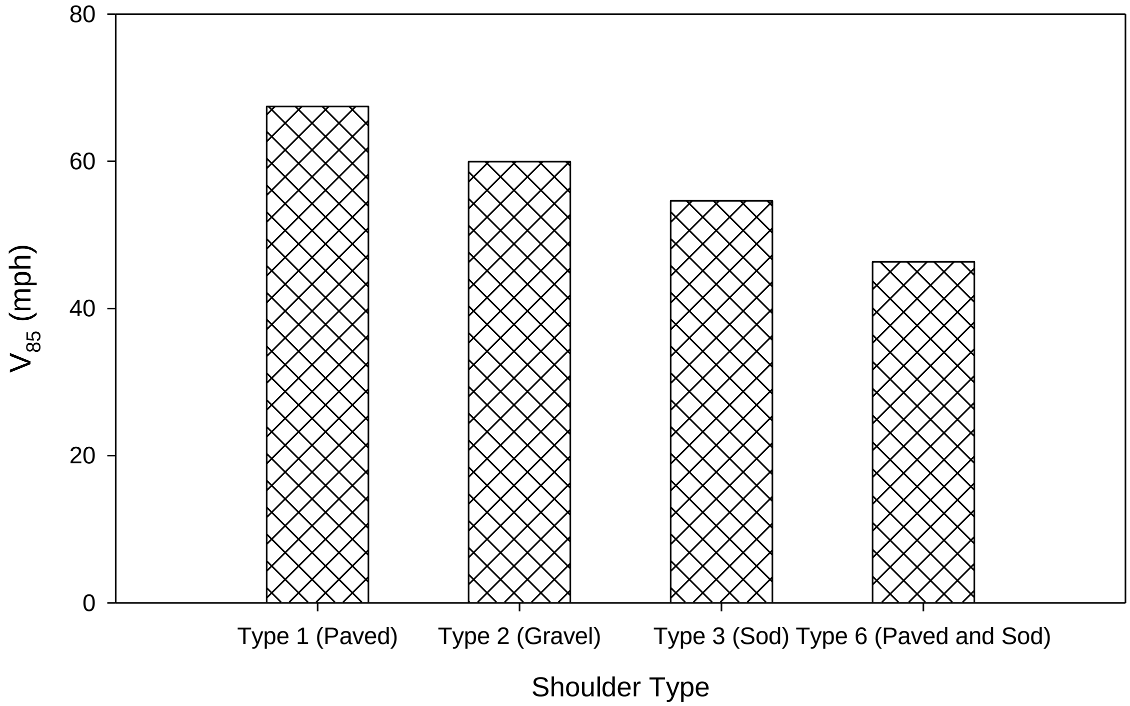

Figure 4.19 Variation of V_{85} with Shoulder Type

Variation of V_{85} with ST is shown in Figure 4.19. Four different types of shoulders are selected: Type 1 (Paved), Type 2 (Gravel), Type 3 (Sod), and Type 6 (Combination of Paved and Sod). Two-lane rural road with paved shoulders (Type -1) results in a higher V_{85} compared to the other types of shoulder (Type 2, Type 3, and Type 6). Type 2 (Gravel) shoulder exhibits about 7 mph lower speed than Type 1 (Paved). Similarly, Type 3 (Sod) shoulder showed 13 mph lower speed compared to Type 1 (Paved). Although not expected, Type 6 shoulder (Combination of Paved + Sod) results in the lowest V_{85}. It is expected that drivers would consider paved shoulder the safest, and hence the driving speed would be higher. With Gravel, Sod, and Combination shoulders, they are likely to become more cautious, which would cause a reduction in the V_{85}. Similar results are reported by Fitzpatrick et al. (2002), where a survey was conducted to document drivers' experience with different types of shoulders geometry. It was reported that V_{85} in paved shoulders is higher than in other shoulders.

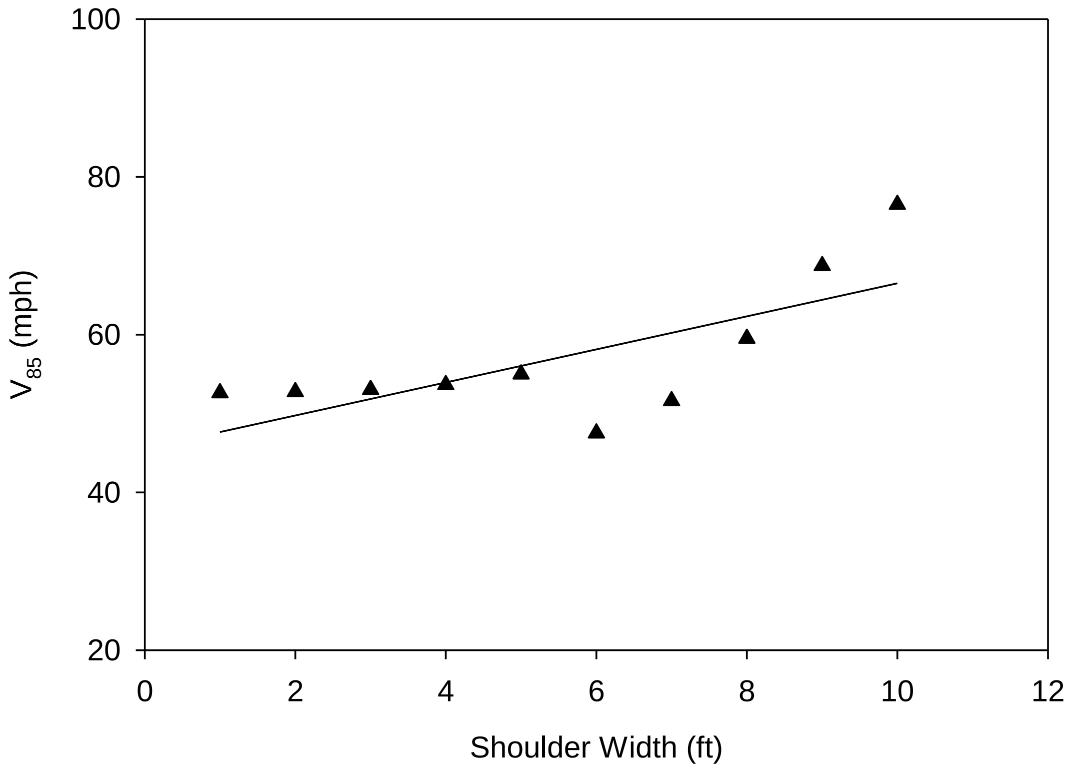

Figure 4.20 Variation of V_{85} with Shoulder Width

Figure 4.20 shows the variation of V_{85} with shoulder width (SHW). An increase in shoulder width results in a higher $V_{85,}$ as shown in Figure 4.20. V_{85} is constant for shoulder width less than 4 feet, and then it increases with an increase in SHW. It is believed that an increase in shoulder width changes drivers' perceptions and they are encouraged to drive faster compared to a more narrow shoulder. Similar observations were reported by Fitzpatrick et al. (2002), and Najjar et al. (2000). In a survey conducted by Fitzpatrick et al. (2002), it was found that almost 89% of drivers believed that a narrow shoulder causes drivers to drive slower. Similarly, Najjar et al. (2000) reported that V_{85} increases with an increase in width for turf/gravel (T/G) type of shoulder.

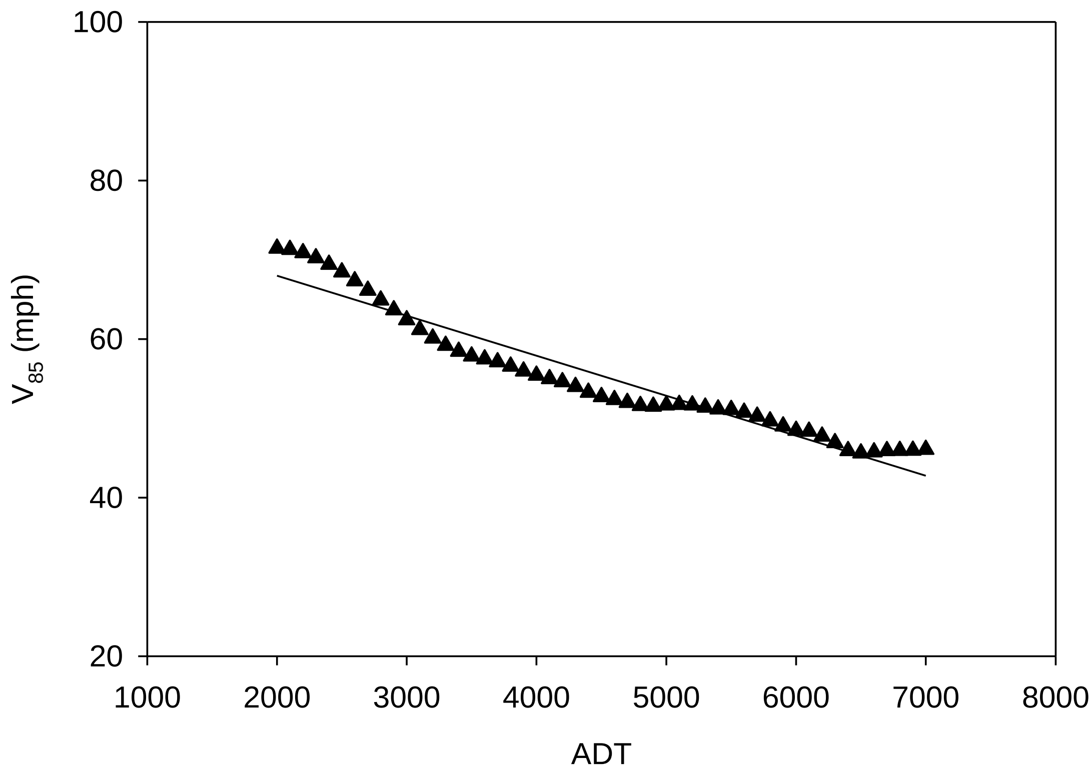

Figure 4.21 Variation of V_{85} with ADT

Variation of V_{85} with ADT is shown in Figure 4.21. V_{85} is found to decrease with an increase in ADT, as expected. For example, increasing ADT from 2000 to 5000 results in a reduction in V_{85} from 71 mph to 51 mph. It is expected that a higher traffic volume would significantly increase the queue length that pushes a driver to drive slow, consequently resulting in a slower V_{85} speed. In addition, roadways with higher ADT values may be perceived by drivers as having a higher likelihood of speed enforcement by authorities, resulting in lower operating speeds to guard against ticketing for speeding violations (Schurr et al., 2002). A lower traffic volume would result in less traffic density, which would make drivers to drive faster. Thus, the results from the present study are consistent with the previous studies conducted by Najjar et al. (2000), HCM (2000), and Pursula et al. (1991). Pursula et al. (1991) reported that an increase in two-lane flow rate from 400 to 1600 vehicles/hour decreased the traffic speed from 43.5 mph to 37.3 mph. Similarly, Najjar et al. (2000) noted that roadway speed decreases significantly if ADT values increase to 2000 vehicles for (pavement/combination) P/C shoulder type roads.

Driver's speed largely depends upon the pavement condition. For example, a smoother pavement would tempt drivers to drive faster, whereas a rough pavement (higher SN or IRI index) would force drivers to drive slowly. IRI index is also used by the Federal Highway Administration (FHWA) to assess changes in the condition of the nation's highways and to forecast highway investment needs. Variation of V_{85} with two different pavement condition indices, SN and IRI are given in Figures 4.22 and 4.23, respectively. As expected, V_{85} decreases with an increase in road roughness. For example, an increase in SN from 30 to 60 decreased V_{85} from 60 mph to 40 mph. Similarly, for smoother pavements with IRI < 60 in/mile, the V_{85} was found to be above 68 mph; however, it drops to 50 mph when the IRI value goes above 200 in/mile.

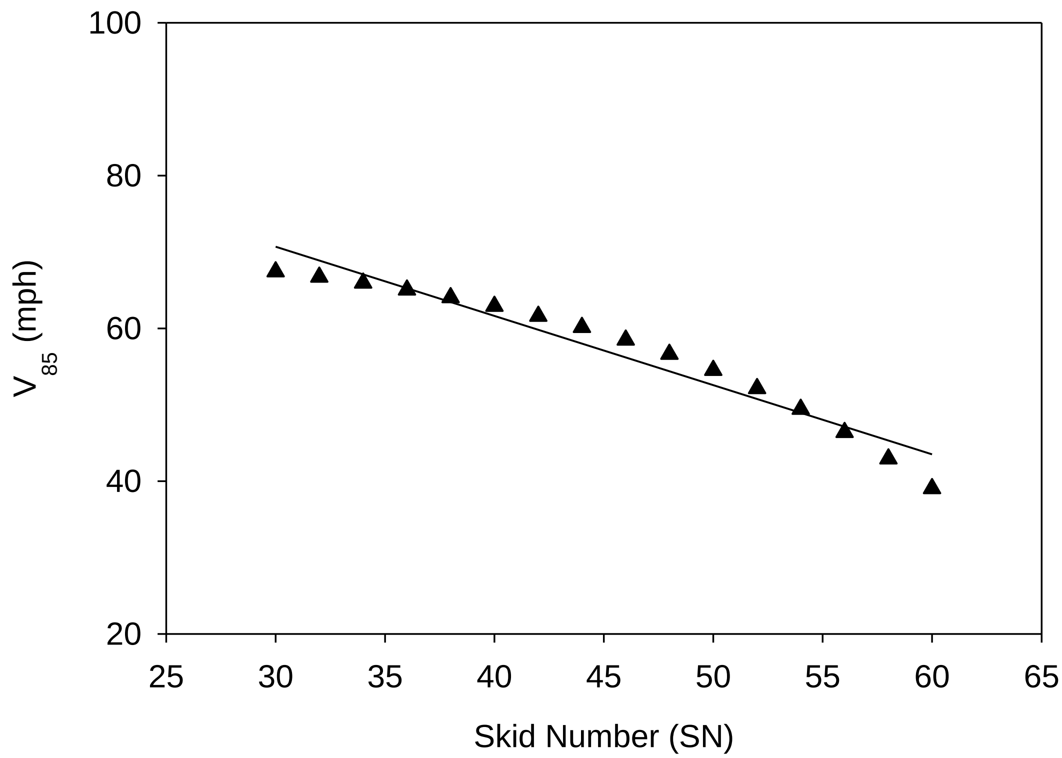

Figure 4.22 Variation of V_{85} with Skid Number (SN)

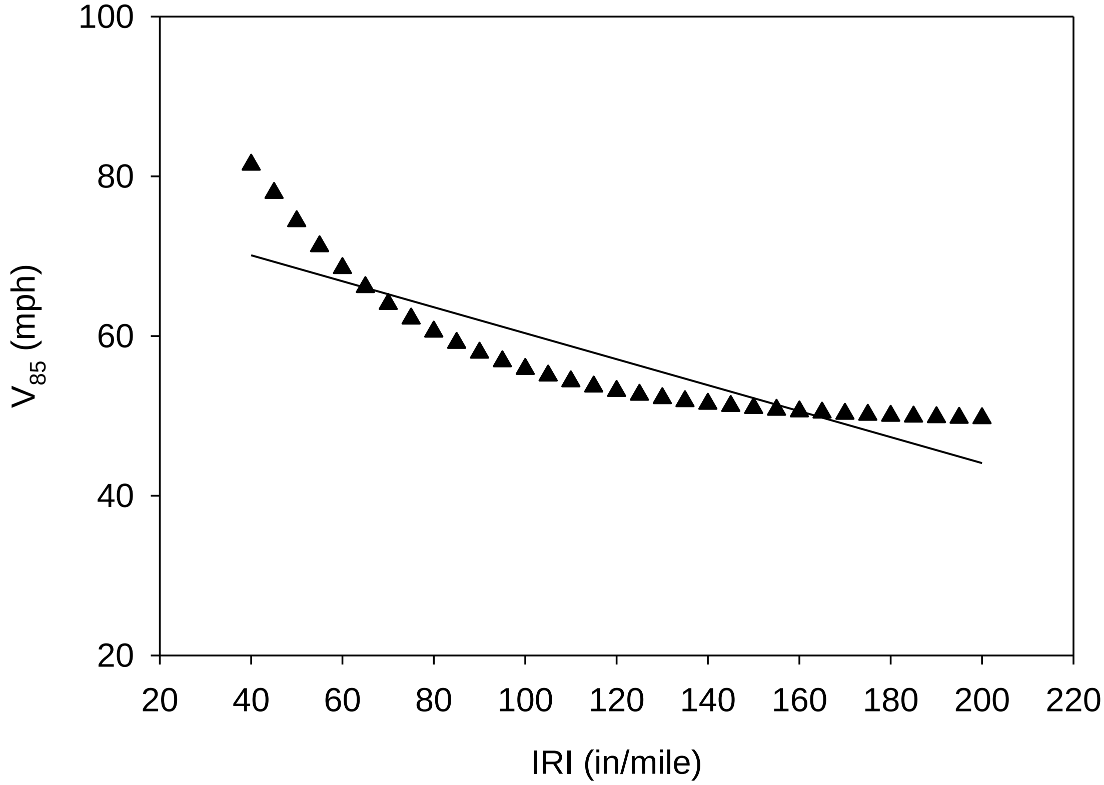

Figure 4.23 Variation of V_{85} with International Roughness Index (IRI)

Variations of V_{85} with accident parameters, namely LCRO, LCRF, LCRI, SCRO, SCRF, SCRI, and USD are shown in Figures 4.24 through 4.30. An increase in LCRO causes a reduction in the V_{85} speed. For example, with zero LCRO (no accident), V_{85} was calculated approximately 64 mph and it decreased to 41 mph when LCRO increased to 700 (100 million vehicle miles) (Figure 4.24). It is evident from these results that accident experiences cause a driver to be cautious, hence a reduction in speed. A similar variation is observed for LCRF (Figure 4.25). V_{85} does not vary much with change in LCRI and it remains constant with an increase in LCRI (Figure 4.26). Similar variations of V_{85} with SCRO, SCRF, and SCRI are seen in Figures 4.27 to 4.29. V_{85} decreases with an increase in the SCRO, while it remains constant for SCRF and SCRI. Also, V_{85} does not vary much with USD (Figure 4.30).

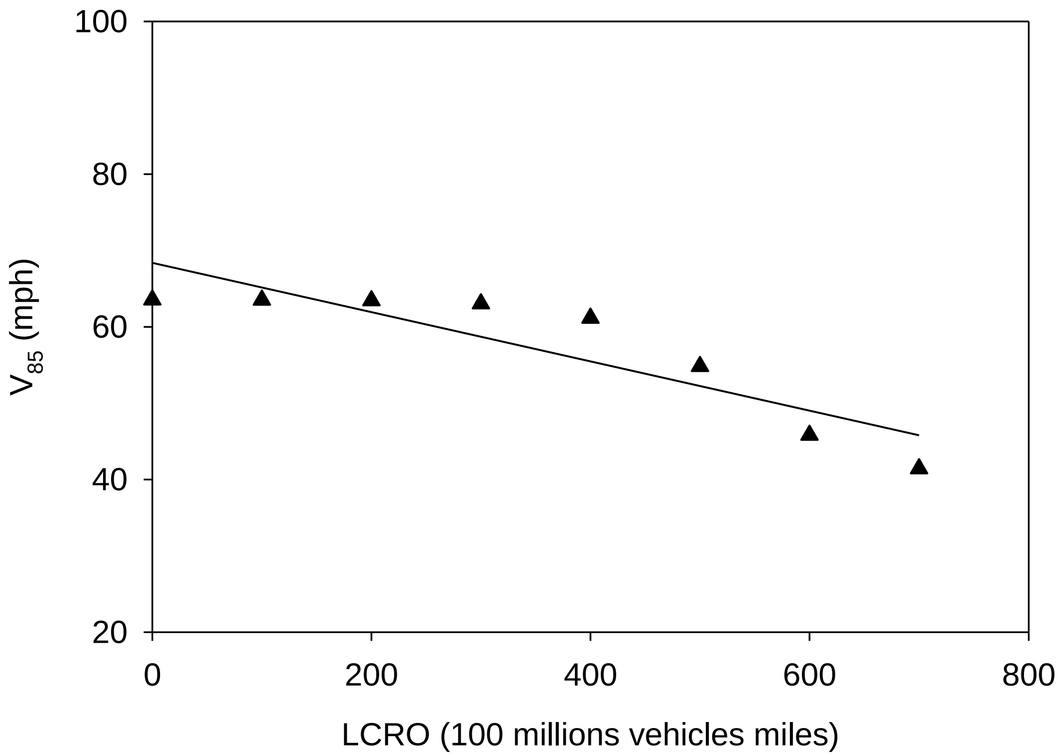

Figure 4.24 Variation of V_{85} with Location Collision Rate Overall (LCRO)

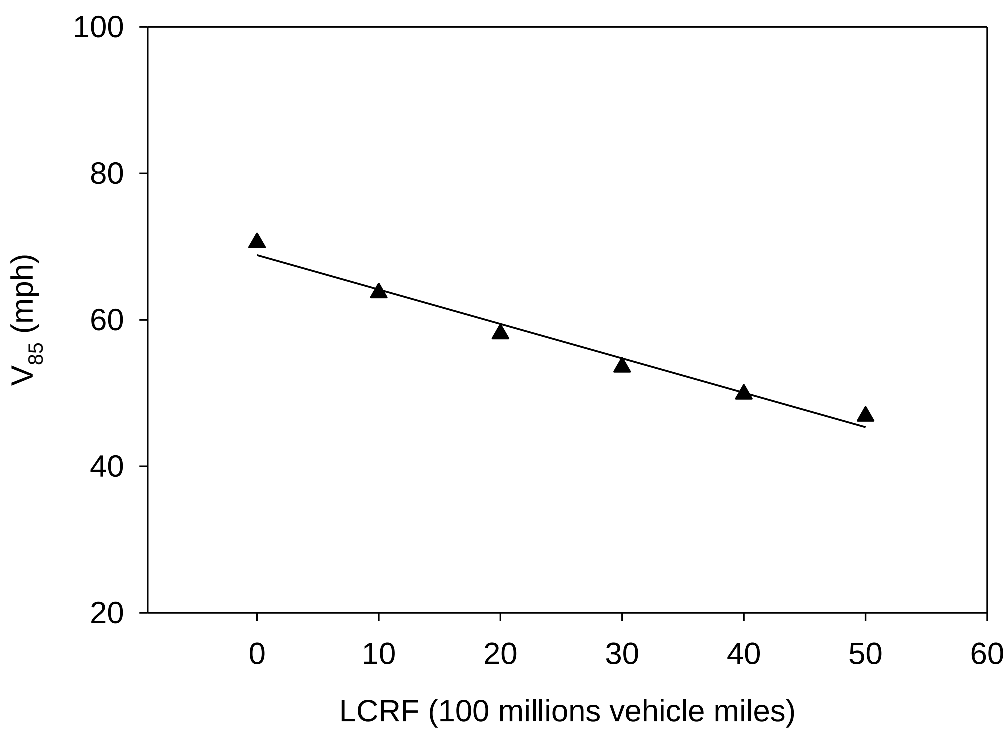

Figure 4.25 Variation of V_{85} with Location Collision Rate Fatal (LCRF)

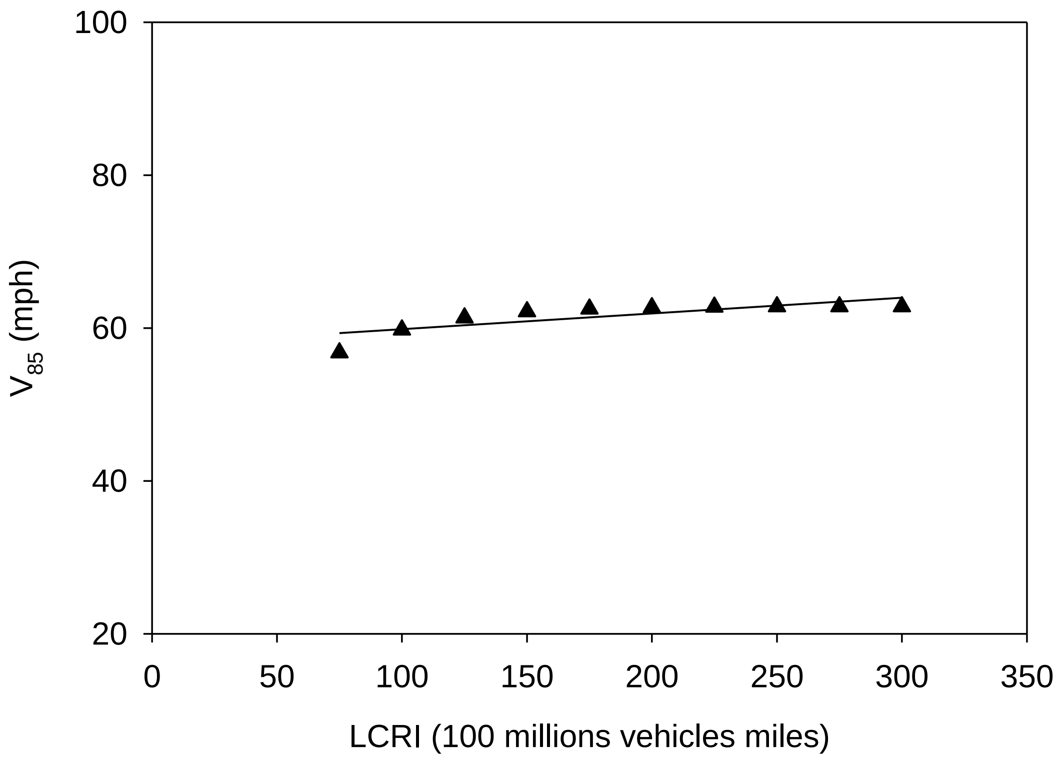

Figure 4.26 Variation of V_{85} with Location Collision Rate Injury (LCRI)

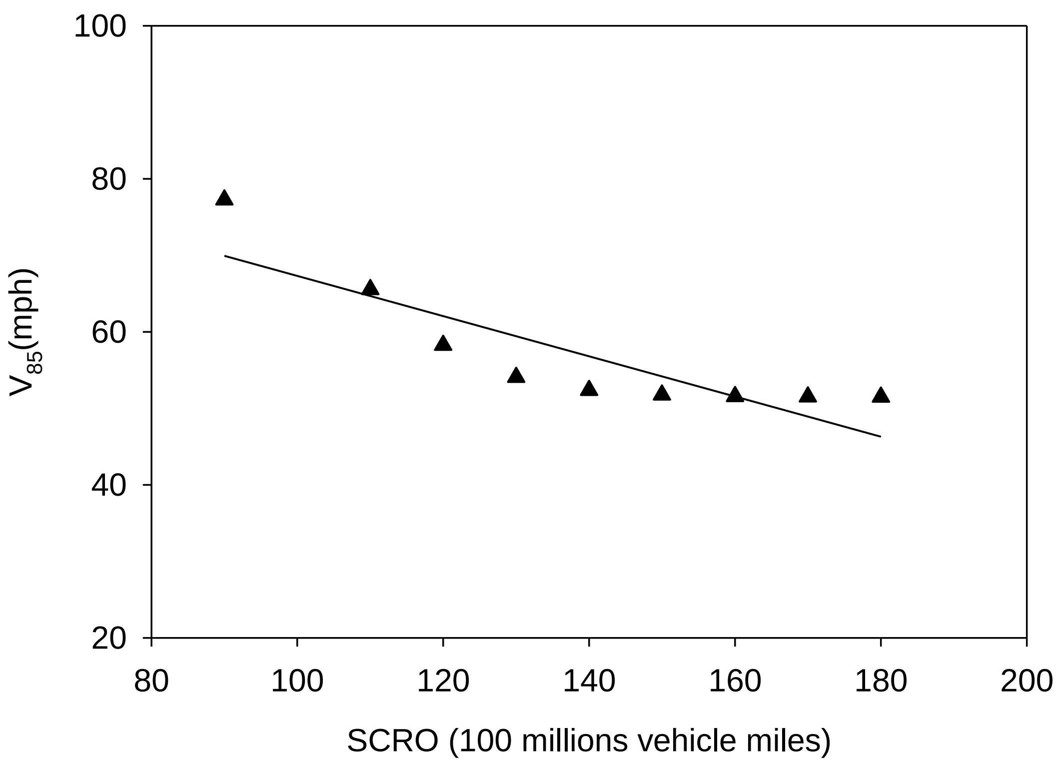

Figure 4.27 Variation of V_{85} with Statewide Collision Rate Overall (SCRO)

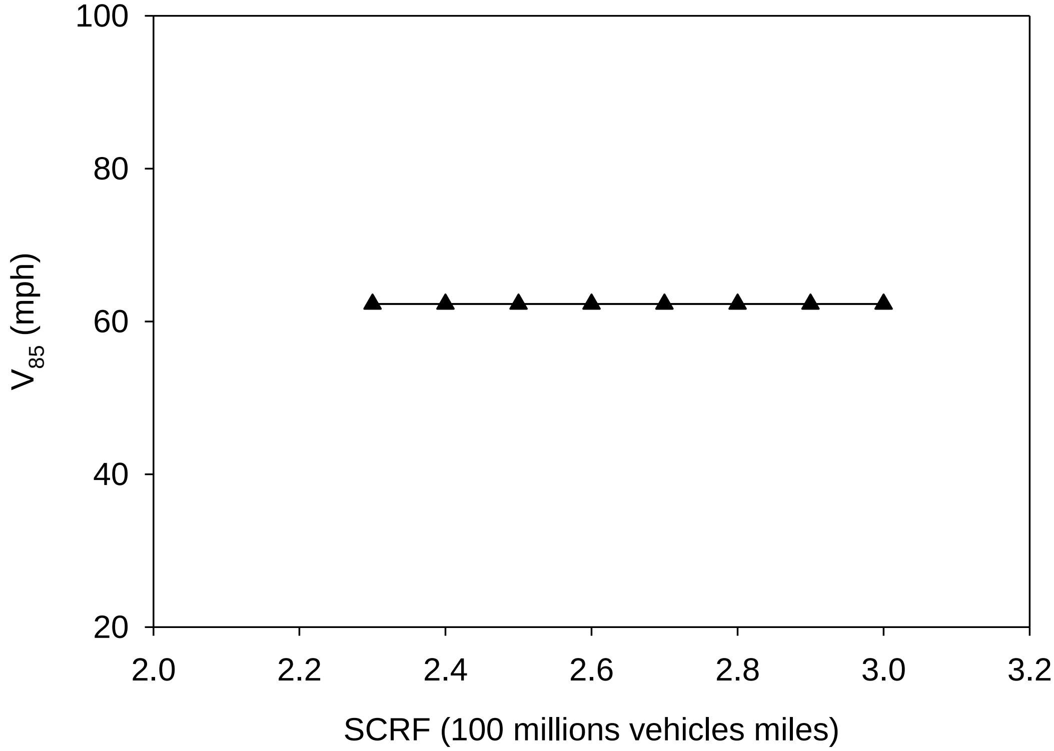

Figure 4.28 Variation of V_{85} with Statewide Collision Rate Fatal (SCRF)

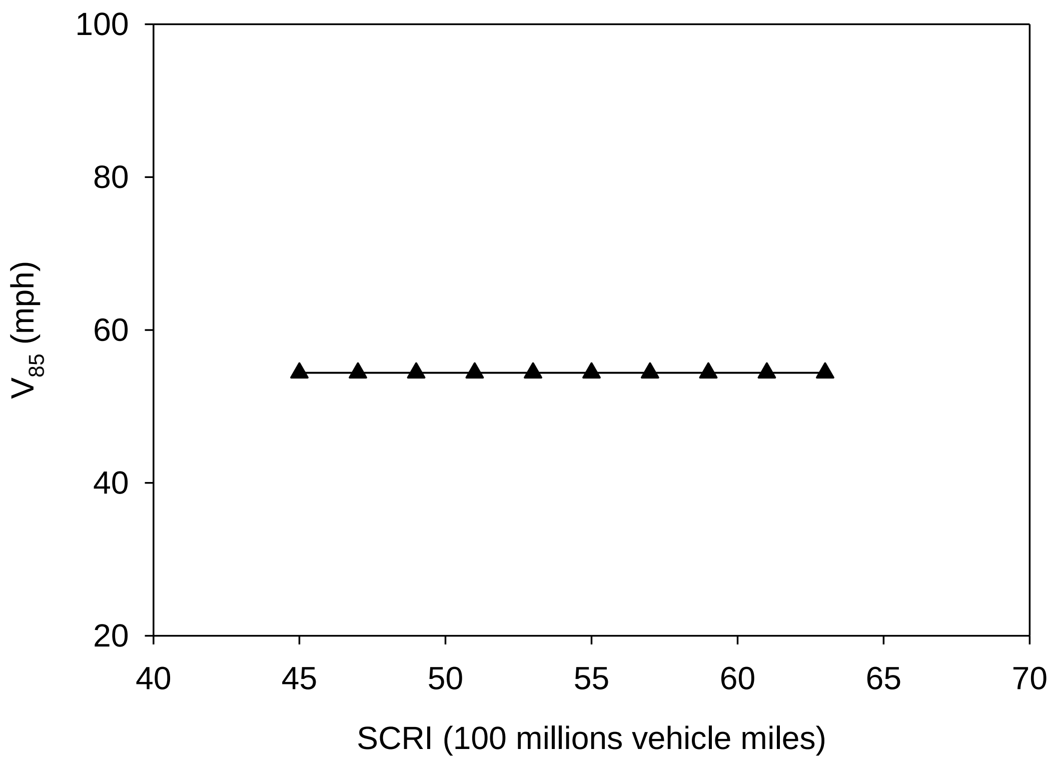

Figure 4.29 Variation of V_{85} with Statewide Collision Rate Injury (SCRI)

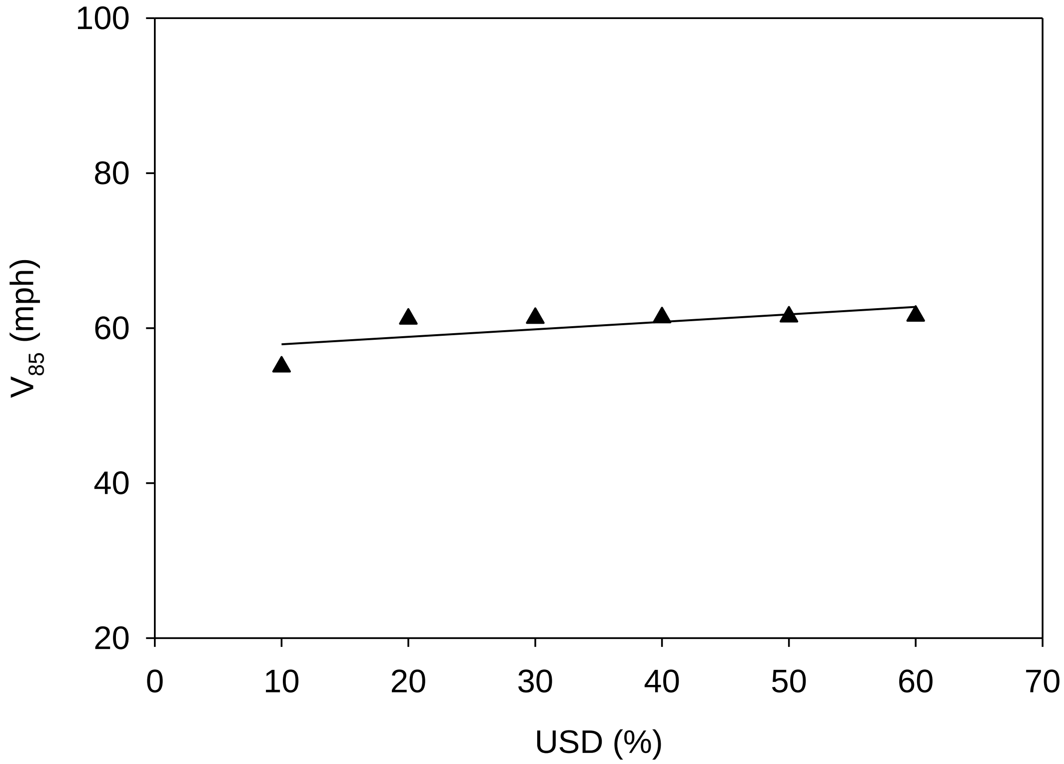

Figure 4.30 Variation of V_{85} with Unsafe Speed Driver (%)

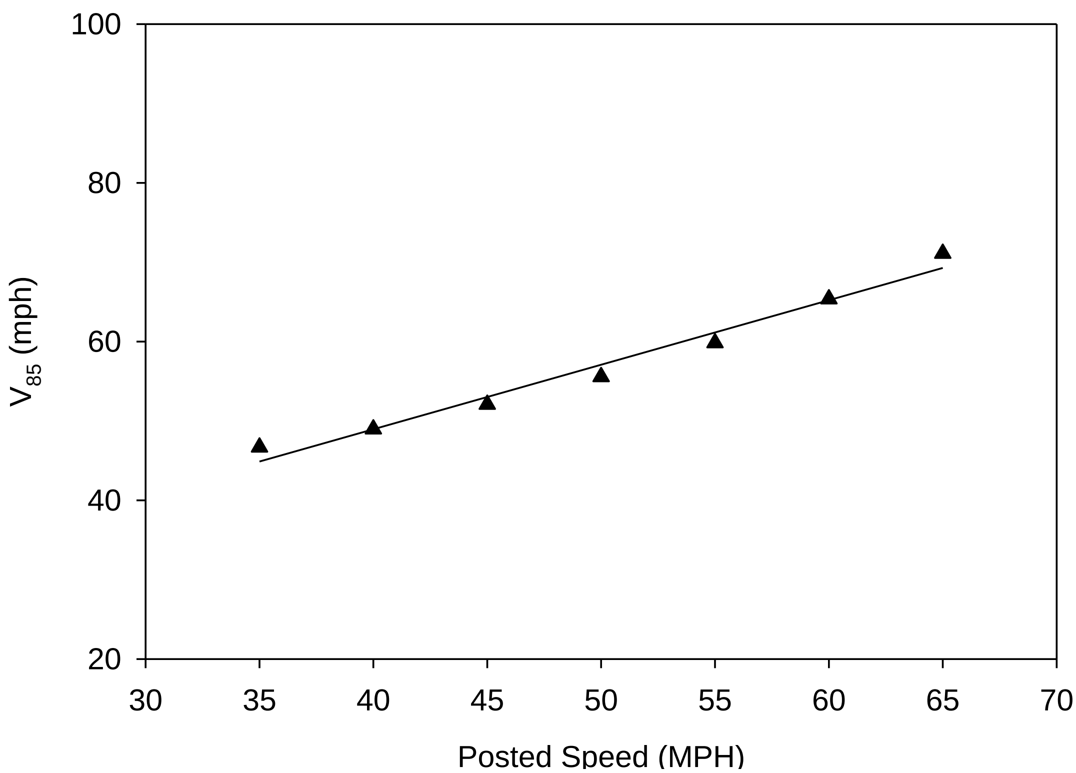

Figure 4.31 Variation of V_{85} with Posted Speed

V_{85} is highly correlated with PS, as shown in Figure 4.31. An increase in PS causes an increase in V_{85}, as expected. These results indicate that a driver is aware of the PS while driving. Overall, the results in this section show that the variation of V_{85} is sensitive to different parameters, and thus capable of capturing the effect of selected parameters.

4.5 USER MANUAL

A user manual is developed to give an overview of the development ANN models. Moreover, it also provides information on how to add more data to the existing dataset and to train the developed models with the revised dataset. Appendix - D provides details of the User Manual.

A one-day workshop on the 85th percentile project was held at ODOT on October 27, 2010. Several ODOT people from the traffic and planning divisions attended this workshop. The research team provided a brief overview of the developed models. Specifically, the presentation included a demonstration of all four ANN models. Also, sensitivity of selected model parameters was demonstrated, and the User Manual was briefly reviewed.

CHAPTER 5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

Traffic operation on two-lane rural highways and setting of posted speed limits are some of the difficult tasks faced by the Oklahoma Department of Transportation (ODOT) and other transportation agencies in the country. For such highways, overtaking slower vehicles is possible only by the use of the opposing lane where sight distance and gap in the opposing traffic stream play a key role. While many states, including Oklahoma, uses the 85^{th} percentile speed (V_{85}) as a major factor in determining the posted speed for rural highways, other factors such as pavement width, shoulder type, shoulder width, topography, weather, roadside development, and accident experience also play an important role in determining the posted speed. Therefore, it becomes important to establish relationships between V_{85} and various traffic and pavement-related parameters.

The present study was undertaken to develop artificial neural network (ANN)-based models to estimate V_{85} using a number of independent variables. The University of Oklahoma research team worked closely with the ODOT Traffic Engineering Division's staff to develop a database that was used for the development of ANN models. A comprehensive literature review was conducted. The following parameters were included in the development of ANN models: physical characteristics of road (i.e., surface width (SW), shoulder type (ST), and shoulder width (SHW)), traffic parameters (i.e., average daily traffic (ADT) and posted speed (PS)), pavement condition parameters (i.e., skid number (SN) and international roughness index (IRI)), and accident data (i.e, LCRO, LCRF, LCRI, SCRO, SCRF, SCRI, USD). A total of 241 two-lane rural highway sites were selected and used for modeling V_{85}. Four different ANN models were developed: Model 1: With Posted Speed but Without Accident Data; Model 2: Without Posted Speed and Without Accident Data; Model 3: With Posted Speed but With Accident Data; and Model 4: Without Posted Speed and With Accident Data. Thus, Model 1 and Model 2 were developed without considering accident data, while Model 3 and Model 4 were developed by including accident data. The only difference between Model 1 and Model 2 was the posted speed; Model 1 includes the PS, while Model 2 does not. Similarly, Model 3 considered PS, while Model 4 did not include posted speed. The codes for the ANN models were developed using the commercial software MATLAB® tool box. After many trials, the best architecture was found to contain one hidden layer with 6 neurons. Model 1 has 7-6-1 architecture, where 7 indicates the input parameters, 6 indicates one hidden layer with 6 neurons in it, and 1 indicates an output layer with one neuron. Similarly, the architecture of Model 2, Model 3, and Model 4 were 6-6-1, 14-6-1, and 13-6-1, respectively. All developed models provided an overall accuracy of above 90%. Model 1 and Model 2 exhibited an overall accuracy of 97% and 91.5%, respectively. Similarly, Model 3 and Model 4 showed an overall accuracy of 97.5%, and 94.1%, respectively.

5.2 CONCLUSIONS

The developed ANN models are expected to be a useful and robust tool for determining V_{85} for two-lane rural highways in Oklahoma. The models are expected to be useful in reducing accident and fatalities resulting from improper posting of speed limits on such highways. Moreover, usage of the developed ANN-based V_{85} prediction models are expected to help ODOT engineers in setting posted speeds in a rational manner. ANN-based models are expected to help ODOT-traffic engineers in performing the following tasks:

1. Predict V_{85} with reasonable accuracy based on a few roadway and traffic related parameters without the need to perform a costly V_{85} measurement (spot study), particularly in situations where time and financial resources are scarce.
2. Validate field observations/studies. The proposed ANN models can be used to investigate the impact of any proposed changes or variations in roadway-related input parameters on V_{85} at a given section of a two-lane rural highway.

3. The developed models provide flexibility in using selected input parameters in the estimation of V_{85}. In this regard, the following guidelines may be used:
    a. Model 1 and Model 2 should be used in the absence of accident data. Model 1 uses the following parameters: SW, ST, SHW, ADT, PS, SN, and IRI. Model 2 uses all of the parameters listed in Model 1, except PS.
    b. Model 3 and Model 4 should be used when accident data is available. Model 3 uses all of the parameters listed in Model 1, as well as accident data (LCRO, LCRF, LCRI, SCRO, SCRF, SCRI, USD). Model 4 uses all the input parameters as in Model 3, except PS.
    c. Inclusion of accident data is found to improve the performance of the model but only marginally.
4. The previous model developed by the University of Oklahoma research team resulted in over fitting problems due to not enough sites in the dataset and insufficient distribution of data for the entire range of a model parameter. The ANN models developed in the present study were able to eliminate the over fitting problems by increasing the number of sites in the dataset and their distribution.
5. It is important to normalize the data so that the mean and variance become zero and unity, respectively. The normalization of the data resulted in significant improvement in the performance of the models.
6. A principal component analysis may be useful to reduce the number of variables in a model. In the present study, the number of variables was sufficiently small. Consequently, the principal component analysis was not found to be useful.

5.3 RECOMMENDATIONS

The ANN models developed in the present study should be used with caution. In cases where preliminary, planning-level estimates of highway speeds are needed, the developed ANN models would be useful. It is recommended that these models be validated against a new set of data that has not been used previously in either training or testing of the model. Also, periodic re-training of the developed models (with updated input and output data) is recommended in order for this model to implicitly take into consideration any changes in driver behavior and/or traffic regulations. A retraining attempt should be performed only by individuals with appropriate experience and expertise in ANN modeling, training and testing. It should be noted that ANN models are preferred when input parameters are within the applicable range used in the development of the model. Specifying input value(s) outside the applicable range(s) compels a model to extrapolate. In such cases, the reliability of the model may be questionable.

The main focus of the present study was to develop ANN models for estimation of V_{85} speed for only two-lane rural highways. Other parameters such as driveways, horizontal and vertical curves, and % passing, and sight distance may be included in future studies.

In the present study, the codes for the ANN models were developed using a commercial software, called MATLAB®. Since many agencies do not have this software, it is recommended that a user-interface be developed either using a Visual basic or a C^{++} program. Addition of new data and user-interface as well as other implementation issues can be pursued under an extension of the current project or as a new project. It is recommended that a meeting with the pertinent ODOT divisions be organized soon to bring clarity on the implementation issues and associated tasks.

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APPENDIX - A

Dataset

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
1	1	Adair	1	14	0	4.32	E	SH-051	2	24	3	4	2700	25.8	125	65	67.5	89.9	4.6	48.4	86.29	3.15	41.47	24.6
2	1	Adair	1	8	9.8	9.8	W/E	US-62	2	24	3	3	1300	43.6	114	65	60.5	158.9	0	75.7	86.29	3.15	41.47	26.7
3	1	Adair	1	8	2.1	2.1	W/E	US-62	2	24	3	3	1145	44.7	114	65	63.5	135.1	0	36.8	86.29	3.15	41.47	13.3
4	2	Alfalfa	6	4	2.04	2.42	E	US-64	2	24	1	8	2200	44.2	76	40	47.5	29.8	0	0	189.05	1.89	65.19	0
5	2	Alfalfa	6	4	2.19	2.19	N/S	US-64	2	24	1	8	980	40.4	39	40	47.5	81	0	23.1	86.29	3.15	41.47	0
6	2	Alfalfa	6	34	0.3	0.3	N/S	SH-38	2	24	6	8	330	30.9	115	45	42.5	0	0	0	86.29	3.15	41.47	0
7	2	Alfalfa	6	12	10.8	10.8	W/E	SH-8	2	24	6	8	670	30.9	67	45	45.5	0	0	0	86.29	3.15	41.47	0
8	2	Alfalfa	6	12	10.5	10.5	W/E	SH-8	2	24	1	8	670	30.9	129	35	42.5	192.3	0	0	189.05	1.89	65.19	0
9	4	Beaver	6	20	6.15	6.15	N/S	US-270	2	24	1	8	2300	38.5	169	45	51.5	105.4	15.1	45.2	86.29	3.15	41.47	44.4
10	6	Blaine	5	14	23.83	24.26	N	SH-08	2	24	3	4	1300	37.2	105	65	66.5	0	0	0	189.05	1.89	65.19	0
11	6	Blaine	5	22	0.22	0.5	E	SH-051	2	24	3	5	2000	34.9	64	35	41.5	44.5	0	0	189.05	1.89	65.19	0
12	6	Blaine	5	22	0.5	1	E	SH-051	2	24	3	5	1200	40.9	80	55	57.5	35.6	0	35.6	189.05	1.89	65.19	0
13	6	Blaine	5	14	23.59	23.59	S	SH-008	2	24	6	4	1200	35.0	71	45	45.5	0	0	0	189.05	1.89	65.19	0
14	6	Blaine	5	14	23.74	23.74	N/S	SH-008	2	24	6	4	1200	34.2	103	55	55.5	0	0	0	189.05	1.89	65.19	0
15	6	Blain	5	14	24.1	24.1	N/S	SH-008	2	24	6	4	1400	36.8	93	65	66.5	33.6	0	0	86.29	3.15	41.47	0
16	7	Bryan	2	10	17.94	19.56	E	US-70	2	24	1	8	3000	49.0	118	65	65.5	27.3	3.4	13.7	189.05	1.89	65.19	25
17	7	Bryan	2	10	19.56	19.99	E	US-70	2	24	1	8	3000	47.4	128	65	66.5	38.6	0	25.7	189.05	1.89	65.19	0
18	7	Bryan	2	26	0.17	0.17	W/E	SH-22	2	24	3	4	1300	47.7	134	55	60.5	163.7	54.6	54.6	189.05	1.89	65.19	0
19	7	Bryan	2	26	0.34	0.34	W/E	SH-22	2	24	2	6	1300	40.2	202	65	64.5	171.8	0	85.9	189.05	1.89	65.19	0
20	8	Caddo	7	14	15.53	15.72	N	US-281	2	24	1	8	1000	45.6	68	55	61.5	357.5	0	0	86.29	3.15	41.47	0
21	8	Caddo	7	14	16.41	16.78	N	US-281	2	24	3	8	950	49.0	115	55	53.5	70.1	0	0	189.05	1.89	65.19	0
22	8	Caddo	7	18	12.45	12.53	E	SH-009	2	24	1	8	2600	31.9	190	35	42.5	0	0	0	189.05	1.89	65.19	0
23	8	Caddo	7	14	15.7	15.7	N/S	US-281	2	24	1	8	3300	42.5	73	55	59.5	225.3	7.3	87.2	86.29	3.15	41.47	7.4
24	8	Caddo	7	18	12.5	12.5	N/S	SH-9	2	24	3	4	3300	33.4	130	35	42.5	92.8	0	0	189.05	1.89	65.19	20
25	8	Caddo	7	18	12.95	12.95	N/S	SH-9	2	24	3	3	2000	37.2	123	55	59.5	45	7.5	15	86.29	3.15	41.47	0
26	8	Caddo	7	36	7.6	7.6	S	SH-58	2	24	3	4	2100	45.8	55	65	69.5	143.3	0	92.7	86.29	3.15	41.47	22.7
27	8	Caddo	7	36	8.6	8.6	N/S	SH-58	2	24	3	4	2100	45.8	73	65	67.5	134.9	0	101.2	86.29	3.15	41.47	25
28	8	Caddo	7	36	9.6	9.6	N/S	SH-58	2	24	3	4	2100	45.8	56	65	70.5	118	0	101.2	86.29	3.15	41.47	31.3
29	9	Canadian	4	8	2.37	4.56	N	US-81	2	24	3	2	4800	41.9	128	55	57.5	37.9	2.4	16.6	189.05	1.89	65.19	4.2
30	9	Canadian	4	36	0	0.95	E	SH-152	2	20	3	4	2100	43.1	84	55	59.5	99.9	0	37.5	189.05	1.89	65.19	0
31	9	Canadian	4	36	1.3	2.05	E	SH-152	2	20	3	4	2200	42.0	81	65	67.5	45.3	0	0	189.05	1.89	65.19	0
32	9	Canadian	4	36	3.05	5.25	E	SH-152	2	20	3	4	2200	44.2	114	65	66.5	41.2	0	15.4	189.05	1.89	65.19	25
33	9	Canadian	4	36	7.95	9	E	SH-152	2	20	3	5	3400	40.5	105	55	58.5	146.5	7	76.7	189.05	1.89	65.19	2.9
34	10	Carter	7	4	5.28	9.75	E	SH-199	2	24	1	10	6700	30.7	87	55	57.5	65	6.8	30.4	189.05	1.89	65.19	13.7
35	10	Carter	7	4	9.75	12.77	E	SH-199	2	24	1	10	5400	36.8	77	45	42.5	33.6	1.5	16.8	189.05	1.89	65.19	13.9
36	11	Cherokee	1	16	0	3	E	SH-051	2	24	3	3	2800	34.9	136	65	66.5	199.9	3.1	79.9	86.29	3.15	41.47	40.4
37	11	Cherokee	1	32	3.9	3.9	W/E	US-62	2	24	6	6	1800	36.5	127	65	56.5	144.8	4.1	66.2	86.29	3.15	41.47	18.5
38	11	Cherokee	1	32	6.5	6.5	W/E	US-62	2	24	3	4	3800	36.2	106	65	55.5	136.4	0	80.2	86.29	3.15	41.47	32.1
39	11	Cherokee	1	6	0.7	0.7	W/E	US-62	2	24	3	2	3800	37.6	185	65	64.5	284.6	0	189.8	86.29	3.15	41.47	61.9
40	13	Cimarron	6	16	7.45	7.45	W/E	US-56	2	24	3	6	660	40.4	150	45	47.5	0	0	0	86.29	3.15	41.47	0

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
41	13	Cimarron	6	16	7.6	7.6	W/E	US-56	2	24	3	6	660	40.4	102	40	39.5	0	0	0	189.05	1.89	65.19	0
42	13	Cimarron	6	16	8.2	8.2	W/E	US-56	2	24	3	5	660	40.4	157	45	43.5	0	0	0	189.05	1.89	65.19	0
43	14	Cleveland	3	4	4.21	6.11	N	US-77	2	24	1	4	6200	25.6	158	50	53.5	165.5	6.4	90.3	189.05	1.89	65.19	27.4
44	14	Cleveland	3	11	2.73	5.76	E	SH-09	2	24	1	10	9100	44.3	86	60	63.5	142.7	6.3	57.8	189.05	1.89	65.19	9.6
45	14	Cleveland	3	11	5.76	8.6	E	SH-09	2	24	1	10	9100	43.6	87	60	65.5	111.8	1	39.5	189.05	1.89	65.19	8.3
46	14	Cleveland	3	11	11.28	13.73	E	SH-09	2	24	1	10	6800	26.4	109	65	65.5	119.9	7.6	47	189.05	1.89	65.19	7.3
47	14	Cleveland	3	11	13.73	15.07	E	SH-09	2	24	1	8	6800	28.0	80	65	67.5	130.4	2.8	58.3	189.05	1.89	65.19	2.5
48	14	Cleveland	3	11	15.07	17.25	E	SH-09	2	24	1	8	5600	27.7	87	65	65.5	273.4	2	148.9	86.29	3.15	41.47	15.2
49	14	Cleveland	3	11	7.5	7.5	W/E	SH-009	2	24	1	10	6900	47.6	77	60	65.5	125.6	2.7	58.1	189.05	1.89	65.19	7.1
50	14	Cleveland	3	11	8.5	8.5	W/E	SH-009	2	24	1	10	6900	47.6	79	65	66.5	117.5	2.9	60.9	189.05	1.89	65.19	5.6
51	14	Cleveland	3	11	12.8	12.8	W/E	SH-009	2	24	1	10	3900	30.3	82	65	65.5	127.5	5.1	61.2	189.05	1.89	65.19	4.8
52	14	Cleveland	3	11	15.6	15.6	W/E	SH-009	2	24	1	10	1600	29.1	74	65	65.5	179.4	6.3	82.3	86.29	3.15	41.47	7.6
53	14	Cleveland	3	11	13.85	13.85	W/E	SH-009	2	24	1	10	3800	34.2	63	65	67.5	177.6	5.2	83.6	189.05	1.89	65.19	5.5
54	14	Cleveland	3	11	14.35	14.35	W/E	SH-009	2	24	1	10	3800	34.2	64	65	67.5	181.1	7.1	81.7	189.05	1.89	65.19	0.1
55	14	Cleveland	3	11	5.2	5.2	W/E	SH-009	2	24	1	10	6900	45.2	41	60	63.5	139.1	2.5	67.7	189.05	1.89	65.19	8.4
56	14	Cleveland	3	11	13.5	13.5	W/E	SH-009	2	24	6	8	3900	30.3	179	65	60.5	141.5	5.2	69	189.05	1.89	65.19	5.7
57	14	Cleveland	3	11	4.82	4.82	W/E	SH-009	2	24	1	8	6900	45.2	68	60	63.5	130	2.7	58.8	189.05	1.89	65.19	9.6
58	16	Comanche	7	5	1.24	2.34	N	US-62	2	24	1	8	5900	41.6	69	65	65.5	135.1	7.3	69.4	86.29	3.15	41.47	25
59	16	Comanche	7	26	5	5	N/S	SH-36	2	24	6	6	1400	47.7	51	55	62.5	58.7	0	29.3	86.29	3.15	41.47	21.4
60	16	Comanche	7	26	5.85	5.85	N/S	SH-36	2	24	1	8	1400	49.0	72	55	63.5	50.1	0	33.4	86.29	3.15	41.47	8.3
61	16	Comanche	7	22	0.5	0.5	N/S	SH-281	2	24	1	8	1400	50.3	61	55	49.5	117.4	0	58.7	86.29	3.15	41.47	50
62	17	Cotton	7	14	0	4.98	E	SH-005	2	24	1	8	2600	29.5	107	65	62.5	44.5	3.7	24.1	189.05	1.89	65.19	20
63	17	Cotton	7	22	0.8	3.93	N	SH-36	2	20	3	3	1800	28.0	100	65	64.5	229.4	4.7	121.7	86.29	3.15	41.47	13.3
64	17	Cotton	7	14	4.63	4.63	W/E	SH-5	2	24	1	8	1200	38.3	85	65	62.5	61.2	0	20.4	189.05	1.89	65.19	3.8
65	18	Craig	8	24	0	1	N	SH-82	2	24	1	5	5900	42.5	54	65	64	163.2	4.3	77.3	86.29	3.15	41.47	10.3
66	18	Craig	8	24	1	8.1	N	SH-82	2	24	1	5	4000	42.1	61	65	68	104.3	0	56.3	86.29	3.15	41.47	28.6
67	18	Craig	8	24	0.5	0.5	N	SH-82	2	24	6	8	4000	41.6	50	65	64	93.5	0	36	86.29	3.15	41.47	14.3
68	18	Craig	8	24	1.5	1.5	N	SH-82	2	24	6	8	4000	39.7	62	65	68	81.2	0	33.6	86.29	3.15	41.47	17
69	19	Creek	8	8	1.89	5.17	N	US-75A	2	24	3	6	3900	35.9	100	65	67.5	1.9	0	54	86.29	3.15	41.47	25
70	19	Creek	8	10	8.7	9.22	E	SH-016	2	24	3	4	2100	55.4	93	65	68.5	45.6	0	22.8	86.29	3.15	41.47	0
71	19	Creek	8	10	9.22	9.69	E	SH-016	2	24	3	4	2000	47.5	91	55	57.5	0	0	0	189.05	1.89	65.19	0
72	19	Creek	8	10	9.98	15.38	E	SH-019	2	24	3	4	1200	48.9	86	35	42.5	130	0	92.2	86.29	3.15	41.47	27.5
73	19	Creek	8	8	4.45	4.45	N/S	US-75A	2	24	1	8	4000	35.4	76	65	66.5	13.9	0	6.9	86.29	3.15	41.47	44.4
74	19	Creek	8	10	9.13	9.13	N/S	SH-16	2	24	1	8	1200	50.9	67	65	68.5	10.4	0	5.2	86.29	3.15	41.47	33.3
75	19	Creek	8	10	9.52	9.52	N/S	SH-16	2	24	3	3	1200	55.3	86	55	57.5	11	0	5.5	86.29	3.15	41.47	33.3
76	19	Creek	8	10	10.07	10.07	N/S	SH-16	2	24	3	5	1200	47.0	102	35	42.5	12	0	6	86.29	3.15	41.47	33.3
77	19	Creek	8	10	10.3	10.3	N/S	SH-16	2	24	3	5	1200	47.0	82	55	58.5	11.9	0	5.9	86.29	3.15	41.47	33.3
78	19	Creek	8	10	10.65	10.65	N/S	SH-16	2	24	3	4	1200	47.0	66	65	66.5	19.8	0	13.2	86.29	3.15	41.47	40
79	21	Delaware	8	2	12.98	13.48	N	US-412	2	24	3	3	3900	50.6	66	55	56.5	78.7	0	52.4	189.05	1.89	65.19	25
80	21	Delaware	8	4	0.25	0.59	N	US-590	2	24	1	10	3200	52.3	106	55	53.5	355.2	0	177.6	86.29	3.15	41.47	29.2

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
81	21	Delaware	8	10	0	2.38	N	SH-10	2	24	3	4	2900	53.7	111	55	55.5	173.1	0	116.7	86.29	3.15	41.47	47.3
82	21	Delaware	8	10	2.38	3.3	N	SH-10	2	24	3	4	2700	53.8	89	55	56.5	83.3	0	52.1	189.05	1.89	65.19	6.7
83	21	Delaware	8	30	12.1	13.6	E	US-412	2	24	3	3	5800	43.8	75	45	45.5	188.9	0	88.7	189.05	1.89	65.19	14
84	21	Delaware	8	38	0	2.4	E	SH-85A	2	22	3	1	2700	43.2	109	50	43.5	161.4	3.8	84.6	86.29	3.15	41.47	41
85	21	Delaware	8	38	2.8	3.2	E	SH-85A	2	20	3	4	2700	53.0	92	45	44.5	46.1	0	23.1	189.05	1.89	65.19	0
86	21	Delaware	8	38	3.2	3.98	E	SH-85A	2	24	3	4	3100	50.9	78	50	50.5	67.7	9.7	58.1	189.05	1.89	65.19	8.3
87	21	Delaware	8	38	3.98	4.93	E	SH-85A	2	24	3	4	3300	44.6	90	55	55.5	139.3	16.4	73.7	86.29	3.15	41.47	27.6
88	21	Delaware	8	4	0.4	0.4	N/S	US-59	2	24	2	8	2900	45.9	80	55	53.5	117.9	0	58.5	86.29	3.15	41.47	16.7
89	21	Delaware	8	10	2.9	2.9	N/S	SH-10	2	24	3	6	2200	51.9	68	55	56.5	273.8	0	171.8	86.29	3.15	41.47	20.2
90	21	Delaware	8	10	1.78	1.78	N/S	SH-10	2	24	3	8	2000	56.9	84	55	55.5	259.8	0	160.6	86.29	3.15	41.47	21.5
91	21	Delaware	8	2	13.55	13.55	W/E	US-59	2	24	3	6	3500	49.6	78	45	51.5	192.8	0	101	86.29	3.15	41.47	18.7
92	21	Delaware	8	2	13.1	13.1	W/E	US-59	2	24	3	5	3500	49.6	60	55	56.5	171.7	0	93.7	86.29	3.15	41.47	17.9
93	21	Delaware	8	30	13.1	13.1	W/E	US-412A	2	24	3	5	2900	44.6	70	45	48.5	153.9	0	83.6	86.29	3.15	41.47	6.6
94	21	Delaware	8	30	12.6	12.6	W/E	US-412A	2	24	2	8	2900	44.6	92	45	45.5	143.7	0	77.9	86.29	3.15	41.47	6.5
95	21	Delaware	8	38	2.3	2.3	W/E	SH-85a	2	24	3	4	3000	50.2	91	50	43.5	81.4	2.7	46.1	86.29	3.15	41.47	28.9
96	21	Delaware	8	38	2.81	2.81	W/E	SH-85a	2	24	3	3	3000	50.2	92	45	44.5	58.7	3.1	37.1	86.29	3.15	41.47	40
97	21	Delaware	8	38	3.18	3.18	W/E	SH-85a	2	24	3	3	3000	50.2	52	45	46.5	85.3	3	48.7	86.29	3.15	41.47	31.7
98	21	Delaware	8	38	3.85	3.85	W/E	SH-85a	2	24	3	4	2200	46.6	64	50	50.5	93.5	3.5	52	86.29	3.15	41.47	30
99	21	Delaware	8	38	4.25	4.25	W/E	SH-85a	2	24	3	3	2200	47.7	74	55	55.5	93.5	3.5	52	86.29	3.15	41.47	30
100	21	Delaware	8	30	3.9	3.9	W/E	US-412	2	24	3	4	1500	53.6	61	55	62.5	98.6	0	43.8	86.29	3.15	41.47	39.4
101	21	Delaware	8	30	4.5	4.5	W/E	US-412	2	24	3	4	2050	53.6	58	55	62.5	102.3	0	40.2	86.29	3.15	41.47	33.3
102	21	Delaware	8	30	4.85	4.85	W/E	US-412	2	24	3	4	2050	53.6	80	55	62.5	98.6	0	40.2	86.29	3.15	41.47	34.3
103	21	Delaware	8	30	5.5	5.5	W/E	US-412	2	24	3	5	2050	53.6	88	55	62.5	91.3	0	47.5	86.29	3.15	41.47	22.9
104	21	Delaware	8	30	5.95	5	W/E	US-412	2	24	3	3	2050	53.6	48	50	54.5	95	0	43.8	86.29	3.15	41.47	21.6
105	22	Dewey	5	20	13.68	14.85	N	SH-034	2	24	1	6	1100	44.0	144	50	51.5	38.7	0	19.4	86.29	3.15	41.47	0
106	22	Dewey	5	20	15	15.14	N	SH-034	2	24	1	10	1100	36.2	88	40	41.5	161.7	0	0	189.05	1.89	65.19	0
107	22	Dewey	5	20	15.14	15.37	N	SH-034	2	24	1	4	1100	42.8	103	50	54.5	0	0	0	189.05	1.89	65.19	0
108	23	Ellis	6	2	0	0.9	E	US-46	2	24	1	8	1600	36.5	83	35	38.5	17.3	0	17.3	86.29	3.15	41.47	0
109	23	Ellis	6	2	6.77	12.57	E	US-60	2	24	6	4	1200	41.5	57	55	60.5	57.3	0	35.8	86.29	3.15	41.47	13.2
110	23	Ellis	6	4	11.07	21.15	E	US-60	2	24	6	6	930	39.1	102	35	38.5	35.3	5.4	10.9	86.29	3.15	41.47	18.8
111	23	Ellis	6	20	1.27	7.68	E	SH-015	2	24	6	7	2000	37.3	127	50	54.5	46.6	1.9	19.4	86.29	3.15	41.47	9.4
112	23	Ellis	6	20	8.13	8.42	E	SH-015	2	24	6	6	2400	35.6	101	50	54.5	74.7	0	37.3	86.29	3.15	41.47	33.3
113	23	Ellis	6	20	8.42	10.34	E	SH-015	2	24	1	8	1900	36.5	67	65	66.5	90.8	6.5	58.4	86.29	3.15	41.47	23.5
114	23	Ellis	6	22	0.15	2.6	N	SH-046	2	24	3	4	470	36.6	169	45	54.5	132.6	0	44.2	86.29	3.15	41.47	12.5
115	23	Ellis	6	4	13.5	13.5	N/S	US-60	2	24	3	3	930	40.6	105	45	53.5	21.1	7	7	86.29	3.15	41.47	0
116	23	Ellis	6	2	12.55	12.55	W/E	US-60	2	24	1	4	2100	44.0	53	35	41.5	78.1	0	43.4	86.29	3.15	41.47	5.9
117	23	Ellis	6	2	12.45	12.45	W/E	US-60	2	24	2	1	2100	44.0	112	45	53.5	70.6	0	36.3	86.29	3.15	41.47	11.1
118	23	Ellis	6	2	12.2	12.2	W/E	US-60	2	24	1	6	2100	44.0	53	55	60.5	66.8	0	33.4	86.29	3.15	41.47	11.1
119	23	Ellis	6	2	1.1	1.1	N/S	US-60	2	24	1	8	1200	40.9	95	35	38.5	64.2	0	42.8	86.29	3.15	41.47	50
120	23	Ellis	6	4	0.3	0.3	N/S	US-60	2	24	1	8	1200	38.9	60	45	54.5	69.9	0	15.5	86.29	3.15	41.47	0

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
121	23	Ellis	6	4	0.5	0.5	N/S	US-60	2	24	1	8	1200	38.9	128	55	58.5	72.5	0	14.5	86.29	3.15	41.47	0
122	23	Ellis	6	20	7.6	7.6	W/E	SH-15	2	24	3	3	2400	41.3	107	50	54.5	93.6	4.7	42.1	86.29	3.15	41.47	16
123	23	Ellis	6	20	8.3	8.3	W/E	SH-15	2	24	6	6	2400	36.6	107	50	54.5	88.8	4.7	42	86.29	3.15	41.47	16
124	23	Ellis	6	20	8.8	8.8	W/E	SH-15	2	24	1	8	2400	38.0	43	65	66.5	78.2	4.6	41.4	86.29	3.15	41.47	17.4
125	25	Garvin	3	2	1.77	2.4	N	US-77	2	24	1	8	5300	34.2	112	55	54.5	63	0	39.5	86.29	3.15	41.47	41.7
126	25	Garvin	3	2	2.4	3.46	N	US-77	2	24	1	10	5300	38.2	179	65	66.5	135	10.4	62.7	86.29	3.15	41.47	11.1
127	25	Garvin	3	26	0.85	11.72	E	SH-29	2	24	3	3	980	56.0	79	45	50.5	136.5	0	60.9	86.29	3.15	41.47	14.8
128	25	Garvin	3	26	1.32	1.32	W/E	SH-29	2	24	3	4	1900	54.2	76	45	50.5	239.6	8.9	88.7	86.29	3.15	41.47	2.3
129	26	Grady	7	4	8.24	10.52	E	SH-062	2	24	1	8	3500	37.0	57	65	66.5	75.9	3	39.4	189.05	1.89	65.19	27.8
130	26	Grady	7	50	3.75	3.75	N/S	SH-4	2	24	3	4	8700	44.4	62	55	60.5	88.4	0	30.2	86.29	3.15	41	41.47
131	29	Harmon	5	4	0	0.14	E	US-062	2	24	1	10	2400	26.9	111	35	38.5	518.9	0	74.1	189.05	1.89	65.19	0
132	29	Harmon	5	4	0.62	1	E	US-062	2	24	1	8	2300	37.5	86	45	50.5	28.5	0	28.5	86.29	3.15	41.47	0
133	29	Harmon	5	4	0.14	0.14	W/E	US-062	2	24	1	10	2100	35.5	112	35	38.5	278	0	72.7	86.29	3.15	41.4	2.4
134	29	Harmon	5	4	0.7	0.7	W/E	US-062	2	24	1	10	2100	38.7	101	45	50.5	97	0	26.7	86.29	3.15	41.47	11.6
135	29	Harmon	5	4	1	1	W/E	US-062	2	24	1	10	2100	40.8	120	55	57.5	97.9	0	26.7	86.29	2.66	41.47	6.9
136	31	Haskell	1	16	7.01	8.01	E	SH-031	2	24	6	5	1600	62.2	117	65	67.5	93.4	15.6	31.1	86.29	3.15	41.47	12.5
137	32	Hughes	3	16	5.43	6.14	E	SH-1	2	24	1	8	2200	50.6	56	65	68.5	79.7	0	15.9	189.05	1.89	65.19	12.5
138	35	Johnston	3	24	0	4.93	N	SH-99	2	24	3	5	1900	47.8	107	65	61.5	114.3	2.7	39.9	86.29	3.15	41.47	21.1
139	35	Johnston	3	34	5.72	10	N	SH-078	2	24	3	2	1400	34.3	118	55	55.5	317.8	9	147.7	86.29	3.15	41.47	43.2
140	35	Johnston	3	34	11.2	13.82	N	SH-078	2	22	3	8	2500	43.0	121	65	65.5	154.5	11.9	91.1	86.29	3.15	41.47	19.6
141	35	Johnston	3	24	4.8	4.8	N/S	SH-99	2	24	6	8	1000	45.6	85	65	61.5	159.1	0	49.7	86.29	3.15	41.47	12
142	35	Johnston	3	16	3	3	W/E	SH-22	2	24	1	8	560	42.9	149	55	50.5	138.6	8.2	40.8	86.29	3.15	41.47	3.4
143	35	Johnston	3	4	5.3	5.3	W/E	SH-22	2	24	3	4	560	38.6	76	55	51.5	43.8	0	32.9	86.29	3.15	41.47	22.2
144	35	Johnston	3	24	5.1	5.1	W/E	SH-22	2	24	6	6	560	45.6	106	55	51.5	159.1	0	49.7	86.29	3.15	41.47	12
145	36	Kay	4	10	19.8	22.78	N	US-77	2	24	1	10	4400	32.0	92	65	64.5	106.4	9.5	60.8	86.29	3.15	41.47	21.1
146	36	Kay	4	10	21.4	21.4	N/S	US-077	2	24	1	10	4900	30.9	106	65	64.5	126.6	12.3	77.4	86.29	3.15	41.47	16.1
147	36	Kay	4	10	21.4	21.4	N/S	US-77	2	24	1	8	4400	30.9	106	65	61.5	126.6	12.3	77.4	86.29	3.15	41.47	16.1
148	36	Kay	4	10	21.4	21.4	N/S	US-77	2	24	1	8	4400	30.9	106	65	61.5	126.6	12.3	77.4	86.29	3.15	41.47	16.1
149	39	Latimer	2	2	11.02	11.53	E	US-270	2	24	1	4	4800	33.1	162	55	54.5	428.6	0	139.5	189.05	1.89	65.19	23.1
150	39	Latimer	2	10	0	0.76	N	SH-02	2	24	1	4	3700	28.1	150	45	44.5	603.7	0	163.9	189.05	1.89	65.19	2.1
151	39	Latimer	2	10	0.76	2.51	N	SH-02	2	24	1	4	2400	39.8	147	65	61.5	187.6	12.9	77.6	86.29	3.15	41.47	23.3
152	39	Latimer	2	10	0.48	0.48	N/S	SH-002	2	24	3	4	2000	32.1	128	45	44.5	332.4	0	91.9	86.29	3.15	41.47	7.8
153	39	Latimer	2	2	11.53	11.53	W/E	US-270	2	24	6	3	5400	44.8	85	45	44.5	113.2	0	30.5	86.29	3.15	41.47	13
154	39	Latimer	2	2	11.1	11.1	W/E	US-270	2	24	6	4	5400	44.8	133	55	54.5	99.8	0	25.9	86.29	3.15	41.47	12.5
155	40	Leflore	2	58	1.12	1.12	N/S	SH-112	2	24	3	8	8797	55.5	49	65	65.5	45.5	2.2	23.8	86.29	3.15	41.47	28.9
156	40	Leflore	2	58	1.36	1.36	N/S	SH-112	2	24	1	8	8797	55.5	98	65	66.5	50.2	2	28.1	86.29	3.15	41.47	28.9
157	41	Lincoln	3	10	0	2.58	N	SH-18	2	24	3	5	3700	40.6	105	65	59.5	108.1	3.9	50.2	189.05	1.89	65.19	11.3
158	41	Lincoln	3	30	0.86	3.28	N	SH-099	2	22	3	7	2500	45.7	83	55	57.5	65.5	3.1	34.3	189.05	1.89	65.19	2.9
159	42	Logan	4	8	12.22	12.45	E	SH-033	2	24	1	8	4200	38.9	41	65	67.5	90.2	0	60.2	189.05	1.89	65.19	50
160	42	Logan	4	31	2.52	3.3	E	SH-105	2	24	3	2	3200	36.5	81	65	68.5	39.9	0	20	86.29	3.15	41.47	20

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI
161	42	Logan	4	31	3.3	7.49	E	SH-105	2	24	3	1	2700	56.8	137	65	68.5	57.2	2.2	33	86.29	3.15	41.47
162	44	McClain	3	16	2.47	4.1	E	SH-39	2	24	3	5	1700	42.2	84	45	38.5	107.9	0	44.9	189.05	1.89	65.19
163	44	McClain	3	44	0.89	2.69	N	SH-76	2	24	1	8	4200	35.4	55	65	65.5	76.9	3.8	30.7	86.29	3.15	41.47
164	44	McClain	3	45	1.79	4.76	N	SH-76	2	24	3	4	5200	27.5	66	65	66.5	89.2	0	42.8	189.05	1.89	65.19
165	44	McClain	3	45	4.76	5.4	N	SH-76	2	24	3	4	5100	39.8	69	65	64.5	93.4	0	62.3	189.05	1.89	65.19
166	44	McClain	3	45	7.76	10.76	N	SH-76	2	24	3	5	6200	26.3	50	65	64.5	332.1	4.2	142.1	189.05	1.89	65.19
167	44	Mcclain	3	16	2.64	2.64	W/E	SH-39	2	24	6	5	2800	45.6	91	45	38.5	50.6	0	21.7	86.29	3.15	41.47
168	44	McClain	3	45	1.9	1.9	N/S	SH-76	2	24	6	5	5800	34.9	69	65	65.5	200.8	2.6	67.8	189.05	1.89	65.19
169	44	Mcclain	3	4	10.16	10.16	N	US-77	2	24	1	8	2700	36.5	167	65	61.5	73.3	5.6	33.8	86.29	3.15	41.47
170	44	Mcclain	3	4	9.86	9.86	N/S	US-77	2	24	1	8	2700	36.9	142	65	66.5	67.9	5.2	31.3	86.29	3.15	41.47
171	46	Mcintosh	1	6	3	7.6	E	US-266	2	24	3	5	1200	41.9	136	65	66.5	103.8	9	67.7	86.29	3.15	41.47
172	46	Mcintosh	1	6	10.75	12.55	E	US-266	2	24	1	6	2500	61.0	142	65	69.5	63.9	0	26.6	86.29	3.15	41.47
173	46	Mcintosh	1	6	12.55	16.77	E	US-266	2	24	1	6	3600	51.8	102	65	65.5	109.6	5.6	53.4	86.29	3.15	41.47
174	46	Mcintosh	1	10	20.9	21.9	E	SH-009	2	24	1	6	2600	53.0	148	45	51.5	229.1	0	139.5	86.29	3.15	41.47
175	46	Mcintosh	1	10	21.9	22.25	E	SH-009	2	24	1	6	3000	46.3	115	45	44.5	237.2	0	71.2	86.29	3.15	41.47
176	46	Mcintosh	1	10	21.85	21.85	W/E	SH-9	2	24	1	8	6900	51.2	91	45	51.5	172.1	3.4	48.2	86.29	3.15	41.47
177	46	Mcintosh	1	10	22.12	22.12	W/E	SH-9	2	24	1	8	6900	58.4	65	45	44.5	170.7	3.6	46.2	86.29	3.15	41.47
178	46	Mcintosh	1	10	22.57	22.57	W/E	SH-9	2	24	1	8	6900	54.3	131	45	48.5	169.4	3.8	45.2	86.29	3.15	41.47
179	48	Marshall	2	4	1.9	2.02	S	US-70	2	24	1	7	6400	41.4	128	55	58.5	356.7	0	194.6	86.29	3.15	41.47
180	48	marshall	**2**	4	2	2	W/E	US-70	2	24	6	6	4600	46.8	95	55	58.5	60.8	0	40.5	86.29	3.15	41.47
181	48	Marshall	2	26	10.62	10.62	N/S	US-377	2	24	1	8	2800	47.7	38	65	68.5	119.2	5	39.7	86.29	3.15	41.47
182	48	Marshall	2	6	9.25	9.25	W/E	SH-32	2	24	1	8	2800	48.9	66	65	65.5	30.2	0	0	86.29	3.15	41.47
183	48	Marshall	2	6	8.25	8.25	W/E	SH-32	2	24	3	4	2800	49.6	93	65	64.5	109.2	0	43.7	86.29	3.15	41.47
184	49	Mayes	8	36	0	0.12	N	SH-082	2	24	1	5	6900	45.1	116	45	40.5	518.9	0	159.7	189.05	1.89	65.19
185	49	Mayes	8	36	0.12	2.01	N	SH-082	2	24	1	5	6900	45.1	110	45	48.5	50.4	0	38.8	86.29	3.15	41.47
186	49	Mayes	8	36	0.5	0.5	N	SH-82	2	24	6	5	4000	51.9	158	55	58	0	0	0	86.29	3.15	41.47
187	49	Mayes	8	36	1	1	N	SH-82	2	24	1	8	4000	51.9	166	55	58	0	0	0	86.29	3.15	41.47
188	49	Mayes	8	36	1.5	1.5	N	SH-82	2	24	1	8	4000	51.9	108	55	60	18	0	18	86.29	3.15	41.47
189	49	Mayes	8	36	1.96	2.12	N	SH-82	2	24	6	5	4000	51.9	144	55	62	241.8	0	207.3	86.29	3.15	41.47
190	52	Noble	4	28	1	1.22	N	US-177	2	24	1	8	4000	40.2	86	55	62.5	254.7	0	169.8	86.29	3.15	41.47
191	52	Noble	4	28	1.84	2.68	N	US-177	2	24	1	8	4000	56.6	76	60	62.5	59.3	7.4	29.7	86.29	3.15	41.47
192	52	Noble	4	28	2.04	2.04	W/E	US-177	2	24	1	8	5400	51.7	53	60	62.5	62	0	62	86.29	3.15	41.47
193	52	Noble	4	28	2.55	2.55	W/E	US-177	2	24	1	8	5400	51.7	69	60	64.5	41.5	0	23	86.29	3.15	41.47
194	52	Noble	4	28	1.12	1.12	W/E	US-177	2	24	1	8	5400	44.9	59	55	62.5	164.5	0	101.3	86.29	3.15	41.47
195	54	Okfuskee	3	8	9.8	10.29	N	SH-27	2	24	1	10	6400	42.7	158	40	39.5	762.4	0	213.2	189.05	1.89	65.19
196	54	Okfuskee	3	2	3.43	3.43	W/E	US-62	2	24	1	10	2400	37.5	198	40	40.5	50.2	0	0	189.05	1.89	65.19
197	54	Okfuskee	3	8	10.1	10.1	N/S	SH-27	2	24	1	10	810	37.5	67	40	39.5	314.6	5.2	61.9	86.29	3.15	41.47
198	56	Okfuskee	1	10	4	4.67	N	US-75A	2	22	3	4	1800	28.9	101	45	42.5	144.6	0	41.3	189.05	1.89	65.19
199	56	Okfuskee	1	10	4.67	11.76	N	US-75A	2	22	3	3	1800	30.0	74	45	42.5	187.4	7.8	128.8	86.29	3.15	41.47
200	56	Okmulgee	1	10	4.24	4.24	N/S	US-75A	2	24	3	3	1800	36.2	99	45	42.5	80.5	0	67.1	86.29	3.15	41.47

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
201	56	Okmulgee	1	10	4.56	4.56	N/S	US-75A	2	24	3	4	1800	36.2	71	45	42.5	95.3	0	71.5	86.29	3.15	41.47	27.3
202	56	Okmulgee	1	10	5.5	5.5	N/S	US-75A	2	24	3	3	1800	44.4	54	65	66.5	152.7	0	107.8	86.29	3.15	41.47	27.3
203	57	Osage	8	2	10.15	12.64	E	US-60	2	24	1	10	2200	50.8	71	65	69.5	70	5	40	86.29	3.15	41.47	11.1
204	57	Osage	8	2	12.64	19.14	E	US-60	2	24	1	8	2200	53.3	78	65	69.5	48.4	4	28.2	86.29	3.15	41.47	15.6
205	57	Osage	8	12	0.26	4.47	N	SH-18	2	24	3	5	1600	45.7	104	65	63.5	167	7	59.2	86.29	3.15	41.47	2.6
206	57	Osage	8	2	12.3	13.3	W/E	US-60	2	24	1	8	2200	48.2	112	65	69.5	44.3	4.9	24.6	86.29	3.15	41.47	16.7
207	57	Osage	8	2	13.3	13.3	W/E	US-60	2	24	1	8	2200	48.4	98	65	69.5	39.9	5	19.9	86.29	3.15	41.47	18.2
208	57	Osage	8	2	14.3	14.3	W/E	US-60	2	24	1	8	2200	48.4	76	65	69.5	39.9	5	14.9	86.29	3.15	41.47	20
209	57	Osage	8	12	3.5	3.5	N/S	SH-18	2	24	3	5	600	43.8	131	65	63.5	112.7	11.3	78.9	86.29	3.15	41.47	7.1
210	57	Osage	8	12	4	4	N/S	SH-18	2	24	3	3	1500	43.8	98	65	63.5	88.8	12.7	63.4	86.29	3.15	41.47	10
211	57	Osage	8	12	4.2	4.2	N/S	SH-18	2	24	3	4	1500	43.8	94	55	55.5	207.6	0	155.7	86.29	3.15	41.47	0
212	57	Osage	8	37	1.65	1.65	N/S	SH-97	2	24	3	2	4800	41.3	116	50	55.5	427	0	142.3	86.29	3.15	41.47	20
213	57	Osage	8	37	2.5	2.5	N/S	SH-97	2	24	3	4	4800	41.3	114	50	50.5	265.7	0	132.8	86.29	3.15	41.47	33.3
214	57	Osage	8	37	3.25	3.25	N/S	SH-97	2	24	3	4	4800	41.3	85	50	53.5	715.9	0	330.4	86.29	3.15	41.47	47.1
215	58	Ottawa	8	26	4.05	4.05	W/E	SH-10C	2	24	3	3	3700	44.5	102	55	60.5	105.8	35.3	35.3	86.29	3.15	41.47	0
216	58	Ottawa	8	26	3.78	3.78	W/E	SH-10C	2	24	3	3	3700	44.5	76	55	54.5	365.3	52.2	104.4	86.29	3.15	41.47	0
217	58	Ottawa	8	26	3.55	3.55	W/E	SH-10C	2	24	3	3	6900	44.5	44	55	61.5	104.4	0	0	86.29	3.15	41.47	0
218	58	Ottawa	8	26	3.31	3.31	W/E	SH-10C	2	24	3	3	6900	44.5	94	55	59.5	130.5	0	78.3	86.29	3.15	41.47	28.6
219	61	Pittsburg	2	10	1.44	2.7	E	SH-09	2	24	1	6	6500	58.3	100	55	57.5	185.5	0	88.2	86.29	3.15	41.47	22.4
220	61	Pittsburg	2	10	2.7	4.7	E	SH-09	2	24	1	6	6500	59.4	102	55	57.5	151.4	5.7	82.4	86.29	3.15	41.47	26.7
221	61	Pittsburg	2	10	4.7	6.62	E	SH-09	2	24	1	6	6000	62.8	96	55	60.5	143	16.6	73.2	86.29	3.15	41.47	15.8
222	61	Pittsburg	2	10	1.9	1.9	W/E	SH-09	2	24	1	8	6500	60.6	99	55	57.5	92.5	2.9	54.9	86.29	3.15	41.47	7.8
223	61	Pittsburg	2	10	2.23	2.23	W/E	SH-09	2	24	1	8	6500	60.6	142	55	57.5	83.4	2.6	49.5	86.29	3.15	41.47	7.8
224	61	Pittsburg	2	10	1.9	1.9	W/E	SH-09	2	24	1	8	4800	60.6	99	55	57.5	92.5	2.9	54.9	86.29	3.15	41.47	7.8
225	61	Pittsburg	2	10	2.23	2.23	W/E	SH-09	2	24	1	8	6500	60.6	142	55	57.5	83.4	2.6	49.5	86.29	3.15	41.47	7.8
226	62	Pontotoc	3	16	6.08	10.63	E	SH-019	2	24	3	5	6300	49.0	119	55	62.5	128.8	1.7	55.6	86.29	3.15	41.47	27.7
227	62	Pontotoc	3	6	12.68	12.68	W/E	SH-1	2	24	1	8	6000	35.7	114	55	60.5	287.3	5.7	109.2	86.29	3.15	41.47	8
228	66	Rogers	8	33	4.64	7.95	E	SH-266	2	24	1	10	8100	40.8	112	55	59.5	115.6	8.7	54.5	86.29	3.15	41.47	20.8
229	66	Rogers	8	28	0.86	0.86	N/S	SH-88	2	24	1	8	4300	43.3	86	55	55.5	128.4	0	42.8	189.05	1.89	65.19	0
230	66	Rogers	8	28	1.15	1.15	N/S	SH-88	2	24	1	8	4300	45.0	102	65	63.5	285.2	0	107	189.05	1.89	65.19	0
231	66	Rogers	8	28	1.65	1.65	N/S	SH-88	2	24	1	8	4300	49.1	125	65	66.5	73.1	0	31.3	86.29	3.15	41.47	8.3
232	68	Sequoyah	1	6	0	5.75	E	US-064	2	24	1	4	1800	36.9	176	55	52.5	58.9	0	27.7	86.29	3.15	41.47	20
233	69	Stephens	7	12	0.73	1.87	E	SH-29	2	24	1	8	3500	35.9	97	65	61.5	21.1	0	7	86.29	3.15	41.47	16.7
234	69	Stephens	7	12	7.75	11.75	E	SH-29	2	24	3	6	2000	27.4	93	65	57.5	121.4	3.1	62.3	189.05	1.89	65.19	17.1
235	70	Texas	6	10	21.14	21.14	N/S	US-064	2	24	1	8	780	40.8	60	55	57.5	66.1	0	11	86.29	3.15	41.47	12.5
236	71	Tillman	5	4	2.55	2.99	E	US-70	2	24	1	8	2000	38.2	105	45	47.5	169.8	0	84.9	189.05	1.89	65.19	14.3
237	71	Tillman	5	4	3.04	3.36	N	US-70	2	24	1	8	2000	40.3	115	45	49.5	155.7	0	38.9	86.29	3.15	41.47	16.7
238	71	Tillman	5	4	2.8	2.8	N/S	US-70	2	24	6	3	560	34.2	49	45	47.5	227.7	0	75.9	189.05	1.89	65.19	25
239	71	Tillman	5	4	2.94	2.94	N/S	US-70	2	24	1	8	560	34.2	53	35	44.5	250.8	0	125.4	189.05	1.89	65.19	0
240	71	Tillman	5	4	3.2	3.2	N/S	US-70	2	24	1	8	560	37.9	44	45	49.5	66.9	0	0	86.29	3.15	41.47	0
241	72	Tulsa	8	31	1	1	W/E	SH-266	2	24	1	8	1800	30.4	114	65	61.5	181.9	28	70	189.05	1.89	65.19	26.9

APPENDIX - B

Training Dataset

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
1	1	Adair	1	14	0	4.32	E	SH-051	2	24	3	4	2700	25.8	125	65	67.5	89.9	4.6	48.4	86.29	3.15	41.47	24.6
2	1	Adair	1	8	9.8	9.8	W/E	US-62	2	24	3	3	1300	43.6	114	65	60.5	158.9	0	75.7	86.29	3.15	41.47	26.7
3	1	Adair	1	8	2.1	2.1	W/E	US-62	2	24	3	3	1145	44.7	114	65	63.5	135.1	0	36.8	86.29	3.15	41.47	13.3
4	2	Alfalfa	6	4	2.04	2.42	E	US-64	2	24	1	8	2200	44.2	76	40	47.5	29.8	0	0	189.05	1.89	65.19	0
5	2	Alfalfa	6	34	0.3	0.3	N/S	SH-38	2	24	6	8	330	30.9	115	45	42.5	0	0	0	86.29	3.15	41.47	0
6	2	Alfalfa	6	12	10.8	10.8	W/E	SH-8	2	24	6	8	670	30.9	67	45	45.5	0	0	0	86.29	3.15	41.47	0
7	2	Alfalfa	6	12	10.5	10.5	W/E	SH-8	2	24	1	8	670	30.9	129	35	42.5	192.3	0	0	189.05	1.89	65.19	0
8	4	Beaver	6	20	6.15	6.15	N/S	US-270	2	24	1	8	2300	38.5	169	45	51.5	105.4	15.1	45.2	86.29	3.15	41.47	44.4
9	6	Blaine	5	22	0.22	0.5	E	SH-051	2	24	3	5	2000	34.9	64	35	41.5	44.5	0	0	189.05	1.89	65.19	0
10	6	Blaine	5	22	0.5	1	E	SH-051	2	24	3	5	1200	40.9	80	55	57.5	35.6	0	35.6	189.05	1.89	65.19	0
11	6	Blaine	5	14	23.59	23.59	S	SH-008	2	24	6	4	1200	35.0	71	45	45.5	0	0	0	189.05	1.89	65.19	0
12	6	Blaine	5	14	23.74	23.74	N/S	SH-008	2	24	6	4	1200	34.2	103	55	55.5	0	0	0	189.05	1.89	65.19	0
13	7	Bryan	2	10	17.94	19.56	E	US-70	2	24	1	8	3000	49.0	118	65	65.5	27.3	3.4	13.7	189.05	1.89	65.19	25
14	7	Bryan	2	10	19.56	19.99	E	US-70	2	24	1	8	3000	47.4	128	65	66.5	38.6	0	25.7	189.05	1.89	65.19	0
15	7	Bryan	2	26	0.17	0.17	W/E	SH-22	2	24	3	4	1300	47.7	134	55	60.5	163.7	54.6	54.6	189.05	1.89	65.19	0
16	7	Bryan	2	26	0.34	0.34	W/E	SH-22	2	24	2	6	1300	40.2	202	65	64.5	171.8	0	85.9	189.05	1.89	65.19	0
17	8	Caddo	7	14	16.41	16.78	N	US-281	2	24	3	8	950	49.0	115	55	53.5	70.1	0	0	189.05	1.89	65.19	0
18	8	Caddo	7	18	12.45	12.53	E	SH-009	2	24	1	8	2600	31.9	190	35	42.5	0	0	0	189.05	1.89	65.19	0
19	8	Caddo	7	14	15.7	15.7	N/S	US-281	2	24	1	8	3300	42.5	73	55	59.5	225.3	7.3	87.2	86.29	3.15	41.47	7.4
20	8	Caddo	7	18	12.5	12.5	N/S	SH-9	2	24	3	4	3300	33.4	130	35	42.5	92.8	0	0	189.05	1.89	65.19	20
21	8	Caddo	7	36	7.6	7.6	S	SH-58	2	24	3	4	2100	45.8	55	65	69.5	143.3	0	92.7	86.29	3.15	41.47	22.7
22	8	Caddo	7	36	8.6	8.6	N/S	SH-58	2	24	3	4	2100	45.8	73	65	67.5	134.9	0	101.2	86.29	3.15	41.47	25
23	8	Caddo	7	36	9.6	9.6	N/S	SH-58	2	24	3	4	2100	45.8	56	65	70.5	118	0	101.2	86.29	3.15	41.47	31.3
24	9	Canadian	4	8	2.37	4.56	N	US-81	2	24	3	2	4800	41.9	128	55	57.5	37.9	2.4	16.6	189.05	1.89	65.19	4.2
25	9	Canadian	4	36	1.3	2.05	E	SH-152	2	20	3	4	2200	42.0	81	65	67.5	45.3	0	0	189.05	1.89	65.19	0
26	9	Canadian	4	36	3.05	5.25	E	SH-152	2	20	3	4	2200	44.2	114	65	66.5	41.2	0	15.4	189.05	1.89	65.19	25
27	9	Canadian	4	36	7.95	9	E	SH-152	2	20	3	5	3400	40.5	105	55	58.5	146.5	7	76.7	189.05	1.89	65.19	2.9
28	10	Carter	7	4	5.28	9.75	E	SH-199	2	24	1	10	6700	30.7	87	55	57.5	65	6.8	30.4	189.05	1.89	65.19	13.7
29	11	Cherokee	1	16	0	3	E	SH-051	2	24	3	3	2800	34.9	136	65	66.5	199.9	3.1	79.9	86.29	3.15	41.47	40.4
30	11	Cherokee	1	32	3.9	3.9	W/E	US-62	2	24	6	6	1800	36.5	127	65	56.5	144.8	4.1	66.2	86.29	3.15	41.47	18.5
31	11	Cherokee	1	32	6.5	6.5	W/E	US-62	2	24	3	4	3800	36.2	106	65	55.5	136.4	0	80.2	86.29	3.15	41.47	32.1
32	11	Cherokee	1	6	0.7	0.7	W/E	US-62	2	24	3	2	3800	37.6	185	65	64.5	284.6	0	189.8	86.29	3.15	41.47	61.9
33	13	Cimarron	6	16	7.6	7.6	W/E	US-56	2	24	3	6	660	40.4	102	40	39.5	0	0	0	189.05	1.89	65.19	0
34	13	Cimarron	6	16	8.2	8.2	W/E	US-56	2	24	3	5	660	40.4	157	45	43.5	0	0	0	189.05	1.89	65.19	0
35	14	Cleveland	3	4	4.21	6.11	N	US-77	2	24	1	4	6200	25.6	158	50	53.5	165.5	6.4	90.3	189.05	1.89	65.19	27.4
36	14	Cleveland	3	11	2.73	5.76	E	SH-09	2	24	1	10	9100	44.3	86	60	63.5	142.7	6.3	57.8	189.05	1.89	65.19	9.6
37	14	Cleveland	3	11	11.28	13.73	E	SH-09	2	24	1	10	6800	26.4	109	65	65.5	119.9	7.6	47	189.05	1.89	65.19	7.3
38	14	Cleveland	3	11	13.73	15.07	E	SH-09	2	24	1	8	6800	28.0	80	65	67.5	130.4	2.8	58.3	189.05	1.89	65.19	2.5
39	14	Cleveland	3	11	15.07	17.25	E	SH-09	2	24	1	8	5600	27.7	87	65	65.5	273.4	2	148.9	86.29	3.15	41.47	15.2
40	14	Cleveland	3	11	7.5	7.5	W/E	SH-009	2	24	1	10	6900	47.6	77	60	65.5	125.6	2.7	58.1	189.05	1.89	65.19	7.1

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
41	14	Cleveland	3	11	12.8	12.8	W/E	SH-009	2	24	1	10	3900	30.3	82	65	65.5	127.5	5.1	61.2	189.05	1.89	65.19	4.8
42	14	Cleveland	3	11	15.6	15.6	W/E	SH-009	2	24	1	10	1600	29.1	74	65	65.5	179.4	6.3	82.3	86.29	3.15	41.47	7.6
43	14	Cleveland	3	11	13.85	13.85	W/E	SH-009	2	24	1	10	3800	34.2	63	65	67.5	177.6	5.2	83.6	189.05	1.89	65.19	5.5
44	14	Cleveland	3	11	14.35	14.35	W/E	SH-009	2	24	1	10	3800	34.2	64	65	67.5	181.1	7.1	81.7	189.05	1.89	65.19	0.1
45	14	Cleveland	3	11	13.5	13.5	W/E	SH-009	2	24	6	8	3900	30.3	179	65	60.5	141.5	5.2	69	189.05	1.89	65.19	5.7
46	14	Cleveland	3	11	4.82	4.82	W/E	SH-009	2	24	1	8	6900	45.2	68	60	63.5	130	2.7	58.8	189.05	1.89	65.19	9.6
47	16	Comanche	7	5	1.24	2.34	N	US-62	2	24	1	8	5900	41.6	69	65	65.5	135.1	7.3	69.4	86.29	3.15	41.47	25
48	16	Comanche	7	26	5	5	N/S	SH-36	2	24	6	6	1400	47.7	51	55	62.5	58.7	0	29.3	86.29	3.15	41.47	21.4
49	16	Comanche	7	22	0.5	0.5	N/S	SH-281	2	24	1	8	1400	50.3	61	55	49.5	117.4	0	58.7	86.29	3.15	41.47	50
50	17	Cotton	7	14	0	4.98	E	SH-005	2	24	1	8	2600	29.5	107	65	62.5	44.5	3.7	24.1	189.05	1.89	65.19	20
51	17	Cotton	7	22	0.8	3.93	N	SH-36	2	20	3	3	1800	28.0	100	65	64.5	229.4	4.7	121.7	86.29	3.15	41.47	13.3
52	17	Cotton	7	14	4.63	4.63	W/E	SH-5	2	24	1	8	1200	38.3	85	65	62.5	61.2	0	20.4	189.05	1.89	65.19	3.8
53	18	Craig	8	24	1	8.1	N	SH-82	2	24	1	5	4000	42.1	61	65	68	104.3	0	56.3	86.29	3.15	41.47	28.6
54	18	Craig	8	24	0.5	0.5	N	SH-82	2	24	6	8	4000	41.6	50	65	64	93.5	0	36	86.29	3.15	41.47	14.3
55	18	Craig	8	24	1.5	1.5	N	SH-82	2	24	6	8	4000	39.7	62	65	68	81.2	0	33.6	86.29	3.15	41.47	17
56	19	Creek	8	8	1.89	5.17	N	US-75A	2	24	3	6	3900	35.9	100	65	67.5	1.9	0	54	86.29	3.15	41.47	25
57	19	Creek	8	10	9.22	9.69	E	SH-016	2	24	3	4	2000	47.5	91	55	57.5	0	0	0	189.05	1.89	65.19	0
58	19	Creek	8	10	9.98	15.38	E	SH-019	2	24	3	4	1200	48.9	86	35	42.5	130	0	92.2	86.29	3.15	41.47	27.5
59	19	Creek	8	8	4.45	4.45	N/S	US-75A	2	24	1	8	4000	35.4	76	65	66.5	13.9	0	6.9	86.29	3.15	41.47	44.4
60	19	Creek	8	10	9.13	9.13	N/S	SH-16	2	24	1	8	1200	50.9	67	65	68.5	10.4	0	5.2	86.29	3.15	41.47	33.3
61	19	Creek	8	10	10.07	10.07	N/S	SH-16	2	24	3	5	1200	47.0	102	35	42.5	12	0	6	86.29	3.15	41.47	33.3
62	19	Creek	8	10	10.3	10.3	N/S	SH-16	2	24	3	5	1200	47.0	82	55	58.5	11.9	0	5.9	86.29	3.15	41.47	33.3
63	19	Creek	8	10	10.65	10.65	N/S	SH-16	2	24	3	4	1200	47.0	66	65	66.5	19.8	0	13.2	86.29	3.15	41.47	40
64	21	Delaware	8	2	12.98	13.48	N	US-412	2	24	3	3	3900	50.6	66	55	56.5	78.7	0	52.4	189.05	1.89	65.19	25
65	21	Delaware	8	10	0	2.38	N	SH-10	2	24	3	4	2900	53.7	111	55	55.5	173.1	0	116.7	86.29	3.15	41.47	47.3
66	21	Delaware	8	10	2.38	3.3	N	SH-10	2	24	3	4	2700	53.8	89	55	56.5	83.3	0	52.1	189.05	1.89	65.19	6.7
67	21	Delaware	8	30	12.1	13.6	E	US-412	2	24	3	3	5800	43.8	75	45	45.5	188.9	0	88.7	189.05	1.89	65.19	14
68	21	Delaware	8	38	0	2.4	E	SH-85A	2	22	3	1	2700	43.2	109	50	43.5	161.4	3.8	84.6	86.29	3.15	41.47	41
69	21	Delaware	8	38	3.2	3.98	E	SH-85A	2	24	3	4	3100	50.9	78	50	50.5	67.7	9.7	58.1	189.05	1.89	65.19	8.3
70	21	Delaware	8	38	3.98	4.93	E	SH-85A	2	24	3	4	3300	44.6	90	55	55.5	139.3	16.4	73.7	86.29	3.15	41.47	27.6
71	21	Delaware	8	4	0.4	0.4	N/S	US-59	2	24	2	8	2900	45.9	80	55	53.5	117.9	0	58.5	86.29	3.15	41.47	16.7
72	21	Delaware	8	10	2.9	2.9	N/S	SH-10	2	24	3	6	2200	51.9	68	55	56.5	273.8	0	171.8	86.29	3.15	41.47	20.2
73	21	Delaware	8	2	13.55	13.55	W/E	US-59	2	24	3	6	3500	49.6	78	45	51.5	192.8	0	101	86.29	3.15	41.47	18.7
74	21	Delaware	8	2	13.1	13.1	W/E	US-59	2	24	3	5	3500	49.6	60	55	56.5	171.7	0	93.7	86.29	3.15	41.47	17.9
75	21	Delaware	8	30	13.1	13.1	W/E	US-412A	2	24	3	5	2900	44.6	70	45	48.5	153.9	0	83.6	86.29	3.15	41.47	6.6
76	21	Delaware	8	30	12.6	12.6	W/E	US-412A	2	24	2	8	2900	44.6	92	45	45.5	143.7	0	77.9	86.29	3.15	41.47	6.5
77	21	Delaware	8	38	2.81	2.81	W/E	SH-85a	2	24	3	3	3000	50.2	92	45	44.5	58.7	3.1	37.1	86.29	3.15	41.47	40
78	21	Delaware	8	38	3.18	3.18	W/E	SH-85a	2	24	3	3	3000	50.2	52	45	46.5	85.3	3	48.7	86.29	3.15	41.47	31.7
79	21	Delaware	8	38	3.85	3.85	W/E	SH-85a	2	24	3	4	2200	46.6	64	50	50.5	93.5	3.5	52	86.29	3.15	41.47	30
80	21	Delaware	8	38	4.25	4.25	W/E	SH-85a	2	24	3	3	2200	47.7	74	55	55.5	93.5	3.5	52	86.29	3.15	41.47	30

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
81	21	Delaware	8	30	4.5	4.5	W/E	US-412	2	24	3	4	2050	53.6	58	55	62.5	102.3	0	40.2	86.29	3.15	41.47	33.3
82	21	Delaware	8	30	4.85	4.85	W/E	US-412	2	24	3	4	2050	53.6	80	55	62.5	98.6	0	40.2	86.29	3.15	41.47	34.3
83	21	Delaware	8	30	5.5	5.5	W/E	US-412	2	24	3	5	2050	53.6	88	55	62.5	91.3	0	47.5	86.29	3.15	41.47	22.9
84	21	Delaware	8	30	5.95	5	W/E	US-412	2	24	3	3	2050	53.6	48	50	54.5	95	0	43.8	86.29	3.15	41.47	21.6
85	22	Dewey	5	20	15	15.14	N	SH-034	2	24	1	10	1100	36.2	88	40	41.5	161.7	0	0	189.05	1.89	65.19	0
86	22	Dewey	5	20	15.14	15.37	N	SH-034	2	24	1	4	1100	42.8	103	50	54.5	0	0	0	189.05	1.89	65.19	0
87	23	Ellis	6	2	0	0.9	E	US-46	2	24	1	8	1600	36.5	83	35	38.5	17.3	0	17.3	86.29	3.15	41.47	0
88	23	Ellis	6	2	6.77	12.57	E	US-60	2	24	6	4	1200	41.5	57	55	60.5	57.3	0	35.8	86.29	3.15	41.47	13.2
89	23	Ellis	6	20	1.27	7.68	E	SH-015	2	24	6	7	2000	37.3	127	50	54.5	46.6	1.9	19.4	86.29	3.15	41.47	9.4
90	23	Ellis	6	20	8.13	8.42	E	SH-015	2	24	6	6	2400	35.6	101	50	54.5	74.7	0	37.3	86.29	3.15	41.47	33.3
91	23	Ellis	6	20	8.42	10.34	E	SH-015	2	24	1	8	1900	36.5	67	65	66.5	90.8	6.5	58.4	86.29	3.15	41.47	23.5
92	23	Ellis	6	22	0.15	2.6	N	SH-046	2	24	3	4	470	36.6	169	45	54.5	132.6	0	44.2	86.29	3.15	41.47	12.5
93	23	Ellis	6	2	12.55	12.55	W/E	US-60	2	24	1	4	2100	44.0	53	35	41.5	78.1	0	43.4	86.29	3.15	41.47	5.9
94	23	Ellis	6	2	12.45	12.45	W/E	US-60	2	24	2	1	2100	44.0	112	45	53.5	70.6	0	36.3	86.29	3.15	41.47	11.1
95	23	Ellis	6	2	12.2	12.2	W/E	US-60	2	24	1	6	2100	44.0	53	55	60.5	66.8	0	33.4	86.29	3.15	41.47	11.1
96	23	Ellis	6	2	1.1	1.1	N/S	US-60	2	24	1	8	1200	40.9	95	35	38.5	64.2	0	42.8	86.29	3.15	41.47	50
97	23	Ellis	6	4	0.5	0.5	N/S	US-60	2	24	1	8	1200	38.9	128	55	58.5	72.5	0	14.5	86.29	3.15	41.47	0
98	23	Ellis	6	20	7.6	7.6	W/E	SH-15	2	24	3	3	2400	41.3	107	50	54.5	93.6	4.7	42.1	86.29	3.15	41.47	16
99	23	Ellis	6	20	8.3	8.3	W/E	SH-15	2	24	6	6	2400	36.6	107	50	54.5	88.8	4.7	42	86.29	3.15	41.47	16
100	23	Ellis	6	20	8.8	8.8	W/E	SH-15	2	24	1	8	2400	38.0	43	65	66.5	78.2	4.6	41.4	86.29	3.15	41.47	17.4
101	25	Garvin	3	2	2.4	3.46	N	US-77	2	24	1	10	5300	38.2	179	65	66.5	135	10.4	62.7	86.29	3.15	41.47	11.1
102	25	Garvin	3	26	0.85	11.72	E	SH-29	2	24	3	3	980	56.0	79	45	50.5	136.5	0	60.9	86.29	3.15	41.47	14.8
103	25	Garvin	3	26	1.32	1.32	W/E	SH-29	2	24	3	4	1900	54.2	76	45	50.5	239.6	8.9	88.7	86.29	3.15	41.47	2.3
104	26	Grady	7	4	8.24	10.52	E	SH-062	2	24	1	8	3500	37.0	57	65	66.5	75.9	3	39.4	189.05	1.89	65.19	27.8
105	29	Harmon	5	4	0	0.14	E	US-062	2	24	1	10	2400	26.9	111	35	38.5	518.9	0	74.1	189.05	1.89	65.19	0
106	29	Harmon	5	4	0.62	1	E	US-062	2	24	1	8	2300	37.5	86	45	50.5	28.5	0	28.5	86.29	3.15	41.47	0
107	29	Harmon	5	4	0.14	0.14	W/E	US-062	2	24	1	10	2100	35.5	112	35	38.5	278	0	72.7	86.29	3.15	41.4	2.4
108	29	Harmon	5	4	0.7	0.7	W/E	US-062	2	24	1	10	2100	38.7	101	45	50.5	97	0	26.7	86.29	3.15	41.47	11.6
109	31	Haskell	1	16	7.01	8.01	E	SH-031	2	24	6	5	1600	62.2	117	65	67.5	93.4	15.6	31.1	86.29	3.15	41.47	12.5
110	32	Hughes	3	16	5.43	6.14	E	SH-1	2	24	1	8	2200	50.6	56	65	68.5	79.7	0	15.9	189.05	1.89	65.19	12.5
111	35	Johnston	3	24	0	4.93	N	SH-99	2	24	3	5	1900	47.8	107	65	61.5	114.3	2.7	39.9	86.29	3.15	41.47	21.1
112	35	Johnston	3	34	5.72	10	N	SH-078	2	24	3	2	1400	34.3	118	55	55.5	317.8	9	147.7	86.29	3.15	41.47	43.2
113	35	Johnston	3	24	4.8	4.8	N/S	SH-99	2	24	6	8	1000	45.6	85	65	61.5	159.1	0	49.7	86.29	3.15	41.47	12
114	35	Johnston	3	16	3	3	W/E	SH-22	2	24	1	8	560	42.9	149	55	50.5	138.6	8.2	40.8	86.29	3.15	41.47	3.4
115	35	Johnston	3	4	5.3	5.3	W/E	SH-22	2	24	3	4	560	38.6	76	55	51.5	43.8	0	32.9	86.29	3.15	41.47	22.2
116	35	Johnston	3	24	5.1	5.1	W/E	SH-22	2	24	6	6	560	45.6	106	55	51.5	159.1	0	49.7	86.29	3.15	41.47	12
117	36	Kay	4	10	21.4	21.4	N/S	US-077	2	24	1	10	4900	30.9	106	65	64.5	126.6	12.3	77.4	86.29	3.15	41.47	16.1
118	36	Kay	4	10	21.4	21.4	N/S	US-77	2	24	1	8	4400	30.9	106	65	61.5	126.6	12.3	77.4	86.29	3.15	41.47	16.1
119	36	Kay	4	10	21.4	21.4	N/S	US-77	2	24	1	8	4400	30.9	106	65	61.5	126.6	12.3	77.4	86.29	3.15	41.47	16.1
120	39	Latimer	2	2	11.02	11.53	E	US-270	2	24	1	4	4800	33.1	162	55	54.5	428.6	0	139.5	189.05	1.89	65.19	23.1

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
121	39	Latimer	2	10	0.76	2.51	N	SH-02	2	24	1	4	2400	39.8	147	65	61.5	187.6	12.9	77.6	86.29	3.15	41.47	23.3
122	39	Latimer	2	10	0.48	0.48	N/S	SH-002	2	24	3	4	2000	32.1	128	45	44.5	332.4	0	91.9	86.29	3.15	41.47	7.8
123	39	Latimer	2	2	11.53	11.53	W/E	US-270	2	24	6	3	5400	44.8	85	45	44.5	113.2	0	30.5	86.29	3.15	41.47	13
124	39	Latimer	2	2	11.1	11.1	W/E	US-270	2	24	6	4	5400	44.8	133	55	54.5	99.8	0	25.9	86.29	3.15	41.47	12.5
125	40	Leflore	2	58	1.36	1.36	N/S	SH-112	2	24	1	8	8797	55.5	98	65	66.5	50.2	2	28.1	86.29	3.15	41.47	28.9
126	41	Lincoln	3	10	0	2.58	N	SH-18	2	24	3	5	3700	40.6	105	65	59.5	108.1	3.9	50.2	189.05	1.89	65.19	11.3
127	41	Lincoln	3	30	0.86	3.28	N	SH-099	2	22	3	7	2500	45.7	83	55	57.5	65.5	3.1	34.3	189.05	1.89	65.19	2.9
128	42	Logan	4	8	12.22	12.45	E	SH-033	2	24	1	8	4200	38.9	41	65	67.5	90.2	0	60.2	189.05	1.89	65.19	50
129	42	Logan	4	31	3.3	7.49	E	SH-105	2	24	3	1	2700	56.8	137	65	68.5	57.2	2.2	33	86.29	3.15	41.47	20.5
130	44	McClain	3	16	2.47	4.1	E	SH-39	2	24	3	5	1700	42.2	84	45	38.5	107.9	0	44.9	189.05	1.89	65.19	20
131	44	McClain	3	44	0.89	2.69	N	SH-76	2	24	1	8	4200	35.4	55	65	65.5	76.9	3.8	30.7	86.29	3.15	41.47	16.2
132	44	McClain	3	45	1.79	4.76	N	SH-76	2	24	3	4	5200	27.5	66	65	66.5	89.2	0	42.8	189.05	1.89	65.19	27.6
133	44	McClain	3	45	7.76	10.76	N	SH-76	2	24	3	5	6200	26.3	50	65	64.5	332.1	4.2	142.1	189.05	1.89	65.19	9.9
134	44	Mcclain	3	16	2.64	2.64	W/E	SH-39	2	24	6	5	2800	45.6	91	45	38.5	50.6	0	21.7	86.29	3.15	41.47	33.3
135	44	McClain	3	45	1.9	1.9	N/S	SH-76	2	24	6	5	5800	34.9	69	65	65.5	200.8	2.6	67.8	189.05	1.89	65.19	3.6
136	44	Mcclain	3	4	10.16	10.16	N	US-77	2	24	1	8	2700	36.5	167	65	61.5	73.3	5.6	33.8	86.29	3.15	41.47	35.3
137	46	Mcintosh	1	6	3	7.6	E	US-266	2	24	3	5	1200	41.9	136	65	66.5	103.8	9	67.7	86.29	3.15	41.47	14.3
138	46	Mcintosh	1	6	10.75	12.55	E	US-266	2	24	1	6	2500	61.0	142	65	69.5	63.9	0	26.6	86.29	3.15	41.47	5.9
139	46	Mcintosh	1	6	12.55	16.77	E	US-266	2	24	1	6	3600	51.8	102	65	65.5	109.6	5.6	53.4	86.29	3.15	41.47	6.2
140	46	Mcintosh	1	10	20.9	21.9	E	SH-009	2	24	1	6	2600	53.0	148	45	51.5	229.1	0	139.5	86.29	3.15	41.47	0
141	46	Mcintosh	1	10	21.85	21.85	W/E	SH-9	2	24	1	8	6900	51.2	91	45	51.5	172.1	3.4	48.2	86.29	3.15	41.47	4.6
142	46	Mcintosh	1	10	22.12	22.12	W/E	SH-9	2	24	1	8	6900	58.4	65	45	44.5	170.7	3.6	46.2	86.29	3.15	41.47	4.7
143	46	Mcintosh	1	10	22.57	22.57	W/E	SH-9	2	24	1	8	6900	54.3	131	45	48.5	169.4	3.8	45.2	86.29	3.15	41.47	5
144	48	Marshall	2	4	1.9	2.02	S	US-70	2	24	1	7	6400	41.4	128	55	58.5	356.7	0	194.6	86.29	3.15	41.47	17.4
145	48	Marshall	2	26	10.62	10.62	N/S	US-377	2	24	1	8	2800	47.7	38	65	68.5	119.2	5	39.7	86.29	3.15	41.47	10
146	48	Marshall	2	6	9.25	9.25	W/E	SH-32	2	24	1	8	2800	48.9	66	65	65.5	30.2	0	0	86.29	3.15	41.47	0
147	48	Marshall	2	6	8.25	8.25	W/E	SH-32	2	24	3	4	2800	49.6	93	65	64.5	109.2	0	43.7	86.29	3.15	41.47	0
148	49	Mayes	8	36	0	0.12	N	SH-082	2	24	1	5	6900	45.1	116	45	40.5	518.9	0	159.7	189.05	1.89	65.19	4.2
149	49	Mayes	8	36	0.5	0.5	N	SH-82	2	24	6	5	4000	51.9	158	55	58	0	0	0	86.29	3.15	41.47	0
150	49	Mayes	8	36	1	1	N	SH-82	2	24	1	8	4000	51.9	166	55	58	0	0	0	86.29	3.15	41.47	0
151	49	Mayes	8	36	1.5	1.5	N	SH-82	2	24	1	8	4000	51.9	108	55	60	18	0	18	86.29	3.15	41.47	0
152	49	Mayes	8	36	1.96	2.12	N	SH-82	2	24	6	5	4000	51.9	144	55	62	241.8	0	207.3	86.29	3.15	41.47	13.3
153	52	Noble	4	28	1.84	2.68	N	US-177	2	24	1	8	4000	56.6	76	60	62.5	59.3	7.4	29.7	86.29	3.15	41.47	33.3
154	52	Noble	4	28	2.04	2.04	W/E	US-177	2	24	1	8	5400	51.7	53	60	62.5	62	0	62	86.29	3.15	41.47	20
155	52	Noble	4	28	2.55	2.55	W/E	US-177	2	24	1	8	5400	51.7	69	60	64.5	41.5	0	23	86.29	3.15	41.47	21.5
156	52	Noble	4	28	1.12	1.12	W/E	US-177	2	24	1	8	5400	44.9	59	55	62.5	164.5	0	101.3	86.29	3.15	41.47	8.7
157	54	Okfuskee	3	2	3.43	3.43	W/E	US-62	2	24	1	10	2400	37.5	198	40	40.5	50.2	0	0	189.05	1.89	65.19	0
158	54	Okfuskee	3	8	10.1	10.1	N/S	SH-27	2	24	1	10	810	37.5	67	40	39.5	314.6	5.2	61.9	86.29	3.15	41.47	2.7
159	56	Okfuskee	1	10	4	4.67	N	US-75A	2	22	3	4	1800	28.9	101	45	42.5	144.6	0	41.3	189.05	1.89	65.19	18.2
160	56	Okfuskee	1	10	4.67	11.76	N	US-75A	2	22	3	3	1800	30.0	74	45	42.5	187.4	7.8	128.8	86.29	3.15	41.47	15.4

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
161	56	Okmulgee	1	10	4.56	4.56	N/S	US-75A	2	24	3	4	1800	36.2	71	45	42.5	95.3	0	71.5	86.29	3.15	41.47	27.3
162	56	Okmulgee	1	10	5.5	5.5	N/S	US-75A	2	24	3	3	1800	44.4	54	65	66.5	152.7	0	107.8	86.29	3.15	41.47	27.3
163	57	Osage	8	2	10.15	12.64	E	US-60	2	24	1	10	2200	50.8	71	65	69.5	70	5	40	86.29	3.15	41.47	11.1
164	57	Osage	8	2	12.64	19.14	E	US-60	2	24	1	8	2200	53.3	78	65	69.5	48.4	4	28.2	86.29	3.15	41.47	15.6
165	57	Osage	8	2	12.3	13.3	W/E	US-60	2	24	1	8	2200	48.2	112	65	69.5	44.3	4.9	24.6	86.29	3.15	41.47	16.7
166	57	Osage	8	2	13.3	13.3	W/E	US-60	2	24	1	8	2200	48.4	98	65	69.5	39.9	5	19.9	86.29	3.15	41.47	18.2
167	57	Osage	8	2	14.3	14.3	W/E	US-60	2	24	1	8	2200	48.4	76	65	69.5	39.9	5	14.9	86.29	3.15	41.47	20
168	57	Osage	8	12	3.5	3.5	N/S	SH-18	2	24	3	5	600	43.8	131	65	63.5	112.7	11.3	78.9	86.29	3.15	41.47	7.1
169	57	Osage	8	12	4.2	4.2	N/S	SH-18	2	24	3	4	1500	43.8	94	55	55.5	207.6	0	155.7	86.29	3.15	41.47	0
170	57	Osage	8	37	1.65	1.65	N/S	SH-97	2	24	3	2	4800	41.3	116	50	55.5	427	0	142.3	86.29	3.15	41.47	20
171	57	Osage	8	37	2.5	2.5	N/S	SH-97	2	24	3	4	4800	41.3	114	50	50.5	265.7	0	132.8	86.29	3.15	41.47	33.3
172	57	Osage	8	37	3.25	3.25	N/S	SH-97	2	24	3	4	4800	41.3	85	50	53.5	715.9	0	330.4	86.29	3.15	41.47	47.1
173	58	Ottawa	8	26	3.78	3.78	W/E	SH-10C	2	24	3	3	3700	44.5	76	55	54.5	365.3	52.2	104.4	86.29	3.15	41.47	0
174	58	Ottawa	8	26	3.55	3.55	W/E	SH-10C	2	24	3	3	6900	44.5	44	55	61.5	104.4	0	0	86.29	3.15	41.47	0
175	58	Ottawa	8	26	3.31	3.31	W/E	SH-10C	2	24	3	3	6900	44.5	94	55	59.5	130.5	0	78.3	86.29	3.15	41.47	28.6
176	61	Pittsburg	2	10	1.44	2.7	E	SH-09	2	24	1	6	6500	58.3	100	55	57.5	185.5	0	88.2	86.29	3.15	41.47	22.4
177	61	Pittsburg	2	10	4.7	6.62	E	SH-09	2	24	1	6	6000	62.8	96	55	60.5	143	16.6	73.2	86.29	3.15	41.47	15.8
178	61	Pittsburg	2	10	1.9	1.9	W/E	SH-09	2	24	1	8	6500	60.6	99	55	57.5	92.5	2.9	54.9	86.29	3.15	41.47	7.8
179	61	Pittsburg	2	10	2.23	2.23	W/E	SH-09	2	24	1	8	6500	60.6	142	55	57.5	83.4	2.6	49.5	86.29	3.15	41.47	7.8
180	61	Pittsburg	2	10	1.9	1.9	W/E	SH-09	2	24	1	8	4800	60.6	99	55	57.5	92.5	2.9	54.9	86.29	3.15	41.47	7.8
181	62	Pontotoc	3	16	6.08	10.63	E	SH-019	2	24	3	5	6300	49.0	119	55	62.5	128.8	1.7	55.6	86.29	3.15	41.47	27.7
182	62	Pontotoc	3	6	12.68	12.68	W/E	SH-1	2	24	1	8	6000	35.7	114	55	60.5	287.3	5.7	109.2	86.29	3.15	41.47	8
183	66	Rogers	8	33	4.64	7.95	E	SH-266	2	24	1	10	8100	40.8	112	55	59.5	115.6	8.7	54.5	86.29	3.15	41.47	20.8
184	66	Rogers	8	28	0.86	0.86	N/S	SH-88	2	24	1	8	4300	43.3	86	55	55.5	128.4	0	42.8	189.05	1.89	65.19	0
185	66	Rogers	8	28	1.65	1.65	N/S	SH-88	2	24	1	8	4300	49.1	125	65	66.5	73.1	0	31.3	86.29	3.15	41.47	8.3
186	68	Sequoyah	1	6	0	5.75	E	US-064	2	24	1	4	1800	36.9	176	55	52.5	58.9	0	27.7	86.29	3.15	41.47	20
187	69	Stephens	7	12	0.73	1.87	E	SH-29	2	24	1	8	3500	35.9	97	65	61.5	21.1	0	7	86.29	3.15	41.47	16.7
188	69	Stephens	7	12	7.75	11.75	E	SH-29	2	24	3	6	2000	27.4	93	65	57.5	121.4	3.1	62.3	189.05	1.89	65.19	17.1
189	71	Tillman	5	4	2.55	2.99	E	US-70	2	24	1	8	2000	38.2	105	45	47.5	169.8	0	84.9	189.05	1.89	65.19	14.3
190	71	Tillman	5	4	3.04	3.36	N	US-70	2	24	1	8	2000	40.3	115	45	49.5	155.7	0	38.9	86.29	3.15	41.47	16.7
191	71	Tillman	5	4	2.8	2.8	N/S	US-70	2	24	6	3	560	34.2	49	45	47.5	227.7	0	75.9	189.05	1.89	65.19	25
192	71	Tillman	5	4	2.94	2.94	N/S	US-70	2	24	1	8	560	34.2	53	35	44.5	250.8	0	125.4	189.05	1.89	65.19	0
193	72	Tulsa	8	31	1	1	W/E	SH-266	2	24	1	8	1800	30.4	114	65	61.5	181.9	28	70	189.05	1.89	65.19	26.9

Testing Dataset

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
1	2	Alfalfa	6	4	2.19	2.19	N/S	US-64	2	24	1	8	980	40.4	39	40	47.5	81	0	23.1	86.29	3.15	41.47	0
2	6	Blaine	5	14	23.83	24.26	N	SH-08	2	24	3	4	1300	37.2	105	65	66.5	0	0	0	189.05	1.89	65.19	0
3	6	Blain	5	14	24.1	24.1	N/S	SH-008	2	24	6	4	1400	36.8	93	65	66.5	33.6	0	0	86.29	3.15	41.47	0
4	8	Caddo	7	14	15.53	15.72	N	US-281	2	24	1	8	1000	45.6	68	55	61.5	357.5	0	0	86.29	3.15	41.47	0
5	8	Caddo	7	18	12.95	12.95	N/S	SH-9	2	24	3	3	2000	37.2	123	55	59.5	45	7.5	15	86.29	3.15	41.47	0
6	9	Canadian	4	36	0	0.95	E	SH-152	2	20	3	4	2100	43.1	84	55	59.5	99.9	0	37.5	189.05	1.89	65.19	0
7	10	Carter	7	4	9.75	12.77	E	SH-199	2	24	1	10	5400	36.8	77	45	42.5	33.6	1.5	16.8	189.05	1.89	65.19	13.9
8	13	Cimarron	6	16	7.45	7.45	W/E	US-56	2	24	3	6	660	40.4	150	45	47.5	0	0	0	86.29	3.15	41.47	0
9	14	Cleveland	3	11	5.76	8.6	E	SH-09	2	24	1	10	9100	43.6	87	60	65.5	111.8	1	39.5	189.05	1.89	65.19	8.3
10	14	Cleveland	3	11	8.5	8.5	W/E	SH-009	2	24	1	10	6900	47.6	79	65	66.5	117.5	2.9	60.9	189.05	1.89	65.19	5.6
11	14	Cleveland	3	11	5.2	5.2	W/E	SH-009	2	24	1	10	6900	45.2	41	60	63.5	139.1	2.5	67.7	189.05	1.89	65.19	8.4
12	16	Comanche	7	26	5.85	5.85	N/S	SH-36	2	24	1	8	1400	49.0	72	55	63.5	50.1	0	33.4	86.29	3.15	41.47	8.3
13	18	Craig	8	24	0	1	N	SH-82	2	24	1	5	5900	42.5	54	65	64	163.2	4.3	77.3	86.29	3.15	41.47	10.3
14	19	Creek	8	10	8.7	9.22	E	SH-016	2	24	3	4	2100	55.4	93	65	68.5	45.6	0	22.8	86.29	3.15	41.47	0
15	19	Creek	8	10	9.52	9.52	N/S	SH-16	2	24	3	3	1200	55.3	86	55	57.5	11	0	5.5	86.29	3.15	41.47	33.3
16	21	Delaware	8	4	0.25	0.59	N	US-590	2	24	1	10	3200	52.3	106	55	53.5	355.2	0	177.6	86.29	3.15	41.47	29.2
17	21	Delaware	8	38	2.8	3.2	E	SH-85A	2	20	3	4	2700	53.0	92	45	44.5	46.1	0	23.1	189.05	1.89	65.19	0
18	21	Delaware	8	10	1.78	1.78	N/S	SH-10	2	24	3	8	2000	56.9	84	55	55.5	259.8	0	160.6	86.29	3.15	41.47	21.5
19	21	Delaware	8	38	2.3	2.3	W/E	SH-85a	2	24	3	4	3000	50.2	91	50	43.5	81.4	2.7	46.1	86.29	3.15	41.47	28.9
20	21	Delaware	8	30	3.9	3.9	W/E	US-412	2	24	3	4	1500	53.6	61	55	62.5	98.6	0	43.8	86.29	3.15	41.47	39.4
21	22	Dewey	5	20	13.68	14.85	N	SH-034	2	24	1	6	1100	44.0	144	50	51.5	38.7	0	19.4	86.29	3.15	41.47	0
22	23	Ellis	6	4	11.07	21.15	E	US-60	2	24	6	6	930	39.1	102	35	38.5	35.3	5.4	10.9	86.29	3.15	41.47	18.8
23	23	Ellis	6	4	13.5	13.5	N/S	US-60	2	24	3	3	930	40.6	105	45	53.5	21.1	7	7	86.29	3.15	41.47	0
24	23	Ellis	6	4	0.3	0.3	N/S	US-60	2	24	1	8	1200	38.9	60	45	54.5	69.9	0	15.5	86.29	3.15	41.47	0
25	25	Garvin	3	2	1.77	2.4	N	US-77	2	24	1	8	5300	34.2	112	55	54.5	63	0	39.5	86.29	3.15	41.47	41.7
26	26	Grady	7	50	3.75	3.75	N/S	SH-4	2	24	3	4	8700	44.4	62	55	60.5	88.4	0	30.2	86.29	3.15	41	41.47
27	29	Harmon	5	4	1	1	W/E	US-062	2	24	1	10	2100	40.8	120	55	57.5	97.9	0	26.7	86.29	2.66	41.47	6.9
28	35	Johnston	3	34	11.2	13.82	N	SH-078	2	22	3	8	2500	43.0	121	65	65.5	154.5	11.9	91.1	86.29	3.15	41.47	19.6
29	36	Kay	4	10	19.8	22.78	N	US-77	2	24	1	10	4400	32.0	92	65	64.5	106.4	9.5	60.8	86.29	3.15	41.47	21.1
30	39	Latimer	2	10	0	0.76	N	SH-02	2	24	1	4	3700	28.1	150	45	44.5	603.7	0	163.9	189.05	1.89	65.19	2.1
31	40	Leflore	2	58	1.12	1.12	N/S	SH-112	2	24	3	8	8797	55.5	49	65	65.5	45.5	2.2	23.8	86.29	3.15	41.47	28.9
32	42	Logan	4	31	2.52	3.3	E	SH-105	2	24	3	2	3200	36.5	81	65	68.5	39.9	0	20	86.29	3.15	41.47	20
33	44	McClain	3	45	4.76	5.4	N	SH-76	2	24	3	4	5100	39.8	69	65	64.5	93.4	0	62.3	189.05	1.89	65.19	20
34	44	Mcclain	3	4	9.86	9.86	N/S	US-77	2	24	1	8	2700	36.9	142	65	66.5	67.9	5.2	31.3	86.29	3.15	41.47	35.3
35	46	Mcintosh	1	10	21.9	22.25	E	SH-009	2	24	1	6	3000	46.3	115	45	44.5	237.2	0	71.2	86.29	3.15	41.47	0
36	48	marshall	**2**	4	2	2	W/E	US-70	2	24	6	6	4600	46.8	95	55	58.5	60.8	0	40.5	86.29	3.15	41.47	0
37	49	Mayes	8	36	0.12	2.01	N	SH-082	2	24	1	5	6900	45.1	110	45	48.5	50.4	0	38.8	86.29	3.15	41.47	11.1
38	52	Noble	4	28	1	1.22	N	US-177	2	24	1	8	4000	40.2	86	55	62.5	254.7	0	169.8	86.29	3.15	41.47	20
39	54	Okfuskee	3	8	9.8	10.29	N	SH-27	2	24	1	10	6400	42.7	158	40	39.5	762.4	0	213.2	189.05	1.89	65.19	5.8
40	56	Okmulgee	1	10	4.24	4.24	N/S	US-75A	2	24	3	3	1800	36.2	99	45	42.5	80.5	0	67.1	86.29	3.15	41.47	11.1

S.No	CNO	CN	DNO	CSNO	SST	SEM	PD	HD	NL	SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
41	57	Osage	8	12	0.26	4.47	N	SH-18	2	24	3	5	1600	45.7	104	65	63.5	167	7	59.2	86.29	3.15	41.47	2.6
42	57	Osage	8	12	4	4	N/S	SH-18	2	24	3	3	1500	43.8	98	65	63.5	88.8	12.7	63.4	86.29	3.15	41.47	10
43	58	Ottawa	8	26	4.05	4.05	W/E	SH-10C	2	24	3	3	3700	44.5	102	55	60.5	105.8	35.3	35.3	86.29	3.15	41.47	0
44	61	Pittsburg	2	10	2.7	4.7	E	SH-09	2	24	1	6	6500	59.4	102	55	57.5	151.4	5.7	82.4	86.29	3.15	41.47	26.7
45	61	Pittsburg	2	10	2.23	2.23	W/E	SH-09	2	24	1	8	6500	60.6	142	55	57.5	83.4	2.6	49.5	86.29	3.15	41.47	7.8
46	66	Rogers	8	28	1.15	1.15	N/S	SH-88	2	24	1	8	4300	45.0	102	65	63.5	285.2	0	107	189.05	1.89	65.19	0
47	70	Texas	6	10	21.14	21.14	N/S	US-064	2	24	1	8	780	40.8	60	55	57.5	66.1	0	11	86.29	3.15	41.47	12.5
48	71	Tillman	5	4	3.2	3.2	N/S	US-70	2	24	1	8	560	37.9	44	45	49.5	66.9	0	0	86.29	3.15	41.47	0

APPENDIX - C
ANN Models - Training Results

Site No	Measured V_{85} (MPH)	ANN Predicted V_{85} (MPH)			
		Model 1	Model 2	Model 3	Model 4
1	67.5	63.9	59.0	64.9	63.5
2	60.5	43.7	44.1	44.3	45.1
3	63.5	40.4	48.5	41.1	44.4
4	47.5	66.8	64.4	65.6	64.3
5	42.5	54.7	54.5	53.9	52.3
6	45.5	68.2	60.3	68.1	63.9
7	42.5	66.2	63.9	66.5	62.8
8	51.5	64.1	58.1	64.1	61.5
9	41.5	40.8	46.1	40.8	44.9
10	57.5	65.2	63.8	65.3	64.2
11	45.5	65.3	63.7	65.6	65.0
12	55.5	60.8	59.2	61.0	59.4
13	65.5	55.2	60.3	52.0	52.2
14	66.5	67.1	62.6	67.1	65.0
15	60.5	56.8	57.1	57.2	56.0
16	64.5	41.5	53.6	41.2	50.4
17	53.5	57.4	57.8	55.9	56.1
18	42.5	52.0	54.3	51.1	54.5
19	59.5	48.0	55.2	49.3	53.7
20	42.5	46.3	53.7	45.5	51.3
21	69.5	60.3	58.2	60.8	59.2
22	67.5	42.0	44.6	41.8	43.2
23	70.5	52.6	54.7	52.9	54.6
24	57.5	42.1	52.6	41.8	47.6
25	67.5	55.8	51.2	57.0	53.3
26	66.5	65.3	62.6	65.6	64.8
27	58.5	39.5	49.1	38.8	39.7
28	57.5	66.9	64.0	67.0	64.7
29	66.5	62.9	57.9	62.0	57.6
30	56.5	64.6	63.6	64.2	64.2
31	55.5	62.9	58.5	62.3	60.6
32	64.5	67.1	60.6	66.8	64.7
33	39.5	67.3	63.7	67.7	64.5
34	43.5	65.2	64.2	64.4	62.5
35	53.5	63.9	57.8	64.8	64.1

Site No	Measured V_{85} (MPH)	ANN Predicted V_{85} (MPH)			
		Model 1	Model 2	Model 3	Model 4
36	63.5	49.0	54.6	49.9	52.5
37	65.5	68.1	65.3	68.1	66.2
38	67.5	58.4	59.7	57.9	57.9
39	65.5	63.1	62.7	63.0	63.2
40	65.5	42.3	46.4	41.7	44.8
41	65.5	43.9	48.7	44.1	50.2
42	65.5	67.3	63.9	68.3	67.2
43	67.5	55.9	55.1	56.4	54.8
44	67.5	56.0	53.4	55.3	55.5
45	60.5	59.3	59.1	60.2	60.8
46	63.5	59.9	57.6	60.4	60.4
47	65.5	66.4	61.8	66.5	63.2
48	62.5	48.0	50.4	46.6	49.4
49	49.5	62.1	53.6	61.5	61.2
50	62.5	62.9	58.6	62.0	57.5
51	64.5	45.4	47.5	45.6	47.3
52	62.5	55.5	50.7	57.0	54.3
53	68	66.2	63.7	66.3	62.5
54	64	41.9	48.2	41.9	45.5
55	68	66.4	58.2	67.4	63.2
56	67.5	65.6	63.4	65.5	62.6
57	57.5	59.7	54.5	59.1	56.1
58	42.5	46.4	53.7	44.2	46.0
59	66.5	66.3	64.8	66.9	65.5
60	68.5	64.8	55.9	64.8	62.6
61	42.5	63.9	63.0	63.8	63.4
62	58.5	62.3	56.6	62.5	61.5
63	66.5	65.6	64.2	65.4	63.5
64	56.5	42.0	54.4	41.7	52.3
65	55.5	57.1	55.1	58.0	56.3
66	56.5	58.3	56.1	56.7	56.5
67	45.5	55.8	55.2	55.9	56.3
68	43.5	58.0	55.9	57.7	56.5
69	50.5	47.2	53.8	46.5	52.7
70	55.5	59.8	56.7	60.4	58.7

Site No	Measured V_{85} (MPH)	ANN Predicted V_{85} (MPH)			
		Model 1	Model 2	Model 3	Model 4
71	53.5	53.6	54.4	53.7	53.0
72	56.5	52.9	54.4	52.4	54.0
73	51.5	51.2	55.4	52.2	54.9
74	56.5	52.8	56.1	53.6	56.9
75	48.5	49.6	55.5	50.0	53.7
76	45.5	48.3	52.7	49.9	50.1
77	44.5	68.2	65.6	67.5	64.4
78	46.5	53.9	50.6	53.0	54.1
79	50.5	62.9	61.8	62.6	62.5
80	55.5	46.0	50.9	45.6	45.7
81	62.5	62.4	56.5	61.6	57.4
82	62.5	43.8	50.9	41.8	44.1
83	62.5	43.3	50.1	42.2	46.9
84	54.5	68.5	65.3	68.5	65.6
85	41.5	47.0	53.6	46.8	50.2
86	54.5	67.5	64.1	66.7	62.8
87	38.5	57.7	60.7	58.1	60.0
88	60.5	63.8	61.7	63.6	63.9
89	54.5	41.9	45.9	40.3	41.7
90	54.5	66.9	59.6	67.2	63.9
91	66.5	67.7	63.9	68.7	67.9
92	54.5	53.7	54.6	54.1	53.5
93	41.5	60.6	60.3	60.9	59.6
94	53.5	58.1	57.1	58.2	57.3
95	60.5	58.8	61.7	59.3	59.6
96	38.5	54.7	55.4	54.4	53.4
97	58.5	48.3	52.0	48.5	50.0
98	54.5	63.3	58.8	63.1	58.2
99	54.5	41.3	44.3	41.3	42.9
100	66.5	45.4	49.8	45.7	47.9
101	66.5	58.2	59.5	59.5	60.1
102	50.5	57.9	60.0	58.5	58.7
103	50.5	68.1	60.3	68.9	66.0
104	66.5	58.1	60.1	58.2	58.7
105	38.5	61.5	55.7	61.0	57.1

Site No	Measured V_{85} (MPH)	ANN Predicted V_{85} (MPH)			
		Model 1	Model 2	Model 3	Model 4
106	50.5	53.0	55.9	53.2	56.1
107	38.5	65.1	64.7	65.4	63.9
108	50.5	66.8	65.5	66.8	65.8
109	67.5	66.7	64.3	66.0	64.6
110	68.5	64.0	61.3	63.8	59.7
111	61.5	65.8	64.6	66.0	64.5
112	55.5	65.9	65.0	65.7	64.9
113	61.5	66.9	58.2	66.5	59.4
114	50.5	45.9	51.4	45.8	50.1
115	51.5	56.3	56.2	56.0	56.3
116	51.5	46.5	54.6	48.3	51.8
117	64.5	51.6	58.2	50.9	53.9
118	61.5	59.6	58.3	60.6	60.2
119	61.5	40.3	49.4	40.1	46.0
120	54.5	66.0	58.0	66.1	65.8
121	61.5	58.5	58.6	59.7	58.5
122	44.5	52.9	54.6	53.2	55.7
123	44.5	49.1	56.6	50.0	52.2
124	54.5	39.7	45.5	39.1	40.9
125	66.5	63.8	57.8	63.3	59.3
126	59.5	54.2	49.9	54.1	50.9
127	57.5	62.9	61.8	62.6	62.5
128	67.5	45.3	49.8	45.5	48.3
129	68.5	57.2	57.3	57.3	57.7
130	38.5	66.3	66.0	65.7	65.4
131	65.5	65.2	63.0	64.9	62.6
132	66.5	66.8	61.5	66.7	63.3
133	64.5	48.3	53.8	49.1	52.1
134	38.5	65.4	56.4	65.2	59.9
135	65.5	58.4	62.1	59.7	61.7
136	61.5	63.8	60.3	64.0	64.4
137	66.5	43.2	44.8	43.3	44.9
138	69.5	67.9	65.0	68.9	67.8
139	65.5	67.9	63.5	68.8	68.2
140	51.5	52.2	53.6	51.4	53.5

Site No	Measured V_{85} (MPH)	ANN Predicted V_{85} (MPH)			
		Model 1	Model 2	Model 3	Model 4
141	51.5	59.0	56.3	59.4	59.5
142	44.5	58.2	58.0	58.0	58.4
143	48.5	59.4	61.8	59.3	61.4
144	58.5	63.7	60.7	63.5	61.0
145	68.5	46.5	49.3	46.3	47.4
146	65.5	44.8	56.5	45.7	52.3
147	64.5	49.1	52.6	50.3	55.1
148	40.5	55.5	52.7	55.3	51.5
149	58	63.8	58.8	63.7	58.7
150	58	41.5	53.4	41.7	44.6
151	60	57.7	56.4	57.5	56.8
152	62	58.3	63.4	57.5	62.0
153	62.5	64.3	60.7	64.0	61.9
154	62.5	63.8	62.7	63.6	63.3
155	64.5	64.3	64.3	64.5	64.2
156	62.5	66.8	65.5	66.9	65.8
157	40.5	60.3	59.3	60.5	60.7
158	39.5	64.1	49.6	63.5	55.7
159	42.5	63.7	61.0	66.6	66.5
160	42.5	68.0	61.2	68.1	65.3
161	42.5	57.8	53.5	56.6	56.0
162	66.5	45.8	46.4	45.3	46.9
163	69.5	57.7	57.9	56.9	56.4
164	69.5	46.9	54.9	47.1	49.7
165	69.5	56.7	56.5	56.6	54.6
166	69.5	54.2	56.4	54.7	56.2
167	69.5	58.9	56.4	59.4	58.1
168	63.5	50.0	53.8	51.3	53.5
169	55.5	40.3	49.0	39.5	45.9
170	55.5	66.8	64.3	66.8	66.1
171	50.5	66.5	66.0	66.3	65.7
172	53.5	48.2	49.0	48.9	50.9
173	54.5	55.8	54.8	55.3	56.4
174	61.5	54.4	54.0	52.9	52.7
175	59.5	55.5	55.3	54.3	53.0

Site No	Measured V_{85} (MPH)	ANN Predicted V_{85} (MPH)			
		Model 1	Model 2	Model 3	Model 4
176	57.5	56.4	54.7	55.5	54.2
177	60.5	67.2	66.8	66.9	65.9
178	57.5	65.0	64.2	65.6	63.9
179	57.5	62.6	54.2	62.2	60.7
180	57.5	50.3	59.0	51.0	52.8
181	62.5	58.2	58.4	58.4	58.1
182	60.5	44.8	49.9	42.7	43.7
183	59.5	59.0	59.2	61.1	60.6
184	55.5	59.8	64.7	60.8	62.3
185	66.5	43.4	45.3	43.8	46.3
186	52.5	68.5	66.4	69.3	68.3
187	61.5	63.6	56.9	64.1	63.1
188	57.5	52.3	53.5	52.9	53.4
189	47.5	58.4	57.1	57.8	57.2
190	49.5	58.0	59.0	58.1	58.9
191	47.5	57.6	59.4	56.3	56.6
192	44.5	60.3	54.7	59.7	56.1
193	61.5	41.9	48.9	43.5	47.0

ANN Models - Testing Results

Site	Measured V_{85}	ANN Predicted V_{85} (MPH)			
No	(MPH)	Model 1	Model 2	Model 3	Model 4
1	47.5	44.6	55.6	45.3	52.4
2	66.5	63.2	52.1	63.6	47.3
3	66.5	62.4	53.8	63.7	50.6
4	61.5	57.4	54.6	56.2	45.3
5	59.5	57.0	55.9	58.7	58.0
6	59.5	57.5	59.1	58.2	57.5
7	42.5	47.9	64.9	48.2	64.3
8	47.5	46.2	53.4	50.3	53.4
9	65.5	64.3	63.3	64.4	63.7
10	66.5	68.1	64.0	69.0	64.6
11	63.5	65.0	66.4	65.1	65.6
12	63.5	57.3	59.5	60.2	60.7
13	64	67.9	63.7	68.5	62.9
14	68.5	68.4	58.0	68.4	60.6
15	57.5	60.0	57.4	60.9	56.8
16	53.5	58.2	64.7	57.1	57.1
17	44.5	45.4	55.3	50.1	58.0
18	55.5	58.4	61.1	58.9	58.6
19	43.5	52.3	56.6	53.0	55.0
20	62.5	61.0	58.3	60.1	56.6
21	51.5	53.3	56.8	54.4	55.7
22	38.5	38.6	53.2	41.2	55.0
23	53.5	46.8	55.2	50.6	57.3
24	54.5	48.0	53.1	49.2	49.1
25	54.5	57.5	60.6	57.5	61.2
26	60.5	60.7	60.6	56.5	59.9
27	57.5	56.8	49.7	51.4	45.2
28	65.5	62.9	49.4	64.1	57.1
29	64.5	64.8	61.8	65.2	65.3
30	44.5	48.6	58.6	47.9	48.9
31	65.5	68.7	59.3	69.3	63.3
32	68.5	64.4	54.8	65.8	55.2
33	64.5	65.9	60.6	66.1	60.2
34	66.5	63.5	53.5	64.2	59.7
35	44.5	49.0	59.7	50.6	52.8

Site No	Measured V_{85} (MPH)	ANN Predicted V_{85} (MPH)			
		Model 1	Model 2	Model 3	Model 4
36	58.5	58.5	52.8	59.3	56.2
37	48.5	46.5	52.9	51.6	62.0
38	62.5	58.2	61.6	58.7	61.3
39	39.5	43.8	60.1	43.2	50.5
40	42.5	46.3	53.5	49.1	54.2
41	63.5	64.2	56.0	65.2	59.2
42	63.5	64.1	57.1	66.9	59.8
43	60.5	57.1	55.6	59.4	59.7
44	57.5	59.8	59.1	60.1	61.0
45	57.5	59.4	61.1	59.6	61.2
46	63.5	66.7	59.8	66.0	54.2
47	57.5	57.7	51.7	58.5	53.7
48	49.5	48.0	55.1	49.0	50.2

APPENDIX - D
USER MANUAL

USER MANUAL

1. INTRODUCTION

The purpose of this User Manual is to provide information on the estimation of 85th percentile speed (V_{85}) speed using artificial neural network (ANN) models developed in the present study. The User Manual includes the following: input and preprocessing of the dataset, determination of ANN network architecture along with training and testing of the developed ANN models, and finally application of ANN models to a new dataset. The ANN codes were developed using a commercially available software, MATLAB®.

2. INPUT AND PREPROCESSING OF THE DATA

The data is stored in an excel file in which each column represents an input parameter. The following input parameters were used in the dataset.

(i) Surface Width (SW) (ft)
(ii) Shoulder Type (ST)
(iii) Shoulder width (SHW) (ft)
(iv) ADT
(v) SN
(vi) IRI (in/miles)
(vii) Posted speed (PS) (MPH))
(viii) 85th percentile (V_{85}) (MPH)
Location Collision Rates (100 million vehicle miles)
(ix) Location Collision Rates Overall (LCRO)
(x) Location Collision Rates Fatal (LCRF)
(xi) Location Collision Rates Injury (LCRI)
Statewide Collision Rates (100 million vehicle miles)
(xii) Statewide Collision Rates Overall (STRO)
(xiii) Statewide Collision Rates Fatal (SCRF)
(xiv) Statewide Collision Rates Injury (SCRI)
(xv) %Unsafe Speed Drivers (USD)

The first task prior to developing an ANN model is to arrange the data in an excel sheet. Figure D.1 presents an example of an excel sheet in which all input parameters are arranged sequentially.

SW (ft)	ST	SHW (ft)	ADT	SN	IRI (in/mile)	PS (MPH)	V85 (MPH)	LCRO	LCRF	LCRI	SCRO	SCRF	SCRI	USD (%)
24	3	4	2700	25.8	125	65	67.5	89.9	4.6	48.4	86.29	3.15	41.47	24.6
24	3	3	1300	43.6	114	65	60.5	158.9	0	75.7	86.29	3.15	41.47	26.7
24	3	3	1145	44.7	114	65	63.5	135.1	0	36.8	86.29	3.15	41.47	13.3
24	1	8	2200	44.2	76	40	47.5	29.8	0	0	189.05	1.89	65.19	0
24	1	8	980	40.4	39	40	47.5	81	0	23.1	86.29	3.15	41.47	0
24	6	8	330	30.9	115	45	42.5	0	0	0	86.29	3.15	41.47	0
24	6	8	670	30.9	67	45	45.5	0	0	0	86.29	3.15	41.47	0
24	1	8	670	30.9	129	35	42.5	192.3	0	0	189.05	1.89	65.19	0
24	1	8	2300	38.5	169	45	51.5	105.4	15.1	45.2	86.29	3.15	41.47	44.4
24	3	4	1300	37.2	105	65	66.5	0	0	0	189.05	1.89	65.19	0
24	3	5	2000	34.9	64	35	41.5	44.5	0	0	189.05	1.89	65.19	0
24	3	5	1200	40.9	80	55	57.5	35.6	0	35.6	189.05	1.89	65.19	0
24	6	4	1200	35.0	71	45	45.5	0	0	0	189.05	1.89	65.19	0
24	6	4	1200	34.2	103	55	55.5	0	0	0	189.05	1.89	65.19	0
24	6	4	1400	36.8	93	65	66.5	33.6	0	0	86.29	3.15	41.47	0

Figure D. 1 Database arranged in an Excel Sheet

The next step is to copy data from the Excel sheet (Figure D.1) and paste them into a MATLAB® "m-function" file. The MATLAB® code provides the flexibility of using a particular set of data for developing a model. For example, input parameters (i)-(vi) are used as input parameters if one does not include posted speed in the model, while entries (i)-(vii) are used when posted speed is included in the model. Similarly, input parameters (i)-(xv) are used for developing a model using accident data. Data in column (viii) represent measured V_{85}, which is the target parameter. A particular parameter can be de-selected in the code by simply inserting a "%" sign in front of the parameter. For example, if the user does not want to use PS speed, then he/she should insert "%" in front of PS (i.e., %PS). Similarly, this "%" must be removed from a particular parameter if the user wants to use that input in the model.

Once the data is pasted into the MATLAB® "m-function" file, the next step is to open the ANN code. The code reformats the dataset to a more convenient form by taking its transpose.

The dataset is further refined by specifying/selecting a subset of the inputs to be used as independent variables; this matrix is represented by "data2" in the ANN code. In the final step, the data is partitioned into the matrix of input vectors and an associated target vector. The input vectors are designated as “p = data,” while the target vector is represented as “t = trdata.” In the present application, the inputs are the parameters listed above and the target vector is V_{85}.

Finally, the data is partitioned into two subsets; one subset is used for training and the other for testing purposes. In the present code, about 80% data are used for training and the remaining 20% (every fifth data) are used for testing. As noted earlier, out of 241 sites, 193 sites, called training dataset, were used for training the ANN models and the remaining 48 sites, called testing dataset, were used for testing these models. A specific name is given to the training and the testing datasets (i.e., “trn” for training and “tst”for testing). Each training and testing dataset is further dividing two groups: input data and target data (output). Thus, the pre-fixes (“ptrn”) and (“ptst”) mean input training and input target data, respectively. Likewise, prefixes (“ttrn”) and (“ttst”) signify output training and output target data, respectively.

The dataset was normalized so that each input has zero mean and a standard deviation of unity. The normalization of data was done with the command “prestd” that normalizes both the training and testing dataset. The above mentioned steps are automatically performed by the developed code. The user has to just copy the pertinent data from the Excel sheet to the “m-fuction” file and then run the code. However, there are several things that a user should keep in mind before estimating V_{85}. While running a given model, the user should use only those parameters that were used in developing that model. For example, Model 1 uses SW, ST, SHW, ADT, SN, IRI, and PS. Therefore, the user should select only these parameters in running this model for estimation of V_{85}. In addition, the developed code and the “m-function” file should be kept in the same folder.

3. NEURAL NETWORK AND ITS ARCHITECTURE

The network architecture consists of input, hidden, and output layers (Figure D.2). The input layer consists of input parameters used in developing the model. For example, in developing Model 3 the following parameters were used as input parameters: SW, ST, SHW, ADT, SN, IRI, PS, LCRO, LCRF, LCRI, SCRO, SCRF, SCRI, and USD. The hidden layer consists of a number of neurons. In the present code, the number of neurons in the hidden layer is represented by “numn”. For example, in Model 1 six neurons were used in the hidden layer (numn = 6). The output layer consists of a single neuron corresponding to target value (i.e., V_{85}). The "tansig" and “purelin” (linear) functions were used in hidden and output layers, respectively.

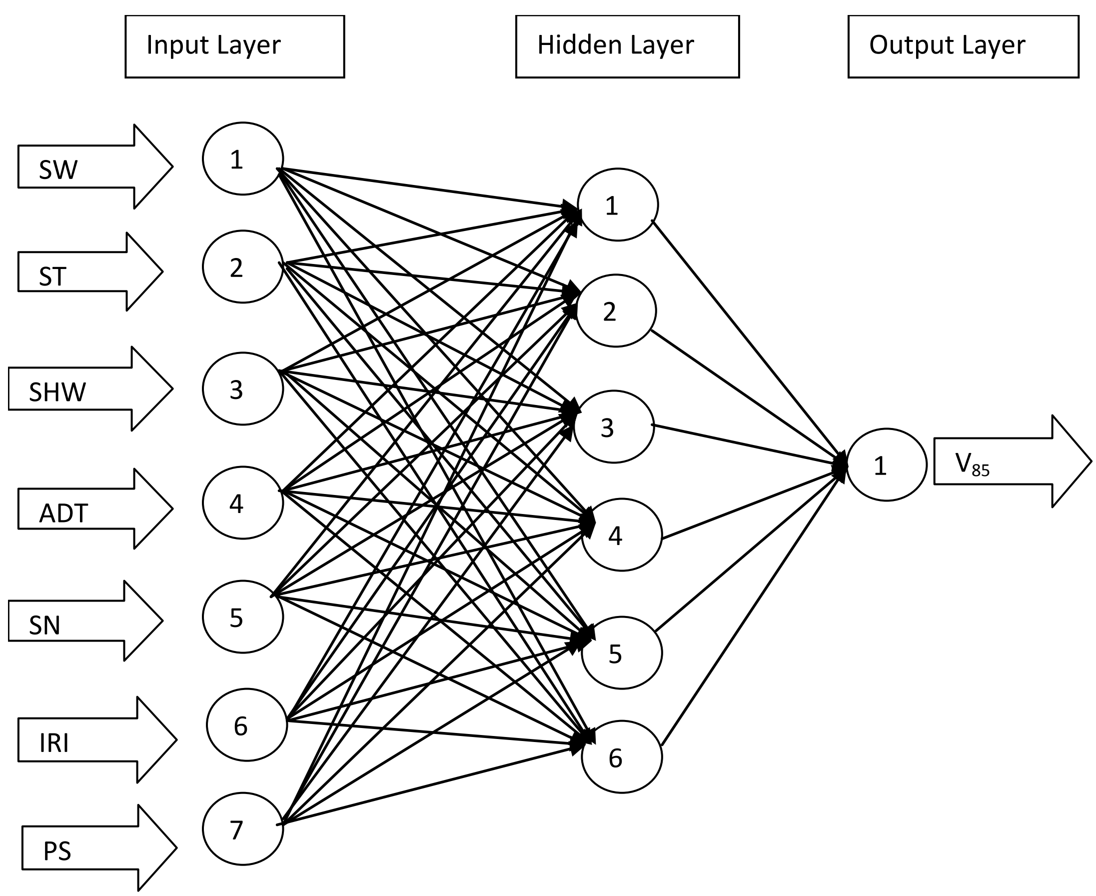

Figure D. 2 Neural Network Architecture

ANN models were trained using the Levenberg Marquardt optimization method. Training a neural network consists of solving an optimization problem to determine network weights. It is an iterative routine that starts from an initial guess to determine a set of weights that minimize the error between the ANN output and the target data. To do this, an initial guess of weights was made to initialize the algorithm. Because the error function may have multiple minima, it is possible that the optimization method is local in nature. It is important to do several trials using different initial weights to get the global minima. The code acknowledges this possibility by making multiple runs (irand=500) with randomly generated initializations. The histogram of ANN output is plotted and the mean of it is taken as the final result.

Finally, the testing of the trained ANN models was done by using the "sim" command. The "sim" command is applied to data that has also been normalized by preprocessing using the "prestd" command. The application of “sim” must then be post-processed using the "poststd" command. This should be done to enable a direct comparison with the test dataset.

The current code is setup to train "nrand" a model using the combined dataset and stores the resulting coefficients. If one wishes to apply these weights to a new dataset, it is possible do that without retraining. In that case, the stored weights should be applied to the pre-processed new dataset. Alternatively, a model can be re-trained for a new dataset.

4. APPLICATION TO NEW DATA

The trained ANN model can be used to predict V_{85} for a new dataset. The “m-file function” is created containing the new input parameters or data. The previously trained ANN model is loaded into MATLAB® and the program is run by using appropriate MATLAB® commands. The resulting output must be post-processed using the mean and standard deviation from the training dataset.

It is worth emphasizing that one must be cautious in using the ANN models to a new dataset. The new dataset should have the same form as the training and testing dataset used in the present study. The whole vector should not be used, in case of any missing data.