An-Najah National University

Faculty of Graduate Studies

Modeling Relationship between Geometric Design Consistency and Road Safety for Two-Lane Rural Highways in the West Bank

By

Mohammed Ghassan Dwikat

Supervised

Dr. Khaled Al-Sahili

This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Roads and Transport Engineering, Faculty of Graduate Studies, An-Najah National University, Nablus- Palestine.

2014

Modeling Relationship between Geometric Design Consistency and Road Safety for Two-Lane Rural Highways in the West Bank

By
Mohammed Ghassan Dwikat

This Thesis was Defended Successfully on 22/05/2014 and approved by:

Defense Committee Members	**Signature**
1. Dr. Khaled Al-Sahili/ Supervisor	....
2. Dr. Yahya Sarraj/ External Examiner	....
3. Prof. Sameer Abu Eisheh/ Internal Examiner	....

DEDICATION

This thesis is dedicated with great love to my Angels; my dear parents who have always supported me. I also dedicate it to the light of my life; my brothers and sisters. Finally, I will not forget my great friends for always being there for me.

ACKNOWLEDGMENT

I am thankful to the almighty God for granting me good health, strength and peace throughout the research period.

It is with great pleasure that I hereby express my appreciation to everyone who has contributed, in one way or another, to the completion of this thesis work. Without your assistance, this work would have proved insurmountable.

I am highly indebted to my supervisors, Dr. Khaled Al-Sahili - Director of Construction and Transportation Research Unit- and Prof. Sameer Abu-Eishes- Interior Examiner, for their constant guidance during the whole project period. I am also grateful for Dr. Wael AlhajYaseen . I am deeply thankful for all the assistance that was rendered to me by the Faculty of Engineering, An Najah National University. I am especially thankful to Eng. Jamil M. J. Hamadneh for all the help he accorded me during writing this thesis.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Modeling Relationship between Geometric Design Consistency and Road Safety for Two-Lane Rural Highways in the West Bank

أقر بأن ما اشتملت عليه هذه الرسالة إنما في نتاج جهدي الخاص ,باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل أية درجة علمية أو بحث علمي أو بحثي لدى أي مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the Researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **الطالب اسم:**

Signature: **التوقيع:**

Date: **التاريخ:**

Table of Contents

List of Tables

List of Figures

List of Abbreviations

PCBS = Palestinian Central Bureau of Statistics

ICBS = Israeli Central Bureau of Statistics

V_D = design speed of the highway

V_{85} = 85^{th} percentile operating speed

ΔV_{85} = absolute difference of the 85^{th} percentile speeds between successive design elements

V_D = design speed

R = radius of the curve

CCR = curvature change rate

AADT = average annual daily traffic

AADT = average daily traffic

V_D = design speed

85MSR = the 85^{th} percentile maximum speed reduction

DC = degree of curvature

DF = deflection angle

Δf_R = difference between side friction supplied and demanded

f_S = side friction supplied

f_D = side friction demanded

f_{TP} = maximum permissible tangential friction factor

$f_{RPerm.}$ = maximum permissible side friction factor

f_r = coefficient of side friction

AVG R = Average radius of curvature

$\frac{\mathbf{MR}}{\mathbf{mR}}$ = Maximum radius of curvature to minimum radius of curvature

AVG T = Average tangent length

CCR = Curvature change rate

CRR = Ratio of individual curve radius to average radius

VD_{LF} = visual demand of familiar drivers

VD_{LU} = visual demand of unfamiliar drivers

N_{br} = predicted number of total accidents per year on a particular roadway segment.

EXPO = exposure in million vehicle-miles of travel per year

Cr./5yrs = predicted crash frequency per 5 years

AASHTO = American Association of State Highways and Transportation Officials

GLM = generalized linear regression method

CPM = Crash prediction model

k_D = dispersion parameter depending on scaled deviance,

k_P = dispersion parameter depending on Pearson χ^2

SD = scaled deviance value of model

Pearson χ^2 = Pearson chi-squared value of model

EXP = Exponential function, e = 2.718282

$k_{\max}$ = maximum dispersion parameter of the model

MPB = mean prediction bias

MAD = mean absolute deviation

MSPE = Mean squared prediction error

MSE = Mean squared error

GOF = goodness-of-fit

HSM = highway safety manual

CMF_H = crash modification factor for horizontal curves

N_{rs} = predicted number of total crashes per year on a section

SCF = safety consistency factor

Modeling Relationship between Geometric Design Consistency and Road Safety for Two-Lane Rural Highways in the West Bank

By
Mohammed Ghassan Dwikat
Supervised
Dr. Khaled Al-Sahili

Abstract

The objectives of this study are to investigate and quantify the relationship between design consistency and road safety for two-lane highways in the West Bank. This study produced speed prediction method using real time traffic speed data obtained from Google Earth maps, which were used to estimate the 85th percentile speed along an alignment that includes both horizontal curve sections and tangent sections. A comprehensive crash and geometric design database of two-lane rural highways has been used to investigate the effect of several design consistency measures on road safety.

Previous studies showed that the most promising consistency measures identified in previous research fall into four main categories, namely: operating speed, vehicle stability, alignment indices, and driver workload. Five crash prediction models, which relate design consistency to road safety, have been examined. The generalized linear regression approach has been used for model development. All models adopted in this study showed acceptable levels of goodness of fit and over-dispersion. The developed models verified that the main design consistency measures have an important impact on safety. The consistency measures used in model development are: variation between the design speed and the operating

speed, absolute difference of the 85th percentile speeds between successive design elements, difference between side friction supplied and demanded, average radius of curvature, average tangent length, maximum radius of curvature to minimum radius of curvature, curvature change rate, ratio of individual curve radius to average radius of the section, and visual demand of familiar drivers of the section.

Validation step was performed; the goal was not only to compare the accuracy of different models developed, but also to evaluate the overall accuracy of Crash Prediction Models for use on rural two-lane highways in the West Bank. Validation requirement was to demonstrate that a model is appropriate, meaningful, and useful for the purpose for which it is intended.

The models can be used as a quantitative tool to evaluate the impact of design consistency on road safety. An application is presented where the effectiveness of crash prediction models, which incorporate design consistency measures, is compared with those, which rely on geometric design characteristics. The study concluded that models, which explicitly consider design consistency, can identify the inconsistencies more effectively and reflect the resulting impacts on safety more accurately than those which do not. Finally, a systematic approach to identify geometrically inconsistent locations using the safety consistency factor has been proposed.

Chapter One

Introduction

This chapter gives the necessary background information to understand why a quantitative relationship between design consistency and road safety needs to be investigated. In addition, the sources of design inconsistency in current geometric design practice are presented. Furthermore, this chapter gives a brief summary about evolution of the concept of design consistency. The problem statement and how study area will be chosen is presented. Finally, it presents the objectives and the structure of this thesis.

1.1 Background

The goal of transportation is generally stated as the safe and efficient movement of people and goods. To achieve this goal, designers use many tools and techniques. One technique used to improve safety on roadways is to examine the consistency of the design. Design consistency refers to a highway geometry's conformance with driver expectancy. Generally, drivers make fewer errors at geometric features that conform with their expectations than at features that violate their a priori and/or ad hoc expectancies (Alexander and Lunenfeld, 1986).

Driver expectancy is shaped by experience, which is largely dependent on the number of times a driver has driven on a particular road, the similarity of the road to others in the driver's experience, and the accuracy of recent predictions that have been made about the road (Fitzpatrick et al., 2000a).

Thus, a design inconsistency in a roadway segment implies a geometric feature or features that violate driver expectancy, such as an abrupt change in roadway geometry. Surprising drivers by violating their expectancies increases the chance of delayed response times, speed errors, and unsafe driving maneuvers that may lead to higher crash risk. To avoid these problems, designers should ensure that the roadway design complies with driver expectations through the evaluation of design consistency, and the redesign of inconsistent locations.

Traffic crashes represent obsession for all members of society, and has become one of the most important problems that drain material resources, human potentials and targeting communities in the most important elements of life which is the human element. In addition, the incurred social, psychological problems and material losses are huge, which have become imperative work to find solutions and suggestions and put them into practice to reduce these crashes or at least handling the causes and mitigate the negative effects.

Palestine experiences significant number of road crash at rural-highways in the West-Bank, some of which result in fatal, serious or slightly injuries which are presented in Table (1.1).

Table 1.1. Road Crash At Rural-Highways in the West-Bank (ICBS, 2012).

Year	Total Crash	Fatal Crash	Serious Crash	Minor Crash	Casualties	Dead	Serious injured	Slight injured
2003	525	27	100	398	1291	35	147	1109
2004	485	32	83	370	1205	37	121	1047
2005	516	21	99	396	1437	28	164	1245
2006	501	29	99	373	1440	37	148	1255
2007	548	24	93	431	1417	32	134	1251
2008	577	18	111	448	1473	19	153	1301
2009	552	21	92	439	1408	29	136	1243
2010	594	18	92	484	1450	22	114	1314
2011	542	29	72	441	1319	40	100	1179
2012	586	20	86	480	1395	29	120	1246

Crash data on the study road segments were acquired from the Israeli Central Bureau of Statistics (ICBS), which includes the number of crashes for 10 consecutive years; 2003 through 2012. The reliance on the ICBS for crash data was because most rural highways are located in area (C), which is out of control the Palestinian National Authority. Therefore, very limited data is available for those highways from Palestinian sources.

The importance of design consistency and its significant contribution to road safety can be justified with an understanding of the driver-vehicle-roadway interaction. Roadway geometry, traffic conditions, and roadside environment are the primary inputs to the driving task and determine the workload requirement on the driver. How quickly and how well these inputs are handled depend on driver expectancy and other human factors. Once these inputs are processed, they are translated into vehicle operations.

Lamm et al. (1986) have reported that half of all crashes on two-lane rural highways may be indirectly attributed to inadequate speed adaptation, indicating that design consistency is related to safety. Yet, despite the importance of geometric design consistency to road safety, it is not always ensured in current design practice.

An "*inconsistency in design*" can be described as a geometric feature or combination of features with unusual or extreme characteristics that drivers may drive in an unsafe manner. This situation could lead to speed errors, inappropriate driving maneuvers, and/or an undesirable level of accidents (Gibreel, 1999 and Fitzpatrick et al, 2000a).

1.2 Evolution of the Concept of Design Consistency

The development of consistent design practices has been a goal since at least the 1930s. Barnett (1936) developed the concept of design speed to ensure consistency. The design speed concept has undergone several modifications in recent years, but the underlying theory still exists; roadway alignments should meet or exceed the criteria for a given design speed. Although sound in theory, problems have developed with the design speed concept in its current form.

Design requires alignment features to be developed individually. Difficulties arise when designers do not consider the roadway as a single element consisting of several parts, the driver, geometry, and environment. Conceptually, a breakdown in any one of these parts results in a location with a high potential for crashes. Designers cannot control two of these elements, but may account for them through the geometry. A relationship exists between traffic safety and geometric design consistency, and alignment consistency represents a key issue in modern highway geometric design (Lamm et al., 1999). A consistent alignment will allow most drivers to operate safely at their desired speed along the entire alignment.

Existing design speed-based alignment policies in AASHTO (2011) encourage the selection of design speeds that are “. . . consistent with the speeds that drivers are likely to expect on a given highway facility” and that “fit the travel desires and habits of nearly all drivers expected to use a particular facility”. Researchers have focused on developing methods to account for problems associated with design consistency. The principal focus in most of these studies has been on developing measures or techniques to identify locations that may pose expectancy problems for the driver. The measures most commonly used in previous studies have focused on driver expectancy, speed prediction, or driver workload. These terms will be explained in details in later chapter of this thesis.

1.3 Problem Statement

Considering sources of design inconsistency in current geometric design practice, the impact of inconsistencies of existing alignments on road safety must be investigated.

The length of main and regional highways in the West Bank is 1757 km (PCBS, 2010); almost all rural roads are two-lane highways. Rural highways have the greatest proportion of crashes on the West Bank highway system. These crashes are frequently attributed to either driver error or inadequate design. Unfortunately, the definition of inadequate design is not clear because a combination of factors can all be detrimental to a roadway design that meets or exceeds design standards. Although designers attempt to address these issues, there has been concern that designers are not doing enough to address them. Most research focuses on geometric design elements and their relationships to safety. However, the inconsistency in design affects driver's expectation; this may lead to human error and potential road crash.

In the Palestinian area, there are no studies that address the effect of design inconsistency, a factor that is related to road geometry and affects human behavior, on road safety. Therefore, this thesis investigates the relationship between design inconsistency and road safety on two-lane rural highways in the West Bank, which form the vast majority of rural highways.

1.4 Study Area

Four two-lane rural highway segments located in the West Bank were chosen in this study. The selection of these highways was mainly based on limitations in data availability. However, it was ensured that the selected highways encompass a variety of highway classifications, locations, terrain, design speed, traffic volume, and crash history in West Bank. Figure (1.1) presents locations of the study highway segments in the West Bank. Most of these highways and their segments were used for modeling the relationship between design consistency and road safety and part of them was set aside for validation purposes once the models are developed, as will be explained later.

1.5 Objectives and Scope

This research is conducted with the following objectives:

1. To investigate and to quantify the relationship between design consistency and road safety in terms of expected crash frequency.

2. To determine whether models which explicitly consider design consistency are more effective in identifying inconsistencies on an alignment and reflecting the impact on crash frequency than existing models which rely on geometric design characteristics to predict crash frequency.

3. To develop a systematic approach to identify geometric design inconsistencies using crash prediction models.

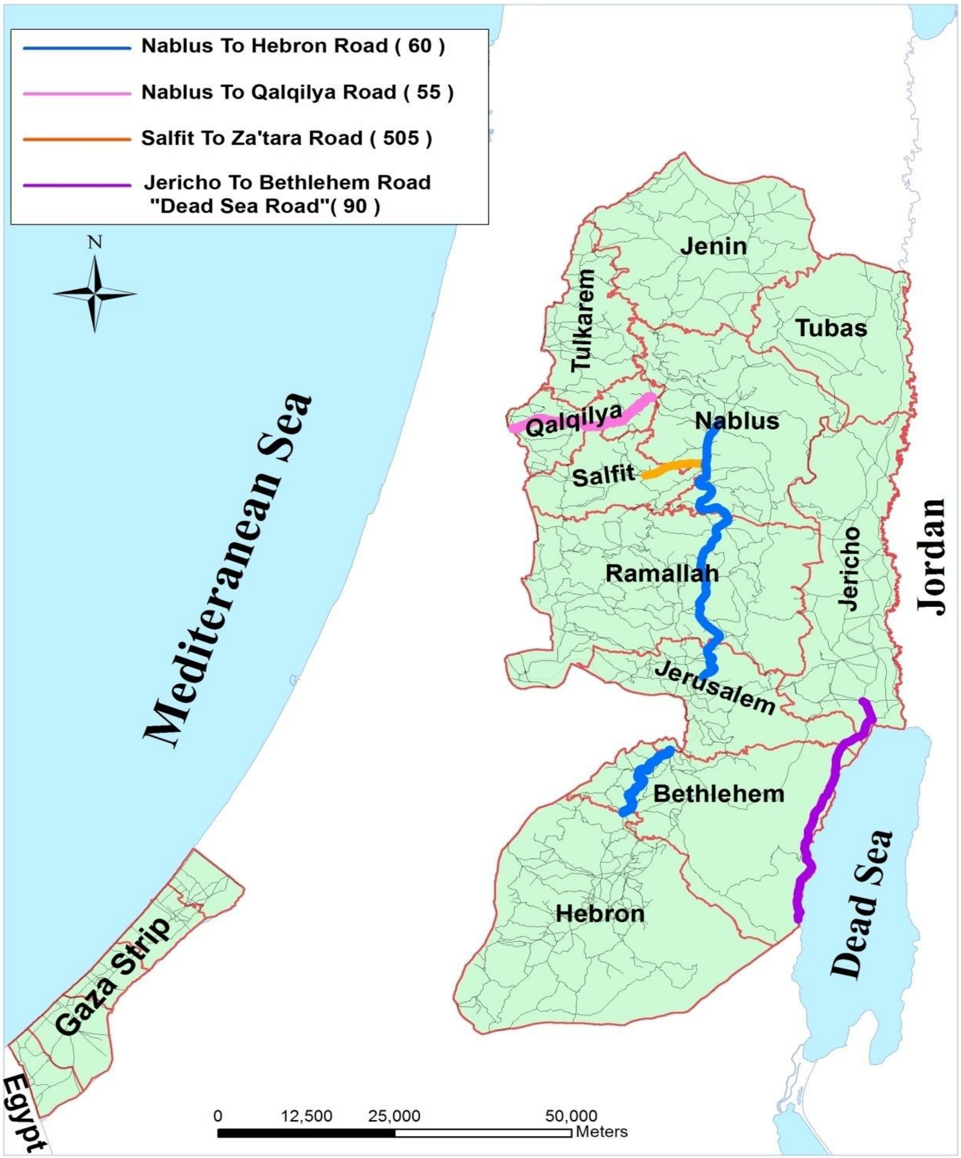

Figure 1.1. Location of the Study Highway Segments in the West Bank

1.6 Thesis Structure

This thesis consists of nine chapters. Chapter one presents the necessary background information to understand why a quantitative relationship between design consistency and road safety needs to be investigated besides the sources of design inconsistency in current geometric design practice. Chapter two provides an extensive literature review on design consistency and its relationship to safety. Chapter three describes the methodology adopted for analysis. Chapter four describes the data used to develop quantitative relationships between design consistency and safety. Chapter five explain the methodology to develop the models relating design consistency to safety. Chapter six shows the modeling results along with a detailed discussion. Chapter seven evaluate the accuracy of the West-Bank crash prediction models (CPM) developed. Chapter eight includes three applications of the developed models. Finally, Chapter nine brings forward the conclusions and gives some recommendations for future research. The references are included in the end of this thesis.

Chapter Two

Literature Review

This chapter provides a review for potential measures of geometric design consistency and its relationship to road safety. It also provides a review of some models used for predicting consistency measures and corresponding evaluation criteria.

2.1 Design Consistency Measures

Researches in design consistency focused on quantifying measures of design consistency and developing models and evaluation criteria to identifying them. The measures can be classified into four main classes: operating speed, vehicle stability, alignment indices, and driver workload.

2.1.1 Operating Speed

The 85^{th} percentile of free-flow speed distribution is commonly used to represent "operating speed" for design consistency evaluations. **Operating speed** is defined as the speed selected by highway users when not restricted by other users, and is normally represented by the 85^{th} percentile speed. In terms of geometric design consistency, operating speed (V_{85}) is widely considered to be the most notable and straightforward geometric design consistency measure (Poe and Mason, 2000). The change in speed of vehicles is a visible indicator of inconsistency in geometric design. Several interpretations of operating speed as a geometric design consistency measure have been made in the literature. The operating speed can be used in consistency evaluation by examining the variation between the design speed (V_D) and (V_{85}) on a particular section of highway or examining the differences between (V_{85}) on consecutive highway elements (ΔV_{85}).

Speed errors may be related to inconsistencies in horizontal alignment that cause the driver to be surprised by sudden changes in the road's characteristic, to exceed the critical speed of a curve and to lose control of the vehicle. These inconsistencies can and should be controlled by the engineer, when a roadway section is designed or improved (Lamm et al., 1999).

Predicted operating speeds are compared to each other or to the designated design speed to evaluate design consistency and crash risk (Cafiso and Cerni, 2011). It is therefore of primary interest to develop methodologies suitable for estimating the speed behavior of drivers. The traditional approach to evaluating design consistency is based on calculating the operating speed of the drivers separately on the curved and the tangent sections. Speed differential between curve and tangent is used to evaluate the consistency in the transition between two successive geometric elements (Lamm et al., 2007). Based on these assumptions, numerous models for estimating the operating speed exist in the literature.

2.1.1.1 Design Speed Based Measures

Since the 1930s, the design-speed concept has been the principal quantitative mechanism for ensuring consistency of safe operating speeds along rural highway alignments. The concept arose from safety concerns about differentials between the speeds at which drivers could safely operate their vehicles on tangents and the lower speeds at which they could safely operate on horizontal curves. The solution implemented by the design speed concept was that all alignment features should be designed to accommodate the desired speeds of most drivers using the roadway or, in other words, that an appropriate design speed should be uniformly applied to all alignment elements of the roadway (Fitzpatrick et al., 2000a).

The design speed consistency measure is based on the deviation of design speed from operating speed. The greater the difference between operating speed and design speed, the worse the consistency evaluation. This measure is used to check if actual driver speed meets design speed or not.

2.1.1.2 Operating Speed Based Measures

Speed differential between curve and tangent is used to evaluate the consistency in the transition between two successive geometric elements, which is usually expressed as the difference in the 85^{th} percentile operating speeds (ΔV_{85}) between successive design elements.

Hirsh (1987) argued that calculating the speed differential by the simple subtraction of the two related 85^{th} percentile speed values on tangent and curve would not give reasonable results due to the fact that the speed distributions at the two locations are different. In addition, each driver responds differently to the horizontal curve based on his/her desirable tangent speed and the actual side friction factor. Thus, the 85th percentile driver at one section is not necessarily the same 85th percentile driver at the second section. As an alternative to subtraction of operating speeds, Hirsh (1987) suggested that the full distribution of speed changes as incurred by each driver should be examined to calculate the speed differential value.

Another approach has been proposed to examine by McFadden and Elefteriadou (1999) for analyzing design consistency; the 85th percentile maximum reduction in speed (85MSR). This parameter is calculated using each drivers speed profile from approach tangent to horizontal curve and determining the maximum speed reduction each driver experiences. The 85MSR was compared to the difference in 85th percentile speeds and was found that the 85MSR is significantly larger than the difference in 85th percentile speeds. The data showed that on average, 85MSR is two times larger than the difference in 85th percentile speeds.

2.1.1.3 Geometric Design Consistency Evaluation Criteria Based on Design Speed and Operating Speed

Leisch and Leisch (1977) concluded that design speed reductions should be avoided, but if they are necessary, they should not exceed 15 km/h. Lamm et al. (1999) considered individual design elements (curves or tangents) along the observed roadway section, the absolute difference between the 85th percentile speed and the selected design speed should correspond to certain ranges:

1. Good design: $V_{85} - V_D \leq 10$ km/h (consistency),

2. Fair design: 10 km/h < $V_{85} - V_D \leq 20$ km/h (minor inconsistency; traffic warning devices required),

3. Poor design: $V_{85} - V_D > 20$ km/h (strong inconsistency; redesign recommended).

Note: V_{85} = 85th percentile operating speed (km/h); V_D = design speed of the roadway.

2.1.1.4 Geometric Design Consistency Evaluation Criteria Based on Operating Speed

Lamm et al. (1998) quantified design consistency based on operating speed depending on the absolute difference of the 85th percentile speeds between successive design elements (tangent to curve or curve to curve) should fall into certain ranges:

1. Good design: $\Delta V_{85} \leq 10$ km/h (consistency),

2. Fair design: 10 km/h < $\Delta V_{85} \leq 20$ km/h (minor inconsistency; traffic warning devices required),

3. Poor design: $\Delta V_{85} > 20$ km/h (strong inconsistency; redesign recommended).

Note: ΔV_{85} = absolute difference of the 85th percentile speeds between successive design elements (km/h).

A consistent and safe design when the difference between the operating speeds as on two successive elements must be less than 15% of the speed on the preceding quoted element (Babkov, 1975). Speed reduction from tangent to the following curve design consistency evaluation criteria also concluded by Kanellaidis et al. (1990) and Al-Masaeid et al. (1995) that speed reduction from tangent to the following curve does not exceed 10 km/h (Good design).

2.1.1.5 Operating Speed Prediction Models on Curves

Numerous operating speed prediction models have been developed worldwide. Table (2.1) reviewed some previously developed speed prediction models.

Lamm and Choueiri (1987) found that the most significant parameter that affects operating speed was the radius of horizontal curve. Another study was performed by Kanellaidis et al. (1990) on driver's speed behavior on horizontal alignments. The authors found that the radius of horizontal curve was the most significant parameter affecting operating speed using regression analysis.

Table 2.1. A Sample of Previously Developed Speed Prediction Models on Horizontal Curves.

Author	Model	R^2
Lamm and Choueiri (1987) (Note: Several potential variables and model forms were tested as presented)	V_{85}=88.72-0.084CCR [LW=3.0 m] V_{85}=89.55-(2862.69/R) [LW=3.0 m] V_{85}=92.69-0.080CCR [LW=3.3 m] V_{85}=93.83-(2955.40/R) [LW=3.3 m] V_{85}=95.77-0.076CCR [LW=3.6 m] V_{85}=96.15-(2803.70/R) [LW=3.6 m] V_{85}=94.39-(3,188.57/R)=93.85-0.045CCR V_{85}=55.84-(2,809.32/R)+0.634LW+0.053SW+ 0.0004 AADT	0.860 0.753 0.731 0.746 0.836 0.824 0.787 0.842
Kanellaidis et al. (1990) (Note: Several potential variables and model forms were tested as presented)	V_{85}=109.09-(3837.55/R) V_{85}=32.20+0.839V_D+(2226.9/R)-(533.6/√R) V_{85}=129.88-(623.1/√R)	0.647 0.925 0.777
Morrall and Talarico (1994)	$V_{85}=e^{(4.561 - 0.00586 DC)}$	0.631
Islam and Seneviratne (1994) (Note: Several model forms were tested as presented)	V_{85}=95.41-1.48DC-0.012DC^2; (At PC) V_{85}=103.30-2.41DC-0.029DC^2; (At MC) V_{85}=96.11-1.07DC; (At PT) V_{85}=103.66-1.95DC	0.990 0.980 0.980 0.800
Krammes et al. (1995)	V_{85}=102.45-1.57DC+0.0037L_C-0.10DF	0.820
McFadden and Elefteriadou (1997)	V_{85}=41.62-1.29DC+ 0.0049L_C-0.12DF+0.95 V_T	0.90
Note : V_{85} = 85th percentile speed (km/h); R = radius of the curve (m); CCR = curvature change rate (degree/km); LW = lane width (m); SW = shoulder width (m); AADT = average annual daily traffic (vehicles/day); V_D = design speed (km/h); DC = degree of curvature (degrees) expressed in degree per 30 m; PC = point of curvature; MC = middle of curve; PT = point of tangent; L_C = length of horizontal circular curve (m); DF = deflection angle of horizontal curve (degrees); V_T = approach tangent speed (km/h).		

In another study, three operating speed prediction models were developed by Islam and Seneviratne (1994) at different points along horizontal curves. It was noticed that there were significant differences between the operating speed values on the same horizontal curve at the point of curve (PC), the middle of curve (MC), and point of tangent (PT). Therefore, they recommended that design consistency should be evaluated based on the difference between the operating speed at the point of tangent (PT) and the design speed of the horizontal curve. These differences were found to increase as the degree of curvature increased. Therefore, Gibreel et al. (1999) suggested that speed consistency problems may tend to arise along sharp horizontal curves. Morall and Talarico (1994) collected speed data for nine horizontal curve sites on rural two-lane highways in Alberta, Canada using a radar speedometer. Linear, multiplicative, exponential, and reciprocal regression models were investigated and were found to provide the best fit to the data. Krammes et al. (1995) and McFadden and Elefteriadou (1997) developed new models taking into consideration new parameters (length of horizontal circular curve, deflection angle of horizontal curve and approach tangent speed) which reflect better model fit.

Several different efforts were undertaken from Fitzpatrick et al. (2000b) to predict operating speed for different conditions such as on horizontal curves, vertical curves, and on a combination of horizontal and vertical curves; on tangent sections; and prior to or after a horizontal curve. Speed data were collected at over 200 two-lane rural highway sites for use in the project. Regression equations were developed for passenger car speeds for most combinations of horizontal and vertical alignment. Table (2.2) lists the developed equations and/or the assumptions made for the different alignment conditions for passenger cars.

Table (2.2) shows that, in most cases, V_{85} was predicted using the inverse of the horizontal curve radius or the inverse of the rate of vertical curvature. In cases where the sample size was too small to estimate a model, the desired speed was assumed to be 100 km/h, based on the earlier study by Krammes et al. (1995).

Although the models in Table (2.2) were developed with the consideration of the presence of grade and/or vertical curves, the length of either horizontal or vertical curve was not included. Gibreel et al. (2001) developed a set of models, which considered the three-dimensional nature of highways. The resulted coefficients of determination (R^2) of the 3-D models ranged from 0.79 to 0.98. Operating speed data were collected at five points on each site to establish the effect of the 3-D alignment combination on the trend of operating speed of the traveling vehicles (see Figure 2.1).

Multiple linear regression technique was used to estimate the operating speed models based on data collected on Highway 61 and Highway 102 in Ontario, Canada. The results show that there is a significant difference between the predicted operating speed using the 2-D and 3-D models.

Table 2.2. Operating Speed Prediction Equations for Passenger Vehicles on Two-Lane Highways (Fitzpatrick et al., 2000b).

ACEQ#	Alignment Condition	Equation	R^2
1.	Horizontal Curve on Grade : -9% ≤ G < -4%	V_{85}=102.10 - 3077.13/R	0.58
2.	Horizontal Curve on Grade : -4% ≤ G < 0%	V_{85}=105.98 - 3709.90/R	0.76
3.	Horizontal Curve on Grade : 0% ≤ G < +4%	V_{85}=104.82 - 3574.51/R	0.76
4.	Horizontal Curve on Grade : +9% ≤ G < +4%	V_{85}=96.61 - 2752.19/R	0.53
5.	Horizontal Curve Combined with Sag Vertical Curve	V_{85}=105.32 - 3438.19/R	0.92
6.	Horizontal Curve Combined with Non-Limited Sight Distance Crest Vertical Curve	(see note 3)	N/A
7.	Horizontal Curve Combined with Limited Sight Distance Crest Vertical Curve i.e., K ≤ 43 m/%	V_{85}=103.24 - 3576.51/R (See note 4)	0.74
8.	Sag Vertical Curve on Horizontal Tangent	V_{85}= assumed desired speed	N/A
9.	Vertical Crest Curve with Non Limited Sight Distance (i.e., K > 43 m/%) on Horizontal Tangent	V_{85}= assumed desired speed	N/A
10.	Vertical Crest Curve with Limited Sight Distance (i.e., K ≤ 43 m/%) on Horizontal Tangent	V_{85}=105.08 - 105.08/K	0.60

NOTES:
1. ACEQ# = Alignment Condition Equation Number;
2. Where: V_{85} = 85th percentile speed of passenger cars (km/h); K = rate of vertical curvature; R = radius of curvature (m); G = grade (%);
3. Use lowest speed of the speeds predicted from equations 1 or 2 (for the downgrade) and equations 3 or 4 (for the upgrade);
4. In addition, check the speeds predicted from equations 1 or 2 (for the downgrade) and equations 3 or 4 (for the upgrade) and use the lowest speed.

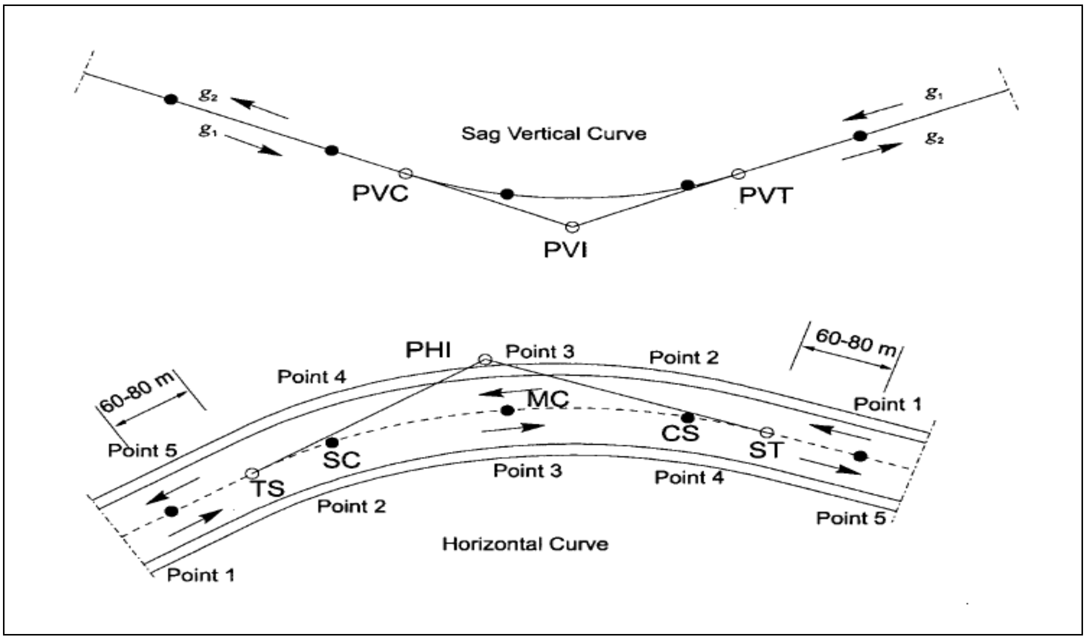

Figure 2.1. Distribution of Observation Points on a Typical 3D Combination (Gibreel et al., 2001).

It is noteworthy that all previous models for predicting operating speed use passenger car to develop the model for predicting operating speed neglecting the effect of other types of vehicles in road.

2.1.1.6 Speed Reduction Prediction Models on Successive Element

Al-Masaeid et al. (1995) studied the effects of horizontal alignments on speeds both along curves and tangents in Jordan. Speed data were collected on 57 simple horizontal curve sections and 36 continuous horizontal curves of four primary two-lane rural roads. The simple horizontal curve was defined as a circular curve proceeded by a straight tangent section with a length of at least 800 m. The curve may or may not be accompanied by a transition section. A continuous curve consists of two successive horizontal curves separated by a short tangent with a maximum length of 300 m. For simple horizontal curves the correlation analysis showed that speed reduction is highly correlated with the degree of horizontal curve, length of vertical curve within horizontal curve, gradient, and pavement conditions. The analysis revealed that lane and shoulder width, superelevation, prevailing terrain, and posted speed had no effect on speed reduction. The degree of the horizontal curve was the most important variable for predicting the speed reduction. Models which have been developed by Al-Masaeid et al. (1995) to predict speed reduction are shown in Table (2.3).

Abdelwahab et al. (1998) developed a new model to predict speed reduction taking degree of curvature and deflection angel as independent variable, shown in Equation 2.1.

$$\Delta V_{85} = 0.9433DC + 0.0847DF; \; R^2 = 0.92 \qquad (2.1)$$

Where:

ΔV_{85} = speed reduction between tangent and of curve (km/h);

DC = degree of curvature (degrees) expressed in degree per 30 m;

DF = deflection angle (degree).

The study size was 46 curves, 35 observations per curve, which were located in Jordan. The authors argued that despite the statistical correlation that may exist between degree of curvature and deflection angle, the inclusion of these two basic variables in a speed reduction model is expected to improve its performance.

Table 2.3. Speed Reduction Models on Horizontal Curve (Al-Masaeid et al., 1995).

Models	R^2
Simple curves	
1. $\Delta V_{85\mathbf{PC}}$ =3.64+1.78DC	0.51
2. $\Delta V_{85\mathbf{LT}}$ =2.0DC	0.69
3. $\Delta V_{85\mathbf{HT}}$ =4.32+1.44DC	0.42
4. $\Delta V_{85\mathbf{ALL}}$ =3.30+1.58DC	0.62
5. $\Delta V_{85\mathbf{ALL}}$ =1.84+1.39DC+4.39Pcon.+0.07G^2	0.77
6. $\Delta V_{85\mathbf{ALL}}$ =1.45+1.55DC+4.0Pcon+0.00004L_{VC}^2	0.76
Compound Curves	
7. $\Delta V_{85\mathbf{PC}}$ = (5708/R_2)-(5689/R_1)	0.72
8. $\Delta V_{85\mathbf{LT}}$ = (4957/R_2)-(4888/R_1)	0.77
9. $\Delta V_{85\mathbf{HT}}$ = (5463/R_2)-(5463/R_1)	0.66
10. $\Delta V_{85\mathbf{ALL}}$ = (5081/R_2)-(5081/R_1)	0.81
Note: ΔV85 = speed reduction between tangent and of curve (km/h); DC = degree of curvature (degrees) expressed in degree per 30 m; Pcon. = pavement condition (PSR ≥ 3, Pcon = 0, otherwise = Pcon=0, PSR: Present Serviceability Rating; G = gradient (average slope between the points of speed measurements on the tangent and the curve center, (%)); LVC = length of vertical curve within the horizontal curve (m); R_1, R_2 = radius of preceding and succeeding curves respectively (m); PC = Passenger car; LT = Light Truck; HT = Heavy Truck; ALL = all type of vehicles.	

Another study was done by McFadden and Elefteriadou (1999) for the purpose of using V_{85} profiles to evaluate design consistency on two-lane, rural highways. Speed data were collected at 21 horizontal curves. The 85th percentile maximum speed reduction (85MSR) was modeled as a function of road geometry.

Studies of Al-Masaeid et al. (1995); Abdelwahab et al. (1998); and McFadden and Elefteriadou (1999) focused on developing models for the speed reduction from a tangent to a curve. However, only one of them, McFadden and Elefteriadou (1999), considered the speed reduction through tracking the speed of individual vehicles along the curve. The other two just subtracted the 85^{th} percentile speed value at the middle of the curve from that of the tangent.

2.1.1.7 Operating Speed Prediction on Tangents

Based on Lamm et al. (1999) independent tangents are those tangents long enough to permit acceleration to and deceleration from the free-flow speed. On the other hand, non-independent tangents are those tangents that are too short to permit acceleration and have speeds similar to their preceding curve. Tangents less than approximately 180 m in length were considered to be non-independent (Lamm et al., 1999). Misaghi and Hassan (2005) suggested that length of non-independent tangents is less than 200 m. For operating speed on approach tangents, average values of the observed 85^{th} percentile speed were recommended as 103.0 km/h for independent tangents and 95.8 km/h for non-independent tangents. On the other hand, Lamm and Choueiri (1987) used a value of 94.7 km/hr and Krammes et al. (1995) used a value of 97.9 km/hr for the 85th speed of the independent tangents. Hassan et al. (2000) recommended the value 102.0 km/h for independent tangent.

Several models were developed to predict the operating speed on independent tangent based on data collected in Jordan (Al-Masaeid et al., 1995). It is found that the operating speed is affected by the length of the independent, the degree of successive horizontal curves, and the deflection angles of the two curves.

The operating speed on independent tangents is more complex and depends on a whole array of roadway character, making it difficult to develop reasonably accurate prediction models. It is significantly influenced by the preceding and succeeding horizontal curves (Joanne, 2002).

Polus et al. (2000) developed models for predicting operating speeds on 162 non-independent and independent tangents. In addition, operating speed models were estimated based on the geometric characteristics of the study sites. Tangents found between horizontal curves have been classified into one of five groups, and the corresponding models are summarized in Table (2.4).

GMS and GML are geometric measures of the tangent and the attached curves, and are formulated as

$$GMS = (R1+R_2)/2 \text{ , for } L_T < t \qquad (2.2)$$

$$GML = LT \times (R_1 \times R_2)^{0.5} / 100, \text{ for } L_T \geq t \qquad (2.3)$$

Where:

R_1, R_2 = radii of preceding and succeeding curves respectively (m),

L_T = length of tangent (m), and

t = selected threshold for length of tangent (m).

The combination of all these variables would make the prediction of V_{85} on tangents a relatively complex task. In addition, the analyses showed that, when determining V_{85} at the middle of a tangent section, it is necessary to observe a longer section that includes the preceding and succeeding curves because these constitute the primary variables affecting speed.

Table 2.4. Operating Speed Prediction Models on Tangents (Polus et al., 2000).

Conditions	Model	R^2
Group I: Small radii (R_1 and R_2 < 250 m) and small TL (TL = 150 m).	V_{85}=101.11-3420/GMS	0.55
Group II: Small radii (R_1 and R_2 < 250 m) and intermediate TL (TL = 150 to 1,000 m).If maximum 85th percentile speed is established as 105 km/h	V_{85}=98.405-3184/GML V_{85}=105.0-28.107/$e^{(0.00108GML)}$	0.68 0.74
Group II: Intermediate radii (R_1 and R_2 > 250 m) and intermediate TL (TL = 150 to 1,000 m).	V_{85}=97.73+0.00067GM	0.20
Group IV: Large TL (TL > 1,000 m) and any reasonable radii.	V_{85}=105.0-22.253/$e^{(0.000128GML)}$	0.84
Note: V_{85} = 85th percentile operating speed on tangent (km/h); R_1 , R_2 = radius of preceding and succeeding curves respectively (m); TL = tangent length.		

2.1.1.8 Operating Speed Profile

A speed profile is a plot of operating speeds versus distance along the alignment of a roadway. Design consistencies are identified in light of the differentials in operating speed between successive alignment features (Fitzpatrick et al., 2000c).

The speed profile model applies the operating speed on curves and tangents, and the acceleration and deceleration rates in combination with the basic equations of motion to estimate the operating speed at each point along the horizontal alignment (Krammes et al., 1995). Fitzpatrick et al. (2000c) developed models for calculating acceleration and deceleration rates based on curve radius, which were shown in Table (2.5).

Table 2.5. Deceleration and Acceleration Rates at Different Curve Radius (Fitzpatrick et al., 2000c).

Radius of Curvature (m)	**Deceleration Rate (m/s^2)**
R < 175 m	–1.0
175 m < R < 436 m	0.6794 - 295.14/R; **R^2 = 0.4778**
436 m < R	0.0
Radius of Curvature (m)	**Acceleration Rate (m/s^2)**
175 m < R < 250 m	0.54
250 m < R < 436 m	0.43
436 m < R < 875 m	0.21
875 m < R	0.0

2.1.2 Vehicle Stability

In the field of geometric design, the most important characteristic of the road surface is its skid resistance. Superelevation is a geometric feature used to reduce side friction demand by counterbalancing a portion of the centripetal acceleration encountered by drivers. Excessive centrifugal forces acting on vehicles traveling on a curve may lead to skidding, vehicle rollover, and head on crashes. Thus, for the highway design to be consistent and ensure a level of vehicle stability and driver comfort, it should supply the side friction demanded to balance centrifugal forces. McLean (1976) stated that side friction is fundamental to curve design, but that the "design values must be based on a realistic assessment of driver behavior and comfort tolerance of modern drivers".

The design consistency evaluation can be done based on a margin of safety of the difference between side friction supply and side friction demand on a curve (Δf_R). If friction demand exceeds supply, this may prohibit safe vehicle operation and would imply inconsistency and vehicle instability. Locations that do not provide vehicle stability can be considered geometric design inconsistencies (Gibreel et al, 1999).

2.1.2.1 Geometric Design Consistency Evaluation Criteria Based on Vehicle Stability

Lamm et al. (1999) presented a design consistency criterion, which includes the difference between side friction supplied (f_S, that depends on the design speed) and demanded (f_D, that depends on the operating speed), denoted as (Δf_R), was used to represent vehicle stability. Criterion suggested by Lamm et al. (1999) for consistency evaluation was based on vehicle stability shown hereafter:

1. Good design: $\Delta f_R \geq +0.01$ (no improvement is required),

2. Fair design: +0.01 $>$ Δf_R $\geq$ -0.04 (the superelevation must be related to the operating speed to ensure that the side friction assumed will accommodate the side friction demanded),

3. Poor design: $\Delta f_R <$ -0.04 (strong inconsistency; redesign recommended).

Note: Δf_r = difference between side friction supplied and demand

2.1.2.2 Vehicle Stability Prediction Models on Curves

A different approach for measuring side friction factors was adopted in worldwide. Several models have been developed to predict side friction supplied and side friction demanded separately.

Side Friction Supplied

Available friction, which is the friction provided by the pavement depends on the vehicle speed. It has been theoretically established in the model developed by Pennsylvania State University (Kulakowski, 1991), and it has also been empirically verified through many experiments, Wambold and Henry (1995). Such studies showed that skid resistance diminishes as speed augments, at a nonlinear rate defined by the macro texture of the pavement. Likewise, it has been verified by Lamm et al. (1999) that show the decreasing tendency of friction as speed increases. They proposed relationship for finding relevant side friction factors in highway curve design. Side friction is directly related to the tangential friction factor as shown in Equation (2.4) below.

$f_{TP} = 0.59 - 4.85 \times 10^{-3} \times V_D + 1.51 \times 10^{-5} \times V_D^2$ (2.4)

Where:

f_{TP} = maximum permissible tangential friction factor, and

V_D = design speed (km/h).

After the establishment of the relationship between the maximum permissible tangential friction factor and the design speed, the range from which the utilization ratio "n" of the maximum permissible side friction factor shall be selected. Based on international experiences, this value varies between n = 40% and n = 50% for rural roads. That means that there will be still 90% and 87%, respectively of friction available in the tangential direction for acceleration, deceleration, braking, or evasive maneuvers when driving through curves (Lamm, 1984). Thus, the equation for the maximum permissible side friction factor is:

$f_{RPerm.} = n \times 0.925 \times f_{TP}$ (2.5)

Where:

$f_{RPerm.}$ = maximum permissible side friction factor,

n = utilization ratio, and

0.925 = reduction factor corresponds to tire-specific influences.

Based on Lamm et al. (1994) specific topographic conditions (flat, hilly and mountainous topography) different utilization ratios were considered as reasonable for side friction factors. The recommended equations (2.6) and (2.7) for maximum permissible side friction factors ($f_{RPerm.}$) with respect to topography are given:

- Flat Topography (n = 45 %)

$$f_{RPerm.} = 0.25 - 2.04 \times 10^{-3} \times V_D + 0.63 \times 10^{-5} \times V_D^2 \quad (2.6)$$

- Hilly and Mountainous Topography (n = 40 %)

$$f_{RPerm.} = 0.22 - 1.79 \times 10^{-5} \times V_D + 0.56 \times 10^{-5} \times V_D^2 \quad (2.7)$$

Where:

$f_{RPerm.}$ = maximum permissible side friction factor.

Side Friction Demanded

Side friction demand is based on operating speed of drivers. It is calculated using the point mass formula by simply inserting the operating speed in place of the design speed. When a vehicle moves in a circular path, it is forced radially outward by centrifugal force. To counterbalance the force and stay moving in the circular path, the friction force that is developed by vehicle weight and friction factor between tires and pavement must be greater than the centrifugal force. In the design of highway curves, there exists the relation between design speed and curvature and also the joint relations with superelevation and side friction (AASHTO, 2011). This relationship is expressed as follows (AASHTO, 2011).

$f_r + e = V_{85}^2 / 127\ R$ (2.8)

Where:

f_r = coefficient of side friction,

e = superelevation rate (m/ m),

V_{85} = operating speed (km/h), and

R = radius of horizontal curve (m).

Lamm et al. (1991) observed vehicle speeds on curves and used equation (2.8) to calculate the amount of friction demanded. Bonneson (2001) developed a side friction prediction model based on the hypothesis that drivers will modify their side friction demand to achieve a combination of safe and efficient travel. Bonneson's model was mainly based on the approach speed and operating speed reduction of a curve. The form of the model is as follows:

$f_D = 0.256 - 0.0022\ V_a + B \times (V_a - V_c),\ R^2 = 0.88$ (2.9)

$V_c = 63.5 \times (-B\ (B^2 + 4c/(127R)^{0.5}) \leq V_a$ (2.10)

With

$c = e/100 + 0.256 + (B - 0.0022) \times V_a$ (2.11)

$B = 0.0133 - 0.00741 \times I_{TR}$ (2.12)

Where:

f_D = side friction demanded,

V_a = 85th percentile approach speed (km/h),

V_c = 85th percentile curve speed (km/h),

e = super elevation rate (percent), and

I_{TR} = indicator variable (=1.0 for turning roadways; 0.0 otherwise).

2.1.3 Alignment Indices

Alignment indices are quantitative measures of the general character of a highway segment's alignment (Anderson et al, 1999). They are not subject to any evaluation criteria; however, it is noted that geometric inconsistencies will occur when the general character of an alignment changes significantly (Hassan et al, 2001, and Fitzpatrick et al, 2000a).

2.1.3.1 Identification of Alignment Indices

Determining the alignment indices consisted of identifying all possible indices that may be useful for this study. Therefore, some of the alignment indices that had been used in other countries or proposed for use were included. All of these alignment indices could possibly provide an indication of the geometry motorists experience on the roadway.

2.1.3.2 Proposed Alignment Indices

A number of potential alignment indices have been studied, some of which are not recommended by researchers. The alignment indices recommended as potential measures of design consistency on a road section were:

1. Average radius of curvature (AVG R);
2. Maximum radius of curvature to minimum radius of curvature ($\frac{\mathbf{MR}}{\mathbf{mR}}$);
3. Average tangent length (AVG T);
4. Curvature change rate (CCR); and
5. Ratio of individual curve radius to average radius (CRR).

Fitzpatrick et al. (2000a) recommended that the first four alignment indices are to be investigated as possible measures of rating the design consistency of rural two-lane highways. Based on crash analysis, Anderson et al. (1999) suggested that the ratio of the curve radius to average radius has a significant relationship to safety.

Average Radius of Curvature

The average radius (AVG R) expresses the sharpness of curves representative of a given section of the roadway and what motorists typically encounter on curved sections of the road. Deacon (1986) argued sharper curves are associated with higher accident rates than milder curves. AVG R determined by dividing the sum of curve radii on a highway section by the number of curves on that section as shown in Equation (2.13).

AVG R (m) = ($\sum_{i=1}^{n}$ R_i) / n (2.13)

Where:

R_i = radius of curve (m), and

n = number of curves within section.

Ratio of Maximum Radius to Minimum Radius

The range of the radii along a roadway can be determined by computing the ratio of the maximum to minimum radius ($\frac{\mathbf{MR}}{\mathbf{mR}}$). This ratio can represent "the consistency of the design in terms of the use of similar horizontal radii along the road. As this value approaches one, a reduced accident rate may be expected" (Polus, 1980). Anderson et al. (1999) stated that the ratio of the maximum radius to the minimum radius is not recommended as a design consistency measure due to its relatively low sensitivity to crash frequency compared to other alignment indices studied. Fitzpatrick et al. (2000a) recommended that a better using the average radius as an alignment index rather than the maximum radius to minimum radius. Maximum radius to minimum radius is calculated as follows in Equation (2.14).

$\frac{\mathbf{MR}}{\mathbf{mR}}$ = R_{max} / R_{min}

(2.14) Where: R_{max} = the maximum radius of a highway section, and

R_{min} = the minimum radius of a highway section.

Average Tangent Length

If a tangent is long enough, then motorists will drive at their desired speed, which is defined as "the speed at which drivers choose to travel under free-flow conditions when they are not constrained by alignment features" (McLean, 1981). Therefore, if motorists are driving at a high speed on the tangent and a large reduction in speed is required at the following curve, they may not be able to decrease their speed as needed (Fitzpatrick et al, 2000a). The average tangent length (AVG T) indicates the length of tangent that is typically available to motorists between curved sections of the roadway. Average tangent is calculated as follows in Equation (2.15).

$$AVG\ T\ (m) = \left(\sum_{i=1}^{n} T_i\right) / n \qquad (2.15)$$

Where:

T_i = tangent length (m), and

n = number of tangents within section.

Curvature Change Rate

Curvature change rate (CCR) expresses the absolute sum of the angular changes in the horizontal alignment divided by the length of the highway section (Fitzpatrick et al, 2000a). This parameter assumed to be more representative of the general character of the alignment of the roadway, a large value for this index indicates that the road either contains a large number of curves or there are long or sharp curves in that section. It was expected that an increase in the value of these indices would decrease the desired speeds of motorists (Fitzpatrick et al, 2000b). Curvature change rate is calculated as follows in Equation (2.16).

$$\text{CCR (deg./km)} = \left(\sum_{i=1}^{n} \Delta_i\right) / L_i \tag{2.16}$$

Where: Δ_i = deflection angle (deg), and

L_i = length of section (km).

Chen et al. (2011) found that the CRR is a more appropriate value to describe the geometric properties of several elements. In general, a higher CRR is associated with higher accident rate.

Curve Radius to Average Radius

The CRR characterizes the relationship between each individual horizontal curve radius to the average radius of the roadway section as a whole. Anderson et al. (1999) found that highway safety is sensitive to CRR and suggested using this ratio as a consistency measure. When the radius of a horizontal curve deviates greatly from the average radius along the roadway section, that curve may violate driver expectancy, creating inconsistency. The ratio CRR for specific curve can be calculated as in Equation (2.17).

$$CRR_i = R_i / AVG\ R \qquad (2.17)$$

Where:

R_i = radius of the i^{th} curve on the roadway section (m), and

AVG R = Average Radius (m).

The ratio CRR as the value approaches 1.0, a reduced crash frequency is expected. A curve with a CRR value of 0.5 will be considered by many to have a relatively higher potential for crashes.

2.1.4 Driver Workload

Messer (1980) defined driver workload as “the time rate at which drivers must perform a given amount of work or driving tasks”. He indicated that driver workload increases with reductions in sight distance and increasing complexity of geometric features, as the complexity of highway geometric features increases, the time rate required to perform a given driving task is expected to increase also, consequently reflecting higher driver workload.

Mental workload can be generally defined as the expenditure of mental capacity required when performing a task or a combination of tasks. How the driving task is performed is influenced by driver mental characteristics including expectancy, attention level, and mental workload capacity (Heger, 1998). Consistent roadway geometry allows a driver to accurately predict the correct path while using little visual information processing capacity, thus allowing attention or capacity to be dedicated to obstacle avoidance and navigation (Fitzpatrick et al., 2000d).

It was found that locations with high driver workload values tended to experience higher crash frequency due to driver confusion or overload resulting in dangerous reactions to roadway situations. On the other hand, highway sections with extremely low driver workloads may cause driver boredom and less concentration on the road (Wooldridge, 1994). Thus, geometric features resulting in extremely high or low driver workloads should be avoided to improve road consistency.

There is a strong relationship between crashes, roadway-based geometric inconsistency, and driver workload (Messer, 1980); drivers who fail to identify the disparity between their expectation and the actual workload level may make speed or path errors, consequently increasing their crash risk (Krammes et al., 1995).

Driver workload is not easily measurable by analytical models; however, several methods have been developed to quantify the effects of design consistency on driver workload. In general, workload measurement techniques fit into five broad categories: primary task measurement, secondary task measurement, subjective rating, physiological measure, and visual occlusion.

2.1.4.1 Primary Task Measurement

In a primary task measurement the operator performs a task, and some aspect of the task is varied to increase task loading (e.g., for steering a car, the mean and variance of a cross wind is increased).

2.1.4.2 Secondary Task Measurement

In a secondary task measurement, the operator performs two tasks: the primary task, the operational task of interest (steering, for a car), and a secondary task which is imposed to occupy the part of the operator's "capacity" not required by the primary task

2.1.4.3 Subjective Rating

A subjective rating scale has been developed by Messer (1980) to estimate the average workload and the level of consistency of nine basic geometric roadway features: bridges, divided highway transitions, lane drops, intersections, railroad grade crossings, shoulder width changes, alignment, lane width reductions, and the presence of cross road overpasses.

2.1.4.4 Physiological Measure

Several noninvasive physiological measurements are thought to measure aspects of operator state that correlate with the ability to perform tasks. Wierwille and Eggemeier (1993) identify the most widely used measurements to be heart rate (HR), heart rate variability (HRV), brain activity, and eye activity.

2.1.4.5 Visual Occlusion

Vision occlusion was used to determine the effective workload on the driver under the assumption that the driver only needs to observe the roadway part of the time, this method blanks out the driver's vision of the roadway using a visor or other similar device. By measuring the amount of time the driver is viewing the roadway, a measure of the information load of the driver is obtained. This measure of workload, termed visual demand (V_D), has been found to increase as the difficulty of driving increases. Thus, Vision occlusion is a technique that measures driver visual demand on a roadway.

Visual demand was defined as the amount of visual information needed by the driver to maintain an acceptable path on the roadway (Wooldridge et. al, 2000). Visual demand reflects the percentage of time that a driver is observing the roadway and is measured using a vision occlusion procedure. During the procedure, drivers wore an LCD visor that was opaque except when the driver requested a 0.5-second glimpse through the use of a floor-mounted switch. Visual demand was measured as the ratio of the glimpse length divided by the time elapsed from the last glimpse until the time of the present request (Fitzpatrick et al., 2000a).

Fitzpatrick et al., (2000a) recommended simulator results, which can provide reasonable estimates of real world estimates of workload and should be considered for use in future studies of visual demand. Simulator study size was 24 drivers, 6 repetitions per curve per driver. The authors developed two different regression models for visual demand based on Simulator study. One model represents drivers familiar with the road (VD_{LF}), while the other represents drivers unfamiliar with the road (VD_{LU}):

$$VD_{LF} = 0.388 + 34.7 \times {}^{1}/_{R} \quad (2.18)$$

$$VD_{LU} = 0.367 + 36.5 \times {}^{1}/_{R} \quad (2.19)$$

Where:

VD_{LF} = visual demand of familiar drivers,

VD_{LU} = visual demand of unfamiliar drivers, and

R = radius of curvature (m).

Visual demand increases linearly with the inverse of radius. That is, as radius becomes smaller, visual demand increases. Wooldridge et al. (2000) recommended the use of visual demand as a measure of consistency.

2.2 Relationships of Consistency Measures to Safety

Geometric design consistency is emerging as an important component in highway design (Glennon et al. 1978). Some researchers have explicitly noted that treating any inconsistency in a highway alignment can significantly improve its safety performance (Joanne and Sayed, 2004). A criterion has been suggested by Lamm et al. (1987) to evaluate design consistency based on crash rates, the crash rates should correspond to certain ranges:

1. Good design: Cr.Rate $\leq$ 2.27,

2. Fair design: 2.27 $<$ Cr.Rate $\leq$ 5.00,

3. Poor design: Cr.Rate $>$ 5.00.

Note: Cr.Rate = mean crash rate (crash / 10^6 veh-km).

Joanne and Sayed (2004) investigated the effects of several design consistency measures on safety. The design consistency measures mentioned were difference between the 85th percentile operating speed and design speed (V_{85} - V_D), speed reduction (ΔV_{85}), difference between side friction supplied and side friction demanded on a curve (Δf_R), the ratio of the curve radius to average radius (CRR) and visual demand (VD).

Anderson et al. (1999) investigated the relationship between design consistency and safety using log linear regression models. Two models were developed relating accident frequency to traffic volume, curve length, and speed reduction (ΔV_{85}). A separate model was developed relating accident frequency to curve length and the ratio of the curve radius to average radius (CRR). He suggested that CRR has a significant relationship to safety.

Polus (1980) investigated the relationship between longitudinal geometric measures (such as the average radius, or the ratio between the minimum and maximum radius of an alignment) and safety levels on two-lane rural highways and proposed that safety correlated with consistency.

Easa (2003) presented a method to distribute superelevation to maximize highway-design consistency based on safety margins defined as the difference between the maximum-limit safe speed and the design speed.

Analyses of crashes on the two-lane rural highways have shown that a significant relationship exists between crash frequency and alignment indices, which are quantitative measures of the general character of an alignment in a section of road. Alignment indices include average radius (AR), ratio of maximum to minimum radius ($\frac{\mathbf{MR}}{\mathbf{mR}}$), average rate of vertical curvature (AVC) and the CRR (Hassan, 2004).

Cafiso et al. (2007) presented a methodological approach for the safety evaluation of two-lane rural highway segments that uses both analytical procedures referring to alignment design consistency models and safety inspection processes. They developed a safety index (SI) that quantitatively measures the relative safety performance of a road segment. The SI is formulated by combining three components of risk: the exposure of road users to road hazards, the probability of a vehicle being involved in an accident, and the resulting consequences should an accident occur.

2.3 Previously Developed Crash Prediction Models

Vogt and Bared (1998) developed a model for predicting the safety performance of road sections on two-lane rural highways. The model is shown below in US customary units:

N_{br} = EXPO x exp(0.6409 + 0.1388STATE - 0.0846LW - 0.0591SW + 0.0668RHR + 0.0084DD) x ($\sum WH_i$ x exp(0.0450DEG_i)) x ($\sum WV_j$ x exp (0.4652V_i)) x ($\sum WG_i$ x exp(0.1048GR_i) (2.20)

Where:

N_{br} = predicted number of total accidents per year on a particular roadway segment.

EXPO = exposure in million vehicle-miles of travel per year = (ADT)(365)(L)(10^{-6}),

ADT = average daily traffic volume (veh/day) on roadway segment,

L = length of roadway segment (mi),

STATE = location of roadway segment (0 in Minnesota, 1 in Washington),

LW = lane width (ft); average lane width if the two directions of travel differ,

SW = shoulder width (ft); average shoulder width if the two directions of travel differ,

RHR = roadside hazard rating; this measure takes integer values from 1 to 7 and represents the average level of hazard in the roadside environment along the roadway segment,

DD = driveway density (driveways per mi) on the roadway segment,

WHi = weight factor for the ith horizontal curve in the roadway segment; the proportion of the total roadway segment length represented by the portion of the ith horizontal curve that lies within the segment. (The weights, WHi, must sum to 1.0.),

DEGi = degree of curvature for the ith horizontal curve in the roadway segment (degrees per 100 ft),

WVj = weight factor for the jth crest vertical curve in the roadway segment; the proportion of the total roadway segment length represented by the portion of the jth crest vertical curve that lies within the segment. (The weights, WVj, must sum to 1.0.),

Vj = crest vertical curve grade rate for the jth crest vertical curve within the roadway segment in percent change in grade per 31 m (100 ft) = |gj2 - gj1| / lj,

gjl, gj2 = roadway grades at the beginning and end of the jth vertical curve (percent),

lj = length of the jth vertical curve (in hundreds of feet),

WGk = weight factor for the kth straight grade segment; the proportion of the total roadway segment length represented by the portion of the kth straight grade segment that lies within the segment. (The weights, WGk, must sum to 1.0.); and

GRk = absolute value of grade for the kth straight grade on the segment (percent).

This model was developed with negative binomial regression analysis for data from 619 rural two-lane highway segments in Minnesota and 712 roadway segments in Washington. These roadway segments including approximately 1,130 km of two-lane roadways in Minnesota and 850 km of roadways in Washington.

Joanne and Sayed (2004) conducted a study to quantify the safety benefits of each of the consistency measures presented in this study based on 319 horizontal curves and 511 tangents located in the province of British Colombia, Canada. The models are as follows:

$$Cr./5yrs = \exp(-3.369) \times L^{0.8858} \times V^{0.5841} \times \exp[\,0.0049 \times (V_{85} - V_D) + 0.0253\Delta V_{85} - 1.177\Delta f_R \quad (2.21)$$

$$Cr./5yrs = \exp(-2.338) \times L^{1.092} \times V^{0.4629} \times \exp[\,IC \times (0.022 \times \Delta V_{85} - 1.189\Delta f_R)] \quad (2.22)$$

Where:

Cr./5yrs = predicted crash frequency per 5 years,

L = length of section (km),

V = average annual daily traffic (veh/day),

V_{85} - V_D = difference between the 85th percentile operating speed and design speed,

ΔV_{85} = speed reduction between tangent and curve (km/h),

Δf_R = difference between side friction supplied and side friction demanded on a curve, and

IC = dummy variable (IC = 0 for tangents or IC = 1 for horizontal curves).

Equation (2.22) was developed based on horizontal curves data only while Equation (2.23) was developed based on both horizontal curves and tangents. Both models were statistically significant at the 10% significance level.

The followings model is a sample that shows the relationship between consistency measures and crash rate (Hassan et al, 2001):

$$CR = 5.078 \times 10^{-9} \exp(\Delta V85) - 8.386 \exp(\Delta f_R) + 8.024 \exp(VD_{LU})$$

$$(R^2 = 0.954) \qquad (2.23)$$

Where:

CR = crash / million vehicle-km,

ΔV_{85} = differences between V_{85} on consecutive highway elements,

Δf_R = difference between side friction assumed and demanded,

VD_{LU} = visual demand of unfamiliar drivers,

R^2 = coefficient of multiple correlation.

The authors concluded that the model could be used as a basis for selecting the proper alignment out of alternatives for two-lane rural highways.

2.4 Summary

Several measures of geometric design consistency have been identified in the literature and can be classified into four main categories: operating speed, vehicle stability, alignment indices, and driver workload. Models, which can be used to estimate these measures and design consistency evaluation criteria, have been presented.

This chapter provides a review of potential measures of geometric design consistency and its relationship to road safety. It also provides a review of some models used for predicting consistency measures and corresponding evaluation criteria beside previously developed crash prediction models.

Finally, the objectives of this study include investigating and quantifying the relationship between design consistency and road safety, as well as estimating the safety benefits of implementing a consistent design. Specifically, the relationships between various measures of design consistency and road safety in terms of expected crash occurrence are to be studied.

Chapter Three

Research Methodology

The methodology used in this research is based on the development of Crash Prediction Models (CPM) incorporating design consistency measures.

3.1 Literature Review

Literature review provides a review for potential measures of geometric design consistency and their relationships to road safety. It also provides a review of some models used for predicting consistency measures and corresponding evaluation criteria.

3.2 Data Collection

Data collection provides a detailed description of the database developed in this study for model development. Population of selected highways is introduced, in addition to the sources from which data were obtained and an outline of the main data variables collected. Subsequently, the collection of the horizontal alignment, traffic volume, crash data, design speed, and operating speed are introduced.

3.3 Modeling Methodology

The methodology used in this study is based on the development of Crash Prediction Models (CPM) incorporating design consistency measures. The generalized linear regression modeling (GLM) approach is adopted for model development.

3.3.1 Selection of Analysis Sites

Because the available database was limited, a careful review was required to select sections that were suitable for analysis. A minimum section length of 4 miles and a maximum section length of 20 miles were established for this analysis. These minimum and maximum section lengths were primarily intended to make the database appropriate for the analysis of roadway alignment indices. Fitzpatrick et al., 2000b concluded that sections shorter than 6.4 km (4 miles) might not provide enough individual geometric features to compute a representative value of the alignment indices. Furthermore, sections longer than 32 km (20 miles) might be so varied that no single value of an alignment index would be representative of the section as a whole. Therefore, these constraints were adopted in this study.

Based on reviewing the data for each route and eliminating portions of the roadway with features that might interfere and affect the accuracy of the analysis, the following constraints were imposed for the selection of highway segments:

- Rural area: all locations near town or built up area were eliminated (not rural; out of scope).

- All locations within 50 m of an intersection were eliminated (intersection area).
- Marked and paved roadways with constant lane width were chosen (uniform section).
- No recent roadway improvements (no change in geometry).
- All locations within 100m of an Israeli Military checkpoint were eliminated (disturbance of normal traffic flow).
- Horizontal curves with radius ≤ 100 m were eliminated and those with curve radius ≥ 1000 m length were treated as tangents (based on recommendations of previous research; Awatta, 2003).

These criteria generally attempt to eliminate features that may inhibit an accurate analysis, and are mostly based on an understanding of the impact of different roadway features on safety (Awatta, 2003). For example, although crashes may occur at curves with radius less than 100 m, but these were not considered as they might be directly related to the geometric feature of that curve (sharp curve) and not necessarily the design consistency aspect of it. Segments were also subdivided at intersections with major changes in average daily traffic (ADT). The remaining segments that were less than 6.4 km (4 miles) in length were then discarded and roadway segments more than 32 km (20 miles) in length were subdivided.

3.3.2 Horizontal Alignment

The horizontal alignment data were extracted from drawing the centerline of the road segments using aerial photograph (year 2012) for the West Bank. The data obtained from drawing includes: the stations at the beginning of the curve (PC); the end of the curve (PT); the radius of curvature; and the length of curve; in addition to the approach and departure tangent lengths associated with each curve. Highway numbers and classification information were obtained from the Israeli Central Bureau of Statistics (ICBS) because most of the rural-highways roads are located in area (C), which is out of control the Palestinian National Authority. Therefore, limited data is available for those highways from Palestinian sources. Traffic volumes (ADT) were obtained from in situ traffic counts, traffic counted by students work at An-Najah National University, and the ICBS.

3.3.3 Statistical Analysis

Statistical analysis used in model development is based on the development of crash prediction models incorporating design consistency measures. Crash prediction model (CPM) is an appropriate approach to evaluate the safety performance of a location. The generalized linear regression modeling (GLM) approach is adopted for model development. The GLM has the advantage of overcoming the limitations associated with the use of conventional linear regression in modeling crash occurrence, which is random, discrete, and non-negative in nature. Furthermore, GLM has the flexibility of assuming different error distributions and link functions that allow the conversion of nonlinear models into linear models.

For the GLM approach, the error structure that best fits the crash occurrence is usually assumed to be Poisson or Negative Binomial. It is important to understand that neither the Poisson nor Negative Binomial approach is always best. The selection of either regression technique should always be based on an analysis of the data under study.

3.3.4 Estimating Consistency Measures

Relationships between road safety and each of the four categories of geometric design consistency measures: operating speed, vehicle stability, alignment indices, and driver workload are studied. The measures selected to represent each category and the corresponding methods used will be estimated as described below.

3.3.4.1 Operating Speed

The difference between operating speed and design speed (V_{85} - V_D) and the speed reduction between two successive elements (ΔV_{85}) are used. The operating speed on curves and tangents (V_{85}) was estimated using Google Earth maps, real time traffic data were obtained from the maps, a spot speed measurements for tangents and curves are usually collected, as explained in section (4.6).

The traffic data on Google Maps comes from users of Google Maps for mobile phone who contribute anonymous speed information through traffic crowd sourcing feature regardless of who they are; Palestinians or others. A minimum of thirty spot speed measurements for tangents and curves were collected. Speed data were useful for studying the actual operating speed with regard to acceleration/declaration behavior.

The design speed for the studied highways was calculated depending on the speed limit, which has been explained in section (4.6).

The 85^{th} percentile of the speed reductions from tangent to curve or from two successive curves (ΔV_{85}) were calculated depending on Abdelwahab et al. (1998) model to predict speed reduction shown in Equation (2.1).

3.3.4.2 Vehicle Stability

The difference between side friction supplied (f_S, that depends on the design speed) and demanded (f_D, that depends on the operating speed), denoted as (Δf_R), was used to represent vehicle stability. If friction demand exceeds supply, this may prohibit safe vehicle operation and would imply inconsistency and vehicle instability. Thus, vehicle stability on horizontal curves is paramount in ensuring road safety.

Side friction supplied is based on operating speed of highway sections. Lamm et al. (1999) proposed relationship for finding relevant side friction demand factors in highway curve design, based on Lamm et al. (1994) specific topographic conditions (flat, hilly and mountainous topography) different utilization ratios were considered as reasonable for side friction factors. The recommended Equations (2.6) and (2.7) for maximum permissible side friction factors ($f_{RPerm.}$) with respect to topography are given as explained in section (2.1.2.2).

Bonneson (2001) developed a side friction prediction model based on the hypothesis that drivers will modify their side friction demand to achieve a combination of safe and efficient travel. Bonneson's model was mainly based on the approach speed and operating speed reduction of a curve. Used with the allowed speed reduction, this model can provide the maximum allowable side friction for the design of critical design control elements. The model form is shown in Equations (2.9, 10, 11, and 12), as explained in section (2.1.2).

3.3.4.3 Alignment Indices

Alignment indices are quantitative measures of the general character of a highway segment's alignment (Anderson et al, 1999). The alignment indices recommended as potential measures of design consistency on a road section were:

1. Average radius of curvature (AVG R);
2. Maximum radius of curvature to minimum radius of curvature (MR/mR);
3. Average tangent length (AVG T);
4. Curvature change rate (CCR); and
5. Ratio of individual curve radius to average radius (CRR).

AVG R calculated based on equation (2.13), MR/mR is calculated based on equation (2.14), AVG T is calculated based on equation (2.15), CCR is calculated based on equation (2.16), and CRR is calculated based on equation (2.17). Alignment indices have been explained in section (2.1.3).

3.3.4.4 Driver Workload

The models, which estimate visual demand of drivers unfamiliar VD_{LU} (Equation 2.19) and of drivers familiar VD_{LF} (Equation 2.18) with the road developed by Fitzpatrick et al., (2000a) were adopted. To overcome the selection between the familiar and unfamiliar visual demand models, only one of the visual demand models was included in this analysis. The model predicting visual demand of familiar drivers will be developed because most of drivers drive regularly or know well the roads.

3.4 Modeling Validation

To evaluate the accuracy of the West Bank crash prediction models (CPM) developed, a validation step was performed. The goal of this validation step is not only to compare the accuracy of different models developed, but also to evaluate the overall accuracy of CPMs for use on rural two-lane highways in the West Bank.

3.5 Modeling Application

A qualitative comparison has also been made to compare collision prediction models, which explicitly consider design consistency with those that rely on geometric design characteristics for predicting collision occurrence. A systematic approach to identify geometrically inconsistent locations using the safety consistency factor has been proposed.

3.6 Conclusions and Recommendations

The main conclusions are presented and future recommendations are given at the end of this research.

Chapter Four

Data Collection

This chapter provides a detailed description of the database developed in this study for model development and validation. In section 4.1, the sample of selected highways is introduced, in addition to the sources from which data were obtained and an outline of the main data variables collected. Subsequently, sections 4.2 to 4.6 discuss the collection of the horizontal alignment, traffic volume, crash data, design speed, and operating speed.

4.1 Overview of Data Collected

Four two-lane rural highway segments located in the West-Bank were chosen for analysis. The selection of these highways was mainly based on limitations in data availability. However, it was ensured that the selected highways encompass a variety of highway classifications, locations, terrain, design speed, traffic volume, and crash history, hoping that this sample would cover most of the two-lane rural highway conditions found in West Bank. Figure (4.1) shows highway locations chosen for analysis in the West Bank. Horizontal alignment, traffic volume, crashes, design speed, and operating speed for two-lane rural highway located in West Bank, Palestine, are used. Summary of selected highways is shown in Table (4.1).

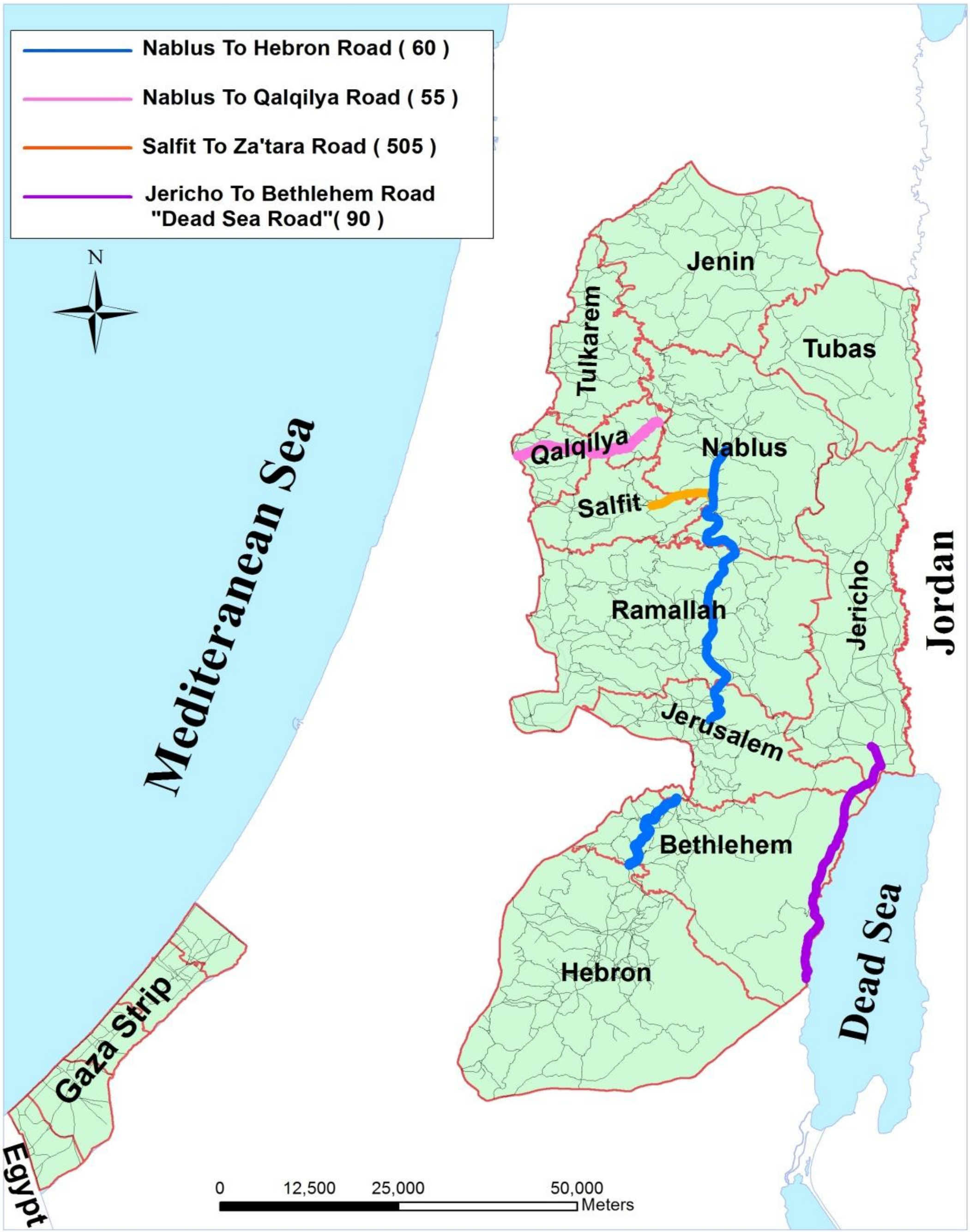

Figure 4.1. Location of the Study Highway Segments in the West Bank

Table 4.1. Summary of Selected Highway Segments.

Highway Number	Highway Classification	Highway Location	Segment Length (km)
55	Main Highway / Two-Lanes	Nablus to Qalqilya	22.8
60	Main Highway / Two-Lanes	Nablus to Hebron	45.9
505	Regional Highway / Two-Lanes	Salfit to Za'tara	9.4
90	Main Highway / Two- Lanes	Jericho to Bethlehem "Dead Sea Road"	39.5
Total Length			117.6

It should be mentioned that data related to Salfit to Za’tara Road (Highway No. 505) and Highway No. 60 from Bethlehem to Hebron were set aside for validation purposes once the model is developed.

4.2 Horizontal Alignment

The horizontal alignment data were extracted from drawing the centerline of the road segments using aerial photograph (year 2012) for the West Bank. The two-lane rural highways chosen for analysis are summarized below:

Highway 60 (Nablus - Hebron)

Connects Nablus to Hebron through Jerusalem and Ramallah; length of 45.9 km with rolling and mountainous terrain. The summary of statistics for the main geometric variables is illustrated in Table (4.2). Figure (4.2) shows ortho-drawing for this highway with crash locations, the number of crashes for 10 consecutive years (2003 – 2012).

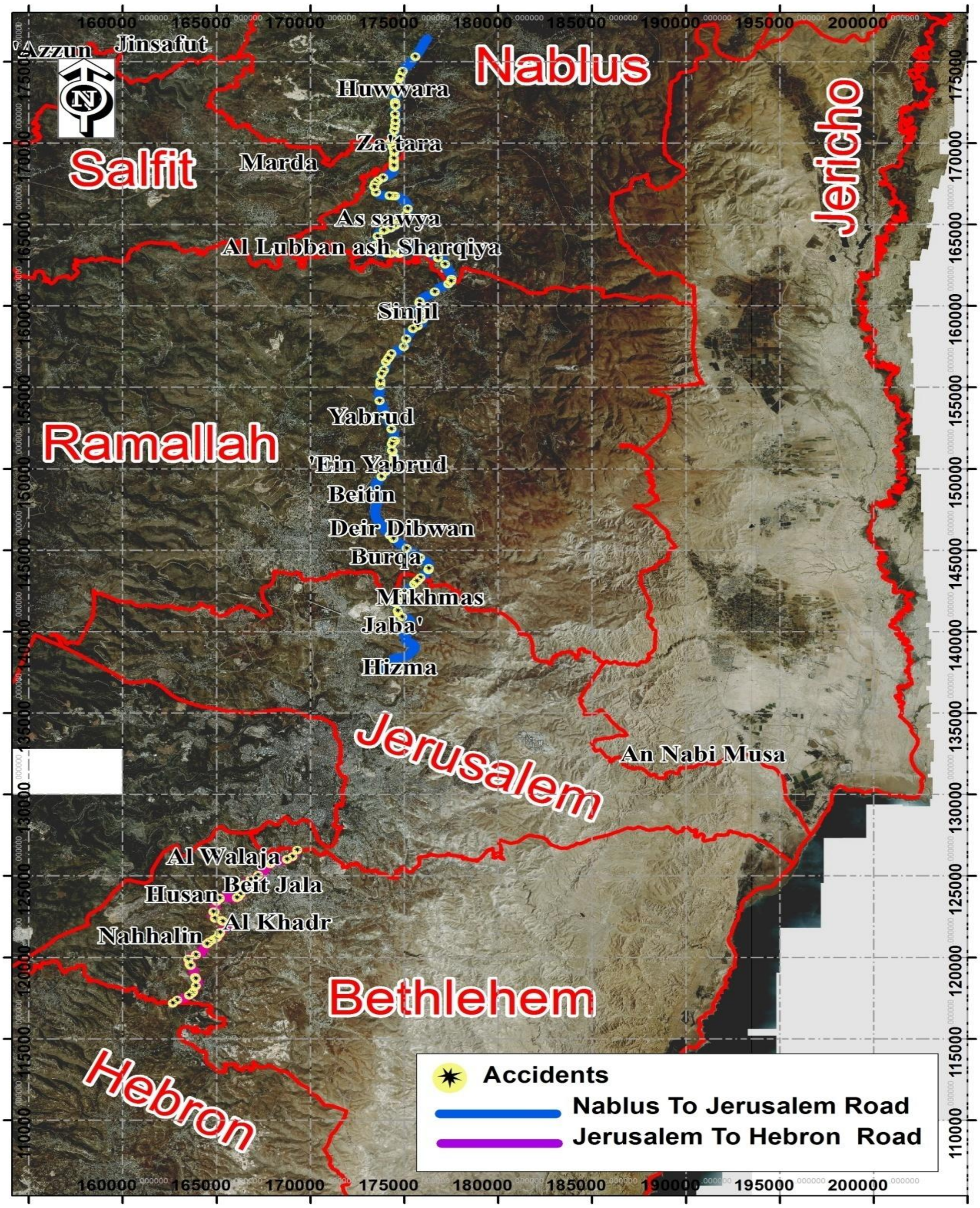

Figure 4.2: Ortho-Drawing for Highway 60 with Accident Locations.

Table 4.2. Summary of Statistics for Main Variables Used in Highway 60.

Data Element	Minimum	Maximum	Mean	Standard Deviation
Curve Radius (m)*	231.08	982.14	479.12	180.91
Curve Length (m)	91.2	1687.47	332.05	270.96
Tangent Length (m)	86.12	4905.41	556.87	820.12
* Curves with radius less than 100 m were eliminate from the data				

Road section from Nablus to Jerusalem was used for model development and from Jerusalem to Hebron was used for model validation.

Highway 55 (Nablus to Qalqilya)

Connects Nablus to Qalqilya; road length is 22.8 km with rolling and mountainous topographic segments. The summary of statistics for the main geometric variables is illustrated in Table (4.3). Figure (4.3) shows ortho-drawing for Highway 55 with crash locations along the highway segments, the number of crashes for 10 consecutive years, 2003 through 2012.

Table 4.3. Summary Statistics for Main Variables Used in Highway 55.

Data Element	Minimum	Maximum	Mean	Standard Deviation
Curve Radius (m)*	108.7	988.84	415.10	249.8
Curve Length (m)	61.03	625.21	225.27	159.48
Tangent Length (m)	65.52	2163.89	432.97	544.14
* Curves with radius less than 100 m were eliminate from the data				

Figure 4.3 shows ortho-drawing for Highway 55 with accident locations along the highway segments.

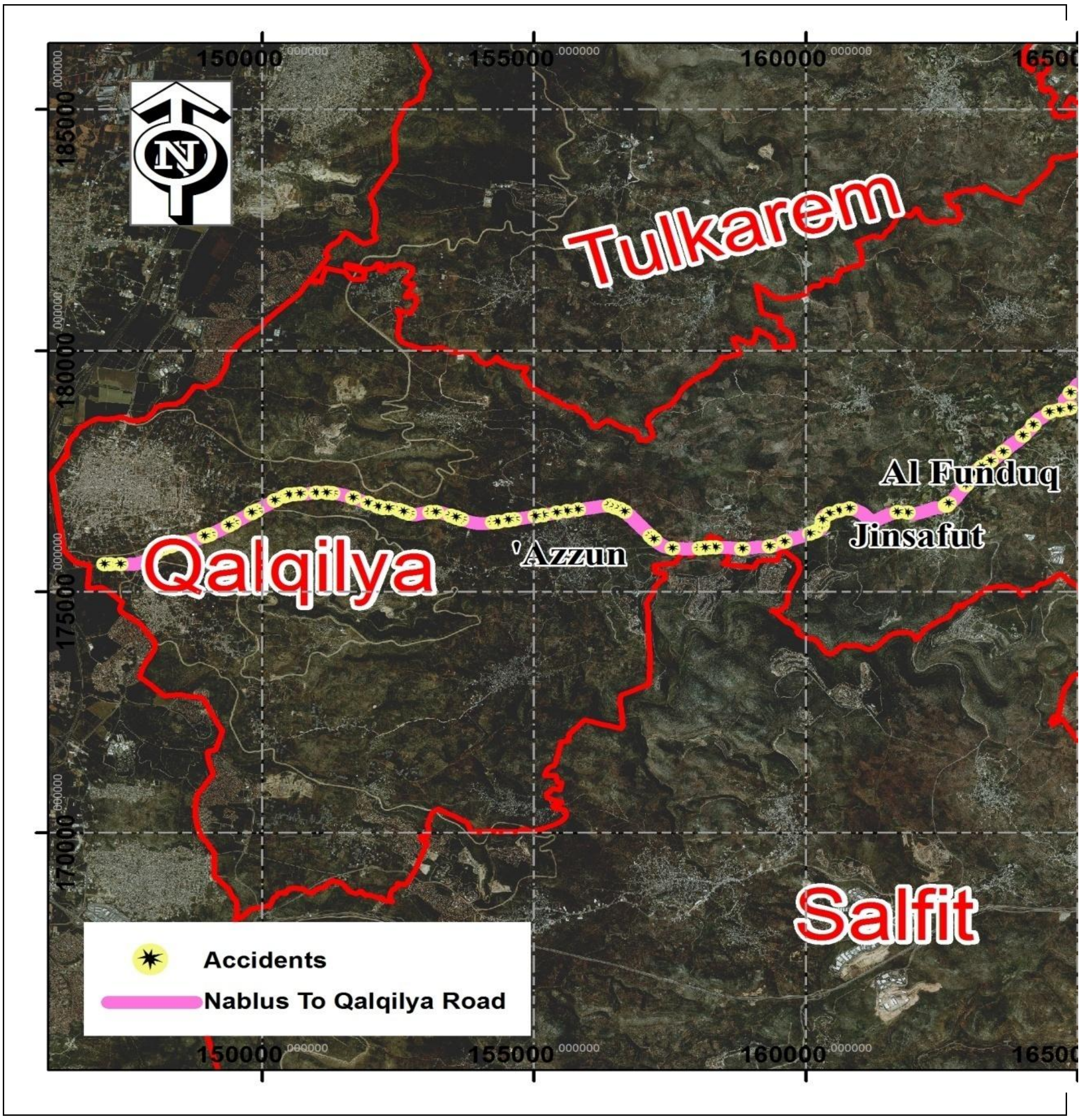

Figure 4.3. Ortho-Drawing for Highway 55 with Crash Locations

Highway 505 (Salfit to Za'tara)

Connects Za’tara to Salfit; road length is 9.4 km with rolling topographic segments. The summary of statistics for the main geometric variables is illustrated in Table (3.4). Figure (3.4) shows ortho-drawing for Highway 505 with crash locations along the highway segments, the number of crashes for 5 consecutive years, 2008 through 2012. Road section from Salfit to Za'tara used for model validation.

Table 4.4. Summary of Statistics for Main Variables Used in Highway 505.

Data Element	Minimum	Maximum	Mean	Standard Deviation
Curve Radius (m) *	331.26	985.42	685.41	204.16
Curve Length (m)	104.42	854.86	240.44	201.53
Tangent Length (m)	157.77	1656	676.75	556.17
* Curves with radius less than 100 m were eliminate from the data				

Highway 90 (Jericho to Bethlehem) “Dead Sea Road"

Connects Jericho to Bethlehem Governorate; it is known as the Dead Sea Road. The road length is 39.5 km with level terrain. The summary of statistics for the main geometric variables is illustrated in Table (4.5). Figure (4.5) shows ortho-drawing for Highway 90 with crash locations along the highway segments, the number of crashes for 10 consecutive years, 2003 through 2012. Road section from Jericho to Bethlehem used for model development and Bethlehem governorate road section used for model validation.

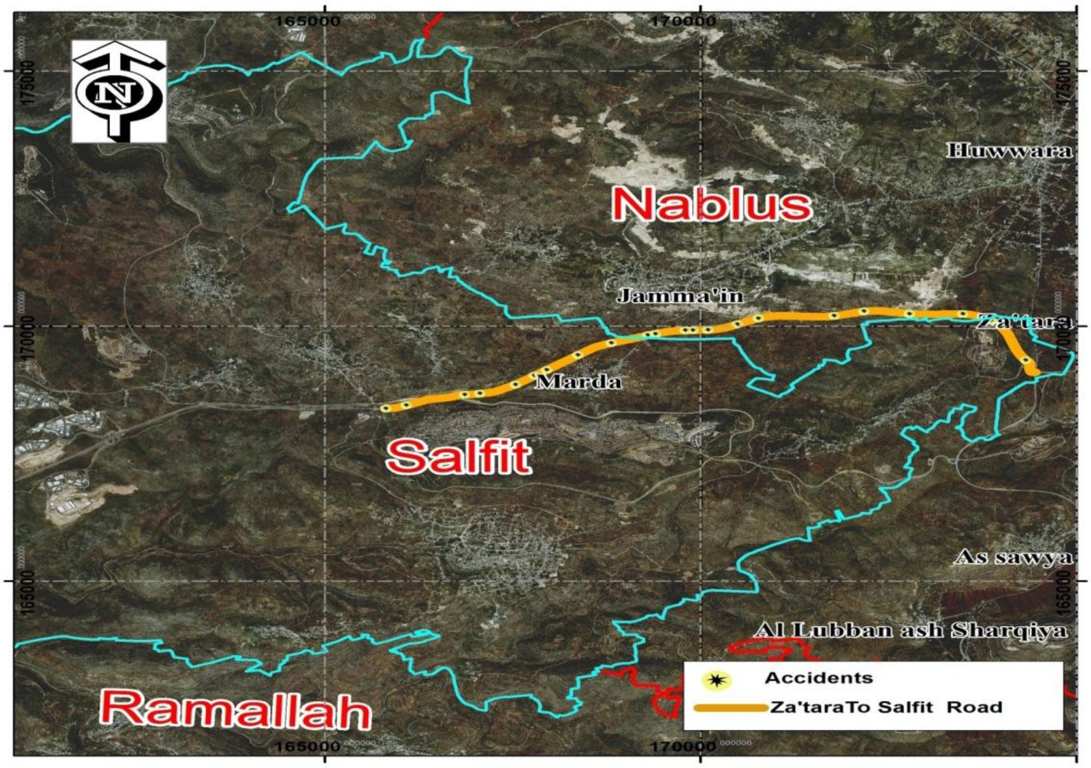

Figure 4.4. Ortho-Drawing for Highway 505 with Crash Locations.

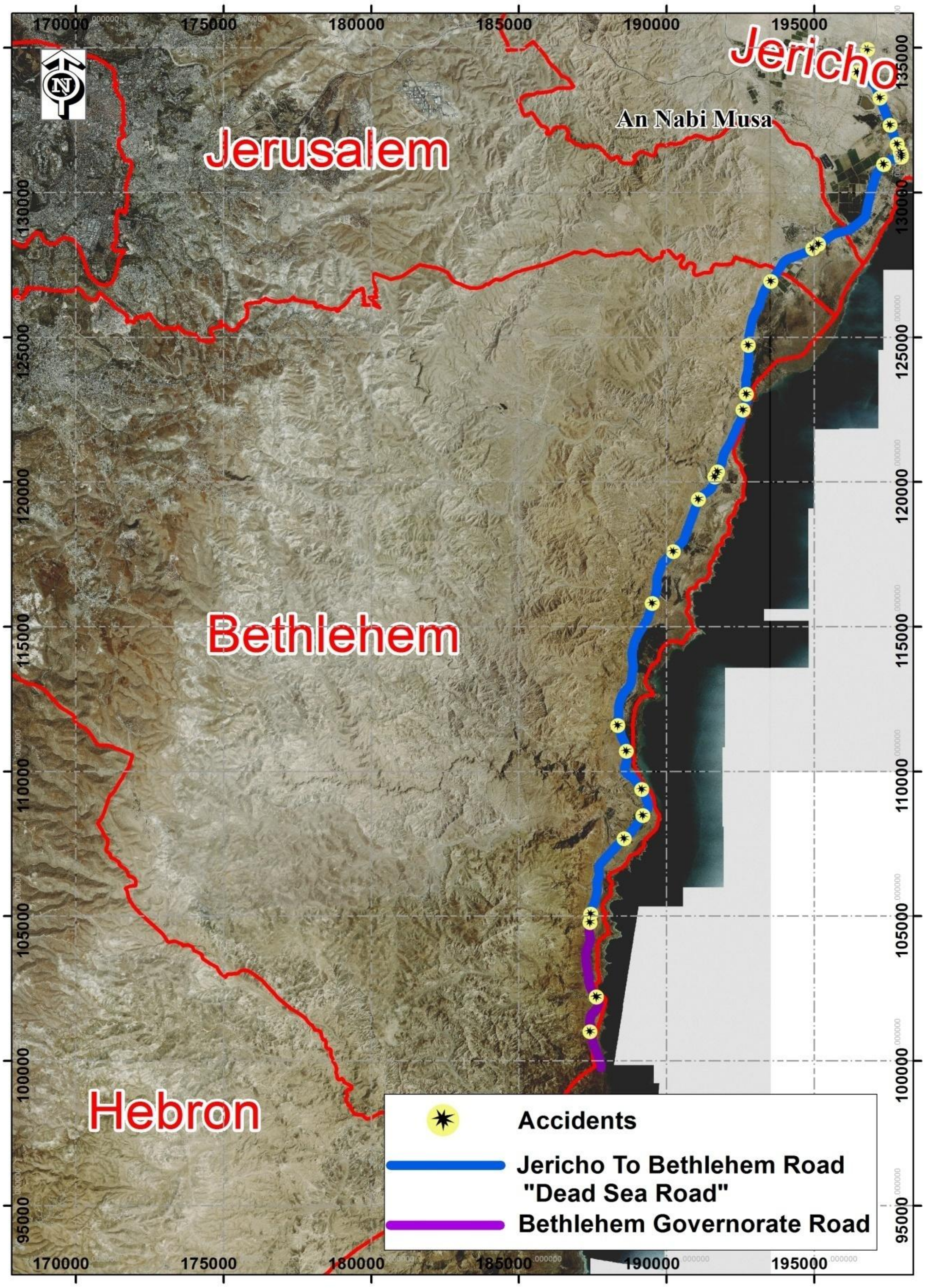

Figure 4.5. Ortho-Drawing for Highway 90 with Accident Locations.

Table 4.5. Summary of Statistics for Main Variables Used in Highway 90.

Data element	Minimum	Maximum	Mean	Standard Deviation
Curve Radius (m) *	129.67	937.79	471.32	226.12
Curve Length (m)	59.65	416.69	181.67	70
Tangent Length (m)	77.26	2523.35	443.11	437.41
* Curves with radius less than 100 m were eliminate from the data				

4.3 Traffic Volume

The traffic volume data for Highway 60 (Nablus to Hebron) were obtained from Rabaya et. al (2012) study, which provides traffic counts for two sections along the highway. Highway 55 (Nablus to Qalqilya) traffic volume data were obtained from in situ traffic count in year (2012) for the first section, the second section was obtained from the ICBS in year (2012). Highway 505 (Za'tara to Salfit) traffic volume data were obtained from in situ traffic count in year 2012. Highway 90 (Jericho to Bethlehem "Dead Sea Road") traffic volume data were obtained from the ICBS in year (2012).

Average daily traffic volumes for the studied roads were needed for five years. Unfortunately, the only data of traffic volume were obtained for one year from Rabaya et al. (2012) study and from in situ traffic counts, therefore, it is needed to be expanded for five years (2008-2012) to use in model development.

Although the crashes data does not distinguish between those involving Palestinian or Israeli settlers, the growth rate for the population in the West Bank was used to represent the growth rate for vehicle volumes because the majority of drivers on these highway sections are Palestinians and the population growth rate for Israeli settlers is different from the Palestinians. Population and growth rates in the West Bank are illustrated in Table (4.6) (Palestinian Central Bureau of Statics, 2012).

Table 4.6. Population and Growth Rate in West Bank (PCBS, 2012).

	2008	**2009**	**2010**	**2011**	**2012**
Population	2385180	2448433	2513283	2580168	2649020
Growth Rate		2.65%	2.65%	2.66%	2.67%

The average daily traffic (ADT) for the studied roads were calculated using population growth rate and K factor (Design Hour Factor) estimated at 15%; values for K typically range from (8-12)% for urban facilities and (12-18)% for rural facilities (AASHTO, 2001). The K factor allows for the conversion from a peak hour volume to a daily volume. The ADT for the studied road sections is illustrated in Table (4.7).

4.4 Crashes Data

The crash data from the ICBS were used to extract 5-year crash experience of each individual tangent and horizontal curve for (2008- 2012) years. The crash analysis considers only non-intersection crashes that involved:

(1) a single vehicle running off the road; (2) two or more vehicle crash. All crashes involving parking, hitting pedestrian, and crash with inanimate object, drop- off elevated pavement, and others were excluded. These are the crash types that have been identified as being "over-represented on curves as compared to tangents" (Fitzpatrick et al, 2000b). In addition, these are crashes that might not be directly related to geometric aspects of the roads.

Table 4.7. Average Daily Traffic for the Studied Roadway Sections.

Year / Highway	2008	2009	2010	2011	2012	ADT Veh./Day
60 (Section1) Nablus−Ramallah	10196	10474	10759	11053	11348	10766
60 (Section2) Ramallah−Bethlahem	7122	7316	7515	7715	7920	7518
60 (Section2) Bethlehem−Hebron	12100	14000	12783	11500	9900	12057
55 (Section1) Nablus−Al-Funduq	13700	15100	15200	15500	16300	15160
55 (Section2) Al-Funduq−Qalqilya	2772	2847	2925	3005	3087	2927
505 Za'tara−Salfit	2957	3037	3120	3205	3293	3122
90 Jericho−Bethlahem	3507	3602	3700	3796	3900	3800

This database contains summarized traffic crash data for all crashes on the highway sections. Some of the main variables provided by the crash databases are described below:

- Date of crash (year, month, and day of week);
- crash coordinate based on the Palestinian grid;
- Lighting condition in which crash took place (day and night);

- Type of crash (head-on crashes, rear-end crashes, side by side crashes, front-side crashes, skidding, over-turn crashes, ran-off crashes);
- Number of vehicles involved in crashes;
- Crash severity (slight, serious, and fatal).

The number of the crashes in the studied highways during 5 years can be summarized on tangents and horizontal curve locations are illustrated in Table (4.8), taking into consideration the number of crashes in the table and excluding all crashes located near town or built up area (urban area), within 50m of an intersection, and within 100m of an military checkpoints. It should be noted that the crash date extracted from the ICBS in the Israeli coordination, which is need to transfer to the Palestinian coordination one by one, which great effort needed.

Table 4.8. Number of Crashes on Highway Segments During 5 Years.

Highway Number	On Tangent	On Horizontal Curve	Total
55	52	27	79
60	68	66	134
505	14	10	24
90	19	7	26

4.5 Design Speed

The Design speed is not known. This value was estimated depending on the speed limit, which is known for the studied highways. Wooldridge et al. (2003) presented different considerations to select the design speed value: AASHTO (2011) consideration of the traditional factors, such as functional classification and terrain, legal speed limit plus a value (5 to 10 mph [8 to 16 km/h]). Some agencies select design speed values within 0 to 10 mph (0 to 16 km/h) above the legislatively mandated maximum posted speed limit for the road's functional classification under consideration. Others select a design speed value of 5 to 10 mph (8 to 16 km/h) above the anticipated operating speed. Depending on the previous discussion, 15 km/hr was added to the posted speed limit to estimate the design speed for the selected highways, as illustrated in Table (4.9).

Table 4.9. Legal Speed Limit and Design Speed for Selected Highways

Highway Number	Legal Speed Limit	Design Speed
55	80	95
60	90	105
505	80	95
90	90	105

4.6 Operating Speed

Operating speed is defined as the speed selected by drivers under free-flow conditions, commonly taken as the 85th percentile speed, i.e. the speed that 85% of drivers will not exceed (Poe and Mason, 2000). A new approach had been used to estimate the operating speed (V_{85}) along two-lane rural roads using Google Earth maps. Real-time speed traffic data were obtained from the maps. The traffic data on Google Maps comes from a variety of sources, including governmental departments of transportation, private data providers, and users of Google Maps for mobile phone who contribute anonymous speed information through traffic crowd sourcing feature. Speed data regarding individual car drivers travelling on selected two-lane rural highways were collected using real-time speed traffic data as show in Figure (4.6); minimum of thirty spot speed measurements for tangents and curves were collected then compared with the minimum sample size in Equation (4.1). Speed data were useful for studying the actual operating speed with regard to acceleration/declaration behavior.

It should be noted that the speed data using Google Earth Map can be collected for only those with mobile/GPS-determined locations transmitted by subscribed users. Also, the speed data was taken during off-peak hours to represent the free-flow speed, day/night, and for all days of week. Although the speed sample may be biased towards those using mobile/GPS-determined locations; however, the data is still considered representative and is the best available data to compute the actual operating speed. Table (4.10) summarizes operating speeds results for the studied highway sections.

Table 4.10. Summary of Statistics for Operating Speed Used in the Studied Highway Sections (in Km/hr).

Highway Location	Minimum	Maximum	Mean	Standard Deviation
Nablus to Qalqilya	46.4	106.3	84.1	10.2
Nablus to Hebron	75.2	115.8	91.5	8.6
Za'tara to Salfit	72	120	99.5	12.8
Jericho to Bethlehem "Dead Sea Road"	49.6	106.4	84.2	11.7

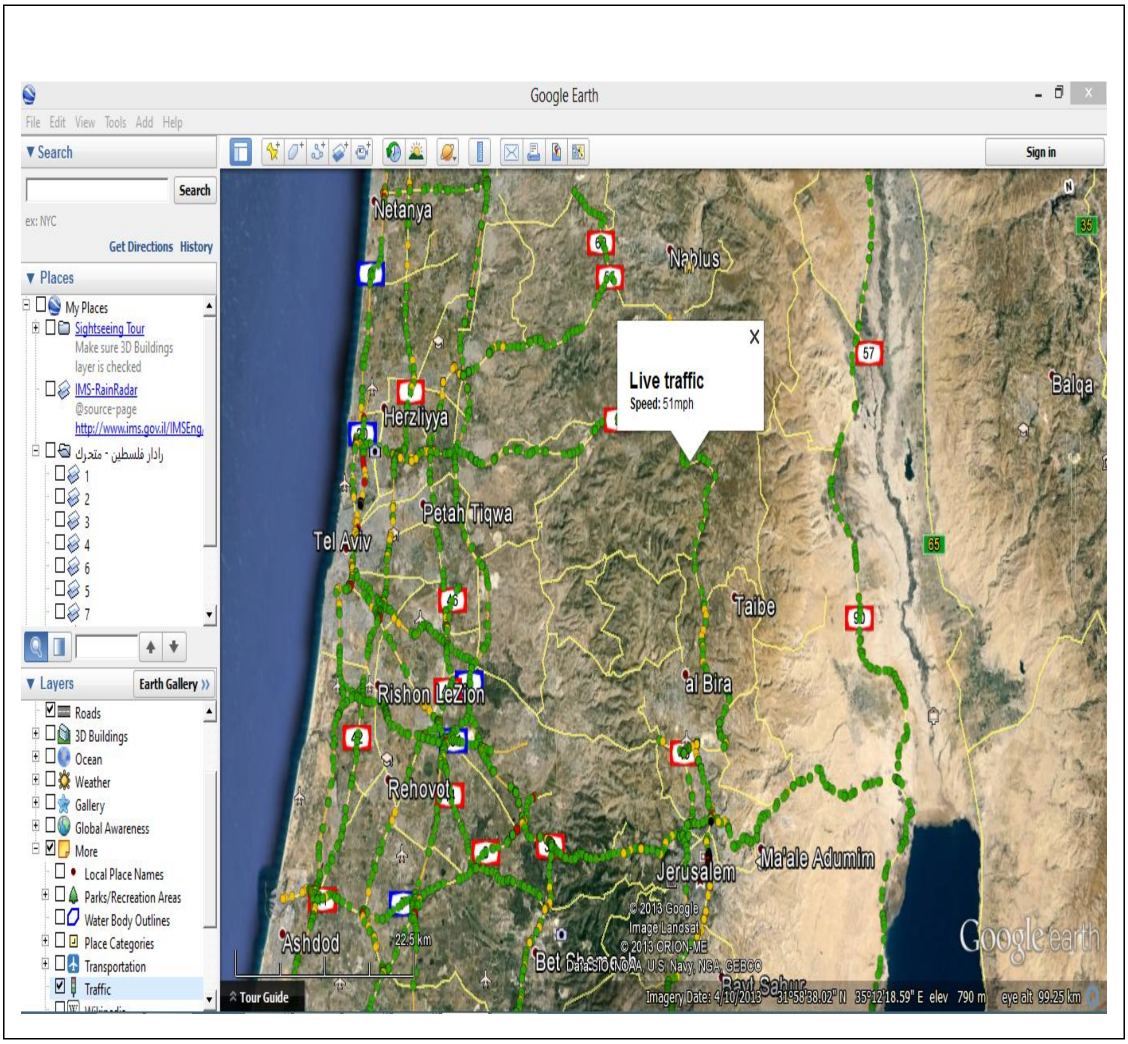

Figure 4.6. Real Time Speed for Individual Car Driver.

Using Equation (4.1), the minimum sample size of spot speed counts needed for each road segments (tangent and curve) were computed depending on Z-value of 1.96 (for 95 percent confidence level), the limits of acceptable error (d) used (depending on the purpose of the study) traffic operations, economic evaluation, and trend analysis $\pm$ 3.0 to $\pm$ 6 km/hr (Garber and Hoel, 2009), and standard deviation (σ) computed depending on the number of spot speed counts, which were already counted in the off-peak hours for each road segments. The spot speed counts for each road segments must be more than the minimum sample size resulting from Equation (4.1). The spot speed counts used the study is usually more than thirty for most locations, which implies that Z-distribution is appropriate and yields higher than 95% confidence level.

$$N = (Z \times \sigma^2) / d^2 \qquad (4.1)$$

Where:

N = minimum sample size,

Z = number of the standard deviation corresponding to the required confidence = level 1.96 for 95 percent confidence level

σ = standard deviation (km/hr),

d = limits of acceptable error of the speed estimate (km/hr).

Chapter Five

Model Development

The methodology used in model development is based on the development of crash prediction models incorporating design consistency measures. Crash prediction model (CPM) is an appropriate approach to evaluate the safety performance of a location (Sayed and Rodriguez, 1999) which is explained in Section (5.1). The generalized linear regression modeling (GLM) approach is adopted for model development, the theoretical basis and the advantages of are presented in Section (5.2). To develop CPM, selecting significant variables from numerous candidate variables is a critical step. The measures selected to represent each category are shown in Section (5.3).

5.1 Crash Prediction Models

In modern highway safety research, the application of regression analysis plays a vital role in understanding the impact of roadway features on safety. Regression models developed for highway safety studies can be divided into two main uses, crash causation models and crash prediction models (Persaud, 2001).

Crash prediction models (CPM) are appropriate approach to evaluate the safety performance of a location. They are statistical regression models which relate crash occurrence to traffic and geometric characteristics of a location, and are developed based on a group of locations of similar geometric make-up. The models can be used to predict future crash occurrence at other locations of similar characteristics (Sayed and Rodriguez, 1999). Crash prediction models attempt to estimate the expected crash experience as a function of the strongest predictor variables, thus there is an emphasis on prediction errors.

5.2 Modeling Techniques

Most of the earlier studies used the conventional linear regression approach to develop models relating crashes to traffic volumes. However, the past decades have seen a significant development and advances in crash data analysis and modeling. Crash prediction models are no longer limited to conventional linear regression approach, as more accurate and less restrictive nonlinear models are considered. Jovanis and Chang (1986) identified three shortcomings associated with the assumption of a normal distribution error structure. The first shortcoming is found in the relationship between the mean and the variance of accident frequency, under a normal distribution assumption, the variance remains constant. The second shortcoming is associated with the non-negativity of accident occurrence. The third problem is related with the non-normality of the error distribution, due to the characteristics of non-negativity and small value of discrete dependent variable.

To estimate the parameters of crash prediction models, the generalized linear regression method (GLM) is used. GLM has the advantage of overcoming the limitations associated with the use of conventional linear regression in modeling crash occurrence, which is random, discrete, and non-negative in nature. GLM has the flexibility of assuming different error distributions and link functions that allow the conversion of nonlinear models into linear models.

5.2.1 Selection of Regression Technique

For the GLM approach, the error structure that best fits the crash occurrence is usually assumed to be Poisson or Negative Binomial. It is important to understand that neither the Poisson nor Negative Binomial approach is always best. The selection of either regression technique should always be based on an analysis of the data under study.

The main advantage of the Poisson error structure is the simplicity of the calculations, because the mean and variance are equal. However, this advantage is also a limitation. It has been shown by Kallberg et al. (1987) that most accident data is likely to be over dispersed (the variance is greater than the mean), which indicates that the negative binomial distribution is the more realistic assumption. The negative binomial regression technique was then implemented to determine whether it could accommodate the problem of over-dispersion.

Bonneson and McCoy (1993) proposed a methodology to decide whether to use a Poisson or Negative Binomial error structure. First, the model parameters are estimated based on a Poisson distribution error structure. Secondly, dispersion parameter (k) is calculated depending on scaled deviance (SD) and Pearson χ^2. Dispersion parameters are calculated as follow in Equations (5.1 and 5.2):

$$k_D = SD\ /\ n - p \tag{5.1}$$

$$k_P = \text{Pearson}\ \chi^2\ /\ n - p \tag{5.2}$$

Where:

k_D = dispersion parameter depending on scaled deviance,

k_P = dispersion parameter depending on Pearson χ^2,

SD = scaled deviance value of model,

Pearson χ^2 = Pearson chi-squared value of model,

n = number of observations,

p = number of coefficients considered in model.

If (k) is greater than 1.0, then the data has greater dispersion than is explained by the Poisson distribution, and a further analysis using a Negative Binomial distribution is required. If (k) is near 1.0, then the assumed error structure approximately fits the Poisson distribution. Scaled Deviance and Pearson chi-squared measures were provided as SPSS goodness of fit output (SD and Pearson χ^2 test will be described in Section 5.2.3).

5.2.2 Model Structure and Development

Neter et al. (1996) argued that general form typically found in crash models is the multiplicative model form shown in Equation (5.3). This multiplicative form ensures zero values of crash frequency at zero values of the exposure variable. It also ensures that the mean value of crashes remains positive, since an additive model may result in negative values for certain parameter combinations.

The model structure relates crashes to exposure and other explanatory variables such as geometric design features or design consistency measures. The form of the model equation for negative binomial regression is the same as that for Poisson regression. The “Ln” of the outcome is predicted with a linear combination of the predictors, using Ln as link functions allow the conversion of nonlinear models into linear models. The following general model forms can be adopted when studying highway sections:

$$\text{Ln}(Y) = \text{Intercept} + \beta_1 (X_1) + \beta_2 (X_2) + \beta_n (X_n) \qquad (5.3)$$

This implies:

$$Y = \text{EXP}^{(\text{Intercept} + \beta_1 (x_1) + \beta_2 (x_2) + \beta_n (x_n))} =$$

$$= \text{EXP}^{(\text{Intercept})} \times \text{EXP}^{(\beta_1 (x_1))} \times \text{EXP}^{(\beta_2 (x_2))} \times \text{EXP}^{(\beta_n (x_n))}$$

Where:

Y = expected mean crash frequency,

$\beta_1, \beta_2, \beta_n$ = model parameters,

X_1, X_2, X_n = model predictor variables, and

EXP = Exponential function, e = 2.718282.

The chief variable that explains the occurrence of crashes on roadway segments is the amount of exposure to traffic that is experienced. There were two main methods for expressing exposure in crash models. The first approach includes traffic volume and section length separately, with each variable having a separate coefficient. This approach predicts the crash frequency for the number of years of crash data included in the database (Anderson et al., 1999). The second approach combines traffic volume and section length into a single exposure term as expressed in Equation (5.4).

$$\text{Expo} = (\text{Number of Years})(\text{ADT})(365)(L)(10^{-6}) \quad (5.4)$$

Where:

Expo = single exposure term (million vehicle-km),

ADT = average daily traffic volume (veh/day),

L = section length (m).

Thus, the selection of a model form in this study was based on the best fit for the data at hand. Depending on Equation 5.3, two forms can be modeled for the data in the study as follow:

$$Y = EXP^{(Intercept)} \times EXP^{(ADT(X_1))} \times EXP^{(L(X_2))} \times EXP^{(\beta_1(X_3))} \times EXP^{(\beta_2(X_4))} \times EXP^{(\beta_n(X_n))} \qquad (5.5)$$

$$Y = EXP^{(Intercept)} \times EXP^{(Expo(X_1))} \times EXP^{(\beta_1(X_2))} \times EXP^{(\beta_2(X_3))} \times EXP^{(\beta_n(X_n))} \qquad (5.6)$$

Where:

Y = expected mean crash frequency,

$\beta_1, \beta_2, \beta_n$ = model parameters,

X_1, X_2, X_n = model predictor variables, and

ADT = average daily traffic volume (veh/day),

L = section length (m),

Expo = single exposure term (million vehicle-km), and

EXP = Exponential function, e = 2.718282.

Anderson et al. (1999) examined the two approaches for incorporating exposure expressed in Equations (5.5) and (5.6), and found that including the natural logarithms traffic volume and curve length as separate terms improved the model's goodness of fit. Taking the natural logarithm of the variables was recommended in previous research. Lovegrove and Sayed (2006) proposed a generalized linear model form that can be adopted when studying highway sections, which is presented in Equations (5.7) and (5.8) as:

$$Y = EXP^{(Intercept)} \times ADT^{(X_1)} \times L^{(X_2)} \times EXP^{(\beta_1(X_3))} \times EXP^{(\beta_2(X_4))} \times EXP^{(\beta_n(X_n))} \quad (5.7)$$

$$Y = EXP^{(Intercept)} \times Expo^{(X_1)} \times EXP^{(\beta_1(X_2))} \times EXP^{(\beta_2(X_3))} \times EXP^{(\beta_n(X_n))} \quad (5.8)$$

Where:

Y = expected mean crash frequency,

β_1, β_2, β_n = model parameters,

X_1, X_2, X_n = model predictor variables, and

ADT = average daily traffic volume (veh/day),

L = section length (m),

Expo = single exposure term (million vehicle-km), and

EXP = Exponential function, e = 2.718282.

This form not only takes account of the influence of different independent variables, but also fairly represents the non-negative, non-linear, and non-normal nature of the crashes. Depending on previous studied, this form examined and gave reasonable results.

5.2.3 Goodness of Fit

It is always important to thoroughly check model goodness of fit, or in other words, the discrepancy between the original data values and the fitted values generated from the model. Two statistical measures can be used to assess the goodness of fit of crash prediction models developed using GLM. A GLM model is usually assessed using the SD and the Person χ^2 test. The SD is defined as the likelihood test ratios measuring the difference between the log likelihood of the studied model, and the saturated model (Kulmala, 1995). The scaled deviance can be obtained using Equation (5.9) if the error structure follows the Poisson distribution and Equation (5.10) if the error structure follows the Negative Binomial distribution, as follows:

$$SD = 2\sum_{i=1}^{n}[yi \times ln\left(\frac{yi}{E(\Lambda)i}\right)] \quad (5.9)$$

$$SD = 2\sum_{i=1}^{n}[yi \times ln\left(\frac{yi}{E(\Lambda)i}\right) - (yi + k)ln\left(\frac{yi+k}{E(\Lambda)i+k}\right)] \quad (5.10)$$

where:

SD = scaled deviance,

yi = observed number of crashes on section,

$E(\Lambda)i$ = predicted number of crashes on section, and

k = dispersion parameter

The SD is asymptotically χ^2 distributed with n-p-1 degrees of freedom, where n is the number of observations, and p is the number of model parameters. Another measure to assess the significance of the GLM models is the Person χ^2 statistics defined as (Bonneson and McCoy, 1993):

$$\text{Pearson } \chi^2 = \sum_{i=1}^{n} \left(\frac{yi - E(\Lambda)i}{Var(yi)} \right)^2 \tag{5.11}$$

where:

Pearson χ^2 = Pearson chi-squared value of model,

yi = observed number of crashes on section,

$E(\Lambda)i$ = predicted number of crashes on section, and

$Var(yi)$ = the variance of observed accidents.

The Pearson χ^2 statistics follows the χ^2 distribution with n-p-1 degrees of freedom, where n is the number of observations and p is the number of model parameters. The variance of observed crashes ($Var(yi)$) is defined in Equations (5.12) and (5.13) for Poisson and negative binomial distributions, respectively.

$$E(yi) = \mu; \; Var(yi) = (\mu^2 / \; k) \tag{5.12}$$

$$E(yi) = \mu; \; Var(yi) = \mu + (\mu^2 / \; k) \tag{5.13}$$

where:

$E(yi) = \mu$ = average number of crashes on section,

k = dispersion parameter.

The goodness-of-fit statistics for the model shows that the model fits reasonably well with the data. The Pearson χ^2 and SD statistics divided by its degrees of freedom values must be within the permissible range of (0.8 - 1.2), which indicate that the Negative Binomial distribution assumption is acceptable (Dissanayeke and Ratnayake, 2006).

The use of the traditional coefficient of determination (R^2) is considered not appropriate for Poisson or Negative Binomial regression models as goodness of fit measure. Miaou et al. (1995) showed several drawbacks associated with the use of (R^2) for assessing the goodness of fit of crash prediction models. They proposed another goodness of fit for Negative binomial models. It is a dispersion based R^2, which is calculated as follows

$$R_k^2 = 1 - k_M / k_{\max} \qquad (5.14)$$

where:

R_k^2 = coefficient of determination,

k_M = model dispersion parameter, and

$k_{\max}$ = maximum dispersion parameter of the model.

Maximum dispersion parameter of the negative binomial distribution is estimated in the model with only a constant term and no predictor variables. Maximum dispersion parameter of the model was provided as SPSS goodness of fit output.

5.3 Selected Consistency Measures

All the design consistency measures mentioned in Chapter 3 (V_{85} - V_D, ΔV_{85}, Δf_R, AVG R, MR/mR, AVG T, CCR, CRR, and VD_{LF}), were computed for each section of the study highways. Table (5.1) provides a summary of the design consistency measures as applied to these alignments. It should be noted that Table (5.1) shows the summary of statistics for the consistency measures used for highway section used for model development only.

Table 5.1. Summary of Statistics of the Design Consistency Measures as Applied to the Alignments under Study.

Design Consistency Measure	Maximum	Minimum	Average	Std. Dev
Horizontal Curves Data Only (3 Roads with 136 Horizontal Curves)				
V_{85} - V_D (km/hr)	8.59	-47.00	-15.32	-8.59
ΔV_{85} (km/hr)	20.07	2.49	7.21	3.67
Δf_R	0.27	-0.13	0.12	0.10
AVG R (m)	509.60	296.9	479.86	57.78
$\frac{MR}{mR}$	8.60	3.20	5.68	1.78
AVG T (m)	1009.60	182.90	485.15	207.76
CCR	108.60	38.60	55.79	19.08
CRR	2.02	0.23	1.00	0.42
VD_{LF}	0.71	0.42	0.48	0.06
Tangent Data Only (111 Tangents)				
V_{85} - V_D	11.29	-48.60	-14.33	9.88
Horizontal Curves and Tangents Data Combined (3 Roads with 136 Horizontal Curves and 111 Tangents)				
Design Consistency Measure	**Maximum**	**Minimum**	**Average**	**Std. Dev**
V_{85} - V_D (km/hr)	11.29	-48.60	-14.83	9.19
ΔV_{85} (km/hr)	20.07	0.00	3.96	4.59
Δf_R	0.27	-0.13	0.07	0.10
AVG R (m)	509.60	0.00	263.01	243.32
$\frac{MR}{mR}$	8.60	0.00	3.12	3.11
AVG T (m)	1009.60	0.00	266.39	288.61
CCR	108.60	0.00	30.56	31.43
CRR	2.02	0.00	0.55	0.59
VD_{LF}	0.71	0.00	0.26	0.24

Chapter Six

Modeling Results

This chapter presents the models developed in this study. Two groups of models have been developed with different objectives. The first group was the ‘Core’ models; the objectives of the first group were to decide which technique is most appropriate in this study, whether Poisson or Negative Binomial regression technique and the form of exposure variable that will be used, in addition the ‘core’ models were also useful as a rough guide for identification of locations with a high frequency of crashes (black-spots). The second group was the ‘full’ models; the objective of the second group was to develop quantitative relationships, which can serve as evaluation tools to investigate the impact of design consistency on road safety.

6.1 Variable Selection

Selecting significant variables from numerous candidate variables is a critical step. The variable selection is a forward stepwise procedure by which all candidate variables were added to a model one by one. Sawalha and Sayed (2006) recommended that the first variable to be added should be the leading exposure variable(s) due to its dominating prediction influence. In this study, the leading variables were section length, traffic (ADT), and or Expo (single exposure term (million vehicle-km)). The decision to keep a variable in the model was based on meeting four criteria (Sawalha and Sayed, 2006). First, the logic (i.e. ±) of the estimated parameter was intuitively associated with crashes, relying on previous research evidence. Second, the Wald χ^2 -statistic for each parameter needed to be significant at the 95% confidence level; many researches accept 90% confidence level. The W.χ^2 statistics give an indication how the variable relate to crash frequency, higher value means more relate indicative. Third, each added variable has to have minimal correlation (i.e. <0.3) with other independent variables in the same model. (Persaud et al., 2001) argued that highly correlated variables are those with correlation values (Pearson's product moment correlation coefficients) of (0.7) or higher.

6.2 Regression Technique and Exposure Variable Selection

It is required to decide whether the Poisson or Negative Binomial regression technique is more suitable for this study. The Poisson distribution and Negative Binomial technique were examined depending on their dispersion parameters, which have been explained in section (5.2.1).

Three main techniques for incorporating exposure in the crash models were examined. The first approach includes traffic volume and curve length separately, while the second approach combines traffic volume and curve length into a single exposure term (Equation 5.4). Taking the natural logarithm of these variables was recommended in previous research, and was thus investigated in this study. The third approach considers the untransformed value of the exposure term.

In order to decide which approach is most appropriate in this study, each approach was modeled based and Poisson or Negative Binomial regression technique. The model that fits reasonably well with the data will be chosen depending on goodness-of-fit statistics, which have been explained in section (5.2.3). The resulting model has been determined to be as follows:

Tangent data only (111 Tangents)

Several models will be examined based on Poisson and Negative Binomial regression technique. The results of this group were detailed in Table (6.1).

The Poisson and Negative Binomial regression models were compared based on (k_D) and (k_P), since these model parameters were found to provide the best results. If (k) is greater than 1.0, then the data has greater dispersion than is explained by the Poisson distribution, and a further analysis using a Negative Binomial distribution is required. If (k) is near 1.0, then the assumed error structure approximately fits the Poisson distribution.

In the Poisson regression models the dispersion parameters based on the SD ranged from (1.060 to 1.572). On the other hand, the dispersion parameters based on the Pearson χ^2 ranged from (1.179 to 1.779). Considering (k) value is greater than 1.0, then the data has greater dispersion depending on Poisson regression models developed in this study, which is found to experience an unacceptably high level of over-dispersion, thus considered unsatisfactory. The application of negative binomial regression was found to considerably improve the over-dispersion of all models.

Table 6.1 Models Developed Depending on Tangent Data Only (111 Tangents).

Model Form	Model Parameters	Estimated Model Parameters	W.χ^2	k_D / k_P	k_M / R_k^2
P.1) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2 (Section))} \times EXP^{(\beta_3 (Traffic))}$	β_1 β_2 β_3	-1.978 0.001 0.000171	55.047 131.781 62.184	1.397 1.527	N/A N/A
B.1) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2 (Section))} \times EXP^{(\beta_3 (Traffic))}$	β_1 β_2 β_3	-2.123 0.001 0.000159	39.640 30.419 28.795	0.872 0.933	0.533 0.78
P.2) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2 (Expo))}$	β_1 β_2	-0.543 0.0000486	19.403 191.206	1.572 1.779	N/A N/A
B.2) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2 (Expo))}$	β_1 β_2	0.250 0.0000348	0.030 0.630	1.143 0.505	1.00 0.42
P.3) Y = $EXP^{(\beta_1)} \times Section^{(\beta_2)} \times Traffic^{(\beta_3)}$	β_1 β_2 β_3	-17.120 1.004 1.225	94.866 126.742 45.801	1.060 1.179	N/A N/A
B.3)Y = $EXP^{(\beta_1)} \times Section^{(\beta_2)} \times Traffic^{(\beta_3)}$	β_1 β_2 β_3	-17.151 1.015 1.220	88.771 112.825 42.719	1.030 1.154	N/A N/A
P.4) Y = $EXP^{(\beta_1)} \times Expo^{(\beta_2)}$	β_1 β_2	-9.205 1.048	146.842 177.390	1.061 1.179	N/A N/A
B.4) Y = $EXP^{(\beta_1)} \times Expo^{(\beta_2)}$	β_1 β_2	-9.301 1.059	133.568 157.913	1.030 1.154	N/A N/A

Note : 1.W.χ^2 = Wald χ^2 -statistic; k_D = dispersion parameter depending on Scaled Deviance; k_P = dispersion parameter depending on Pearson χ^2; k_M = model dispersion parameter; R_k^2 = coefficient of determination. P = Poisson regression technique used; B = Negative Binomial regression technique used. 2. Models statistically significant at the 95% significance level.

The Negative Binomial regression models were compared based on (k_D) and (k_P), (R_k^2) since these model parameters were found to provide the best results. (k) must be within the permissible range of (0.8 - 1.2), which indicates that the Negative Binomial distribution assumption is acceptable, and higher R_k^2 indicates better model fit. In the Negative Binomial regression models, the dispersion parameters based on the SD ranged from (0.872 to 1.143). On the other hand, the dispersion parameters based on the Pearson χ^2 ranged from (0.505 to 1.154), (R_k^2) ranged from (0.42 to 0.78), (k_{max} - maximum dispersion parameter of the group data- equals 2.412). Model, which has (k_D) and (k_P) within the acceptable range of (0.8 - 1.2) and higher (R_k^2) is considered the best fitted to the data in the study, and will be taken as the 'core' model for the group under study (the 'core' model will be explained in section (6.4.1). Depending on the parameters above, (**B.1**) model is considered to represent the 'core' model for this group because (k) is within the permissible range and has higher (R_k^2) among the others.

Horizontal Curves Data Only (136 Horizontal Curves)

Several models will be examined based on Poisson and Negative Binomial regression technique. The results of this group are detailed in Table (6.2).

In the Poisson regression models, (k_D) ranged from (1.210 to 1.323). On the other hand, (k_P) ranged from (1.481 to 1.654). Considering (k) value is greater than 1.0, and then the data has greater dispersion depending on Poisson regression models developed in this study, which is found to experience an unacceptably high level of over-dispersion, thus considered unsatisfactory. The application of negative binomial regression was found to considerably improve the over-dispersion of all models.

Table 6.2 Models Developed Depending on Horizontal Curves Data Only (136 Horizontal Curves).

Model Form	Model Parameters	Estimated Model Parameters	W.χ^2	k_D k_P	k_M R_k^2
P.5) Y = EXP$^{(\beta_1)}$×EXP$(\beta_2(^{Section}))$ × EXP$(\beta_3(^{Traffic}))$	β_1 β_2 β_3	-2.393 0.002 0.000144	57.492 65.752 26.222	1.214 1.481	N/A N/A
B.5) Y = EXP$^{(\beta_1)}$×EXP$(\beta_2(^{Section}))$ × EXP$(\beta_3(^{Traffic}))$	β_1 β_2 β_3	-2.585 0.002 0.000147	42.644 16.123 15.583	0.771 0.991	0.877 0.70
P.6) Y = EXP$^{(\beta_1)}$ × EXP$(\beta_2(^{Expo}))$	β_1 β_2	-1.135 0.000107	58.543 114.116	1.323 1.654	N/A N/A
B.6) Y = EXP$^{(\beta_1)}$ × EXP$(\beta_2(^{Expo}))$	β_1 β_2	-1.399 0.000151	37.888 23.562	0.766 1.028	1.147 0.60
P.7) Y = EXP$^{(\beta_1)}$× Section$^{(\beta_2)}$ × Traffic$^{(\beta_3)}$	β_1 β_2 β_3	-15.692 1.003 1.070	51.940 40.011 19.078	1.219 1.643	N/A N/A
B.7) Y = EXP$^{(\beta_1)}$× Section$^{(\beta_2)}$ × Traffic$^{(\beta_3)}$	β_1 β_2 β_3	-15.385 0.845 1.134	32.403 13.358 14.322	0.781 1.079	0.937 0.68
P.8) Y = EXP$^{(\beta_1)}$× Expo$^{(\beta_2)}$	β_1 β_2	-8.952 1.025	80.55 81.925	1.210 1.626	N/A N/A
B.8) Y = EXP$^{(\beta_1)}$× Expo$^{(\beta_2)}$	β_1 β_2	-8.423 0.961	39.974 36.783	0.781 1.066	0.927 0.68
Note: 1.W.χ^2 = Wald χ^2 -statistic; k_D = dispersion parameter depending on Scaled Deviance; k_P = dispersion parameter depending on Pearson χ^2; k_M = model dispersion parameter; R_k^2 = coefficient of determination; P = Poisson regression technique used; B = Negative Binomial regression technique used. 2. Models statistically significant at the 95% significance level.					

In the Negative Binomial regression models, (k_D) ranged from (0.766 to 0.781). Although the range (0.766 to 0.781) is slightly lower than the minimum acceptable value of (0.8), it is still considered acceptable in this study. On the other hand, (k_P) ranged from (0.991 to 1.079). (R_k^2) ranged from (0.60 to 0.70), and (k_{max} - maximum dispersion parameter of the group data- equals 2.892). Depending on the parameters above, (**B.5**) model is considered to represent the ‘core’ model for this group because (k) is within the permissible range and has higher (R_k^2) among the others.

Horizontal Curves and Tangents Data Combined (136 Horizontal Curves and 111 Tangents)

Several models were examined based on Poisson and Negative Binomial regression technique. The results of this group are presented in Table (6.3).

In the Poisson regression models, (k_D) ranged from (1.134 to1.522). On the other hand, (k_P) ranged from approximately (1.428 to1.844). Considering (k) value is greater than 1.0, and then the data has greater dispersion depending on Poisson regression models developed in this study, which is found to experience an unacceptably high level of over-dispersion, thus considered unsatisfactory. The application of negative binomial regression was found to considerably improve the over-dispersion of all models.

Table 6.3 Models Developed Depending on Horizontal Curves and Tangents Data Combined (136 Horizontal Curves and 111 Tangents).

Model Form	Model Parameters	Estimated Model Parameters	W.χ^2	k_D k_P	k_M R_k^2
P.9) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2(Section))} \times EXP^{(\beta_3(Traffic))}$	β_1 β_2 β_3	*-2.112* *0.001* *0.000168*	*111.813* *219.332* *100.459*	*1.362* *1.620*	*N/A* *N/A*
B.9) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2(Section))} \times EXP^{(\beta_3(Traffic))}$	β_1 β_2 β_3	*-2.331* *0.001* *0.000160*	*78.651* *39.273* *44.855*	*0.797* *0.941*	*0.771* *0.72*
P.10) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2(Expo))}$	β_1 β_2	*-0.701* *0.0000537*	*62.926* *327.269*	*1.522* *1.844*	*N/A* *N/A*
B.10) Y = $EXP^{(\beta_1)} \times EXP^{(\beta_2(Expo))}$	β_1 β_2	*-1.090* *0.000101*	*48.492* *38.104*	*0.795* *0.946*	*1.108* *0.60*
P.11) Y = $EXP^{(\beta_1)} \times Section^{(\beta_2)} \times Traffic^{(\beta_3)}$	β_1 β_2 β_3	*-16.579* *0.998* *1.169*	*147.424* *201.625* *66.113*	*1.135* *1.443*	*N/A* *N/A*
B.11) Y = $EXP^{(\beta_1)} \times Section^{(\beta_2)} \times Traffic^{(\beta_3)}$	β_1 β_2 β_3	*-16.627* *1.010* *1.167*	*93.785* *86.278* *43.566*	*0.842* *1.125*	*0.439* *0.84*
P.12) Y = $EXP^{(\beta_1)} \times Expo^{(\beta_2)}$	β_1 β_2	*-9.054* *1.034*	*257.115* *291.154*	*1.134* *1.428*	*N/A* *N/A*
B.12) Y = $EXP^{(\beta_1)} \times Expo^{(\beta_2)}$	β_1 β_2	*-9.232* *1.054*	*130.741* *132.858*	*0.781* *1.066*	*0.443* *0.84*

Note: 1.W.χ^2 = Wald χ^2 -statistic; k_D = dispersion parameter depending on Scaled Deviance; k_P = dispersion parameter depending on Pearson χ^2; k_M = model dispersion parameter; R_k^2 = coefficient of determination; P = Poisson regression technique used; B = Negative Binomial regression technique used.
2. Models statistically significant at the 95% significance level.

In the Negative Binomial regression models, (k_D) ranged from (0.781 to 0.842). Although the value (0.781) is slightly lower the minimum acceptable value of (0.8), it is still considered acceptable in this study. On the other hand (k_P) ranged from (0.941 to 1.125), (R_k^2) ranged from (0.60 to 0.84), (k_{max} - maximum dispersion parameter of the group data- equal

2.765). Depending on the parameter above, (**B.11**) model is considered to represent the 'core' model for this group. Although (**B.12**) has (R_k^2) equals to that for (**B.11**), model (**B.11**) is adopted because it gives better goodness-of-fit depending on (k_D) value, which is closer to 1.

6.3 Multiple Regression Analysis

The main objective of modeling with several variables simultaneously is to permit greater insight into the relative effects of the different highway variables on crashes. Modeling was undertaken at two stages; select the 'core' model, which includes key traffic exposure variables only as explained in section (6.2) and develop the 'full' model that includes a wider range of variables. All are within the framework of Generalized Linear Models (GLM).

6.3.1 Select the 'Core' Models

The 'core' model includes exposure variables only. Apart from the fact that 'core' models have the advantage of being simple in form, they are also useful as a rough guide for identification of locations with a high frequency of crashes (black-spots) as well as for the prediction of the effect of traffic flow changes on crash occurrence (Salifu, 2004).

Three models will be chosen to represent the 'core' model depending on the data used in developing the model; Horizontal Curves Data Only (136 Horizontal Curves), Tangent Data Only (111 Tangents), and Horizontal Curves and Tangents Data Combined (136 Horizontal Curves and 111

Tangents). The ‘core’ model decides which technique is most appropriate in this study, whether Poisson or Negative Binomial regression and the form of exposure variable that will be used depending on the three approaches, which have been explained in section (6.3.1). The resulting ‘core’ model has been determined to be as shown in Table (6.4):

It should be noted that the ‘core’ model (3) selected for horizontal curves and tangents data combined represents the model relating exposure to road safety. Exposure was represented by two separate terms: section length and traffic volume. Both variables are statistically significant at the 95% significance level and are positively correlated to crash frequency as expected, indicating that the longer the section length and the larger the traffic volume, the higher the crash frequency would be.

Table 6.4 The ‘Core’ Models.

Model Form	**k_D k_P**	**k_M R_k^2**
Tangent data only (111 Tangents) 1.Cr./5years = $EXP^{(-2.123)} \times EXP^{(0.001(Section))} \times EXP^{(0.000159(Traffic))}$	*0.872* *0.933*	*0.533* *0.78*
Horizontal Curves Data Only (136 Horizontal Curves) 2.Cr./5years = $EXP^{(-2.585)} \times EXP^{(0.002(Section))} \times EXP^{(0.000147(Traffic))}$	*0.771* *0.991*	*0.877* *0.70*
Horizontal Curves and Tangents Data Combined (136 Horizontal Curves and 111 Tangents) 3.Cr./5years = $EXP^{(-16.627)} \times Section^{(1.010))} \times Traffic^{(1.167)}$	*0.842* *1.125*	*0.439* *0.84*
Note : 1.Cr. = crash; k_D = dispersion parameter depending on Scaled Deviance; k_P = dispersion parameter depending on Pearson χ^2; k_M = model dispersion parameter; R_k^2 = coefficient of determination; 2. Models statistically significant at the 95% significance level.		

6.3.2 Develop the 'Full' Models

The 'full' model included exposure variables ('Core' Model) and wider range of variables developed as detailed in Table (5.1). Although a large number of variables were collected and considered for inclusion in the 'full' model development, only variables with significant estimated parameter coefficients (less than 10%) were maintained in the model.

Three sets of models will be chosen to represent the 'full' model depending on the data used to develop the model; as in the case of 'Core' model.

6.3.2.1 Variable Selection for 'Full' Model

The availability of an overall model that reflects the varying relationships of alternative consistency measures to safety is considered a promising approach for assessing the tradeoffs between results provided by different consistency measures (Awatta, 2003). To achieve this, the development of a crash model containing as many consistency measures as are statistically significant was attempted.

The criterion for retaining a variable in the overall model was the validity of the sign of each estimated coefficient depending on the engineering judgment and previous research, in addition, each variable must be statistical significant at the 95% confidence level. It should be noted that the exposure term (the 'core' model) is basic to all models, which will be developed. The final set of variables is recommended and selected as potential variables in an overall consistency model.

The ‘core’ model was used to check the validity of the sign of each estimated coefficient for variables detailed in Table (4.1) by which all candidate variables were added to a model one by one in separate.

Crash frequency was positively correlated to V_{85} - V_D, ΔV_{85}, $\Delta \mathbf{f_R}$, VD_{LU}, AVG T and CCR, and is negatively correlated to CCR, AVG R and $\frac{\mathbf{MR}}{\mathbf{mR}}$ in the models. The resulting models show the direction of correlation as expected except Δf_R and $\frac{\mathbf{MR}}{\mathbf{mR}}$. This conclusion is valid for the three groups (tangent data only, horizontal curves data only, horizontal curves and tangents data combined).

The larger the difference between the operating speed of drivers and the design speed of a section (V_{85} - V_D), the more crashes are expected to occur. Similarly, the larger the speed reduction required when moving from one section to the next (ΔV_{85}), the more crashes are expected to occur. Also, the higher the visual demand of a driver on a roadway, the more crashes are expected to occur. For alignment index average tangent (AVG T), a larger value for this index would indicate that the road has tangent sections that are typically long, therefore, motorists’ speeds would be expected to be higher than for roads with a smaller value; more crashes are expected to occur. For alignment index CCR, a larger value for this index indicates that the road either contains a large number of curves or there are long or sharp curves in that section, more crashes are expected to occur.

For alignment index CRR, crash frequency decreases when the radius of a given section is significantly higher than the average radius, and increases when the radius is significantly lower than the average. For average radius (AVG R), a large average radius would indicate curves that are typically not sharp. Sharper curves are associated with higher crash rates than milder curves. A larger value for this index indicates a decrease crashes is expected to occur.

The larger the difference between side friction assumed and side friction demanded (Δf_R), the less crashes are expected to occur. On the contrary, after adding (Δf_R) on the 'core' models, a negative result was found, which means that the larger the (Δf_R), more crashes would occur, which is not true. It was stated that it is likely that variables may give inverse direction of correlation not due to a lack of a safety relationship, but due to limitations in data accuracy obtained. The alignment index is ratio of the maximum to minimum radius ($\frac{\mathbf{MR}}{\mathbf{mR}}$). This ratio can represent "the consistency of the design in terms of the use of similar horizontal radii along the road". As this value approaches one, a reduced crash rate may be expected. On the contrary, after adding ($\frac{\mathbf{MR}}{\mathbf{mR}}$) on the core model, a negative result was found, which means as this value approaches one, more crashes occur, which is not true. Anderson et al. (1999) argued that the use of ($\frac{\mathbf{MR}}{\mathbf{mR}}$) is not recommended as a design consistency measure due to its relatively low sensitivity to crash frequency compared to other alignment indices studied. Also Fitzpatrick et al. (2000a) recommended that a better representation of the variation of radii along a roadway may be gained by using (AVG R) as an alignment index rather than ($\frac{\mathbf{MR}}{\mathbf{mR}}$).

After the preliminary screening of alternative consistency, the following seven main variables were selected for potential inclusion in the final model: V_{85} - V_D, ΔV_{85}, VD_{LU}, AVG T, CCR, CCR, and AVG R. It is very likely that several of these consistency measures are highly correlated to each other. Multi co-linearity can greatly increase sampling variation of coefficients. diminish the models descriptive abilities, increase the problem of round off errors, and may worsen the models predictive ability, since ($\Delta V_{85,}$ $VD_{LU,}$ CCR, CCR, and AVG R) consistency measures is a function of curve radius (R). A correlation matrix was developed to check correlation between variables is shown in Table (6.5). Highly correlated variables are those with correlation values of 0.7 or higher (Persaud et al. 2001).

6.3.2.2 'Full' model Output

After the preliminary screening of alternative consistency measures depending on validity of the sign of each estimated coefficient was done, and correlation matrix of each consistency measure to others was established, the development of an overall safety-based consistency model through regression analysis was attempted. The resulting 'full' model has been determined.

Model Investigating Safety Performance of Tangents

Depending on the ‘core’ model, a model has been developed to predict the safety performance of tangents of two-lane rural highways and is shown in Table (6.6). The exposure variables (section length and traffic volume) and (V_{85} - V_D) were statistically significant.

The W.χ^2 statistics of traffic volume is higher than that of section length, meaning that traffic volume is more related to crash frequency than section length for this group of data.

Table 6.5. Pearson's Correlation Coefficients Matrix for Potential Variables Measure.

	Group 1 *Group 2*						
Variables	**V_{85} - V_D**	**ΔV_{85}**	**AVG R**	**AVG T**	**CCR**	**CRR**	**VD_{LU}**
V_{85} - V_D	*1* *1*	*-0.099* *-0.099*	*-0.097* *-0.081*	*0.216* *0.025*	*0.046* *-0.047*	*0.204* *0.018*	*-0.195* *-0.097*
ΔV85	*-0.099* *-0.099*	*1* *1*	*-0.211* *0. 761*	*0.004* *0.673*	*0.191* *0.761*	*-0.759* *0.434*	*0.867* *0.888*
AVG R	*-0.097* *-0.081*	*-0.211* *0.761*	*1* *1*	*0.501* *0.878*	*-0.887* *0.805*	*0* *0.837*	*-0.34* *0.967*
AVG T	*0.216* *0.025*	*0.004* *0.673*	*0.501* *0.878*	*1* *1*	*-0.693* *0.581*	*0* *0.717*	*-0.18* *0.825*
CCR	*0.046* *-0.047*	*0.191* *0.761*	*-0.887* *0.805*	*-0.693* *0.581*	*1* *1*	*0* *0.756*	*0.273* *0.907*
CRR	*0.204* *0.018*	*-0.759* *0.434*	*0* *0.837*	*0* *0.717*	*0* *0.756*	*1* *1*	*-0.812* *0.747*
VD_{LU}	*-0.195* *-0.097*	*0.867* *0.888*	*-0.34* *0.967*	*-0.18* *0.825*	*0.273* *0.907*	*-0.812* *.747*	*1* *1*
Note: Group 1 = Pearson's correlation matrix for horizontal curves data only; Group 2 = Pearson's correlation matrix for horizontal curves and tangents data combined.							

Table 6.6 Model for Predicting Safety Performance of Tangent Sections Only.

I. Crash / 5years = $EXP^{(-1.441)} \times EXP^{(0.001(Section))} \times EXP^{(0.00014(Traffic))} \times EXP^{(0.034(V_{85} - V_D))}$							
Variable	**Parameter**	**Significant**	**W.χ2**	k_D	k_P	k_M	R_k^2
Intercept	β_1	*< 0.0001*	*12.658*	*0.887*	*0.948*	*0.432*	*0.82*
Section	β_2	*0.002*	*9.852*				
Traffic	β_3	*< 0.0001*	*29.075*				
$V_{85} - V_D$	β_4	*0.003*	*8.588*				
Note : 1. k_{max} (maximum dispersion parameter of the group data equal 2.412) 2. Model statistically significant at the 95% significance level.							

Models Investigating Safety Performance of Horizontal Curves

Depending on the 'core' model, a model has been developed to predict the safety performance of tangents of two-lane rural highways. Three sets of models were developed taking into consideration ΔV_{85}, CRR , and VD_{LU} variables and were statistically significant in separate models. The exposure variables (section length and traffic volume), (V_{85} - V_D), and ΔV_{85} were statistically significant; the model is shown in Table (6.7).

Table 6.7 Model for Predicting Safety Performance of Horizontal Curves Only Depending on V_{85} - V_D and ΔV_{85}.

II. Crash / 5years = $EXP^{(-2.094)} \times EXP^{(0.001(Section))} \times EXP^{(0.000132(Traffic))} \times EXP^{(0.054(V_{85} - V_D))} \times EXP^{(0.076(\Delta V_{85}))}$							
Variable	**Parameter**	**Significant**	**W.χ2**	k_D	k_P	k_M	R_k^2
Intercept	β_1	*< 0.0001*	*21.936*	*0.794*	*0.956*	*0.518*	*0.82*
Section	β_2	*0.001*	*10.871*				
Traffic	β_3	*< 0.0001*	*14.484*				
$\mathbf{V_{85} - V_D}$	β_4	*0.001*	*11.487*				
$\mathbf{\Delta V_{85}}$	β_5	*0.043*	*4.085*				
Note: 1. k_{max} (maximum dispersion parameter of the group data equal 2.892) 2. Model statistically significant at the 95% significance level.							

Also, the exposure variables (section length and traffic volume), (V_{85} - V_D), and CRR were statistically significant; the model is shown in Table (6.8).

Table 6.8 Model for Predicting Safety Performance of Horizontal Curves Only Depending on V_{85} - V_D and CRR.

III. Crash / 5years = $EXP^{(-1.006)} \times EXP^{(0.002(Section))} \times EXP^{(0.000130(Traffic))} \times EXP^{(0.054(V_{85} - V_D))} \times EXP^{(-0.682(CRR))}$							
Variable	**Parameter**	**Significant**	**W.χ2**	**k_D**	**k_P**	**k_M**	**R_k^2**
Intercept	β_1	*0.093*	*2.813*	*0.806*	*0.988*	*0.488*	*0.83*
Section	β_2	*< 0.0001*	*25.186*				
Traffic	β_3	*< 0.0001*	*14.756*				
V_{85} - V_D	β_4	*0.001*	*11.257*				
CRR	β_5	*0.099*	*2.728*				
Note: 1. k_{max} (maximum dispersion parameter of the group data equal 2.892) 2. Model statistically significant at the 90% significance level.							

Also, the exposure variables (section length and traffic volume), (V_{85} - V_D), and VD_{LU} were statistically significant; the model is shown in Table (6.9).

Table 6.9 Model for Predicting Safety Performance of Horizontal Curves Only Depending on V_{85} - V_D and VD_{LF}.

IV. Crash / 5years = $EXP^{(-3.796)} \times EXP^{(0.002(Section))} \times EXP^{(0.000134(Traffic))} \times EXP^{(0.053(V_{85} - V_D))} \times EXP^{(4.298(VD_{LF}))}$							
Variable	**Parameter**	**Significant**	**W.χ2**	**k_D**	**k_P**	**k_M**	**R_k^2**
Intercept	β_1	*< 0.0001*	*12.346*	*0.782*	*0.921*	*0.588*	*0.80*
Section	β_2	*< 0.0001*	*23.547*				
Traffic	β_3	*< 0.0001*	*15.708*				
V_{85} - V_D	β_4	*0.002*	*9.730*				
VD_{LU}	β_5	*0.047*	*3.963*				
Note: 1. k_{max} (maximum dispersion parameter of the group data equal 2.892) 2. Model statistically significant at the 95% significance level.							

Quantitative Relationship between Geometric Design Consistency and Road Safety.

A quantitative relationship between design consistency and crash occurrence is an important tool in the evaluation of the impact of design consistency on road safety (Joanne, 2002).

The models presented before (I, II, III, and IV) reveal the relationship between significant consistency measures to road safety, whether based on tangent data only or horizontal data only.

Therefore, one model relating as many design consistency measures as were statistically significant to road safety to improve the model prediction accuracy are developed depending on tangent and horizontal data combined, which are presented in Table (6.11). Table (6.10) presents a summary of variables used in developing model "V".

Exposure was represented in two separate terms (section and traffic) as this approach fits the data better. Model "V" was developed based on both horizontal curves and tangents data combined, and three design consistency measures are statistically significant (V_{85} - V_D, ΔV_{85}, and CRR). It should be noted that model "V" was applicable to both horizontal curves and tangents with the provision of the H variable (dummy variable as in Table 6.11).

Table 6.10. Summary for Variables Used in Developing Model "V".

Variable	Details
Sections length	90.46 km
Number of Sections	247 sections
Horizontal Curves Sections length	34.826 km
Number of Horizontal Curves Sections	136 sections
Tangent Sections length	55.220 km
Number of Tangent Sections	111 sections
Traffic (volume)	(2927 - 15160) vehicles/ day
V_{85} - V_D	((-48.60) - (11.29)) km/hour
ΔV_{85}	(0 - 20.7) km/hour
CRR	(0 - 2.02)
No. of Crashes	204 crashes in 5 years
No. of Crashes on Horizontal Curve	83 crashes in 5 years
No. of Crashes on Tangents	121 crashes in 5 years

Furthermore, from the (k_D, $k_{P,}$ and R_k^2) goodness of fit for model III, it can be concluded that the model fits its data better than models I, II fitting their tangent and horizontal curves data, respectively. In conclusion, because model "V" is applicable to both horizontal curves and tangents and it demonstrates a relatively better fit to its data, model "V" is recommended for use in future evaluation of the impact of design consistency on road safety.

Table 6.11 Model for Predicting Safety Performance of Tangent and Horizontal Curves Combined.

V. Crash / 5years $= EXP^{(-14.070)} \times Section^{(0.851)} \times Traffic^{(1.034)} \times EXP^{(0.037(V_{85} - V_D))} \times EXP^{\{H\ (0.052\ \Delta V_{85}) - (0.398\ (CRR))\}}$

Where: **H = 0 for tangents or H = 1 for horizontal curves.**

Variable	Parameter	Significant	W.χ2	k_D	k_P	k_M	R_k^2
Intercept	β_1	*< 0.0001*	*71.285*	*0.847*	*1.050*	*0.307*	*0.89*
Section	β_2	*< 0.0001*	*56.439*				
Traffic	β_3	*< 0.0001*	*32.386*				
$V_{85} - V_D$	β_4	*< 0.0001*	*14.426*				
ΔV_{85}	β_5	*0.013*	*6.142*				
CRR	β_6	*0.047*	*3.951*				

Note : 1. k_{max} (maximum dispersion parameter of the group data equal 2.765)

2. Model statistically significant at the 95% significance level.

3. Units: Section= meter; Traffic= vehicles/day; $V_{85} - V_D$= km/hour; ΔV_{85}= km/hour; and CRR= unitless.

Chapter Seven

Modeling Validation

To evaluate the accuracy of the West-Bank crash prediction models (CPM) developed, a validation step was performed. The goal of this validation step is not only to compare the accuracy of different models developed, but also to evaluate the overall accuracy of CPMs for use on rural two-lane highways in the West-Bank.

The necessary data for model validation were identical to the data used in modeling development. Therefore, sources and techniques for gathering data for modeling were used for validation.

Figure (7.1) shows the location of the highway segments for validation in the West Bank, which are : Jerusalem to Hebron, Salfit to Za'tara, and Bethlehem Governorate Roads. Total length of highways used for validation is 21.4 km.

7.1 Validation of Crash Prediction Models

Validation can be thought of as a requirement to demonstrate that a model is appropriate, meaningful, and useful for the purpose for which it is intended. Validation exercises are often associated with assessment of the prediction ability of a statistical model (Pedhazur and Schmelkin, 2013).

Figure 7.1. Location of the Highway Segments for Validation in the West Bank

However, it is possible for a model to predict an underlying data-generating process adequately but fails to illuminate and explain the nature of the underlying process. Washington et al. (2005) explained a model validation which was broken down into two distinct aspects: internal validity and external validity.

Internal model validity, which has been explained in chapter (5), was concerned with the ability of the crash models to explain the underlying phenomenon and focused on the logical defensibility, whereas external model validity is concerned with the ability of the models to predict crashes over time and space. The external validation tools applied are described here.

7.1.1 The External Validation

Three sets of external validation activities were done:

1. Validation of the crash prediction algorithm. This validation activity is used to validate the crash prediction algorithms as a whole, which is considered to be important, provides quantitative evidence of how well it is predicting crashes, and provides comparisons between models performance.

2. Validation of the models against additional years of crash data for the same sections used in the model development. This validation activity is used to assess the models ability to forecast crashes across time and determining the model's temporal capability and stability; meaning that the

effect of time or covariates that are influenced by time either is not important or, if it is important, is included in the model in some relevant variable expression.

3. Validation of the models against West-Bank data. This validation activity assesses the models' ability to forecast crashes across space; meaning that assessing the model's ability to forecast crash on sections whose data were not used in model development.

External validation is focused on the goodness of fit (GOF) of statistical models. Several GOF measures were used to assess model performance in this study. It is important to note that an objective assessment of the predictive performance of a particular model can be made only through the evaluation of several GOF criteria. The GOF measures used to conduct external model validation include the following:

1. Pearson's product moment correlation coefficients between observed and predicted crash frequencies. Pearson's product moment correlation coefficient, usually denoted by r, is one example of a correlation coefficient. It is a measure of the linear association between two variables, Y_1 and Y_2 that have been measured on interval or ratio scales and is given by

$$r_{12} = \sum (Y_{i1} - \square_1)(Y_{i2} - \square_2) \div [\sum (Y_{i1} - \square_1)^2 \sum (Y_{i2} - \square_2)^2]^{1/2} \quad (7.1)$$

Where □ is the mean of Y_i observations. Theoretically, a model that predicts observed data perfectly will produce a straight-line plot between the observed and the predicted values, a correlation coefficient of exactly1.

2. Mean prediction bias (MPB). MPB provides a measure of the magnitude and direction of the average model bias in comparison with validation data. The smaller the absolute value of average prediction bias is, the better the model does at predicting the observed data. A positive MPB indicates that a model over-predicts crashes, on average, while a negative MPB indicates systematic under-prediction of crashes, on average. MPB is given by

$$\text{MPB} = \sum_{i=1}^{n} (\hat{Y}i - Yi) \div \text{n} \tag{7.2}$$

Where n is the validation data sample size, and $\hat{Y}_i$ is the fitted value of Y_i.

3. Mean absolute deviation (MAD). MAD provides a measure of the average miss-prediction of the model. It differs from MPB in that positive and negative prediction errors do not cancel. A value close to 0 suggests that, on average, the model predicts the observed data well. MAD is given by

$$\text{MAD} = \sum_{i=1}^{n} |(\hat{Y}i - Yi)| \div \text{n} \tag{7.3}$$

Where n is the validation data sample size.

4. Mean squared prediction error (MSPE) and mean squared error (MSE). MSPE is the sum of the squared differences between observed and predicted crashes frequencies divided by sample size. MSPE is typically

used to assess the error associated with a validation or external data set and is given by

$$\text{MSPE} = \sum_{i=1}^{n}(\hat{Y}i - Yi)^2 \div n_2 \qquad (7.4)$$

where n_2 is the validation data sample size. MSE is the sum of the squared differences between observed and predicted crashes frequencies divided by the sample size minus the number of model parameters:.

$$\text{MSE} = \sum_{i=1}^{n}(\hat{Y}i - Yi)^2 \div (n_2 - p) \qquad (7.5)$$

where n_1 is the estimation data sample size and p is the number of degrees of freedom. A comparison of MSPE and MSE reveals potential over or under fitting of the models to the estimation data. An MSPE that is higher than MSE may indicate that the models may have been over-fit to the estimation data and that some of the observed relationships may have been spurious instead of real. This finding could also indicate that important variables were omitted from the model or the model was miss-specified.

To normalize the GOF measures to compensate for the different numbers of years associated with different data sets, GOF measures computed on a per-year basis. For MPB and MAD per year, MPB and MAD were divided by the number of years. However, because MSPE and MSE are the mean values of the squared errors, MSPE and MSE are divided by the square of the number of years to calculate MSPE and MSE per year, which resulted in a fair comparison of predictions based on different numbers of years. This correction is needed because the models developed predict crashes per unit of time. Because the variance in crashes is a function of the mean, a larger time period results in both a larger number of crashes and a larger variance in crashes, all else being equal. Computation of GOF statistics on a per year basis normalized comparisons across models with different numbers of years of observation.

When calculating results that were aiming for known values, the percent error formula is useful tool for determining the precision of the calculations. The formula is given by:

$$\%_{error} = |(\sum_{i=1}^{n} \hat{Y}p - \sum_{i=1}^{n} Yo) \div Yo| \times 100 \quad (7.6)$$

Where ($\hat{Y}p$) was the predicted crashes frequency and (Yo) was the observed crashes frequency for n sample size (number of sites). A percentage very close to zero means you are very close to your targeted value, which is good.

Several goodness-of-fit (GOF) statistics to assess model fit to validation data were employed. Assessment and comparisons between models, however, were generally subjective. Washington et al. (2005) suggests in the documentation to follow, the terms “serious,” “moderate,” and “marginal” denote subjective evaluations of GOF for assessment and comparisons between models. Serious (high) differences in GOF are suggestive of noteworthy or significant model deficiencies. Moderate (medium) differences in GOF suggest cases where models could be improved, but improvements might be difficult to obtain. Marginal (low) differences in GOF are thought to be negligible and are potentially explained by random fluctuations in the observed data.

External Validity: Predictive Ability of Model Algorithm

For Model I, in terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed (0.46) value which means moderate association between predicted and observed crashes frequency. MSE per $year^2$ value (1.96) indicated serious variation between predicted and observed crash frequency. MPB per year value (0.17) indicates moderate model over-predicting crashes, on average. MAD per year value (0.3) indicates serious miss-prediction of the model, on average. "$\%_{error}$" value (77%) indicates unacceptable precision of the calculations.

For Model II, in terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed (0.66) value, which means moderate association between predicted and observed crash frequency. MSE per $year^2$ value (0.05) indicated marginal variation between predicted and observed crashes frequency. MPB per year value (-0.01) indicates marginal model under-predicting crashes, on average. MAD per year value (0.12) indicates moderate miss-prediction of the model, on average. "$\%_{error}$" value (10%) indicates high precision of the calculations.

For Model III, in terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed (0.69) value, which means moderate to high association between predicted and observed crash frequency. MSE per year^2 value (0.04) indicates marginal variation between predicted and observed crashes frequency. MPB per year value (0) indicates model predicts future crashes well. MAD per year value (0.09) indicates marginal miss-prediction of the model, on average. "$\%_{error}$" value (2%) indicates high precision of the calculations.

For Model IV, in terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed (0.64) value, which means moderate association between predicted and observed crashes frequency. MSE per year^2 value (0.05) indicates marginal variation between predicted and observed crash frequency. MPB per year value (0) indicates model predicts future crashes well. MAD per year value (0.13) indicates moderate miss-prediction of the model, on average. "$\%_{error}$" value (2%) indicates high precision of the calculations.

For Model V, in terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed (0.77) value, which means high association between predicted and observed crash frequency. MSE per year^2 value (0.05) indicates marginal variation between predicted and observed crash frequency. MPB per year value (0) indicates model predicts future crashes well. MAD per year value (0.14) indicates moderate miss-prediction of the model, on average. "$\%_{error}$" value (1%) indicates high precision of the calculations.

External Validity: Predictive Ability across Time

For Model I, a comparison of the parameter estimates is shown in Table (7.1) for the original model and the one based on the additional years (2003-2007) of data. In terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed a marginal decline when calculated on the basis of the additional years data. A comparison of MSE per $year^2$ and MSPE per $year^2$ suggested a marginal improvement in the fit to the later data. Similarly, the MPB per year showed marginal increases in the lack of fit, and the MAD per year showed a marginal improvement in the fit to the later data. "$\%_{error}$" value (95%) indicates unacceptable precision of the calculations.

Table 7.1 Validation Statistics for Models I to V Total Section-Related Accidents.

Measure	Model No.														
	I			II			III			IV			V		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
No. of sites	*111*	*111*	*25*	*136*	*136*	*48*	*136*	*136*	*48*	*136*	*136*	*48*	*247*	*247*	*73*
P. Product	*0.46*	*0.43*	*0.79*	*0.66*	*0.64*	*0.40*	*0.69*	*.68*	*0.46*	*.64*	*.63*	*.52*	*0.77*	*.76*	*.73*
MPB / Year	*0.17*	*0.18*	*-0.03*	*-0.01*	*-0.04*	*-0.02*	*0*	*-0.04*	*-0.02*	*0*	*-0.04*	*-0.02*	*0*	*0.03*	*-0.02*
MAD/ Year	*0.3*	*0.29*	*.18*	*0.12*	*0.09*	*0.11*	*.12*	*0.09*	*0.11*	*.13*	*0.09*	*0.1*	*0.14*	*0.12*	*0.14*
MSE/ Year^2	*1.96*			*0.05*			*0.04*			*0.05*			*0.05*		
MSPE/ Year^2		*1.75*	*0.12*		*0.04*	*0.03*		*0.03*	*0.03*		*0.03*	*0.03*		*0.04*	*0.05*
$\%_{error}$	*77%*	*95%*	*12%*	*10%*	*7%*	*16%*	*2%*	*17%*	*13%*	*2%*	*17%*	*17%*	*1%*	*20%*	*12%*

NOTE: A = original data (2008 to 2012); B = additional years of data (2003 to 2007); C = West Bank data (2008 to 2012).

For Model II, III, IV, and V a comparison of the parameter estimates is shown in Table (7.1) for the original model and the additional years of data. In terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed a marginal decline when calculated on the basis of the additional years data. A comparison of MSE per $year^2$ and MSPE per $year^2$ suggests a marginal improvement in the fit to the later data. Similarly, the MPB per year and the MAD per year showed a marginal improvement in the fit to the later data. "$\%_{error}$" value (7%, 17%, 17%, and 20%) for Model II, III, IV, and V respectively, indicates moderate to high precision of the calculations based on a relative scale.

External Validity: Predictive Ability Across Space

For Model I, a comparison of the parameter estimates is shown in Table (7.1) for the original model and the additional years data. In terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed a serious ascent when calculated on the basis of the additional years data. A comparison of MSE per $year^2$ and MSPE per $year^2$ suggested a serious improvement in the fit to the later data. Similarly, the MPB per year and the MAD per year showed a serious improvement in the fit to the later data. "$\%_{error}$" value (13%) indicates moderate precision of the calculations.

For Model II, III, IV, and V a comparison of the parameter estimates is shown in Table (7.1) for the original model and the additional years of data. In terms of the GOF statistics in Table (7.1), the linear correlation coefficient showed a marginal decline when calculated on the basis of the additional years data. A comparison of MSE per $year^2$ and MSPE per $year^2$ suggested a marginal improvement in the fit to the later data. Similarly, the MPB per year and the MAD per year showed a marginal improvement in the fit to the later data. "$\%_{error}$" value (17%, 14%, 18%, and 13%) for Model II, III, IV, and V, respectively, indicates moderate precision of the calculations.

Overall External Model Validation Results

Model I had deficiencies ranging from moderate to serious. The model performed well across space with the associated $\%_{error}$, but was seriously deficient in model algorithm validation, across time, and linear correlation coefficient with the associated "$\%_{error}$". The reason for this is due to the presence of significant long sections in data used to develop the model longer than 2 km, which increases the effect of section length on the predicted frequency of crashes while the data used to validate the model across space had maximum section's length of 1.4 km. This problem was overcome in developing model V, which had larger number of sections used and more variables participate in the model development, which reduces the effect of the section length.

Model II, III, and IV had fairly mixed validation results. The models performed well across space, time, validation of model algorithm, and $\%_{error}$ with moderate linear correlation coefficient. Although Model II, III, and IV had fairly (GOF) parameters but the weakness point was predicting crash frequency for the horizontal curves only, which was compensated in Model V, which was developed to predict crash frequency on both horizontal curves and tangents.

Model V has good mixed validation results. The model performed well across space, time, validation of model algorithm, and "$\%_{error}$" with high linear correlation coefficient.

In summary, Model V is recommended for use in future evaluation of the impact of design consistency on road safety.

Chapter Eight

Modeling Application

The overall purpose of investigating the relationship between geometric design consistency and road safety is to identify inconsistent sections of an alignment so they may be treated to improve safety. The crash prediction models developed in this study can be used to identify inconsistent sections and to estimate the safety benefits of improving design consistency. Joanne (2002) suggested three applications, which make use of the. The first application illustrates how to evaluate the safety performance of two-lane rural highways. The second application compares the results of crash prediction models, which explicitly consider design consistency to those which do not. The third application presents a systematic approach to identify inconsistent locations.

All applications use two fictitious alignments designed with intended inconsistencies by Hassan et al. (2001). The alignments are denoted A-I and A-II with design speed of 70 and 100 km/h, respectively. The geometric design data are shown in Table (8.1) and the planes are shown in Figure (8.1). All alignments are assumed to have constant lane width, constant maximum superelevation rate, and no intersections. An average annual daily traffic of 17500 vehicles per day is assumed for all applications. Each alignment has eight horizontal curves (C1-C8), which are separated by tangents and are described below:

Table 8.1. Horizontal Alignment Data of Two Fictitious Alignments (Hassan et al, 2001).

	Alignments A-I (V_D = 70 km/h)			Alignments A-II (V_D = 100 km/h)		
Element	**L (m)**	**R (m)**	**L_S (m)**	**L (m)**	**R (m)**	**L_S (m)**
T1	*500*	—	—	*464.1*	—	—
C1	*424.8*	*600*	*60*	*391.2*	*600*	*60*
T2	*300*	—	—	*177.4*	—	—
C2	*174.5*	*190*	*70*	*394.1*	*440*	*80*
T3	*300*	—	—	*110.1*	—	—
C3	*137.9*	*190*	*70*	*334*	*440*	*80*
T4	*464.4*	—	—	*292.7*	—	—
C4-1	*150*	*200*	*0*	*300*	*440*	*0*
C4-2	*250*	*400*	*0*	*500*	*660*	*0*
T5	*1402.4*	—	—	*1000.2*	—	—
C5	*508.3*	*450*	*40*	*709.7*	*600*	*60*
T6	*611.4*	—	—	*350.3*	—	—
C6	*891.2*	*1000*	*0*	*765.2*	*1000*	*0*
T7	*380.8*	—	—	*374*	—	—
C7	*130*	*190*	*70*	*234*	*440*	*80*
T8	*277.4*	—	—	*253.9*	—	—
C8	*120.3*	*200*	*60*	*77.7*	*200*	*60*
T9	*500*	—	—	*502.4*	—	—

Note: V_D = design speed; L = length of circular curve or tangent; R = radius of horizontal curve; and L_S = length of spiral curve.

- C_1 has a design speed of 100 km/h and C_8 of 70 km/h; both allow for the testing of the effects of transition on successive highway sections with different design speeds.
- C_2 and C_3 are reverse curves separated by a short tangent.

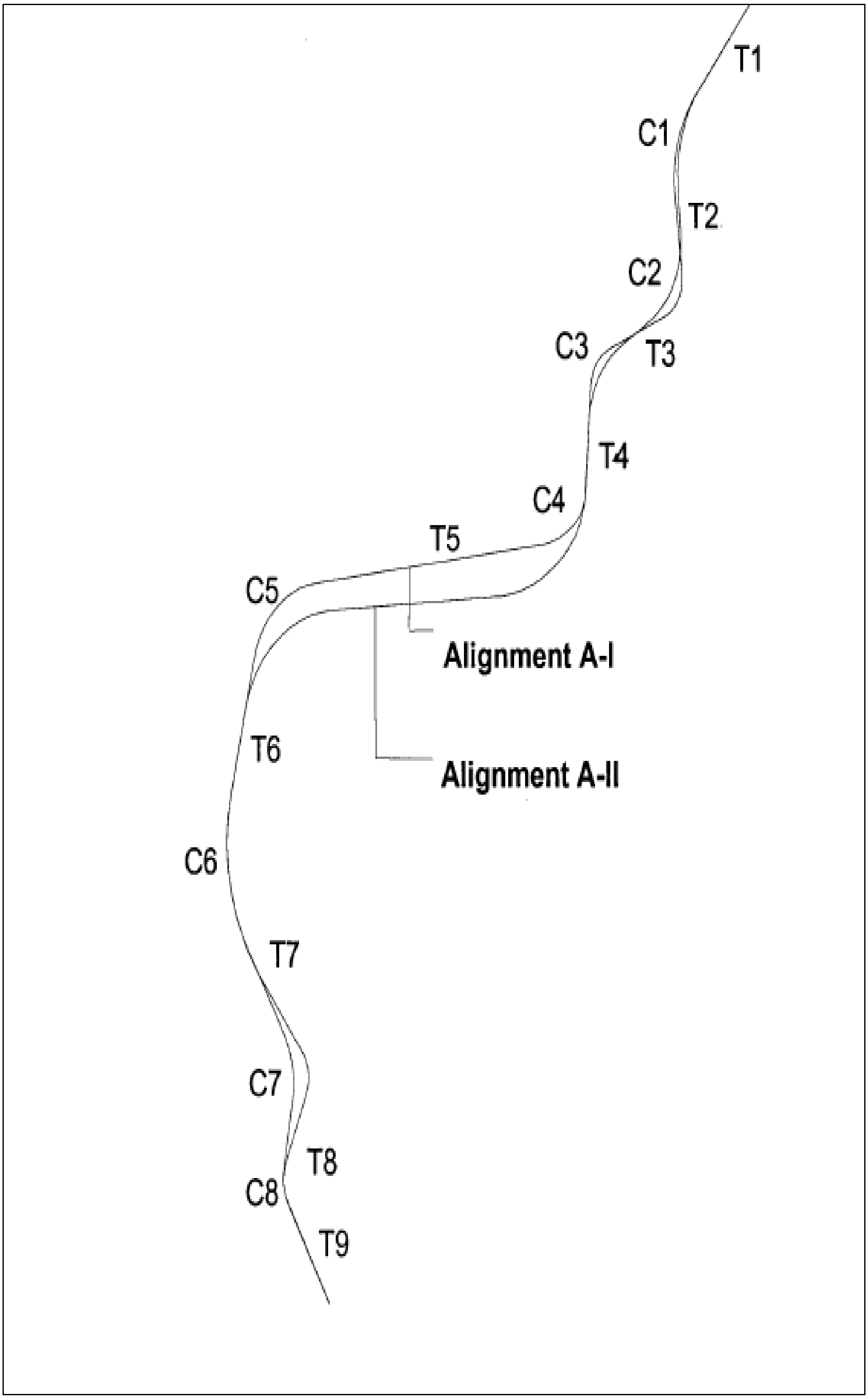

Figure 8.1. Plans of the Two Fictitious Alignments (Hassan et al, 2001).

- C_4 is a compound curve made up of two curves.
- C_5 is preceded by a long tangent T_5.
- C_6 is a long simple curve with a radius greater than the minimum value required.
- C_7 has a higher design speed than C_8 on alignment A-II but not on A-I.

In addition, the applications use model V developed in this study to represent crash prediction models, which incorporate design consistency measures as explanatory variables. The model has been modified slightly to predict crash frequency for a period of one year instead of five years, as shown in Table (8.2) below:

Table 8.2. Model (V) Crash Prediction Frequency per-Year.

$\text{Cr./years} = \left\{ EXP^{(-14.070)} \times L^{(0.851)} \times V^{(1.034)} \times EXP^{(0.037(V_{85} - V_D))} \times EXP^{\{H\ (0.052\ \Delta V_{85} - 0.398\ (CRR))\}} \right\} \div 5$
Note : Cr./yr = predicted crash frequency per year (coll./yr); L = length of section (m), V = average annual daily traffic (veh/day); H = dummy variable (H = 0 for tangents or H = 1 for horizontal curves); V_{85}-V_D = the difference between operating speed and design speed; ΔV_{85} = speed reduction between the approach tangent and the horizontal curve (km/h); and CRR = ratio of individual curve radius to average radius.

8.1 Model Variables Computation

The necessary data for fictitious alignments are identical to the data necessary for modeling development and validation. Therefore, all of the same techniques for gathering data for modeling and validation were used as explained in section (5.3), except the 85th percentile operating speed used in the difference between operating speed and design speed (V_{85} - V_D) variable which was computed using real time traffic speed data obtained from Google Earth maps for modeling development and validation . The 85th percentile operating speed on tangent sections for model application was calculated based on Al-Masaeid et al. (1995) model to predict operating speed on tangent sections shown in Equation (8.1).

$$V_{85} = 105.47 - (3792/L_T) - 0.27\times(DC_1\times DC_2);\ R^2 = 0.80 \qquad (8.1)$$

Where:

V_{85} = 85th percentile operating speed (km/h);

L_T = length of non-independent tangent (m); and

DC_1 and DC_2 = degree of successive curves for the preceding and succeeding curves respectively/degrees/expressed in degree per 30m.

Based on Lamm et al. (1999), tangents longer than 180m are considered independent, tangents less than 180 m in length are considered non-independent tangent sections. It should be noted that the model above is applicable on independent tangent. The non-independent tangent sections operating speed was calculated as average of operating speed of the preceding and succeeding horizontal curves.

On the other hand, the 85th percentile operating speed on horizontal curve sections for model application were calculated based on Kanellaidis et al.

(1990) model to predict operating speed on horizontal curve sections shown in Equation (7.2).

$$V_{85} = 32.20 + 0.839V_D + (2226.9 \div R) - (533.6 \div \sqrt{R}) \quad (8.2)$$

Where:

V_{85} = 85th percentile operating speed (km/h);

V_D = design speed (km/h); and

R = radius of the curve (m).

8.2 Evaluating the Safety Performance of Two-Lane Rural Highways

To illustrate how the crash prediction models developed in this study can be used to evaluate the safety performance of two-lane rural highways, model (V) has been applied on the two fictitious alignments. The results are shown in Figure (8.2) below.

The total predicted crash frequency of alignment A-I is 20.8 crashes/year, while that of alignment A-II is 9 crashes/year. Thus, alignment A-II is a safer alternative than alignment A-I.

In other situations, the alignment alternative suggested may have approximate predicted crash frequency. The role of designers is to perform a benefit to cost analysis to determine which alternative has higher safety benefits and reasonable economic costs.

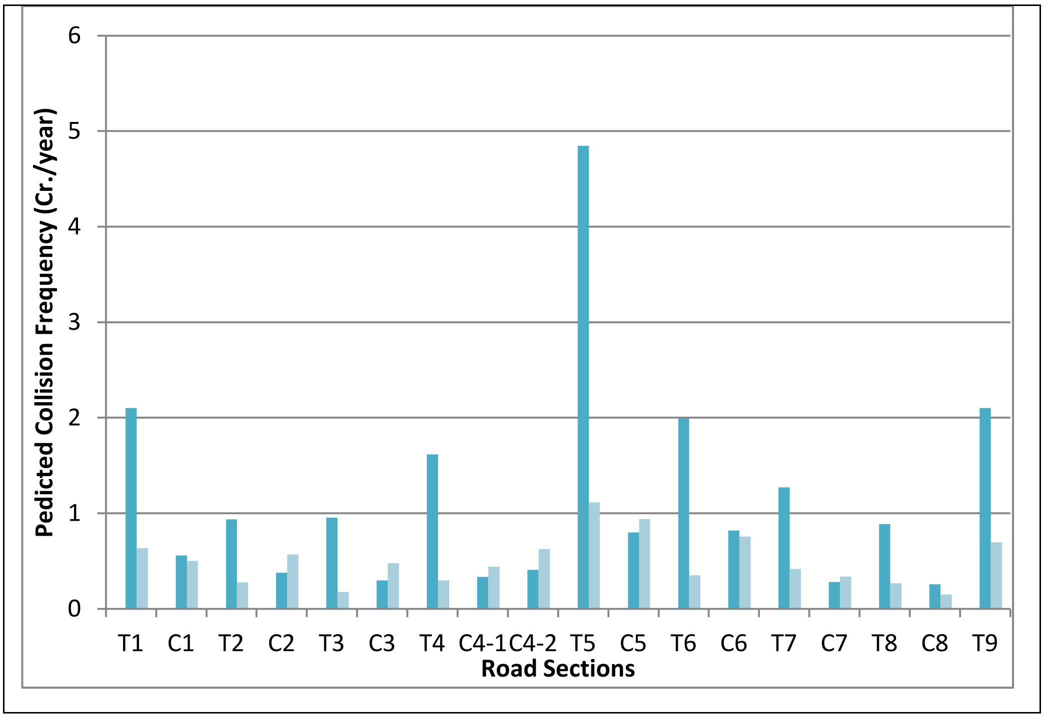

Figure 8.2. Predicted Crash Frequency of the Two Fictitious Alignments Based on Model (V).

8.3 Comparing the Results of Two Different Types of Crash Prediction Models in Evaluating Road Safety

The objective of the second application is to compare the results of two different types of CPM. Model (V), which represents the first type while the model incorporated in the crash prediction module of the Highway Safety Manual (HSM, 2009) represents the second type.

HSM developed predictive model for predicting average crash frequency for base conditions on a particular rural two-lane, two-way roadway segment, and is presented in Equation (8.3) in English units. The effects of geometric design features are incorporated through the crash modification factor (CMF_h) shown in Equation (8.4).

$$N_{br} = ADT \times 365 \times 10^{-6} \times L \times Exp^{(-0.312)} \quad (8.3)$$

Where:

N_{br} = predicted number of total crashes per year for base case (coll./yr),

ADT = average daily traffic (veh/day),

L = length of section (mi), and

EXP = Exponential function, e = 2.718282.

The N_{br} for roadway segments on rural two-lane highways were applicable to the ADT range from zero to 17,800 vehicles per day. Application to sites with ADTs substantially outside this range may not provide reliable results.

The base condition for horizontal alignments is a tangent roadway segment. A CMF_h has been developed to represent the manner in which crash experience on curved alignments differ from of tangents. This CMF_h applies to total roadway segment crashes. The CMF_h for horizontal curvature is in the form of an equation taking into consideration the length, radius, and presence or absence of spiral transitions on horizontal curves, which yields a factor as determined in Equation (8.4) in English units (HSM, 2009).

$$CMF_H = (1.55L_c + \frac{80.2}{R} - 0.012S) \div 1.55L_c \quad (8.4)$$

Where:

CMF_H = crash modification factor for horizontal curves;

L_c = length of horizontal curve (mi);

R = radius of horizontal curve (ft); and

S = 1 if spiral transition curve is present, 0 if spiral transition curve is not present.

In applying Equation (8.4), if the radius of curvature (R) is less than 100-ft, R is set to 100 ft. If the length of the horizontal curve (L_c) is less than 100 feet, L_c is set to 100 ft. CMF_h Values are computed separately for each horizontal curve set (a curve set consists of series of consecutive curve elements). For each individual curve, the value L_c is the total length of the compound curve set and the value of R is the radius of the individual curve. If the value of CMF_h is less than 1.00, the value of CMF_h is set equal to 1.00.

Due to the simplicity of the fictitious alignments, predicted number of total crashes per year on a section was determined using Equation (8.5).

$$N_{rs} = N_{br} \times CMF_h \tag{8.5}$$

Where: N_{rs} = predicted number of total crashes per year on a section (coll./yr),

Both models have been applied to the two fictitious alignments, the results of which are discussed in the following sections.

8.3.1 Qualitative Analysis

The profile generated by model (V) and that by the model incorporated in the crashes prediction module of HSM are shown in Figure (8.2) and Figure (8.3), respectively for an average annual daily traffic of 17,500 vehicles per day. Although the general outlook of the two profiles are somewhat similar, it should be noted that the HSM module has not been calibrated for West-Bank conditions, thus causing differences in the magnitude of the predicted crash frequency by the two models.

Nonetheless, the comparison is performed qualitatively as it is the difference in the predicted crash frequency between sections, rather than the value of an individual section. The results of the comparison are discussed below.

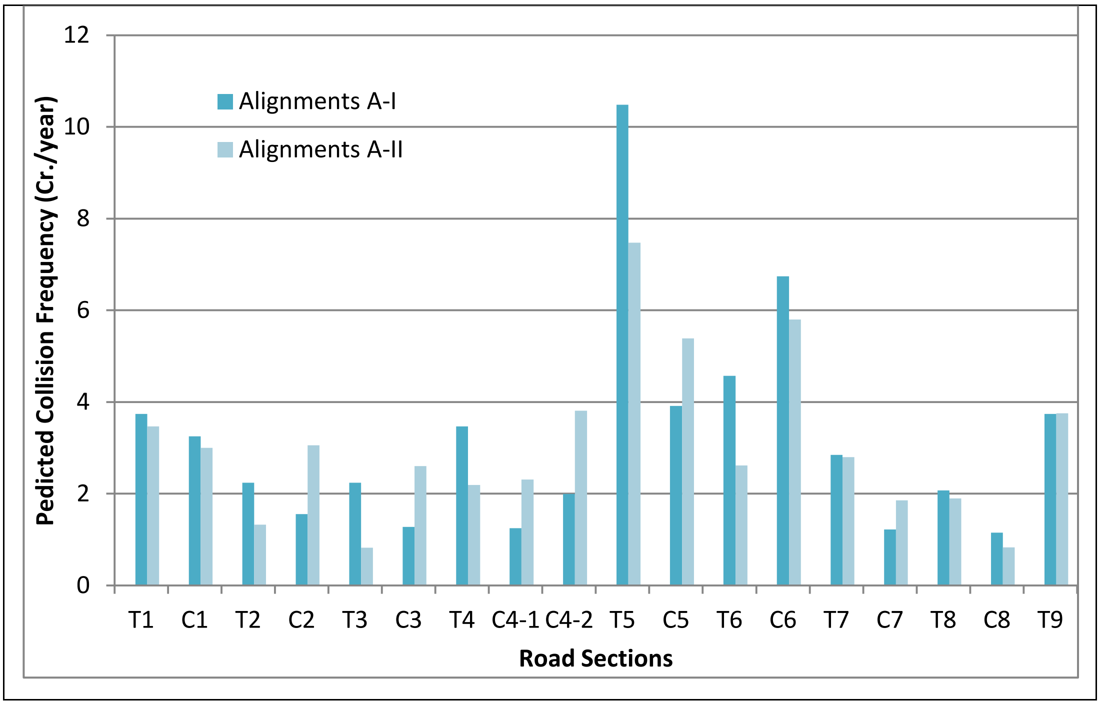

Figure 8.3. Predicted Crash Frequency of the Two Fictitious Alignments Based on the Algorithm in HSM.

Both profiles show a considerable decrease from C_l to C_2, with the decrease being especially significant for alignment A-I, while both profiles show equality from C_1 to C_2 for alignment A-II.

Both profiles show a slight decrease from C_2 to C_3 and similarly from C_3 to C_{4-1}. In addition, the steady decrease extends to C_{4-1}. Both models predict increase from C_{4-1} to C_{4-2}.From C_{4-2} to C_5, both profiles show an increase in crash potential. Model V profile show a considerable decrease from C_5 to C_6, with the decrease being especially significant for alignment A-II, while show equality from C_5 to C_6 for alignment A-I. HSM model profile show a considerable increase from C_5 to C_6, with the increase being especially significant for alignment A-I, while show slightly increase from C_5 to C_6 for alignment A-II. Also, both models predict that the crash potential at C_7 decreased after C_6. Finally, both models show a decrease from C_7 to C_8 on A-II.

Both profiles show a considerable similarity in predicting potential crashes, but the ability to identify inconsistent sections that may be distinguished, which will be discussed in the following section.

8.4 A Systematic Approach to Identify Geometric Design Inconsistencies

Although inconsistent sections may be identified by their relatively higher crash frequency, the designer may find it difficult to decide how high is high enough. The safety-consistency factor (SCF) proposed herein is a practical approach to systematically identify geometrically inconsistent sections using crash prediction models (Hassan et al, 2001). . It indicates how much the predicted crash frequency of a section differs from that of a tangent with identical section length and traffic volume. It is also easy to compute. First, estimate the crash frequency of the section using model

(V). Then, assuming that the section is converted to a tangent, predict its crash frequency. The ratio of the first crash frequency to the second is the safety-consistency factor. Thus, the greater the safety-consistency factor is, the greater the predicted crash frequency will be. A threshold value of the safety-consistency factor should be established for a systematic identification.

8.4.1 Establishing the Threshold Value of the Safety-Consistency Factor

To illustrate how the threshold value of the SCF can be obtained, the two-lane rural highway used for model development is used again. The factor is computed for each of the 136 horizontal curves of this highway, and a cumulative distribution of the factor is plotted in Figure (8.4). The distribution has an average value of 1.034 and a variance of 0.147. To establish the threshold value, the 85^{th} percentile value is selected (Joanne, 2002). Thus, sections of the alignment with a safety-consistency factor greater than (1.37) can be identified as geometrically inconsistent and should be investigated.

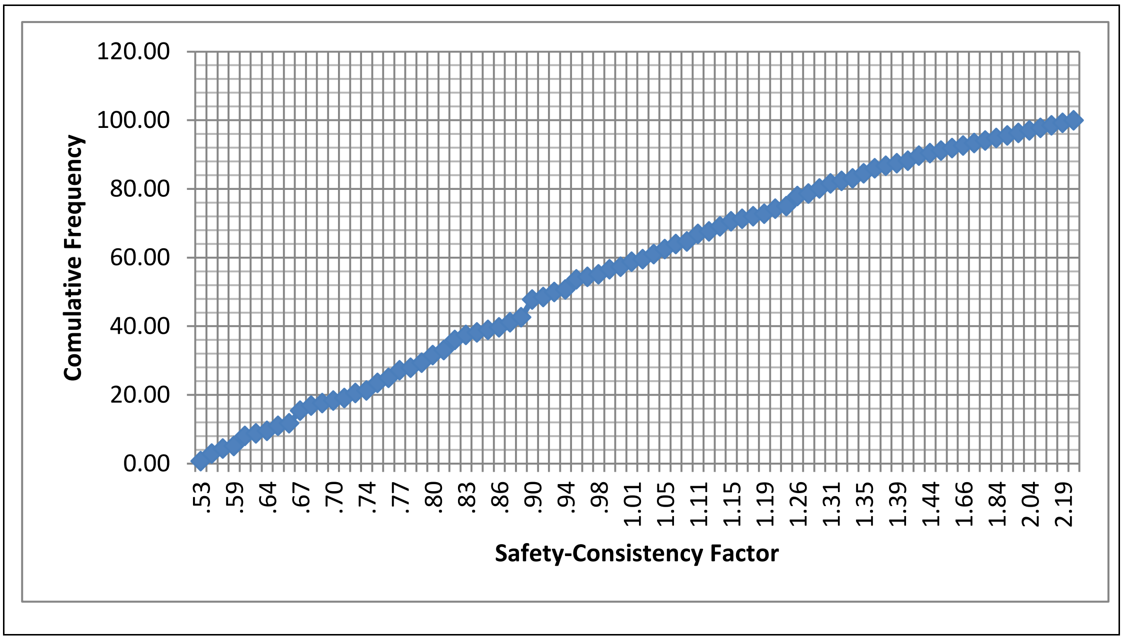

Figure 8.4. Cumulative Distribution of the Safety-Consistency Factors of Horizontal Curves of an Existing Alignment.

8.4.2 Quantitative Analysis

To systematically identify inconsistent sections of the two fictitious alignments, the SCF of model (V) has been computed for each section as shown in Figure (8.5). An ADT of 17500 vehicles per day is assumed. Using the threshold value of (1.37) established above, horizontal curves C_2, C_3, C_{4-1}, C_7, and C_8 of alignment A-I and C_8 of alignment A-II can be considered inconsistent. The following discusses these sections in greater details.

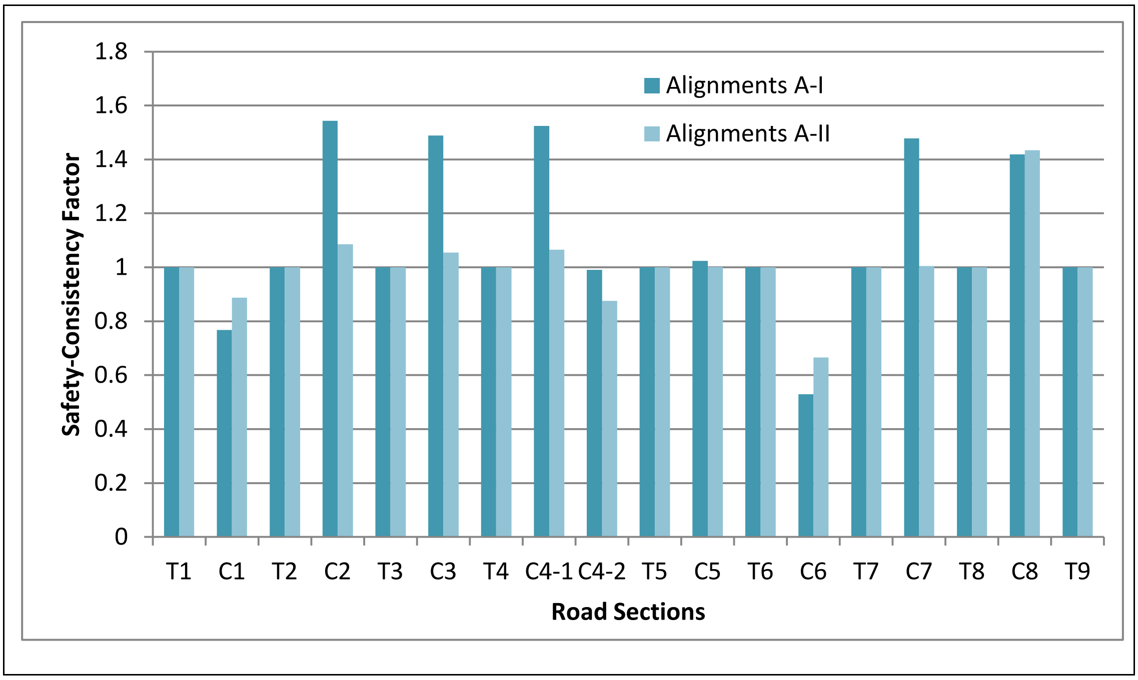

Figure 8.5. Safety-Consistency Factors Based on Model (V) of the Two Fictitious Alignments.

Model (V) predicts a considerable increase from C_l to C_2, with a high increase for alignment A-I where the design speed is reduced by 30 km/h from C_l to C_2. Thus, model can identify the inconsistency at C_2 due to the difference in its design speed to that of C_1.

Model (V) predicts a slight decrease from C2 to C3 and approximately equal from C3 to C4-1. It can be argued that the driver's level of attention should be maintained from C2 to C3; two reverse curves with identical curvature separated by a short tangent section. After it has been raised when the driver travels from the flatter curve C_l to the tighter curve C_2. The crash potential on C_3 should be slightly lower than that at C_2 because of the maintained level of attention. In addition, the steady equality should extend to C4-1; the first part of the compound curve designed with a curvature similar to that of C_2 and C_3 for the same reason. Model (V) accurately predicts a notable drop from C_{4-1} to C_{4-2} because of the larger radius of the second part of this compound curve.

From C_{4-2} to C_5, model (V) predicts a slight increase in crash potential. The emergence of C_5 with a moderate curvature at the end of a long tangent may violate the driver's expectation; therefore, the crash potential at C5 is expected to increase. Model (V) shows that C_6 is the safest curve because it is designed with a radius greater than the minimum value required. Also, model (V) accurately predicts that the crash potential at C_7 rises remarkably after C_6. The driver may expect another flat curve at C_7, the element which follows C_6 after a relatively short tangent. Although both C_6 and C_7 share the same design speed, the selection of radius greatly affects the consistency of the geometric design of an alignment.

Finally, model (V) shows an increase from C_7 to C_8 on A-II, while it shows equality from C_7 to C_8 for alignment A-I. The inconsistency between C7 and C8 on A-II becomes more severe due to the design speed reduction of 30 km/h between these two elements.

To compare results for identifying inconsistent sections of the two fictitious alignments, the safety-consistency factor of HSM module has been computed for each section as shown in Figure (8.5). An ADT of 17500 vehicles per day is assumed. Using the threshold value of (1.3), horizontal curve C_8 of alignment A-II can be considered inconsistent.

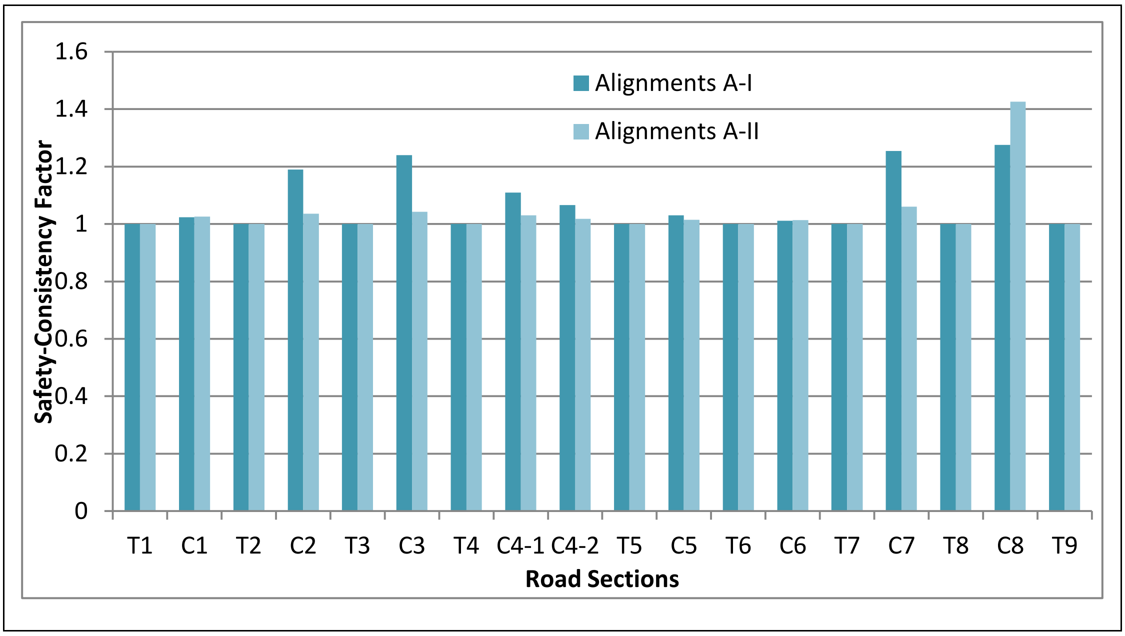

Figure 8.6. Safety-Consistency Factors Based on HSM Module of the Two Fictitious Alignments.

8.4.3 Ability to Identify Geometrically Inconsistent Sections

There were differences between model (V) and HSM module, which distinguish their ability to identify geometrically inconsistent sections as reflected in SCF of the sections.

The objective of SCF was to determine which models are more effective in identifying inconsistent sections of a highway and reflecting the impact on crash frequency than existing models (HSM module) that rely on geometric design characteristics only.

Using the threshold value of (1.37), horizontal curves C_2, C_3, C_{4-1}, C_7, and C_8 of alignment A-I and C_8 of alignment A-II can be considered inconsistent. While using threshold value of (1.3) established for HSM module, horizontal curve C_8 of alignment A-II can be considered inconsistent. Thus, crash prediction models, which explicitly consider design consistency can locate more inconsistencies and reflect the resulting effect on crash potential more accurately than models which rely on geometric design characteristics to predict crash frequency.

8.4.4 Proposed Alignments

Horizontal curves C_2, C_3, C_{4-1}, and C_7 of alignment A-I are more inconsistent than the corresponding elements of alignment A-II. This may be due to the lower design speed of A-I (70 km/h) compared to that of A-II (100 km/h), which results in smaller radii and; therefore, lower predicted operating speeds. Since the operating speed on tangents is almost similar, significant speed reduction is observed from preceding tangents to these horizontal curves of alignment A-I. Moreover, the side friction assumed is insufficient to meet the demand on these horizontal curves of alignment A-I due to the lower design speed. Therefore, the larger speed reduction and the inadequate supply of side friction of alignment A-I result in higher values of the safety-consistency factor.

Similar level of inconsistency can be observed on horizontal curve C_8 of both alignments. Since C_8 is designed with a design speed of 70 km/h, high speed reduction is observed for both alignments. The slight difference in the value of the safety-consistency factor of the two alignments is due to the lower side friction assumed of alignment A-II. In conclusion, the horizontal curves, which have been identified as inconsistent should be modified, if possible, to improve the overall safety performance of the alignments.

On a separate note, although the two parts of the compound curve C_4 is designed with an identical design speed, C_{4-1} is classified as inconsistent for alignment A-I while C_{4-2} is not. The larger radius of C_{4-2} allows for a greater predicted operating speed and a lower side friction demanded; therefore, the safety-consistency factor is lower for C_{4-2} than C_{4-l}.

Chapter Nine

Conclusions and Recommendations

9.1 Conclusions

The concept of design consistency is one of several tools used by highway designers to improve roadway safety. Geometric design consistency is the conformance of a highway's geometry with driver's expectancy. When an inconsistency exists, which violates driver's expectation; the driver may adopt an inappropriate speed or inappropriate maneuver, leading to crashes. Despite its importance to road safety, geometric design consistency is not always ensured in current design practice. The most promising consistency measures identified in previous research fall into four main categories, namely: operating speed, vehicle stability, alignment indices, and driver workload. This research investigates and quantifies the relationship between design consistency and road safety in terms of expected collision prediction frequency.

It should be noted that because of limitations in data availability, there was a need to relay on non-Palestinian sources; Israeli sources since most study highways are currently under Israeli control. Furthermore, speed data were obtained from Google Maps, which comes from mobile phone users who contribute anonymous speed information to the system. Therefore, it was necessary to use such information although such information may be biased towards such users and not totally random.

Five crash prediction models, which relate design consistency to road safety, have been developed. These models are expected to serve as a useful tool to help designers maximize highway safety. For a more comprehensive evaluation of the impact of design consistency on road safety, a model which incorporates several design consistency measures to quantify the impact have been developed. The model shows that when design consistency is considered, the safety performance of an alignment is improved.

The main results and conclusions from the regression analyses are summarized as follows:

- A new approach had been used to estimate the operating speed (V_{85}) along two-lane rural roads using Google Earth maps. Real-time speed traffic data were obtained from the maps. This study produced speed prediction method using real time traffic speed data obtained from Google Earth maps, which can be used to calculate the 85th percentile speed along an alignment that includes both horizontal curve sections and tangent sections.
- The generalized linear regression modeling (GLM) approach is adopted for model development. The application of both Poisson and Negative Binomial regression techniques were investigated, and the use of negative binomial regression was selected. The application of negative binomial regression was found to considerably improve the over-dispersion of all models.

- The developed models verified that the main design consistency measures have an important impact on safety, excluding Δf_R and $\frac{MR}{mR}$. For Δf_R It was stated that it is likely that variables may give inverse direction of correlation not due to a lack of a safety relationship, but due to limitations in data accuracy obtained. For alignment index ratio of the maximum to minimum radius ($\frac{MR}{mR}$), previous research argued that the use of ($\frac{MR}{mR}$) is not recommended as a design consistency measure due to its relatively low sensitivity to collision frequency compared to other alignment indices studied.
- All models adopted in this study experienced acceptable levels of goodness of fit and over-dispersion. Furthermore, the R_k^2 values of these models were relatively high, ranging from approximately 80% to 89%. This indicates that these models explain a large proportion of the systematic variability in collision frequency. These results are very promising, especially considering the complicated nature of collision occurrence.
- Validation step was performed. The goal of this validation step was not only to compare the accuracy of different models developed, but also to evaluate the overall accuracy of Crash Prediction Models for use on rural two-lane highways in the West-Bank. Validation requirement was used to demonstrate that a model is appropriate, meaningful, and useful for the purpose for which it is intended.
- A qualitative comparison has also been made to compare collision prediction models, which explicitly consider design consistency with

those that rely on geometric design characteristics for predicting collision occurrence. It has been shown that the first type is superior as it can locate more inconsistencies and reflect the resulting effect on collision potential more accurately than the second.

- A systematic approach to identify geometrically inconsistent locations using the safety consistency factor has been proposed.
- In conclusion, because model "V" is applicable to both horizontal curves and tangents and it demonstrates a relatively better fit to its data, model "V" is recommended for use in future evaluation of the impact of design consistency on road safety. The following is the final format of the adopted model.

Model (V) Crash Prediction Frequency per-Year.

$$V.\ Crash / 5years = EXP^{(-4.070)} \times Section^{(0.851))} \times Traffic^{(1.034)} \times EXP^{(0.037(V_{85} - V_D))} \times EXP^{\{H\ (0.052\,\Delta V_{85})\ -\ (0.398\,(CRR\,))\}}$$

Where: **H = 0 for tangents or H = 1 for horizontal curves**

Note: Crash/ 5yr = predicted crash frequency per 5 year; L = length of section (m), V = average annual daily traffic (veh/day); H = dummy variable (H = 0 for tangents or H = 1 for horizontal curves); V_{85}-V_D = the difference between operating speed and design speed; ΔV_{85} = speed reduction between the approach tangent and the horizontal curve (km/h); and CRR = ratio of individual curve radius to average radius.

9.2 Recommendations

The following recommendations are made based on the findings and conclusions of this study:

- There was a lack of information of crashes on the study highways from Palestinian sources; therefore, it is strongly recommended that Palestinians make the necessary arrangement to get access to such information especially those related to crashes involving Palestinians.
- Furthermore, operating speed data were obtained from users of Google Maps for mobile phones. Such a mobile system (3G) is not yet available to Palestinian users, and it has to be approved by the Israeli authority. Therefore, it is recommended that the Palestinian Authority insists on the Israelis to give such access, as agreed with the Israelis, because such a system carries high potential for various traffic and transportation applications.
- The prediction accuracy of crash prediction models is limited by the quality of their independent variables. Therefore, future research effort should be devoted to improving the prediction of these measures.
- Further research should be conducted to construct "As-Built" drawing for major roads in the West-Bank taking into consideration lane width, shoulder width and type, superelevation, grades, driveway density, and lighting because the effect of changes in cross-

section and the environment of highways is another source of geometric design inconsistency.

- Additional work should be conducted to obtain average annual daily traffic (AADT) for major roads using automatic counts or in situ counts with vehicle classifications.
- Further research should be conducted to construct a database for the crashes frequency in the West Bank. A concerted effort should be taken from the competent authorities to gathering and documenting these data.
- Operating speed models should be developed, which reflect local conditions for both horizontal curves and tangents. Additional insight into the influence of speeds on tangent sections of various lengths and grades is needed.
- Alignment indices do not appear appropriate as primary measures of design consistency because curvature change rate (CCR) only used from the alignment indices were identified as input to the developed models.
- Additional research is desired to develop a better theoretical model of visual demand considering design conditions (i.e., more complex curves, intersections, signs and signals, and traffic).
- The models developed in this study are limited to horizontal curves and tangents of two-lane rural highways. More work is needed to expand the applicability to sections, which are combined with vertical curves. The effect of changes in cross-section is another

source of geometric design inconsistency, which requires further investigation.

- The models developed are expected to serve as a useful tool to help designers maximize highway safety by identify inconsistent sections of an alignment so they may be treated to improve safety. An "*inconsistency in design*" can be described as the absence of transition curves, the presence of reverse curves, the presence of compound curves, the curves preceded by a lone tangents, and the simple curves with radius less than the minimum value required which, may led the drivers to drive in an unsafe manner. This situation could lead to speed errors, inappropriate driving maneuvers, and/or an undesirable level of accidents.
- The model did not directly take into consideration the impact of reverse and compound curves on road safety. Therefore, it is recommended that future research takes this into consideration.

References

AASHTO. **A Policy on Geometric Design of Highways and Streets**. Washington D.C., USA: American Association of State Highway and Transportation Officials; 2011. 912 p.

Abdelwahab, W. M ., Aboul-Ela, M. T., Morrall, J. F. 1998. **Geometric Design Consistency Based on Speed Change on Horizontal Curves**. Road and Transport Research. 7 (1): 13-23.

Alexander, J., Lunenfeld, H. **Driver Expectancy in Highway Design and Traffic Operations.** Washington, US: Federal Highway Administration, Report, FHWA-TO-86-1; 1986. 39 p.

Al-Masaeid, H., Flamed, M., Aboul-Ela, M., Ghannam, A. 1995. **Consistency of Horizontal Alignment for Different Vehicle Classes. Transportation Research Record: Journal of the Transportation Research Board**. 1500: 178-183.

Al-Masaeid, H. R., Hammory, K. K., Al-Omari, B. H. 1999. **Consistency of Horizontal Alignment Under Adverse Weather Conditions.** Road and Transport Research. 8 (3): 55-67.

Anderson, I. B., Bauer, K. M., Harwood, D. W. Fitzpatrick, K. 1999. **Relationship to Safety of Geometric Design Consistency Measures for Rural Two-Lane Highways. Transportation Research Record.** 1658: 43-51.

Awatta, M. **Highway Design Consistency and Safety: Individual and Overall Evaluation Criteria.** Ottawa, Canada: Carleton University; 2003. 174 p.

Babkov, V . F. **Road Conditions and Traffic Safety**. Moscow: MIR Publishers; 1975. 371 p.

Barnett, J. 1936. **Safe Friction Factors and Superelevation Design**. Highway Research Board, National Research Council, 16 : 69-80.

Bonneson, J. 2001. **Controls for horizontal curve design. Transportation Research Record**. 1751: 82-89p.

Bonneson, A. McCoy, T. 1993. **Estimation of Safety at Two-Way Stop-Controlled Intersections on Rural Highways.** Transportation Research Record: National Research Council.1401: 83-89.

Cafiso, S., Cerni, G. 2011. **A New Approach to Define Continuous Speed Profile Models for Two-Lane Rural Roads**. ***Transportation Research Record: Journal of the Transportation Research Board.*** 2309: 157–167.

Cafiso, S., La Cava, G. Montella, A. 2007**. Safety Index for Evaluation of Two-Lane Rural Highways.** ***Transportation Research Record: Journal of the Transportation Research Board***. 2019: 136-156.

Chen, T., Wei, L., Zhou, W. 2011. **11th International Conference of Chinese Transportation Professionals (ICCTP): Study on the Relationship between the Horizontal Alignment Indices and Traffic**

Safety in Mountainous Freeway. 2011 August 14-17; Nanjing, China. Reston, USA: American Society of Civil Engineers. 4419p.

Deacon, J. 1986. **Relationship Between Accidents and Horizontal Curvature. Appendix D, Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation. Transportation Research Board.** Special Report 214 SR 214: 256-264.

Dissanayeke, S., Ratnayake, I. 2006. **Statistical Modeling of Crash Frequency on Rural Freeways and Two-Lane Highways Using Negative Binomial Distribution. Advance in Transportation Studies an International Journal.** B9: 81-96.

Easa, M. 2003. **Distributing Superelevation to Maximize Highway Design Consistency**. ***Journal of Transportation Engineering***. 129(2): 127-133.

Fitzpatrick, K., Collins, J. M. 2000. **Speed-Profile Model for Two-Lane Rural Highways. *Transportation Research Record: Journal of the Transportation Research Board***. 1737: 42–49.

Fitzpatrick, K., Wooldridge, M . D., Tsimhoni, O., Collins, J. N., Green, P., Bauer, K . M. , Parma, K . D., Koppa, R., Harwood, D. W., Anderson, I., Krammes, R. A., and Poggioli, B. **Alternative Design Consistency Rating Methods for Two-Lane Rural Highways.** Washington, US: Federal Highway Administration, Report FHWA-RD-99-172; 2000a. 162p.

Fitzpatrick, K., Elefteriadou, L., Harwood, D., Collins, J., McFadden, J., Anderson, I. B., Krammes, R. A., Irizarry, N., Parma, K., Bauer, K., and Passetti, K. **Speed Prediction for Two-Lane Rural Highways**. Washington, US: Federal Highway Administration, Report FHWA-RD-99-171; 2000b. 217 p.

Fitzpatrick, K., Carlson, P. J., Wooldridge, M. D., Brewer, M. A. **Design Factors that Affect Driver Speed on Suburban Arterials**. US: Texas Transportation Institute, Report FHWA/TX-00/1769-3; 2000c. 166 p.

Fitzpatrick, K., I. Anderson, K. Bauer, J. Collins, L. Elefteriadou, P. Green, et al. August. **Evaluation of Design Consistency Methods for Two Lane Rural Highways, Executive Summary.** Washington, US: Federal Highway Administration, Report FHWA-RD-99-173: 2000d. 31p.

Garber, N., Hoel, L. **Traffic and Highway Engineering**. Washington, USA: Cengage Learning; 2009. 1200 p.

Gibreel, G. M. , Easa, S. M. , El-Dimeery I. A . 2001. **Prediction of Operating Speed on Three-Dimensional Highway Alignments**. ***Journal of Transportation Engineering.*** 127(1): 21-30.

Gibreel, G. M., Easa, S. M., Hassan, Y., El-Dimeery, I. A. 1999 August. **State of the Art of Highway Geometric Design Consistency**. ***ASCE Journal of Transportation Engineering,*** 125(2): 305-313.

Glennon, J.C., Harwood, D.W., Free, S., Gray, C.W. 1978. **Highway Design Consistency and Systematic Design Related to Highway Safety.** Transportation Research Record. 681: 77-88.

Hassan, Y. 2004. **Highway Design Consistency: Refining the State of Knowledge and Practice**. ***Transportation Research Record: Journal of the Transportation Research Board***. 1881: 63-71.

Hassan, Y., Sayed, T. Tabernero, V. 2001. **Establishing a Practical Approach for Design Consistency Evaluation.** ***ASCE Journal of Transportation Engineering.*** 127(4): 295-302.

Hassan, Y., Gibreel, G., Easa, S. 2000. **Evaluation of Highway Consistency and Safety: Practical Application.** ***Journal of Transportation Engineering.*** 126 (3): 193–201.

Heger, R. 1998. **Driving Behavior and Driver Mental Workload As Criteria Of Highway Geometric Design Quality.** Transportation Research Circular. E-C003: 1-10.

Hirsh, M. 1987. **Probabilistic Approach to Consistency in Geometric Design. American Society of Civil Engineers**. 113(3): 268–276.

HSM. Highway Safety Manual. Washington D.C., USA: **American Associations of State Highway and Transportation Officials;** 2009. 1057 p.

Islam, M . N., Seneviratne, P. N. 1994. **Evaluation of Design Consistency of Two-Lane Highways.** ***Institute of Transportation Engineering Journal***. 64 (2): 28-31.

Joanne, C. and Sayed, T. 2004. **Effect of Geometric Design Consistency on Road Safety.** ***Canadian Journal of Civil Engineering***. 31(2): 218-227.

Joanne, C.W. **Quantifying the Relationship Between Geometric Design Consistency and Road Safety**. British Columbia, UK: The University of British Columbia; 2002. 103 p.

Jovanis, P. Chang, L. 1986. **Modeling the Relationship of Accidents to Miles Traveled. Transportation Research Record: National Research Council.** 1068: 42-183.

Kallberg, P. Kulmala, R. Roine, M. **Accident Prediction Models for Two Lane Roads in Finland.** Espoo, Finland: Technical Research Centre of Finland; 1987. 74 p.

Kanellaidis, G., Golias, J., Efstathiadis, S. 1990 July. **Drivers Speed Behavior on Rural Road Curves. Traffic Engineering and Control**. 31 (7/8): 414–415.

Krammes, R. A., Rao, K. S., Oh, H. 1995. **Highway Geometric Design Consistency Evaluation Software. Transportation Research Record:** ***Journal of the Transportation Research Board***. 1500: 19-24.

Kulakowski, B. 1991. **Mathematical Model for Skid Resistance as Function of Speed. Transportation Research Record**. 1311: 26 - 32.

Kulmala, R. **Safety at Rural Three and Four-Arm Junctions. Development of Accident Prediction Models.** Espoo, Finland: Technical Research Centre of Finland; 1995. 104 p.

Lamm, R., Beck A., Ruscher T., Mailaender T., Cafiso S., La Cava G. **How to Make Two Lane Rural Roads Safer.** Southampton, UK: Witpress; 2007. 144 p.

Lamm, R., Psarianos, B., Mailaender T. **Highway Design and Traffic Safety Engineering Handbook.** New York, US: McGraw-Hill Companies; 1999. 1088 p.

Lamm, R., Psarianos, B., Choueri, E.M., Soilemezoglou, G. 1998. **A Practical Safety Approach to Highway Geometric Design International Case Studies: Germany, Greece, Lebanon, and the United States.** Transportation Research Circular: Journal of the Transportation Research Board. E-C003: 9:1-14.

Lamm, R., Psarianos, B., Guenther, A.K. 1994. **The Third International Conference on Safety and the Environment in the 21st Century: Interrelationships Between Three Safety Criteria: Modern Highway Geometric Design, as well as High Risk Target Locations and Groups**; 1994 Nov 7-10; Tel-Aviv, Israel. Tel-Aviv: Israel Ministry of Transport. 640p.

Lamm, R., Choueiri, E. M., Mailaender, T. 1991. **Side Friction Demand Versus Side Friction Assumed for Curve Design on Two-Lane Rural Highways**. Transportation Research Record. 1303: 11-21.

Lamm, R., Choueiri, E. M., Hayward, J. C. 1988. **Tangent as an Independent Design Element. Transportation Research Record: *Journal of the Transportation Research Board***. 1195: 123–131.

Lamm, R., Choueiri, E. M. 1987. **Recommendations for Evaluating Horizontal Design Consistency Based on Investigations in the State of New York. Transportation Research Record: *Journal of the Transportation Research Board***. 1122: 68–78.

Lamm, R., Hayward, J., Cargin, G. 1986 .**Comparison of Different Procedures for Evaluating Speed Consistency**. Transportation Research Record, National Research Council. 1100: 10-20.

Lamm, R. 1984. **Driving Dynamic Considerations: A Comparison of German and American Friction Coefficients for Highway Design**. Transportation Research Record . 960: 13-20.

Leisch, J. E., Leisch, J. P. **New Concept in Design Speed Applications, as a Control in Achieving Consistent Highway Design.** Evanston, IL, USA: Jack E. Leisch & Associates; 1977.43 p.

Lovegrove, G., Sayed, T. 2006. **Using Macro-Level Crash Prediction Models in Road Safety Planning Applications. Transportation**

Research Record: ***Journal of the Transportation Research Board***. 1950: 73-82.

McFadden, J., Elefteriadou , L. 1999. **Evaluating Horizontal Alignment Design Consistency of Two-Lane Rural Highways: Development of New Procedure. Transportation Research Record:** ***Journal of the Transportation Research Board***. 1737: 9-17.

McFadden, J., Elefteriadou, L. 1997. **Formulation and Validation of Operating Speed-Based Models Using Bootstrapping. Transportation Research Record:** ***Journal of the Transportation Research Board***. 1579: 97-103.

McLean, J.R. 1976. **Traffic Engineering: Sessions 20-27 Proceedings of the Eighth ARRB Conference: Vehicle Speeds on High Standard Curves**; 1976 August 23-27; Perth, Australia. Perth: Australian Road Research Board; 8(5), Session 21. 1-8.

Messer, C.J. 1980. **Methodology for Evaluating Geometric Design Consistency. Facility Design and Operational Effects, Transportation Research Record.** 757: 7–14.

Miaou, P., Lu, A., Lum. H. 1995. **Pitfalls of Using R^2 to Evaluate the Goodness of Fit of Accident Prediction Models. Transportation Research Record:** ***Journal of the Transportation Research Board*****.** 1542: 6-13.

Misaghi, P. Hassan, Y. 2005. **Modeling Operating Speed and Speed Differential on Two-Lane Rural Roads.** ***Journal of Transportation Engineering***.131 (6): 408–418.

Morrall, J., Talarico, R. J. 1994. **Side Friction Demanded and Margins of Safety on Horizontal Curves. Transportation Research Record:** ***Journal of the Transportation Research Board***. 1435: 145–152.

Neter, J., Kutner, M., Nachtsheim, C., William, L. **Applied Linear Statistical Models.** Illinois, USA: Irwin Professional Pub; 2004. 1408 p.

Palestinian Central Bureau of Statistics, 2011. **Statistics of Transport and Communications in the Palestinian Territories: Annual Report**. Ramallah, Palestine.

Pedhazur, J., Schmelkin, L. Measurement, Design, and Analysis: **An Integrated Approach.** London, UK: Psychology Press; 2013. 840 p.

Persaud, B. **Statistical Methods in Highway Safety Analysis: A Synthesis of Highway Safety Practice**. Washington, US: National Research Council, NCHRP Synthesis 295; 2001. 75 p.

Poe, C.M., Mason, J.M. 2000. **Analyzing Influence of Geometric Design on Operating Speeds Along Low-Speed Urban Streets: Mixed Model Approach. Transportation Research Record:** ***Journal of the Transportation Research Board***. 1737: 18–25.

Polus A., Fitzpatrick, K., Fambro, D. 2000. **Predicting Operating Speeds on Tangent Sections of Two-Lane Rural Highways.** ***Transportation Research Record: Journal of the Transportation Research Board***. 1737: 50- 57.

Polus, A. 1980. **The Relationship of Overall Geometric Characteristics to the Safety Level of Rural Highways. Eno Transportation Foundation, Traffic Quarterly**. 34(4): 575-585.

Rabaya, R., Daifi, S., Zitawy, J. **Trans West Bank Highway**. Nablus, Palestine: An-Najah National University; 2012. 123 p.

Salifu, M. **Analysis Of Accident Potential at Unsignalised Urban Junctions in Ghana.** Newcastle, UK: Newcastle Upon Tyne University; 2002. 209 p.

Sawalha, Z., Sayed, T. 2006. **Traffic Accident Modeling: Some Statistical Issues.** ***Canadian Journal of Civil Engineering***. 33(9): 1115–1123.

Sayed, T., Rodriguez, F. 1999. **Accident Prediction Models for Urban Unsignalized Intersections in British Columbia**. Transportation Research Record: 1665: 93-99.

Wambold, J. C., Henry, J. J. **International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurements.**

Paris, France: PIARC Technical Committee on Surface Characteristics; 1995. 430p.

Washington, S., Persaud, B., Lyon, C., Jutaek, O. **Validation of Accident Models for Intersections. Washington, US: Federal Highway Administration**, Report, FHWA-RD-03-037; 2005. 311 p.

Wierwille, W.W. Eggemeier, F.T. 1993. **Recommendations for Mental Workload Measurement in a Test and Evaluation Environment. Human Factors: *The Journal of the Human Factors and Ergonomics Society***. 35(2): 263-281.

Wooldridge, M., Fitzpatrick, K., Harwood, D., Potts, I., Elefteriadou, L., Torbic, D. **Geometric Design Consistency on High-Speed Rural Two-Lane Roadways. Washington, US: American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration**, NCHRP Report 502; 2003. 92 p.

Wooldridge, M . D., Fitzpatrick, K., Koppa, R, Bauer, K. 2000. **Effects of Horizontal Curvature on Driver Visual Demand**. Transportation Research Record. 1737: 71-77.

Wooldridge, M. 1994. **Design Consistency and Driver Error. Transportation Research Record.** 1445: 48-155.

Vogt, A., Bared, J. G. 1998. **Accident Models for Two-Lane Rural Segments and Intersection. Transportation Research Record.** 1635: 18-29.

Appendix A:

Alignment ,Traffic Volume, and Consistency Measures Data for Highway Segments

Table A.1: Alignment ,Traffic Volume, and Consistency Measures Data for Highway 55 (Nablus to Qalqilya Road)

Stations	Section	Radius	$A_{2003-2007}$	$A_{2008-2012}$	ADT	V_{85}	$V_{85}-V_D$	Δf_R	ΔV_{85}	VD_{LU}	AVG T	CRR	AVG R	MR/mR	CCR
0															
	465.50		2	2	15160	84.58	-10.42								
0+465.5															
	504.91	365.76	0	0	15160	79.09	-15.91	0.16	11.14	0.47	611.6	0.72	509.60	8.60	46.50
0+831.26															
	186.37		3	1	15160	86.54	-8.46								
1+017.63															
	297.34	632.36	1	0	15160	70.29	-24.71	0.10	4.85	0.42	611.6	1.24	509.60	8.60	46.50
1+314.97															
	2163.89		5	1	15160	88.03	-6.97								
3+478.86															
	435.70	755.35	1	0	15160	78.86	-16.14	0.15	4.95	0.42	611.6	1.48	509.60	8.60	46.50
3+914.56															
	705.95		7	1	15160	85.02	-9.98								
4+620.50															
	173.31	988.84	0	0	15160	74.05	-20.95	0.14	2.49	0.40	611.6	1.94	509.60	8.60	46.50
4+793.81															
Stations	**Section**	**Radius**	$A_{2003-2007}$	$A_{2008-2012}$	**ADT**	V_{85}	$V_{85}-V_D$	Δf_R	ΔV_{85}	VD_{LU}	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	137.83														
4+931.64															
	232.10	3688.3													

		1													
5+163.74															
	319.45														
5+483.19															
	94.01	199.36													
5+577.20															
	106.32		0	0	15160	81.89	-13.11								
5+683.52															
	120.07	235.80	0	0	15160	92.87	-2.13	0.24	9.35	0.52	611.6	0.46	509.60	8.60	46.50
5+803.59															
	254.98		5	0	15160	85.54	-9.46								
6+058.57															
	128.45	224.00	1	0	15160	82.96	-12.04	0.16	10.02	0.53	611.6	0.44	509.60	8.60	46.50
6+187.03															
	300.63		0	0	15160	91.7	-3.3								
6+487.66															
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
	227.73	525.41	0	0	15160	87.86	-7.14	0.15	5.19	0.44	611.6	1.03	509.60	8.60	46.50
6+715.39															
	431.96		0	0	15160	104.4	9.4								
7+147.35															
	467.12	823.91	2	0	15160	96.86	1.86	0.19	4.72	0.41	611.6	1.62	509.60	8.60	46.50
7+614.46															
	2016.88		9	0	1516	106.2	11.29								

					0	9									
9+631.34															
	625.21	606.84	1	0	15160	101.47	6.47	0.22	7.67	0.43	611.6	1.19	509.60	8.60	46.50
10+256.56															
	630.79		0	0	15160	94.048	-0.952								
10+887.35															
	605.68	480.29	1	0	15160	89.04	-5.96	0.19	9.50	0.44	611.6	0.94	509.60	8.60	46.50
11+493.03															
	135.88	878.68	0	0	15160	90.95	-4.05	0.22	2.60	0.41	611.6	1.72	509.60	8.60	46.50
11+628.91															
	605.76														
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/m R**	**CCR**
12+234.67															
	54.43	319.10													
12+289.11															
	188.60														
12+477.71															
	184.25	566.06													
12+661.96															
	118.29	1354.22													
12+780.25															
	118.53	829.06													
12+898.78															
	188.89	1524.65													
13+087.66															

	80.32	285.11													
13+167.98															
	134.75	1857.80													
13+302.73															
	690.62		5	3	15160	80.68	-14.32								
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
13+993.35															
	189.74	168.09	2	0	15160	75.35	-19.65	0.15	15.13	0.58	611.6	0.33	509.60	8.60	46.50
14+183.09															
	131.35		0	0	15160	82.17	-12.83								
14+314.44															
	143.50	115.50	0	0	15160	85.5	-9.5	0.19	20.07	0.68	611.6	0.23	509.60	8.60	46.50
14+457.94															
	305.23		1	0	15160	87.58	-7.42								
14+763.17															
	179.67	250.53	3	1	15160	81.8	-13.2	0.17	9.95	0.51	611.6	0.49	509.60	8.60	46.50
14+942.84															
	187.24	593.05	0	0	15160	85.9	-9.1	0.22	4.27	0.43	611.6	1.16	509.60	8.60	46.50
15+130.08															
	171.78		0	0	15160	82.24	-12.76								
15+301.86	Fix point														
	153.24	128.66	0	0	2927	79.08	-15.92	0.16	18.3	0.65	182.9	0.43	296.90	5.60	108.60

									9						
15+455.10															
	158.42		0	0	2927	87.32	-7.68								
Stations	**Section**	**Radius**	**$A_{2003\text{-}2007}$**	**$A_{2008\text{-}2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
15+613.52															
	61.03	258.23	0	0	2927	81.6	-13.4	0.17	7.43	0.51	182.9	0.87	296.90	5.60	108.60
15+674.55															
	168.91		0	0	2927	84.8	-10.2								
15+843.46															
	163.52	305.37	1	0	2927	97.31	2.31	0.27	7.91	0.49	182.9	1.03	296.90	5.60	75.40
16+006.98															
	124.45				2927	86.4	-8.6								
16+131.43															
	74.91	179.77													
16+206.34															
	106.12														
16+312.46															
	47.50	392.57													
16+359.96															
	63.88	212.14													
16+423.84															
	105.05														
Stations	**Section**	**Radius**	**$A_{2003\text{-}2007}$**	**$A_{2008\text{-}2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
16+528.89															
	69.93	182.87													
16+598.82															
	63.47														
16+662.29															
	188.64	328.13													
16+850.94															

	218.32	1174.89													
17+069.26															
	224.14	3302.54													
17+293.40															
	118.45	4888.58													
17+411.85															
	14.05														
17+425.90															
	19.86	128.43													
17+455.76															
	181.43														
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
17+637.19															
	32.26	1138.73													
17+669.44															
	97.06	221.85													
17+766.50															
	1416.23				2927	99.46	4.46								
19+182.73															
	162.41	327.16	0	0	2927	98.24	3.24	0.27	7.37	0.48	182.9	1.10	296.90	5.60	108.60
19+345.14															
	246.99		0	0	2927	85	-10								
19+592.13															
	65.14	108.70	0	0	2927	75	-20	0.14	17.83	0.70	182.9	0.37	296.90	5.60	108.60
19+657.27															
	65.52		0	0	2927	59.2	-35.8								

19+722.79															
	76.49	466.36	0	0	2927	80	-15	0.27	4.27	0.45	182.9	1.57	296.90	5.60	108.60
19+799.29															
	103.40		1	0	2927	46.4	-48.6								
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/m R**	**CCR**
19+902.69															
	130.47	52.25													
20+033.16															
	62.79														
20+095.95															
	84.48	50.79													
20+180.43															
	350.66		0	0	2927	88	-7								
20+531.09															
	80.64	141.24	0	0	2927	76.8	-18.2	0.14	14.25	0.63	182.9	0.48	296.90	5.60	108.60
20+611.73															
	171.03														
20+782.76															
	142.88	296.66													
20+925.64															
	138.86	253.02	0	0	2927	85	-10	0.22	9.07	0.51	182.9	0.85	296.90	5.60	108.60
21+064.50															
	102.18		0	0	2927	80.02	-14.98								
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/m R**	**CCR**
21+166.68															
	189.94	375.79	0	0	2927	88.29	-6.71	0.24	6.77	0.46	182.9	1.27	296.90	5.60	108.60
21+356.62															
	117.97		0	0	2927	76.8	-18.2								
21+474.59															

	249.71	598.90	0	0	2927	83.2	-11.8	0.20	4.73	0.43	182.9	2.02	296.90	5.60	108.60
21+724.30															
	383.31		2	0	2927	81.6	-13.4								
22+077.61															
	140.55	285.10													
22+218.15															
	56.91														
22+275.06															
	50.00	322.13													
22+325.05															
	131.73		0	0	2927	75.2	-19.8								
22+456.78															
	186.19	180.92	0	0	2927	74.72	-20.28	0.17	13.96	0.57	182.9	0.61	296.90	5.60	108.60
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
22+642.98															
	133.67	418.83	0	0	2927	76.54		0.19	5.42	0.45	182.9	1.41	296.90	5.60	108.60
22+776.66															

 curve (m); A_{Years} = Accident per 5 year; ADT = average daily traffic volume (veh/day); V_{85} = 85th percentile speed
km/h); Δf_R = deference between side friction supply and demand; ΔV85 = speed reduction between tangent and of curve
ngent length (m); CRR = Ratio of individual curve radius to average radius; AVG R = Average radius of curvature;
CCR = Ratio of individual curve radius to average radius.
ections located in Urban areas which were neglected.

Table A.2: Alignment ,Traffic Volume, and Consistency Measures Data for Highway 60 (Nablus to Jerusalem Road)

Stations	Section	Radius	$A_{2003-2007}$	$A_{2008-2012}$	ADT	V_{85}	V_{85} - V_D	Δf_R	ΔV_{85}	VD_{LU}	AVG T	CRR	AVG R	MR/mR	CCR
0+000.00	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	103.92	_	0	0	7518	83.20	-21.80	_	_	_	_	_	_	_	_
0+103.92	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	91.20	318.19	0	0	7518	89.60	-15.40	0.24	6.49	0.48	1009.60	0.63	504.60	3.20	38.60
0+195.12	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	776.28	324.65	0	1	7518	79.89	-25.11	0.16	16.60	0.48	1009.60	0.64	504.60	3.20	38.60
0+971.40	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	212.78	_	0	0	7518	86.40	-18.60	_	_	_	_	_	_	_	_
1+184.18	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	339.02	288.38	0	0	7518	84.72	-20.28	0.17	11.33	0.49	1009.60	0.57	504.60	3.20	38.60
1+523.20	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	648.34	_	0	1	7518	94.72	-10.28	_	_	_	_	_	_	_	_
2+171.53	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	447.28	344.02	0	0	7518	95.14	-9.86	0.23	11.03	0.47	1009.60	0.68	504.60	3.20	38.60
2+618.81	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	231.77	_	0	0	7518	85.66	-19.34	_	_	_	_	_	_	_	_
2+850.58	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Stations	**Section**	**Radius**	$A_{2003-2007}$	$A_{2008-2012}$	**ADT**	V_{85}	V_{85} - V_D	Δf_R	ΔV_{85}	VD_{LU}	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
_	276.88	380.96	0	1	7518	93.79	-11.21	0.25	7.79	0.46	1009.60	0.75	504.60	3.20	38.60
3+127.46	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	180.70	_	0	0	7518	87.33	-17.67	_	_	_	_	_	_	_	_
3+308.16	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_

_	278.47	742.12	0	0	7518	91.11	-13.89	0.21	4.01	0.42	1009.60	1.47	504.60	3.20	38.60
3+586.63	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	1148.35	_	0	0	7518	96.10	-8.90	_	_	_	_	_	_	_	_
4+734.99	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	781.91	447.22	0	1	7518	103.33	-1.67	0.27	12.11	0.45	1009.60	0.89	504.60	3.20	38.60
5+516.90	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	4905.41	_	2	1	7518	99.41	-5.59	_	_	_	_	_	_	_	_
10+422.30	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	472.23	625.85	1	0	7518	94.79	-10.21	0.22	6.25	0.43	1009.60	1.24	504.60	3.20	38.60
10+894.53	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	181.91	_	0	0	7518	98.92	-6.08	_	_	_	_	_	_	_	_
11+076.43	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	484.10	506.57	0	0	7518	94.67	-10.33	0.16	7.84	0.44	1009.60	1.00	504.60	3.20	38.60
11+560.53	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
_	1412.04	_	0	0	7518	115.07	10.07	_	_	_	_	_	_	_	_
12+972.57	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	500.22	583.71	3	1	7518	113.59	8.59	0.27	6.94	0.43	1009.60	1.16	504.60	3.20	38.60
13+472.79	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	441.02	_	0	0	7518	96.08	-8.92	_	_	_	_	_	_	_	_
13+913.82	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	368.67	639.23	0	0	7518	99.69	-5.31	0.23	5.34	0.42	1009.60	1.27	504.60	3.20	38.60
14+282.49	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	326.98	_	3	0	7518	103.22	-1.78	_	_	_	_	_	_	_	_
14+609.47	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	371.06	694.81	0	0	7518	106.63	1.63	0.27	4.93	0.42	1009.60	1.38	504.60	3.20	38.60
14+980.53	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_

	3094.63		6	1	7518	104.49	-0.51								
18+075.16															
	147.83	892.39	0	0	7518	98.73	-6.27	0.22	2.62	0.41	1009.60	1.77	504.60	3.20	38.60
18+222.99															
	237.46		0	0	7518	92.26	-12.74								
18+460.45															
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	192.35	276.51	0	0	7518	93.88	-11.12	0.24	9.24	0.50	1009.60	0.55	504.60	3.20	38.60
18+652.80	fix point														
	222.57		0	0	10766	85.94	-19.06								
18+875.37															
	109.83	260.49	2	0	10766	90.96	-14.04	0.20	8.27	0.51	351.30	0.53	495.60	3.70	65.50
18+985.20															
	86.12		0	0	10766	97.60	-7.40								
19+071.32															
	138.00	607.21	0	0	10766	85.68	-19.32	0.17	3.77	0.43	351.30	1.23	495.60	3.70	65.50
19+209.32															
	94.07	437.44	0	0	10766	81.12	-23.88	0.19	4.75	0.45	351.30	0.88	495.60	3.70	65.50
19+303.39															
	106.96		0	0	10766	80.00	-25.00								
19+410.35															
	187.32	307.08	0	0	10766	84.37	-20.63	0.19	8.24	0.49	351.30	0.62	495.60	3.70	65.50
19+597.67															
	125.85	419.96	0	1	10766	90.25	-14.75	0.24	5.32	0.45	351.30	0.85	495.60	3.70	65.50
19+723.52															
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	246.43		0	0	10766	86.60	-18.40								
19+969.95															
	179.15	271.52	0	0	10766	86.96	-18.04	0.20	9.18	0.50	351.30	0.55	495.60	3.70	65.50
20+149.10															

_	257.14	501.34	0	0	10766	90.26	-14.74	0.23	5.72	0.44	351.30	1.01	495.60	3.70	65.50
20+406.24	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	254.10	571.66	0	0	10766	89.47	-15.53	0.22	4.99	0.43	351.30	1.15	495.60	3.70	65.50
20+660.34	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	406.10	360.63	1	0	10766	83.12	-21.88	0.18	9.96	0.47	351.30	0.73	495.60	3.70	65.50
21+066.44	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	177.16	_	0	0	10766	78.69	-26.31	_	_	_	_	_	_	_	_
21+243.60	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	454.91	847.03	0	0	10766	82.74	-22.26	0.18	4.52	0.41	351.30	1.71	495.60	3.70	65.50
21+698.51	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	180.75	663.57	1	0	10766	90.70	-14.30	0.22	3.77	0.42	351.30	1.34	495.60	3.70	65.50
21+879.26	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	183.33	326.90	1	0	10766	92.60	-12.40	0.22	7.68	0.48	351.30	0.66	495.60	3.70	65.50
22+062.59	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
_	487.36	_	0	0	10766	94.80	-10.20	_	_	_	_	_	_	_	_
22+549.95	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	157.62	260.68	0	0	10766	86.02	-18.98	0.18	9.16	0.51	351.30	0.53	495.60	3.70	65.50
22+707.57	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	237.28	616.63	0	2	10766	92.14	-12.86	0.25	4.50	0.43	351.30	1.24	495.60	3.70	65.50
22+944.85	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	136.62	231.08	5	0	10766	80.69	-24.31	0.16	9.89	0.52	351.30	0.47	495.60	3.70	65.50
23+081.47	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	260.35	_	0	0	10766	84.40	-20.60	_	_	_	_	_	_	_	_
23+341.82	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	246.87	521.83	0	0	10766	83.08	-21.92	0.17	5.40	0.44	351.30	1.05	495.60	3.70	65.50
23+588.69	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	233.56	_	0	0	10766	92.26	-12.74	_	_	_	_	_	_	_	_
23+822.25	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	626.17	620.17	0	1	10766	86.72	-18.28	0.16	7.52	0.43	351.30	1.25	495.60	3.70	65.50
24+448.42	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	419.98	_	0	0	10766	102.7	-2.28	_	_	_	_	_	_	_	_

						2									
24+868.40	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
_	239.00	745.90	1	0	10766	105.89	0.89	0.27	3.73	0.42	351.30	1.51	495.60	3.70	65.50
25+107.40	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	265.35	_	0	0	10766	90.86	-14.14	_	_	_	_	_	_	_	_
25+372.75	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	214.99	487.22	0	0	10766	91.31	-13.69	0.21	5.47	0.44	351.30	0.98	495.60	3.70	65.50
25+587.74	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	280.86	_	0	0	10766	94.55	-10.45	_	_	_	_	_	_	_	_
25+868.60	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	515.66	357.25	0	2	10766	92.17	-12.83	0.22	11.55	0.47	351.30	0.72	495.60	3.70	65.50
26+384.26	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	994.29	_	0	0	10766	82.60	-22.40	_	_	_	_	_	_	_	_
27+378.55	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	333.64	469.71	0	0	10766	93.89	-11.11	0.25	6.90	0.44	351.30	0.95	495.60	3.70	65.50
27+712.19	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	373.92	_	0	0	10766	89.12	-15.88	_	_	_	_	_	_	_	_
28+086.11	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	210.34	594.26	0	0	10766	90.64	-14.36	0.21	4.45	0.43	351.30	1.20	495.60	3.70	65.50
28+296.45	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
_	267.99	_	0	0	10766	92.99	-12.01	_	_	_	_	_	_	_	_
28+564.43	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	565.92	504.89	0	0	10766	92.57	-12.43	0.23	8.65	0.44	351.30	1.02	495.60	3.70	65.50
29+130.35	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	938.35	_	0	1	10766	89.97	-15.03	_	_	_	_	_	_	_	_
30+068.70	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	270.18	688.93	0	0	10766	96.36	-8.64	0.22	4.26	0.42	351.30	1.39	495.60	3.70	65.50

30+338.88															
	658.02		1	0	10766	100.52	-4.48								
30+996.90															
	330.98	460.71	0	0	10766	90.01	-14.99	0.18	7.01	0.45	351.30	0.93	495.60	3.70	65.50
31+327.88															
	117.44		0	0	10766	86.22	-18.78								
31+445.32															
	368.87	346.26	1	0	10766	83.31	-21.69	0.19	9.86	0.47	351.30	0.70	495.60	3.70	65.50
31+814.19															
	165.31		0	0	10766	89.14	-15.86								
31+979.50															
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	164.24	539.33	0	0	10766	83.55	-21.45	0.19	4.49	0.43	351.30	1.09	495.60	3.70	65.50
32+143.74															
	220.58		0	0	10766	81.88	-23.12								
32+364.32															
	217.10	249.64	0	0	10766	81.95	-23.05	0.20	10.72	0.51	351.30	0.50	495.60	3.70	65.50
32+581.42															
	245.89		1	0	10766	76.92	-28.08								
32+827.31															
	172.73	704.21	1	0	10766	78.48	-26.52	0.20	3.49	0.42	351.30	1.42	495.60	3.70	65.50
33+000.04															
	132.84		0	0	10766	76.11	-28.89								
33+132.88															
	128.55	580.90	0	0	10766	77.38	-27.62	0.19	3.87	0.43	351.30	1.17	495.60	3.70	65.50
33+261.43															
	263.88	588.61	0	1	10766	77.14	-27.86	0.19	4.93	0.43	351.30	1.19	495.60	3.70	65.50
33+525.31															
	123.81		0	0	10766	75.20	-29.80								
33+649.12															

Stations	Section	Radius	$A_{2003-2007}$	$A_{2008-2012}$	ADT	V_{85}	V_{85} - V_D	Δf_R	ΔV_{85}	VD_{LU}	AVG T	CRR	AVG R	MR/mR	CCR
	173.35	375.64	1	1	10766	85.86	-19.14	0.24	6.56	0.46	351.30	0.76	495.60	3.70	65.50
33+822.47															
	429.60		0	0	10766	77.46	-27.54								
34+252.07															
	1687.47	791.28	2	1	10766	88.27	-16.73	0.23	12.40	0.41	351.30	1.60	495.60	3.70	65.50
35+939.54															
	591.63		1	0	10766	83.91	-21.09								
36+531.17															
	1261.23	498.94	9	2	10766	95.85	-9.15	0.21	15.52	0.44	351.30	1.01	495.60	3.70	65.50
37+792.40															
	697.89		1	0	10766	103.51	-1.49								
38+490.29															
	522.81	537.14	0	1	10766	99.80	-5.20	0.23	7.74	0.43	351.30	1.08	495.60	3.70	65.50
39+013.10															
	388.99		1	0	10766	82.31	-22.69								
39+402.09															

Table A.3: Alignment ,Traffic Volume, and Consistency Measures Data for Highway 60 (Jerusalem to Hebron Road)														
Stations	**Section**	**Radius**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
0+000.00														
	396.44		0	11875	92.80	-12.20								
0+396.44														
	137.97	289.24	3	11875	91.80	-13.20	0.22	7.92	0.49	479.70	0.72	401.30	4.20	81.50
0+534.41														
	218.19		2	11875	86.40	-18.60								
0+752.60														
	410.94	236.15	0	11875	102.40	-2.60	0.23	15.32	0.52	479.70	0.59	401.30	4.20	81.50
1+163.54														
	557.11		2	11875	108.80	3.80								
1+720.65														
	187.90	247.64	0	11875	93.04	-11.96	0.14	10.23	0.51	479.70	0.62	401.30	4.20	81.50
1+908.55														
	846.71		12	11875	115.80	10.80								
2+755.26														
	161.33	982.14	1	11875	94.40	-10.60	0.15	2.45	0.40	479.70	2.45	401.30	4.20	81.50
2+916.59														
Stations	**Section**	**Radius**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	330.58	445.93	1	11875	99.20	-5.80	0.24	7.24	0.45	479.70	1.11	401.30	4.20	81.50
3+247.17														
	541.07		0	11875	100.80	-4.20								
3+788.24														
	302.04	263.77	0	11875	99.20	-5.80	0.24	11.71	0.51	479.70	0.66	401.30	4.20	81.50
4+090.28														
	195.71	561.26	3	11875	97.60	-7.40	0.22	4.58	0.43	479.70	1.40	401.30	4.20	81.50

4+285.99														
	157.08	350.32	3	11875	103.60	-1.40	0.27	6.81	0.47	479.70	0.87	401.30	4.20	81.50
4+443.07														
	216.54		0	11875	99.20	-5.80								
4+659.60														
	405.37	278.54	1	11875	96.00	-9.00	0.22	12.89	0.50	479.70	0.69	401.30	4.20	81.50
5+064.97														
	99.55	314.79	0	11875	94.40	-10.60	0.23	6.69	0.48	479.70	0.78	401.30	4.20	81.50
5+164.52														
	581.50		1	11875	88.00	-17.00								
5+746.02														
Stations	**Section**	**Radius**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	126.13	372.24	0	11875	88.00	-17.00	0.12	6.00	0.47	479.70	0.93	401.30	4.20	81.50
5+872.15														
	597.15	473.87	3	11875	93.60	-11.40	0.25	9.54	0.44	479.70	1.18	401.30	4.20	81.50
6+469.30														

Table A.4: Alignment ,Traffic Volume, and Consistency Measures Data for Highway 505 (Salfit to Za'tara Road)

Stations	Section	Radius	$A_{2008-2012}$	ADT	V_{85}	V_{85} - V_D	Δf_R	ΔV_{85}	VD_{LU}	AVG T	CRR	AVG R	MR/mR	CCR
0+000.00														
	188.04	808.84	1	3122	72.00	-23.00	0.16	3.13	0.41	594	1.18	685.40	3.00	30.50
0+188.04														
	181.30	775.81	0	3122	75.20	-19.80	0.11	3.22	0.41	594	1.13	685.40	3.00	30.50
0+369.34														
	197.00		0	3122	92.80	-2.20								
0+566.34														
	854.86	695.98	2	3122	91.20	-3.80	0.12	8.29	0.42	594	1.02	685.40	3.00	30.50
1+421.20														
	1656.00		3	3122	115.20	20.20								
3+077.20														
	285.60	899.85	2	3122	115.20	20.20	0.27	3.34	0.41	594	1.31	685.40	3.00	30.50
3+362.80														
	420.92		0	3122	92.33	-2.67								
3+783.72														
Stations	**Section**	**Radius**	$A_{2008-2012}$	**ADT**	V_{85}	V_{85} - V_D	Δf_R	ΔV_{85}	VD_{LU}	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	445.99	985.42	2	3122	113.60	18.60	0.27	3.84	0.40	594	1.44	685.40	3.00	30.50
4+229.71														
	321.63		1	3122	104.37	9.37								
4+551.34														
	319.06	975.80	1	3122	108.80	13.80	0.23	3.25	0.40	594	1.42	685.40	3.00	30.50
4+870.40														
	1396.91		3	3122	113.60	18.60								
6+267.31														
	193.84	497.64	0	3122	96.00	1.00	0.14	5.15	0.44	594	0.73	685.40	3.00	30.50
6+461.15														
	1129.98		5	3122	120.00	25.00								

7+591.13														
	157.86	706.26	1	3122	118.40	23.40	0.27	3.38	0.42	594	1.03	685.40	3.00	30.50
7+748.99														
	196.42		0	3122	100.80	5.80								
7+945.41														
	106.81	331.26	0	3122	95.13	0.13	0.17	6.46	0.48	594	0.48	685.40	3.00	30.50
8+052.22														
Stations	**Section**	**Radius**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	169.53		1	3122	108.80	13.80								
8+221.75														
	157.38	709.94	0	3122	91.20	-3.80	0.15	3.36	0.42	594	1.04	685.40	3.00	30.50
8+379.13														
	133.13	407.68	1	3122	92.80	-2.20	0.20	5.56	0.46	594	0.59	685.40	3.00	30.50
8+512.26														
	130.61	720.92	0	3122	97.60	2.60	0.25	3.13	0.42	594	1.05	685.40	3.00	30.50
8+642.87														
	157.77		0	3122	92.80	-2.20								
8+800.64														
	159.46	451.56	0	3122	92.80	-2.20	0.19	5.31	0.45	594	0.66	685.40	3.00	30.50
8+960.10														
	293.42		1	3122	98.80	3.80								
9+253.52														
	104.42	628.76	0	3122	88.00	-7.00	0.17	3.39	0.43	594	0.92	685.40	3.00	30.50
9+357.94														

Table A.5: Alignment ,Traffic Volume, and Consistency Measures Data for Highway 90 (Jericho to Bethlehem Road)

Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
0+000															
	490.11		1	1	3701	89.29	-15.71								
0+490.11															
	251.04	335.19	0	0	3701	86.12	-18.88	0.01	8.47	0.48	470.20	0.67	497.60	6.80	45.00
0+741.15															
	2522.35		3	0	3701										
3+263.50															
	36.13	20.41			3701										
3+299.63															
	357.21		0	1	3701										
3+656.84															
	196.80	317.00	0	0	3701	76.26	-28.74	0.01	8.13	0.48	470.20	0.64	497.60	6.80	45.00
3+853.64															
	351.24		0	0	3701	79.13	-25.87								
4+204.89															
	209.94	544.07	0	0	3701	87.08	-17.92	0.01	4.85	0.43	470.20	1.09	497.60	6.80	45.00
4+414.83															
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	1399.09		0	0	3701	96.23	-8.77								
5+813.92															
	218.81	295.04	0	0	3701	87.42	-17.58	0.01	9.10	0.49	470.20	0.59	497.60	6.80	45.00
6+032.73															
	421.87		1	0	3701	86.67	-18.33								
6+454.60															
	211.11	488.24	0	0	3701	86.74	-18.26	0.04	5.42	0.44	470.20	0.98	497.60	6.80	45.00
6+665.71															
	343.07		0	0	3701	86.85	-18.15								
7+008.78															

	301.61	658.43	7	0	3701	87.73	-17.27	0.03	4.69	0.42	470.20	1.32	497.60	6.80	45.00
7+310.39															
	701.77		0	1	3701	91.35	-13.65								
8+012.16															
	270.39	827.89	0	0	3701	92.18	-12.82	0.06	3.54	0.41	470.20	1.66	497.60	6.80	45.00
8+282.55															
	524.97		0	0	3701	88.32	-16.68								
8+807.51															
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	416.69	627.86	0	0	3701	86.70	-18.30	0.03	5.81	0.43	470.20	1.26	497.60	6.80	45.00
9+224.20															
	908.98		1	0	3701	85.68	-19.32								
10+133.18															
	264.40	590.62	0	0	3701	89.86	-15.14	0.06	4.92	0.43	470.20	1.19	497.60	6.80	45.00
10+397.57															
	364.59		0	0	3701	87.53	-17.47								
10+762.16															
	200.18	684.99	0	0	3701	87.06	-17.94	0.04	3.79	0.42	470.20	1.38	497.60	6.80	45.00
10+962.34															
	151.27		0	0	3701	82.00	-23.00								
11+113.60															
	262.30	749.63	0	0	3701	91.27	-13.73	0.05	3.86	0.42	470.20	1.51	497.60	6.80	45.00
11+375.91															
	618.56		0	0	3701	92.45	-12.55								
11+994.46															
	225.87	769.69	0	0	3701	92.33	-12.67	0.05	3.53	0.41	470.20	1.55	497.60	6.80	45.00
12+220.33															
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	470.44		0	0	3701	86.40	-18.60								
12+690.77															
	209.64	857.73	0	0	3701	90.85	-14.15	0.05	3.08	0.41	470.20	1.72	497.60	6.80	45.00

12+900.41															
	201.70		0	0	3701	90.79	-14.21								
13+102.10															
	250.61	829.25	0	0	3701	90.51	-14.49	0.05	3.42	0.41	470.20	1.67	497.60	6.80	45.00
13+352.72															
	179.69	433.51	0	0	3701	89.15	-15.85	0.04	5.75	0.45	470.20	0.87	497.60	6.80	45.00
13+532.41															
	198.59		0	0	3701	89.27	-15.73								
13+728															
	204.85	742.65	0	0	3701	94.54	-10.46	0.06	3.52	0.42	470.20	1.49	497.60	6.80	45.00
13+932.58															
	231.55		0	0	3701	93.75	-11.25								
14+164.13															
	112.91	150.57	0	0	3701	81.37	-23.63	-0.02	14.41	0.61	470.20	0.30	497.60	6.80	45.00
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
14+277.04															
	211.49	542.57	0	0	3701	87.86	-17.14	0.02	4.88	0.43	470.20	1.09	497.60	6.80	45.00
14+488.53															
	146.61		0	0	3701	93.41	-11.59								
14+635.14															
	184.11	349.89	0	0	3701	88.91	-16.09	0.03	7.19	0.47	470.20	0.70	497.60	6.80	45.00
14+819.25															
	95.19	132.20	0	0	3701	90.35	-14.65	0.05	15.76	0.64	470.20	0.27	497.60	6.80	45.00
14+914.45															
	189.97	802.07	0	1	3701	90.63	-14.37	0.04	3.17	0.41	470.20	1.61	497.60	6.80	45.00
15+104.42															
	1005.59		0	0	3701	93.70	-11.30								
16+109.98															
	193.65	496.99	0	0	3701	96.44	-8.56	0.06	5.15	0.44	470.20	1.00	497.60	6.80	45.00
16+303.63															
	274.91		0	0	3701	97.47	-7.53								

16+578.54															
	119.36	447.62	0	0	3701	98.10	-6.90	0.05	4.92	0.45	470.20	0.90	497.60	6.80	45.00
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
16+697.89															
	306.32		0	0	3701	102.68	-2.32								
17+004.22															
	102.52	321.10	1	1	3701	103.27	-1.73	0.08	6.60	0.48	470.20	0.65	497.60	6.80	45.00
17+106.74															
	273.94		0	0	3701	93.92	-11.08								
17+380.67															
	245.29	366.61	0	0	3701	93.92	-11.08	0.03	7.67	0.47	470.20	0.74	497.60	6.80	45.00
17+625.97															
	286.93		0	0	3701	99.60	-5.40								
17+912.89															
	218.07	320.27	1	0	3701	104.67	-0.33	0.08	8.37	0.48	470.20	0.64	497.60	6.80	45.00
18+130.96															
	1365.78		0	0	3701	103.88	-1.12								
19+496.74															
	257.39	504.33	0	0	3701	90.32	-14.68	0.00	5.69	0.44	470.20	1.01	497.60	6.80	45.00
19+754.13															
	804.75		1	0	3701	86.28	-18.72								
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
20+558.88															
	231.14	456.34	0	0	3701	90.60	-14.40	0.05	6.01	0.45	470.20	0.92	497.60	6.80	45.00
20+790.02															
	321.11		1	0	3701	90.45	-14.55								
21+111.13															
	227.11	562.80	3	0	3701	90.83	-14.17	0.04	4.84	0.43	470.20	1.13	497.60	6.80	45.00
21+338.24															
	162.46		0	0	3701	93.42	-11.58								
21+500.70															

	207.69	603.28	0	0	3701	90.98	-14.02	0.03	4.36	0.43	470.20	1.21	497.60	6.80	45.00
21+708.38															
	884.63		0	0	3701	96.93	-8.07								
22+593.01															
	136.70	469.95	0	0	3701	90.83	-14.17	0.03	4.86	0.44	470.20	0.94	497.60	6.80	45.00
22+729.71															
	884.62		0	0	3701	96.83	-8.17								
23+576.66															
	189.45	756.24	0	0	3701	97.21	-7.79	0.05	3.36	0.42	470.20	1.52	497.60	6.80	45.00
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
23+766.11															
	97.04		0	0	3701	100.00	-5.00								
23+863.15															
	176.44	610.93	0	0	3701	91.36	-13.64	0.02	4.06	0.43	470.20	1.23	497.60	6.80	45.00
24+039.59															
	201.06		0	0	3701	92.50	-12.50								
24+240.65															
	89.91	685.96	0	0	3701	106.36	1.36	0.11	3.00	0.42	470.20	1.38	497.60	6.80	45.00
24+330.56															
	212.20	640.74	0	0	3701	92.17	-12.83	0.00	4.14	0.42	470.20	1.29	497.60	6.80	45.00
24+542.75															
	409.12		0	0	3701	87.00	-18.00								
24+951.88															
	210.23	341.93	0	0	3701	85.92	-19.08	0.03	7.73	0.47	470.20	0.69	497.60	6.80	45.00
25+162.10															
	219.72		0	0	3701	84.60	-20.40								
25+381.82															
	126.16	298.73	0	0	3701	94.08	-10.92	0.08	7.48	0.49	470.20	0.60	497.60	6.80	45.00
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
25+507.98															
	157.54		0	0	3701	88.26	-16.74								

25+665.52															
	136.77	365.91	0	0	3701	89.06	-15.94	0.02	6.25	0.47	470.20	0.74	497.60	6.80	45.00
25+802.29															
	108.66		0	0	3701	96.00	-9.00								
25+910.95															
	147.31	717.13	0	0	3701	95.13	-9.87	0.06	3.26	0.42	470.20	1.44	497.60	6.80	45.00
26+058.27															
	204.13		0	0	3701	88.00	-17.00								
26+262.40															
	122.25	385.03	0	0	3701	86.15	-18.85	0.02	5.75	0.46	470.20	0.77	497.60	6.80	45.00
26+384.65															
	84.64		0	0	3701	92.52	-12.48								
26+469.29															
	109.86	171.80	0	0	3701	85.63	-19.37	0.01	12.54	0.58	470.20	0.35	497.60	6.80	45.00
26+579.15															
	181.14	540.64	0	0	3701	84.00	-21.00	0.03	4.63	0.43	470.20	1.09	497.60	6.80	45.00
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
26+760.29															
	106.15	129.67	0	0	3701	78.64	-26.36	0.00	16.48	0.65	470.20	0.26	497.60	6.80	45.00
26+866.44															
	158.62	275.48	0	0	3701	77.23	-27.77	0.01	8.68	0.50	470.20	0.55	497.60	6.80	45.00
27+025.08															
	121.52		1	0	3701	76.00	-29.00								
27+146.60															
	386.82	862.21	0	0	3701	73.64	-31.36	-0.01	4.06	0.41	470.20	1.73	497.60	6.80	45.00
27+533.42															
	318.41			0	3701	79.69	-25.31								
27+851.83															
	116.71	261.01	0	0	3701	74.45	-30.55	-0.01	8.38	0.51	470.20	0.52	497.60	6.80	45.00
27+968.54															

	171.46	876.70	0	0	3701	69.76	-35.24	-0.01	2.80	0.41	470.20	1.76	497.60	6.80	45.00
28+140															
	170.46	192.90	0	0	3701	73.48	-31.52	0.02	12.70	0.56	470.20	0.39	497.60	6.80	45.00
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
28+310.47															
	84.22	202.45	0	0	3701	66.80	-38.20	-0.06	10.03	0.55	470.20	0.41	497.60	6.80	45.00
28+394.69															
	156.38		0	0	3701	82.02	-22.98								
28+551.07															
	183.90	567.43	0	0	3701	58.00	-47.00	-0.13	4.43	0.43	470.20	1.14	497.60	6.80	45.00
28+734.97															
	369.50		0	0	3701	85.96	-19.04								
29+104.47															
	189.83	572.60	0	0	3701	81.90	-23.10	0.00	4.44	0.43	470.20	1.15	497.60	6.80	45.00
29+294.30															
	272.49		0	0	3701	89.12	-15.88								
29+566.80															
	317.75	314.26	0	0	3701	86.16	-18.84	-0.02	10.07	0.48	470.20	0.63	497.60	6.80	45.00
29+884.55															
	849.61		1	0	3701	102.42	-2.58								
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
30+734.16															
	274.17	810.37	0	0	3701	90.90	-14.10	0.01	3.64	0.41	470.20	1.63	497.60	6.80	45.00
31+008.33															
	1285.76		0	0	3701	96.44	-8.56								
32+294.09															
	212.76	261.88	0	0	3701	85.51	-19.49	0.00	10.14	0.51	470.20	0.53	497.60	6.80	45.00

32+506.85															
	202.31		0	0	3701	85.89	-19.11								
32+709.16															
	157.53	335.77	0	0	3701	82.13	-22.87	0.02	7.11	0.48	470.20	0.67	497.60	6.80	45.00
32+866.69															
	226.54	455.63	0	0	3701	82.42	-22.58	0.03	5.97	0.45	470.20	0.92	497.60	6.80	45.00
33+093.22															
	133.90		0	0	3701	79.00	-26.00								
33+227.12															
	94.42	339.67	0	0	3701	77.90	-27.10	0.00	6.12	0.47	470.20	0.68	497.60	6.80	45.00
33+321.55															
	252.70		0	0	3701	84.70	-20.30								
Stations	**Section**	**Radius**	**$A_{2003-2007}$**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**$V_{85}-V_D$**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
33+574.25															
	116.50	425.74	0	0	3701	84.82	-20.18	0.02	5.14	0.45	470.20	0.86	497.60	6.80	45.00
33+690.75															
	150.47		0	0	3701	88.42	-16.58								
33+841.22															
	178.39	864.98	0	0	3701	88.82	-16.18	0.05	2.88	0.41	470.20	1.74	497.60	6.80	45.00
34+019.60															
	145.64	311.33	0	0	3701	82.13	-22.87	0.01	7.48	0.48	470.20	0.63	497.60	6.80	45.00

Table A.6.: Alignment ,Traffic Volume, and Consistency Measures Data for Highway 90 (Bethlehem Governorate Road)

Stations	Section	Radius	$A_{2008-2012}$	ADT	V_{85}	V_{85} - V_D	Δf_R	ΔV_{85}	VD_{LU}	AVG T	CRR	AVG R	MR/mR	CCR
0+000.00	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	101.45	236.19	0	3701	72.00	-33.00	0.03	8.95	0.52	280.60	0.59	400.00	6.20	102.40
0+101.45	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	173.27	433.10	1	3701	67.00	-38.00	-0.02	5.69	0.45	280.60	1.08	400.00	6.20	102.40
0+274.72	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	105.00	276.79	0	3701	61.32	-43.68	-0.04	7.70	0.50	280.60	0.69	400.00	6.20	102.40
0+379.72	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	85.65	155.53	0	3701	57.07	-47.93	-0.04	13.10	0.60	280.60	0.39	400.00	6.20	102.40
0+465.37	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	171.73	_	0	3701	60.00	-45.00	_	_	_	_	_	_	_	_
0+637.10	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	77.11	370.56	0	3701	53.44	-51.56	-0.06	5.39	0.47	280.60	0.93	400.00	6.20	102.40
0+714.21	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	59.65	357.95	0	3701	49.60	-55.40	-0.08	5.34	0.47	280.60	0.89	400.00	6.20	102.40
0+773.86	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	190.43	498.48	0	3701	60.00	-45.00	-0.04	5.11	0.44	280.60	1.25	400.00	6.20	102.40
0+964.29	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Stations	Section	Radius	$A_{2008-2012}$	ADT	V_{85}	V_{85} - V_D	Δf_R	ΔV_{85}	VD_{LU}	AVG T	CRR	AVG R	MR/mR	CCR
_	139.48	_	0	3701	66.00	-39.00	_	_	_	_	_	_	_	_
1+103.77	_	_	_	_	_	_	_	_	_	_	_	_	_	_
_	310.64	937.79	0	3701	68.00	-37.00	0.00	3.34	0.41	280.60	2.34	400.00	6.20	102.40

1+414.41														
	375.94		0	3701	68.00	-37.00								
1+790.35														
	181.80	826.03	0	3701	63.00	-42.00	-0.03	3.03	0.41	280.60	2.07	400.00	6.20	102.40
1+972.15														
	97.22	174.22	0	3701	62.00	-43.00	-0.03	12.02	0.58	280.60	0.44	400.00	6.20	102.40
2+069.37														
	93.86	179.13	0	3701	66.00	-39.00	0.01	11.60	0.57	280.60	0.45	400.00	6.20	102.40
2+163.23														
	76.44	353.98	0	3701	62.00	-43.00	-0.03	5.63	0.47	280.60	0.88	400.00	6.20	102.40
2+239.67														
	103.53	184.90	0	3701	62.00	-43.00	-0.01	11.49	0.56	280.60	0.46	400.00	6.20	102.40
2+343.20														
	138.95		0	3701	61.00	-44.00								
2+482.15														
Stations	**Section**	**Radius**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVG T**	**CRR**	**AVG R**	**MR/mR**	**CCR**
	203.72	843.21	0	3701	64.00	-41.00	-0.02	3.10	0.41	280.60	2.11	400.00	6.20	102.40
2+685.87														
	369.48		1	3701	67.00	-38.00								
3+055.34														
	183.95	197.03	0	3701	77.74	-27.26	0.03	12.76	0.55	280.60	0.49	400.00	6.20	102.40
3+239.29														
	91.73		0	3701	75.74	-29.26								
3+331.02														
	249.48	667.98	0	3701	84.50	-20.50	0.07	4.24	0.42	280.60	1.67	400.00	6.20	102.40
3+580.50														
	226.87	290.00	0	3701	85.10	-19.90	0.04	9.39	0.49	280.60	0.73	400.00	6.20	102.40

3+807.37														
	134.68	226.60	0	3701	84.62	-20.38	0.03	10.04	0.53	280.60	0.57	400.00	6.20	102.40
3+942.05														
	77.26		0	3701	67.00	-38.00								
4+019.31														
	117.78	152.26	0	3701	71.00	-34.00	-0.02	14.41	0.61	280.60	0.38	400.00	6.20	102.40
4+137.09														
Stations	**Section**	**Radius**	**$A_{2008-2012}$**	**ADT**	**V_{85}**	**V_{85} - V_D**	**Δf_R**	**ΔV_{85}**	**VD_{LU}**	**AVGT**	**CRR**	**AVGR**	**MR/mR**	**CCR**
	140.30	242.48	1	3701	79.15	-25.85	0.01	9.50	0.52	280.60	0.61	400.00	6.20	102.40
4+277.39														
	142.92	698.35	0	3701	84.07	-20.93	0.01	3.32	0.42	280.60	1.75	400.00	6.20	102.40
4+420.31														
	879.84		0	3701	89.79	-15.21								
5+300.15														
	241.30	492.46	0	3701	84.39	-20.61	0.01	5.67	0.44	280.60	1.23	400.00	6.20	102.40
5+541.45														

Appendix B

Crash Data for Highway Segments

Table B.1: Crash Data for Highway 55 (Nablus to Qalqilya Road)

Year	Month	Day of the Week	Day / Night	Crash Severity	Type of Crash	Casualties	Vehicle	X	Y
2003	July	Wednesday	Day	Slight	Over-Turn Crash	1	1	166751	180307
2003	July	Tuesday	Day	Slight	Front-Side Crash	1	2	149804	176643
2003	July	Wednesday	Day	Slight	Head-On Crash	4	3	147395	175581
2003	July	Tuesday	Day	Serious	Head-On Crash	4	2	152127	176770
2003	July	Sunday	Day	Slight	Ran-Off Crash	1	1	160073	176223
2003	July	Thursday	Day	Serious	Rear-End Crash	5	2	148939	176159
2003	July	Sunday	Night	Slight	Skidding Crash	1	1	148021	175803
2003	March	Sunday	Day	Slight	Front-Side Crash	2	2	151758	176922
2003	April	Tuesday	Night	Slight	Over-Turn Crash	1	1	150691	177038
2003	December	Thursday	Night	Slight	Front-Side Crash	1	2	159129	175935
2003	December	Wednesday	Night	Slight	Front-Side Crash	5	2	148939	176160
2003	January	Sunday	Night	Slight	Over-Turn Crash	1	1	160806	176737
2003	January	Tuesday	Night	Slight	Front-Side Crash	2	3	152602	176665
2003	October	Thursday	Night	Slight	Rear-End Crash	4	2	162449	176757
2003	October	Wednesday	Night	Slight	Ran-Off Crash	4	1	165922	180092
2003	November	Monday	Day	Slight	Ran-Off Crash	1	2	154037	176424
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2003	June	Sunday	Day	Fatal	Ran-Off Crash	1	2	165922	180093
2003	June	Monday	Day	Slight	Rear-End Crash	8	2	163239	177600
2003	June	Wednesday	Day	Serious	Over-Turn Crash	2	1	152602	176665
2003	May	Saturday	Night	Slight	Over-Turn Crash	1	1	152791	176606
2003	January	Monday	Day	Slight	Rear-End Crash	1	2	155017	176577

2003	September	Sunday	Night	Slight	Front-Side Crash	2	2	149380	176387
2003	November	Wednesday	Night	Slight	Front-Side Crash	1	2	148187	175911
2003	December	Sunday	Night	Serious	Rear-End Crash	2	2	149804	176646
2003	December	Tuesday	Night	Fatal	Front-Side Crash	1	2	159608	176049
2003	September	Tuesday	Day	Slight	Front-Side Crash	1	2	148305	175952
2004	May	Saturday	Day	Serious	Front-Side Crash	4	2	148305	175952
2004	May	Thursday	Day	Slight	Front-Side Crash	2	2	152127	176772
2004	May	Sunday	Day	Slight	Ran-Off Crash	2	1	157541	175909
2004	January	Sunday	Day	Slight	Front-Side Crash	1	2	154528	176496
2004	January	Thursday	Night	Slight	Head-On Crash	2	2	150692	177036
2004	October	Monday	Day	Serious	Head-On Crash	2	3	152126	176772
2004	July	Sunday	Day	Slight	Rear-End Crash	1	2	148021	175804
2004	August	Monday	Night	Fatal	Front-Side Crash	2	2	151665	176957
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2004	August	Tuesday	Day	Slight	Front-Side Crash	3	2	154528	176496
2004	August	Tuesday	Day	Slight	Rear-End Crash	7	3	154528	176496
2004	April	Saturday	Night	Slight	Over-Turn Crash	2	1	152602	176664
2004	January	Thursday	Night	Slight	Front-Side Crash	2	2	147194	175579
2004	February	Friday	Day	Slight	Front-Side Crash	2	2	149803	176645
2004	February	Saturday	Night	Slight	Front-Side Crash	4	3	166783	180300
2004	December	Saturday	Night	Serious	Rear-End Crash	8	2	155955	176746
2004	December	Tuesday	Day	Serious	Rear-End Crash	6	2	149804	176644
2004	June	Tuesday	Day	Slight	Front-Side Crash	2	3	160074	176224
2004	June	Monday	Day	Slight	Rear-End Crash	2	3	147492	175581
2004	July	Tuesday	Day	Slight	Front-Side Crash	1	2	151850	176885

2004	September	Sunday	Night	Slight	Front-Side Crash	2	2	154037	176423
2004	September	Wednesday	Day	Slight	Front-Side Crash	4	2	157541	175911
2004	September	Friday	Day	Slight	Head-On Crash	4	3	160806	176736
2004	September	Thursday	Night	Slight	Rear-End Crash	3	2	152602	176665
2004	December	Wednesday	Day	Slight	Over-Turn Crash	1	1	159609	176049
2004	December	Friday	Day	Serious	Rear-End Crash	2	3	151183	177065
2005	February	Wednesday	Day	Serious	Front-Side Crash	3	2	158341	175931
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2005	March	Sunday	Day	Slight	Side By Side Crash	1	2	155166	176595
2005	March	Tuesday	Day	Slight	Front-Side Crash	1	2	162569	176797
2005	March	Sunday	Day	Slight	Over-Turn Crash	3	2	155995	176746
2005	July	Sunday	Day	Slight	Front-Side Crash	2	2	150474	177014
2005	July	Friday	Day	Serious	Over-Turn Crash	2	1	162569	176797
2005	July	Thursday	Day	Slight	Ran-Off Crash	3	1	161679	176659
2005	August	Sunday	Day	Serious	Over-Turn Crash	2	1	166783	180299
2005	January	Wednesday	Day	Slight	Front-Side Crash	2	2	152126	176773
2005	January	Sunday	Night	Slight	Front-Side Crash	2	3	150224	176903
2005	February	Friday	Night	Slight	Front-Side Crash	3	2	157541	175910
2005	February	Sunday	Day	Serious	Rear-End Crash	4	3	160429	176628
2005	November	Wednesday	Day	Slight	Head-On Crash	1	2	150692	177039
2005	November	Monday	Day	Slight	Rear-End Crash	2	2	151666	176956
2005	November	Tuesday	Day	Slight	Front-Side Crash	1	2	151666	176956
2005	November	Monday	Night	Slight	Rear-End Crash	6	2	160168	176258
2005	December	Tuesday	Day	Slight	Front-Side Crash	4	2	148021	175804
2005	September	Friday	Day	Slight	Front-Side Crash	2	2	150692	177037

Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2005	April	Monday	Day	Slight	Front-Side Crash	8	2	160074	176222
2005	December	Friday	Day	Slight	Head-On Crash	5	2	150471	177014
2005	August	Tuesday	Day	Slight	Rear-End Crash	6	3	147093	175579
2005	July	Wednesday	Day	Slight	Side By Side Crash	2	2	163697	177983
2005	January	Sunday	Day	Slight	Over-Turn Crash	1	1	158637	175921
2006	February	Wednesday	Night	Slight	Front-Side Crash	2	2	150056	176800
2006	February	Sunday	Night	Slight	Front-Side Crash	5	2	150693	177037
2006	February	Saturday	Night	Slight	Front-Side Crash	5	3	150495	177018
2006	February	Thursday	Night	Serious	Rear-End Crash	12	3	157944	175907
2006	May	Wednesday	Night	Slight	Front-Side Crash	1	2	165247	179442
2006	December	Wednesday	Day	Slight	Ran-Off Crash	1	1	147093	175579
2006	December	Friday	Day	Slight	Front-Side Crash	4	3	150472	177015
2006	December	Sunday	Day	Slight	Front-Side Crash	1	2	150472	177015
2006	September	Thursday	Day	Serious	Head-On Crash	4	4	155994	176745
2006	January	Tuesday	Day	Slight	Ran-Off Crash	3	1	166748	180307
2006	January	Thursday	Day	Slight	Front-Side Crash	1	2	152603	176667
2006	November	Sunday	Night	Slight	Front-Side Crash	2	2	148101	175864
2006	November	Wednesday	Day	Slight	Rear-End Crash	2	2	165246	179441
2006	November	Thursday	Day	Slight	Ran-Off Crash	1	1	152602	176666
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2006	November	Sunday	Night	Slight	Front-Side Crash	3	2	155507	176659
2006	March	Sunday	Day	Slight	Head-On Crash	5	2	157275	176025
2006	January	Tuesday	Night	Slight	Head-On Crash	3	2	148187	175908
2006	October	Monday	Night	Slight	Front-Side Crash	2	2	162569	176796

2006	October	Saturday	Night	Fatal	Front-Side Crash	5	2	160708	176725
2006	October	Friday	Day	Serious	Over-Turn Crash	1	1	156574	176721
2006	October	Wednesday	Day	Serious	Side By Side Crash	8	2	166748	180306
2006	October	Friday	Night	Slight	Head-On Crash	3	2	150472	177014
2006	July	Tuesday	Day	Fatal	Over-Turn Crash	2	2	166748	180306
2006	July	Thursday	Day	Slight	Rear-End Crash	6	3	152125	176772
2006	August	Tuesday	Night	Slight	Head-On Crash	4	3	148101	175864
2006	August	Monday	Day	Slight	Front-Side Crash	3	2	150471	177015
2006	April	Monday	Day	Slight	Front-Side Crash	4	2	158818	175896
2006	June	Monday	Day	Serious	Front-Side Crash	7	2	150691	177037
2007	November	Saturday	Night	Serious	Head-On Crash	2	2	147092	175579
2007	November	Thursday	Night	Slight	Over-Turn Crash	3	1	160168	176255
2007	March	Wednesday	Night	Slight	Front-Side Crash	2	2	150471	177015
2007	April	Thursday	Day	Slight	Side By Side Crash	1	2	164760	178791
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2007	May	Wednesday	Day	Slight	Head-On Crash	2	3	164853	178815
2007	June	Tuesday	Night	Slight	Front-Side Crash	4	3	148469	176001
2007	June	Thursday	Day	Slight	Front-Side Crash	2	2	162570	176796
2007	June	Wednesday	Day	Slight	Front-Side Crash	2	2	150471	177016
2007	June	Tuesday	Day	Slight	Front-Side Crash	2	2	149804	176645
2007	August	Monday	Day	Slight	Head-On Crash	1	3	159129	175934
2007	January	Monday	Day	Slight	Front-Side Crash	2	2	157542	175909
2007	February	Wednesday	Day	Slight	Front-Side Crash	1	2	162624	176840
2007	October	Tuesday	Night	Fatal	Over-Turn Crash	2	1	166088	180269
2007	November	Thursday	Night	Fatal	Head-On Crash	2	2	154528	176494

2007	December	Thursday	Day	Slight	Front-Side Crash	2	2	148305	175951
2007	February	Saturday	Night	Slight	Rear-End Crash	7	3	149887	176696
2007	March	Thursday	Night	Slight	Head-On Crash	2	2	152127	176773
2008	June	Sunday	Day	Serious	Head-On Crash	6	2	149022	176196
2008	June	Sunday	Day	Slight	Rear-End Crash	1	2	157136	176166
2008	June	Wednesday	Night	Slight	Side By Side Crash	1	2	153560	176547
2008	June	Thursday	Night	Slight	Side By Side Crash	3	2	155155	176593
2008	June	Thursday	Night	Slight	Rear-End Crash	5	3	155017	176577
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	July	Friday	Day	Slight	Over-Turn Crash	1	1	165247	179440
2008	July	Monday	Day	Slight	Front-Side Crash	5	3	160167	176256
2008	July	Wednesday	Day	Slight	Front-Side Crash	2	2	160616	176691
2008	April	Thursday	Day	Slight	Rear-End Crash	4	3	162570	176797
2008	April	Tuesday	Day	Slight	Front-Side Crash	2	2	163238	177600
2008	January	Wednesday	Day	Slight	Side By Side Crash	2	2	148023	175803
2008	January	Saturday	Night	Slight	Rear-End Crash	6	2	152695	176628
2008	February	Monday	Day	Slight	Rear-End Crash	1	2	148023	175803
2008	February	Wednesday	Day	Slight	Front-Side Crash	1	2	151942	176848
2008	February	Monday	Day	Slight	Over-Turn Crash	1	1	166748	180307
2008	January	Friday	Night	Slight	Side By Side Crash	5	2	165987	180166
2008	January	Saturday	Day	Slight	Front-Side Crash	4	2	152320	176745
2008	November	Friday	Night	Serious	Head-On Crash	7	2	152693	176630
2008	November	Wednesday	Night	Slight	Front-Side Crash	3	2	150470	177013
2008	March	Friday	Night	Slight	Front-Side Crash	2	2	152512	176702
2008	March	Tuesday	Day	Slight	Front-Side Crash	4	2	150691	177037

2008	November	Sunday	Day	Slight	Head-On Crash	4	2	156388	176799
2008	November	Wednesday	Night	Slight	Head-On Crash	3	2	149804	176644
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	December	Monday	Day	Slight	Front-Side Crash	2	2	150471	177014
2008	July	Saturday	Day	Slight	Over-Turn Crash	1	1	158141	175918
2008	July	Saturday	Night	Slight	Head-On Crash	6	2	166747	180308
2008	August	Monday	Day	Slight	Front-Side Crash	1	2	163624	177911
2008	May	Thursday	Night	Slight	Rear-End Crash	1	2	158042	175913
2008	May	Wednesday	Day	Serious	Head-On Crash	2	2	149466	176435
2008	May	Thursday	Day	Slight	Front-Side Crash	3	2	153467	176582
2008	June	Thursday	Day	Serious	Front-Side Crash	3	3	155801	176710
2008	August	Tuesday	Night	Slight	Over-Turn Crash	2	1	166747	180308
2008	August	Tuesday	Night	Slight	Front-Side Crash	2	2	150471	177014
2008	September	Saturday	Day	Slight	Front-Side Crash	2	2	151182	177064
2008	September	Sunday	Night	Slight	Front-Side Crash	2	2	149803	176643
2009	January	Wednesday	Day	Slight	Front-Side Crash	2	2	164853	178817
2009	January	Wednesday	Night	Slight	Front-Side Crash	1	2	149804	176642
2009	January	Thursday	Night	Slight	Rear-End Crash	7	2	165659	179675
2009	January	Thursday	Night	Slight	Head-On Crash	6	3	148307	175949
2009	December	Wednesday	Night	Slight	Front-Side Crash	4	2	152605	176661
2009	December	Monday	Day	Slight	Front-Side Crash	3	3	158820	175897
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	December	Sunday	Day	Slight	Front-Side Crash	5	2	150471	177014
2009	December	Tuesday	Night	Slight	Rear-End Crash	1	2	148021	175803
2009	December	Tuesday	Night	Slight	Head-On Crash	3	3	165246	179440

2009	January	Sunday	Night	Serious	Head-On Crash	2	2	158041	175912
2009	October	Monday	Night	Slight	Rear-End Crash	2	3	154234	176444
2009	November	Tuesday	Day	Fatal	Front-Side Crash	4	2	153467	176583
2009	November	Sunday	Night	Slight	Head-On Crash	3	2	150471	177014
2009	August	Thursday	Day	Slight	Side By Side Crash	6	3	151665	176955
2009	August	Thursday	Night	Slight	Head-On Crash	5	2	164869	179139
2009	September	Wednesday	Night	Serious	Over-Turn Crash	1	1	158241	175926
2009	September	Thursday	Day	Slight	Front-Side Crash	1	2	155605	176677
2009	September	Saturday	Day	Serious	Rear-End Crash	2	2	147193	175580
2009	October	Thursday	Day	Slight	Front-Side Crash	1	2	151942	176850
2009	October	Sunday	Day	Serious	Rear-End Crash	1	2	159327	175952
2009	October	Friday	Day	Slight	Front-Side Crash	2	2	153188	176664
2009	October	Monday	Day	Slight	Front-Side Crash	4	2	156483	176759
2009	October	Monday	Day	Slight	Rear-End Crash	2	2	160167	176255
2009	May	Thursday	Day	Slight	Front-Side Crash	2	2	150591	177032
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	June	Thursday	Day	Slight	Front-Side Crash	2	2	147094	175579
2009	June	Thursday	Day	Serious	Head-On Crash	3	2	152694	176629
2009	June	Thursday	Day	Slight	Rear-End Crash	1	2	152125	176772
2009	April	Thursday	Night	Slight	Head-On Crash	3	2	160806	176737
2009	July	Wednesday	Day	Slight	Front-Side Crash	4	2	161875	176644
2009	July	Sunday	Day	Serious	Head-On Crash	3	3	156575	176720
2010	February	Thursday	Night	Slight	Front-Side Crash	4	2	151283	177052
2010	March	Tuesday	Day	Slight	Front-Side Crash	3	2	148021	175805
2010	March	Sunday	Day	Slight	Front-Side Crash	2	2	163074	177467

2010	March	Sunday	Night	Slight	Front-Side Crash	4	3	152219	176743
2010	March	Wednesday	Night	Slight	Head-On Crash	1	2	150471	177015
2010	January	Sunday	Night	Serious	Over-Turn Crash	1	1	162939	177223
2010	January	Sunday	Day	Slight	Front-Side Crash	3	2	150471	177015
2010	August	Wednesday	Day	Slight	Head-On Crash	2	2	158242	175925
2010	August	Thursday	Day	Serious	Head-On Crash	3	2	150224	176903
2010	August	Wednesday	Day	Slight	Front-Side Crash	12	2	149887	176694
2010	August	Tuesday	Day	Slight	Rear-End Crash	4	5	151664	176956
2010	July	Friday	Night	Slight	Head-On Crash	2	2	152695	176627
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2010	July	Thursday	Day	Slight	Front-Side Crash	2	2	150471	177015
2010	July	Monday	Day	Slight	Front-Side Crash	1	2	153182	176664
2010	July	Tuesday	Day	Slight	Front-Side Crash	1	2	150471	177015
2010	September	Wednesday	Night	Slight	Front-Side Crash	2	2	158819	175897
2010	October	Sunday	Day	Slight	Rear-End Crash	4	2	165246	179441
2010	October	Friday	Day	Slight	Side By Side Crash	1	2	166508	180407
2010	January	Thursday	Day	Slight	Front-Side Crash	1	2	151665	176956
2010	January	Friday	Day	Slight	Over-Turn Crash	1	1	155409	176646
2010	January	Saturday	Day	Serious	Front-Side Crash	2	2	153652	176514
2010	January	Friday	Day	Slight	Side By Side Crash	7	2	150691	177038
2010	February	Tuesday	Day	Slight	Head-On Crash	4	3	147392	175580
2010	March	Friday	Night	Slight	Head-On Crash	2	2	148306	175949
2010	April	Wednesday	Day	Slight	Front-Side Crash	2	2	160427	176631
2010	April	Tuesday	Day	Slight	Front-Side Crash	2	2	163075	177467
2010	April	Thursday	Day	Slight	Rear-End Crash	3	2	154626	176510

2010	May	Friday	Night	Slight	Front-Side Crash	2	2	158820	175898
2010	December	Monday	Day	Serious	Front-Side Crash	2	3	148567	176027
2010	December	Thursday	Night	Slight	Rear-End Crash	1	2	148306	175949
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2010	December	Thursday	Night	Slight	Rear-End Crash	2	2	158340	175931
2010	October	Tuesday	Day	Slight	Front-Side Crash	2	2	149803	176643
2010	October	Wednesday	Night	Serious	Side By Side Crash	1	2	149032	176198
2010	November	Sunday	Day	Slight	Front-Side Crash	1	2	157541	175910
2010	November	Sunday	Day	Slight	Front-Side Crash	2	2	150471	177015
2010	November	Thursday	Day	Slight	Head-On Crash	6	2	150471	177015
2010	November	Wednesday	Day	Serious	Over-Turn Crash	2	1	164662	178779
2010	December	Wednesday	Day	Slight	Front-Side Crash	2	2	150987	177065
2010	August	Friday	Day	Slight	Rear-End Crash	1	3	152602	176664
2010	August	Sunday	Night	Slight	Head-On Crash	2	2	164476	178731
2010	August	Sunday	Night	Fatal	Side By Side Crash	6	3	164182	178473
2010	May	Thursday	Day	Slight	Head-On Crash	5	2	150471	177015
2010	May	Thursday	Night	Slight	Side By Side Crash	1	2	153082	176662
2010	May	Monday	Night	Slight	Front-Side Crash	3	2	149380	176385
2010	June	Saturday	Night	Slight	Skidding Crash	1	1	154528	176495
2010	June	Thursday	Day	Slight	Front-Side Crash	5	2	150471	177015
2011	February	Saturday	Day	Slight	Front-Side Crash	1	2	148306	175952.5
2011	February	Wednesday	Day	Slight	Head-On Crash	5	2	157541	175909
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	February	Thursday	Day	Slight	Front-Side Crash	3	2	166750	180305.5
2011	March	Wednesday	Night	Slight	Side By Side Crash	3	3	158141	175919.7

2011	March	Thursday	Night	Slight	Over-Turn Crash	5	1	151183	177064
2011	January	Monday	Day	Slight	Front-Side Crash	3	2	162569	176796
2011	May	Friday	Night	Slight	Front-Side Crash	2	2	160807	176736
2011	June	Monday	Day	Slight	Front-Side Crash	2	2	152127	176773
2011	July	Friday	Day	Slight	Front-Side Crash	4	2	152602	176664
2011	August	Monday	Day	Slight	Front-Side Crash	2	2	149803	176645
2011	August	Monday	Day	Slight	Front-Side Crash	3	2	147095	175579
2011	August	Monday	Day	Slight	Rear-End Crash	6	2	147095	175579
2011	August	Monday	Day	Slight	Head-On Crash	4	2	163991	178247
2011	October	Tuesday	Day	Fatal	Head-On Crash	2	2	160805	176736
2011	October	Monday	Night	Slight	Head-On Crash	3	2	150223	176904
2011	August	Thursday	Night	Slight	Front-Side Crash	1	2	155017	176578
2011	September	Monday	Night	Slight	Rear-End Crash	2	3	151665	176957
2011	September	Tuesday	Day	Slight	Front-Side Crash	6	2	160290	176396
2011	September	Thursday	Day	Slight	Front-Side Crash	2	3	160073	176220
2011	September	Saturday	Day	Slight	Head-On Crash	6	2	150691	177037
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	September	Thursday	Day	Slight	Front-Side Crash	1	2	151665	176955
2011	October	Friday	Night	Serious	Head-On Crash	5	2	156659	176668
2011	February	Saturday	Night	Slight	Front-Side Crash	2	2	148021	175804
2011	November	Sunday	Night	Slight	Side By Side Crash	2	2	162596	176796
2011	December	Thursday	Night	Slight	Front-Side Crash	2	2	148939	176160
2011	December	Wednesday	Day	Slight	Front-Side Crash	1	2	150691	177039
2011	December	Saturday	Day	Serious	Head-On Crash	5	2	153188	176664
2011	December	Sunday	Night	Slight	Rear-End Crash	1	2	147093	175578

2011	April	Tuesday	Day	Slight	Head-On Crash	1	2	166749	180305
2011	April	Wednesday	Night	Slight	Front-Side Crash	6	2	147093	175578
2011	April	Tuesday	Night	Slight	Head-On Crash	5	3	152126	176772
2011	May	Friday	Day	Slight	Front-Side Crash	1	2	166782	180299
2011	May	Friday	Day	Slight	Front-Side Crash	1	2	148939	176158
2012	February	Wednesday	Night	Slight	Front-Side Crash	2	2	166687	180324
2012	February	Sunday	Day	Slight	Rear-End Crash	1	2	153559	176549
2012	February	Tuesday	Day	Slight	Front-Side Crash	3	2	151665	176955
2012	March	Sunday	Day	Slight	Front-Side Crash	3	2	166750	180308
2012	April	Thursday	Day	Fatal	Front-Side Crash	1	3	147093	175580
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	April	Friday	Day	Slight	Front-Side Crash	1	2	149803	176645
2012	April	Friday	Day	Slight	Front-Side Crash	5	2	162624	176841
2012	April	Saturday	Day	Slight	Front-Side Crash	1	2	160806	176737
2012	February	Sunday	Day	Slight	Head-On Crash	4	2	150691	177038
2012	February	Saturday	Night	Slight	Head-On Crash	4	2	150494	177019
2012	December	Sunday	Night	Slight	Ran-Off Crash	2	1	148471	176000
2012	December	Thursday	Night	Serious	Front-Side Crash	1	2	157203	176095
2012	December	Tuesday	Night	Slight	Front-Side Crash	6	2	158834	175896
2012	April	Monday	Day	Slight	Front-Side Crash	1	2	161678	176659
2012	April	Sunday	Night	Slight	Head-On Crash	3	2	149803	176645
2012	May	Wednesday	Day	Slight	Head-On Crash	3	2	154528	176495
2012	May	Saturday	Day	Slight	Front-Side Crash	1	2	150691	177037
2012	May	Thursday	Day	Slight	Front-Side Crash	1	2	148186	175910
2012	May	Wednesday	Day	Slight	Front-Side Crash	2	2	163989	178246

2012	May	Sunday	Day	Slight	Front-Side Crash	5	2	163074	177466
2012	May	Wednesday	Day	Slight	Front-Side Crash	2	2	150691	177038
2012	May	Friday	Day	Slight	Front-Side Crash	1	2	151666	176955
2012	June	Wednesday	Day	Slight	Front-Side Crash	3	2	150400	176991
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	June	Wednesday	Day	Serious	Head-On Crash	6	2	165246	179439
2012	July	Thursday	Day	Serious	Front-Side Crash	1	3	148938	176159
2012	July	Friday	Day	Slight	Front-Side Crash	4	2	163238	177599
2012	July	Sunday	Day	Slight	Front-Side Crash	2	2	150691	177038
2012	September	Thursday	Day	Slight	Rear-End Crash	1	3	157204	176093
2012	September	Monday	Day	Slight	Head-On Crash	3	2	150222	176902
2012	October	Tuesday	Day	Slight	Over-Turn Crash	1	1	157203	176094
2012	October	Thursday	Night	Slight	Front-Side Crash	1	2	151667	176955
2012	August	Thursday	Day	Slight	Side By Side Crash	4	2	161680	176659
2012	August	Sunday	Day	Slight	Front-Side Crash	1	2	159608	176048
2012	August	Tuesday	Night	Slight	Front-Side Crash	3	2	165245	179440
2012	August	Monday	Night	Slight	Side By Side Crash	1	2	154528	176496
2012	July	Wednesday	Day	Slight	Front-Side Crash	2	2	162624	176841
2012	November	Thursday	Day	Slight	Ran-Off Crash	1	1	152601	176665
2012	November	Sunday	Day	Slight	Side By Side Crash	2	2	149803	176645
2012	December	Friday	Day	Slight	Front-Side Crash	1	3	162625	176841

Table B.2: Crash Data for Highway 60 (Nablus to Hebron Road)

Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2003	February	Sunday	Day	Slight	Head-On Crash	3	3	175578	175334
2003	July	Wednesday	Day	Slight	Over-Turn Crash	1	1	166751	180305
2003	December	Friday	Day	Slight	Side By Side Crash	3	2	174445	170704
2003	April	Saturday	Night	Fatal	Over-Turn Crash	2	1	174516	172317
2003	July	Sunday	Day	Slight	Front-Side Crash	3	2	174495	172745
2003	January	Tuesday	Day	Slight	Front-Side Crash	5	2	167911	185636
2003	January	Wednesday	Day	Slight	Front-Side Crash	2	2	174453	150651
2003	January	Wednesday	Night	Slight	Front-Side Crash	5	3	173924	156082
2003	November	Friday	Day	Slight	Ran-Off Crash	2	1	174454	169531
2004	August	Wednesday	Day	Slight	Over-Turn Crash	7	1	174315	152459
2004	August	Thursday	Day	Slight	Head-On Crash	4	2	173398	167390
2004	August	Thursday	Day	Slight	Front-Side Crash	6	2	174694	165207
2004	December	Friday	Day	Slight	Front-Side Crash	1	2	174440	169106
2004	December	Wednesday	Day	Slight	Front-Side Crash	1	2	174023	175332
2004	December	Thursday	Night	Slight	Front-Side Crash	2	2	174394	151739
2004	May	Friday	Night	Slight	Over-Turn Crash	3	1	174897	174449
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2004	September	Friday	Day	Slight	Front-Side Crash	2	2	174598	174737
2004	September	Wednesday	Day	Slight	Front-Side Crash	3	2	175327	158445
2004	July	Friday	Night	Fatal	Front-Side Crash	4	2	174700	173810
2004	July	Tuesday	Day	Slight	Side By Side Crash	1	2	174522	171394

2004	July	Monday	Day	Slight	Head-On Crash	2	2	173706	175604
2004	December	Monday	Night	Slight	Ran-Off Crash	1	1	174440	169105
2004	January	Monday	Day	Serious	Rear-End Crash	4	2	174950	166545
2004	October	Thursday	Day	Slight	Over-Turn Crash	1	1	177510	161678
2004	October	Saturday	Day	Slight	Front-Side Crash	2	2	174831	174236
2004	February	Thursday	Day	Serious	Over-Turn Crash	1	1	173427	147374
2004	June	Thursday	Day	Fatal	Head-On Crash	2	3	175172	165984
2004	June	Saturday	Day	Slight	Front-Side Crash	1	2	174291	169914
2004	November	Tuesday	Day	Serious	Front-Side Crash	1	2	174471	170801
2004	March	Friday	Day	Slight	Over-Turn Crash	3	1	174454	169531
2004	March	Monday	Day	Slight	Rear-End Crash	4	2	174505	172812
2004	July	Saturday	Day	Serious	Ran-Off Crash	1	1	174597	174739
2004	July	Wednesday	Night	Slight	Over-Turn Crash	2	1	174644	174669
2004	December	Monday	Night	Slight	Front-Side Crash	5	2	174745	163245
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2005	June	Thursday	Day	Slight	Front-Side Crash	4	3	175985	159326
2005	October	Sunday	Day	Slight	Head-On Crash	4	2	174291	169917
2005	July	Wednesday	Day	Serious	Head-On Crash	3	2	174441	169107
2005	July	Tuesday	Day	Serious	Head-On Crash	9	2	174443	168648
2005	July	Thursday	Day	Serious	Over-Turn Crash	1	1	175987	159323
2005	September	Friday	Day	Slight	Front-Side Crash	1	2	174351	175073
2005	September	Monday	Day	Slight	Head-On Crash	3	2	174291	169917
2005	September	Friday	Day	Slight	Front-Side Crash	6	2	174316	152460
2005	March	Monday	Day	Slight	Head-On Crash	2	2	176614	160887
2005	November	Sunday	Night	Slight	Front-Side Crash	4	2	174291	169917

2005	February	Thursday	Night	Slight	Front-Side Crash	1	2	174023	175332
2005	July	Sunday	Day	Slight	Front-Side Crash	1	2	174523	171293
2005	December	Friday	Day	Fatal	Front-Side Crash	3	2	174270	163243
2005	December	Thursday	Night	Slight	Side By Side Crash	2	4	173718	164571
2005	March	Thursday	Night	Slight	Rear-End Crash	3	2	174831	174239
2005	August	Sunday	Day	Slight	Front-Side Crash	1	2	173399	167390
2005	August	Saturday	Day	Slight	Front-Side Crash	4	2	173399	167390
2005	August	Friday	Day	Slight	Rear-End Crash	10	2	174515	171523
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2005	January	Thursday	Night	Fatal	Head-On Crash	4	4	173964	153416
2005	June	Sunday	Day	Slight	Over-Turn Crash	1	1	174291	169916
2005	June	Tuesday	Day	Slight	Front-Side Crash	1	3	174619	173374
2006	August	Thursday	Day	Slight	Front-Side Crash	2	2	174450	150745
2006	January	Tuesday	Day	Slight	Ran-Off Crash	3	1	166748	180307
2006	June	Tuesday	Day	Slight	Front-Side Crash	1	2	177511	161680
2006	November	Sunday	Day	Slight	Front-Side Crash	1	2	173399	167391
2006	November	Sunday	Day	Slight	Head-On Crash	3	2	166317	182408
2006	January	Monday	Night	Serious	Front-Side Crash	6	2	174450	150743
2006	July	Tuesday	Day	Slight	Over-Turn Crash	1	1	173493	167006
2006	April	Monday	Day	Fatal	Head-On Crash	8	2	175985	159327
2006	April	Friday	Day	Slight	Head-On Crash	4	2	175985	159327
2006	September	Tuesday	Day	Slight	Head-On Crash	4	2	173923	156083
2006	September	Wednesday	Day	Slight	Front-Side Crash	4	2	177510	161678
2006	December	Monday	Night	Slight	Front-Side Crash	5	2	173398	167390
2006	August	Sunday	Day	Slight	Front-Side Crash	2	2	167910	185636

2006	August	Friday	Day	Slight	Head-On Crash	1	3	174498	171097
2006	August	Friday	Day	Slight	Over-Turn Crash	1	1	174351	175075
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2006	August	Wednesday	Day	Slight	Head-On Crash	4	2	174619	173375
2006	August	Thursday	Day	Slight	Front-Side Crash	2	2	174401	170514
2006	October	Wednesday	Day	Serious	Side By Side Crash	8	2	166748	180307
2006	January	Sunday	Night	Slight	Over-Turn Crash	1	1	174511	172848
2006	May	Wednesday	Night	Fatal	Head-On Crash	11	2	174000	164712
2006	May	Tuesday	Day	Slight	Front-Side Crash	3	2	174510	172424
2006	March	Monday	Day	Slight	Over-Turn Crash	5	1	174510	167007
2006	September	Saturday	Night	Slight	Over-Turn Crash	4	1	173872	167891
2006	July	Tuesday	Day	Fatal	Over-Turn Crash	2	2	166748	180307
2006	July	Tuesday	Day	Slight	Rear-End Crash	1	2	174510	171786
2006	July	Friday	Day	Slight	Side By Side Crash	6	2	174639	173484
2006	December	Tuesday	Day	Slight	Front-Side Crash	2	2	174831	174239
2007	March	Tuesday	Day	Serious	Rear-End Crash	2	2	173629	148280
2007	March	Sunday	Night	Slight	Rear-End Crash	1	2	174619	173375
2007	March	Saturday	Night	Slight	Head-On Crash	3	2	174291	169917
2007	April	Monday	Day	Slight	Rear-End Crash	1	2	175378	158541
2007	September	Monday	Day	Slight	Front-Side Crash	2	2	174440	169179
2007	January	Monday	Day	Serious	Rear-End Crash	2	3	174521	171395
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2007	June	Tuesday	Day	Slight	Rear-End Crash	3	2	173427	147374
2007	October	Tuesday	Day	Slight	Head-On Crash	6	2	174296	166786
2007	October	Saturday	Night	Slight	Front-Side Crash	6	2	173489	163560

2007	July	Sunday	Day	Slight	Head-On Crash	2	2	173716	155213
2007	December	Thursday	Day	Slight	Rear-End Crash	2	2	173398	167390
2007	November	Thursday	Day	Slight	Rear-End Crash	9	2	173398	167390
2007	November	Friday	Day	Slight	Over-Turn Crash	2	1	174896	174451
2007	March	Tuesday	Day	Slight	Head-On Crash	3	2	174432	169710
2007	March	Sunday	Day	Slight	Front-Side Crash	3	2	174394	151739
2007	August	Sunday	Day	Slight	Front-Side Crash	4	2	174744	163244
2007	August	Thursday	Day	Slight	Rear-End Crash	4	2	174512	171908
2007	August	Saturday	Day	Slight	Rear-End Crash	4	2	174523	171292
2007	July	Friday	Day	Slight	Head-On Crash	1	2	175022	157604
2007	July	Sunday	Day	Slight	Front-Side Crash	2	2	173717	155215
2007	January	Sunday	Day	Slight	Head-On Crash	3	2	174897	174449
2007	January	Wednesday	Day	Slight	Front-Side Crash	2	2	174395	151740
2007	May	Thursday	Day	Serious	Front-Side Crash	4	2	175985	159326
2007	May	Monday	Day	Slight	Head-On Crash	2	2	173398	167390
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2007	November	Sunday	Day	Slight	Front-Side Crash	2	2	174896	174452
2007	October	Friday	Day	Slight	Head-On Crash	2	2	174502	174875
2008	August	Friday	Night	Slight	Over-Turn Crash	3	1	145704	84135
2008	August	Sunday	Day	Slight	Front-Side Crash	1	2	161457	110337
2008	August	Thursday	Day	Slight	Side By Side Crash	1	2	174897	174451
2008	August	Sunday	Day	Slight	Front-Side Crash	3	2	164488	120848
2008	August	Wednesday	Day	Slight	Front-Side Crash	2	2	171860	138504
2008	August	Tuesday	Day	Slight	Front-Side Crash	3	2	173398	167390
2008	August	Wednesday	Day	Slight	Rear-End Crash	1	3	167911	185634

2008	August	Wednesday	Day	Fatal	Head-On Crash	2	2	165177	123649
2008	August	Sunday	Day	Slight	Front-Side Crash	1	2	161458	110337
2008	August	Thursday	Day	Serious	Head-On Crash	2	2	174502	174875
2008	January	Monday	Day	Slight	Front-Side Crash	2	2	162895	117384
2008	January	Sunday	Night	Slight	Front-Side Crash	6	2	162585	117092
2008	January	Wednesday	Night	Serious	Front-Side Crash	3	2	163743	117898
2008	January	Monday	Night	Slight	Rear-End Crash	1	2	169597	126527
2008	July	Monday	Day	Slight	Rear-End Crash	2	2	174000	164708
2008	July	Thursday	Day	Slight	Front-Side Crash	1	2	165006	123463
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	July	Wednesday	Day	Serious	Front-Side Crash	2	2	174645	174666
2008	July	Sunday	Day	Slight	Front-Side Crash	5	3	160567	111433
2008	July	Thursday	Day	Slight	Rear-End Crash	1	2	164892	122819
2008	November	Saturday	Night	Fatal	Head-On Crash	9	2	162535	116518
2008	November	Sunday	Night	Serious	Skidding Crash	1	1	160567	111432
2008	December	Wednesday	Day	Slight	Head-On Crash	2	2	161410	108363
2008	December	Wednesday	Day	Slight	Head-On Crash	1	4	160443	111499
2008	December	Sunday	Day	Slight	Over-Turn Crash	1	1	160814	113167
2008	December	Thursday	Day	Slight	Rear-End Crash	5	2	174767	174025
2008	March	Monday	Day	Slight	Front-Side Crash	1	2	163548	117698
2008	March	Thursday	Day	Slight	Over-Turn Crash	6	1	153386	92482
2008	March	Thursday	Day	Serious	Front-Side Crash	3	2	177512	161679
2008	March	Tuesday	Night	Serious	Head-On Crash	3	2	177512	161679
2008	March	Sunday	Night	Slight	Rear-End Crash	1	4	174510	172426
2008	August	Tuesday	Night	Slight	Over-Turn Crash	2	1	166750	180306

2008	August	Thursday	Night	Slight	Rear-End Crash	2	2	162677	117203
2008	September	Friday	Day	Serious	Front-Side Crash	2	2	166477	124496
2008	September	Thursday	Day	Slight	Front-Side Crash	4	2	166998	180142
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	September	Friday	Day	Serious	Front-Side Crash	8	2	163621	119516
2008	September	Monday	Day	Slight	Over-Turn Crash	3	1	174398	170314
2008	February	Monday	Day	Slight	Rear-End Crash	2	2	165153	121146
2008	February	Monday	Day	Slight	Head-On Crash	2	2	174761	174550
2008	February	Monday	Day	Slight	Over-Turn Crash	1	1	166750	180307
2008	June	Sunday	Day	Slight	Head-On Crash	3	2	173399	167390
2008	June	Wednesday	Day	Fatal	Front-Side Crash	3	2	161186	110468
2008	June	Thursday	Day	Slight	Front-Side Crash	1	2	169597	126528
2008	November	Wednesday	Day	Serious	Front-Side Crash	2	2	160567	111432
2008	November	Wednesday	Day	Slight	Side By Side Crash	1	2	174761	174550
2008	November	Tuesday	Day	Slight	Ran-Off Crash	3	1	153397	91546
2008	November	Thursday	Day	Slight	Front-Side Crash	6	3	165005	123466
2008	November	Thursday	Night	Slight	Side By Side Crash	1	2	163549	117698
2008	November	Sunday	Night	Slight	Front-Side Crash	5	2	173398	167393
2008	November	Tuesday	Night	Slight	Front-Side Crash	5	2	152020	94884
2008	November	Thursday	Night	Slight	Front-Side Crash	2	2	165004	123464
2008	November	Sunday	Night	Slight	Front-Side Crash	2	2	175737	143192
2008	May	Wednesday	Day	Slight	Front-Side Crash	2	2	173399	167389
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	September	Friday	Day	Slight	Head-On Crash	4	2	162350	114671
2008	September	Wednesday	Day	Slight	Head-On Crash	1	2	160745	112687

2008	September	Monday	Day	Slight	Front-Side Crash	5	2	165006	123465
2008	September	Monday	Day	Slight	Head-On Crash	2	2	161458	110336
2008	September	Wednesday	Day	Serious	Head-On Crash	4	2	176336	163276
2008	September	Monday	Day	Slight	Front-Side Crash	3	2	174869	142202
2008	September	Monday	Day	Slight	Head-On Crash	11	4	162631	105145
2008	April	Wednesday	Night	Serious	Front-Side Crash	3	2	174515	166773
2008	April	Saturday	Day	Slight	Front-Side Crash	3	2	164489	120849
2008	September	Friday	Night	Slight	Front-Side Crash	6	2	165176	121508
2008	September	Saturday	Night	Slight	Rear-End Crash	6	2	174511	171803
2008	September	Tuesday	Night	Serious	Over-Turn Crash	2	1	173717	155215
2008	October	Wednesday	Night	Serious	Front-Side Crash	3	2	165175	121511
2008	October	Thursday	Day	Slight	Front-Side Crash	1	2	169598	126529
2008	October	Thursday	Day	Slight	Head-On Crash	8	3	174432	169705
2008	April	Sunday	Night	Slight	Head-On Crash	6	2	174952	140199
2008	April	Tuesday	Night	Slight	Head-On Crash	1	2	172460	137158
2008	July	Wednesday	Day	Slight	Front-Side Crash	1	2	174951	140199
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	July	Sunday	Night	Slight	Front-Side Crash	1	2	163549	117698
2008	July	Thursday	Night	Slight	Front-Side Crash	4	2	162585	117094
2008	July	Saturday	Night	Slight	Head-On Crash	6	2	166748	180306
2008	December	Wednesday	Night	Slight	Head-On Crash	3	2	160567	111432
2008	January	Thursday	Day	Slight	Rear-End Crash	1	2	165267	122284
2008	January	Tuesday	Day	Serious	Rear-End Crash	5	2	173492	167009
2008	January	Tuesday	Day	Slight	Side By Side Crash	1	2	162711	102367
2008	January	Tuesday	Day	Slight	Over-Turn Crash	3	1	173579	164297

2008	October	Saturday	Night	Slight	Front-Side Crash	1	2	168664	177519
2008	October	Thursday	Night	Slight	Front-Side Crash	4	2	169291	126609
2008	October	Thursday	Night	Serious	Rear-End Crash	4	3	174897	174515
2008	October	Sunday	Night	Slight	Rear-End Crash	2	2	163549	117698
2008	October	Monday	Night	Slight	Front-Side Crash	2	2	172461	137158
2008	November	Friday	Day	Slight	Side By Side Crash	1	2	174387	169781
2008	November	Thursday	Day	Slight	Head-On Crash	2	2	164552	120916
2008	December	Wednesday	Day	Slight	Front-Side Crash	2	2	177512	161680
2009	January	Sunday	Night	Slight	Front-Side Crash	3	2	162121	109535
2009	February	Saturday	Night	Fatal	Front-Side Crash	4	3	175985	159328
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	February	Monday	Night	Slight	Front-Side Crash	2	2	176276	143826
2009	February	Wednesday	Day	Slight	Over-Turn Crash	1	1	175125	142385
2009	February	Sunday	Day	Serious	Front-Side Crash	1	2	163549	117699
2009	January	Sunday	Day	Slight	Side By Side Crash	3	2	174744	163244
2009	January	Thursday	Day	Slight	Head-On Crash	2	2	163860	118787
2009	January	Saturday	Night	Slight	Front-Side Crash	5	2	161377	108068
2009	March	Saturday	Day	Slight	Front-Side Crash	1	2	163548	117700
2009	March	Sunday	Day	Slight	Front-Side Crash	2	2	163548	117700
2009	March	Sunday	Day	Fatal	Head-On Crash	9	2	163563	119590
2009	March	Friday	Day	Slight	Front-Side Crash	6	2	165007	123467
2009	March	Sunday	Day	Slight	Head-On Crash	2	2	145703	84134
2009	March	Wednesday	Day	Slight	Rear-End Crash	1	2	166002	184838
2009	February	Saturday	Night	Slight	Front-Side Crash	1	2	172461	137158
2009	June	Wednesday	Day	Slight	Head-On Crash	5	3	164917	122403

2009	June	Thursday	Day	Slight	Head-On Crash	3	2	174744	163245
2009	July	Wednesday	Day	Slight	Rear-End Crash	2	2	173716	155215
2009	July	Thursday	Day	Slight	Rear-End Crash	3	3	174657	173594
2009	June	Saturday	Day	Slight	Front-Side Crash	1	2	164488	120848
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	June	Friday	Day	Fatal	Front-Side Crash	9	2	164488	120848
2009	June	Friday	Day	Slight	Front-Side Crash	1	2	166311	182488
2009	June	Saturday	Day	Slight	Ran-Off Crash	1	1	160773	112779
2009	June	Saturday	Day	Slight	Front-Side Crash	5	2	176795	162971
2009	June	Monday	Day	Slight	Front-Side Crash	1	2	163548	117700
2009	March	Wednesday	Night	Slight	Front-Side Crash	2	2	165267	122284
2009	April	Friday	Day	Slight	Over-Turn Crash	5	2	171610	139602
2009	April	Sunday	Day	Slight	Skidding Crash	6	1	149842	86975
2009	February	Wednesday	Day	Serious	Head-On Crash	5	2	174962	157522
2009	February	Sunday	Day	Slight	Front-Side Crash	3	2	174619	173375
2009	February	Wednesday	Day	Slight	Head-On Crash	1	2	161664	107799
2009	February	Wednesday	Day	Slight	Front-Side Crash	1	3	163690	117818
2009	February	Tuesday	Day	Slight	Side By Side Crash	4	2	165177	123615
2009	July	Friday	Day	Serious	Side By Side Crash	9	2	161097	114064
2009	July	Sunday	Day	Serious	Front-Side Crash	5	2	152062	94963
2009	July	Thursday	Day	Slight	Front-Side Crash	1	4	174369	151110
2009	July	Thursday	Day	Serious	Head-On Crash	2	2	161493	114334
2009	July	Wednesday	Day	Slight	Side By Side Crash	4	2	174450	150743
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	December	Tuesday	Day	Slight	Rear-End Crash	2	3	165916	184604

2009	December	Sunday	Night	Slight	Front-Side Crash	4	2	167910	185636
2009	December	Friday	Night	Slight	Front-Side Crash	5	2	165177	121509
2009	December	Wednesday	Night	Slight	Front-Side Crash	2	2	174952	140199
2009	April	Tuesday	Day	Slight	Front-Side Crash	1	2	163549	117699
2009	April	Saturday	Night	Slight	Front-Side Crash	3	2	170771	128447
2009	April	Saturday	Night	Fatal	Front-Side Crash	3	3	167911	185638
2009	April	Sunday	Night	Slight	Front-Side Crash	3	2	174744	163246
2009	April	Thursday	Night	Slight	Head-On Crash	5	3	176276	143828
2009	September	Monday	Night	Slight	Front-Side Crash	4	2	175990	159225
2009	October	Wednesday	Day	Slight	Front-Side Crash	2	2	174451	150742
2009	October	Saturday	Day	Slight	Front-Side Crash	4	2	163690	117816
2009	October	Tuesday	Day	Slight	Head-On Crash	6	2	162181	109406
2009	October	Monday	Day	Slight	Front-Side Crash	3	2	174744	163245
2009	October	Wednesday	Day	Slight	Front-Side Crash	5	2	174801	174131
2009	May	Tuesday	Day	Slight	Front-Side Crash	1	2	145807	84156
2009	May	Monday	Day	Serious	Head-On Crash	1	2	165005	123457
2009	October	Thursday	Day	Slight	Front-Side Crash	2	2	161502	108470
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	October	Wednesday	Day	Slight	Front-Side Crash	1	2	174897	174450
2009	October	Thursday	Day	Slight	Front-Side Crash	4	2	175674	143124
2009	October	Sunday	Night	Slight	Front-Side Crash	1	2	147995	86121
2009	October	Saturday	Night	Slight	Front-Side Crash	6	3	162585	117092
2009	October	Wednesday	Night	Slight	Front-Side Crash	1	2	175530	142965
2009	October	Tuesday	Night	Slight	Front-Side Crash	2	2	166161	123736
2009	October	Saturday	Night	Slight	Over-Turn Crash	1	1	174464	169444

2009	November	Sunday	Night	Slight	Over-Turn Crash	3	1	173768	175548
2009	November	Tuesday	Day	Serious	Head-On Crash	1	2	162120	109536
2009	May	Thursday	Night	Slight	Front-Side Crash	5	2	173397	167391
2009	June	Monday	Night	Slight	Front-Side Crash	4	2	161081	100940
2009	September	Monday	Day	Slight	Head-On Crash	2	2	154113	98140
2009	September	Tuesday	Day	Slight	Head-On Crash	1	2	160773	112778
2009	September	Monday	Day	Slight	Front-Side Crash	3	2	160443	111498
2009	September	Monday	Day	Serious	Head-On Crash	5	2	174199	156906
2009	September	Tuesday	Day	Slight	Head-On Crash	5	2	173923	156080
2009	September	Tuesday	Day	Slight	Side By Side Crash	1	2	165343	122231
2009	September	Monday	Day	Slight	Front-Side Crash	1	2	171814	139066
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	September	Thursday	Day	Slight	Front-Side Crash	4	2	174504	172529
2009	September	Thursday	Night	Slight	Head-On Crash	3	2	175087	165617
2009	September	Tuesday	Night	Slight	Front-Side Crash	1	2	161502	108468
2009	August	Wednesday	Day	Slight	Front-Side Crash	3	2	173716	155214
2009	August	Saturday	Day	Slight	Side By Side Crash	1	2	163691	117817
2009	August	Wednesday	Day	Slight	Head-On Crash	1	2	165006	123463
2009	August	Saturday	Day	Slight	Front-Side Crash	3	2	160926	113633
2009	December	Monday	Night	Slight	Head-On Crash	5	2	152020	94884
2009	December	Tuesday	Night	Slight	Front-Side Crash	1	2	174952	140198
2009	December	Thursday	Night	Slight	Front-Side Crash	2	2	174952	140198
2009	December	Sunday	Day	Slight	Front-Side Crash	1	2	173398	167389
2009	December	Wednesday	Day	Slight	Front-Side Crash	2	3	174273	170092
2009	July	Wednesday	Day	Serious	Front-Side Crash	6	2	164999	123470

2009	November	Tuesday	Day	Slight	Front-Side Crash	1	2	156332	99787
2009	November	Thursday	Day	Slight	Front-Side Crash	3	2	176276	143826
2009	November	Thursday	Day	Serious	Side By Side Crash	2	2	163621	119518
2009	November	Thursday	Day	Fatal	Head-On Crash	13	3	163621	119518
2009	November	Thursday	Night	Slight	Front-Side Crash	4	2	160774	112777
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	November	Wednesday	Night	Slight	Front-Side Crash	5	2	160774	112779
2009	November	Sunday	Night	Slight	Front-Side Crash	4	2	165005	123465
2009	November	Tuesday	Night	Slight	Head-On Crash	4	2	174270	163243
2009	December	Thursday	Night	Slight	Head-On Crash	3	3	175713	158804
2009	September	Monday	Day	Slight	Head-On Crash	3	2	174695	165208
2010	February	Saturday	Day	Slight	Front-Side Crash	4	2	160927	113633
2010	February	Sunday	Day	Slight	Head-On Crash	5	2	152020	94885
2010	March	Monday	Night	Slight	Over-Turn Crash	2	3	170053	177338
2010	March	Tuesday	Night	Slight	Front-Side Crash	1	2	174951	140200
2010	April	Tuesday	Night	Serious	Over-Turn Crash	1	1	145704	84134
2010	May	Sunday	Day	Slight	Rear-End Crash	4	3	153238	90478
2010	May	Thursday	Day	Slight	Front-Side Crash	1	2	174338	151156
2010	May	Monday	Day	Slight	Front-Side Crash	1	2	174951	140197
2010	May	Monday	Day	Slight	Front-Side Crash	2	2	174272	170093
2010	May	Tuesday	Day	Slight	Front-Side Crash	3	2	152972	92572
2010	May	Sunday	Day	Serious	Head-On Crash	2	3	160374	111622
2010	May	Wednesday	Day	Slight	Over-Turn Crash	1	1	175713	158803
2010	January	Monday	Day	Slight	Over-Turn Crash	4	1	174640	173482
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**

2010	January	Monday	Day	Serious	Head-On Crash	3	2	166404	124329
2010	January	Saturday	Day	Serious	Over-Turn Crash	5	1	152249	93856
2010	January	Monday	Day	Serious	Front-Side Crash	7	2	175097	157999
2010	January	Saturday	Day	Slight	Front-Side Crash	2	2	165196	121540
2010	June	Thursday	Day	Slight	Front-Side Crash	5	2	163498	119913
2010	June	Monday	Day	Slight	Front-Side Crash	1	5	162585	117092
2010	June	Wednesday	Day	Slight	Head-On Crash	1	2	174510	172426
2010	June	Friday	Day	Slight	Front-Side Crash	1	2	163548	117697
2010	July	Tuesday	Night	Slight	Head-On Crash	1	2	174954	140197
2010	July	Monday	Day	Slight	Head-On Crash	2	2	162459	103661
2010	July	Tuesday	Day	Slight	Rear-End Crash	4	3	174764	165271
2010	April	Thursday	Day	Slight	Front-Side Crash	3	2	174954	140197
2010	April	Wednesday	Night	Slight	Ran-Off Crash	1	1	174453	169532
2010	April	Saturday	Night	Slight	Head-On Crash	2	2	154604	98843
2010	April	Monday	Night	Slight	Rear-End Crash	6	2	162534	116518
2010	September	Monday	Day	Slight	Front-Side Crash	1	2	174952	140198
2010	September	Saturday	Day	Slight	Front-Side Crash	2	2	166086	123682
2010	September	Saturday	Night	Slight	Rear-End Crash	3	2	164490	120848
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2010	April	Thursday	Night	Serious	Head-On Crash	6	2	175738	143193
2010	April	Sunday	Day	Slight	Head-On Crash	2	2	153397	91544
2010	April	Tuesday	Day	Slight	Front-Side Crash	2	2	164488	120849
2010	April	Friday	Day	Serious	Front-Side Crash	4	2	176627	143828
2010	October	Friday	Day	Slight	Front-Side Crash	3	2	174951	140200
2010	October	Friday	Day	Slight	Front-Side Crash	4	2	162220	101389

2010	October	Wednesday	Day	Serious	Front-Side Crash	2	3	165381	121429
2010	October	Friday	Day	Slight	Front-Side Crash	2	2	152248	93857
2010	October	Tuesday	Night	Slight	Front-Side Crash	5	2	167911	185635
2010	October	Sunday	Night	Slight	Head-On Crash	1	2	174951	140199
2010	February	Sunday	Day	Slight	Side By Side Crash	1	2	164999	123470
2010	February	Monday	Night	Slight	Front-Side Crash	1	2	174515	172317
2010	August	Monday	Night	Slight	Head-On Crash	4	2	165196	121542
2010	August	Sunday	Day	Slight	Head-On Crash	2	3	162592	115492
2010	August	Sunday	Day	Slight	Front-Side Crash	3	3	162592	114492
2010	August	Monday	Day	Slight	Rear-End Crash	1	3	174516	172317
2010	August	Monday	Day	Slight	Head-On Crash	1	2	171492	114335
2010	June	Tuesday	Day	Slight	Head-On Crash	4	2	174657	173595
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2010	June	Friday	Day	Slight	Head-On Crash	5	4	174951	140197
2010	June	Wednesday	Day	Slight	Front-Side Crash	1	2	165175	121508
2010	June	Friday	Day	Slight	Front-Side Crash	1	2	174658	141311
2010	June	Sunday	Day	Slight	Front-Side Crash	2	3	174338	151563
2010	June	Sunday	Day	Slight	Front-Side Crash	1	2	165196	121543
2010	November	Sunday	Night	Slight	Front-Side Crash	3	2	162219	101392
2010	November	Wednesday	Night	Slight	Head-On Crash	1	2	175579	175333
2010	November	Friday	Night	Slight	Head-On Crash	1	2	175896	159508
2010	November	Thursday	Night	Slight	Head-On Crash	5	2	161292	110380
2010	January	Saturday	Night	Serious	Front-Side Crash	1	2	175842	144559
2010	January	Sunday	Night	Slight	Front-Side Crash	8	2	162534	116520
2010	February	Wednesday	Day	Slight	Front-Side Crash	1	2	162534	116520

2010	February	Sunday	Day	Slight	Front-Side Crash	4	3	174599	173268
2010	July	Monday	Day	Slight	Front-Side Crash	4	2	162456	114674
2010	July	Thursday	Day	Slight	Rear-End Crash	1	2	174470	170801
2010	July	Wednesday	Day	Serious	Front-Side Crash	7	2	174952	140199
2010	July	Friday	Day	Slight	Front-Side Crash	2	2	174270	163242
2010	July	Friday	Day	Slight	Front-Side Crash	5	2	150365	87302
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2010	July	Tuesday	Night	Serious	Front-Side Crash	5	2	173840	140177
2010	March	Thursday	Day	Slight	Front-Side Crash	3	2	173398	167391
2010	March	Monday	Day	Slight	Front-Side Crash	1	2	164862	121113
2010	August	Tuesday	Day	Slight	Front-Side Crash	5	2	174316	152460
2010	August	Wednesday	Night	Slight	Side By Side Crash	4	2	173997	153331
2010	September	Thursday	Night	Slight	Front-Side Crash	7	2	175187	140293
2010	September	Friday	Night	Slight	Front-Side Crash	1	2	162350	114668
2010	September	Saturday	Night	Slight	Front-Side Crash	1	2	164621	120980
2010	September	Monday	Day	Slight	Front-Side Crash	1	2	165153	121458
2010	September	Sunday	Day	Slight	Head-On Crash	6	2	174952	140199
2010	October	Friday	Night	Slight	Head-On Crash	5	2	172330	140625
2010	October	Sunday	Day	Slight	Head-On Crash	1	2	174952	140199
2010	December	Sunday	Day	Slight	Head-On Crash	2	2	174952	140199
2010	December	Sunday	Day	Slight	Front-Side Crash	1	2	165153	121462
2010	December	Monday	Day	Slight	Rear-End Crash	5	2	161054	111027
2010	December	Monday	Day	Slight	Front-Side Crash	4	5	167849	125760
2010	December	Wednesday	Day	Slight	Front-Side Crash	7	2	161377	108068
2010	December	Friday	Day	Slight	Rear-End Crash	1	2	162534	116517

Year	Month	Day of the Week	Day / Night	Crash Severity	Type of Crash	Casualties	Vehicle	X	Y
2010	December	Tuesday	Night	Slight	Head-On Crash	8	2	174439	169001
2010	December	Friday	Night	Slight	Front-Side Crash	4	2	154603	98845
2010	December	Saturday	Night	Slight	Front-Side Crash	8	2	175674	143125
2010	December	Saturday	Night	Slight	Rear-End Crash	13	4	164488	120851
2010	December	Thursday	Night	Slight	Side By Side Crash	6	2	165175	121509
2010	May	Tuesday	Day	Slight	Over-Turn Crash	2	1	174267	150232
2010	May	Monday	Night	Slight	Side By Side Crash	6	2	152248	93858
2011	January	Thursday	Day	Slight	Rear-End Crash	2	2	174498	171097
2011	January	Sunday	Day	Slight	Front-Side Crash	10	2	154583	98823
2011	January	Thursday	Day	Slight	Skidding Crash	1	1	174548	141764
2011	January	Wednesday	Day	Slight	Front-Side Crash	1	2	174300	140148
2011	January	Thursday	Night	Fatal	Front-Side Crash	6	2	174222	145945
2011	February	Tuesday	Night	Slight	Head-On Crash	2	2	174954	140197
2011	March	Tuesday	Day	Slight	Skidding Crash	3	1	166477	124498
2011	March	Tuesday	Day	Slight	Skidding Crash	3	1	166477	124498
2011	March	Thursday	Day	Slight	Rear-End Crash	1	2	164488	120851
2011	February	Friday	Day	Slight	Head-On Crash	4	2	174338	151563
2011	February	Thursday	Day	Slight	Front-Side Crash	2	2	165196	121542
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	February	Wednesday	Day	Slight	Side By Side Crash	3	2	175990	159226
2011	February	Saturday	Day	Slight	Front-Side Crash	2	2	166266	123887
2011	February	Friday	Day	Serious	Front-Side Crash	1	2	163861	118787
2011	February	Thursday	Day	Slight	Front-Side Crash	3	2	166748	180306
2011	February	Wednesday	Night	Slight	Front-Side Crash	2	2	150365	87302

2011	February	Saturday	Night	Fatal	Head-On Crash	7	4	174047	163261
2011	June	Sunday	Day	Serious	Over-Turn Crash	1	2	163907	120166
2011	June	Tuesday	Day	Slight	Front-Side Crash	2	2	172461	137158
2011	June	Saturday	Day	Fatal	Head-On Crash	4	2	177170	162587
2011	August	Monday	Day	Slight	Front-Side Crash	1	3	174911	142218
2011	August	Tuesday	Day	Slight	Front-Side Crash	3	2	174548	141763
2011	March	Thursday	Day	Slight	Front-Side Crash	3	2	174954	140197
2011	March	Thursday	Day	Slight	Front-Side Crash	1	2	177345	161374
2011	April	Saturday	Night	Slight	Head-On Crash	2	4	160926	113634
2011	April	Sunday	Day	Slight	Over-Turn Crash	2	1	152019	94886
2011	April	Sunday	Day	Slight	Front-Side Crash	2	2	161875	110052
2011	April	Sunday	Day	Slight	Front-Side Crash	1	2	174954	140197
2011	April	Wednesday	Day	Serious	Head-On Crash	5	7	175096	158002
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	July	Monday	Day	Slight	Front-Side Crash	3	2	172567	176775
2011	July	Monday	Day	Slight	Front-Side Crash	2	2	172461	137158
2011	July	Saturday	Day	Slight	Skidding Crash	3	2	149842	86975
2011	July	Sunday	Day	Slight	Front-Side Crash	7	2	161377	108068
2011	July	Monday	Day	Slight	Side By Side Crash	3	2	174659	141313
2011	July	Sunday	Day	Slight	Head-On Crash	1	2	162534	116520
2011	July	Saturday	Day	Slight	Front-Side Crash	5	3	161377	108068
2011	April	Wednesday	Day	Slight	Head-On Crash	8	2	177486	161542
2011	April	Tuesday	Day	Slight	Head-On Crash	1	2	166748	180306
2011	April	Tuesday	Night	Slight	Head-On Crash	3	3	164829	122818
2011	April	Tuesday	Night	Slight	Front-Side Crash	4	2	174954	140197

2011	July	Saturday	Night	Slight	Head-On Crash	4	3	174954	140197
2011	July	Sunday	Night	Slight	Head-On Crash	2	2	174451	150653
2011	July	Thursday	Night	Fatal	Head-On Crash	8	2	173717	155121
2011	August	Monday	Day	Slight	Head-On Crash	4	2	174659	141312
2011	August	Tuesday	Day	Slight	Head-On Crash	1	2	160567	111434
2011	August	Tuesday	Day	Slight	Front-Side Crash	4	3	165153	121461
2011	May	Sunday	Day	Slight	Side By Side Crash	6	2	168663	177521
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	May	Sunday	Day	Slight	Front-Side Crash	6	2	175864	143330
2011	May	Tuesday	Day	Slight	Head-On Crash	2	2	163861	118788
2011	May	Monday	Day	Serious	Front-Side Crash	2	2	161142	110604
2011	May	Tuesday	Day	Slight	Front-Side Crash	2	2	165154	121460
2011	May	Sunday	Day	Slight	Front-Side Crash	4	2	151952	94787
2011	May	Tuesday	Day	Fatal	Head-On Crash	5	2	163621	119518
2011	May	Sunday	Day	Slight	Over-Turn Crash	1	1	159781	100651
2011	September	Monday	Day	Slight	Front-Side Crash	5	3	176276	143828
2011	September	Thursday	Day	Slight	Front-Side Crash	1	2	162350	114671
2011	September	Thursday	Day	Slight	Head-On Crash	2	2	174954	140197
2011	September	Thursday	Night	Slight	Front-Side Crash	1	2	174954	140197
2011	October	Sunday	Night	Slight	Front-Side Crash	3	2	174619	173375
2011	August	Tuesday	Night	Slight	Front-Side Crash	2	2	174954	140197
2011	August	Monday	Night	Slight	Front-Side Crash	1	2	172461	137158
2011	September	Monday	Night	Slight	Over-Turn Crash	3	1	153237	90477
2011	September	Tuesday	Day	Slight	Front-Side Crash	1	2	174453	169533
2011	September	Thursday	Day	Slight	Front-Side Crash	7	2	174954	140197

2011	September	Thursday	Day	Slight	Front-Side Crash	1	2	175991	159227
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	September	Friday	Day	Fatal	Head-On Crash	4	2	162350	114670
2011	September	Wednesday	Day	Slight	Head-On Crash	2	2	174954	140197
2011	January	Friday	Night	Serious	Head-On Crash	7	2	165196	121544
2011	January	Sunday	Night	Slight	Skidding Crash	2	1	175675	143126
2011	February	Friday	Night	Slight	Head-On Crash	1	2	173790	149548
2011	February	Friday	Day	Slight	Head-On Crash	2	2	173996	153332
2011	May	Tuesday	Day	Slight	Over-Turn Crash	2	1	173715	155400
2011	June	Thursday	Night	Slight	Head-On Crash	3	2	174954	140197
2011	June	Sunday	Day	Slight	Head-On Crash	6	2	173715	143058
2011	June	Friday	Day	Slight	Side By Side Crash	4	3	172700	135545
2011	June	Friday	Day	Serious	Head-On Crash	6	3	174761	174552
2011	June	Monday	Day	Slight	Head-On Crash	1	2	174002	149853
2011	November	Friday	Night	Slight	Head-On Crash	4	2	171438	140660
2011	November	Wednesday	Night	Slight	Rear-End Crash	2	2	163908	118698
2011	December	Sunday	Night	Slight	Head-On Crash	3	3	166477	124498
2011	December	Tuesday	Day	Slight	Front-Side Crash	2	2	161377	108068
2011	December	Monday	Day	Slight	Front-Side Crash	1	2	163909	118699
2011	January	Friday	Day	Slight	Over-Turn Crash	5	1	176614	160887
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	October	Tuesday	Night	Slight	Side By Side Crash	2	2	161292	110380
2011	November	Friday	Night	Slight	Side By Side Crash	1	2	174150	156808
2011	November	Monday	Day	Slight	Front-Side Crash	2	2	172461	137158
2011	November	Sunday	Day	Fatal	Head-On Crash	2	2	165343	122231

2011	November	Tuesday	Day	Slight	Front-Side Crash	7	3	172461	137158
2011	November	Tuesday	Night	Slight	Head-On Crash	3	2	174954	140197
2011	July	Friday	Day	Slight	Head-On Crash	5	3	174199	166795
2011	July	Monday	Day	Slight	Front-Side Crash	4	2	161096	114065
2011	July	Monday	Day	Serious	Head-On Crash	6	2	162623	105002
2011	July	Saturday	Night	Slight	Head-On Crash	4	2	164999	123470
2011	December	Friday	Day	Slight	Head-On Crash	1	2	174954	140197
2011	December	Monday	Day	Slight	Front-Side Crash	3	2	145704	84136
2011	December	Friday	Day	Serious	Front-Side Crash	1	2	164488	120852
2011	December	Thursday	Night	Slight	Head-On Crash	2	2	171439	140660
2011	December	Sunday	Night	Slight	Front-Side Crash	5	2	170161	127324
2011	March	Tuesday	Day	Slight	Front-Side Crash	3	2	161708	110278
2011	March	Monday	Day	Slight	Head-On Crash	1	2	152310	95721
2011	October	Saturday	Day	Slight	Front-Side Crash	1	2	174954	140197
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	October	Monday	Day	Slight	Front-Side Crash	1	2	163549	117698
2011	October	Wednesday	Day	Slight	Head-On Crash	2	2	175676	143125
2011	October	Wednesday	Day	Slight	Head-On Crash	8	3	162622	105003
2011	October	Thursday	Night	Serious	Over-Turn Crash	2	1	174694	165210
2011	October	Saturday	Night	Serious	Head-On Crash	5	2	175990	159228
2011	August	Saturday	Day	Slight	Front-Side Crash	8	2	174522	171396
2011	August	Saturday	Day	Slight	Rear-End Crash	2	3	174511	171805
2011	June	Sunday	Day	Serious	Over-Turn Crash	1	1	145704	84136
2011	June	Thursday	Day	Slight	Head-On Crash	2	4	149842	86975
2011	June	Wednesday	Night	Slight	Front-Side Crash	4	2	174516	172318

2011	July	Tuesday	Day	Slight	Front-Side Crash	2	2	154603	98845
2012	February	Saturday	Night	Slight	Head-On Crash	2	2	165153	121458
2012	February	Sunday	Night	Slight	Head-On Crash	1	2	174954	140197
2012	February	Wednesday	Day	Slight	Side By Side Crash	1	2	175114	145132
2012	January	Monday	Day	Slight	Front-Side Crash	3	2	160567	111433
2012	January	Friday	Day	Slight	Front-Side Crash	1	2	165153	121461
2012	January	Wednesday	Day	Slight	Front-Side Crash	1	2	152733	96591
2012	January	Tuesday	Day	Slight	Front-Side Crash	3	4	174350	175073
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	April	Friday	Night	Slight	Front-Side Crash	3	2	172461	137158
2012	April	Monday	Day	Slight	Front-Side Crash	2	3	159781	100650
2012	April	Wednesday	Day	Slight	Head-On Crash	3	2	173872	167891
2012	April	Wednesday	Day	Slight	Front-Side Crash	2	2	167230	125051
2012	April	Thursday	Day	Slight	Rear-End Crash	1	2	174351	175075
2012	August	Friday	Day	Slight	Head-On Crash	2	2	174548	141763
2012	August	Monday	Day	Slight	Front-Side Crash	1	2	174577	173165
2012	May	Monday	Day	Slight	Front-Side Crash	2	2	174577	173165
2012	May	Sunday	Day	Slight	Side By Side Crash	4	2	161292	110382
2012	May	Sunday	Day	Slight	Front-Side Crash	2	2	173181	176251
2012	May	Friday	Day	Slight	Front-Side Crash	2	2	172461	137158
2012	May	Thursday	Day	Slight	Front-Side Crash	9	2	160926	113635
2012	May	Tuesday	Day	Slight	Front-Side Crash	1	2	160503	112020
2012	February	Monday	Night	Slight	Front-Side Crash	2	2	174954	140197
2012	March	Friday	Day	Slight	Front-Side Crash	3	2	163549	117698
2012	March	Sunday	Day	Slight	Front-Side Crash	3	2	166748	180306

2012	March	Monday	Day	Slight	Front-Side Crash	3	2	173492	167008
2012	March	Tuesday	Day	Slight	Front-Side Crash	2	2	173492	167008
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	March	Wednesday	Day	Slight	Over-Turn Crash	5	1	165343	122234
2012	March	Friday	Day	Serious	Front-Side Crash	3	2	172461	137158
2012	July	Friday	Day	Slight	Front-Side Crash	6	2	166124	185563
2012	January	Saturday	Day	Slight	Head-On Crash	1	3	164999	123470
2012	January	Friday	Day	Slight	Head-On Crash	6	2	174394	151740
2012	January	Wednesday	Day	Slight	Front-Side Crash	4	3	174577	173165
2012	January	Tuesday	Night	Slight	Front-Side Crash	2	2	174954	140197
2012	January	Saturday	Night	Slight	Front-Side Crash	2	2	160926	113633
2012	January	Thursday	Night	Serious	Front-Side Crash	2	2	174577	173162
2012	January	Saturday	Night	Slight	Head-On Crash	4	2	174750	140139
2012	June	Monday	Day	Slight	Front-Side Crash	1	2	160505	112021
2012	June	Wednesday	Day	Slight	Front-Side Crash	1	3	174954	140197
2012	June	Wednesday	Day	Serious	Head-On Crash	2	3	154603	98846
2012	June	Saturday	Day	Slight	Over-Turn Crash	16	1	171206	129497
2012	June	Tuesday	Day	Slight	Front-Side Crash	1	2	174659	141311
2012	June	Saturday	Day	Slight	Front-Side Crash	8	2	151952	94787
2012	June	Monday	Day	Serious	Head-On Crash	2	3	163909	118700
2012	June	Saturday	Day	Slight	Front-Side Crash	4	2	173450	163779
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	August	Tuesday	Day	Slight	Head-On Crash	1	2	174022	156587
2012	August	Friday	Day	Slight	Head-On Crash	3	2	174549	141762
2012	August	Friday	Day	Fatal	Head-On Crash	6	4	171573	131590

2012	August	Monday	Day	Slight	Rear-End Crash	4	3	169594	126534
2012	August	Friday	Day	Slight	Head-On Crash	3	2	175795	160193
2012	August	Wednesday	Day	Slight	Front-Side Crash	2	2	174577	173164
2012	August	Monday	Day	Slight	Front-Side Crash	5	2	174620	173375
2012	August	Friday	Day	Slight	Head-On Crash	6	3	163907	120165
2012	August	Friday	Day	Fatal	Head-On Crash	2	2	174705	141132
2012	August	Friday	Day	Slight	Skidding Crash	1	1	163908	118699
2012	August	Wednesday	Day	Slight	Rear-End Crash	4	2	174896	174453
2012	August	Tuesday	Night	Slight	Head-On Crash	4	2	171905	177248
2012	August	Tuesday	Night	Slight	Side By Side Crash	1	2	174397	170316
2012	August	Tuesday	Night	Slight	Front-Side Crash	3	2	173448	167537
2012	February	Thursday	Day	Fatal	Front-Side Crash	36	2	173448	167537
2012	February	Sunday	Day	Slight	Front-Side Crash	2	2	172461	137158
2012	February	Friday	Day	Slight	Front-Side Crash	1	2	162028	114460
2012	April	Wednesday	Day	Slight	Over-Turn Crash	5	1	162711	102369
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	April	Thursday	Night	Slight	Front-Side Crash	3	2	172461	137158
2012	September	Sunday	Day	Slight	Front-Side Crash	2	2	174451	150652
2012	September	Thursday	Day	Slight	Head-On Crash	4	4	174441	169092
2012	September	Tuesday	Day	Slight	Head-On Crash	1	2	174896	174451
2012	September	Sunday	Day	Slight	Head-On Crash	1	2	174954	140197
2012	September	Saturday	Night	Slight	Head-On Crash	5	2	161411	108362
2012	September	Thursday	Night	Serious	Front-Side Crash	1	2	169594	126533
2012	October	Sunday	Night	Slight	Front-Side Crash	2	2	161377	108068
2012	October	Friday	Night	Serious	Head-On Crash	4	3	174411	145740

2012	October	Friday	Day	Serious	Head-On Crash	3	2	174316	157098
2012	October	Monday	Day	Slight	Head-On Crash	3	2	168744	126042
2012	October	Saturday	Day	Serious	Head-On Crash	8	3	165013	121223
2012	October	Sunday	Day	Slight	Front-Side Crash	1	2	174578	173165
2012	October	Friday	Day	Slight	Rear-End Crash	4	2	175172	165986
2012	October	Saturday	Day	Serious	Front-Side Crash	6	2	174577	173165
2012	October	Tuesday	Day	Slight	Front-Side Crash	1	2	164488	120850
2012	October	Saturday	Day	Slight	Front-Side Crash	1	2	174300	140147
2012	October	Tuesday	Day	Serious	Front-Side Crash	4	2	168745	126040
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	October	Friday	Night	Slight	Over-Turn Crash	2	1	169594	126535
2012	October	Thursday	Night	Slight	Front-Side Crash	1	2	174351	175076
2012	May	Tuesday	Day	Slight	Front-Side Crash	1	2	177485	161542
2012	May	Saturday	Night	Slight	Head-On Crash	5	2	174954	140197
2012	May	Monday	Night	Slight	Front-Side Crash	2	2	174954	140197
2012	June	Sunday	Night	Slight	Over-Turn Crash	1	1	152027	94380
2012	December	Thursday	Day	Slight	Front-Side Crash	5	3	174954	140197
2012	December	Monday	Day	Slight	Front-Side Crash	3	3	175126	142384
2012	December	Wednesday	Night	Slight	Front-Side Crash	1	3	175828	160296
2012	December	Monday	Night	Slight	Front-Side Crash	6	2	174577	173165
2012	December	Saturday	Night	Slight	Rear-End Crash	6	4	174443	168648
2012	December	Thursday	Night	Slight	Side By Side Crash	4	2	173996	153330
2012	December	Sunday	Night	Slight	Front-Side Crash	6	2	165197	121541
2012	December	Monday	Night	Slight	Front-Side Crash	4	2	174338	151563
2012	December	Thursday	Night	Slight	Rear-End Crash	1	5	167849	125760

2012	December	Monday	Night	Fatal	Head-On Crash	3	2	162459	103665
2012	December	Wednesday	Night	Slight	Front-Side Crash	1	2	165344	122233
2012	June	Tuesday	Day	Slight	Front-Side Crash	5	3	174149	156809
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	June	Sunday	Day	Slight	Front-Side Crash	1	2	173781	155852
2012	June	Friday	Day	Slight	Front-Side Crash	3	2	173841	140177
2012	June	Monday	Night	Slight	Head-On Crash	5	3	173687	154208
2012	October	Thursday	Night	Slight	Head-On Crash	5	2	172461	137158
2012	October	Monday	Night	Slight	Front-Side Crash	3	2	174888	140932
2012	October	Tuesday	Night	Serious	Head-On Crash	1	2	162592	115492
2012	November	Sunday	Night	Slight	Over-Turn Crash	2	1	152751	93012
2012	November	Sunday	Night	Slight	Front-Side Crash	1	2	174619	173376
2012	November	Monday	Day	Fatal	Skidding Crash	1	2	166825	124810
2012	November	Thursday	Day	Serious	Front-Side Crash	6	2	174451	150652
2012	November	Saturday	Night	Slight	Front-Side Crash	1	2	166086	123682
2012	November	Wednesday	Day	Slight	Rear-End Crash	3	2	165177	123652
2012	July	Tuesday	Night	Serious	Front-Side Crash	5	2	176299	143918
2012	July	Wednesday	Night	Slight	Over-Turn Crash	4	1	174411	145738
2012	July	Thursday	Day	Slight	Front-Side Crash	1	2	163549	117698
2012	July	Tuesday	Day	Slight	Front-Side Crash	2	2	173393	167323
2012	July	Tuesday	Day	Slight	Front-Side Crash	2	2	165154	121458
2012	July	Tuesday	Day	Slight	Head-On Crash	1	3	174620	173374
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	July	Tuesday	Day	Slight	Front-Side Crash	2	2	172461	137158
2012	July	Friday	Day	Serious	Skidding Crash	1	1	174824	142185

2012	December	Friday	Day	Slight	Front-Side Crash	1	2	174954	140197
2012	December	Sunday	Day	Slight	Rear-End Crash	2	2	163549	117698
2012	August	Tuesday	Night	Serious	Head-On Crash	2	2	174002	149852
2012	September	Wednesday	Night	Slight	Ran-Off Crash	1	1	169594	126530
2012	September	Monday	Day	Slight	Front-Side Crash	4	2	161377	108068
2012	July	Wednesday	Night	Slight	Front-Side Crash	4	2	172461	137158
2012	July	Sunday	Night	Slight	Front-Side Crash	5	2	172461	137158
2012	July	Saturday	Night	Slight	Rear-End Crash	5	2	162459	103663
2012	July	Saturday	Night	Serious	Head-On Crash	3	3	162819	106418
2012	August	Wednesday	Night	Slight	Head-On Crash	1	3	161572	110317
2012	August	Sunday	Night	Slight	Front-Side Crash	9	2	172461	137158
2012	August	Sunday	Night	Slight	Front-Side Crash	1	2	172461	137158
2012	August	Wednesday	Night	Slight	Front-Side Crash	1	2	172461	137158
2012	August	Friday	Day	Slight	Front-Side Crash	3	2	165196	121543

Table B.3: Crash Data for Highway 505 (Salfit to Za'tara Road)

Year	Month	Day of the Week	Day / Night	Crash Severity	Type of Crash	Casualties	Vehicle	X	Y
2008	September	Saturday	Day	Slight	Over-Turn Crash	1	1	168362	169442
2008	September	Tuesday	Day	Slight	Rear-End Crash	2	2	181104	169649
2008	September	Thursday	Day	Slight	Rear-End Crash	1	2	166855	168667
2008	July	Friday	Day	Slight	Rear-End Crash	1	2	165805	168393
2008	July	Wednesday	Day	Slight	Over-Turn Crash	1	1	172165	170301
2008	July	Monday	Day	Slight	Ran-Off Crash	4	1	167779	169039
2008	August	Tuesday	Day	Slight	Over-Turn Crash	2	1	182409	168167
2008	August	Wednesday	Day	Slight	Rear-End Crash	4	3	170762	170164
2008	June	Thursday	Day	Slight	Front-Side Crash	3	2	165805	168393
2008	June	Tuesday	Day	Slight	Head-On Crash	3	3	173857	170117
2008	June	Wednesday	Night	Slight	Front-Side Crash	4	2	167528	168864
2008	May	Wednesday	Night	Slight	Over-Turn Crash	1	1	181105	169651
2008	May	Thursday	Day	Slight	Side By Side Crash	3	2	170091	169938
2008	January	Wednesday	Day	Serious	Rear-End Crash	2	2	168361	169445
2008	September	Monday	Night	Slight	Front-Side Crash	1	2	182772	167218
2008	October	Thursday	Day	Slight	Front-Side Crash	5	2	165805	168393
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	December	Wednesday	Day	Slight	Front-Side Crash	2	2	184601	164247
2009	April	Friday	Day	Slight	Rear-End Crash	1	2	169889	169931
2009	February	Tuesday	Day	Serious	Over-Turn Crash	1	2	165805	168393
2009	December	Sunday	Day	Fatal	Over-Turn Crash	1	1	176143	169351
2009	November	Sunday	Night	Slight	Skidding Crash	1	1	176143	169350

2010	April	Sunday	Day	Slight	Front-Side Crash	6	3	193201	161565
2010	April	Tuesday	Night	Slight	Head-On Crash	1	2	179093	169714
2010	March	Friday	Night	Slight	Rear-End Crash	4	3	183549	164435
2010	February	Tuesday	Night	Slight	Front-Side Crash	2	2	183549	164435
2010	June	Thursday	Day	Serious	Front-Side Crash	3	2	170480	170047
2010	September	Monday	Night	Slight	Over-Turn Crash	1	1	171769	170212
2011	March	Sunday	Day	Slight	Ran-Off Crash	5	2	189300	163565
2011	March	Thursday	Day	Slight	Front-Side Crash	2	2	172770	170255
2011	March	Saturday	Day	Slight	Skidding Crash	1	1	167945	169155
2011	May	Sunday	Night	Slight	Head-On Crash	3	2	169786	169928
2011	June	Thursday	Day	Slight	Over-Turn Crash	1	2	184870	164384
2011	June	Friday	Day	Slight	Front-Side Crash	3	2	173480	170251
2011	July	Tuesday	Day	Slight	Side By Side Crash	8	2	169290	169833
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	October	Saturday	Day	Fatal	Over-Turn Crash	1	1	190022	162843
2011	November	Wednesday	Night	Slight	Front-Side Crash	1	2	172770	170253
2011	August	Sunday	Night	Slight	Front-Side Crash	4	2	165805	168394
2012	May	Thursday	Night	Slight	Front-Side Crash	1	2	165805	168394
2012	January	Thursday	Night	Slight	Head-On Crash	5	3	170762	170162
2012	February	Saturday	Night	Slight	Front-Side Crash	5	2	180099	169569
2012	February	Sunday	Day	Slight	Front-Side Crash	2	2	165805	168394
2012	January	Wednesday	Day	Serious	Head-On Crash	3	2	167056	168688
2012	June	Tuesday	Day	Slight	Side By Side Crash	1	3	168807	169679
2012	July	Saturday	Day	Slight	Front-Side Crash	3	2	176143	169351
2012	August	Sunday	Day	Slight	Front-Side Crash	2	2	165805	168394

2012	September	Thursday	Day	Slight	Head-On Crash	3	2	171770	170212
2012	September	Tuesday	Day	Slight	Front-Side Crash	2	3	169393	169861
2012	September	Saturday	Night	Fatal	Head-On Crash	2	2	181104	169652
2012	October	Monday	Day	Slight	Head-On Crash	1	2	174318	169345
2012	October	Wednesday	Day	Slight	Side By Side Crash	8	2	167945	169154
2012	October	Saturday	Night	Serious	Rear-End Crash	1	2	180803	169642
2012	November	Tuesday	Night	Slight	Front-Side Crash	3	3	165805	168394
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	November	Wednesday	Day	Slight	Front-Side Crash	1	2	166077	168459
2012	November	Thursday	Day	Serious	Over-Turn Crash	1	2	182772	167219
2012	November	Sunday	Day	Slight	Front-Side Crash	2	2	186092	166219
2012	November	Sunday	Night	Slight	Front-Side Crash	1	2	175145	169181

Table B.4: Crash Data for Highway 90 (Jericho to Bethlehem Road " Dead Sea Road")

Year	Month	Day of the Week	Day / Night	Crash Severity	Type of Crash	Casualties	Vehicle	X	Y
2003	June	Monday	Day	Slight	Side By Side Crash	2	2	196567	134082
2003	September	Friday	Night	Slight	Ran-Off Crash	2	1	196567	134082
2003	September	Friday	Night	Serious	Over-Turn Crash	3	1	197190	133371
2003	October	Thursday	Day	Slight	Rear-End Crash	2	2	195712	128598
2003	October	Thursday	Day	Slight	Rear-End Crash	3	2	196752	134880
2003	August	Saturday	Night	Slight	Front-Side Crash	6	2	197875	131495
2003	August	Saturday	Night	Serious	Head-On Crash	6	2	195611	128551
2003	April	Sunday	Day	Slight	Head-On Crash	5	2	196567	134080
2003	April	Monday	Night	Slight	Rear-End Crash	1	2	187566	102288
2003	April	Thursday	Night	Slight	Over-Turn Crash	2	1	195712	128598
2003	June	Saturday	Day	Serious	Over-Turn Crash	3	1	196752	134880
2003	July	Thursday	Day	Slight	Rear-End Crash	3	2	196641	134023
2003	February	Wednesday	Night	Slight	Ran-Off Crash	5	1	195611	128551
2003	March	Sunday	Night	Serious	Rear-End Crash	5	3	187566	102288
2004	April	Thursday	Day	Fatal	Front-Side Crash	7	2	189709	116777
2004	April	Saturday	Day	Slight	Head-On Crash	5	2	195712	128598
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2004	January	Thursday	Day	Fatal	Front-Side Crash	7	2	196567	134080
2004	June	Wednesday	Night	Slight	Over-Turn Crash	3	1	188316	107443
2005	April	Friday	Day	Serious	Over-Turn Crash	5	1	191637	120176
2005	August	Thursday	Day	Slight	Over-Turn Crash	1	1	197571	132337
2005	December	Friday	Day	Serious	Side By Side Crash	11	2	190296	117679

2005	July	Sunday	Day	Serious	Head-On Crash	9	2	195611	128551
2005	July	Wednesday	Day	Slight	Front-Side Crash	2	2	195712	128598
2006	December	Sunday	Day	Slight	Skidding Crash	3	1	196641	-165976
2006	December	Monday	Night	Slight	Head-On Crash	1	2	196567	134080
2006	January	Wednesday	Night	Slight	Rear-End Crash	7	2	196752	134880
2006	January	Saturday	Night	Slight	Rear-End Crash	9	4	189194	108475
2006	January	Sunday	Night	Serious	Over-Turn Crash	3	1	193470	126863
2006	October	Wednesday	Night	Serious	Head-On Crash	3	2	197190	133371
2006	October	Thursday	Day	Slight	Over-Turn Crash	3	1	197190	133371
2006	March	Wednesday	Day	Serious	Over-Turn Crash	4	1	187671	102117
2006	July	Thursday	Night	Serious	Side By Side Crash	1	2	191201	119550
2007	May	Saturday	Day	Slight	Front-Side Crash	8	2	189709	116778
2007	August	Thursday	Night	Slight	Over-Turn Crash	1	1	189709	116778
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2007	September	Sunday	Day	Serious	Over-Turn Crash	1	1	196641	134023
2007	June	Tuesday	Day	Slight	Over-Turn Crash	4	1	196606	129061
2007	June	Wednesday	Night	Slight	Side By Side Crash	4	2	189772	116965
2007	April	Wednesday	Day	Slight	Skidding Crash	2	1	188517	111122
2008	August	Wednesday	Night	Slight	Front-Side Crash	1	2	197236	198215
2008	September	Thursday	Day	Slight	Over-Turn Crash	5	1	192399	158975
2008	February	Friday	Night	Slight	Front-Side Crash	3	2	198033	197472
2008	March	Sunday	Day	Slight	Front-Side Crash	1	2	197064	199095
2008	March	Friday	Day	Slight	Side By Side Crash	5	2	194502	151238
2008	July	Thursday	Day	Slight	Front-Side Crash	1	2	201922	187666
2008	July	Friday	Day	Slight	Front-Side Crash	1	2	196456	134158

2008	July	Thursday	Day	Slight	Over-Turn Crash	2	1	192375	158037
2008	July	Thursday	Day	Serious	Skidding Crash	2	1	198324	141246
2008	August	Sunday	Day	Fatal	Over-Turn Crash	1	1	192508	157331
2008	August	Tuesday	Day	Slight	Head-On Crash	5	2	194511	150648
2008	April	Monday	Night	Serious	Over-Turn Crash	3	1	198701	197113
2008	April	Sunday	Day	Slight	Over-Turn Crash	1	1	194384	149116
2008	April	Monday	Day	Slight	Front-Side Crash	4	2	193938	161685
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2008	April	Thursday	Day	Serious	Over-Turn Crash	8	1	193940	147030
2008	April	Saturday	Day	Slight	Front-Side Crash	1	3	192805	156761
2008	December	Tuesday	Night	Slight	Front-Side Crash	3	2	196456	134158
2008	January	Sunday	Night	Serious	Rear-End Crash	1	2	202238	182715
2008	February	Sunday	Day	Slight	Rear-End Crash	9	2	201617	189073
2008	February	Thursday	Day	Slight	Over-Turn Crash	1	1	201435	189415
2008	February	Thursday	Day	Slight	Rear-End Crash	6	2	201435	189415
2008	December	Monday	Night	Slight	Rear-End Crash	6	2	197113	166187
2008	December	Thursday	Day	Serious	Front-Side Crash	5	2	202311	185704
2008	June	Tuesday	Day	Slight	Head-On Crash	3	2	195281	163028
2008	July	Tuesday	Day	Slight	Front-Side Crash	2	2	198407	170491
2008	July	Monday	Day	Slight	Over-Turn Crash	1	1	192451	157480
2008	January	Tuesday	Day	Slight	Over-Turn Crash	5	1	200673	195440
2008	October	Wednesday	Day	Fatal	Head-On Crash	6	2	202296	182800
2008	October	Saturday	Day	Serious	Over-Turn Crash	4	1	193712	155025
2008	October	Thursday	Night	Slight	Over-Turn Crash	1	1	193941	147027
2008	May	Monday	Night	Slight	Front-Side Crash	5	2	194563	151730

2009	July	Friday	Day	Slight	Over-Turn Crash	2	1	198783	140000
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	July	Monday	Day	Serious	Over-Turn Crash	1	1	196035	163669
2009	August	Sunday	Night	Slight	Over-Turn Crash	2	1	192439	157557
2009	February	Sunday	Day	Slight	Over-Turn Crash	4	1	202310	185704
2009	February	Saturday	Day	Serious	Over-Turn Crash	2	1	192451	157481
2009	March	Thursday	Night	Fatal	Over-Turn Crash	1	1	192451	157481
2009	December	Thursday	Night	Serious	Over-Turn Crash	1	1	197225	133278
2009	December	Friday	Night	Slight	Over-Turn Crash	2	1	189155	109385
2009	December	Monday	Day	Slight	Over-Turn Crash	1	1	202199	185862
2009	December	Wednesday	Day	Slight	Rear-End Crash	1	4	202312	185702
2009	December	Tuesday	Day	Serious	Head-On Crash	1	2	187408	101011
2009	December	Thursday	Day	Slight	Over-Turn Crash	5	1	201487	178027
2009	December	Saturday	Night	Slight	Over-Turn Crash	4	1	201550	189149
2009	May	Saturday	Day	Serious	Head-On Crash	2	2	190226	117606
2009	May	Friday	Day	Slight	Rear-End Crash	4	2	197947	131299
2009	May	Wednesday	Night	Slight	Over-Turn Crash	3	1	197299	198141
2009	June	Thursday	Day	Slight	Over-Turn Crash	2	1	191638	120178
2009	June	Monday	Day	Slight	Front-Side Crash	2	2	192450	159065
2009	January	Monday	Night	Slight	Over-Turn Crash	2	1	197901	197547
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	January	Friday	Day	Serious	Head-On Crash	5	2	193719	161215
2009	October	Wednesday	Day	Serious	Over-Turn Crash	11	3	202310	185704
2009	October	Monday	Day	Slight	Over-Turn Crash	2	1	201399	191571
2009	October	Wednesday	Night	Slight	Over-Turn Crash	5	1	192544	157260

2009	November	Friday	Day	Slight	Front-Side Crash	4	2	197953	131229
2009	November	Sunday	Day	Serious	Front-Side Crash	6	2	192769	159590
2009	November	Friday	Day	Slight	Over-Turn Crash	4	1	201445	191076
2009	November	Friday	Night	Slight	Over-Turn Crash	2	1	193450	160771
2009	March	Saturday	Day	Slight	Front-Side Crash	3	2	194948	128076
2009	April	Thursday	Day	Slight	Front-Side Crash	4	2	194591	152686
2009	August	Tuesday	Day	Serious	Over-Turn Crash	4	1	192451	157480
2009	August	Tuesday	Day	Slight	Over-Turn Crash	1	1	201058	193407
2009	August	Tuesday	Day	Serious	Head-On Crash	7	2	200723	175938
2009	August	Thursday	Day	Fatal	Head-On Crash	8	2	191071	119400
2009	August	Saturday	Day	Slight	Over-Turn Crash	2	1	197754	197627
2009	August	Friday	Night	Serious	Over-Turn Crash	4	1	192304	158806
2009	April	Sunday	Day	Serious	Head-On Crash	6	2	192587	122488
2009	April	Thursday	Day	Serious	Front-Side Crash	3	2	189195	108474
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2009	April	Monday	Day	Slight	Over-Turn Crash	2	1	196800	134958
2009	April	Wednesday	Day	Slight	Front-Side Crash	1	2	199537	173649
2009	April	Thursday	Day	Slight	Over-Turn Crash	5	1	193450	160770
2009	May	Tuesday	Day	Fatal	Front-Side Crash	11	2	202284	184525
2010	May	Saturday	Day	Slight	Rear-End Crash	1	2	194572	150272
2010	May	Sunday	Day	Slight	Ran-Off Crash	4	1	197051	165000
2010	May	Sunday	Night	Serious	Over-Turn Crash	37	1	196640	134026
2010	June	Friday	Day	Slight	Over-Turn Crash	3	1	201954	181641
2010	June	Friday	Day	Serious	Over-Turn Crash	7	1	202029	180658
2010	January	Sunday	Night	Fatal	Rear-End Crash	5	2	194099	154294

2010	April	Monday	Day	Slight	Side By Side Crash	3	2	191718	120357
2010	May	Friday	Night	Slight	Front-Side Crash	1	2	192399	158975
2010	October	Wednesday	Night	Slight	Rear-End Crash	1	3	195823	163461
2010	August	Thursday	Night	Slight	Over-Turn Crash	5	1	197910	131402
2010	August	Wednesday	Night	Slight	Rear-End Crash	1	2	193719	161216
2010	August	Sunday	Day	Fatal	Head-On Crash	9	2	199856	174347
2010	August	Sunday	Day	Serious	Front-Side Crash	7	2	198324	170340
2010	August	Thursday	Night	Slight	Over-Turn Crash	5	1	202184	186737
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2010	August	Sunday	Night	Slight	Front-Side Crash	2	2	194505	151341
2010	January	Monday	Day	Slight	Head-On Crash	3	2	202334	185606
2010	January	Thursday	Day	Slight	Over-Turn Crash	3	1	195146	128219
2010	February	Tuesday	Day	Serious	Front-Side Crash	6	2	201977	181921
2010	December	Tuesday	Day	Slight	Front-Side Crash	1	2	197907	142067
2010	December	Thursday	Night	Slight	Front-Side Crash	7	2	194568	151826
2010	December	Sunday	Night	Slight	Over-Turn Crash	9	1	196640	134025
2010	July	Thursday	Night	Slight	Front-Side Crash	1	2	196949	168338
2010	February	Friday	Day	Slight	Over-Turn Crash	2	2	196035	163667
2010	February	Friday	Night	Slight	Skidding Crash	1	1	197322	136543
2010	October	Wednesday	Night	Fatal	Head-On Crash	2	5	201967	179659
2010	November	Sunday	Day	Slight	Head-On Crash	6	2	193502	160859
2010	November	Saturday	Night	Slight	Ran-Off Crash	1	1	197808	131680
2011	April	Monday	Day	Slight	Over-Turn Crash	2	1	201935	187569
2011	April	Tuesday	Day	Slight	Front-Side Crash	3	4	200888	192837
2011	April	Friday	Night	Slight	Over-Turn Crash	1	1	192544	157263

2011	May	Saturday	Night	Slight	Ran-Off Crash	2	1	196987	164813
2011	March	Saturday	Day	Slight	Front-Side Crash	4	2	193067	156263
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	July	Monday	Day	Slight	Front-Side Crash	4	2	198763	140454
2011	July	Tuesday	Day	Fatal	Front-Side Crash	3	5	202331	183004
2011	January	Thursday	Night	Slight	Head-On Crash	2	2	194495	153471
2011	January	Saturday	Day	Slight	Ran-Off Crash	5	1	196456	134158
2011	January	Sunday	Day	Slight	Head-On Crash	11	3	194505	151340
2011	November	Friday	Night	Slight	Over-Turn Crash	1	1	187435	105077
2011	June	Thursday	Day	Slight	Front-Side Crash	2	2	196456	134158
2011	June	Wednesday	Day	Slight	Front-Side Crash	1	2	195481	143028
2011	July	Friday	Night	Slight	Over-Turn Crash	3	1	187410	104779
2011	May	Friday	Day	Fatal	Head-On Crash	5	2	193533	126945
2011	May	Friday	Day	Slight	Front-Side Crash	1	2	193066	156264
2011	February	Friday	Day	Fatal	Over-Turn Crash	9	1	201435	189413
2011	April	Sunday	Day	Slight	Front-Side Crash	6	2	187616	102208
2011	December	Friday	Night	Slight	Front-Side Crash	4	2	197930	169998
2011	December	Sunday	Day	Slight	Side By Side Crash	4	2	199897	174432
2011	December	Thursday	Day	Slight	Rear-End Crash	1	2	199897	174432
2011	December	Sunday	Day	Slight	Head-On Crash	1	2	202238	182715
2011	September	Thursday	Night	Serious	Rear-End Crash	6	3	193399	160677
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2011	September	Thursday	Day	Serious	Head-On Crash	4	2	193112	156176
2011	August	Monday	Day	Slight	Over-Turn Crash	2	1	192768	124726
2011	August	Sunday	Day	Slight	Head-On Crash	6	2	201367	190094

2011	October	Friday	Day	Serious	Head-On Crash	1	2	197009	167279
2011	October	Thursday	Night	Slight	Front-Side Crash	1	3	196456	134158
2011	November	Friday	Night	Serious	Front-Side Crash	4	2	200841	176220
2011	November	Thursday	Night	Slight	Head-On Crash	1	2	192544	157263
2012	June	Friday	Day	Slight	Over-Turn Crash	4	1	188641	110707
2012	April	Wednesday	Day	Slight	Front-Side Crash	4	2	194512	150648
2012	April	Friday	Night	Slight	Head-On Crash	9	3	197570	132335
2012	April	Monday	Night	Slight	Front-Side Crash	3	2	198597	138635
2012	May	Sunday	Night	Slight	Rear-End Crash	3	3	200108	174891
2012	January	Friday	Day	Slight	Head-On Crash	2	2	198104	137028
2012	February	Thursday	Day	Slight	Over-Turn Crash	5	1	196640	134027
2012	February	Saturday	Day	Slight	Side By Side Crash	2	2	194358	148721
2012	March	Monday	Night	Fatal	Head-On Crash	8	2	194259	147760
2012	March	Friday	Day	Slight	Ran-Off Crash	2	1	193940	147027
2012	April	Wednesday	Day	Slight	Rear-End Crash	1	3	197011	167276
Year	**Month**	**Day of the Week**	**Day / Night**	**Crash Severity**	**Type of Crash**	**Casualties**	**Vehicle**	**X**	**Y**
2012	January	Thursday	Day	Serious	Front-Side Crash	1	2	192304	158805
2012	June	Thursday	Day	Slight	Over-Turn Crash	1	2	196456	134157
2012	June	Saturday	Day	Slight	Over-Turn Crash	2	1	197347	130975
2012	June	Monday	Day	Slight	Over-Turn Crash	1	1	199496	173565
2012	June	Monday	Day	Slight	Over-Turn Crash	2	1	197347	130975
2012	July	Sunday	Night	Slight	Over-Turn Crash	4	1	196554	142829
2012	July	Tuesday	Night	Slight	Rear-End Crash	1	2	194259	147759
2012	October	Wednesday	Night	Slight	Head-On Crash	5	2	189519	115804
2012	October	Friday	Day	Slight	Over-Turn Crash	6	1	199584	196693

2012	August	Friday	Day	Slight	Over-Turn Crash	1	1	197364	198070
2012	August	Thursday	Day	Slight	Head-On Crash	5	2	202239	182713
2012	August	Sunday	Day	Slight	Head-On Crash	2	2	199584	196694
2012	September	Tuesday	Day	Slight	Ran-Off Crash	1	2	198635	171696
2012	October	Thursday	Night	Slight	Over-Turn Crash	1	1	192290	158710
2012	December	Wednesday	Night	Serious	Over-Turn Crash	4	1	197347	130975
2012	December	Sunday	Day	Slight	Skidding Crash	1	1	200664	193957

جامعة النجاح الوطنية

كلية الدراسات العليا

نمذجة العلاقة بين التناسق للتصميم الهندسي والسلامة على الطرق للطرق الخارجية ذات المسربين في الضفة الغربية

إعداد

محمد غسان يوسف دويكات

إشراف

د. خالد الساحلي

قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطرق والمواصلات بكلية الدراسات العليا، جامعة النجاح الوطنية في نابلس– فلسطين.

2014

نمذجة العلاقة بين التناسق للتصميم الهندسي والسلامة على الطرق للطرق الخارجية ذات المسربين في الضفة الغربية

إعداد

محمد غسان يوسف دويكات

إشراف

د. خالد الساحلي

الملخص

شملت أهداف هذه الدراسة التحقق من وتحديد العلاقة بين تناسق التصميم والسلامة على الطرق لطرق سريعة خارجية ذات مسربين في الضفة الغربية.

أنتجت هذه الدراسة طريقة للتنبؤ بسرعة المركبة باستخدام بيانات حقيقية لسرعة حركة المرور تم الحصول عليها من خرائط جوجل.

استخدمت قاعدة بيانات شاملة للحوادث والتصميم الهندسي للطرق السريعة الخارجية ذات المسربين في الضفة الغربية، وذلك لدراسة تأثير اتساق عدة تصاميم هندسية بشأن السلامة على الطرق.

ان تدابير الاتساق الواعدة والتي تم تحديدها في الابحاث السابقة تندرج تحت اربع فئات رئيسية: سرعة المركبة وثبات السيارة اثناء اجتياز المنحنيات ومؤشرات التوافق ومقدار الجهد الذي يبذله السائق عند اجتياز المنحنيات.

خمسة نماذج تم تطويرها تخص التنبؤ بالحوادث والتي تتضمن تدابير اتساق التصميم. وقد تم استخدام نهج الانحدار الخطي المعمم لتطوير النموذج. وتم اتخاذ خطوة للتحقق من صلاحيته، ولم يكن الهدف من هذه الخطوة فقط مقارنة دقة النماذج المختلفة التي وضعت، ولكن أيضا لتقييم الدقة الكلية لنماذج التنبؤ بالحوادث للاستخدام على الطرق السريعة الخارجية ذات المسربين في الضفة الغربية.

وقد كان شرط التحقق من صلاحية النموذج هو اظهار أن النموذج ملائم، ذا مغزى، ومفيد للهدف المرجو له. حيث أنه يمكن استخدام هذه النماذج كأداة كمية لتقييم أثر اتساق التصميم على السلامة على الطرق. تم التحقق من النماذج بمقارنة وقياس فعالية النماذج للتنبؤ بالحوادث، والتي تتضمن تدابير اتساق التصميم مع تلك التي تعتمد على خصائص التصميم الهندسي فقط وقد وجد أن النماذج التي تعبر بوضوح عن اتساق التصميم يمكنها تحديد أوجه عدم الاتساق بفعالية أكثر مما يعكس الآثار الناجمة عنها على السلامة والأمان بدقة أكبر من تلك التي لا تفعل ذلك.

وأخيرا، تم اقتراح نهج منتظم لتحديد المواقع غير المتناسقة هندسيا باستخدام عامل اتساق السلامة.