Validation of Accident Models for Intersections

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FOREWORD

The existing crash prediction models for rural intersections developed for the Interactive Highway Safety Design Model (IHSDM) require validation and recalibration to improve their credibility and enhance their applicability. This report describes the results of validation and calibration of motor vehicle crash models for rural intersections. Both the validation and recalibration activities were conducted in pursuit of one overriding research objective, which was to make marginal improvements to an existing set of statistical models for predicting crashes at two- and four-lane intersections, with the primary intent to be used in the IHSDM.

The five types of intersection models for which conclusions are drawn and recommendations are made are: three-legged stop controlled intersections of two-lane roads; four-legged stop controlled intersections of two-lane roads; three-legged stop controlled intersections with two lanes on minor and four lanes on major road; and four-legged stop controlled intersections with two lanes on minor and four lanes on major road, and signalized intersections of two-lane roads.

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16. Abstract
This report describes the results of validation and calibration of motor vehicle crash models for rural intersections. Both the validation and recalibration activities were conducted in pursuit of one overriding research objective, which was to make marginal improvements to an existing set of statistical models for predicting crashes at two and four lane intersections, with the primary intent to be used in the Interactive Highway Safety Design Module (IHSDM).

The five types of intersection models for which conclusions are drawn and recommendations are made are: Three-legged stop controlled intersections of two-lane roads; four-legged stop controlled intersections of two-lane roads; three-legged stop controlled intersections with two lanes on minor and four lanes on major road; and four-legged stop controlled intersections with two lanes on minor and four lanes on major road, and signalized intersections of two-lane roads.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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EXECUTIVE SUMMARY

The research described in this report consists of two separate yet complimentary activities—validation and calibration of crash models for rural intersections. Both the validation and recalibration activities were conducted with one overriding research objective:

Given existing database limitations, make marginal improvements to an existing set of statistical models for predicting crashes at two- and four-lane intersections, with the primary intent to provide robust predictive models for use in the Interactive Highway Safety Design Module (IHSDM).

The five types of intersection models addressed in this research effort include:

Type I:	Three-legged stop controlled intersections of two-lane roads.
Type II:	Four-legged stop controlled intersections of two-lane roads.
Type III:	Three-legged stop controlled intersections with two lanes on minor and four lanes on major roads.
Type IV:	Four-legged stop controlled intersections with two lanes on minor and four lanes on major roads.
Type V:	Signalized intersections of two-lane roads.

The models that are the focus of this research are presented in three different Federal Highway Administration (FHWA) reports: Vogt and Bared (Types I and II);[1] Vogt (Types III, IV, and V);[2] and Harwood et al. (Types I, II, and V).[3] Each report presents several variants of the models for each type of intersection. The first two reports include models for total as well as injury accidents and present what are referred to as full models. The Harwood et al. report presents base models for Types I, II, and V intersections.[3] These base models included variables that were statistically significant at the 15 percent level and are at the backbone of an algorithm for predicting accidents at intersections that are different in one or more features from the specified base conditions. Specifically, accident modification factors (AMF) for the features of interest are applied to the base model prediction to estimate accidents per unit of time for a specific intersection. This algorithm is intended for use in the Crash Prediction Module of FHWA's IHSDM. The anticipated practical application of these models has motivated research directions taken throughout the course of this investigation.

The data in support of this research were derived from three sources:

1. The original data used for the calibration of the main models for total accidents were obtained from the researchers who developed those models.
2. Highway Safety Information Systems (HSIS) data were obtained for additional years for the same intersections used in the calibration and for injury accidents for the original and additional years.
3. An independent validation data set of intersections and their relevant crash, traffic, and geometric data in Georgia was specially assembled for this project.[4]

The research team faced a number of challenges while conducting this research, including data collection, independent variable characteristics, and the models' intended end-use:

1. The observational data on which the statistical models are based suffered from intercorrelation.
2. The interactions among variables had to be carefully considered in model estimation.
3. The need to forecast crashes across States posed significant difficulties.
4. The observational data limited the amount of variation in independent variables, reducing overall model precision.
5. Resource and data reliability restrictions prohibited a sufficiently large, randomly selected, fully comprehensive data set on which to estimate statistical models.
6. Incongruencies between data sets across States and across time periods posed serious challenges.

Despite these challenges, the research team conducted a model validation and then recalibrated the five intersection models.

VALIDATION FINDINGS

The four sets of validation activities were:

1. *Re-estimation of the model coefficients using the original data.* This validation activity was used to determine the reproducibility of the published results and to ensure an "equivalent" launching point for all validation and calibration activities. This activity represented a logical starting point for the research effort and was successful in that modeling results were reproduced satisfactorily.

2. *Validation of the models against additional years of accident data for the same intersections used in the calibration*. Because the crash models were developed as direct inputs into the IHSDM's Accident Analysis Module, the models will be used by highway agencies to estimate the safety performance of an existing or proposed roadway. Therefore, the models should be able to forecast crashes across time and space. This validation activity was used to assess the models' ability to forecast crashes across time, determining the models temporal capability and stability.

3. *Validation of the models against Georgia data*. This validation activity assessed the models' ability to forecast crashes across space. This activity tested numerous aspects of model prediction: comparing data from different jurisdictions; capturing variables that describe regional and jurisdictional differences; and consistency of crash processes across space.

4. *Validation of the Accident Prediction Algorithm*. While this research's primary focus was to validate crash models, validating the Accident Prediction Algorithms based on these models was also important.

Two basic sets of performance tests were employed. First, the models were re-estimated using the same variables and functional forms as those published in the original reports; the parameters for the original and re-estimated models were then compared, using a level of alpha = 0.10 to establish statistical significance. Second, the model (or algorithm) was used to predict accident frequencies at individual intersections, from which the following summary statistics were calculated:

- Pearson product-moment linear correlation coefficients.
- Mean Prediction Bias (MPB); MPB/year.
- Mean Absolute Deviation (MAD); MAD/year.
- Mean Squared Error (MSE); MSE/year^2.
- Mean Square Prediction Error (MSPE); MSPE/year^2.

The details of validation activities 1 through 4 are presented in sections 3.4 through 3.7 respectively, while the results are discussed in section 3.8.

RECALIBRATION FINDINGS

Model recalibration was focused on improving the existing set of intersection crash models through use of an improved and expanded database and through lessons learned in the validation and recalibration activities.

For each the five intersection types, the research team developed and/or refined three different sets of models, described in detail in chapter 3. The first type is Annual Average Daily Traffic (AADT) Models, which represent base models for predicting crashes as a function of major and minor road AADT. The analytical results of these models can be found in subsequent sections of this report. The second type of model is Full Models. These statistical models forecast crashes as a function of a relatively large set of independent variables. Details of the Full Models can be found in section 3.4 of this report. The third type of model is AMF. These models, better described as countermeasure correction factors, represent our best efforts to estimate the effect of geometric countermeasures on safety relative to base model predictions. AMF details can be found in section 3.5 of this report.

Sensitivity analyses—tables of AMFs as a function of AADT and other factors are provided in section 3.6.

RECOMMENDATIONS

The research supported the proposed IHSDM accident prediction algorithm. An updated set of base models for predicting crashes using only AADT are recommended (see Summary, Discussion, and Conclusions section and Table 235). The updated statistical models are based on larger sample sizes and, in some cases, resulted in slightly modified sets of independent variables compared to the originally estimated models. AMFs should be selected on a case-by-case basis, and should be updated continually to improve the predictive ability of the crash models. Expert opinion derived AMFs should be replaced with the results of state-of-the-practice before-after studies as time progresses and research allows. If expert opinion accurately reflects safety conditions, then carefully conducted future studies should reveal general agreement with expert expectation. When expert opinions are not confirmed over time, then empirical results should replace expert opinion. Full regression models are recommended for crash forecasts and find logical applications in the *Highway Safety Manual* and SafetyAnalyst (see Summary, Discussion, and Conclusions section and Table 236).

1. INTRODUCTION

Effective safety management of a highway system requires that engineers know the present safety performance of a roadway and how it will perform if contemplated actions are taken. In effect, a reliable method of estimating safety performance is required. To this end, FHWA and its contractors have developed a new approach that combines historical accident data, regression analysis, before-and-after studies, and expert judgment to make safety performance predictions that are expected to be better than those obtained by any of the individual approaches. A recent report documents an accident prediction algorithm for implementing the new approach for two-lane rural highway sections that include road segments and five types of intersections.[3] Ongoing efforts aim to produce similar documents for other types of facilities.

The accident prediction algorithm has been developed for incorporation in the IHSDM as the Crash Prediction Module, but is suitable for stand-alone applications. The structure of the accident prediction algorithm for the five types of rural at-grade intersections is as follows:

$$N_{int} = N_b\ (AMF_1\ AMF_2\ \ldots\ AMF_n) \tag{1}$$

where

N_{int} = predicted number of total intersection-related accidents per year after application of AMFs;

N_b = predicted number of total intersection-related accidents per year for base conditions; and

$AMF_1\ AMF_2\ \ldots\ AMF_n$ = AMFs for various intersection features.

Harwood et al. presented base models and AMFs for three- and four-legged intersections of two-lane rural roads with STOP control, and four-legged signalized intersections of two-lane roads.[3] These base models were the best of available accident prediction models developed in earlier FHWA projects and retained model variables that were statistically significant at the 15 percent level.[1,2] Those projects also resulted in regression models with additional variables indented for use as AMFs in IHSDM. The full models, along with several variants, are presented in two FHWA reports: Vogt and Bared present models for three- and four-legged intersections of two-lane roads, while Vogt documents models for three other types of rural intersections: three- and four-legged stop controlled with four lanes on the major and two on the minor; and signalized intersections of two-lane roads. [1,2] In summary, there are five types of intersection accident prediction models pertaining to the research efforts described:

- Type I: Three-legged stop controlled intersections of two-lane roads.
- Type II: Four-legged stop controlled intersections of two-lane roads.
- Type III: Three-legged stop controlled intersections with two lanes on the minor and four lanes on the major road.
- Type IV: Four-legged stop controlled intersections with two lanes on the minor and four lanes on the major road.

Type V: Signalized intersections of two-lane roads.

The models were developed using data that were limited in terms of geographical diversity and, in the case of Types III, IV, and V, sample size. Thus, validation of these models across both space and time has become of paramount importance. It was also of interest to validate the accident prediction algorithm as a whole, given its novelty and the fact that it relies on expert judgment for deriving the AMFs. An additional report provides additional AMFs for left- and right-turn lanes for at-grade intersections at type I, II and V sites.(5) These AMFs are also included in the validation effort.

A natural follow-on to model validation is model recalibration using validation data and findings to improve the specification of the intersection models. This report presents recalibration results for the five types of rural intersections that were the subject of the validation exercise that was undertaken in the first part of the project. This model recalibration effort complemented the comprehensive model validation conducted as part of a larger technical evaluation of crash prediction models. AADT models and fully parameterized models were recalibrated, and their results are discussed in the recalibration chapter.

This report consists of three chapters. This first chapter provides an introduction and presents the description of the variables used in this research. The second chapter describes four different sets of activities conducted to assess the validity of prediction models for the five types of rural intersections. The third chapter presents the recalibration efforts for the five types of intersections. The model recalibration efforts described in this chapter complement the comprehensive model validation exercise presented in the previous chapter as a part of larger technical evaluation of the models.

1.1 VARIABLE ABBREVIATIONS

This section provides, for ease of reference, the definitions of model types, accident types, and variables applied in this research investigation.

1.1.1 Model Types

Type I: Three-legged stop controlled intersections of two-lane roads.
Type II: Four-legged stop controlled intersections of two-lane roads.
Type III: Three-legged stop controlled intersections with two lanes on the minor and four lanes on the major road.
Type IV: Four-legged stop controlled intersections with two lanes on the minor and four lanes on the major road.
Type V: Signalized intersections of two-lane roads.

1.1.2 Accident Models

Models I and II

Total: Total number of police-reported intersection-related accidents within 76.25 meters (m) (76.25 m (250 ft) (ft)) of the intersection.
Injury: Total number of police-reported intersection-related injury accidents within 76.25 m (250 ft) of the intersection.

Models III, IV, and V
TOTACC: Total number of accidents within 76.25 m (250 ft) of the intersection.
TOTACCI: Only those crashes considered intersection-related and within 76.25 m (250 ft) of the intersection.
INJACC: Total number of injury crashes within 76.25 m (250 ft) of the intersection.
INJACCI: Only those injury crashes considered intersection-related and within 76.25 m (250 ft) of the intersection.

1.1.3 Definitions of Variables

AADT1: Average daily traffic on major road (vehicles per day). This variable is identical to ADT1 in the original (published) models. This change was made after determining that the traffic flow variables were, in fact, estimated AADT.
AADT2: Average daily traffic on minor roads (vehicles per day). This variable is identical to ADT2 in the original models.
COMDRWY1: Commercial driveways on major roads within 76.25 m (250 ft) of the intersection center. This variable is identical to NODRWYC1 in the original models.
COMDRWY2: Commercial driveways on minor roads within 76.25 m (250 ft) of the intersection center. This variable is identical to NODRWYC2 in the original models.
DRWY1: Driveways on major roads within 76.25 m (250 ft) of the intersection. This variable is identical to ND and NODRWY1 in the original models for Type I–II and III–V intersections, respectively.
DRWY2: Driveways on minor roads within 76.25 m (250 ft) of the intersection. This variable is identical to NODRWY2 in the original models.
GRADE1: Average absolute grade on major roads within ±244 m (±800 ft) of the intersection center (percent).
GRADE2: Average absolute grade on minor road within ±244 m (±800 ft) of the intersection center (percent).
HAU: Intersection angle variable defined where the angle between the major and minor roads is measured from the far side of the minor road:

- Three-legged intersections: Angle minus 90 if minor road is to the right of the major road in the increasing direction; 90 minus angle if minor road is to the left of the major road in the increasing direction.
- Four-legged intersections: (right angle - left angle)/2.

HAZRAT1: Roadside hazard rating on major road within 76.25 m (250 ft) of the intersection center (from 1, least hazardous case, to 7, most hazardous case).[6] This variable is identical to RHRI in the original models for Type I and II intersections.
HAZRAT2: Roadside hazard rating on minor road within 76.25 m (250 ft) of the intersection center (from 1, least hazardous case, to 7, most hazardous case).[6]
HEI1: Sum of degree of curve in degrees per hundred feet of each horizontal curve on major road, any portion of which is within ±244 m (±800 ft) of the intersection center divided by the number of such curves.
HEI2: Sum of degree of curve in degrees per hundred feet of each horizontal curve on minor road, any portion of which is within ±244 m (±800 ft) of the intersection center divided by the number of such curves.
HEICOM: (1 / 2) (HEI1 + HEI2).

HI: Sum of degree of curve in degrees per hundred feet of each horizontal curve on major road, any portion of which is within 76.25 m (250 ft) of the intersection center divided by the number of such curves.
HI1: Sum of degree of curve in degrees per hundred feet of each horizontal curve on major road, any portion of which is within 76.25 m (250 ft) of the intersection center divided by the number of such curves. This variable is identical to HI in the original models for Type I and II intersections.
HI2: Sum of degree of curve in degrees per hundred feet of each horizontal curve on minor road, any portion of which is within 76.25 m (250 ft) of the intersection center divided by the number of such curves.
HICOM: (1 / 2) (HI1 + HI2).
L1LT (Type III-V): Left-turn lane on major roads (0 = no, 1 for one approach, and 2 for both approaches). This variable is identical to LTLN1 in the original models for Type III–V intersections.
L1RT (Type III-V): Right-turn lane on major roads (0 = no, 1 for one approach, and 2 for both approaches). This variable is identical to RTLN1 in the original models for Type III–V intersections.
L3LT (Type III-V): Left-turn lane on minor roads (0 = no, 1 for one approach, and 2 for both approaches). This variable is identical to LTLN2 in the original models for Type III–V intersections.
L3RT (Type III-V): Right-turn lane on minor roads (0 = no, 1 for one approach, and 2 for both approaches). This variable is identical to RTLN2 in the original models for Type III–V intersections.
LEGACC1: Acceleration lane on major roads (0 = no, 1 = yes).
LEGACC2: Acceleration lane on minor roads (0 = no, 1 = yes).
LIGHT: Light at intersection (0 = no, 1 = yes).
LTLN1S (Type III-V): Left-turn lane on major roads (0 = no, 1 = yes).
LT MAJ (Type I-II): 1 if left-turn lane exists on at least one approach of major roads, 0 otherwise.
LT MIN (Type I-II): 1 if left-turn lane exists on at least one approach of minor roads, 0 otherwise.
MEDIAN (Type I-II): 1 if median exists on major roads, 0 otherwise.
MEDTYPE (Type III-V): Median type (0 = no median, 1 = painted, 2 = curbed, 3 = others).
MEDWDTH1: Median width on major roads (feet). This variable is identical to MEDWIDTH1 in the original models.
MEDWDTH2: Median width on minor roads (feet).
PKLEFT: Peak left-turn percentage (percent).
PKLEFT1: Peak left-turn percentage on major roads (percent).
PKLEFT2: Peak left-turn percentage on minor roads (percent).
PKTHRU1: Peak through percentage on major roads (percent).
PKTHRU2: Peak through percentage on minor roads (percent).
PKTRUCK: Peak truck percentage passing through the intersection (percent).
PKTURN: Peak turning percentage (percent).
PROT_LT: Protected left lane (0 = no, 1 = yes).
RESDRWY1: Residential driveways on major roads within 76.25 m (250 ft) of the intersection center. This variable is identical to NODRWYR1 in the original models.

RESDRWY2: Residential driveways on minor roads within 76.25 m (250 ft) of the intersection center. This variable is identical to NODRWYR2 in the original models.
RT MAJ (Type I-II): 1 if right-turn lane exists on major roads, 0 otherwise.
RT MIN (Type I-II): 1 if right-turn lane exists on minor roads, 0 otherwise.
SD1: Longitudinal sight distance on major roads (feet).
SDL2: Left-side sight distance on minor roads (feet).
SDR2: Right-side sight distance on minor roads (feet).
SHOULDER1: Shoulder width on major roads (feet).
SHOULDER2: Shoulder width on minor roads (feet).
SPD1: The average posted speed on major roads in vicinity of the intersection (miles per hour). This variable is identical to SPDI in the original models for Type I and II intersections.
SPD2: The average posted speed on minor roads in vicinity of the intersection (miles per hour).
TERRAIN (Type I-II): 1 if flat, 2 if rolling, or 3 if mountainous terrain.
TERRAIN1 (Type III-V): Terrain on major roads within 76.25 m (250 ft) of the intersection center (0 = flat, 1 = rolling, 2 = mountainous).
TERRAIN2 (Type III-V): Terrain on minor roads within 76.25 m (250 ft) of the intersection center (0 = flat, 1 = rolling, 2 = mountainous).
VCEI1: Sum of absolute change of grade in percent per hundred feet for each crest curve on major roads, any portion of which is within 800 feet of the intersection center, divided by the number of such curves.
VCEI2: Sum of absolute change of grade in percent per hundred feet for each crest curve on minor roads, any portion of which is within 800 feet of the intersection center, divided by the number of such curves.
VCI1: Sum of absolute change of grade in percent per hundred feet for each crest curve on major roads, any portion of which is within 76.25 m (250 ft) of the intersection center, divided by the number of such curves. This variable is identical to VCI in the original models for Type I and II intersections.
VCI2: Sum of absolute change of grade in percent per hundred feet for each crest curve on minor roads, any portion of which is within 76.25 m (250 ft) of the intersection center, divided by the number of such curves.
VEI1: Sum of absolute change of grade in percent per hundred feet for each curve on major roads, any portion of which is within ±244 m (±800 ft) of the intersection center, divided by the number of such curves.
VEI2: Sum of absolute change of grade in percent per hundred feet for each curve on minor roads, any portion of which is within ±244 m (±800 ft) of the intersection center, divided by the number of such curves.
VEICOM: (1 / 2) (VEI1 + VEI2).
VI1: Sum of absolute change of grade in percent per hundred feet for each curve on major roads, any portion of which is within 76.25 m (250 ft) of the intersection center, divided by the number of such curves.
VI2: Sum of absolute change of grade in percent per hundred feet for each curve on minor roads, any portion of which is within 76.25 m (250 ft) of the intersection center, divided by the number of such curves.
VICOM (Type III-V): (1 / 2) (VI1 + VI2).

2. VALIDATION OF ACCIDENT MODELS

This chapter presents validation results for the five types of rural intersections. It first provides a description of the overall validation approach. Second, the data sources and issues are discussed. Third, the individual validation activities and their results are presented. Finally, a discussion of these results is provided.

2.1 VALIDATION APPROACH AND PRELIMINARIES

Several objectives were identified to guide the validation efforts:

1. Determine whether the existing accident models developed by FHWA were "over-fit" to the estimation data, thus making elements (factors) appear to affect accidents when, in fact, they do not.
2. Determine whether important variables were omitted from the models due to lack of representative data, insufficient sample size, lack of power, or some combination of thereof.
3. Determine whether the functional forms of the models have been properly specified.
4. Determine whether the models are valid at other locations (across space) and at the same intersections in the future (across time).

To meet these objectives, researchers conducted two aspects of model validation: internal and external model validations. The first aspect of model validation consists of qualitative assessments of statistical models, including examining the collection of variables used to identify missing or irrelevant variables, inspecting the functional form of the models, and assessing the implications of the models regarding an underlying theory of the data generating process—motor vehicle crashes, in this case. External model validation is more quantitative and is focused on various quantitative measures of a statistical model's prediction ability. Three model validation activities comprising both internal and external validation activities were undertaken:

1. *Validation of the models against additional years of accident data for the same intersections used in the calibration.* Because the existing accident models were developed as direct inputs into the IHSDM's Crash Prediction Module, highway agencies will use the models to estimate the safety performance of an existing or proposed roadway. Therefore, the models should be able to forecast accidents over time and space. This validation was used to assess the models' ability to forecast accidents across time. Temporal stability of a model suggests that it will predict accident frequencies well across time; the effect of time, or covariates that are influenced by time, are either not important or, if important, are included in the model by some relevant explanatory variable.
2. *Validation of the models against Georgia data.* This validation was used to assess the models' ability to forecast accidents over space. The primary application of the models is to forecast the impact of design considerations and countermeasures in regions and jurisdictions not represented in the calibration data. Thus, this

validation exercise attempts to assess the ability of the models to capture differences across regions as reflected through relevant variable expressions in the models.

3. *Validation of the Accident Prediction Algorithm*. Validation of the Accident Prediction Algorithm as a whole was considered to be important. This validation activity addresses the logical defensibility of the algorithm used for predicting accidents, and provides quantitative evidence of how well it is predicting accidents.

The validation exercises in this chapter focus primarily on external validation—validation concerned with assessing performance of the models when compared to external data. The discussion section mentions internal validation concerns—the internal coherence, structure, theoretical soundness, and plausibility of the models proposed. And more focus is given to internal validation in the recalibration activities documentation, which follows the report on these validation efforts. In these validation activities, all model specifications were validated "as is," that is, no changes to model specifications were considered or assessed.

Throughout the report the subjective criteria of alpha (α) equal to 0.10 is applied. The support for this level of α is as follows. In statistical models of accident occurrence, a type II error can be argued to be more serious than a type I error. With a type I error, the analyst concludes that the null hypothesis is false, when in fact it is true with α probability. This translation is not precise, but the precise and correct conditional probability interpretation is cumbersome and, for practical purposes, does not lend any additional insights. This means that the analyst would conclude, for example, that the presence of a left-turn lane reduces accidents when, in reality, it does not. As a result of this conclusion, one might install left-turn lanes without realizing a reduction in crashes. A type II error occurs with beta (β) probability. In general, choosing a larger α results in a smallerβ, all else being equal. Thus, continuing with the previous example, making a type II error results in concluding that the presence of a left-turn lane does not reduce crashes when in fact it does. The risk is in failing to install an effective countermeasure. To summarize, committing a type I error results in applying an ineffective countermeasure, while committing a type II error results in failing to apply an effective countermeasure. Computing the actual β in negative binomial models is extremely difficult. However, applying a liberal α equal to 0.10 suggests that this study has simultaneously accepted a smaller level of beta.

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

2.2 DATA SOURCES AND ISSUES

This section presents the data sources used for the validation and some general data issues. The data used came from three sources:

1. The original data used for the calibration of the main models for total accidents were obtained from the researchers who developed those models.
2. HSIS data were obtained for additional years for the same intersections used in the calibration for the additional years available.
3. An independent validation data set was assembled specifically for this project.

The first validation activity employed the original datasets with the objective of reproducing the original models. In the second validation activity, additional years of accident data (1990 to 1998) from Minnesota were used to validate models I and II over time. The Washington data collected, but not used, for the final development of models I and II, plus accident data for one more year (1996) also were utilized. For models III, IV, and V, additional years of accident data (1996 and 1997) from California and Michigan were used to validate the models over time. For the third validation activity, data from Georgia were assembled during this project and used to further assess the models' ability to predict accidents over space (in a different jurisdiction). The fourth validation activity assessed the "Red Book" accident prediction algorithm, including recommended base models.(3)

Models I and II, which were developed using Minnesota data, modeled police reported "intersection" or "intersection-related" accidents which occurred within 76.25 m (250 ft) of the intersection. Models III, IV, and V were each developed using Michigan and California data for two dependent variables. The first used all accidents occurring within 76.25 m (250 ft) of the intersection. The second used only those accidents considered to be "intersection-related" and occurring within 76.25 m (250 ft) of the intersection. Special criteria were needed for the latter case because California data does not include a variable indicating if an accident was "intersection-related." An accident was considered to be intersection related accidents if it was:

1. Vehicle-pedestrian accident.
2. An accident where one vehicle involved was making a left turn, right turn or U-turn before the crash.
3. A multivehicle accident in which the accident type is either a sideswipe, rearend, or broadside/angle.

Vehicle-bicyclist, head-on, and run-off-the-road crashes may could possibly be classified as intersection related but were not included in the analysis in order to maintain consistencyand comparability with previously estimated models from which this research was based.(2) According to discussions with FHWA, for four-leg STOP-controlled intersections, these crashes typically represent about 6 percent of the total crashes occurring within 76.25 m (250 ft) of the intersection. For three-leg STOP-controlled intersections, these crashes typically represent about 13 percent of the total crashed occurring within 76.25 m (250 ft) of the intersection.

Table 1. Basic Statistics for the Data Sources

Basic statistics for the data sources (Blank cells indicate accident types not validated; x indicates accident types validated)		Model I[1]	Model II[1]	Model III[2]	Model IV[2]	Model V[2]
Sample size	Original Years	389	327	84	72	49
	Georgia Data	121	114	52	52	51
States[3]	Original years	MN	MN	CA and MI	CA and MI	CA and MI
	Subsequent Years	MN and WA	MN and WA	CA and MI	CA and MI	CA and MI
	Georgia Data	GA	GA	GA	GA	GA
Years covered	Original Years	5 (1985 to 1989)	5 (1985 to 1989)	3 (1993 to 1995)	3 (1993 to 1995)	3 (1993 to 1995)
	Subsequent Years	9 (1990 to 1998 for MN 1993 to 1996 for WA)	9 (1990 to 1998 for MN 1993 to 1996 for WA)	2 (1996 to 1997)	2 (1996 to 1997)	2 (1996 to 1997)
	Georgia Data	2 (1996 to 1997)	2 (1996 to 1997)	2 (1996 to 1997)	2 (1996 to 1997)	2 (1996 to 1997)
Accident types validated	Total	X	X			
	Injury	X	X			
	TOTACC[4]			X	X	X
	TOTACCI[4]			X	X	X
	INJACC			X	X	X
	INJACCI			X	X	X

[1] Vogt and Bared 1998, (pp. 60–67)
[2] Vogt, 1999, (pp. 53–64)
[3] MN: Minnesota, WA: Washington, CA: California, MI: Michigan, GA: Georgia.
[4] TOTACC: Total number of accidents within 76.25 m (250 ft); TOTACCI: Only those crashes considered intersection-related and within 76.25 m (250 ft); Similar distinction between INJACC and INJACCI

The Georgia data specially collected for this validation also do not include a variable coded as “intersection” or “intersection-related” by the police. As such, the above criteria for determining an “intersection-related” accident were used.

To use the Georgia data to validate the original models, consistency of accident location definitions had to be resolved. The original models included accidents only within 76.25 m (250 ft) from the intersection center. However, the accident data recorded in Georgia measures the distance of an accident from an intersection within two decimal places of a mile, i.e., within 8.05 m (26.4 ft). The issue was whether or not to include accidents within 0.06 or .08 kilometers (km) (0.04 or 0.05 miles, or 211 or 264 ft). In the end, both the 0.04- and 0.05-mile buffers were used in separate validation efforts, mainly to check the sensitivity of the results to this definition.

2.3 MODEL PERFORMANCE MEASURES

Several GOF measures were used to assess model performance. It is important to note at the outset that only after an assessment of many GOF criteria is made can the performance of a particular model or set of models be assessed. In addition, a model must be internally plausible, and agree with known theory about crash causation and processes. The GOF measures used were:

Pearson's Product Moment Correlation Coefficients Between Observed and Predicted Crash Frequencies

Pearson's product moment correlation coefficient, usually denoted by *r*, is a measure of the linear association between the two variables Y_1 and Y_2 that have been measured on interval or ratio scales. A different correlation coefficient is needed when one or more variable is ordinal. Pearson's product moment correlation coefficient is given as:

$$r = \frac{\sum (Y_{i1} - \overline{Y}_1)(Y_{i2} - \overline{Y}_2)}{\left[\sum (Y_{i1} - Y_1)^2 \sum (Y_{i2} - Y_2)^2\right]^{1/2}} \tag{2}$$

where

$\overline{Y} =$ the mean of the Y_i observations.

A model that predicts observed data perfectly will produce a straight line plot between observed (Y_1) and predicted values (Y_2), and will result in a correlation coefficient of exactly 1. Conversely, a linear correlation coefficient of 0 suggests a complete lack of a linear association between observed and predicted variables. The expectation during model validation is a high correlation coefficient. A low coefficient suggests that the model is not performing well and that variables influential in the calibration data are not as influential in the validation data. Random sampling error, which is expected, will not reduce the correlation coefficient significantly.

Mean Prediction Bias (MPB)

The MPB is the sum of predicted accident frequencies minus observed accident frequencies in the validation data set, divided by the number of validation data points. This statistic provides a measure of the magnitude and direction of the average model bias as compared to validation data. The smaller the average prediction bias, the better the model is at predicting observed data. The MPB can be positive or negative, and is given by:

$$MPB = \frac{\sum_{i=1}^{n} \left(\hat{Y}_i - Y_i\right)}{n} \tag{3}$$

where

n = validation data sample size; and

$\hat{Y} =$ the fitted value Y_i observation.

A positive MPB suggests that on average the model overpredicts the observed validation data. Conversely, a negative value suggests systematic underprediction. The magnitude of MPB provides the magnitude of the average bias.

Mean Absolute Deviation (MAD)
MAD is the sum of the absolute value of predicted validation observations minus observed validation observations, divided by the number of validation observations. It differs from MPB in that positive and negative prediction errors will not cancel each other out. Unlike MPB, MAD can only be positive.

$$MAD = \frac{\sum_{i=1}^{n} \left| \hat{Y}_i - Y_i \right|}{n} \tag{4}$$

where
n = validation data sample size.

The MAD gives a measure of the average magnitude of variability of prediction. Smaller values are preferred to larger values.

Mean Squared Prediction Error (MSPE) and Mean Squared Error (MSE)
MSPE is the sum of squared differences between observed and predicted crash frequencies, divided by sample size. MSPE is typically used to assess error associated with a validation or external data set. MSE is the sum of squared differences between observed and predicted crash frequencies, divided by the sample size minus the number of model parameters. MSE is typically a measure of model error associated with the calibration or estimation data, and so degrees of freedom are lost (p) as a result of producing Y_{hat}, the predicted response.

$$\text{MSE} = \frac{\sum_{i=1}^{n} \left(Y_i - \hat{Y}_i \right)^2}{n_1 - p} \tag{5}$$

$$\text{MPSE} = \frac{\sum_{i=1}^{n} \left(Y_i - \hat{Y}_i \right)^2}{n_2} \tag{6}$$

where
n_1 = estimation data sample size; and
n_2 = validation data sample size.

A comparison of MSPE and MSE reveals potential overfitting or underfitting of the models to the estimation data. An MSPE that is higher than MSE may indicate that the models may have been overfit 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 misspecified. Finally, data inconsistencies could cause a relatively high value of MSPE. Values of MSPE and MSE that are similar in magnitude indicate that validation data fit the model similar to the estimation data and that deterministic and stochastic components are stable across the comparison being made. Typically this is the desired result.

To normalize the GOF measures to compensate for the different numbers of years associated with different data sets, GOF measures were computed on a per year basis. For MPB and MAD per year, MPB and MAD were divided by number of years. However, since MSPE and MSE are the mean values of the squared errors (MPB or MAD were squared and divided by n or n-p), MSPE and MSE were divided by the square of number of years to calculate MSPE and MSE per year, resulting in a fair comparison of predictions based on different numbers of years.

Overdispersion Parameter, *K*

The overdispersion parameter, *K*, in the negative binomial distribution has been reported in different forms by various researchers. In the model results presented in this report, *K* is reported from the variance equation expressed as:

$$Var\{m\} = E\{m\} + K * E\{m\}^2 \tag{7}$$

where
$Var\{m\}$ = the estimated variance of the mean accident rate;
$E\{m\}$ = the estimated mean accident rate; and
K = the estimated overdispersion parameter.

Variance overdispersion in a Poisson process can lead to a negative binomial dispersion of errors, particularly when the Poisson means are themselves approximately gamma distributed, or possess gamma heterogeneity. The negative binomial distribution has been shown to adequately describe errors in motor vehicle crash models in many instances. Because the Poisson rate is overdispersed, the estimated variance term is larger than the same under a Poisson process. As overdispersion gets larger, so does the estimated variance, and consequently all of the standard errors of estimates become inflated. As a result, all else being equal, a model with smaller overdispersion (i.e., a smaller value of *K*) is preferred to a model with larger overdispersion.

2.4 VALIDATION ACTIVITY 1: VALIDATION USING ADDITIONAL YEARS OF ACCIDENT DATA

The acquisition of subsequent years of accident data allowed for the validation of the models across time. For the type I and II models, although data from both Minnesota and Washington were collected, only data from Minnesota were used for the final calibration. Only the models developed using Minnesota data were validated because a report by Vogt and Bared states that "in view of the small size of the Washington State sample … the non-random and ad hoc character of the Washington intersections, the lesser quality of the collected Washington data … we take the Minnesota models as fundamental." (p. 123)[(1)] However, the Washington data were still obtained to further assess the transferability of these models over time and across jurisdictions. The original report performed a similar validation exercise with Washington data but with fewer years of accident data. The validation undertaken for this activity included applying the original models to the new data and assessing various measures of GOF. It also included recalibrating the models using the additional years of data and comparing the parameter estimates with those of the original models.

The Type I and II models were originally calibrated on accident data from 1985 to 1989. In the original report, 1990 to 1993 data were used to validate the models in addition to the Washington data. The results for the MAD are given in Table 2.

Table 2. Validation Statistics from Original Report[1]

Measure	Model I (90-93 Minnesota data)	Model II (90-93 Minnesota data)	Model I (93-95 Washington data)	Model II (93-95 Washington data)
MAD	1.02	1.28	1.17	2.68

[1] Vogt and Bared, 1998, (p. 131–132)

For the new validation of Type I and II models, accident data from 1990 to 1998 were obtained to expand the validation dataset.

For the Type III, IV, and V models, the original models were developed with accident data that were collected between 1993 and 1995. Accident data collected between 1996 and 1997 at the same locations were acquired to validate the models.

Data Limitations in the Minnesota Data

Because site characteristics change over time, the original sites were examined on important variables to determine which ones were no longer suitable for inclusion. Also, any sites where any year of accident data was missing was not included. Of the 327 original four-legged sites, 315 were retained while 367 of the original 389 three-legged sites were retained. The sites that were excluded typically changed from being a rural to a suburban environment, changed in the number of legs, and changed traffic control or had missing years of accident data.

Subsequent to the analysis and draft report, it was discovered that the mile log information that identifies the location of an intersection for some sites had changed over the 1990 to 1998 period. Although errors will exist in the accident counts used at these sites, these errors were found to be negligible. For example, for Type I sites, the average number of accidents per site per year in the validation data was 0.25 and 0.11 for total and injury data, respectively. In the corrected data, these averages are 0.26 and 0.11. Therefore, the conclusions drawn from the analysis are not affected and the analysis has not been redone.

Data Limitations in the Michigan Data
Traffic volumes from 1993 to 1995 were not updated for this validation exercise because AADT information for major and minor roads for 1996 and 1997 were not available. One of the complexities regarding AADT acquisition is outlined in the report published originally by Vogt.(2) In the original data, minor road AADT from 1993 to 1995 was not available for Michigan intersections. Therefore in the report, major AADT plus peak-hour turning movement counts were used to estimate missing years of minor road AADT.

Subsequent to the analysis and draft report it was discovered that for type V sites from Michigan, the original researchers manually identified crossroad mileposts for about 40 percent or more of these intersections (State routes) and counted accidents that occurred on the crossroads. At non-State route crossroads, accidents are mileposted to the mainline. However, the Michigan accident data for 1996 and 1997 years obtained did not include the crossroad accidents at intersections with a State route crossroad because the validation team did not have the crossroad milepost information at that time. As a result, the later year crossroad accident numbers at these sites should be systematically lower than expected.

2.4.1 Model I

The summary statistics shown in table 3 indicate that there are similar accident frequencies between the original (1985–89 data for 389 sites) and the additional (1990–98 data for 367 sites) years. Note that the statistics compare 5 years of accident data in the original set to 9 years of accident data for validation over time. The latter years of data exhibit an increased variability amongst the sites. The Washington data shows a higher average accident frequency and a lower variability between sites compared to the original Minnesota data.

Table 3. Accident Summary Statistics for Type I Sites

Dataset	No. of Sites	Mean	Median	Std. Deviation	Min.	Max.
Minnesota Total (85-89)[1]	389	1.35 (0.27/year)	0.00	2.88	0	39
Minnesota Injury (85-89)[1]	389	0.59 (0.12/year)	0.00	N/A[2]	0	17
Minnesota Total (90-98)	367	2.21 (0.25/year)	1.00	3.89	0	32
Minnesota Injury (90-98)	367	0.95 (0.11/year)	0.00	1.79	0	13
Washington Total (93-96)	181	1.43 (0.36/year)	0.00	2.48	0	14
Washington Injury (93-96)	181	0.66 (0.17/year)	0.00	1.33	0	10

[1] Vogt and Bared, 1998, (p. 60)
[2] N/A: not available

Total Accident Model

The model was recalibrated with the additional years of accident data for the original Minnesota sites. Recall that the intersection related variable for vertical curvature, VCI1, did not exactly match those statistics given in the report. The parameter estimates, their standard errors, and *p*-values are provided in table 4, which reveals differences in the parameter estimates of the variables between the two time periods.

VCI1 and RT were estimated with opposite signs to the original models, although in the original calibration these parameter estimates had large standard errors and were not statistically significant. This indicates that variables with large standard errors compared to the parameter estimates should not be included in the model even if engineering "common sense" suggests that they should. The other parameters were estimated with the same sign as originally and in some cases similar magnitude and significance to the original models. The overdispersion parameter, *K*, was estimated with a similar magnitude.

Table 4. Parameter Estimates for Type I Total Accident Model Using Additional Years of Data

Variable	Original Estimates[1] (s.e., *p*-value)	Recalibrated Estimates (s.e., *p*-value)	Additional Years Estimates (s.e., *p*-value)
Constant	-12.9922 (1.1511, 0.0001)	-12.90 (1.16, <0.001)	-13.48 (1.07, <0.001)
Log of AADT1	0.8052 (0.0639, 0.0001)	0.8051 (0.0784, <0.001)	0.8199 (0.0714, <0.001)
Log of AADT2	0.5037 (0.0708, 0.0001)	0.4991 (0.0660, <0.001)	0.4808 (0.0584, <0.001)
HI1	0.0339 (0.0327, 0.3004)	0.0339 (0.0220, 0.124)	0.0145 (0.0206, 0.481)
VCI1	0.2901 (0.2935, 0.3229)	0.1900 (0.2260, 0.402)	-0.245 (0.269, 0.363)
SPD1	0.0285 (0.0177, 0.1072)	0.0273 (0.0144, 0.058)	0.0375 (0.0130, 0.004)
HAZRAT1	0.1726 (0.0677, 0.0108)	0.1806 (0.0754, 0.017)	0.0779 (0.0655, 0.234)
RT MAJ	0.2671 (0.1398, 0.0561)	0.2690 (0.1420, 0.058)	-0.077 (0.126, 0.539)
HAU	0.0045 (0.0032, 0.1578)	0.0043 (0.0024, 0.075)	0.00145 (0.00222, 0.513)
K[2]	0.481	0.485	0.500

[1] Vogt and Bared, 1998, (p. 115)
[2] K: Overdispersion value

GOF measure comparisons are shown in table 5. The Pearson product-moment correlation coefficient was marginally higher for the original data than when the model based on that data were used to predict the additional years of data. The MPB is higher for the prediction of the additional years of data. The MADs per year are similar for the predictions for the two time periods. The MSPE per year squared is lower than the MSE per year squared.

Table 5. Validation Statistics for Type I Total Accident Model Using Additional Years of Data

Measure	Recalibrated 1985-89 Model	Original 1985-89 Model	Recalibrated 1985-89 Model
Years used for validation	1985-89	1990-98	1990-98
Number of sites	389	367	367
Pearson product-moment correlation coefficients	0.662	0.612	0.614
MPB	-0.01	-0.050	-0.52
MPB/yr	0.00	-0.06	-0.06
MAD	1.03	1.84	1.84
MAD/yr	0.21	0.20	0.20
MSE	4.64	N/A[1]	N/A[1]
MSE/yr^2	0.19		
MSPE	N/A[1]	10.93	10.94
MSPE/yr^2		0.13	0.14

[1] N/A: not available

The model was also recalibrated with the Washington data. The parameter estimates, their standard errors, and *p*-values are provided in table 6, which reveals differences in the parameter estimates of the variables between the two locations.

All parameters were estimated with the same sign as the original models, and in some cases with similar magnitude and significance. Notable exceptions are VCI1 and HAZRAT1 which were estimated with the same sign but with a large difference in magnitude. For VCI1 both the original and newly estimated parameters had large standard errors. For the new Washington data HAZRAT1 had a large standard error and the overdispersion parameter, *K*, was higher than the original Minnesota model.

A comparison of validation measures for the model recalibrated with the original data and the original model applied to the Washington data is shown in table 7.

The Pearson product-moment correlation coefficient was slightly higher for the original data as compared to Washington data. The MPB, mean absolute deviations and mean squared prediction errors were similar in magnitude.

Table 6. Parameter Estimates for Type I Total Accident Model Using Washington Data

Variable	Original Estimates (s.e., *p*-value)[1]	Recalibrated Estimate (s.e., *p*-value)	Washington Data Estimates (s.e., *p*-value)
Constant	-12.9922 (1.1511, 0.0001)	-12.90 (1.16, <0.001)	-12.59 (2.01, <0.001)
Log of AADT1	0.8052 (0.0639, 0.0001)	0.8051 (0.0784, <0.001)	0.8730 (0.1750, <0.001)
Log of AADT2	0.5037 (0.0708, 0.0001)	0.4991 (0.0660, <0.001)	0.4858 (0.0805, <0.001)
HI1	0.0339 (0.0327, 0.3004)	0.0339 (0.0220, 0.124)	0.0170 (0.0356, 0.632)
VCI1	0.2901 (0.2935, 0.3229)	0.1900 (0.2260, 0.402)	0.6200 (0.4440, 0.162)
SPD1	0.0285 (0.0177, 0.1072)	0.0273 (0.0144, 0.058)	0.0122 (0.0179, 0.495)
HAZRAT1	0.1726 (0.0677, 0.0108)	0.1806 (0.0754, 0.017)	0.1030 (0.1010, 0.309)
RT MAJ	0.2671 (0.1398, 0.0561)	0.2690 (0.1420, 0.058)	0.2780 (0.2750, 0.311)
HAU	0.0045 (0.0032, 0.1578)	0.0043 (0.0024, 0.075)	0.0032 (0.0127, 0.802)
K[2]	0.481	0.485	0.769

[1] Vogt and Bared, 1998, (p. 115)
[2] K: Overdispersion value

Table 7. Validation Statistics for Type I Total Accident Model Using Washington Data

Measure	Recalibrated 1985-89 Model	Original 1985-89 Model
Years used for validation	1985-89 (Minnesota)	1993-96 (Washington)
Number of sites	389	181
Pearson product-moment correlation coefficients	0.662	0.579
MPB	-0.01	-0.30
MPB/yr	0.00	-0.08
MAD	1.027	1.39
MAD/yr	0.205	0.35
MSE	4.64	N/A[1]
MSE/yr[2]	0.19	
MSPE	N/A[1]	4.45
MSPE/yr[2]		0.28

[1] N/A: not available

Injury Accident Model

Table 8 shows the parameter estimates for the type I injury accident model using additional years of data. VCI1, RT MAJ, and HAU were estimated with opposite signs than the original model, but this is not surprising when the large standard errors are considered. The other parameters were estimated with the same direction of effect, and in some cases similar magnitude and significance as the original model. The overdispersion parameter, *K*, was estimated to be slightly higher than that in the original model.

Table 8. Parameter Estimates for Type I Injury Accident Model Using Additional Years of Data

Variable	Original Estimates (s.e., *p*-value)[1]	Additional Years Estimates (s.e., *p*-value)
Constant	-13.0374 (1.7908, 0.0001)	-15.41 (1.44, <0.001)
Log of AADT1	0.8122 (0.0973, 0.0001)	0.7774 (0.0932, <0.001)
Log of AADT2	0.4551 (0.0977, 0.0001)	0.5815 (0.0760, <0.001)
HI1	0.0335 (0.0327, 0.3047)	0.0067 (0.0268, 0.802)
VCI1	0.1869 (0.3657, 0.6092)	-0.359 (0.393, 0.361)
SPD1	0.0156 (0.0269, 0.5618)	0.0514 (0.0179, 0.004)
HAZRAT1	0.2065 (0.0930, 0.0263)	0.1618 (0.0857, 0.059)
RT MAJ	0.3620 (0.1814, 0.0460)	-0.260 (0.163, 0.159)
HAU	0.0051 (0.0045, 0.2594)	-0.00109 (0.00282, 0.699)
DRWY1	-0.0120 (0.0714, 0.8671)	-0.0008 (0.0541, 0.988)
K[2]	0.494	0.526

[1] Vogt and Bared, 1998, (p. 116)
[2] K: Overdispersion value

Validation statistics are shown in table 9 for the additional years of injury accident data. Since the original injury accident counts were not obtained these measures are not provided for the original years. The Pearson product-moment correlation coefficient was lower (0.553) than that for total accidents (0.614 for the recalibrated model) and the MAD per year (0.106) was about one half of that for total accidents.

The model was also recalibrated with the Washington data. The parameter estimates, their standard errors, and *p*-values are provided in table 10, which reveals differences in the parameter estimates of the variables between the two States.

Table 9. Validation Statistics for Type I Injury Accident Model Using Additional Years of Data

Measure	Additional Years 1990-98
Number of sites	367
Pearson product-moment correlation coefficients	0.553
MPB	-0.219
MPB/yr	-0.024
MAD	0.955
MAD/yr	0.106
MSPE	2.530
MSPE/yr^2	0.031

Table 10. Parameter Estimates for Type I Injury Accident Model UsingWashington Data

Variable	Original Estimates (s.e., *p*-value) [1]	Washington Data Estimates (s.e., *p*-value)
Constant	-13.0374 (1.7908, 0.0001)	-14.64 (2.49, <0.001)
Log of AADT1	0.8122 (0.0973, 0.0001)	1.012 (0.222, <0.001)
Log of AADT2	0.4551 (0.0977, 0.0001)	0.5237 (0.0968, <0.001)
HI1	0.0335 (0.0327, 0.3047)	0.0055 (0.0404, 0.892)
VCI1	0.1869 (0.3657, 0.6092)	0.578 (0.526, 0.272)
SPD1	0.0156 (0.0269, 0.5618)	0.0118 (0.0227, 0.602)
HAZRAT1	0.2065 (0.0930, 0.0263)	0.071 (0.119, 0.552)
RT MAJ	0.3620 (0.1814, 0.0460)	0.190 (0.305, 0.534)
HAU	0.0051 (0.0045, 0.2594)	0.0103 (0.0163, 0.526)
DRWY1	-0.0120 (0.0714, 0.8671)	-0.0111 (0.0695, 0.873)
K[2]	0.494	0.513

[1] Vogt and Bared, 1998, (p. 116)
[2] K: Overdispersion value

The parameters were all estimated with the same sign but in several cases the difference in magnitude was large. The overdispersion parameter, *K*, was estimated with a similar magnitude.

Validation measures for the Washington data are shown in table 11. The Pearson product-moment correlation coefficient was lower (0.505) than that for total (0.579) accidents, and the MADs per year are about one half that for total accidents.

Table 11. Validation Statistics for Type I Injury Accident Model Using Washington Data

Measure	Washington Data 1993-96
Number of sites	181
Pearson product-moment correlation coefficients	0.505
MPB	-0.084
MPB/yr	-0.021
MAD	0.712
MAD/yr	0.178
MSPE	1.343
MSPE/yr[2]	0.08

2.4.2 Model II

The summary statistics shown in table 12 indicate that there is little difference in the mean accident frequencies between original (1985–89) and additional (1990–98) years for the Minnesota sites, although there is more variation in the latter data. The Washington sites exhibit a large increase in the mean accident frequency and a larger variability between sites.

Total Accident Model

The model was recalibrated with the additional years of accident data for the Minnesota sites. Recall that the intersection related variables did not exactly match those statistics given in the report. The parameter estimates, their standard errors, and *p*-values are provided in table 13, which reveals differences in the parameter estimates of the variables between the two time periods.

Table 12. Accident Summary Statistics for Type II Sites

Dataset	No. of Sites	Mean	Median	Std. Deviation	Minimum	Maximum
Minnesota Total (85-89)[1]	327	1.51 (0.30/year)	1.00	2.36	0	16
Minnesota Injury (85-89)[1]	327	0.77 (0.15/year)	0.00	N/A[2]	0	9
Minnesota Total (90-98)	315	2.83 (0.31/year)	2.00	5.17	0	67
Minnesota Injury (90-98)	315	1.50 (0.17/year)	1.00	2.95	0	36
Washington Total (93-96)	90	3.97 (0.99/year)	1.00	5.07	0	20
Washington Injury (93-96)	90	2.46 (0.62/year)	1.00	3.38	0	14

[1] Vogt and Bared, 1998, (p. 64)
[2] N/A: not available

The parameters were estimated with the same sign as the original model and in several cases with similar magnitude and significance. VCI1 and HAU were estimated with a large difference in magnitude. The overdispersion parameter, *K*, was almost twice as large as the original model.

Table 13. Parameter Estimates for Type II Total Accident Model Using Additional Years of Data

Variable	Original Estimates (s.e., *p*-value) [1]	Additional Years Estimates (s.e., *p*-value)
Constant	-10.4260 (1.3167, 0.0001)	-10.74 (1.08, <0.001)
Log of AADT1	0.6026 (0.0836, 0.0001)	0.6673 (0.0768, <0.001)
Log of AADT2	0.6091 (0.0694, 0.0001)	0.6135 (0.0622, <0.001)
HI1	0.0449 (0.0473, 0.3431)	0.0702 (0.0456, 0.123)
VCI1	0.2885 (0.2576, 0.2628)	0.066 (0.199, 0.741)
SPD1	0.0187 (0.0176, 0.2875)	0.0130 (0.0159, 0.415)
DRWY1	0.1235 (0.0519, 0.0173)	0.0988 (0.0417, 0.018)
HAU	-0.0049 (0.0033, 0.1341)	-0.00006 (0.00141, 0.967)
K[2]	0.205	0.385

[1] Vogt and Bared, 1998, (p. 115)
[2] K: Overdispersion value

A comparison of validation measures for the original data additional years is shown in table 14.

The Pearson product-moment correlation coefficient was higher for the original data than for the original model applied to the additional years. The MADs per year are similar. For the additional years model, the MSPE per year squared is higher than the MSE per year squared, indicating that the model is not performing as well on the additional years of data.

Table 14. Validation Statistics for Type II Total Accident Model Using Additional Years of Data

Measure	Original Data 1985-89	Additional Years 1990-98
Number of sites	327	315
Pearson product-moment correlation coefficients	0.760	0.668
MPB	-0.017	-0.392
MPB/yr	-0.003	-0.043
MAD	1.034	2.060
MAD/yr	0.207	0.229
MSE	2.364	N/A[1]
MSE/yr^2	0.095	
MSPE	N/A[1]	15.000
MSPE/yr^2		0.185

[1] N/A: not available

The model was also recalibrated with the Washington data. The parameter estimates, their standard errors, and *p*-values are provided in table 15, which reveals differences in the parameter estimates of the variables between the two States.

HI1, VCI1, and HAU were estimated with opposite signs, which might be expected on the basis of the large standard errors both in the original model and the model estimated using Washington data. Again, this would seem to indicate that variables with large standard errors in the parameter estimates should not be included in the model even if engineering common sense suggests they should. The other parameters were estimated with the same sign but with generally large differences in magnitude. The overdispersion parameter, *K*, was estimated to be over three times as large as that for the original model.

Table 15. Parameter Estimates for Type II Total Accident Model Using Washington Data

Variable	Original Estimates (s.e., *p*-value)[1]	Washington Data Estimates (s.e., *p*-value)
Constant	-10.4260 (1.3167, 0.0001)	-8.64 (2.06, <0.001)
Log of AADT1	0.6026 (0.0836, 0.0001)	0.3680 (0.2030, 0.071)
Log of AADT2	0.6091 (0.0694, 0.0001)	0.7340 (0.1080, <0.001)
HI1	0.0449 (0.0473, 0.3431)	-0.1646 (0.0766, 0.032)
VCI1	0.2885 (0.2576, 0.2628)	-0.0140 (0.2230, 0.950)
SPD1	0.0187 (0.0176, 0.2875)	0.0139 (0.0185, 0.454)
ND	0.1235 (0.0519, 0.0173)	0.0118 (0.0815, 0.884)
HAU	-0.0049 (0.0033, 0.1341)	0.0251 (0.0129, 0.051)
K[2]	0.205	0.667

[1] Vogt and Bared, 1998, (p. 115)
[2] K: Overdispersion value

A comparison of validation measures for the original data and the original model applied to the Washington data is shown in table 16. The Pearson product-moment correlation coefficient was higher for the original data as compared to the Washington data. The MAD per year is much higher for the Washington data, indicating that the model is not performing well on these data.

Table 16. Validation Statistics for Type II Total Accident Model Using Washington Data

Measure	Original Data 1985-89	Washington Data 1993-96
Number of sites	327	90
Pearson product-moment correlation coefficients	0.760	0.517
MPB	-0.017	-0.42
MPB/yr	-0.003	-0.11
MAD	1.034	3.19
MAD/yr	0.207	0.80
MSE	2.364	N/A[1]
MSE/year[2]	0.095	
MSPE	N/A[1]	20.15
MSPE/yr[2]		1.26

[1] N/A: not available

Injury Accident Model

For the injury accident model, the parameter estimates, their standard errors, and *p*-values are provided in table 17. HAU was estimated with the opposite sign to the original model and with a large standard error. The other variables were estimated with the same sign as the original model, but in some cases with large differences in magnitude. The overdispersion parameter, *K*, was estimated to be more than twice that of the original model.

Table 17. Parameter Estimates for Type II Injury Accident Model Using Additional Years of Data

Variable	Original Estimates (s.e., *p*-value)[1]	Additional Years Estimates (s.e., *p*-value)
Constant	-10.7829 (1.7656, 0.0001)	-12.19 (1.39, <0.001)
Log of AADT1	0.6339 (0.1055, 0.0001)	0.6497 (0.0948, <0.001)
Log of AADT2	0.6229 (0.0870, 0.0001)	0.6727 (0.0815, <0.001)
HI1	0.0729 (0.0635, 0.2513)	0.0935 (0.0549, 0.089)
VCI1	0.2789 (0.4623, 0.5464)	0.109 (0.240, 0.650)
SPD1	0.0112 (0.0251, 0.6567)	0.0287 (0.0204, 0.159)
HAZRAT1	-0.1225 (0.0720, 0.0889)	-0.1313 (0.0749, 0.080)
RT MAJ	0.0451 (0.1665, 0.7865)	0.014 (0.148, 0.924)
HAU	-0.0043 (0.0044, 0.3258)	0.00105 (0.00176, 0.552)
ND	0.0857 (0.0639, 0.1799)	0.0791 (0.0513, 0.123)
K[2]	0.1811	0.435

[1] Vogt and Bared, 1998, (p. 117)
[2] K: Overdispersion value

Validation measures for the additional years of data are provided in table 18. Because the original injury accident counts were not obtained these measures are not provided for the original years. The Pearson product-moment correlation coefficient was lower (0.671) than that for total accidents (0.668), and the MAD per year is about twice that for total accidents.

Table 18. Validation Statistics for Type II Injury Accident Model Using Additional Years of Data

Measure	Additional Years 1990-98
Number of sites	315
Pearson product-moment correlation coefficients	0.641
MPB	-0.152
MPB/yr	-0.170
MAD	1.230
MAD/yr	0.137
MSPE	5.130
MSPE/yr^2	0.063

The model was also recalibrated with the Washington data. The parameter estimates, their standard errors, and *p*-values are provided in table 19, which reveals differences in the parameter estimates of the variables between the two States.

HI1, RT MAJ, and HAU were estimated with opposite signs and large differences in magnitude compared to the original estimates. The other variables were estimated with the same sign but with generally large differences in magnitude. The overdispersion parameter, *K*, was estimated to be more than three times that of the original model.

Table 20 shows the validation statistics for the original injury accident model applied to the Washington data. The Pearson product-moment correlation coefficient was lower (0.482) than that for total accidents (0.517) and the MADs per year are about sixty percent of that for total accidents.

Table 19. Parameter Estimates for Type II Injury Accident Model Using Washington Data

Variable	Original Estimates (s.e., *p*-value)[1]	Washington Data Estimates (s.e., *p*-value)
Constant	-10.7829 (1.7656, 0.0001)	-11.62 (2.39, <0.001)
Log of AADT1	0.6339 (0.1055, 0.0001)	0.504 (0.223, 0.024)
Log of AADT2	0.6229 (0.0870, 0.0001)	0.845 (0.135, <0.001)
HI1	0.0729 (0.0635, 0.2513)	-0.1740 (0.0992, 0.080)
VCI1	0.2789 (0.4623, 0.5464)	0.025 (0.223, 0.911)
SPD1	0.0112 (0.0251, 0.6567)	0.0463 (0.0207, 0.025)
HAZRAT1	-0.1225 (0.0720, 0.0889)	-0.299 (0.130, 0.022)
RT MAJ	0.0451 (0.1665, 0.7865)	-0.775 (0.292, 0.008)
HAU	-0.0043 (0.0044, 0.3258)	0.0220 (0.0136, 0.105)
ND	0.0857 (0.0639, 0.1799)	0.0589 (0.0845, 0.486)
K[2]	0.181	0.556

[1] Vogt and Bared, 1998, (p. 117)
[2] K: Overdispersion value

Table 20. Validation Statistics for Type II Injury Accident Model Using Washington Data

Measure	Washington Data 1993-96
Number of sites	90
Pearson product-moment correlation coefficient	0.482
MPB	0.345
MPB/yr	0.086
MAD	2.071
MAD/yr	0.518
MSPE	8.86
$MSPE/yr^2$	0.55

2.4.3 Model III

The summary statistics shown in table 21 indicate that there are differences in the accident frequencies between the original (1993–95) and additional (1996–97) years. Note that the statistics compare 3 years of accident data in the original data to 2 years of accident data for validation using the additional years of data. For example, the means per year of TOTACC and TOTACCI for 1993–95 are 1.29 and 0.87, respectively. The means per year of TOTACC and TOTACCI for 1996–97 are 0.75 and 0.62, respectively. Note that the 1993–95 data for the original INJACC and INJACCI models could not be obtained.

Table 21. Accident Summary Statistics of Type III Sites

Dataset	Mean	Median	Std. Deviation	Minimum	Maximum
TOTACC (93-95)[1]	3.88 (1.29/year)	2	4.33	0	19
TOTACC (96-97)	1.50 (0.75/year)	1	2.42	0	12
TOTACCI (93-95)[1]	2.62 (0.87/year)	1	3.36	0	13
TOTACCI (96-97)	1.23 (0.62/year)	0	2.09	0	10
INJACC (96-97)	0.55 (0.28/year)	0	1.19	0	7
INJACCI (96-97)	0.46 (0.23/year)	0	1.02	0	7

[1] Vogt, 1999, (p. 53)

Total Accident Model (TOTACC)

The models were recalibrated with the additional years of accident data. The parameter estimates, their standard errors, and *p*-values are provided in table 22. All of the variables were estimated with the same sign as in the original model, but the constant term and AADT2 were estimated with larger differences in magnitude than the other parameters. MEDWDTH1 and DRWY1 became insignificant for the recalibration with the additional years of data, and the overdispersion parameter, *K*, was almost twice as large as for the original model (for a discussion of K, see section 2.3).

Table 23 shows a comparison of GOF measures between the original main models in the Vogt report (1999) applied to the original 1993–95 data and to the 1996–97 data. The Pearson product-moment correlation coefficient was higher for the original years of data than for the additional years of data. The MAD per year was similar, but the MPB per year was larger for the model for the additional years of data. The MSPE per year squared for the additional years was higher than the MSE per year squared for the original years, but the difference was not great.

Table 22. Parameter Estimates for TOTACC Type III Model Using Additional Years of Data

Variable	Original Estimates (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-12.2196 (2.3575, 0.0001)	-14.4477 (3.3378, 0.00001)
Log of AADT1	1.1479 (0.2527, 0.0001)	1.1597 (0.3677, 0.0016)
Log of AADT2	0.2624 (0.0866, 0.0024)	0.5214 (0.1286, 0.00001)
MEDWIDTH1	-0.0546 (0.0249, 0.0285)	-0.0515 (0.0440, 0.2414)
DRWY1	0.0391 (0.0239, 0.1023)	0.0127 (0.0439, 0.7719)
K[2]	0.3893	0.6356

[1] Vogt, 1999, (p. 111)
[2] K: Overdispersion value

Table 23. Validation Statistics for TOTACC Type III Model Using Additional Years of Data

Measure	Original Data (1993-95)	Additional Years (1996-98)
Number of sites	84	84
Pearson product-moment correlation coefficients	0.66	0.54
MPB	-0.01	1.07
MPB/yr	0.0	0.53
MAD	2.26	1.75
MAD/yr	0.75	0.88
MSE	11.01	N/A[1]
MSE/yr[2]	1.22	
MSPE	N/A[1]	5.57
MSPE/yr[2]		1.39

[1] N/A: not available

Intersection Related Total Accident Model (TOTACCI)

The parameter estimates, their standard errors, and *p*-values are given in table 24. All of the variables were re-estimated with the same direction of effect as the original model, but the constant term and AADT2 were estimated with larger differences in magnitude. MEDWDTH1 and DRWY1 became statistically insignificant for the additional years data, and the overdispersion parameter was slightly higher than that for the original model.

Table 24. Parameter Estimates for TOTACCI Type III Model Using Additional Years of Data

Variable	Original Estimates (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-15.4661 (3.4685, 0.0001)	-16.7738 (3.8495, 0.00001)
Log of AADT1	1.4331 (0.3608, 0.0001)	1.3497 (0.4098, 0.0010)
Log of AADT2	0.2686 (0.0988, 0.0065)	0.5439 (0.1434, 0.0001)
MEDWIDTH1	-0.0612 (0.0360, 0.0888)	-0.0308 (0.0465, 0.5074)
DRWY1	0.0560 (0.0289, 0.0525)	0.0358 (0.0486, 0.4608)
K[2]	0.5118	0.7220

[1] Vogt, 1999, p112

[2] K: Overdispersion value

Table 25 shows a comparison of GOF measures between the original main model in the Vogt report applied the original data and to the 1996–97 data.(2)

The Pearson product-moment correlation coefficient for the additional years of data was lower than that for the original years. The MAD per year was similar, but the MPB per year was slightly larger for the additional years of data. The MSPE per year squared for the additional years was higher than the MSE per year squared.

Table 25. Validation Statistics for TOTACCI Type III Model Using Additional Years of Data

Measure	Original Data 1993-95	Additional Years 1996-97
Number of sites	84	84
Pearson product-moment correlation coefficients	0.67	0.52
MPB	-0.005	0.52
MPB/yr	-0.002	0.26
MAD	1.76	1.29
MAD/yr	0.59	0.65
MSE	6.50	N/A[1]
MSE/yr^2	0.24	
MSPE	N/A[1]	3.54
MSPE/yr^2		0.89

[1] N/A: not available

Injury Accident Model (INJACC)

There were two variants of the original model for injury accidents. These were validated separately. The original injury accident counts were not obtained. Thus, a comparison of prediction performance measures for the original data and additional years could not be accomplished.

Variant 1

For the recalibration for the additional years of data, the parameter estimates, their standard errors, and *p*-values are given in table 26. All of the variables were estimated with the same sign as the original model, but that the constant term and AADT2 were estimated with larger differences in magnitude than the other parameters. HAU became insignificant for the additional years of data, and the overdispersion parameter was about half of that for the original model.

Table 26. Parameter Estimates for INJACC Type III Model Using Additional Years of Data: Variant 1

Variable	Original Estimates (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-12.3246 (2.8076, 0.0001)	-15.7264 (4.3853, 0.0006)
Log of AADT1	1.1436 (0.2763, 0.0001)	1.2659 (0.4347, 0.0036)
Log of AADT2	0.1357 (0.1029, 0.1872)	0.3883 (0.1574, 0.0136)
HAU	0.0230 (0.0131, 0.0790)	0.0140 (0.0165, 0.3969)
K[2]	0.3787	0.1740

[1] Vogt, 1999, (p. 113)
[2] K: Overdispersion value

Table 27 shows the GOF measures for the original injury accident model (Variant 1) in the Vogt report applied to the additional years of data.(2) The Pearson product-moment correlation coefficient (0.37) was lower than that (0.54) for TOTACC. However, the MPB, MAD, and MSPE per year squared were smaller than those for TOTACC.

Variant 2

The parameter estimates, their standard errors, and *p*-values are given in table 28, which reveals that the variables AADT1, AADT2, HAU, and ABSGRD1 were estimated with the same sign as for the original model, but DRWY1 was estimated with an opposite sign, although its estimate was statistically insignificant. HAU and ABSGRD1 were also statistically insignificant for the additional years. AADT2 was estimated with a higher magnitude and level significance than it was for the original model. The overdispersion parameter was much higher than that for the original model.

Table 27. Validation Statistics for INJACC Type III Model Using Additional Years of Data: Variant 1

Measure	Additional Years 1996-97
Number of sites	84
Pearson product-moment correlation coefficients	0.37
MPB	-0.15
MPB/yr	-0.07
MAD	1.20
MAD/yr	0.60
MSPE	3.76
MSPE/yr^2	0.94

Table 28. Parameter Estimates for INJACC Type III Model Using Additional Years of Data: Variant 2

Variable	Original Estimates (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-11.0061 (2.6937, 0.0001)	-14.3764 (4.5820, 0.0028)
Log of AADT1	0.9526 (0.2843, 0.0008)	1.0147 (0.5101, 0.0467)
Log of AADT2	0.1499 (0.0916, 0.1018)	0.5327 (0.2667, 0.0458)
HAU	0.0289 (0.0105, 0.0061)	0.0202 (0.0155, 0.1936)
DRWY1	0.0481 (0.0262, 0.0664)	-0.0493 (0.0853, 0.5633)
ABSGRD1	0.1838 (0.1130, 0.1038)	0.2565 (0.1987, 0.1967)
K[2]	0.2588	0.9259

[1] Vogt, 1999, (p. 113)
[2] K: Overdispersion value

Table 29 shows the GOF measures for the original injury accident model (Variant 2) in the Vogt report applied to the additional years of data.(2)

The Pearson product-moment correlation coefficient (0.38) was lower than that (0.54) for TOTACC. However, the MPB, MAD, and MSPE per year squared were smaller than those for TOTACC.

Table 29. Validation Statistics for INJACC Type III Model Using Additional Years of Data: Variant 2

Measure	Original 1993-95 Model
Years used for validation	1996 to 1997
Number of sites	84
Pearson product-moment correlation coefficients	0.38
MPB	-0.16
MPB/yr	-0.08
MAD	1.17
MAD/yr	0.58
MSPE	3.73
MSPE/yr^2	0.93

2.4.4 Model IV

The summary statistics shown in table 30 reveal that the accident frequencies were lower during the additional years. Mean, median, and maximum of the accident frequencies were almost half of those for the 1993–1995 period. Recall that the original 1993–95 INJACC and INJACCI data were not obtained.

Table 30. Accident Summary Statistics of Type IV Sites

Dataset	Mean	Median	Std. Deviation	Minimum	Maximum
TOTACC (93-95)[1]	5.53 (1.84/year)	3.5	6.52	0	38
TOTACC (96-97)	2.67 (1.34/year)	1	3.60	0	16
TOTACCI (93-95)[1]	4.13 (1.38/year)	2	5.37	0	27
TOTACCI (96-97)	2.33 (1.17/year)	1	3.21	0	13
INJACC (96-97)	1.43 (0.72/year)	1	1.96	0	9
INJACCI (96-97)	1.26 (0.63/year)	1	1.80	0	8

[1] Vogt, 1999, (p. 57)

Total Accident Model (TOTACC)

The parameter estimates, their standard errors, and *p*-values are shown in table 31, which reveals that the constant term and all of the variables were estimated with the original sign, but some parameters had somewhat large differences in the magnitude compared to the original parameter. The overdispersion parameters were similar.

Table 31. Parameter Estimates for TOTACC Type IV Model Using Additional Years of Data

Variable	Original Estimates (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-9.4631 (2.5991, 0.0003)	-9.6398 (3.0909, 0.0038)
Log of AADT1	0.8503 (0.2779, 0.0022)	0.7258 (0.3342, 0.0299)
Log of AADT2	0.3294 (0.1255, 0.0087)	0.4968 (0.1691, 0.0033)
PKLEFT1	0.1100 (0.0412, 0.0076)	0.1056 (0.0432, 0.0145)
LTLN1S	-0.4841 (0.2311, 0.0362)	-0.5603 (0.2803, 0.0456)
K[2]	0.4578	0.4312

[1] Vogt, 1999, (p. 116)
[2] K: Overdispersion value

Table 32 shows a comparison of the GOF measures for the original main model in the Vogt report and this model applied to the additional years of data.(2) The Pearson product-moment correlation coefficients of the original and additional years of data are similar (0.56 versus 0.58). The MPB per year was slightly larger for the model based on additional years, while the MAD per year was similar. The MSPE per year squared was lower than the MSE per year squared, indicating that the model is performing fairly well on the additional years of data.

Table 32. Validation Statistics for TOTACC Type IV Model Using Additional Years of Data

Measure	Original Data 1993-95	Additional Years 1996-97
Number of sites	72	72
Pearson product-moment correlation coefficients	0.56	0.58
MPB	-0.07	-1.06
MPB/yr	-0.02	-0.53
MAD	3.38	2.22
MAD/yr	1.13	1.11
MSE	30.62	N/A[1]
MSE/yr[2]	3.40	
MSPE	N/A[1]	9.56
MSPE/yr[2]		2.39

[1] N/A: not available

Intersection Related Total Accident Model (TOTACCI)

The parameter estimates, their standard errors, and *p*-values are shown in table 33, which reveals that the parameters were estimated with the same sign as the original model, but that there were some differences in magnitude. In particular, the effect of the log of AADT2 on accident frequency was almost twice as large as for the original model. The overdispersion parameter was slightly lower than that for the original model.

Table 33. Parameter Estimates for TOTACCI Type IV Model Using Additional Years of Data

Variable	Original Estimate (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-11.1096 (3.3345, 0.0008)	-11.8796 (3.6865, 0.0024)
Log of AADT1	0.9299 (0.3433, 0.0067)	0.7982 (0.3764, 0.0339)
Log of AADT2	0.3536 (0.1163, 0.0024)	0.6624 (0.1673, 0.0001)
PKLEFT1	0.1491 (0.0586, 0.0110)	0.1100 (0.0563, 0.0509)
K[2]	0.7096	0.6262

[1] Vogt, 1999, (p. 117)
[2] K: Overdispersion value

Table 34 shows a comparison of GOF measures between the original main model in the Vogt report and for this model applied to the 1996–97 data.(2) The Pearson product-moment correlation coefficient for the additional years of data was estimated as slightly higher than the original years. The MAD per year was similar, but the MPB per year was somewhat larger for the additional years of data. The MSPE per year squared was again lower than the MSE per year squared of the original model, indicating a good fit to the additional years of data.

Table 34. Validation Statistics for TOTACCI Type IV Model Using Additional Years of Data

Measure	Original Data 1993-95	Additional Years 1996-97
Number of sites	72	72
Pearson product-moment correlation coefficients	0.47	0.53
MPB	-0.17	-0.53
MPB/yr	-0.06	-0.27
MAD	3.00	2.11
MAD/yr	1.00	1.05
MSE	24.92	N/A[1]
MSE/yr^2	2.77	
MSPE	N/A[1]	8.29
MSPE/yr^2		2.07

[1] N/A: not available

Injury Accident Model (INJACC)

Because the original injury accident counts were not obtained, a comparison of prediction performance measures for the original data and additional years could not be accomplished.

The parameter estimates, their standard errors, and *p*-values are given in table 35, which reveals that all of the variables were estimated with the same sign as the original model, but that the constant term and AADT1 were estimated with somewhat larger differences in magnitude than the other parameters. The overdispersion parameter was slightly lower than that for the original model.

Table 35. Parameter Estimates for INJACC Type IV Model Using Additional Years of Data

Variable	Original Estimate (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-12.5296 (2.9908, 0.0001)	-8.1672 (3.4344, 0.0295)
Log of AADT1	0.9505 (0.3284, 0.0038)	0.3825 (0.3630, 0.2920)
Log of AADT2	0.3237 (0.1645, 0.0491)	0.4074 (0.1793, 0.0231)
PKLEFT1	0.0994 (0.0433, 0.0216)	0.1050 (0.0557, 0.0594)
SPD2	0.0339 (0.0179, 0.0577)	0.0402 (0.0220, 0.0676)
K[2]	0.4308	0.3720

[1] Vogt, 1999, (p. 118)
[2] K: Overdispersion value

Table 36 shows the GOF measures for the original injury accident model (Variant 1) in the Vogt report applied to the additional years data.(2) The Pearson product-moment correlation coefficient (0.48) was lower than that (0.58) for the TOTACC model. However, the MPB, MAD, and MSPE per year squared were smaller than those for TOTACC.

Intersection Related Injury Accident Model (INJACCI)

Since the original injury accident counts were not obtained, a comparison of prediction performance measures for the original data and additional years could not be accomplished.

The parameter estimates, their standard errors, and *p*-values are given in table 37, which reveals that the constant term and all of the variables were estimated with the same direction of effect as that in the original model. However, the constant term and AADT1 were estimated with somewhat larger differences in magnitude than the other parameters. The overdispersion parameter for the additional years was approximately half that of the original years.

Table 36. Validation Statistics for INJACC Type IV Model Using Additional Years of Data

Measure	Additional Years 1996-97
Number of sites	84
Pearson product-moment correlation coefficients	0.48
MPB	-0.33
MPB/yr	-0.16
MAD	1.32
MAD/yr	0.66
MSPE	3.13
MSPE/yr^2	0.78

Table 37. Parameter Estimates for INJACCI Type IV Model Using Additional Years of Data

Variable	Original Estimate (s.e., *p*-value)[1]	Additional Years Estimate (s.e., *p*-value)
Constant	-13.5576 (3.9998, 0.0008)	-9.4112 (3.6620, 0.0173)
Log of AADT1	0.9918 (0.4268, 0.0201)	0.4707 (0.3896, 0.2270)
Log of AADT2	0.3310 (0.1894, 0.0805)	0.4536 (0.1868, 0.0152)
PKLEFT1	0.1228 (0.0614, 0.0457)	0.1077 (0.0613, 0.0791)
SPD2	0.0429 (0.0240, 0.0740)	0.0399 (0.0229, 0.0815)
K[2]	0.7178	0.3873

[1] Vogt, 1999, p118
[2] K: Overdispersion value

Table 38 shows the GOF measures for the original intersection related injury accident model (Variant 1) in the Vogt report applied to the additional years data.[(2)] The Pearson product-moment correlation coefficient was the same as that for the TOTACCI model. However, the MPB, MAD, and MSPE per year squared were smaller than those for the TOTACCI model.

Table 38. Validation Statistics for INJACCI Type IV Model Using Additional Years of Data

Measure	Additional Years 1996-97
Number of sites	84
Pearson product-moment correlation coefficients	0.53
MPB	-0.03
MPB/yr	-0.014
MAD	1.25
MAD/yr	0.62
MSPE	2.80
MSPE/yr^2	0.70

2.4.5 Model V

The summary statistics shown in table 39 indicate that fewer accidents per year occurred during the additional years (1996–97) than during the original years (1993–95). Again, note that the original years INJACC and INJACCI data were not obtained.

Table 39. Accident Summary Statistics of Type V Sites

Dataset	Mean	Median	Std. Deviation	Minimum	Maximum
TOTACC (93-95)[1]	20.76 (6.92/year)	21	11.66	2	48
TOTACC (96-97)	8.65 (4.33/year)	7	6.58	0	27
TOTACCI (93-95)[1]	16.12 (5.37/year)	17	1.27	1	37
TOTACCI (96-97)	7.86 (3.93/year)	6	0.82	0	23
INJACC (96-97)	3.16 (1.58/year)	2	2.87	0	10
INJACCI (96-97)	2.80 (1.40/year)	2	2.58	0	9

[1] Vogt, 1999, (p. 61)

Total Accident Models (TOTACC)

The original report contained a main model and a variant, both of which were validated.

<u>Main Model</u>

The parameter estimates, their standard errors, and *p*-values are given in table 40, which reveals varying degrees of differences in magnitude and significance for the parameters for additional years data compared to those of the original model. VEICOM was estimated with an opposite sign to that of the original model, but was not statistically significant in the recalibration. The constant term and PKLEFT2 also became insignificant for the additional years of data. The overdispersion parameter was almost twice as large as for the original model.

Table 40. Parameter Estimates for TOTACC Type V Model Using Additional Years of Data: Main Model

Variable	Original Estimate (s.e., *p*-value)[1]	Recalibrated Estimate (s.e., *p*-value)
Constant	-6.9536 (2.7911, 0.0132)	-7.7450 (4.7450, 0.1152)
Log of AADT1	0.6199 (0.2504, 0.0133)	0.7625 (0.4489, 0.0894)
Log of AADT2	0.3948 (0.1737, 0.0133)	0.3221 (0.1857, 0.0830)
PROT_LT	-0.6754 (0.1824, 0.0002)	-0.8238 (0.2688, 0.0022)
PKLEFT2	-0.0142 (0.0047, 0.0023)	-0.0115 (0.0098, 0.2392)
VEICOM	0.1299 (0.045, 0.0039)	-0.0625 (0.0688, 0.3635)
PKTRUCK	0.0315 (0.0143, 0.0275)	0.0262 (0.0154, 0.0874)
K[2]	0.1161	0.2651

[1] Vogt, 1999, (p. 122)
[2] K: Overdispersion value

Table 41 shows a comparison of GOF measures between the original main models in the Vogt report applied to the original data and the 1996–97 data.(2)

The Pearson product-moment correlation coefficient for the additional years of data was significantly lower than the original years. The MPB and MAD per year were larger for the additional years of data. The MSPE per year squared for the additional years of accident data was much higher than the MSE per year squared.

Table 41. Validation Statistics for TOTACC Type V Model Using Additional Years of Data: Main Model

Measure	Original Data 1993-95	Additional Years 1996-97
Number of sites	49	49
Pearson product-moment correlation coefficients	0.73	0.40
MPB	-0.40	-5.45
MPB/yr	-0.13	-2.73
MAD	6.53	6.83
MAD/yr	2.18	3.42
MSE	77.04	N/A[1]
MSE/yr[2]	8.56	
MSPE	N/A[1]	84.75
MSPE/yr[2]		21.19

[1] N/A: not available

Variant 1

The parameter estimates, their standard errors, and *p*-values are given in table 42. The constant term, PKLEFT2, VEICOM, PKTRUCK became insignificant for the additional years of data. VEICOM was estimated with an opposite sign to that for the original model, but it was not statistically significant in the recalibration. The overdispersion parameter was almost twice as large as for the original model.

Table 42. Parameter Estimates for TOTACC Type V Model Using Additional Years of Data: Variant 1

Variable	Original Estimate (s.e., *p*-value)[1]	Recalibrated Estimate (s.e., *p*-value)
Constant	-6.1236 (2.5973, 0.0184)	-6.0566 (3.3474, 0.1091)
Log of AADT1*AADT2	0.4643 (0.1483, 0.0017)	0.4546 (0.1940, 0.0191)
PROT_LT	-0.6110 (0.1507, 0.0001)	-0.7273 (0.2546, 0.0043)
PKLEFT2	-0.0134 (0.0048, 0.0052)	-0.0100 (0.0102, 0.3249)
VEICOM	0.1243 (0.0507, 0.0142)	-0.0692 (0.0681, 0.3093)
PKTRUCK	0.0300 (0.0141, 0.0331)	0.0236 (0.0153, 0.1245)
K[2]	0.1186	0.2801

[1] Vogt, 1999, (p. 122)
[2] K: Overdispersion value

Table 43 shows the GOF measures for the original accident model (Variant 1) in the Vogt report and the model applied to the additional years of data.[(2)] The Pearson product-moment correlation coefficient for the additional years of data was significantly lower than for the original years. The MPB and MAD per year were larger for the additional years of data. The MSPE per year squared was also higher than the MSE per year squared.

Table 43. Validation Statistics for TOTACC Type V Model Using Additional Years of Data: Variant 1

Measure	Original Data 1993-95	Additional Years 1996-97
Number of sites	49	49
Pearson product-moment correlation coefficients	0.73	0.39
MPB	-0.37	-5.43
MPB/yr	-0.12	-2.72
MAD	6.48	6.84
MAD/yr	2.16	3.42
MSE	73.31	N/A[1]
MSE/yr^2	8.15	
MSPE	N/A[1]	83.70
$MSPE/yr^2$		20.93

[1] N/A: not available

Intersection Related Total Accident Model (TOTACCI)

The main model and one variant were validated. Since the base model in the accident prediction algorithm is identical to Variant 3 of the Vogt model for TOTACCI, the Variant 3 model was also validated.

Main Model

The parameter estimates, their standard errors, and *p*-values are given in table 44, which again reveals differences in magnitude and significance in the parameter estimates. The constant term, PKLEFT2, and VEICOM became insignificant for the additional years of data, while VEICOM was estimated with an opposite sign to that of the original model, but was not statistically significant in the recalibration. The overdispersion parameter was almost twice as large as for the original model.

Table 45 shows a comparison of GOF measures between the original main model in the Vogt report for the original data and the original model applied to the 1996–97 data.[(2)]

The Pearson product-moment correlation coefficient for the additional years of data was significantly lower than for the original years. The MPB and MAD per year were larger for the additional years of data. The MSPE per year squared with the additional years of accident data was also higher than the MSE per year squared.

Table 44. Parameter Estimates for TOTACCI Type V Model Using Additional Years of Data: Main Model

Variable	Original Estimate (s.e., *p*-value)[1]	Recalibrated Estimate (s.e., *p*-value)
Constant	-6.0841 (3.3865, 0.0724)	-7.3834 (4.2640, 0.1166)
Log of AADT1	0.5951 (0.2847, 0.0366)	0.7249 (0.4332, 0.0943)
Log of AADT2	0.2935 (0.1972, 0.1366)	0.3110 (0.1893, 0.1004)
PROT_LT	-0.4708 (0.2000, 0.0186)	-0.7381 (0.2702, 0.0063)
PKLEFT2	-0.0165 (0.0057, 0.0036)	-0.0116 (0.0095, 0.2254)
VEICOM	0.1126 (0.0365, 0.0020)	-0.0740 (0.0685, 0.2799)
PKTRUCK	0.0289 (0.0131, 0.0276)	0.0233 (0.0139, 0.0937)
K[2]	0.1313	0.2433

[1] Vogt, 1999, p123
[2] K: Overdispersion value

Table 45. Validation Statistics for TOTACCI Type V Model Using Additional Years of Data: Main Model

Measure	Original Data 1993-95	Additional Years 1996-97
Number of sites	49	49
Pearson product-moment correlation coefficients	0.62	0.37
MPB	-0.28	-3.08
MPB/yr	-0.09	-1.54
MAD	5.63	4.95
MAD/yr	1.88	2.47
MSE	58.24	N/A[1]
MSE/yr[2]	6.47	
MSPE	N/A[1]	44.17
MSPE/yr[2]		11.04

[1] N/A: not available

Variant 3

The parameter estimates, their standard errors, and *p*-values are given in table 46, which reveals that most of the variables showed some differences in magnitude and significance for the additional years. VEICOM and DRWY1 were estimated with an opposite sign to those for the original model, but they were not statistically significant for the recalibrated model. AADT2 and PKLEFT2 also became insignificant for the additional years. The overdispersion parameter was almost twice as large as for the original model.

Table 46. Parameter Estimates for TOTACCI Type V Model Using Additional Years of Data: Variant 3

Variable	Original Estimate (s.e., *p*-value)[1]	Recalibrated Estimate (s.e., *p*-value)
Constant	-5.4581 (3.1937, 0.0874)	-7.8110 (4.3760, 0.1038)
Log of AADT1	0.5995 (0.2795, 0.0319)	0.7354 (0.4443, 0.0909)
Log of AADT2	0.2015 (0.1917, 0.2932)	0.3553 (0.2235, 0.1118)
PROT_LT	-0.4041 (0.1883, 0.0319)	-0.7622 (0.2802, 0.0065)
PKLEFT2	-0.0177 (0.0050, 0.0005)	-0.0112 (0.0098, 0.2527)
VEICOM	0.1114 (0.0326, 0.0006)	-0.0705 (0.0685, 0.3031)
PKTRUCK	0.0256 (0.0117, 0.0287)	0.0247 (0.0144, 0.0873)
DRWY1	0.0407 (0.0246, 0.0983)	-0.0178 (0.0463, 0.7009)
K[2]	0.1145	0.2412

[1] Vogt, 1999, p123
[2] K: Overdispersion value

A comparison of GOF measures is given in table 47, which reveals that the Pearson product-moment correlation coefficient for the additional years of data, is significantly lower than that for the original years. The MPB and MAD per year were larger for the models based on additional years of data. The MSPE per year squared with the additional years data was almost twice as high as the MSE per year squared, suggesting a general lack-of-fit to the additional years of data.

Injury Accident Model (INJACC)

The parameter estimates, their standard errors, and *p*-values are given in table 48, which reveals that the variables AADT1*AADT2 and PKLEFT2 were estimated with a similar degree of magnitude and significance as the original model, but that the other variables showed larger differences in magnitude or significance. VEICOM was estimated with an opposite sign to that for the original years, and PKTRUCK became statistically insignificant, while PRO_LT turned out to be significant in the recalibration. The overdispersion parameter for the additional years was higher than that for the original years.

Table 47. Validation Statistics for TOTACCI Type V Model Using Additional Years of Data: Variant 3

Measure	Original Data 1993-95	Additional Years 1996-97
Number of sites	49	49
Pearson product-moment correlation coefficients	0.67	0.36
MPB	-0.31	-3.10
MPB/yr	-0.10	-1.55
MAD	5.34	5.23
MAD/yr	1.78	2.62
MSE	51.57	N/A[1]
MSE/yr[2]	5.73	
MSPE	N/A[1]	45.75
MSPE/yr[2]		11.44

[1] N/A: not available

Table 48. Parameter Estimates for INJACC Type V Model Using Additional Years of Data

Variable	Original Estimate (s.e., *p*-value)[1]	Recalibrated Estimate (s.e., *p*-value)
Constant	-3.2562 (2.9932, 0.2767)	-4.4380 (3.1219, 0.2303)
Log of AADT1*AADT2	0.2358 (0.1722, 0.1707)	0.3093 (0.1760, 0.0789)
PROT_LT	-0.2943 (0.1864, 0.1144)	-0.4734 (0.2419, 0.0504)
PKLEFT2	-0.0113 (0.0062, 0.0678)	-0.0203 (0.0101, 0.0443)
VEICOM	0.0822 (0.0551, 0.1358)	-0.0642 (0.0748, 0.3907)
PKTRUCK	0.0323 (0.0146, 0.0267)	0.0319 (0.0217, 0.1408)
K^2	0.1630	0.2124

[1] Vogt, 1999, p124
[2] K: Overdispersion value

Table 49 shows the GOF measures for the original injury accident model (Variant 1) in the Vogt report applied to the additional years of data.(2)

The Pearson product-moment correlation coefficient was similar to that for the TOTACC model. However, the MPB, MAD, and MSPE per year squared were significantly smaller than those for the TOTACC model.

Table 49. Validation Statistics for INJACC Type V Model Using Additional Years of Data

Measure	Additional Years 1996-97
Number of sites	49
Pearson product-moment correlation coefficients	0.41
MPB	-1.84
MPB/yr	-0.92
MAD	2.79
MAD/yr	1.39
MSPE	10.66
MSPE/yr^2	2.67

Intersection Related Total Injury Accident Model (INJACCI)

The parameter estimates, their standard errors, and *p*-values are given in table 50, which reveals that all of the variables were insignificant for the additional years. VEICOM was estimated with an opposite sign for the recalibration. The overdispersion parameter for the additional years of data was over twice as large as for the original years.

Table 50. Parameter Estimates for INJACCI Type V Model Using Additional Years of Data

Variable	Original Estimate (s.e., *p*-value)[1]	Recalibrated Estimate (s.e., *p*-value)
Constant	-1.5475 (3.0298, 0.6095)	-2.5686 (3.5706, 0.5994)
Log of AADT1*AADT2	0.1290 (0.1757, 0.4627)	0.1849 (0.2000, 0.3554)
PKLEFT2	-0.0149 (0.0066, 0.0250)	-0.0183 (0.0116, 0.1164)
VEICOM	0.0686 (0.0692, 0.1858)	-0.0548 (0.0827, 0.5075)
PKTRUCK	0.0282 (0.0152, 0.0628)	0.0255 (0.0261, 0.3280)
K[2]	0.1433	0.3496

[1] Vogt, 1999, (p. 124)
[2] K: Overdispersion value

Table 51 shows the GOF measures for the original intersection related injury accident model (Variant 1) in the Vogt report applied to the additional years of data.(2) The Pearson product-moment correlation coefficient was similar to that for the TOTACCI model. However, the MPB, MAD, and MSPE per year squared were smaller than those for the TOTACCI model.

Table 51. Validation Statistics for INJACCI Type V Model Using Additional Years of Data

Measure	Additional Years 1996-97
Number of sites	49
Pearson product-moment correlation coefficients	0.39
MPB	-0.95
MPB/yr	-0.47
MAD	2.45
MAD/yr	1.23
MSPE	7.96
MSPE/yr^2	1.99

2.5 VALIDATION ACTIVITY 2: VALIDATION WITH GEORGIA DATA

For this validation activity, the models were used to predict accidents for the Georgia data that also were used to re-estimate the models. Data from 1996 and 1997 in Georgia were used for accident related variables; Other variables used, such as roadway geometrics and traffic volumes, were based on the 1997 road characteristic files maintained by the Georgia Department of Transportation and on data collected in the field during the summer of 2001. Recall that for Georgia data, two sets of accidents were extracted—those within 0.08 km (0.05 miles) of the intersection and those within 0.06 km (0.04 miles).

2.5.1 Model I

The summary statistics in the original report and for the Georgia data are given in table 52. The summary statistics reveal that Georgia sample had more accidents per year than the original Minnesota data. This difference in underlying safety may be explained by the fact that Georgia sites, for example, had, on average, higher values for the variables related to horizontal curvature, vertical curvature and roadside hazard rating, all of which increase accident risk according to indications from the original model.

Total Accident Model

The model was recalibrated with both sets of the Georgia accident data. The parameter estimates, their standard errors, and *p*-values are provided in table 53, which reveals differences in the parameter estimates between the two States.

HAZRAT1 was estimated with a similar degree of magnitude and significance as the original model. The constant term, AADT1, AADT2, VCI1, and SPD1 were estimated with the same sign but a larger difference in magnitude. HI1, HAU, and RT (for the 0.04 mile limit) were estimated with opposite signs and large differences in magnitude. The overdispersion parameter, *K*, was much smaller for the Georgia data.

Table 54 shows a comparison of validation measures between the original data and the Georgia data. The Pearson product-moment correlation coefficient was much higher for the original data as compared to Georgia. The MPB and mean absolute deviations are also higher than for the original Minnesota data. On a per year squared basis the mean squared prediction errors are much higher than the MSE indicating that the model is not performing well on the Georgia data.

Table 52. Summary of Georgia versus Minnesota Data for Type I Sites

Variable and Abbreviation		N	Mean	Median	Minimum	Maximum	Freq.	% Zero
No. of Crashes	Original Data Total	389	1.35 (0.27/year)	0.00	0	39	524	51.9
	Original Data Injury	389	0.59 (0.12/year)	0.00	0	17	229	69.9
	Georgia Total (0.04 MI)	121	1.45 (0.73/year)	1.00	0	7	176	33.1
	Georgia Total (0.05 MI)	121	1.55 (0.78/year)	1.00	0	7	187	30.6
	Georgia Injury (0.04 MI)	121	0.595 (0.30/year)	0.00	0	4	72	61.2
	Georgia Injury (0.05 MI)	121	0.644 (0.32/year)	0.00	0	4	78	60.3
HI1	Original Data	389	1.21	0.00	0	29	N/A[1]	54.0
	Georgia	121	2.53	0.64	0.00	23.00	N/A[1]	N/A[1]
VCI1	Original Data	389	0.12	0.00	0	4	N/A[1]	53.2
	Georgia	121	1.31	0.88	0.00	14.00	N/A[1]	N/A[1]
SPD1	Original Data	389	52.75	55	23	55	N/A[1]	N/A[1]
	Georgia	121	47.11	45	25	55	N/A[1]	N/A[1]
HAZRAT1	Original Data	389	2.11	2.00	1.0	5.0	N/A[1]	N/A[1]
	Georgia	121	3.57	3.50	1.5	7.0	N/A[1]	N/A[1]
DRWY1	Original Data	389	1.26	1.00	0	9	N/A[1]	37.5
	Georgia	121	2.13	2.00	0	8	N/A[1]	27.3
RT MAJ	Original Data	389	224 (57.6%) without RT MAJ, 165 (42.4%) with RT MAJ					
	Georgia	121	117 (96.7%) without RT MAJ, 4 (3.3%) with RT MAJ					
HAU	Original Data	389	-0.515	0	-90	85	N/A[1]	50.6
	Georgia	121	-3.09	0	-65	60	N/A[1]	N/A[1]
AADT1 on Major Road	Original Data	389	3687	2313	201	19413	N/A[1]	N/A[1]
	Georgia	121	3565	3000	420	16900	N/A[1]	N/A[1]
AADT2 on Minor Road	Original Data	389	413	240	4.53	4206	N/A[1]	N/A[1]
	Georgia	121	616	430	70	6480	N/A[1]	N/A[1]

[1] N/A: not available

Table 53. Parameter Estimates for Type I Total Accident Model Using Georgia Data

Variable	Original Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile (s.e., *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-12.9922 (1.1511, 0.0001)	-6.99 (1.17, <0.001)	-6.84 (1.14, <0.001)
Log of AADT1	0.8052 (0.0639, 0.0001)	0.484 (0.111, <0.001)	0.497 (0.108, <0.001)
Log of AADT2	0.5037 (0.0708, 0.0001)	0.272 (0.130, 0.036)	0.239 (0.127, 0.060)
HI1	0.0339 (0.0327, 0.3004)	-0.0223 (0.0281, 0.427)	-0.0209 (0.0273, 0.443)
VCI1	0.2901 (0.2935, 0.3229)	0.0413 (0.0480, 0.389)	0.0294 (0.0477, 0.537)
SPD1	0.0285 (0.0177, 0.1072)	0.00995 (0.00947, 0.293)	0.00686 (0.00894, 0.443)
HAZRAT1	0.1726 (0.0677, 0.0108)	0.1642 (0.0914, 0.072)	0.2048 (0.0890, 0.021)
RT MAJ	0.2671 (0.1398, 0.0561)	-0.283 (0.580, 0.625)	0.158 (0.490, 0.748)
HAU	0.0045 (0.0032, 0.1578)	-0.00455 (0.00326, 0.163)	-0.00546 (0.00320, 0.088)
K[2]	0.481	0.192	0.185

[1] Vogt and Bared, 1998, (p. 115)
[2] K: Overdispersion value

Table 54. Validation Statistics for Type I Total Accident Model Using Georgia Data

Measure	Original Data	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for the validation	1985 to 1989	1996 to 1997	1996 to 1997
Number of sites	389	121	121
Pearson product-moment correlation coefficients	0.66	0.32	0.31
MPB	-0.01	0.47	0.56
MPB/yr	0.00	0.23	0.28
MAD	1.03	1.21	1.28
MAD/yr	0.21	0.60	0.64
MSE	4.64	N/A[1]	N/A[1]
MSE/yr[2]	0.19		
MSPE	N/A[1]	3.15	3.55
MSPE/yr[2]		0.79	0.89

[1] N/A: not available

Figure 1 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model failed to account for higher accident frequencies in most sites in the Georgia data.

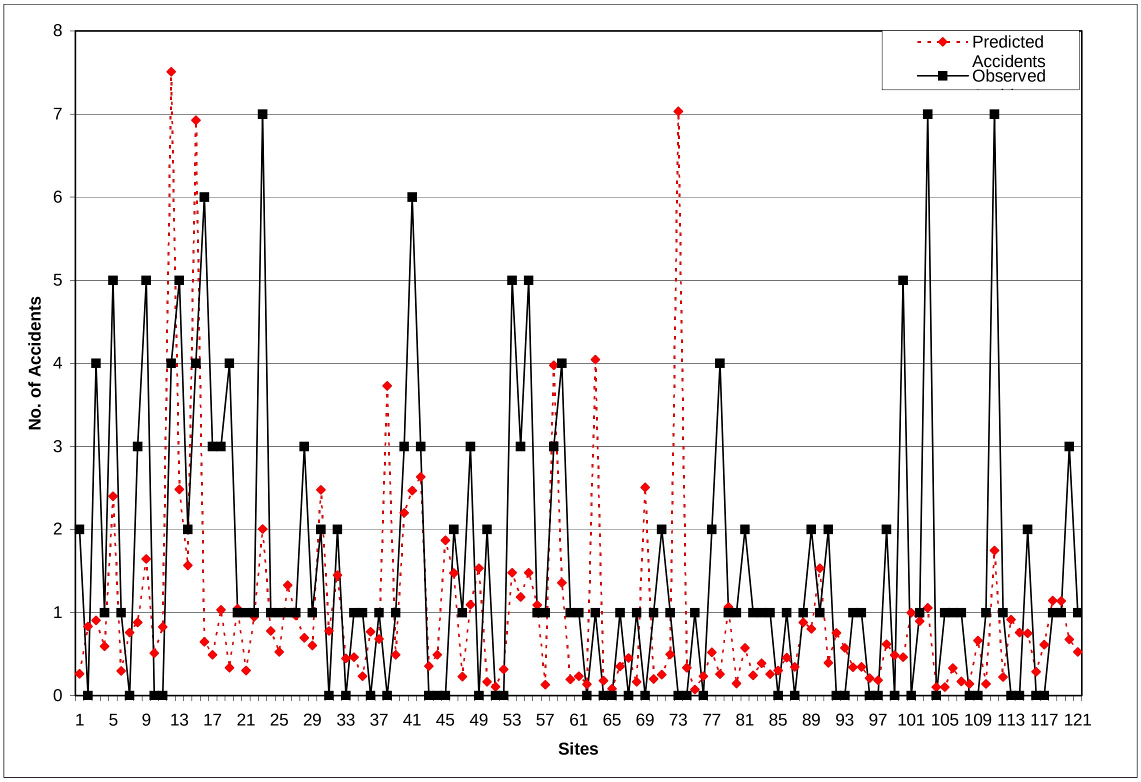

Figure 1. Observed versus Predicted Accident Frequency: Total Accidents Type I

Injury Model

The injury model was recalibrated with both sets of the Georgia accident data. The parameter estimates, their standard errors, and *p*-values are provided in table 55, which reveals differences in the parameter estimates of the variables between the two States.

HI1, RT MAJ, HAU, and SPD1 (for the 0.05-mile buffer only) were estimated with the opposite sign. Aside from the AADT variables, none of the variables were estimated with satisfactory significance for the Georgia data. Perhaps this should not be surprising given that only two years of accident data were available and injury accidents are relatively few compared to total accidents. The overdispersion parameter, *K*, was estimated to be approximately one half of that for the original model.

Table 55. Parameter Estimates for Type I lnjury Accident Model Using Georgia Data

Variable	Original Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile (s.e., *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-13.0374 (1.7908, 0.0001)	-7.56 (2.00, < 0.001)	-7.60 (1.94, < 0.001)
Log of AADT1	0.8122 (0.0973, 0.0001)	0.611 (0.174,< 0.001)	0.699 (0.171,< 0.001)
Log of AADT2	0.4551 (0.0977, 0.0001)	0.149 (0.193, 0.439)	0.098 (0.186, 0.599)
HI1	0.0335 (0.0327, 0.3047)	-0.0091 (0.0418, 0.828)	-0.0102 (0.0414, 0.806)
VCI1	0.1869 (0.3657, 0.6092)	0.0233 (0.0790, 0.768)	0.0061 (0.0778, 0.937)
SPD1	0.0156 (0.0269, 0.5618)	0.0048 (0.0244, 0.842)	-0.0039 (0.0233, 0.869)
HAZRAT1	0.2065 (0.0930, 0.0263)	0.101 (0.138, 0.464)	0.147 (0.133, 0.269)
RT MAJ	0.3620 (0.1814, 0.0460)	-0.81 (1.07, 0.450)	-0.087 (0.788, 0.913)
HAU	0.0051 (0.0045, 0.2594)	-0.00189 (0.00492, 0.701)	-0.00354 (0.00478, 0.459)
DRWY1	-0.0120 (0.0714, 0.8671)	-0.0413 (0.0714, 0.563)	-0.0632 (0.0694, 0.362)
K[2]	0.494	0.299	0.270

[1] Vogt and Bared, 1998, (p. 116)
[2] K: Overdispersion value

The validation measures for the Georgia data is shown in table 56. The Pearson product-moment correlation coefficients were quite low while the MAD was roughly half that for total accidents.

Figure 2 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model failed to account for higher accident frequencies in most sites in the Georgia data.

Table 56. Validation Statistics for Type I Injury Accident Model Using Georgia Data

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for validation	1996 to 1997	1996 to 1997
Number of sites	116	116
Pearson product-moment correlation coefficients	0.23	0.25
MPB	0.24	0.29
MPB/yr	0.12	0.14
MAD	0.61	0.66
MAD/yr	0.31	0.33
MSPE	0.88	1.03
MSPE/yr^2	0.22	0.26

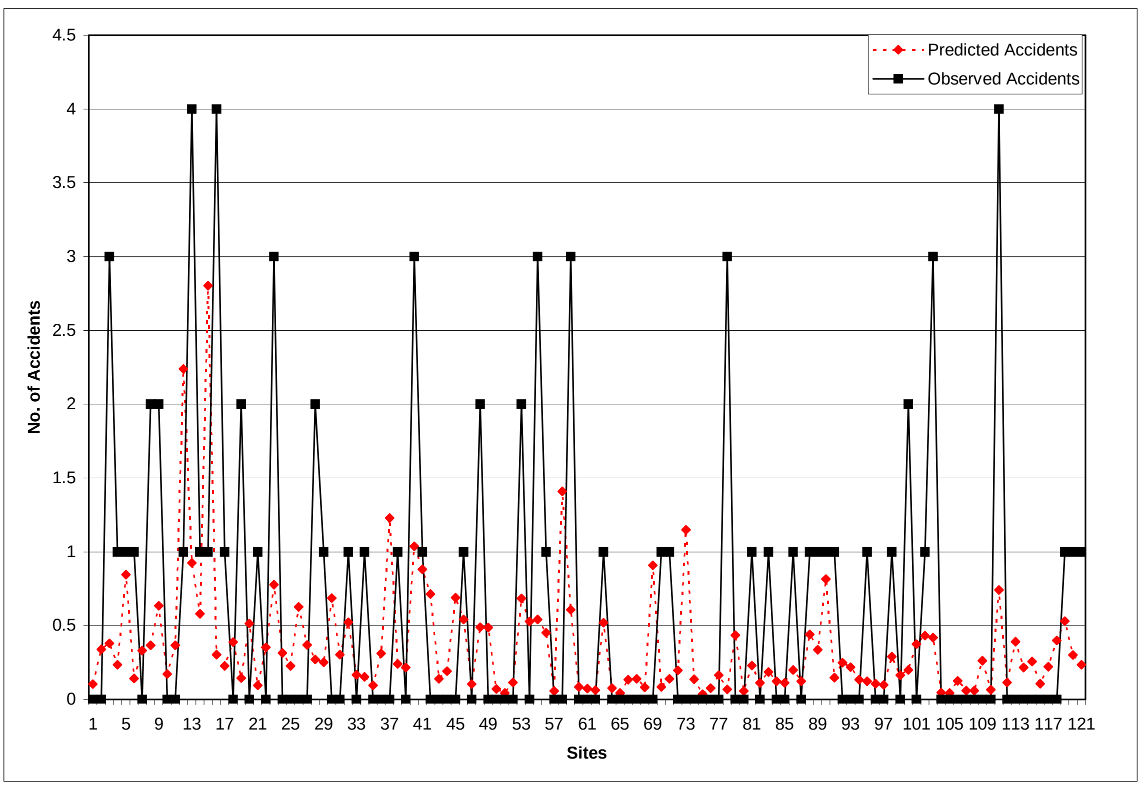

Figure 2. Observed versus Predicted Accident Frequency: Injury Accidents Type I

2.5.2 Model II

The summary statistics in the original report and Georgia data are given provided in table 57. The summary statistics again reveal that the Georgia sample had more accidents per year than the original data.

Table 57. Summary of Georgia versus Minnesota Data for Type II Sites

Variable and Abbreviation		N	Mean	Median	Minimum	Maximum	Freq.	% Zero
No. of Crashes	Original Data Total	327	1.51 (0.30/year)	1.00	0	16	494	39.8
	Original Data Injury	327	0.77 (0.15/year)	0.00	0	9	253	59.9
	Georgia Total (0.04 MI)	114	2.25 (1.13/year)	1.00	0	12	256	29.8
	Georgia Injury (0.04 MI)	114	0.98 (0.49/year)	0.00	0	7	112	55.3
	Georgia Total (0.05 Mile)	114	2.26 (1.13/year)	1.00	0	12	258	28.9
	Georgia Injury (0.05 Mile)	114	0.98 (0.49/year)	0.00	0	7	112	55.3
HI1	Original Data	327	0.49	0.00	0	9	N/A[1]	59.9
	Georgia	114	1.66	0.25	0.00	14.55	N/A[1]	50.0
VCI1	Original Data	327	0.13	0.02	0	2	N/A[1]	48.0
	Georgia	114	1.09	0.89	0.00	7.50	N/A[1]	45.6
SPD1	Original Data	327	53.97	55	30	55	N/A[1]	N/A[1]
	Georgia	114	48.31	47.50	30	55	N/A[1]	N/A[1]
DRWY1	Original Data	327	0.62	0.00	0	6	204	67.6
	Georgia	114	1.19	1.00	0	6	136	40.4
HAU	Original Data	327	-0.03	0	-120	150	N/A[1]	37.9
	Georgia	114	0.27	0.00	-58	50	N/A[1]	3.5
AADT1 on Major Road	Original Data	327	2238	1742	174	14611	N/A[1]	N/A[1]
	Georgia	114	3073	2000	420	12300	N/A[1]	N/A[1]
AADT2 on Minor Road	Original Data	327	308	192	7	3414	N/A[1]	N/A[1]
	Georgia	114	614	430	80	7460	N/A[1]	N/A[1]

[1] N/A: not available

Total Accident Model

The model was recalibrated with both sets of the Georgia accident data. The parameter estimates, their standard errors, and *p*-values are provided in table 58, which reveals differences in the parameter estimates of the variables between the two States.

The variables HI1, VCI1, and SPD1 were estimated with opposite signs while HAU was estimated to have no effect on safety for the Georgia data. The constant term and the other variables were estimated with the same sign but with varying differences in magnitude and significance. The overdispersion parameter, *K*, was estimated to be more than twice as large that of the original model.

Table 58. Parameter Estimates for Type II Total Accident Model Using Georgia Data

Variable	Original Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile (s.e., *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-10.4260 (1.3167, 0.0001)	-7.26 (1.32, <0.001)	-7.21 (1.32, <0.001)
Log of AADT1	0.6026 (0.0836, 0.0001)	0.627 (0.134, <0.001)	0.627 (0.133, <0.001)
Log of AADT2	0.6091 (0.0694, 0.0001)	0.500 (0.154, 0.001)	0.493 (0.154, 0.001)
HI1	0.0449 (0.0473, 0.3431)	-0.0158 (0.0403, 0.695)	-0.0165 (0.0402, 0.681)
VCI1	0.2885 (0.2576, 0.2628)	-0.0606 (0.0794, 0.445)	-0.0438 (0.0781, 0.575)
SPD1	0.0187 (0.0176, 0.2875)	-0.0172 (0.0104, 0.097)	-0.0177 (0.0104, 0.087)
NODRWYS	0.1235 (0.0519, 0.0173)	0.0927 (0.0710, 0.192)	0.0940 (0.0707, 0.184)
HAU	-0.0049 (0.0033, 0.1341)	-0.00038 (0.00450, 0.932)	0.00000 (0.00448, 1.000)
K[2]	0.205	0.455	0.455

[1] Vogt and Bared, 1998, (p. 115)
[2] K: Overdispersion value

Table 59 shows a comparison of validation measures between the original data and the Georgia data. The Pearson product-moment correlation coefficient was much higher for the original data as compared to Georgia. The MPBs and MADs are also higher than for the original Minnesota data. The MSPEs are much higher than the MSE, indicating that the model is not performing well on the Georgia data.

Figure 3 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model failed to account for higher accident frequencies in most sites in the Georgia data.

Table 59. Validation Statistics for Type II Total Accident Model Using Georgia Data

Measure	Original Data	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Number of years	1985 to 1989	1996 to 1997	1996 to 1997
Number of sites	327	114	114
Pearson product-moment correlation coefficients	0.77	0.39	0.39
MPB	0.004	0.70	0.72
MPB/yr	0.00	0.35	0.36
MAD	1.01	1.82	1.82
MAD/yr	0.20	0.91	0.91
MSE	2.38	N/A[1]	N/A[1]
MSE/yr^2	0.10		
MSPE	N/A[1]	6.94	6.94
$MSPE/yr^2$		1.73	1.73

[1] N/A: not available

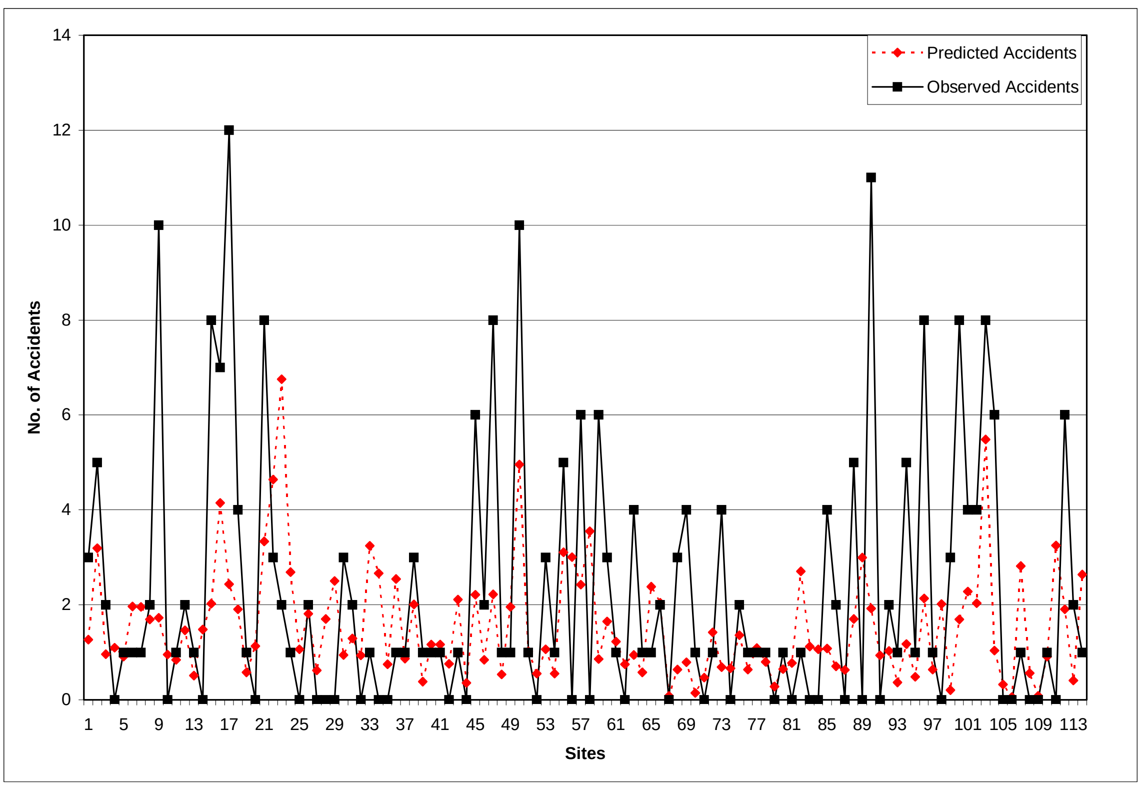

Figure 3. Observed versus Predicted Accident Frequency: Total Accidents Type II

Injury Accident Model

The parameter estimates, their standard errors, and *p*-values are provided in table 60, which reveals that the variables HI1, VCI1, SPD1, HAZRAT1, and HAU were estimated with the opposite signs. With the exception of the AADT variables none were estimated to be highly significant statistically. Only one Georgia model is shown since, as indicated in table 57, the observed number of accidents at each of the Type II sites was equal for the 0.04- and 0.05-mile buffers. The overdispersion parameter, *K*, was estimated to be over twice that of the original model.

Table 60. Parameter Estimates for Type II Injury Accident Model Using Georgia Data

Variable	Original Estimate (s.e., *p*-value)[1]	Georgia Data (s.e., *p*-value)
Constant	-10.7829 (1.7656, 0.0001)	-10.85 (2.01, <0.001)
Log of AADT1	0.6339 (0.1055, 0.0001)	0.702 (0.181, <0.001)
Log of AADT2	0.6229 (0.0870, 0.0001)	0.869 (0.180, <0.001)
HI1	0.0729 (0.0635, 0.2513)	-0.0096 (0.0529, 0.856)
VCI1	0.2789 (0.4623, 0.5464)	-0.094 (0.111, 0.397)
SPD1	0.0112 (0.0251, 0.6567)	-0.0224 (0.0205, 0.274)
HAZRAT1	-0.1225 (0.0720, 0.0889)	0.039 (0.130, 0.766)
RT MAJ	0.0451 (0.1665, 0.7865)	0.070 (0.660, 0.915)
HAU	-0.0043 (0.0044, 0.3258)	0.00603 (0.00631, 0.339)
DRWY1	0.0857 (0.0639, 0.1799)	0.0114 (0.0988, 0.908)
K[2]	0.1811	0.392

[1] Vogt and Bared, 1998, (p. 115)
[2] K: Overdispersion value

The validation measures for the Georgia data are shown in table 61. The Pearson product-moment correlation coefficients were higher than for total accidents but still quite low. The MAD was roughly half that for total accidents.

Figure 4 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model failed to account for higher accident frequencies in most sites in the Georgia data.

Table 61. Validation Statistics for Type II Injury Accident Model Using Georgia Data

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for validation	1996 to 1997	1996 to 1997
Number of sites	114	114
Pearson product-moment correlation coefficients	0.44	0.44
MPB	0.33	0.33
MPB/yr	0.17	0.17
MAD	0.95	0.95
MAD/yr	0.48	0.48
MSE	N/A[1]	N/A[1]
MSE/yr^2		
MSPE	2.00	2.00
MSPE/yr^2	0.50	0.50

[1] N/A: not available

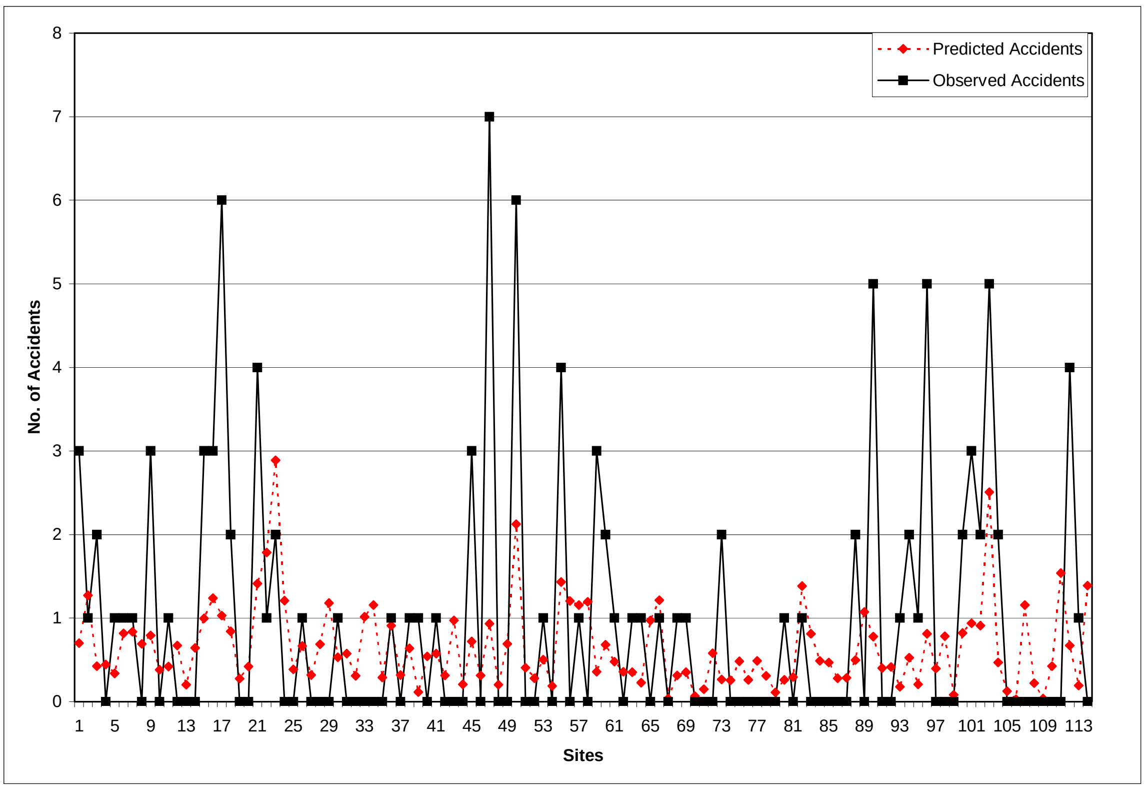

Figure 4. Observed versus Predicted Accident Frequency: Injury Accidents Type II

2.5.3 Model III

The summary statistics in the original report and Georgia data are given in table 62, which reveals that the Georgia sample had on average fewer accidents per year than the original data. This implies that either the Georgia sites were relatively more safe than the sites selected for the original model, or that the passage of time between the period for the original calibration (1993–95) and that for the validation data (1996–97) had resulted in an overall improvement in safety (due to many factors including improved roadway design, improved vehicles, emergency response services, etc.). The Georgia sites may also be safer because they have, on average, wider medians on major roads and fewer numbers of driveways than the original intersections. In addition, more than 50 percent of the sites in the original data had no median, while only 5 percent of sites in Georgia were without a median.

Table 62. Summary Statistics of Georgia Data: Type III Sites

Variable and Abbreviation		N	Mean	Median	Minimum	Maximum	Freq.	% Zero
No. of Crashes (TOTACC)	Original Data	84	3.88	2	0	19	326	21.4
	Georgia (0.05 Mile)	52	2.4	1.5	0	12	124	21.2
	Georgia (0.04 Mile)	52	2.2	1	0	12	116	25.0
No. of Intersection-Type Crashes (TOTACCI)	Original Data	84	2.62	1	0	13	135	34.5
	Georgia (0.05 Mile)	52	1.6	1	0	11	85	32.7
	Georgia (0.04 Mile)	52	1.5	1	0	11	80	36.5
	Georgia (0.05 Mile)	52	1.08	1	0	8	56	44.2
	Georgia (0.04 Mile)	52	1.02	1	0	8	53	48.1
	Georgia (0.05 Mile)	52	0.81	0	0	8	42	57.7
	Georgia (0.04 Mile)	52	0.77	0	0	8	40	61.5
Median Width on Major Road (MEDWIDTH1)	Original Data	84	3.74	0	0	36	N/A[1]	53.6
	Georgia	52	27.0	20	0	63	N/A[1]	5.8
No. of Driveways on Major Road (DRWY1)	Original Data	84	3.1	1	0	15	259	42.9
	Georgia	52	1.5	1	0	9	77	42.3
AADT1 on Major Road	Original Data	84	12870	12050	2367	33058	N/A[1]	N/A[1]
	Georgia	52	13100	12200	6500	28600	N/A[1]	N/A[1]
AADT2 on Minor Road	Original Data	84	596	349	15	3001	N/A[1]	N/A[1]
	Georgia	52	892	430	80	9490	N/A[1]	N/A[1]

[1] N/A: not available

Total Accident Models (TOTACC)

The model was recalibrated using the Georgia data. The parameter estimates, their standard errors, and *p*-values are shown in table 63, which reveals that the constant term, AADT1 and AADT2, were estimated with the same sign but with large differences in magnitude. MEDWDTH2 and DRWY1 were estimated with an opposite sign, although they were not statistically significant. AADT1 was also estimated as insignificant. The overdispersion parameters were lower than that for the original model, but the difference was not great.

Table 63. Parameter Estimates for TOTACC Type III Model Using Georgia Data

Variable	Original Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile (s.e, *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-12.2196 (2.3575, 0.0001)	-8.690 (4.945, 0.1059)	-8.857 (4.585, 0.0750)
Log of AADT1	1.1479 (0.2527, 0.0001)	0.536 (0.459, 0.2434)	0.580 (0.426, 0.1737)
Log of AADT2	0.2624 (0.0866, 0.0024)	0.551 (0.179, 0.0021)	0.536 (0.163, 0.0010)
MEDWIDTH1	-0.0546 (0.0249, 0.0285)	0.004 (0.013, 0.7748)	0.0002 (0.012, 0.9894)
DRWY1	0.0391 (0.0239, 0.1023)	-0.009 (0.088, 0.9156)	0.011 (0.094, 0.9101)
K[2]	0.3893	0.374	0.300

[1] Vogt, 1999, (p. 111)
[2] K: Overdispersion value

Table 64 shows the prediction performance statistics for Model III for TOTACC. Low Pearson product-moment correlation coefficients with the Georgia data indicate that the accident predictions by the original model are marginally correlated with the observed number of accidents in the Georgia data. Other validation statistics also suggest a poor fit of the original model to the Georgia data. The MPB and MAD per year were larger than those for the original model. The MSPE per year squared was almost twice as high as the MSE per year squared.

Figure 5 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model does not do a good job of predicting accidents at the Georgia intersections; this finding was expected on the basis of the low Pearson product-moment coefficients for the Georgia data.

Table 64. Validation Statistics for TOTACC Type III Model Using Georgia Data

Measure	Original Data	Georgia Data	
		0.04 Mile	0.05 Mile
Years used for validation	1993 to 1995	1996 to 1997	1996 to 1997
Number of sites	84	52	52
Pearson product-moment correlation coefficients	0.66	0.03	0.09
MPB	-0.01	-1.34	-1.49
MPB/yr	0.00	-0.45	-0.50
MAD	2.26	5.93	6.14
MAD/yr	0.75	1.98	2.05
MSE	11.01	N/A[1]	N/A[1]
MSE/yr^2	1.22		
MSPE	N/A[1]	9.36	9.64
MSPE/yr^2		2.34	2.41

[1] N/A: not available

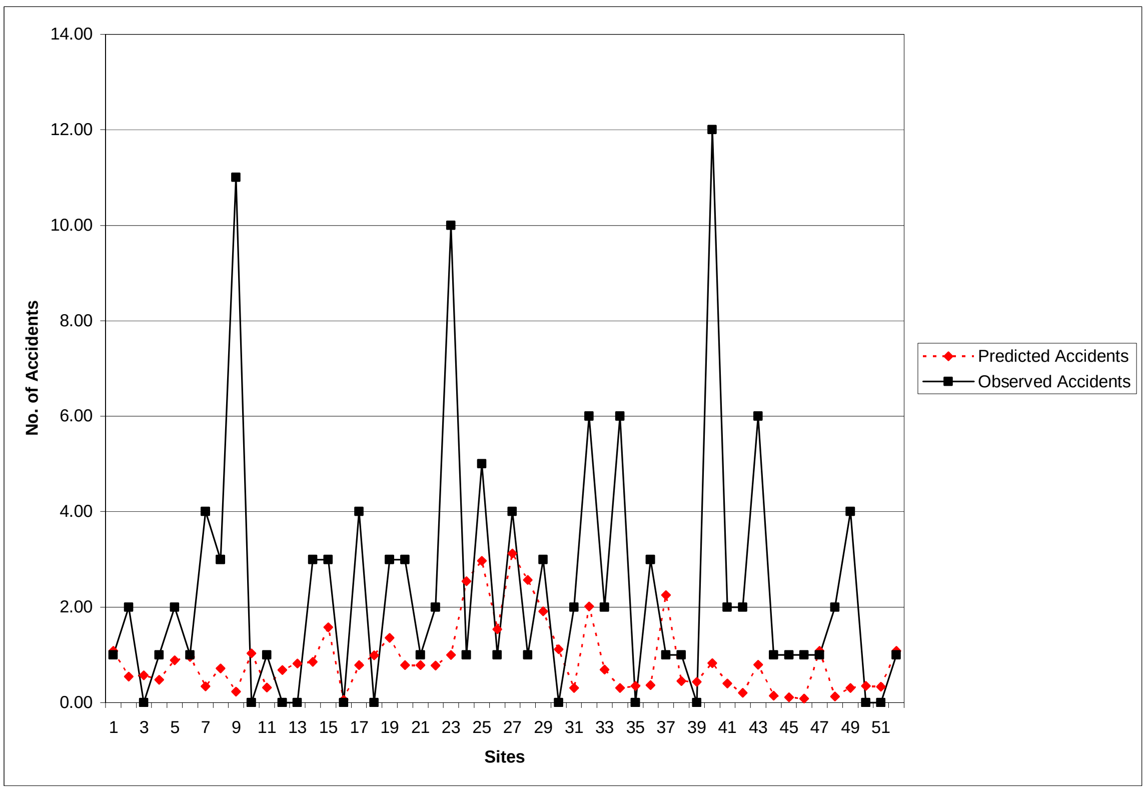

Figure 5. Observed versus Predicted Accident Frequency: TOTACC Type III

Intersection Related Total Accident Model (TOTACCI)

The parameter estimates, their standard errors, and *p*-values are given in table 65. Similar to the model of TOTACC, the variables AADT1, MEDWITH1, and DRWY1 were estimated as statistically insignificant. The constant term and AADT1, AADT2, and DRWY1 were estimated with the same direction of effect but with large differences in magnitude. The overdispersion parameters, *K*, were lower than that for the original model.

Table 65. Parameter Estimates for TOTACCI Type III Model Using Georgia Data

Variable	Original Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile (s.e, *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-15.4661 (3.4685, 0.0001)	-7.774 (4.511, 0.1165)	-8.163 (4.097, 0.0683)
Log of AADT1	1.4331 (0.3608, 0.0001)	0.232 (0.366, 0.5264)	0.301 (0.339, 0.3747)
Log of AADT2	0.2686 (0.0988, 0.0065)	0.764 (0.262, 0.0035)	0.740 (0.229, 0.0012)
MEDWIDTH1	-0.0612 (0.0360, 0.0888)	0.004 (0.013, 0.7719)	0.002 (0.012, 0.8682)
DRWY1	0.0560 (0.0289, 0.0525)	0.090 (0.133, 0.4980)	0.095 (0.126, 0.4504)
K[2]	0.5118	0.352	0.272

[1] Vogt, 1999, (p. 112)
[2] K: Overdispersion value

Table 66 shows the GOF statistics for Model III for TOTACCI. Low Pearson product-moment correlation coefficients with the Georgia data indicate that the accident predictions by the original model are marginally correlated with the observed number of accidents in the Georgia data. Other validation statistics also suggest lack-of-fit to the Georgia data. The MPB and MAD per year were larger than those for the original model. The MSPE per year squared was almost twice as high as the MSE per year squared, indicating a general lack-of-fit to the Georgia data.

A plot of the predicted versus actual accidents using Georgia data will help to understand prediction performances of the original model for the Georgia data. As shown in figure 6, it is quite evident that the original model does not do a good job of predicting accidents at the Georgia intersections; this finding was expected on the basis of the low Pearson product-moment coefficients for the Georgia data.

Table 66. Validation Statistics for TOTACCI Type III Model Using Georgia Data

Measure	Original Data	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for validation	1993 to 1995	1996 to 1997	1996 to 1997
Number of sites	84	52	52
Pearson product-moment correlation coefficients	0.67	0.08	0.10
MPB	-0.005	-1.03	-1.13
MPB/yr	-0.002	-0.52	-0.56
MAD	1.76	1.95	1.95
MAD/yr	0.59	0.97	0.97
MSE	6.50	N/A[1]	N/A[1]
MSE/yr^2	0.72		
MSPE	N/A[1]	5.93	6.14
$MSPE/yr^2$		1.48	1.54

[1] N/A: not available

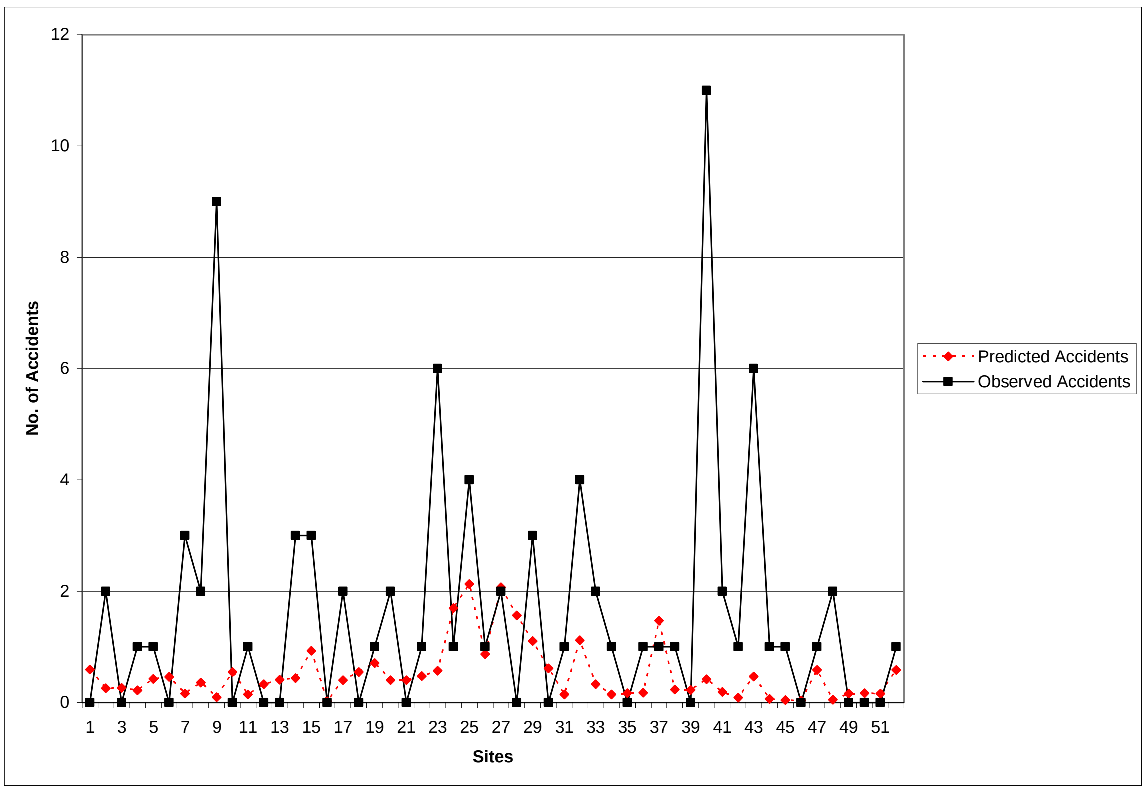

Figure 6. Observed versus Predicted Accident Frequency: TOTACCI Type III

Injury Accident Model (INJACC)

The two original variants for model III were validated.

Variant 1

The parameter estimates, their standard errors, and *p*-values are given in table 67, which reveals that the constant term and all of the variables were estimated with the same sign as in the original model, but there were large differences in their magnitudes. The constant term, AADT1, and HAU became insignificant with the Georgia data. The overdispersion parameters, *K*, were higher than that for the original model.

Table 68 shows the GOF measures for the original injury accident model (Variant 1) in the Vogt report applied to the Georgia data.[(2)]

The Pearson product-moment correlation coefficients were similar to those for the TOTACC model. However, the MPB, MAD, and MSPE per year squared were smaller than those for the TOTACC model.

Table 67. Parameter Estimates for INJACC Type III Model Using Georgia Data: Variant 1

Variable	Report Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile (s.e, *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-12.3246 (2.8076, 0.0001)	-7.642 (6.397, 0.2774)	-6.958 (5.949, 0.2923)
Log of AADT1	1.1436 (0.2763, 0.0001)	0.423 (0.573, 0.4602)	0.381 (0.531, 0.4730)
Log of AADT2	0.1357 (0.1029, 0.1872)	0.454 (0.255, 0.0752)	0.420 (0.243, 0.0838)
HAU	0.0230 (0.0131, 0.0790)	0.001 (0.010, 0.8886)	0.000 (0.009, 0.9743)
K[2]	0.3787	0.682	0.553

[1] Vogt, 1999, (p. 113)
[2] K: Overdispersion value

Table 68. Validation Statistics for INJACC Type III Model Using Georgia Data: Variant 1

Measure	Georgia Data	
	0.04 Mile	0.05 Mile
Years used for validation	1996 to 1997	1996 to 1997
Number of sites	52	52
Pearson product-moment correlation coefficients	0.09	0.08
MPB	0.23	0.19
MPB/yr	0.11	0.10
MAD	0.78	0.78
MAD/yr	0.39	0.39
MSPE	2.30	2.30
MSPE/yr^2	0.58	0.58

Figure 7 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model does not do a good job of predicting accidents at the Georgia intersections, a finding that would have been expected on the basis of the low Pearson product-moment coefficients for the Georgia data.

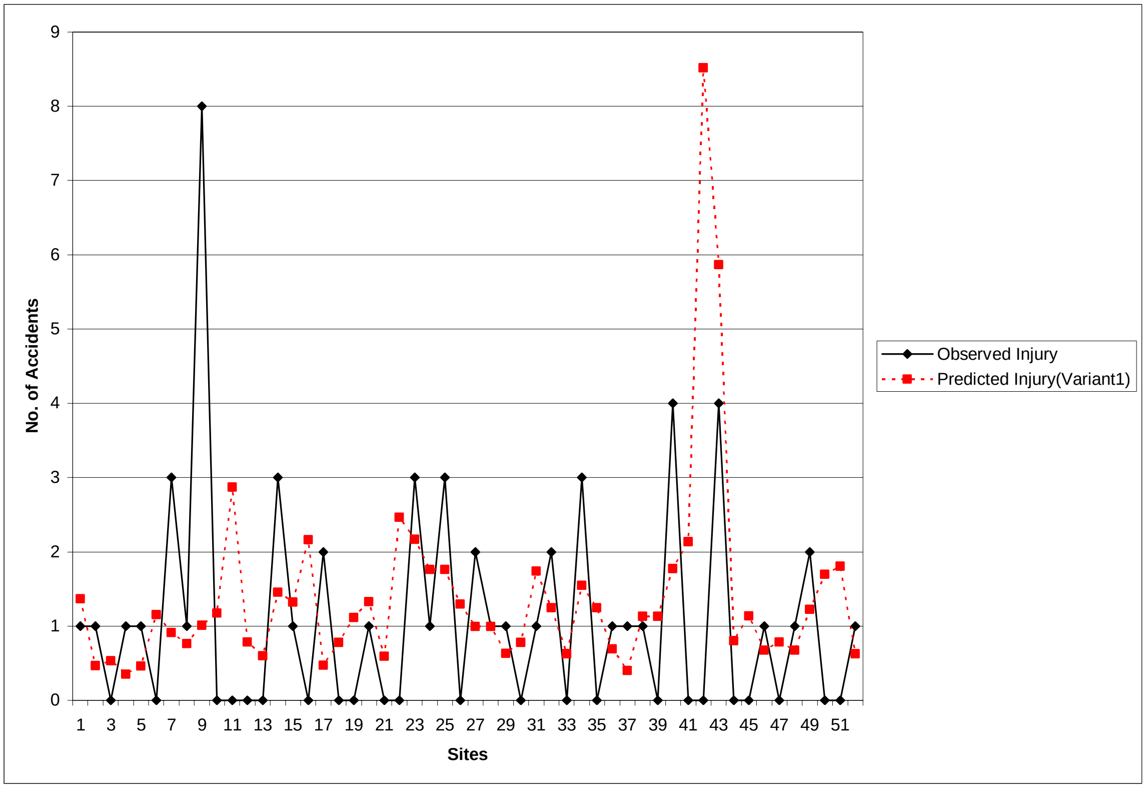

Figure 7. Observed versus Predicted Accident Frequency: Injury Variant 1

<u>Variant 2</u>

The parameter estimates, their standard errors, and *p*-values are given in table 69, which reveals that the constant term and all of the variables were estimated with the same sign as in the original model. However, all of the variables except AADT2 became insignificant, and there were large differences in the magnitudes of the parameters. The overdispersion parameter, *K*, was almost twice as high as for the original model.

Table 70 shows the GOF measures for the original injury accident model (Variant 2) in the Vogt report applied to the Georgia data.(2)

The Pearson product-moment correlation coefficient was similar to that for TOTACC. However, the MPB, MAD, and MSPE per year squared were smaller than those for TOTACC.

Figure 8 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model performs poorly when applied to the Georgia data, a finding that would have been expected on the basis of the low Pearson product-moment coefficients for the Georgia data.

Table 69. Parameter Estimates for INJACC Type III Model Using Georgia Data: Variant 2

Variable	Report Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile (s.e, *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-11.0061 (2.6937, 0.0001)	-8.238 (7.223, 0.2962)	-7.786 (6.571, 0.2803)
Log of AADT1	0.9526 (0.2843, 0.0008)	0.457 (0.627, 0.4663)	0.410 (0.565, 0.4678)
Log of AADT2	0.1499 (0.0916, 0.1018)	0.468 (0.278, 0.0920)	0.457 (0.258, 0.0771)
HAU	0.0289 (0.0105, 0.0061)	0.002 (0.010, 0.8764)	0.001 (0.010, 0.9046)
DRWY1	0.0481 (0.0262, 0.0664)	0.038 (0.120, 0.7488)	0.085 (0.151, 0.5734)
ABSGRD1	0.1838 (0.1130, 0.1038)	0.167 (0.439, 0.7042)	0.225 (0.415, 0.5871)
K[2]	0.2588	0.666	0.501

[1] Vogt, 1999, (p. 113)
[2] K: Overdispersion value

Table 70. Validation Statistics for INJACC Type III Model Using Georgia Data: Variant 2

Measure	Georgia Data	
	0.04 Mile	0.05 Mile
Years used for validation	1996 to 1997	1996 to 1997
Number of sites	52	52
Pearson product-moment correlation coefficients	0.05	0.04
MPB	0.15	0.11
MPB/yr	0.08	0.06
MAD	0.77	0.77
MAD/yr	0.39	0.39
MSPE	2.61	2.61
MSPE/yr^2	0.65	0.65

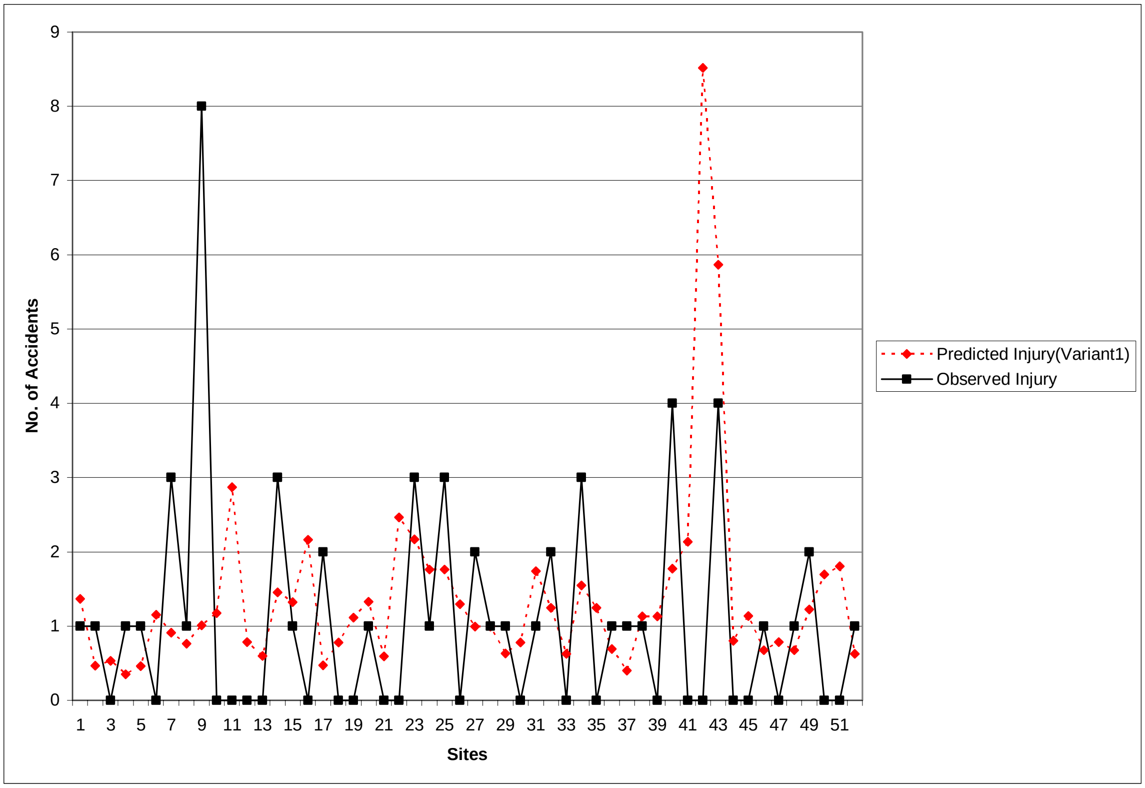

Figure 8. Observed versus Predicted Accident Frequency: Injury Variant 2

2.5.4 Model IV

The summary statistics are provided in table 71. Peak left-turn percentage on major road was not available in the Georgia data, since this variable would be too costly to collect in the field. Since the variable was not present in the Georgia data, modifications to the validation procedure had to be performed. The variable was removed from the original model by dividing both sides of the model equation by the exponential value of the coefficient of the variable times its average effect (the average effect of PKLEFT1 is the average value of PKLEFT1 in the calibration data).

The summary statistics showed that about 31 percent of the sites in the original data had no left-turn lane, while 17 percent in the Georgia data were without a left-turn lane. The summary statistics for all of the three States (California, Michigan, and Georgia) were also compared (refer to table 72). All of the sites in Michigan had no LTLN1S, while frequencies of TOTACC and TOTACCI for Georgia were higher than for the California data.

Pearson correlations of the original data, Georgia, and California are given in table 73. The observation that the coefficients for AADT 2 and LTLN1S estimated using Georgia data resulted in opposite signs than the original model required further investigation. Pearson correlations for these variables with the response (accident frequency) were computed for all three States—California, Michigan, and Georgia. Recall that the Pearson correlation reflects the degree to which the two variables are linearly related. Unlike the original data, AADT2 in Georgia is estimated as negative linearly related with TOTACC and TOTACCI, but these correlations are marginal and statistically insignificant. The variable LTLN1 is positively related with TOTACC and TOTACCI in Georgia and California (not significant), but is negative and significant for the Michigan data.

Table 71. Summary Statistics of Georgia Data: Type IV

Variable and Abbreviation		N	Mean	Median	Minimum	Maximum	Freq.	% Zero
No. of Crashes (TOTACC)	Original Data	72	5.5	3.5	0	38	398	12.5
	Georgia (0.05 Mile)	52	4.27	4.0	0	13	222	13.5
	Georgia (0.04 Mile)	52	4.17	3.0	0	13	217	13.5
No. of Intersection-Type Crashes (TOTACCI)	Original Data	72	4.1	2	0	27	297	22.2
	Georgia (0.05 Mile)	52	3.08	3.0	0	11	160	26.9
	Georgia (0.04 Mile)	52	3.06	3.0	0	11	159	36.5
No. of Injury Crashes (INJACC)	Georgia (0.05 Mile)	52	2.06	2.0	0	9.0	107	32.7
	Georgia (0.04 Mile)	52	2.0	2.0	0	9.0	104	32.7
No. of Intersection-Type Injury Crashes (INJACCI)	Georgia (0.05 Mile)	52	1.67	1.0	0	9.0	87	38.5
	Georgia (0.04 Mile)	52	1.67	1	0	9	87	38.5
Left-Turn Lanes on Major Road (LTLN1S)	Original Data	72	0.7	1	0	1	N/A[1]	30.6
	Georgia	52	0.8	1	0	1	N/A[1]	17.3
Peak Left-Turn Percentage on Major Road (PKLEFT1)	Original Data	72	2.8	1.51	0	13.96	N/A[1]	5.6
	Georgia	N/A[1]						
AADT1 on Major Road	Original Data	72	13018	11166	3350	73000	N/A[1]	N/A[1]
	Georgia	52	13100	12200	6500	28600	N/A[1]	N/A[1]
AADT2 on Minor Road	Original Data	72	559	410	21	2018	N/A[1]	N/A[1]
	Georgia	52	892	430	80	9490	N/A[1]	N/A[1]

[1] N/A: not available

Table 72. Summary Statistics of California, Michigan, and Georgia

Variable	California (N=54)[1]				Michigan (N=18)[1]				Georgia (N=52)[2]			
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
TOTACC	4.2	3	0	22	9.4	8.5	0	38	4.3	4	0	13
TOTACCI	3.5	2	0	21	6	4.5	0	27	3.1	3	0	11
AADT1	13788	11250	3350	73000	10707	10550	5967	19383	12631	12831	5300	25800
AADT2	441	301	21	1850	913	733	254	2018	706	463	300	2990
PKLEFT1	2.25	1	0	14	4.4	3.1	0.8	11.6	N/A	N/A	N/A	N/A
LTLNS	0.93	1	0	1	0	0	0	0	0.9	1	0	1

[1] Summary Statistics for California and Michigan were produced using the obtained original data
[2] Used TOTACC and TOTACCI for 0.05 mile

Table 73. Pearson Correlations: Original, Georgia, and California

The original data (N=72)

Variable		TOTACC	TOTACCI	AADT1	AADT2
TOTACC	Pearson Correlation	1.000	0.961	0.152	0.480
	Sig. (2-tailed)	N/A[1]	0.000	0.203	0.000
TOTACCI	Pearson Correlation	0.961	1.000	0.164	0.461
	Sig. (2-tailed)	0.000	N/A[1]	0.168	0.000
AADT1	Pearson Correlation	0.152	0.164	1.000	-0.108
	Sig. (2-tailed)	0.203	0.168	N/A[1]	0.365
AADT2	Pearson Correlation	0.480	0.461	-0.108	1.000
	Sig. (2-tailed)	0.000	0.000	0.365	N/A[1]
LTLN1	Pearson Correlation	-0.279	-0.169	0.210	-0.219
	Sig. (2-tailed)	0.018	0.156	0.077	0.064

Georgia (N= 52): 0.05 mile

Variable		TOTACC	TOTACCI	AADT1	AADT2
TOTACC	Pearson Correlation	1.000	0.934	0.294	-0.096
	Sig. (2-tailed)	N/A[1]	0.000	0.035	0.501
TOTACCI	Pearson Correlation	0.934	1.000	0.247	-0.096
	Sig. (2-tailed)	0.000	N/A[1]	0.077	0.499
AADT1	Pearson Correlation	0.294	0.247	1.000	-0.008
	Sig. (2-tailed)	0.035	0.077	N/A[1]	0.956
AADT2	Pearson Correlation	-0.096	-0.096	-0.008	1.000
	Sig. (2-tailed)	0.501	0.499	0.956	N/A[1]
LTLN1	Pearson Correlation	0.293	0.250	0.083	0.143
	Sig. (2-tailed)	0.035	0.074	0.558	0.313

[1] N/A: not available

Table 73. Pearson Correlations: Original, Georgia, and California (Continued)

California (N=54)

Variable		TOTACC	TOTACCI	AADT1	AADT2
TOTACC	Pearson Correlation	1	0.987	0.215	0.494
	Sig. (2-tailed)	N/A[1]	0	0.118	0
TOTACCI	Pearson Correlation	0.987	1	0.201	0.508
	Sig. (2-tailed)	0	N/A[1]	0.146	0
AADT1	Pearson Correlation	0.215	0.201	1	-0.035
	Sig. (2-tailed)	0.118	0.146	N/A[1]	0.804
AADT2	Pearson Correlation	0.494	0.508	-0.035	1
	Sig. (2-tailed)	0	0	0.804	N/A[1]
LTLN1	Pearson Correlation	0.074	0.046	0.138	0.266
	Sig. (2-tailed)	0.596	0.742	0.319	0.052

[1] N/A: not available

Total Accident Models (TOTACC)

The parameter estimates, their standard errors, and *p*-values are given in table 74. Since the variable PKLEFT1 (peak left-turn percentage on major road) is not present in the Georgia data, modifications to the validation procedure had to be performed as described earlier. In the validation, the same parameter estimates in the originally published report were used, and the parameter estimates were also reproduced without PKLEFT1 for the revised original model ("Revised Estimates" in table 74).

In the revised original model, all of the variables were estimated with the same sign but with large differences in magnitude. The effect of AADT1 became smaller, while that of AADT2 became larger. The overdispersion values with the Georgia data were higher than for the original models, but the difference was not great.

For the Georgia data, the constant term and AADT1 were estimated with the same sign as for the original models. However, AADT2 and LTLN1S were estimated with an opposite sign to the original model, although AADT2 was insignificant. The values of the overdispersion parameter *K* for the Georgia data were lower than those for the original data.

Table 74. Parameter Estimates for TOTACC Type IV Model Using Georgia Data

Variable	Original Estimates[1] (s.e., *p*-value)	Revised Estimates[2] (s.e, *p*-value)	Georgia Data 0.04 Mile (s.e., *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-9.4631 (2.5991, 0.0003)	-6.705 (2.373, 0.0181)	-5.599 (3.977, 0.2174)	-5.764 (4.110, 0.2173)
Log of AADT1	0.8503 (0.2779, 0.0022)	0.501 (0.231, 0.0301)	0.624 (0.365, 0.0875)	0.653 (0.380, 0.0860)
Log of AADT2	0.3294 (0.1255, 0.0087)	0.478 (0.097, 0.0000)	-0.112 (0.229, 0.6253)	-0.097 (0.241, 0.6867)
PKLEFT1	0.1100 (0.0412, 0.0076)	N/A[4]	N/A[4]	N/A[4]
LTLN1S	-0.4841 (0.2311, 0.0362)	-0.504 (0.245, 0.0393)	1.273 (0.432, 0.0032)	1.085 (0.377, 0.0040)
K[3]	0.4578	0.553	0.382	0.417

[1] Vogt, 1999, (p. 116)
[2] Coefficient estimates of the variables were reproduced without PKLEFT1 using the original data
[3] K: Overdispersion value
[4] N/A: not available

Since PKLEFT1 was not available in the Georgia data, two models (original model and revised original model) were used for the validation activity to determine GOF measures. For the original model, the same parameter estimates in the report were used. For the revised original model, since PKLEFT1 was not available, PKLEFT1 was removed from the original model by dividing by the exponential value of the coefficient of this variable times its average effect, i.e., the average value of PKLEFT1.

GOF measures of the revised original model, shown in table 75, indicate that it could be a good alternative to the original model. Pearson product-moment correlation coefficients, MAD per year, and MSE per year squared were similar to those for the original model. The MPB per year was higher than that for the original model, but the difference was not great.

Values of 0.05 and 0.08 of the Pearson product-moment correlation coefficient indicate that the accidents in the Georgia data are not linearly related with the model-predicted values. This could be the result of a significant nonlinearity in the data and original model. The MPB and MAD per year for the Georgia data were larger than those for the original year data. The MSPEs per year squared were also higher than the MSEs per year squared.

Figure 9 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients for the Georgia data.

Table 75. Validation Statistics for TOTACC Type IV Model Using Georgia Data

Measure	Original Model[1]	Revised Original Model[2]	Georgia[3] (0.04 Mile)	Georgia[3] (0.05 Mile)
Years used for validation	1993-1995	1993-1995	1996-1997	1996-1997
Number of sites	72	72	51	51
Pearson product-moment correlation coefficients	0.56	0.56	0.05	0.08
MPB	-0.07	1.41	2.25	2.27
MPB/yr	-0.02	0.47	1.12	1.13
MAD	3.38	3.49	3.09	3.11
MAD/yr	1.13	1.16	1.54	1.55
MSE	30.62	32.66	N/A[4]	N/A[4]
MSE/yr^2	3.40	3.63		
MSPE	N/A[4]	N/A[4]	17.86	18.51
MSPE/yr^2			4.47	4.63

[1] Used the original main model in the report. This model includes PKLEFT1

[2] Used the same coefficients in the original model, but PKLEFT1 was removed from the model by dividing by the exponential value of the coefficient of this variable times its average effect

[3] Used the revised original model

[4] N/A: not available

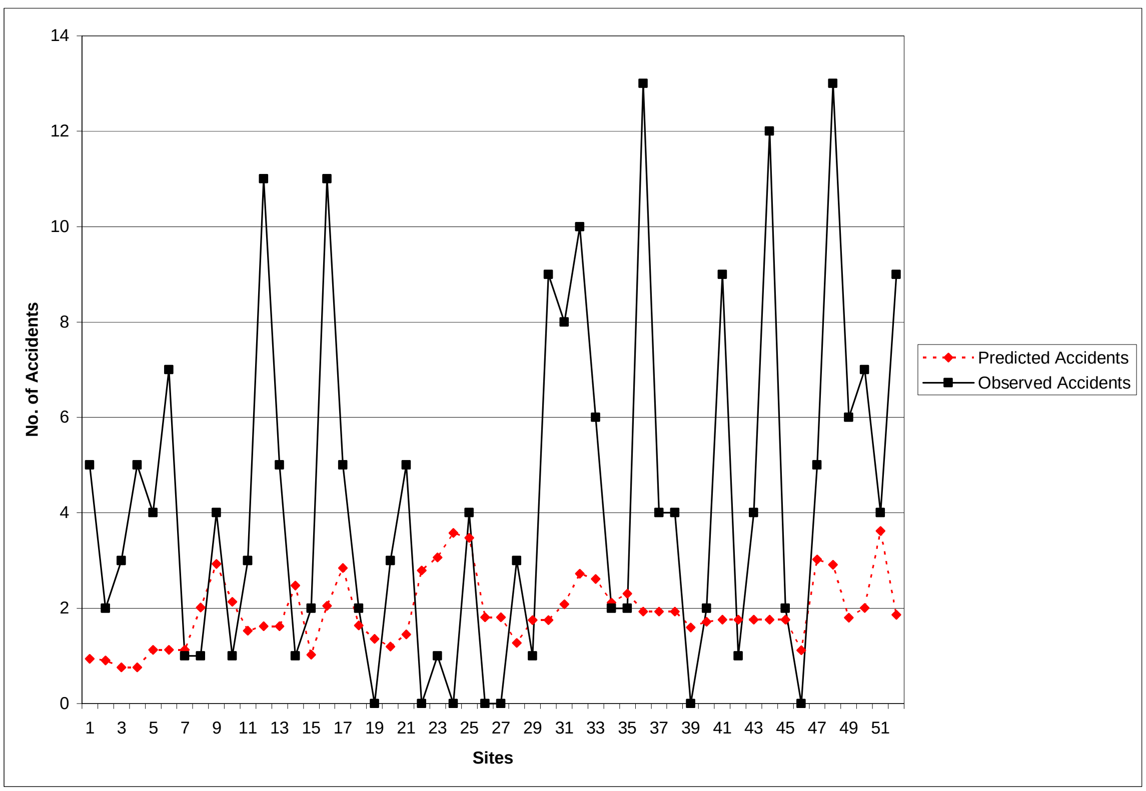

Figure 9. Observed versus Predicted Accident Frequency: TOTACC

Intersection Related Total Accident Model (TOTACCI)

The parameter estimates, their standard errors, and *p*-values are given in table 76. As before, the two models (original model and revised original model) were used for the validation. For the original model, the same parameter estimates in the report were used. Since the report also developed a model with AADT1 and AADT2 only, which model ("Revised Estimates" in table 76) was included for the validation.

In the alternative original model the constant term and parameter estimates of AADT1 and AADT2 were estimated with the same sign but with some difference in magnitude. The effect of AADT1 became smaller, while that of AADT2 became larger. The overdispersion value was slightly higher than for the original model.

For the Georgia data, AADT2 was estimated with an opposite sign to that of the original models. However, it was statistically insignificant, and the impact of the variable on the accident prediction was marginal. The constant term and AADT1 were also estimated as insignificant for the Georgia data. The overdispersion values for the Georgia data were similar to that for the revised original model.

The prediction performance measures are shown in table 77. As was the case for the TOTACC models, the revised model showed similar prediction performance measures to the original model.

Table 76. Parameter Estimates for TOTACCI Type IV Model Using Georgia Data

Variable	Original Estimates[1] (s.e., *p*-value)	Revised Estimates[2] (s.e, *p*-value)	Georgia Data 0.04 Mile (s.e., *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-11.1096 (3.3345, 0.0008)	-7.2501 (2.9094, 0.0130)	-4.604 (5.482, 0.4755)	-4.603 (5.498, 0.4770)
Log of AADT1	0.9299 (0.3433, 0.0067)	0.4582 (0.2844, 0.1071)	0.562 (0.495, 0.2564)	0.563 (0.497, 0.2568)
Log of AADT2	0.3536 (0.1163, 0.0024)	0.5311 (0.0996, 0.0001)	-0.041 (0.325, 0.8996)	-0.043 (0.326, 0.8957)
PKLEFT1	0.1491 (0.0586, 0.0110)	N/A[4]	N/A[4]	N/A[4]
K[3]	0.7096	0.8814	0.857	0.857

[1] Vogt, 1999, (p. 117)
[2] The report presents this model developed with AADT1 and AADT2 only
[3] K: Overdispersion value
[4] N/A: not available

Table 77. Validation Statistics for TOTACCI Type IV Model Using Georgia Data

Measure	Original Model[1]	Revised Original Model[2]	Georgia[3] (0.04 Mile)	Georgia[3] (0.05 Mile)
Years used for validation	1993-1995	1993-1995	1996-1997	1996-1997
Number of sites	72	72	51	51
Pearson product-moment correlation coefficients	0.47	0.47	0.16	0.17
MPB	-0.17	1.28	1.81	1.76
MPB/yr	-0.06	0.43	0.90	0.88
MAD	3.00	3.00	2.59	2.54
MAD/yr	1.00	1.00	1.29	1.27
MSE	24.92	24.85	N/A[4]	N/A[4]
MSE/yr^2	2.77	2.76		
MSPE	N/A[4]	N/A[4]	12.32	12.18
MSPE/yr^2			3.08	3.05

[1] Used the original main model in the report. This model includes PKLEFT1
[2] Used the same coefficients in the original model, but PKLEFT1 was removed from the model by dividing by the exponential value of the coefficient of this variable times its average effect
[3] Used the revised original model
[4] N/A: not available

Values of 0.16 and 0.l7 of the Pearson product-moment correlation coefficients indicate that the accident predictions by the original models are not strongly linearly correlated with the observed number of accidents in the Georgia data. Again, there are several possible explanations for this. The MPBs and MAD per year was larger than those for the original models. The MSPEs per year squared were also slightly higher than the MSEs per year squared.

Figure 10 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

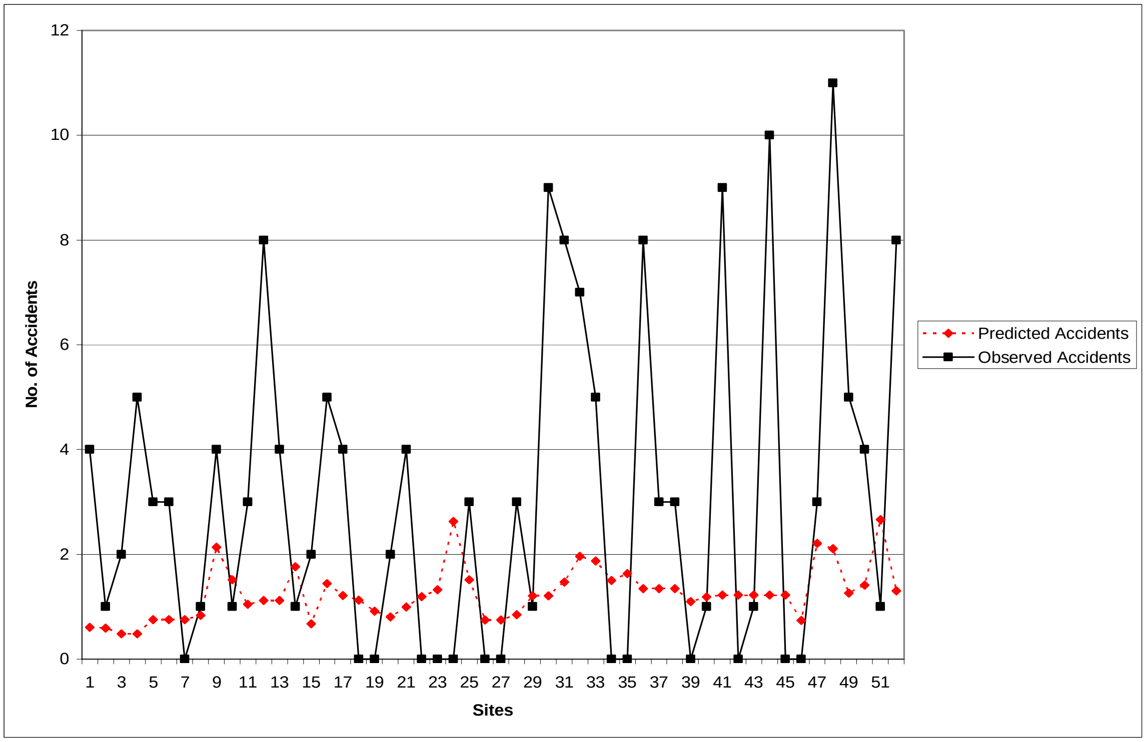

Figure 10. Observed versus Predicted Accident Frequency: TOTACCI

Injury Accident Model (INJACC)

The parameter estimates, their standard errors, and *p*-values are given in table 78. Again, all of the variables including the constant term were insignificant for the Georgia data, and AADT2 was estimated with an opposite sign to that of the original model. The overdispersion values for the Georgia data were higher than that for the original model.

Table 78. Parameter Estimates for INJACC Type IV Model Using Georgia Data

Variable	Original Estimates[1] (s.e., *p*-value)	Georgia Data 0.04 Mile[2] (s.e., *p*-value)	Georgia Data 0.05 Mile[2] (s.e., *p*-value)
Constant	-12.5296 (2.9908, 0.0001)	-4.811 (4.912, 0.4018)	-5.260 (4.778, 0.3392)
Log of AADT1	0.9505 (0.3284, 0.0038)	0.599 (0.467, 0.1990)	0.652 (0.457, 0.1543)
Log of AADT2	0.3237 (0.1645, 0.0491)	-0.191 (0.374, 0.6100)	-0.162 (0.367, 0.6586)
PKLEFT1	0.0994 (0.0433, 0.0216)	N/A[4]	N/A[4]
SPD2	0.0339 (0.0179, 0.0577)	0.010 (0.031, 0.7379)	0.005 (0.031, 0.8732)
K[3]	0.4308	0.649	0.645

[1] Vogt, 1999, (p. 118)
[2] PKLEFT1 was not included in the model
[3] K: Overdispersion value
[4] N/A: not available

Table 79 shows the GOF measures for the original injury accident model (Variant 1) in the Vogt report applied to the Georgia data.(2)

The Pearson product-moment correlation coefficients were higher those for the TOTACC models, and the MPB, MAD, and MSPE per year squared were smaller than those for the TOTACC models.

Table 79. Validation Statistics for INJACC Type IV Model Using Georgia Data

Measure	Georgia[1]	
	0.04 Mile	0.05 Mile
Years used for the validation	1996-1997	1996-1997
Number of sites	52	52
Pearson product-moment correlation coefficients	0.18	0.18
MPB	0.75	0.81
MPB/yr	0.38	0.40
MAD	1.67	1.73
MAD/yr	0.84	0.86
MSPE	5.02	5.23
MSPE/yr^2	1.26	1.31

[1] Used Variant 1, but PKLEFT1 was removed from the model by dividing by the exponential value of the coefficient of this variable times its average effect

Figure 11 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

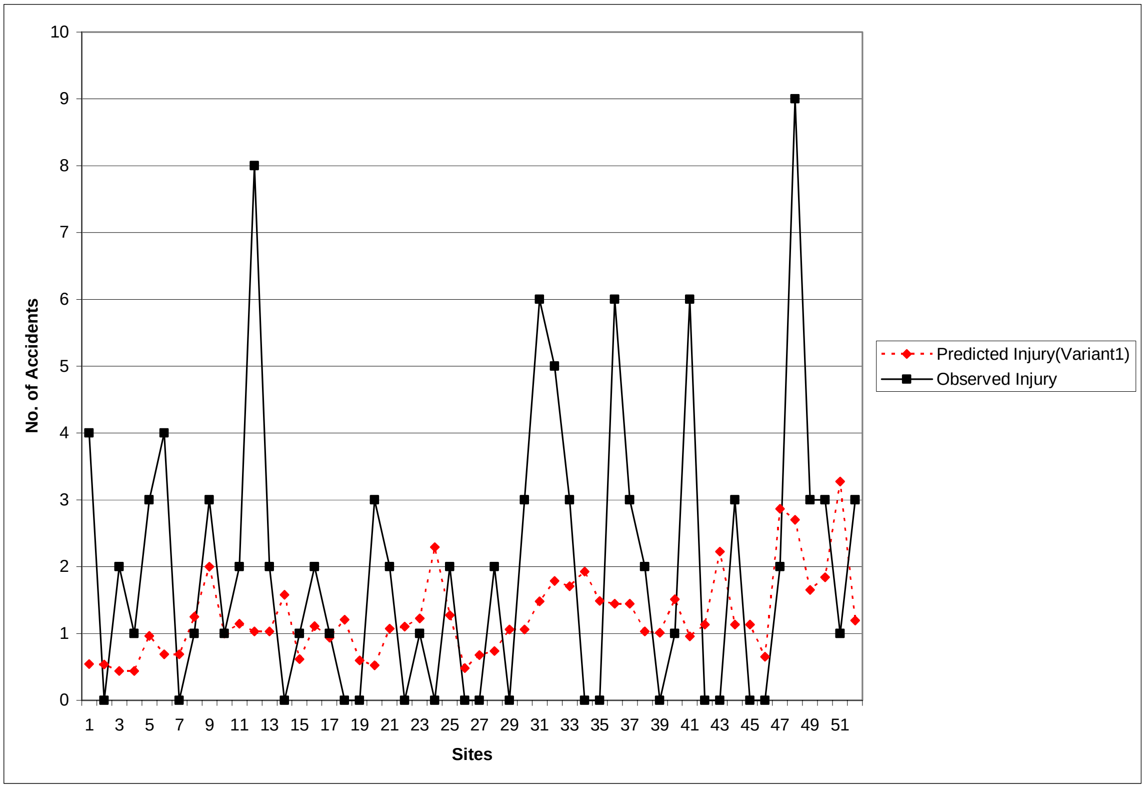

Figure 11. Observed versus Predicted Accident Frequency: INJACC

Intersection Related Injury Accident Model (INJACCI)

The parameter estimates, their standard errors, and *p*-values are given in table 80. As was the case for INJACC, all of the variables were insignificant for the Georgia data. The variable AADT2 was estimated with an opposite sign to that for the original model. The overdispersion values with the Georgia data were similar to that for the original model.

Table 81 shows the GOF measures for the original intersection related injury accident model (Variant 1) in the Vogt report applied to the Georgia data.[(2)]

The Pearson product-moment correlation coefficient was similar to that for the TOTACCI model, but the MPB, MAD, and MSPE per year squared were smaller.

Table 80. Parameter Estimates for INJACCI Type IV Model Using Georgia Data

Variable	Original Estimates[1] (s.e., *p*-value)	Georgia Data 0.04 Mile[2] (s.e., *p*-value)	Georgia Data 0.05 Mile[2] (s.e., *p*-value)
Constant	-13.5576 (3.9998, 0.0008)	-4.475 (5.357, 0.4803)	-4.475 (5.357, 0.4803)
Log of AADT1	0.9918 (0.4268, 0.0201)	0.564 (0.499, 0.2590)	0.564 (0.499, 0.2590)
Log of AADT2	0.3310 (0.1894, 0.0805)	-0.189 (0.407, 0.6430)	-0.189 (0.407, 0.6430)
PKLEFT1	0.1228 (0.0614, 0.0457)	N/A[4]	N/A[4]
SPD2	0.0429 (0.0240, 0.0740)	0.005 (0.036, 0.8892)	0.005 (0.036, 0.8892)
K[3]	0.7178	0.789	0.789

[1] Vogt, 1999, (p. 118)
[2] PKLEFT1 was not included in the model
[3] K: Overdispersion value
[4] N/A: not available

Table 81. Validation Statistics for INJACCI Type IV Model Using Georgia Data

Measure	Georgia Data[1]	
	0.04 Mile	0.05 Mile
Years used for validation	1996-1997	1996-1997
Number of sites	52	52
Pearson product-moment correlation coefficients	0.15	0.15
MPB	1.08	1.14
MPB/yr	0.54	0.57
MAD	1.72	1.78
MAD/yr	0.86	0.89
MSPE	5.59	5.86
MSPE/yr[2]	1.40	1.47

[1] Used Variant 1, but PKLEFT1 was removed from the model by dividing by the exponential value of the coefficient of this variable times its average effect

Figure 12 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

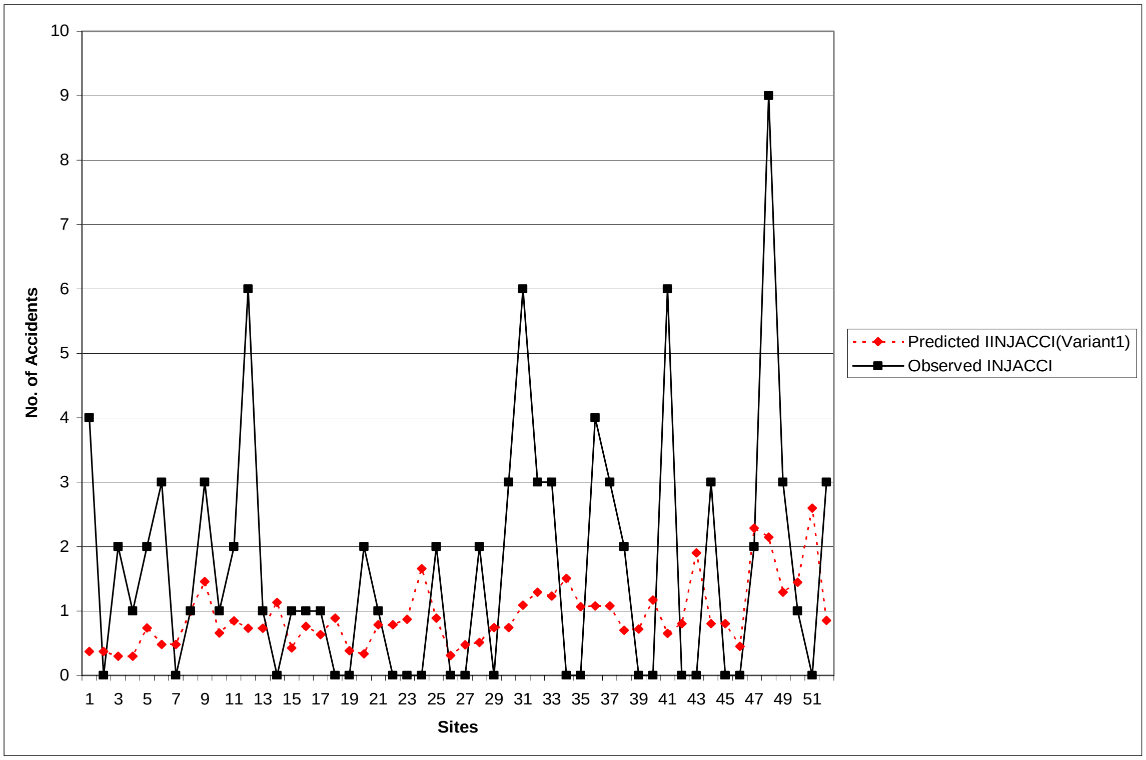

Figure 12. Observed versus Predicted Accident Frequency: INJACCI

2.5.5 Model V

The summary statistics of the variables used in this model are provided in table 82. PKLEFT2 and PKTRUCK were not included in the Georgia data. The summary statistics indicate that the Georgia intersections had fewer accidents, on average, than those in the original data. For example, about 10 percent of the Georgia sites did not have an accident during the period of 1996 and 1997, while all of the original sites experienced at least one accident. The majority of the Georgia sites did not have a protected left-turn lane on the major road (PROT_LT), while PROT_LT was present at almost a half of the sites in the original models. As mentioned previously, some of the data acquired did not exactly match the summary statistics given in the report.[(2)] Specifically, there was a problem reproducing vertical alignment related variables: VEI1, VEI2, and VEICOM.

Table 82. Summary Statistics of Georgia Data: Type V

Variable and Abbreviation[1]		N	Mean	Median	Minimum	Maximum	Freq.	% Zero
No. of Crashes (TOTACC)	Original Data	49	20.8	21	2	48	1017	0.0
	Georgia (0.05 Mile)	51	9.6	7	0	53	489	11.8
	Georgia (0.04 Mile)	51	9.3	7	0	51	473	11.8
No. of Intersection-Type Crashes (TOTACCI)	Original Data	49	16.1	17	1	37	790	0.0
	Georgia (0.05 Mile)	51	8.7	7	0	52	445	11.8
	Georgia (0.04 Mile)	51	8.5	7	0	50	433	13.7
No. of Injury Crashes (INJACC)	Original Data	49	7.47	7	0	25	366	4.1
	Georgia (0.05 Mile)	51	2.3	1	0	13	118	25.5
	Georgia (0.04 Mile)	51	2.2	1	0	13	113	25.5
No. of Intersection-Type Injury Crashes (INJACCI)	Original Data	49	6.14	6	0	21	301	4.1
	Georgia (0.05 Mile)	51	2.2	1	0	13	110	27.5
	Georgia (0.04 Mile)	51	2.1	1	0	13	106	27.5
Peak Left-Turn Percentage on Minor Road (PKLEFT2)	Original Data	49	18.2	17.97	4.2	37.07	N/A[2]	N/A[2]
	Georgia	N/A[2]						
Peak Truck Percentage (PKTRUCK)	Original Data	49	8.96	7.71	2.69	7.71	N/A[2]	N/A[2]
	Georgia	N/A[2]						
Protected Left Turn (PROT_LT)	Original Data	49	N/A[2]					
	0=NO	28						
	1=YES	21						
	Georgia	51						
	0=NO	42						
	1=YES	9						
Combined VEI1 and VEI2 (VEICOM)	Original Data	N/A[2]						
	Georgia	51	1.69	1.60	0	4.79	N/A[2]	7.8
AADT1 on Major Road	Original Data	49	13018	11166	3350	73000	N/A[2]	N/A[2]
	Georgia	51	13100	12200	6500	28600	N/A[2]	N/A[2]
AADT2 on Minor Road	Original Data	49	559	410	21	2018	N/A[2]	N/A[2]
	Georgia	51	892	430	80	9490	N/A[2]	N/A[2]

[1] Vogt, 1999, (p. 61-64)
[2] N/A: not available

Separate summary statistics for three States, shown in table 83, were examined to see if there were differences in the variables between States. These summary statistics indicate that the Michigan sites had, on average, higher accident frequencies than California. They also reveal that the majority of the sites in California had protected left-turn lanes (PROT_LT=1), while the Michigan and Georgia data had no sites with this feature present.

Table 83. Summary Statistics for Three States: California, Michigan, and Georgia[1]

Variable	California (N=18)[1]				Michigan (N=31)[1]				Georgia (N=51)			
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
TOTACC	15.2	16	2	32	24	25	2	48	9.6	7	0	53
TOTACCI	13.8	15	2	30	17.5	18	1	37	8.7	7	0	52
AADT1	13048	12484	7500	25133	9007	8435	4917	17483	7798	7400	430	15200
AADT2	3630	3026	940	10067	4796	4434	1961	12478	2749	2200	420	10400
PKLEFT2	28.83	25.07	2.5	68.57	28.17	25.65	9.91	75.73	N/A[2]			
PKTRUCK	7.36	6.43	2.69	15.45	9.89	8.37	2.97	45.43	N/A[2]			
PROT_LT	0.94	1	0	1	0.13	0	0	1	0.18	0	0	1
VEICOM	1.91	1.08	0	8.13	1.54	1.48	0	6.75	1.69	1.6	0	4.79

[1] Summary Statistics for California and Michigan were produced using the obtained original data
[2] N/A: not available

Total Accident Models (TOTACC)

Since the variables PKLEFT1 and PKTRUCK were not present in the Georgia data, modifications to the validation procedure had to be performed as described earlier. In the validation, the same parameter estimates in the originally original report were used, and the parameter estimates were also reproduced without PKLEFT1 and PKTRUCK for the revised original model.

Two models (original model and revised original model) were used for the validation activity to determine GOF measures. For the original model, the same parameter estimates in the report were used. For the revised original model, since PKLEFT2 and PKTRUCK were not available in the Georgia data, these variables were removed from the original published model by dividing by the exponential value of their coefficients times their average effects, i.e., their average values.

The validation addressed the main model and one variant.

Main Model

The model re-estimation results are shown in table 84. For the revised original model, without the variables PKLEFT2 and PKTRUCK, the constant term and all of the variables were estimated with the same sign as the reported model, but all of them except PROT_LT were insignificant. The overdispersion parameter, *K*, was almost twice as high as that for the original model.

For the Georgia data, the constant term, AADT1, AADT2, and VEICOM were estimated with the same sign as the reported model, but there were differences in magnitude. PROT_LT was estimated with an opposite sign, although it was statistically insignificant. AADT2 and VEICOM were also insignificant. The overdispersion parameter, *K*, was substantially higher than that for the original models.

Table 84. Parameter Estimates for TOTACC Type V Model Using Georgia Data: Main Model

Variable	Original Estimate[1] (s.e., *p*-value)	Revised Estimates[2] (s.e, *p*-value)	Georgia Data 0.04 Mile (s.e., *p*-value)	Georgia Data 0.05 Mile (s.e., *p*-value)
Constant	-6.9536 (2.7911, 0.0132)	-4.084 (3.659, 0.4146)	-5.755 (3.432, 0.1403)	-5.430 (3.816, 0.2144)
Log of AADT1	0.6199 (0.2504, 0.0133)	0.272 (0.308, 0.3761)	0.606 (0.325, 0.0623)	0.575 (0.354, 0.1036)
Log of AADT2	0.3948 (0.1737, 0.0133)	0.422 (0.264, 0.1106)	0.222 (0.151, 0.1412)	0.219 (0.156, 0.1620)
PROT_LT	-0.6754 (0.1824, 0.0002)	-0.462 (0.222, 0.0372)	0.589 (0.437, 0.1782)	0.604 (0.463, 0.1922)
PKLEFT2	-0.0142 (0.0047, 0.0023)	N/A[4]	N/A[4]	N/A[4]
VEICOM	0.1299 (0.045, 0.0039)	0.094 (0.087, 0.2813)	0.012 (0.179, 0.9484)	0.011 (0.188, 0.9522)
PKTRUCK	0.0315 (0.0143, 0.0275)	N/A[4]	N/A[4]	N/A[4]
K[3]	0.1161	0.216	0.730	0.731

[1] Vogt, 1999, (p. 122)
[2] Coefficient estimates of the variables were reproduced without PKLEFT2 and PKTRUCK using the original data
[3] K: Overdispersion value
[4] N/A: not available

The validation statistics are shown in table 85. The revised original model was estimated with the same Pearson product-moment correlation coefficient as that for the original model. The MPB per year was larger than that for the original model, while the MADs were similar. The MSE per year was slightly higher than that for the original model.

The Pearson correlation coefficient for the Georgia data was relatively low, indicating a poor linear fit. A value of 0.18 of the Pearson correlation coefficient indicates that the accident predictions by the original model and the Georgia data are marginally correlated at best. The MPB and MAD per year were larger than those for the original models. The MSPEs per year squared were significantly higher than the MSEs per year squared, indicating a general lack-of-fit.

Table 85. Validation Statistics for TOTACC Type V Model Using Georgia Data: Main Model

Measure	Original 1993-95 Model[1]	Revised 1993-95 Model[2]	Georgia[2] 0.04 Mile	Georgia[2] 0.05 Mile
Years used for validation	1993-1995	1993-1995	1996-1997	1996-1997
Number of sites	49	49	51	51
Pearson product-moment correlation coefficients	0.73	0.73	0.18	0.18
MPB	-0.40	-3.06	-3.38	-3.06
MPB/yr	-0.13	-1.02	-1.69	-1.53
MAD	6.53	6.82	8.50	8.59
MAD/yr	2.18	2.27	4.25	4.30
MSE	77.04	95.92	N/A[3]	N/A[3]
MSE/yr^2	8.56	10.66		
MSPE	N/A[3]	N/A[3]	126.44	130.01
MSPE/yr^2			31.61	32.50

[1] The original main model in the report. This model includes PKLEFT2 and PKTRUCK

[2] Used the same coefficients in the original model, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects

[3] N/A: not available

Figure 13 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

Variant 1

The parameter estimates, their standard errors, and *p*-values are given in table 86. In the revised original model, without the variables PKLEFT2 and PKTRUCK, the constant term, AADT1*AADT2 and PROT_LT were estimated with the same sign as the reported model, but there were differences in magnitude. The constant term and VEICOM were statistically insignificant. The overdispersion parameter, *K*, was almost twice as high as that for the original model.

For the Georgia data, the constant term, AADT1*AADT2, and VEICOM were estimated with the same sign as the reported model, but the constant term and VEICOM were insignificant. PROT_LT was estimated with an opposite sign, but with similar degree of magnitude. The overdispersion parameter *K* was significantly higher than that for the original models.

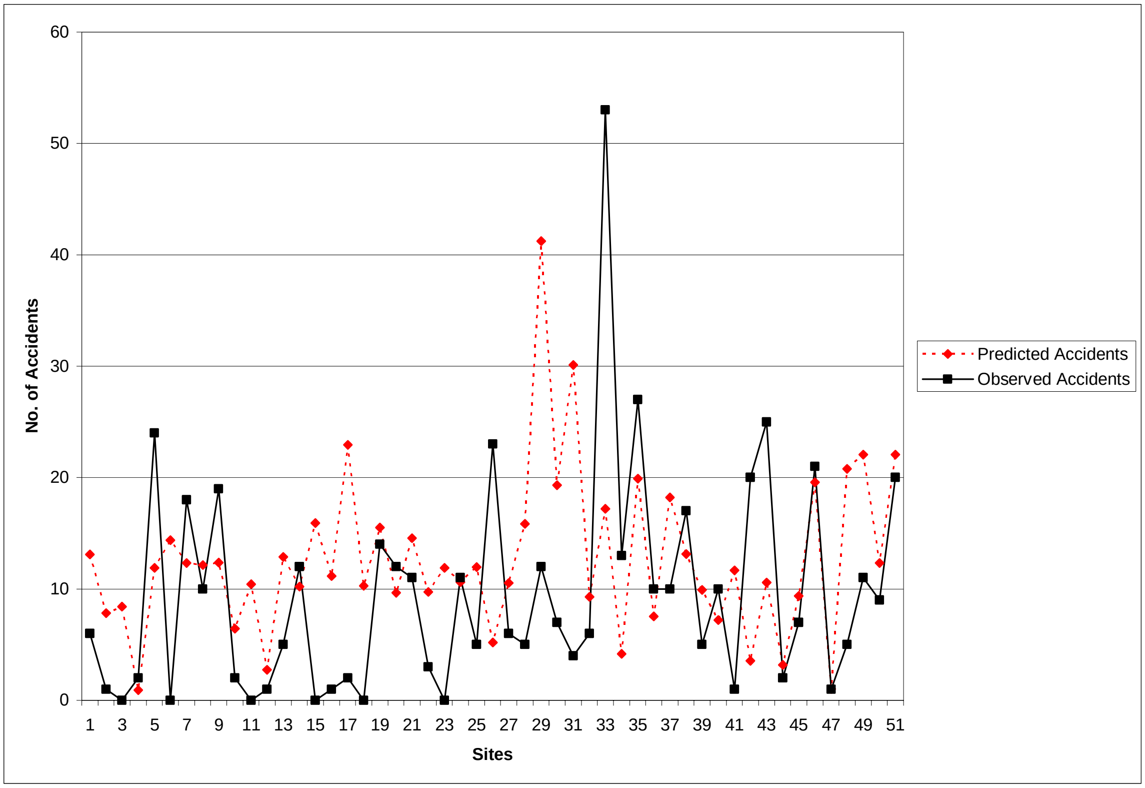

Figure 13. Observed versus Predicted Accident Frequency: TOTACC Main Model

Table 86. Parameter Estimates for TOTACC Type V Model Using Georgia Data:Variant 1

Variable	Original Estimate[1] (s.e., *p*-value)	Revised Estimates[2] (s.e, *p*-value)	Georgia Data[3] 0.04 Mile (s.e., *p*-value)	Georgia Data[3] 0.05 Mile (s.e., *p*-value)
Constant	-6.1236 (2.5973, 0.0184)	-4.589 (3.669, 0.34125)	-3.891 (2.313, 0.1668)	-3.766 (2.386, 0.1978)
Log of AADT1*AADT2	0.4643 (0.1483, 0.0017)	0.373 (0.212, 0.0792)	0.315 (0.141, 0.0256)	0.309 (0.146, 0.0343)
PROT_LT	-0.6110 (0.1507, 0.0001)	-0.501 (0.179, 0.0051)	0.684 (0.405, 0.0917)	0.682 (0.415, 0.1008)
PKLEFT2	-0.0134 (0.0048, 0.0052)	N/A[5]	N/A[5]	N/A[5]
VEICOM	0.1243 (0.0507, 0.0142)	0.097 (0.082, 0.2365)	0.009 (0.174, 0.9601)	0.008 (0.181, 0.9648)
PKTRUCK	0.0300 (0.0141, 0.0331)	N/A[5]	N/A[5]	N/A[5]
K[4]	0.1186	0.217	0.766	0.763

[1] Vogt, 1999, (p. 122)
[2] Coefficient estimates of the variables were reproduced without PKLEFT2 and PKTRUCK using the original data
[3] PKLEFT2 and PKTRUCK were not included in the model
[4] K: Overdispersion value
[5] N/A: not available

The validation statistics are shown in table 87. For the revised original model the Pearson correlation coefficient was the same as that for the reported model. The MPB per year was larger than that for the original model, while the MADs and MSEs per year were similar. A value of 0.19 of the correlation coefficient indicates that the accident predictions by the original model and the Georgia data are marginally correlated at best. The MPBs and MAD per year was almost twice as large as those for the original model. The MSPEs per year squared were also significantly higher than the MSEs per year squared, indicating a general lack-of-fit.

Table 87. Validation Statistics for TOTACC Type V Model Using Georgia Data: Variant 1

Measure	Variant 1[1]	Revised Variant 1[2]	Georgia data[2]	
			0.04 Mile	0.05 Mile
Years used for validation	1993-1995	1993-1995	1996-1997	1997-1997
Number of sites	49	49	51	51
Pearson product-moment correlation coefficients	0.73	0.73	0.19	0.19
MPB	-0.37	-2.81	-3.08	-2.76
MPB/yr	-0.12	-0.94	-1.54	-1.38
MAD	6.48	6.67	8.36	8.51
MAD/yr	2.16	2.22	4.18	4.26
MSE	73.31	88.12	N/A[3]	N/A[3]
MSE/yr^2	8.15	9.79		
MSPE	N/A[3]	N/A[3]	123.18	126.91
$MSPE/yr^2$			30.80	31.73

[1] The Variant 1 in the report. This model includes PKLEFT2 and PKTRUCK

[2] Used the same coefficients as Variant 1, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects

[3] N/A: not available

Figure 14 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

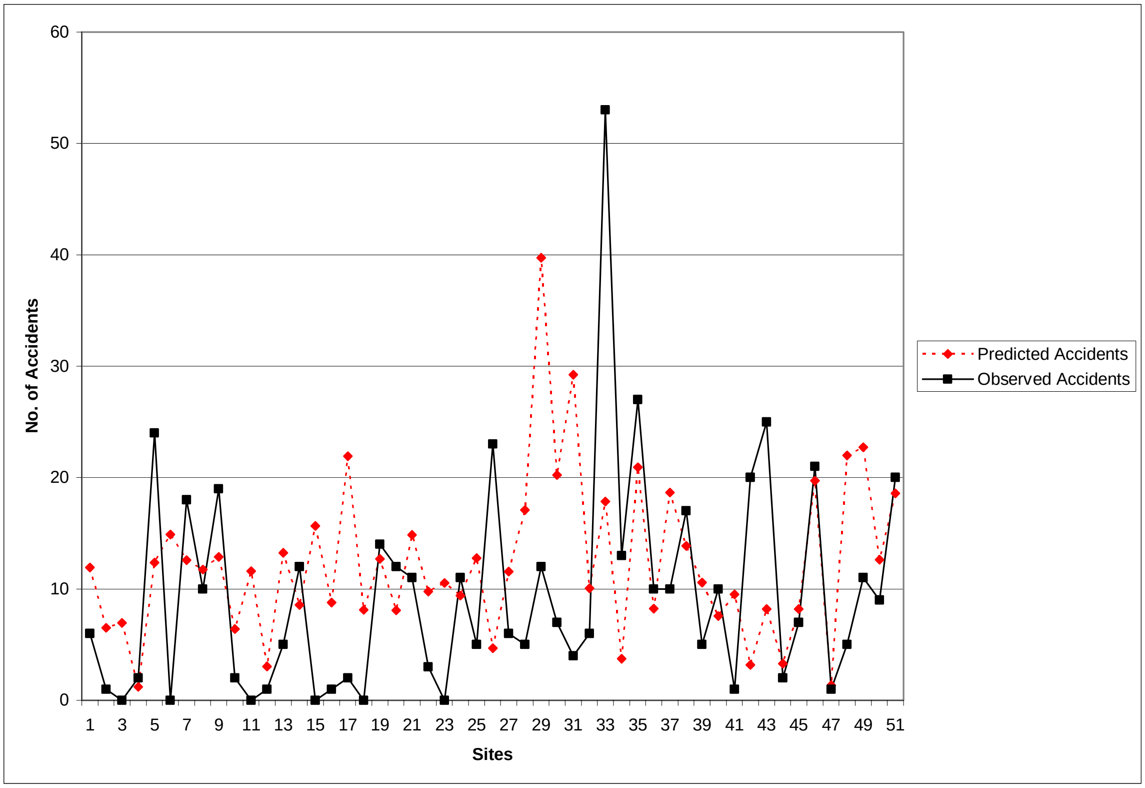

Figure 14. Observed versus Predicted Accident Frequency: TOTACC Variant 1

Intersection Related Total Accident Model (TOTACCI)

As before, since the variables PKLEFT1 and PKTRUCK were not present in the Georgia data, models were re-estimated without PKLEFT1 and PKTRUCK for the revised original model. In addition, the estimation of GOF measures, used a revised original in which these variables were removed from the original published model by dividing by the exponential value of their coefficients times their average effects, i.e., their average values.

The validation addresses the main model and one variant.

Main Model

The parameter estimates, their standard errors, and *p*-values are given in table 88. In the revised original model all of the variables were estimated with the same direction of effect as for the original model, but there were sizeable differences in magnitude and significance. The estimates for all of the variables and the constant term were statistically insignificant. The overdispersion parameter, *K*, was somewhat higher than that for the original model.

Table 88. Parameter Estimates for TOTACCI Type V Model Using Georgia Data: Main Model

Variable	Original Estimate[1] (s.e., *p*-value)	Revised Estimates[2] (s.e, *p*-value)	Georgia Data[3] 0.04 Mile (s.e., *p*-value)	Georgia Data[3] 0.05 Mile (s.e., *p*-value)
Constant	-6.0841 (3.3865, 0.0724)	-3.410 (3.663, 0.5281)	-6.551 (2.968, 0.0485)	-6.061 (3.486, 0.1236)
Log of AADT1	0.5951 (0.2847, 0.0366)	0.245 (0.315, 0.4373)	0.694 (0.286, 0.0151)	0.644 (0.327, 0.0487)
Log of AADT2	0.2935 (0.1972, 0.1366)	0.337 (0.248, 0.1742)	0.206 (0.154, 0.1813)	0.204 (0.158, 0.1981)
PROT_LT	-0.4708 (0.2000, 0.0186)	-0.256 (0.222, 0.2505)	0.610 (0.418, 0.1445)	0.637 (0.441, 0.1490)
PKLEFT2	-0.0165 (0.0057, 0.0036)	N/A[5]	N/A[5]	N/A[5]
VEICOM	0.1126 (0.0365, 0.0020)	0.073 (0.071, 0.3037)	0.021 (0.173, 0.9050)	0.021 (0.179, 0.9078)
PKTRUCK	0.0289 (0.0131, 0.0276)	N/A[5]	N/A[5]	N/A[5]
[4]K	0.1313	0.231	0.730	0.708

[1] Vogt, 1999, (p. 123)
[2] Coefficient estimates of the variables were reproduced without PKLEFT2 and PKTRUCK using the original data
[3] PKLEFT2 and PKTRUCK were not included in the model
[4] K: Overdispersion value
[5] N/A: not available

For the Georgia data, the constant term, AADT1, AADT2, and VEICOM were estimated with the same sign as the reported model, but there were differences in the magnitude and significance. PROT_LT was estimated with an opposite sign, although it was statistically insignificant. AADT2 and VEICOM also became insignificant. The overdispersion parameters, *K*, are significantly higher than for the original models.

The validation statistics are shown in table 89. The Pearson product-moment correlation coefficient of the revised original model was estimated to be the same as that for the original model. The MPB per year was somewhat larger, while the MAD per year was similar to that for the original model. The MSE per was higher than that for the original model, but the difference was not great.

A value of 0.23 of the Pearson correlation coefficient indicates that the accident predictions by the original model are marginally linearly correlated with observed number of accidents in the 1996 to 1997 period. The MPB and MAD per year were larger than those for the original models. The MSPEs per year squared were significantly higher than the MSEs per year squared, indicating a general lack-of-fit.

Figure 15 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

Table 89. Validation Statistics for TOTACCI Type V Model Using Georgia Data: Main Model

Measure	Original 1993-95 Model[1]	Revised 1993-95 Model[2]	Georgia data[2]	
			0.04 Mile	0.05 Mile
Years used for validation	1993-95	1993-95	1996-97	1996-97
Number of sites	49	49	51	51
Pearson product-moment correlation coefficients	0.62	0.61	0.23	0.23
MPB	-0.28	-4.04	-3.39	-3.16
MPB/yr	-0.09	-1.35	-1.70	-1.58
MAD	5.63	6.33	7.53	7.53
MAD/yr	1.88	2.11	3.77	3.77
MSE	58.24	85.81	N/A[3]	N/A[3]
MSE/yr^2	6.47	9.53		
MSPE	N/A[3]	N/A[3]	98.36	100.71
$MSPE/yr^2$			24.59	25.18

[1] The original main model in the report. This model includes PKLEFT2 and PKTRUCK

[2] Used the same coefficients as the original model, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects

[3] N/A: not available

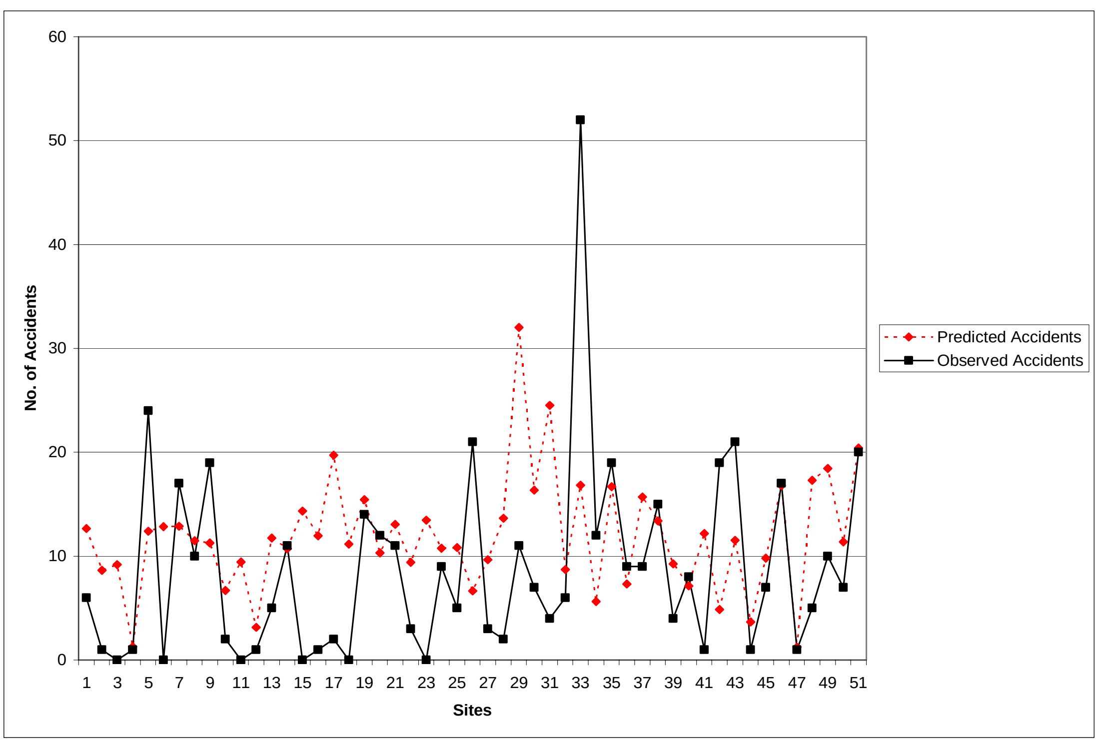

Figure 15. Observed versus Predicted Accident Frequency: TOTACCI Main Model

Variant 3

The parameter estimates, their standard errors, and *p*-values are provided in table 90.

In the revised original model all of the variables were estimated as insignificant, while only AADT2 was insignificant in the original model. There were also differences in the magnitude of the parameters. The overdispersion parameter, *K*, was almost twice as high as that for the original model.

For the Georgia data, the constant term, AADT1, AADT2, and VEICOM were estimated with the same sign as the reported model, but there were slight differences in magnitude. PROT_LT and DRWY1 were estimated with an opposite sign to that in the original model, but these were insignificant. VEICOM was also insignificant. The overdispersion parameter *K* was significantly higher than that for the original model, indicating lack-of-fit to the Georgia data.

Table 90. Parameter Estimates for TOTACC Type V Model Using Georgia Data: Variant 3

Variable	Original Estimate[1] (s.e., *p*-value)	Revised Estimates[2] (s.e, *p*-value)	Georgia Data[3] 0.04 Mile (s.e., *p*-value)	Georgia Data[3] 0.05 Mile (s.e., *p*-value)
Constant	-5.4581 (3.1937, 0.0874)	-2.783 (3.472, 0.6277)	-6.475 (2.872, 0.0441)	-6.006 (3.367, 0.1146)
Log of AADT1	0.5995 (0.2795, 0.0319)	0.265 (0.298, 0.3732)	0.713 (0.289, 0.0137)	0.663 (0.324, 0.0405)
Log of AADT2	0.2015 (0.1917, 0.2932)	0.219 (0.255, 0.3911)	0.188 (0.156, 0.2291)	0.187 (0.159, 0.2397)
PROT_LT	-0.4041 (0.1883, 0.0319)	-0.222 (0.199, 0.2666)	0.591 (0.400, 0.1402)	0.617 (0.422, 0.1437)
PKLEFT2	-0.0177 (0.0050, 0.0005)	N/A[5]	N/A[5]	N/A[5]
VEICOM	0.1114 (0.0326, 0.0006)	0.070 (0.068, 0.3049)	0.021 (0.170, 0.8998)	0.021 (0.175, 0.9023)
PKTRUCK	0.0256 (0.0117, 0.0287)	N/A[5]	N/A[5]	N/A[5]
DRWY1	0.0407 (0.0246, 0.0983)	0.047 (0.036, 0.1874)	-0.033 (0.064, 0.6011)	-0.031 (0.062, 0.6153)
K[4]	0.1145	0.208	0.725	0.704

[1] Vogt, 1999, (p. 123)
[2] Coefficient estimates of the variables were reproduced without PKLEFT2 and PKTRUCK using the original data
[3] PKLEFT2 and PKTRUCK were not included in the model
[4] K: Overdispersion value
[5] N/A: not available

Table 91 shows the validation statistics. The Pearson product-moment correlation coefficient of the revised original model was estimated to be the same as the original model. The MPB and MAD per year were somewhat larger than for the original model. The MSE per was also higher than that for the original model.

Table 91. Validation Statistics for TOTACCI Type V Model Using Georgia Data: Variant 3

Measure	Variant 3[1]	Revised Variant 3[2]	Georgia[2] 0.04 Mile	Georgia[2] 0.05 Mile
Years used for validation	1993-95	1993-95	1996-97	1996-97
Number of sites	49	49	51	51
Pearson product-moment correlation coefficients	0.67	0.67	0.22	0.22
MPB	-0.31	-5.41	-5.49	-5.25
MPB/yr	-0.10	-1.80	-2.74	-2.63
MAD	5.34	6.67	8.68	8.68
MAD/yr	1.78	2.22	4.34	4.34
MSE	51.57	98.20	N/A[3]	N/A[3]
MSE/yr^2	5.73	10.91		
MSPE	N/A[3]	N/A[3]	118.60	119.85
MSPE/yr^2			29.65	29.96

[1] Variant 3 in the report; this model includes PKLEFT2 and PKTRUCK

[2] Used the same coefficients as Variant 3, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects

[3] N/A: not available

A value of 0.22 of the Pearson correlation coefficient indicates that the accident predictions by the original model are marginally linearly correlated with observed number of accidents in the 1996 to 1997 period. The MPBs and MADs per year for the Georgia data were larger than those for the original models. The MSPEs were also significantly higher than the MSEs, which suggests lack-of-fit to the Georgia data.

Figure 16 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

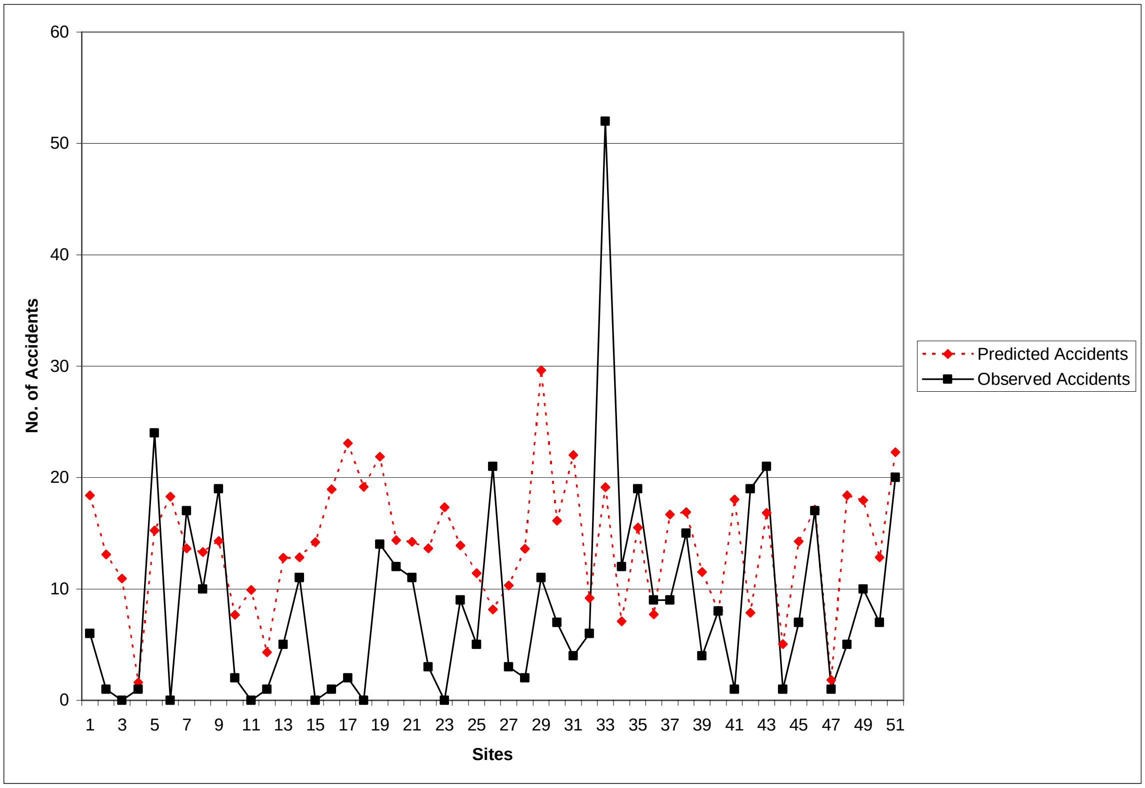

Figure 16. Observed versus Predicted Accident Frequency: TOTACCI Variant 3

Injury Accident Model (INJACC)

The parameter estimates, their standard errors, and *p*-values are provided in table 92. The models estimated with the Georgia data generally showed differences in sign, magnitude, and significance of the parameter estimates. PROT_LT and VEICOM were estimated with an opposite sign to those in the original model, although they were insignificant. The constant term and AADT1*AADT2 were estimated with the same direction of effect and in general a similar degree of magnitude and significance to the original model. The overdispersion parameter *K* was significantly higher than that for the original model.

Table 93 shows the GOF measures for the original injury accident model in the Vogt report applied to the Georgia data.[2]

The Pearson product-moment correlation coefficient was similar to that for the TOTACC model. However, the MPB, MAD, and MSPE per year squared were smaller.

Table 92. Parameter Estimates for INJACC Type V Model Using Georgia Data

Variable	Original Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile[2] (s.e., *p*-value)	Georgia Data 0.05 Mile[2] (s.e., *p*-value)
Constant	-3.2562 (2.9932, 0.2767)	-3.952 (2.455, 0.1845)	-3.815 (2.437, 0.2002)
Log of AADT1*AADT2	0.2358 (0.1722, 0.1707)	0.239 (0.150, 0.1100)	0.234 (0.149, 0.1153)
PROT_LT	-0.2943 (0.1864, 0.1144)	0.439 (0.398, 0.2700)	0.361 (0.397, 0.3640)
PKLEFT2	-0.0113 (0.0062, 0.0678)	N/A[4]	N/A[4]
VEICOM	0.0822 (0.0551, 0.1358)	-0.007 (0.177, 0.9683)	0.008 (0.179, 0.9641)
PKTRUCK	0.0323 (0.0146, 0.0267)	N/A[4]	N/A[4]
K[3]	0.1630	0.647	0.662

[1] Vogt, 1999, (p. 124)
[2] PKLEFT2 and PKTRUCK were not included in the model
[3] K: Overdispersion value
[4] N/A: not available

Table 93. Validation Statistics for INJACC Type V Model Using Georgia Data

Measure	Georgia data[1]	
	0.04 Mile	0.05 Mile
Years used for validation	1996-1997	1996-1997
Number of sites	51	51
Pearson product-moment correlation coefficients	0.15	0.15
MPB	-1.99	-1.89
MPB/yr	-1.00	-0.95
MAD	2.89	2.82
MAD/yr	1.45	1.41
MSPE	11.24	11.00
MSPE/yr[2]	2.81	2.75

[1] Used the same coefficients as the original model, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects
[2] K: Overdispersion value

Figure 17 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

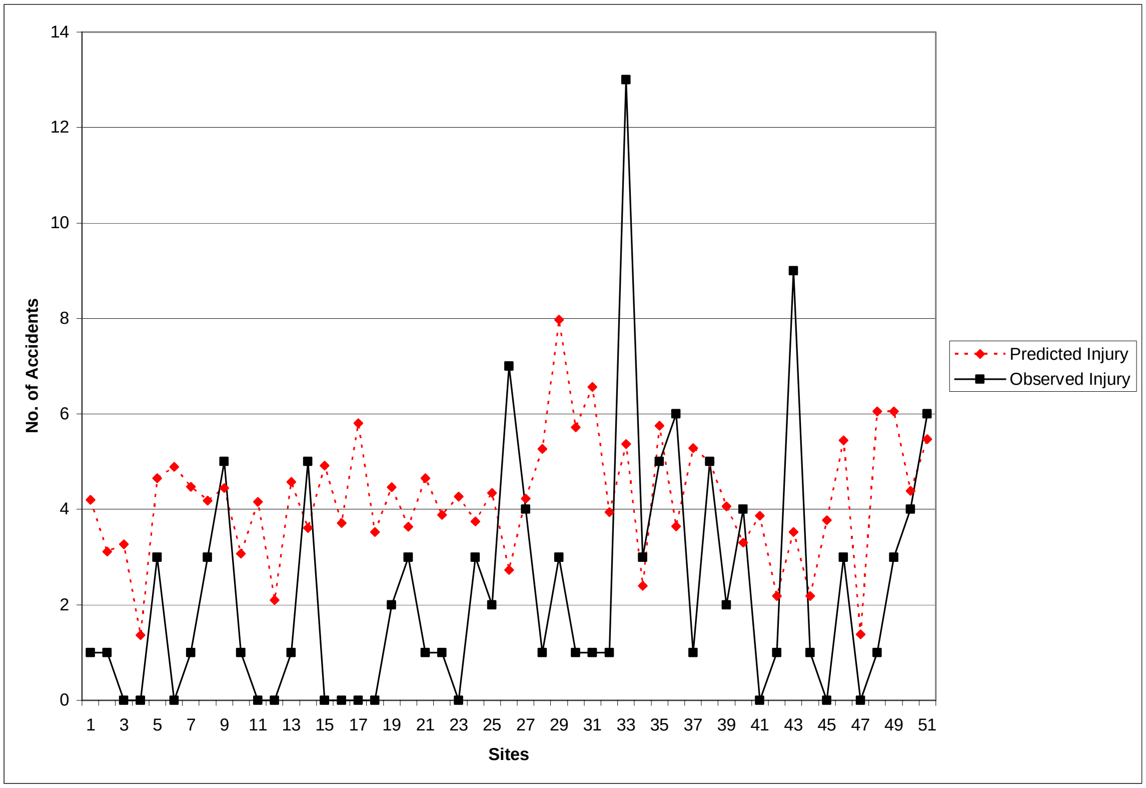

Figure 17. Observed versus Predicted Accident Frequency: INJACC

Intersection Related Total Injury Accident Model (INJACCI)

The parameter estimates, their standard errors, and *p*-values are provided in table 94. For the Georgia data, the constant term, AADT1*AADT2, and VEICOM were estimated with the same sign but with differences in magnitude and significance. The constant term and AADT1*AADT2 were estimated as significant, while they were insignificant in the original model. The overdispersion parameters, *K*, were significantly higher than that for the original model.

Table 95 shows the GOF measures for the original intersection related injury accident model (Variant 1) in the Vogt report applied to the Georgia data.[2]

The Pearson product-moment correlation coefficient was slightly higher than for the TOTACCI model, and the MPB, MAD, and MSPE per year squared were smaller.

Table 94. Parameter Estimates for INJACCI Type V Model Using Georgia Data

Variable	Original Estimate[1] (s.e., *p*-value)	Georgia Data 0.04 Mile[2] (s.e., *p*-value)	Georgia Data 0.05 Mile[2] (s.e., *p*-value)
Constant	-1.5475 (3.0298, 0.6095)	-5.029 (2.904, 0.0384)	-4.777 (2.100, 0.0518)
Log of AADT1*AADT2	0.1290 (0.1757, 0.4627)	0.302 (0.127, 0.0176)	0.288 (0.127, 0.0237)
PKLEFT2	-0.0149 (0.0066, 0.0250)	N/A[4]	N/A[4]
VEICOM	0.0686 (0.0692, 0.1858)	0.054 (0.187, 0.7731)	0.062 (0.188, 0.7420)
PKTRUCK	0.0282 (0.0152, 0.0628)	N/A[4]	N/A[4]
K[3]	0.1433	0.752	0.754

[1] Vogt, 1999, (p. 124)
[2] PKLEFT2 and PKTRUCK were not included in the model
[3] K: Overdispersion value
[4] N/A: not available

Table 95. Validation Statistics for INJACC Type V Model Using Georgia Data

Measure	Georgia[1]	
	0.04 Mile	0.05 Mile
Years used for validation	1996-1997	1996-1997
Number of sites	51	51
Pearson product-moment correlation coefficients	0.27	0.27
MPB	-2.60	-2.52
MPB/yr	-1.30	-1.26
MAD	3.25	3.18
MAD/yr	1.62	1.59
MSPE	12.84	12.56
MSPE/yr[2]	3.21	3.14

[1] Used the same coefficients as the original model, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects
[2] K: Overdispersion value

Figure 18 depicts the prediction performance of the original model for individual sites in the Georgia 0.05-mile data. It is quite evident that the original model generally does not fit the Georgia data well, a finding that would have been expected on the basis of the low Pearson product-moment coefficients.

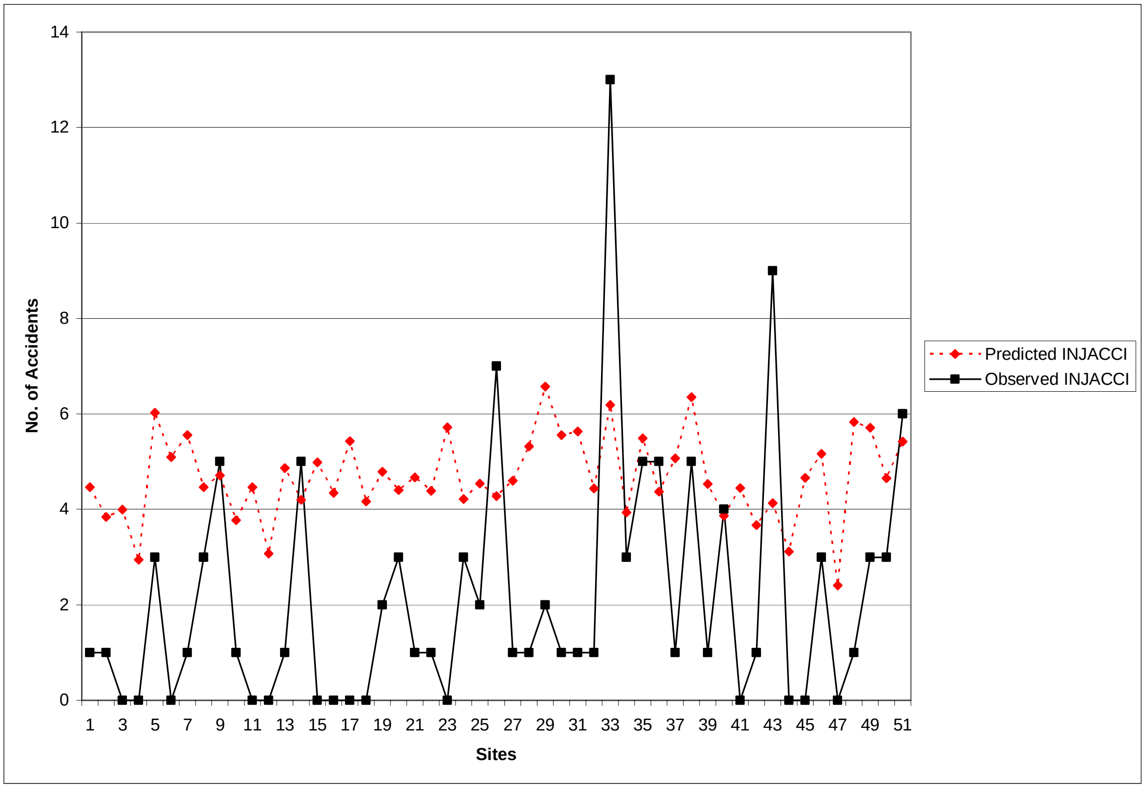

Figure 18. Observed versus Predicted Accident Frequency: INJACCI

2.6 VALIDATION ACTIVITY 3: VALIDATION OF THE ACCIDENT PREDICTION ALGORITHM

Two tasks were undertaken to validate the accident prediction algorithm in Harwood et al.:[(3)]

1. Validate the recommended base models for sites meeting "base" conditions.
2. Validate the accident prediction algorithm against all Georgia sites and California and Michigan datasets for Model V.

The Minnesota and Washington data could not be used for validating the algorithms for models I and II because sight distance, one of the variables for which an AMF is applied, was not known at these sites.

Data Limitations in the Michigan Data

As previously discussed for validation activity 2, it was discovered subsequent to the analysis and draft report that the later year crossroad accident numbers at the Michigan Type V sites should be systematically higher than the values used. The various measures of GOF statistics would be also improved if the higher numbers were used. Although the GOF measures should improve, the conclusions drawn from these data and the Georgia data would not change since Model V is in need of recalibration in any case.

2.6.1 Validation of the Base Models

Model I

The recommended base model for type I intersections is:

$$N_{bi} = \exp(-10.9 + 0.79 \ln AADT_1 + 0.49 \ln AADT_2) \quad (8)$$

where
N_{bi} = the expected number of annual intersection-related collisions;
$AADT_1$ = average daily traffic volume on the major road; and
$AADT_2$ = average daily traffic volume on the minor road.

The following are the base conditions to which the model applies:

- Roadside hazard rating = 2.
- Presence of right-turn lane on major road = none present.
- Presence of left-turn lane on major road = none present.
- Skew = none.
- Sight Distance = no restrictions.

The roadside hazard rating is not a restriction for a "base" intersection because no AMF is provided for roadside hazard rating. Only 11 sites in the Georgia data met the base conditions. Summary accident statistics for these sites are shown in table 96.

Table 96. Summary Accident Statistics for Sites Meeting Base Conditions

No. Sites = 11 No. Years = 2	Mean	Median	Std. Deviation	Minimum	Maximum
Georgia Data 0.04 Mile	1.00 (0.50/year)	1.00	0.77	0	2
Georgia Data 0.05 Mile	1.00 (0.50/year)	1.00	0.77	0	2

Table 97 shows the validation statistics for the 11 Type I base model intersections.

Table 97. Validation Statistics for Type I Base Model Intersections

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for validation	1996-1997	1996-1997
Number of sites	11	11
Pearson product-moment correlation coefficients	-0.26	-0.26
MPB MPB/yr	0.36 0.18	0.36 0.18
MAD MAD/yr	0.94 0.47	0.94 0.47
MSE MSE/yr[2]	N/A[1]	
MSPE MSPE/yr[2]	1.29 0.32	1.29 0.32

[1] MSE is unknown since these statistics were not given in the report (Harwood et al., 2000)
[2] K: Overdispersion value

The Pearson correlation coefficients indicate a negative correlation between the base model predictions and the observed number of accidents. The other statistics also indicate a relatively poor fit, although it should be considered that only eleven sites were available for this validation activity.

Model II
The recommended base model for type II intersections is:

$$N_{bi} = \exp(-9.34 + 0.60 \ln AADT_1 + 0.61 \ln AADT_2) \tag{9}$$

where
N_{bi} = the expected number of annual intersection-related collisions;
$AADT_1$ = average daily traffic volume on the major road; and
$AADT_2$ = average daily traffic volume on the minor road.

The following are the base conditions to which the model applies:

- No driveways within 76.25 m (250 ft) of the intersection on the major road.
- Presence of right-turn lane on major road = none present.
- Presence of left-turn lane on major road = none present.
- Skew = none.
- Sight Distance = no restrictions.

The number of driveways is not a restriction for a ‘base’ intersection because no AMF is provided for driveway density. Only nine sites in the Georgia data met the base conditions. Summary accident statistics for these sites are shown in table 98.

Table 98. Summary Accident Statistics for Sites Meeting Base Conditions

No. Sites = 9 No. Years = 2	Mean	Median	Std. Deviation	Minimum	Maximum
Georgia Data 0.04 Mile	3.00 (1.50/yr)	1.00	4.09	0	12
Georgia Data 0.05 Mile	3.00 (1.50/yr)	1.00	4.09	0	12

Table 99 shows the validation statistics for the nine Type II base model intersections.

Table 99. Validation Statistics for Type II Base Model Intersections

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for validation	1996-1997	1996-1997
Number of sites	9	9
Pearson product-moment correlation coefficients	0.81	0.81
MPB	1.78	1.78
MPB/yr	0.89	0.89
MAD	2.15	2.15
MAD/yr	1.08	1.08
MSE	N/A[1]	
MSE/yr[2]		
MSPE	12.90	12.90
MSPE/yr[2]	3.23	3.23

[1] MSE is unknown since these statistics were not given in the report (Harwood et al., 2000)
[2] K: Overdispersion value

The Pearson correlation coefficients indicate a high correlation between the base model predictions and observed number of accidents. The other statistics, however, indicate a poor fit, although it should be considered that only nine sites were available for validation.

Model V

The base model in the accident prediction algorithm is identical to the Variant 3 of the Vogt model for TOTACCI.

$$N_{bi} = \exp(-5.46 + 0.60 \ln AADT_1 + 0.20 \ln AADT_2 - 0.40\ PROT\_LT - 0.018 PKLEFT2 + 0.11\ VEICOM + 0.026\ PKTRUCK + 0.041 DRWY1) \qquad (10)$$

where

N_{bi} = predicted number of total intersection-related accidents per year for nominal or base conditions;

PROT_LT = presence of protected left-turn signal phase on one or more major-road approaches; = 1 if present; = 0 if not present;

PKLEFT2 = percentage of minor-road traffic that turns left at the signal during the morning and evening hours combined;

VEICOM = grade rate for all vertical curves (crests and sags) within 76.25 m (250 ft)) of the intersection along the major and minor roads;

PKTRUCK = percentage of trucks (vehicles with more than four wheels) entering the intersection for the morning and evening hours combined; and

DRWY1 = number of driveways within 76 m (250 ft) of the intersection on the major road.

With the nominal conditions of PRTO_LT, PKLEFT2, VEICOM, and PKTRUCK, the base model reduces to:

$$N_{bi} = \exp(-5.73 + 0.60 \ln AADT_1 + 0.20 \ln AADT_2) \qquad (11)$$

The following are the base conditions to which the model applies:

- No PROT_LT.
- 28.4 percent of PKLEFT2.
- No VEICOM.
- 9.0 percent of PKTRUCK.
- No DRWY1.

Because none of the Georgia sites met the base conditions for the base model in equation (11), and the independent variables in equation (10) are available in the Georgia data, the base model in equation (10) was used for validation. Table 113 shows the validation statistics for this base model. Because PKLEFT2 and PKTRUCK were not included in the Georgia data, they were removed from the models by dividing both sites of models by the exponential values of the coefficients of the variables times their average effects (the average effects of PKLEFT2 and PKTRUCK are the average values of PKLEFT2 and PKTRUCK).

The validation statistics are shown in table 100. Lower Pearson product-moment correlation coefficients (0.36 and 0.22 in table 100) for the additional years of accidents and the Georgia data indicate that the accident predictions by the base model are not strongly correlated with additional years of accidents and are marginally correlated with the Georgia data, at best. The MPBs and MAD per year was larger than those for the original years. The MSPEs per year squared were higher than the MSEs per year squared. In particular, the MSPEs per year squared with the Georgia data were more than twice as high as the MSEs per year squared, which indicates that the model is performing poorly against the Georgia data.

Table 100. Validation Statistics for Type V Base Model Intersections

Measure	California and Michigan[1]		Georgia[1]	
	93-95 Year	96-97 Year	0.04 Mile	0.05 Mile
Years used for validation	1993-1995	1996-1997	1996-1997	1996-1997
Number of sites	49	49	51	51
Pearson product-moment correlation coefficients	0.68	0.36	0.22	0.22
MPB MPB/yr	-5.22 -1.74	-6.37 -3.18	-5.85 -2.93	-5.18 -2.59
MAD MAD/yr	6.58 2.19	7.39 3.70	9.06 4.53	8.63 4.31
MSE MSE/yr[2]	85.24 10.58	N/A[2]	N/A[2]	N/A[2]
MSPE MSPE/yr[2]	N/A[2]	86.93 21.73	129.00 32.25	118.80 29.70

[1] Used the same coefficients in the Variant 3, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects.
[2] MSE is unknown since these statistics were not given in the report (Harwood et al., 2000)

2.6.2 Validation of the Accident Prediction Algorithm

The accident prediction algorithm was validated against the data collected in Georgia using the recommended base models and AMFs provided in Harwood et al. in 2000.[(3)] These AMFs are shown in table 101. The AMFs provided in a 2002 report by Harwood et al. also were validated.[(5)] These AMFs are shown in table 101 in brackets.

Table 101. The AMFs for Type I, II, and V Intersections

Variable	AMF		
	Type I Intersections	Type II Intersections	Type V Intersections
Intersection Skew	exp(0.004*SKEW)	exp(0.0054*SKEW)	1.00
Left-Turn Lane on Major	1.00 if none exist 0.78 if at least one exists (0.56 if at least one exists)	1.00 if none exist 0.76 on one approach (0.72 on one approach) 0.58 on both approaches (0.52 on both approaches)	1.00 if none exist 0.82 on one approach 0.67 on both approaches
Right-Turn Lane on Major	1.00 if none exist 0.95 on one approach (0.86 on one approach) 0.90 on both approaches (0.74 on both approaches)		1.00 if none exist 0.975 on one approach (0.96 on one approach) 0.95 on both approaches (0.92 on both approaches)
Sight Distance	1.00 if adequate in all quadrants 1.05 if limited in one quadrant 1.10 if limited in two quadrants 1.15 if limited in three quadrants 1.20 if limited in four quadrants		1.00

Intersection skew is defined as the deviation from an intersection angle of 90 degrees and carries a positive or negative sign that indicates whether the minor road intersects the major road at an acute or obtuse angle.

Left-Turn Lane on Major takes a value of one if no left-turn lane exists on the major road and the values in table 101 where one or more exists.

Right-Turn Lane on Major takes a value of one if no right-turn lane exists on the major road and the values in table 101 where one or more exists.

Sight Distance in a quadrant is considered limited if the available sight distance is less than that specified by the American Association of State Highway and Transportation Officials (AASHTO) policy for left and right turns from the minor road for a design speed of 20 km/hour (km/hr) (12.5 miles/hr) less than the major road design speed.(7)

In the Georgia data, design speed of the major road was not known. The posted speed limit of the major road was used in lieu of subtracting 20 km/hr (12.5 miles/hr) from the design speed when using the AASHTO warrant for sight distance.

In applying the algorithm, a calibration factor is applied to the model, calculated as the ratio of the observed number of accidents to the predicted number of accidents prior to the calibration factor being applied. Harwood et al. recommend that the sample for estimating this calibration factor be such that the distribution of traffic volumes is similar to that in the data used for the original calibration.(3) This was not possible for the Georgia data due to the small sample size. It was felt that this should not create a deterrent, because the calibration factor, at least in the procedure as proposed, is independent of traffic volume and is applied to all intersections regardless of the distribution of traffic volumes in the jurisdiction. Therefore, it is of interest to examine if the procedure would work for the likely situation where the distribution of traffic volumes in the new jurisdiction is different from the distribution in the calibration data.

In the tables of results, the calibration factors greater or less than 1.0 indicate whether intersections will experience more or less accidents than the intersections used in the development of the base models for the accident prediction algorithm.

Model I

Table 102 shows the validation statistics for Type I intersections. For comparison, the results for the AMFs provided in the Harwood et al. 2000 report are not bracketed, and the results for AMFs provided in Harwood et al. 2002 report are in brackets.[3,5] Low Pearson product-moment correlation coefficients with the Georgia data indicate that the accident predictions by the algorithm are not correlated strongly with the observed number of accidents in the Georgia data. Other validation statistics also suggest a lack-of-fit to the Georgia data. There is little difference between the two sets of AMFs for turning lanes.

Table 102. Validation Statistics for the Accident Prediction Algorithm: Type I

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for validation	1996-1997	1996-1997
Number of sites	121	121
Pearson product-moment correlation coefficients	0.45 (0.44)	0.47 (0.46)
MPB MPB/yr	0.00 0.00	0.00 0.00
MAD MAD/yr	1.13 0.57 (1.15) (0.58)	1.18 0.59 (1.20) (0.60)
MSE MSE/yr[2]	N/A[1]	
MSPE MSPE/yr[2]	2.59 0.65 (2.66) (0.67)	2.82 0.70 (2.89) (0.72)
Calibration Factor	2.57 (2.60)	2.73 (2.76)

[1] MSE is unknown since these statistics were not given in the report (Harwood et al., 2000)
[2] K: Overdispersion value

To compare further the two sets of AMFs for turning lanes, the validation statistics were calculated for only those sites with a major road turning lane, as shown in table 103. The AMFs from Harwood et al. (2000) provided better validation statistics than those in Harwood et al. (2002), although the differences in validation statistics and sample sizes are small.[3,5]

Table 103. Validation Statistics for the Accident Prediction Algorithm: Type I Sites with a Major Road Turning Lane

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Years used for validation	1996-1997	1996-1997
Number of sites	7 3 with left-turn lane 4 with right-turn lane	7 3 with left-turn lane 4 with right-turn lane
Pearson product-moment correlation coefficients	0.85 (0.78)	0.66 (0.52)
MPB MPB/yr	0.00 0.00	0.00 0.00
MAD MAD/yr	0.036 0.018 (0.052) (0.026)	0.043 0.022 (0.059) (0.030)
MSE MSE/yr[2]	N/A[1]	
MSPE MSPE/yr[2]	0.045 0.011 (0.084) (0.021)	0.059 0.015 (0.097) (0.024)
Calibration factor	2.57 (2.60)	2.73 (2.76)

[1] MSE is unknown since these statistics were not given in the report (Harwood et al., 2000)
[2] K: Overdispersion value

Model II

Table 104 shows the validation statistics for Type II intersections. For comparison, the results for the AMFs provided in Harwood et al. (2000) are not bracketed, and the results for AMFs provided in Harwood et al. (2002) are in brackets.[3,5] Low Pearson product-moment correlation coefficients with the Georgia data indicate that the accident predictions by the algorithm are not correlated strongly with the observed number of accidents in the Georgia data. Other validation statistics also suggest lack-of-fit to the Georgia data. There is little difference between the two sets of AMFs for turning lanes.

Table 104. Validation Statistics for the Accident Prediction Algorithm: Type II

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Number of years	2	2
Number of sites	114	114
Pearson product-moment correlation coefficients	0.53 (0.51)	0.53 (0.51)
MPB MPB/yr	0.00 0.00	0.00 0.00
MAD MAD/yr	1.69 0.85 (1.72) (0.86)	1.70 0.85 (1.72) (0.86)
MSE MSE/yr[2]	N/A[1]	
MSPE MSPE/yr[2]	5.45 1.36 (5.59) (1.40)	5.46 1.36 (5.60) (1.40)
Calibration Factor	2.15 (2.18)	2.17 (2.20)

[1] MSE is unknown because these statistics were not given in the report (Harwood et al., 2000)
[2] K: Overdispersion value

To compare further the two sets of AMFs for turning lanes, the validation statistics were calculated for only those sites with a major road turning lane. As the results in table 105 indicate, the AMFs from Harwood et al. (2000) provided better validation statistics than those in Harwood et al. (2002), although the differences in validation statistics and sample sizes are small.[3,5]

Model V

Again, the base model in the equation (10) was used for the accident prediction algorithm, because none of the sites met the nominal base conditions. PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential values of the coefficients of these variables times their average effects.

Table 106 shows the validation statistics for Type V intersections. For comparison, the results for the AMFs provided in Harwood et al. (2000) are not bracketed, and the results for AMFs provided in Harwood et al. (2002) are in brackets.[3,5] The validation statistics suggest a lack-of-fit to the Georgia data.

Table 105. Validation Statistics for the Accident Prediction Algorithm: Type II Sites with a Major Road Turning Lane

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Number of years	2	2
Number of sites	7 6 with left-turn lane on both approaches 3 with right-turn lane	7 6 with left-turn lane on both approaches 3 with right-turn lane
Pearson product-moment correlation coefficients	0.52 (0.47)	0.52 (0.47)
MPB MPB/yr	0.00 0.00	0.00 0.00
MAD MAD/yr	0.158 0.079 (0.175) (0.088)	0.158 0.079 (0.174) (0.087)
MSE MSE/yr[2]	N/A[1]	
MSPE MSPE/yr[2]	0.74 0.19 (0.89) (0.22)	0.73 0.18 (0.88) (0.22)
Calibration Factor	2.15 (2.18)	2.17 (2.20)

[1] MSE is unknown since these statistics were not given in the report (Harwood et al., 2000)
[2] K: Overdispersion value

Table 106. Validation Statistics for the Accident Prediction Algorithm: Type V

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Number of years	2	2
Number of sites	51	51
Pearson product-moment correlation coefficients	0.04 (0.05)	0.05 (0.05)
MPB MPB/yr	0.00 0.00	0.00 0.00
MAD MAD/yr	6.99 3.49 (6.94) (3.47)	7.14 3.57 (7.09) (3.55)
MSE MSE/yr[2]	N/A[1]	
MSPE MSPE/yr[2]	89.23 22.31 (89.56) (22.39)	93.89 23.47 (94.18) (23.55)
Calibration Factor	0.81 (0.83)	0.83 (0.85)

[1] Used the same coefficients as Variant 3, but PKLEFT2 and PKTRUCK were removed from the model by dividing by the exponential value of the coefficient of these variables times their average effects
[2] MSE is unknown since these statistics were not given in the report (Harwood et al., 2000)

To compare further the two AMFs for right turn on major road, the validation statistics were calculated for only those sites with a major road right-turn lane. These results are shown in table 107. There is little difference between the two AMFs, not surprising given the closeness of their estimates.

Table 107. Validation Statistics for the Accident Prediction Algorithm: Type V Sites with a Major Road Right-Turn Lane

Measure	Georgia Data 0.04 Mile	Georgia Data 0.05 Mile
Number of years	2	2
Number of sites	21 (13 with right-turn lane on one approach, 8 with right-turn lane on both approaches)	21 (13 with right-turn lane on one approach, 8 with right-turn lane on both approaches)
Pearson product-moment correlation coefficients	0.12 (0.11)	0.13 (0.12)
MPB MPB/yr	0.00 0.00	0.00 0.00
MAD MAD/yr	8.21 4.11 (8.24) (4.12)	8.41 4.11 (8.44) (4.22)
MSE MSE/yr^2	N/A[1]	
MSPE MSPE/yr^2	49.55 12.39 (50.07) (12.52)	52.82 13.21 (53.37) (13.34)
Calibration Factor	1.40 (1.43)	1.43 (1.46)

[1] MSE is unknown because these statistics were not given in the report (Harwood et al., 2000)

2.7 DISCUSSION OF RESULTS

Although the body of this report presented validation results in order of validation exercises, the results here are presented by model, beginning with Model I results and ending with Model V results. The validation exercises in the body of this report focused primarily on external validation—validation concerned with assessing performance of the models compared to external data. This discussion is focused on internal validation concerns—the internal coherence, structure, theoretical soundness, and plausibility of the models proposed. More focus is given to internal validation in the recalibration research task scheduled to follow this validation.

The discussion provided here focuses primarily on summarizing the results that are detailed and discussed in the body of this report, and translating these results into meaningful observations and conclusions. The intent of the discussion is to provide insight and lay groundwork for the recalibration of the models to follow. The reader interested in additional details, such as sources of original results and comparison tables, should refer to the body of the report. Descriptions of all variable abbreviations and definitions used in this report are found at the beginning of this document.

It should be noted throughout the discussion that the subjective criteria of alpha equal to 0.10 is used. The support for this level of alpha is as follows. In statistical models of crash occurrence, a Type II error can be argued to be more serious than a Type I error. With a Type I error, the analyst concludes that the null hypothesis is false when in fact it is true with alpha probability (this translation is not precise, but the precise and correct conditional probability interpretation is cumbersome and for practical purposes does not lend any additional insights). This means that the analyst would conclude, for example, that the presence of a left-turn lane reduces crashes when in reality it does not. As a result of this conclusion one might install left-turn lanes without realizing a reduction in crashes. In addition, the relatively small sample sizes and preponderance of engineering theoretical support for variable selection decisions also supports a relatively larger alpha.

A Type II error occurs with beta probability. In general, the larger the alpha, the smaller is the beta. So choosing a larger alpha means that a smaller beta has been chosen, all else being equal. Thus, continuing with the previous example, making a Type II error results in concluding that the presence of a left-turn lane does not reduce crashes when in fact it does. The risk is in failing to install an effective countermeasure. To summarize, committing a Type I error results in applying an ineffective countermeasure, while committing a Type II error results in failing to apply an effective countermeasure. Computing the actual beta in negative binomial models is extremely difficult. However, knowing that a fairly liberal alpha equal to 0.10 has been used suggests that a smaller level of beta has also been selected.

GOF statistics provide an ability to objectively assess the fit of a model to data. Comparisons between models, however, are generally subjective. In the following analyses the terms “serious,” “moderate,” and “marginal” are applied to denote a subjective evaluation of GOF comparisons between models. Serious differences in GOF are suggestive of noteworthy or significant model deficiencies. Moderate differences in GOF suggest cases where models could be improved, but improvements might be difficult to obtain. Marginal differences in GOF are thought to be negligible and are potentially explained by random fluctuations in the observed data.

Before discussing the results, it should be noted that an attempt to reproduce variables in data acquired from the original research revealed some definitional problems. These definitional problems resulted in values of some variables that are different than they would have been in the original research. Small differences in the variable VCI1 for Models I and II are thought to stem from an inability to reproduce “exceptional” cases of vertical curvatures encountered in the database. For Model II, the variables AADT1 and DEV had small differences in the median values, and these were considered to be marginal. For Model V, the vertical-alignment related variables VEI1, VEI2, and VEICOM computed in the original models could not be reproduced precisely in data acquired from the original researchers. For Models III and IV, all of the variables in data acquired from the original researchers were reproduced within rounding-error precision. These differences, on the whole, are unlikely to materially affect the overall conclusions, although they may contribute to an explanation for some individual results.

2.7.1 Model I

Predictive Ability Across Time

To the extent possible, new data were collected from later time periods to validate the crash models (see table 3). Note that it was discovered subsequent to the analysis and draft report that some errors exist in the accident data due to changing mileposts although these errors are negligible and would have no effect on any conclusions drawn from the analysis.

Table 4 shows a comparison of the parameter estimates for the original published total accidents model and one based on the additional data. As might be expected, variables that were not statistically significant in the original model were not statistically significant in the model based on additional years of data, with one exception. The variable SPD1 became a highly significant variable, compared to marginally significant in the original model, while, conversely, the RT MAJ and HAZRAT1 became statistically insignificant, with the former having the opposite sign.

Table 5 shows the GOF statistics of Model I (total accidents model) on the additional years of data. The evidence in the table suggests that the original model is predicting future crashes as well as for the calibration data. All of the GOF statistics showed marginal differences between the validation data and the calibration (estimation) data.

Predictive Ability Across Space

Georgia data were used to investigate the model's performance across jurisdictional boundaries. Data used to estimate Model I were obtained from Minnesota. Comparison of the recalibrated and original models for TOTAL crashes (table 53) shows that HI1, HAU, and RT MAJ had the opposite sign for the Georgia data, with RT MAJ becoming insignificant for Georgia. For INJURY crashes, all model variables, with the exception of the main road AADT, were insignificant when estimated with Georgia data, and HI1, RT MAJ, HAU, and SPD1 had the opposite signs than those in the original model (table 55).

The validation statistics for the TOTAL crashes model (see table 54) show that the correlation coefficient (0.66) between observed and predicted crashes is reduced by about 50 percent (0.31) on Georgia data—a rather serious drop. Other statistics also show considerable lack-of-fit of the Georgia data relative to the Minnesota data. The MSE per year squared of 0.19 for the recalibrated model compares to an MSPE per year squared of 0.89, which represents a serious difference in fit. This difference suggests that the original model is not capturing the variability in crashes in the Georgia data.

Crash Prediction Algorithms

Eleven sites in Georgia were available for validating the base condition for the crash prediction algorithm (see table 96). Despite the small sample size, the correlation coefficient between predicted and observed crashes for the base condition model was -0.26 (see table 97), indicating a marginal to moderate model deficiency—downgraded from serious due to the small sample size. Because of the small sample size and the homogenous nature of the intersections (all possess base conditions in common), the base model predicts as a function of minor and major road AADTs only.

Model I Assessment and Conclusions

The model for three-legged stop controlled intersections with two lanes both on minor and major roads has fairly mixed validation results. The major assessments and conclusions derived from the analysis include the following:

- The model performed better in the same jurisdiction (Minnesota) in a future time period than across a different jurisdiction (Georgia). This suggests that variables that quantify differences in facility design, traffic, or environmental conditions across States are missing from the model.
- Potential missing variables might include number of wet, icy, or foggy days, dark (nighttime) versus light (daylight) crashes.
- Presence of right-turn lanes (RT MAJ) can pose a problem in intersection models. If installed at intersections due to mostly capacity problems, then the presence might indicate an improvement in crashes (due to reduction in conflicts and crashes). If installed due to high-crash conditions or in conjunction with another intersection improvement prompted by high-crash conditions, the presence of a right-turn lane might be associated with increased numbers of crashes. This phenomenon might explain the switching of the sign associated with the RT MAJ variable observed in the validation effort associated with Model I and other models.
- Because the model will be used for predictions in jurisdictions other than Minnesota, improvements to the models predictive power is desired.

2.7.2 Model II

Predictive Ability Across Time

To the extent possible, new data were collected from later time periods to validate the crash models. Note that Minnesota data were used in the original model calibration (estimation), and only the additional years of data for Minnesota data could be used for the validation test across time. It was discovered subsequent to the analysis and draft report that some errors exist in the accident data due to changing mileposts, although these errors are negligible and would have no effect on any conclusions drawn from the analysis.

Table 13 shows a comparison of the parameter estimates for the original TOTAL crash model and one based on the additional years of data. The constant term and all variables had the same signs, but most had large differences in magnitude, in particular those with low significance in both models. The model based on additional years gains the HI1 variable as statistically significant.

Table 14 shows the GOF statistics of the Type II (TOTAL crashes model) on additional years of data. The linear correlation coefficient shows consistent performance into the future, and a comparison of MSE per year squared (0.095) and MSPE per year squared

(0.185) suggests that the variability in future crashes is not being captured as well as for the data on which the original model is based.

Predictive Ability Across Space

Georgia data were used to investigate the model's performance across jurisdictional boundaries (see table 57). Data used to estimate Model II were obtained from Minnesota. Comparison of the original (Minnesota) and Georgia models for TOTAL crashes (table 58) shows that the two AADT variables had similar magnitudes and are the only variables the two models shared as statistically significant. The variable SPD1 became statistically significant for Georgia, whereas the variable DRWY1 was statistically significant in the original (Minnesota) model. For INJURY crashes, the models again shared statistically significant AADT related variables, while the only other statistically significant variable was HAZRAT1 in the original (Minnesota) model (see table 60).

The validation statistics for TOTAL crashes (see table 59) show that the correlation coefficient between observed and predicted crashes is reduced by about 50 percent on Georgia data—a rather serious drop. Other statistics show a moderate to serious increase in lack-of-fit, including increases in MAD (moderate) and a serious increase in MSPE per year squared (1.73) compared to MSE per year squared (0.10) in the original model.

Crash Prediction Algorithms

Nine sites in Georgia were available for validating the base condition for the crash prediction algorithm (see table 98). The correlation coefficient between predicted and observed crashes for the base condition model was 0.81 (see table 99), indicating a strong linear trend between observed and predicted values.

Model II Assessment and Conclusions

The model for four-legged stop controlled intersections with two lanes both on minor and major roads has fairly mixed validation results—although they are more favorable than for Model Type I. The major assessments and conclusions derived from the analysis include the following:

- The model performed better in the same jurisdiction (Minnesota) in a future time period than across a different jurisdiction (Georgia). This suggests that variables that quantify differences in facility design, traffic, or environmental conditions across States are missing from the model.
- Potential missing variables might include number of wet, icy, or foggy days, dark (nighttime) versus light (daylight) crashes.
- The flip-flopping of variables that are statistically significant in original and validation models suggest that sample sizes, in general, are too small to detect the small effects some of the variables have on safety.
- Since the model will be used for predictions in jurisdictions other than Minnesota, improvements to the models predictive power is desired.

2.7.3 Model III

Predictive Ability Across Time

To the extent possible, new data were collected for additional time periods to validate the crash models (see table 21). Data from Michigan and California from the years 1996 and 1997 were used for the validation effort. Recall that the original model was calibrated on data from Michigan and California from 1993 to 1995.

Table 22 shows a comparison of the parameter estimates for the original published TOTAL crash model and one based on additional years of data. Comparison of the original model and the model based on the later data reveals that two variables, MEDWDTH1 and DRWY1, have become statistically insignificant in the additional years model. In addition, the coefficient for log of AADT2 is 0.26 in the original model and 0.52 in the model based on the additional years of data. The re-estimated models for INTERSECTION RELATED total and INJURY crashes (variant 1 and variant 2) are shown in table 24, table 26, and table 28. For the INTERSECTION RELATED total crash model, the additional years of data did not produce statistically significant variables for MEDWDTH1 and DRWY1, while the original model did, and again, the coefficient for log of AADT2 was twice as large for the additional years model. Considering variant 1 of the INJURY models, the variable HAU was not statistically significant for the additional years of data; that is unlike the case for the original calibrated model, and the coefficient for log of AADT2 was again twice as large for the additional years model. Considering variant 2, the variables HAU, DRWY1, and ABSGRD1 became statistically significant for the additional years of data.

Table 23 shows the GOF statistics of Model III for TOTAL crashes on additional years of data. The linear correlation coefficient shows a moderate decline when calculated on the additional years of data. A comparison of MSE per year squared (1.22) and MSPE per year squared (1.39) suggests a marginal increase in lack-of-fit. Similarly, the MAD per year shows a marginal increase in lack-of-fit. Table 25, for INTERSECTION RELATED crashes, shows similar performance assessments as the model for TOTAL crashes.

Predictive Ability Across Space

Georgia data were used to investigate the model's performance across jurisdictional boundaries. A comparison of Georgia data for Model III is shown in table 62. The table shows that many variables have similar magnitudes across the calibration (California and Michigan) and validation (Georgia) data sets. The one notable exception is MEDWIDTH1, which is considerably larger in the Georgia data than in the original data. More than half of the Georgia sites had medians on the major road compared to only 5.8 percent of the original sites.

Comparison of the original and Georgia models for TOTAL crashes (table 63) shows that the models are quite different. In fact, only the variable log of AADT2 is statistically significant in the model calibrated using Georgia data, while the original published model had all variables, log of AADT1, log of AADT 2, MEDWIDTH1, and DRWY1, as statistically significant. Similar results are seen for the TOTAL INTERSECTION

RELATED crash model (table 65), and variant 1 (table 67) and variant 2 (table 69) of the INJURY crash models. Thus, a serious lack of agreement between the originally calibrated models and the models estimated using Georgia data is observed.

All of the validation statistics (see table 64 and table 66) are consistent with the lack of agreement in model specification between original and Georgia data. The correlation between predicted and observed is seriously different on Georgia data. The MPB and MAD statistics show a significant worsening of the fit. Finally, the MSE per year squared for the calibration data is considerably lower than the MSPE per year squared for Georgia data. The plots of observed and predicted crashes for individual intersections in figures 5 and 6 shows that predictions are much less variable than are observations. Thus it is likely that some of the explanatory variables are inadequate for predicting Georgia data.

Crash Prediction Algorithms

There are no AMFs to validate for Model III.

Model III Assessment and Conclusions

The model for three-legged stop controlled intersections with two lanes on minor and four lanes on major roads revealed some serious model concerns. These concerns are summarized below:

- The TOTAL crash model performs moderately well across time. However, even at the same sites the model specification changes significantly in a future time period—with the exclusion of two originally significant variables. The models for INTERSECTION RELATED TOTAL and INJURY crashes perform similarly, but both exhibit moderate to serious model specification difficulties. This suggests that variables thought to be important may in fact not be important, or are highly correlated with truly important variables.
- The model was seriously deficient in predicting Georgia data, despite an apparent similarity in the raw data. It is clear that variables in the California and Michigan model are not specified appropriately for Georgia data.
- Model III is in need of improvement, based on the validation findings across time and space.

2.7.4 Model IV

Predictive Ability Across Time

To the extent possible, new data were collected from later time periods to validate the crash models (see table 30). Data from Michigan and California from 1996 and 1997 were used for this validation effort. Recall that the original model was calibrated on data from Michigan and California from 1993 to 1995.

Table 31 shows a comparison of the parameter estimates for the original published TOTAL crash model and one based on the additional years of data. Comparison of the original model and the model based on the later data reveals that the model performs very well on later data—all of the variables in the model are statistically significant in both models. The largest difference is the coefficient of log of AADT2, which changes from 0.32 in the original published model to 0.50 in the additional years model. All other coefficients are similar in magnitude and share the same sign. The same minor differences exist for the INTERSECTION RELATED total crash model, shown in table 33. For the INJURY crash model (see table 38) and the INTERSECTION RELATED INJURY crash model (see table 40), the variable log of AADT1 becomes statistically insignificant on additional years of data.

Table 32 shows the GOF statistics of Model IV for TOTAL crashes on the additional years of data. The linear correlation coefficient shows a marginal increase when calculated on the additional years of data. A comparison of MSE per year squared (3.40) and MSPE per year squared (2.39) suggests a moderate improvement in the fit to later data. The MADs per year is similar, but the MPBs per year indicates a serious lack-of-fit to later years of data. Table 34 shows similar performance assessments for the INTERSECTION RELATED total crash model.

Predictive Ability Across Space

Georgia data were used to investigate the model's performance across jurisdictional boundaries. A comparison of TOTAL crashes compared to Georgia data for Model IV is shown in table 71. The table shows that many variables are similar across the calibration (California and Michigan) and validation (Georgia) data sets, with the exception of LTLNS, which is moderately smaller (70 percent had left-turn lanes) in the calibration data (Michigan and California) than in the validation (Georgia) data, where 83 percent had left-turn lanes.

Some mathematical "work-arounds" had to be performed to circumvent a missing data problem in the validation data set. The coefficient for log of AADT2 becomes insignificant in Georgia; and the sign of LTLN1S changes from negative to positive, meaning that in the calibration data the presence of a left-turn lane is associated with decreased TOTAL crashes, while in Georgia the presence of a left-turn lane is associated with increased TOTAL crashes.

All of the validation statistics (see table 75) are at least consistent with the lack of agreement in model specification between original and Georgia data, and perhaps suggest a more substantial departure. The correlation between predicted and observed is significantly reduced, going from 0.56 (original) to 0.05 and 0.08 (Georgia). The MPB and MAD statistics show a moderate increase in lack-of-fit. Finally, the MSE per year squared (3.62) for the calibration data is moderately lower than the MSPE per year squared (4.63) for Georgia data.

The plot of observed and predicted crashes for individual intersections in figure 9 shows that predictions are much less variable than are observations. Thus it is likely that some of the explanatory variables are inadequate for predicting Georgia data. The models for INTERSECTION RELATED and the two variants for INJURY crashes are more seriously deficient than the TOTAL crash models. None of the models had statistically significant variables that corresponded with the original models. Table 76, table 78, and table 80 show the serious differences between original published models and the models estimated using Georgia data.

Crash Prediction Algorithms

There are no AMFs to validate for Model IV.

Model IV Assessment and Conclusions

The model for four-legged stop controlled intersections, two lanes on minor roads, and four lanes on major roads revealed model deficiencies ranging from moderate to serious. These concerns are summarized below:

- The model performs well across time. The model for TOTAL crashes performs better than the models for INTERSECTION RELATED and INJURY crashes, but all models show only marginal to moderate deficiencies.
- All models were seriously deficient in predicting Georgia data, as evidenced by the lack-of-fit and the inability of the Georgia data to fit the specified models.
- Model IV needs to be improved, based on the validation findings across time and space. The observations suggest that the most important differences are jurisdictional in nature—pointing towards the consideration of design, traffic, and environmental variables that are not included in the model.

2.7.5 Model V

Predictive Ability Across Time

To the extent possible, new data were collected from later time periods to validate the crash models (see table 39). Data from Michigan and California from years 1996 and 1997 were used for the validation effort. Recall that the original model was calibrated on data from Michigan and California from 1993 to 1995. For signalized intersections in Michigan, the accident data for 1996 and 1997 did not include the crossroad accidents where the crossroad was a State route, because the crossroad milepost information was not available at the time of analysis. As a result, the later year crossroad accident numbers of the State routes should be systematically higher than those supposed to be. However, these differences would not have any effect on the conclusions drawn from the analysis.

Table 40 shows a comparison of the parameter estimates for the original published TOTAL crash model and one based on the later data. This comparison reveals that there are moderate to serious differences between the models. PKLEFT2 and VEICOM are not statistically significant in the model based on additional years of data.

Table 41 shows the GOF statistics of Model V for TOTAL crashes on the later data. The linear correlation coefficient between observed and predicted data shows a moderate to serious decrease when calculated on future year data (0.73 to 0.40). A comparison of MSE per year squared (8.56) and MSPE per year squared (21.19) suggests a poor fit to the additional years of data. The MAD per year shows a moderate increase in lack-of-fit, while the MPB per year indicates a serious lack-of-fit. Table 42, 44, 46, 48, and 50 for INTERSECTION RELATED TOTAL and INJURY crash models and their variants also show serious differences between the original and models based on later data. However, the models are deficient in different ways, with different sets of variables becoming statistically insignificant.

Predictive Ability Across Space

Georgia data (see table 82) were used to investigate the model's performance across jurisdictional boundaries. A comparison of TOTAL crashes compared to Georgia data for model V is shown in table 84. The table shows moderate to serious departures between the original published models and the models based on Georgia data. The variables PROT_LT, log of AADT2, and VEICOM were not statistically significant in the Georgia data.

All of the validation statistics (see table 85) are consistent with the serious lack of agreement in model specification between original and Georgia data. The correlation between predicted and observed is substantially reduced, going from 0.73 (original) to 0.18 (Georgia). The MPB per year and MAD per year statistics show a poor fit. Finally, the MSE per year squared for the calibration data is significantly lower than the MSPE per year squared for Georgia data, again suggesting a serious deficiency.

The plot of observed and predicted crashes for individual intersections in figure 13 shows that predictions are much less variable than are observations, and also shows some systematic prediction error, with a tendency to overpredict crashes.

The predictive ability of the models and their variants for INTERSECTION RELATED Total and INJURY crashes are difficult to assess, since the original models could not be duplicated with similar results. Specifically, many or all of the statistically significant variables in the original published models could not be duplicated in the recalibration-so assessing the predictive ability is difficult, at best.

Crash Prediction Algorithms

Fifty-one sites in Georgia were available for validating the base condition equation for the crash prediction algorithm (see table 100). The correlation coefficient between predicted and observed crashes for the base condition model was 0.22, indicating a weak linear trend between observed and predicted values, and a serious to moderate decline from the same statistics calculated on the original published data (0.68 and 0.36 for different base years). Other statistics show moderate to serious lack-of-fit.

Model V Assessment and Conclusions

The model for signalized intersections of two-lane roads revealed model deficiencies ranging from moderate to serious. These concerns are summarized below:

- The inability to recreate the original data hampered the ability to fully validate these models.
- The models did not appear to perform adequately over time; however, part of the lack-of-fit is likely due to the inability to reproduce the original results. The models exhibited a serious lack-of-fit to the Georgia data.
- Model V is likely in need of improvement; however, a better understanding of the model deficiencies can be gained only by recreating the original data.

3. RECALIBRATION

This chapter presents recalibration results for the five types of rural intersections that were the subject of the validation exercise undertaken in the first part of the project. The first section provides a discussion of the recalibration approach. In the second section, the data and related issues are discussed. Third, AADT model estimation results are presented, followed by fully parameterized model estimation results. Sensitivity analysis results for the AMFs derived in this research then are given. Finally, a discussion and conclusions as a result of model recalibration are provided.

3.1 RESEARCH APPROACH

This model recalibration effort complemented the comprehensive model validation previously conducted as part of a larger technical evaluation of crash prediction models. It should be acknowledged that several anticipated end-uses of the crash prediction models guided all decisions made throughout this careful evaluation, which resulted in some specific overriding considerations while conducting the model recalibration:

- The most likely end-use of the crash prediction models is embedded code within the IHSDM, with the sole intent to predict future crashes at intersections throughout the United States.
- The models need to be able to predict the change in safety as a result of changes in traffic and geometric features relative to nominal conditions, corrected for intersection type and State- or regional-specific effects.
- Environmental effects on safety, such as adverse weather and lighting conditions, while important factors, will be accounted for in State or regional correction factors.

Considering the likely end uses of the crash prediction models within the IHSDM, considerable time was spent identifying a strategy for recalibrating statistical models. A strategy was needed for several reasons. First, there were multiple levels and types of models in the source documents—requiring a prioritization of models to be calibrated. Second, there are numerous methodological approaches reflected in the source documents, which need to be prioritized. Finally, the treatment of explanatory variables is dependent upon the methodological approach taken. Before describing the research technical strategy, some guiding philosophical principles used to guide the model recalibration effort are presented.

It was felt that the majority of effort in the recalibration should be devoted to refinements to existing models. This includes changes to parameter estimates, and perhaps minor changes to model functional forms. This approach is based on the collective opinion that prior work, including the estimation of statistical models, was done carefully by experts in the field of transportation safety, and decisions such as variable selection, model functional form, and statistical model selection represent state-of-the-art knowledge with respect to intersection crash prediction models. Past documentation, critical evaluation, and discussion with other experts in the field confirm prior beliefs that the existing set of models represents a defensible and sound starting point. It is believed that moderate to serious departures from existing models should be accompanied by detailed and defensible descriptions of the how, why, and in what cases departures from previous methods and/or models were thought necessary and useful. Finally, capabilities with regard to model recalibration are limited, simply because of existing data limitations, availability of explanatory variables, and intersection representativeness across States. When these limitations are thought to be critical they are identified and discussed.

The technical strategy applied in this research effort is now described. Each of the strategies represents different possible end uses of the models, influenced by the stated guiding philosophical principles.

<u>AADT Models</u>: One set of models represents intersection crash models that forecast crashes in frequency-per-year based on minor and major road AADT-only. There are no other independent variables in these models. The intended use of these models is to provide a baseline crash forecast, which can then be modified with AMFs representing the effects of various geometric, roadside, and other relevant safety-related factors. The sample available for calibrating these models was much larger than the sample available for calibrating full models that, in a sense, partly compensates for the loss of statistical precision resulting from the omission of variables other than AADT.

<u>Full Models</u>: Another set of models represents statistical models with a full set of explanatory variables, including major and minor road AADT. These models are meant to provide a fuller understanding of the geometric, roadside, and operational features of intersections that influence on crashes. Another use might be to develop or infer additional crash modification factors for the various types of intersections examined in this research.

<u>AMFs</u>: A final set of "models" represents estimated effects of various geometric, roadside, and operational features. These provide a complement to the AADT models. The intended use of the AMFs is to provide percentage corrections to expected crash frequencies that result from the application of various crash countermeasures. AMFs represent a fairly intuitive approach to evaluating safety countermeasures, and are handled rather simply in the IHSDM.

When comparing and refining the three types models, several GOF measures were used in addition to inspection of model coefficients, collection of explanatory variables, and *t*-statistics and their associated *p*-values. Numerous measures are relied upon to avoid basing decisions on one single measure. Unfortunately, there is no one single criterion that dominates to the point of rendering the remaining measures as invalid or unimportant. It is through the assessment of many measures that a "best" model is chosen, and it is not always a clear winner.

3.1.1 Model Functional Forms

The negative binomial model form, which is identical to that used in previous efforts, was used to provide the best fit to the data.[1,2] The following model form and error distribution were assumed to represent the underlying phenomenon:

AADT Only Models

$$\hat{Y}_i = \exp\left(\alpha + \beta_1 AADT_1 + \beta_2 AADT_2\right) \tag{12}$$

where

$\hat{Y}$ = the mean number of accidents to be expected at site *i* in a given time period;
α = the estimated intercept term; and
β_1 β_2, estimated coefficients.

Fully Parameterized Models

The following model form and error distribution were assumed to represent the underlying phenomenon:

$$\hat{Y}_i = AADT_1^{\beta_1} AADT_2^{\beta_2} \exp\left(\alpha + \sum_{j=3}^{n} \beta_{ij} X_{ij}\right) \tag{13}$$

where

$\hat{Y}$ = the mean number of accidents to be expected at site *i* in a given time period;
α = the estimated intercept term;
$X_{i1}, X_{i2}....X_{in}$, = the values of the non-traffic highway variables at site i during that time period; and
β_{i1} β_{i2}.....β_{in}, = estimated coefficients.

$$Var\{m\} = E\{m\} + K * E\{m\}^2 \tag{14}$$

where

$Var\{m\}$ = the estimated variance of the mean accident rate;
$E\{m\}$ = the estimated mean accident rate from the model; and
K = the estimated overdispersion constant.

3.1.2 Goodness-of-Fit Evaluation

Four GOF measures were used in the model selection process (refer to chapter 2 for a description of the GOF measures.). A fifth approach to evaluating the GOF and in particular the suitability of alternate model forms was the Cumulative Residuals (CURE) method, proposed by Hauer and Hauer and Bamfo, in which the cumulative residuals (the difference between the actual and fitted values for each intersection) are plotted in increasing order for each covariate separately.[8,9] The graph shows how well the model fits the data with respect to each individual covariate. Figure 19 illustrates the CURE plot for the covariate AADT1 for the total accidents for the selected AADT-only model for

Type III intersections (presented in table 142). The indication is that the fit is very good for this covariate in that the cumulative residuals oscillate around the value of zero and lie between the two standard deviation boundaries. Figure 20 is a CURE plot for an alternate model. Clearly, the alternate model cannot be judged to be an improvement over the selected model. Appendix D contains CURE plots for the TOTACC AADT models for all intersection types.

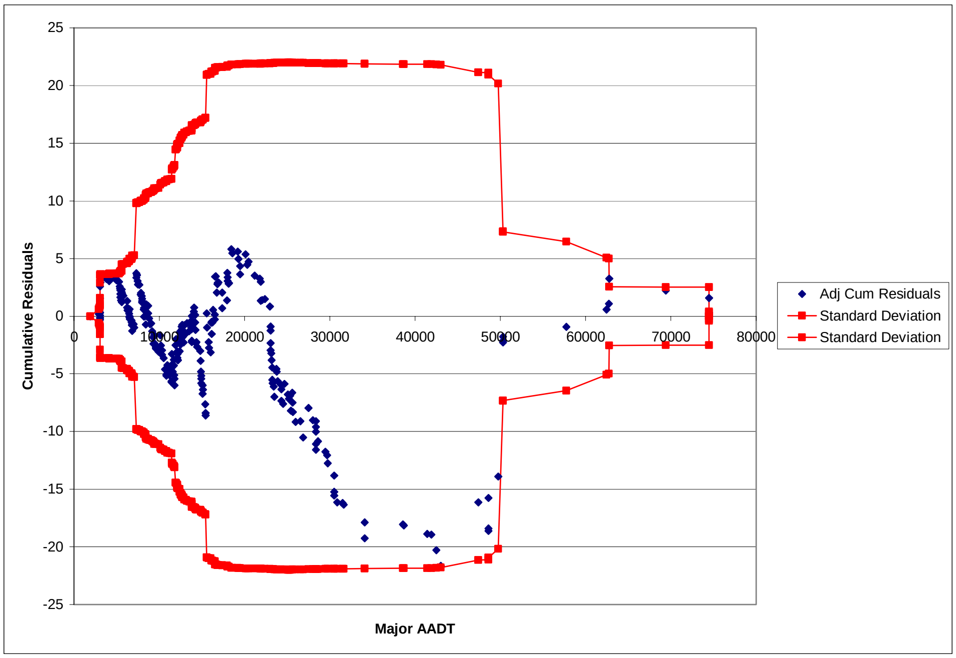

Figure 19. CURE Plot for Type III TOTACC AADT Model

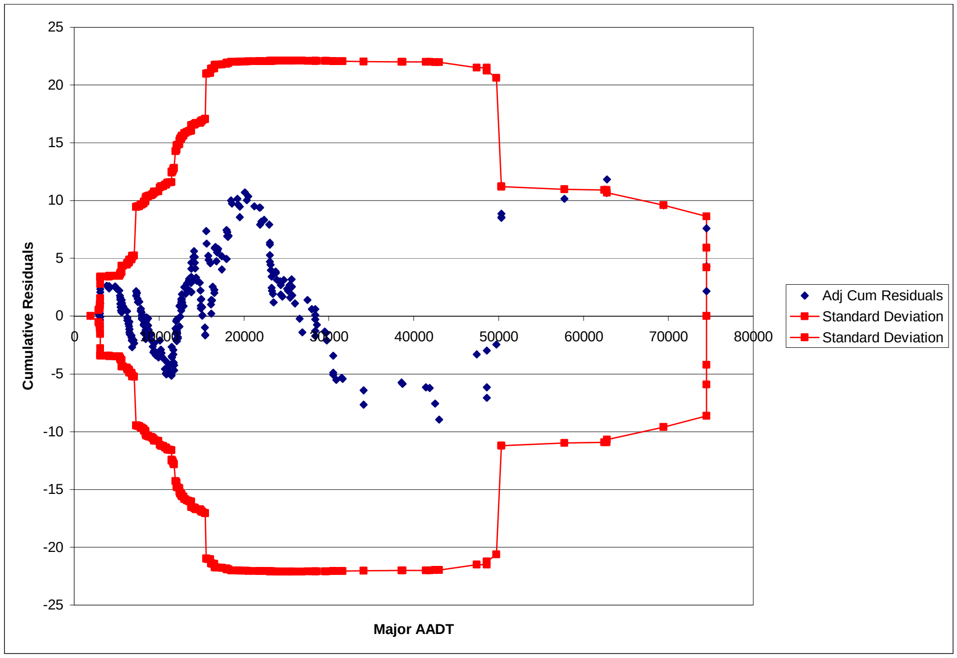

Figure 20. CURE Plot for Type III TOTACC AADT Model Using the CURE Method: Alternative Model

Now that the model's end uses, guiding research philosophies, and technical modeling strategy have been described, the details of the technical modeling efforts are presented and discussed. It is useful to first describe the data that were used in the model recalibration efforts, and to identify any difficulties, anomalies, and peculiar circumstances that needed to be remedied in the effort.

3.2 DESCRIPTION OF DATA

Different variables were used in developing statistical models for Types I and II compared to Types III, IV, and V. Although average daily traffic variables are common to all models, in general there were a larger number of variables available for estimation of model Types III, IV, and V. The abbreviation employed in the modeling efforts and their descriptions are provided in the following section.

3.2.1 Summary of Datasets

The data used for recalibration were obtained from three sources. The first two sets were identical to the data used for the validation exercise described in chapter 2. The first set was the original calibration data used by Vogt and Bared from Minnesota and Vogt from California and Michigan.[1,2] Additional years of accident and traffic data were obtained for those sites which did not experience a change in major variables, such as traffic control or number of legs. There were primarily minor differences in the summary statistics between those calculated on the available data and those stated in the reports, particularly for the vertical curvature variables for Type V sites. However, existing differences are sufficiently minor that further clarification was not necessary. The accident data obtained for the original sites included data for both the original and additional years. Differences were found in the accident counts between the original data obtained and this new dataset for the original years. Again, although small differences exist, their causes are unknown and these discrepancies were small enough that the data could confidently be used for recalibration. The second source of data was for those sites selected in Georgia to provide and an independent set of validation data. The third source of data was the California HSIS database. This data set was acquired to increase the size of the recalibration datasets with the aim of providing improved models with smaller standard errors of parameter estimates. These data were collected with a minimum amount of effort with assistance from the HSIS staff. However, as site visits were not conducted, fewer variables were available for these sites. Table 108 summarizes the sources of data used for recalibrating Models I to V.

Table 108. Sources of Data

State	Years of Data Available	No. of Sites					No. of Total (Injury Accidents)				
		Type I	Type II	Type III	Type IV	Type V	Type I	Type II	Type III	Type IV	Type V
Minnesota	1985-98	270	250	N/A[4]	N/A[4]	N/A[4]	2029 (788)	1892 (878)	N/A[4]	N/A[4]	N/A[4]
California[1]	1991-98	1432	748	294	222	75	6494 (2978)	6063 (3058)	2136 (847)	1956 (899)	1159 (370)
California[2]	1993-98	N/A[4]	N/A[4]	60	54	18	N/A[4]	N/A[4]	427 (196)	478 (268)	507 (200)
Michigan[3]	1993-97	N/A[4]	N/A[4]	24	18	31	N/A[4]	N/A[4]	248 (63)	277 (92)	1262 (159)
Georgia	1996-97	116	108	52	52	51	295 (110)	255 (142)	124 (56)	222 (104)	489 (118)
Total		1818	1106	430	346	124	8818 (3908)	8210 (4078)	2935 (1162)	2933 (1363)	3417 (847)

[1] These data come from the California HSIS database and do not include variables, such as vertical curvature, not available electronically in that database

[2] Only the original sites were used to develop the base models for Types III, IV, and V, and only the California HSIS sites were used to develop the full models

[3] For Type V, Only 1996-97 injury accidents were available

[4] N/A: not available

In this section, summary statistics are provided for the data available for recalibrating the full models (i.e. models with explanatory variables other than traffic volumes). For model Types III, IV, and V, the California HSIS sites were not included due to the limited availability of variables relevant to these models.

It is also appropriate and useful to examine which variables strongly correlate positively or negatively with crashes and which potential independent variables are correlated to one another. These statistics are also provided in this section of the report.

3.2.2 Type I

A summary of the full data for Type I intersections is shown in table 109. This dataset includes the original sites in Minnesota, with the additional years of accident and traffic data, the Georgia sites and the California HSIS sites. Some of the Minnesota sites experienced changes in some design feature or location information during the 1990–98 period and were not included in the analysis. Note that some variables are not available in the data for the Minnesota sites and California sites. The frequency column indicates the number of sites for which the information was available. Summary statistics by State are available in appendix C.

Table 109. Summary Statistics for Type I Sites

Variables	Frequency	Mean	Median	Minimum	Maximum
TOTACC per year	1818	0.6074	0.3750	0	6.75
INJACC per year	1818	0.2660	0.1250	0	4.13
AADT1	1818	6011	4475	401	35750
AADT2	1818	492	270	100	10001
RT MAJ Total 0 1	1818 1563 (86%) 255 (14%)	N/A[1]			
RT MIN Total 0 1	1818 1770 (97.4%) 48 (2.6%)	N/A[1]			
LT MAJ Total 0 1	1818 1382 (76%) 436 (24%)	N/A[1]			
LT MIN Total 0 1	1818 1804 (99.2%) 14 (0.8%)	N/A[1]			
MEDIAN Total 0 1	1818 1738 (95.6%) 80 (4.4%)	N/A[1]			
TERRAIN Total Flat Rolling Mountainous	1548 568 (31.2%) 547 (30.1%) 433 (23.8%)	N/A[1]			
SPD1	381	50.89	55	23	55
DRWY1	386	1.38	1	0	8
HAZRAT1	386	2.56	2	1	7
HAU	386	-1.451	0	-90	85.1
SHOULDER1	1547	4.75	4	0	16
VCI1	386	0.477	0	0	14.0
HI1	386	1.6553	0	0	29.0

[1] N/A: not available

Table 110 shows correlation statistics and *p*-values that indicate the association between crash counts and the independent variables for type I intersections. Table 111 shows correlations between the independent variables. Only those correlations that are significant at the 90 percent level are shown.

As expected, major and minor road AADTs correlate positively with crashes. Turning lanes on the major and minor roads are also positively correlated with crashes, although this correlation is much less than that of vehicle volumes and the correlation for right-turn lane on major roads is not significant. Surprisingly, terrain and posted speed are negatively correlated with crashes, meaning that areas with rolling or mountainous terrain experience a lower crash risk than flatter terrains and that higher speeds are associated with fewer crashes. This counterintuitive result may arise because, as shown in Appendix C, Georgia sites have higher accident frequencies than California and Minnesota sites, as well as lower average posted speeds and a higher percentage of sites in rolling or mountainous terrain. With the presence of a median, VCI1 and HI1 were positively correlated with crashes, while HAU was negatively correlated with crashes although this correlation was not as strong. Shoulder width and number of driveways were not significantly correlated with crashes.

Table 110. Correlation Between Crashes and Independent Variables for Type I Sites

Variables	TOTACC per YEAR		INJACC per YEAR	
	Corr.	*p*-value	Corr.	*p*-value
AADT1	0.426	0.000	0.402	0.000
AADT2	0.428	0.000	0.327	0.000
RT MAJ	0.030	0.202	0.005	0.841
RT MIN	0.116	0.000	0.106	0.000
LT MAJ	0.165	0.000	0.149	0.000
LT MIN	0.059	0.012	0.056	0.016
TERRAIN	-0.085	0.001	-0.101	0.000
MEDIAN	0.076	0.001	0.074	0.002
SPD1[1]	-0.127	0.013	-0.065	0.205
DRWY1[1]	0.030	0.558	0.020	0.694
HAU[1]	-0.072	0.157	-0.052	0.312
SHOULDER1[2]	-0.020	0.427	0.013	0.619
VCI1[1]	0.081	0.110	0.033	0.516
HI1[1]	0.087	0.088	0.089	0.080

[1] These variables are unknown for the California sites
[2] These variables are unknown for the Minnesota sites

Table 111. Summary of Correlations for Independent Variables for Type I Sites

Variable	Positive Correlates[1]	Negative Correlates[1]
AADT1	AADT2, RT MIN, LT MAJ, MEDIAN, SHOULDER1	VCI1, HI1, TERRAIN
AADT2	AADT1, RT MAJ, RT MIN, LT MAJ, LT MIN, MEDIAN, HI1	TERRAIN
RT MAJ	AADT2, RT MIN, LT MAJ, LT MIN, SPD1, SHOULDER1	HAZRAT1, VCI1, HI1
RT MIN	AADT1, AADT2, RT MAJ, LT MAJ, LT MIN, MEDIAN, TERRAIN	
LT MAJ	AADT1, AADT2, RT MAJ, RT MIN, LT MIN, MEDIAN, SHOULDER1	TERRAIN, HAZRAT1, VCI1
LT MIN	AADT2, RT MAJ, RT MIN, LT MAJ, MEDIAN	
MEDIAN	AADT1, AADT2, RT MIN, LT MAJ, LT MIN, VCI1	TERRAIN, SPD1, SHOULDER1
TERRAIN	RT MIN, HAZRAT1, HI1	AADT1, AADT2, LT MAJ, MEDIAN, SPD1, SHOULDER1
SPD1	RT MAJ, SHOULDER1	MEDIAN, TERRAIN, NODRWAY, HAZRAT1, VCI1, HI1
DRWY1	HI1	SPD1
HAZRAT1	TERRAIN, VCI1, HI1	RT MAJ, LT MAJ, SPD1
HAU		
SHOULDER1	AADT1, RT MAJ, LT MAJ, SPD1	MEDIAN, TERRAIN, VCI1
VCI1	MEDIAN, HAZRAT1	AADT1, RT MAJ, LT MAJ, SPD1, SHOULDER1
HI1	AADT2, TERRAIN, DRWY1, HAZRAT1	

[1] Only those correlations are shown for which *p*-values are less than 0.10.
[2] Not all variables are available for Minnesota or California sites

3.2.3 Type II

A summary of the full data for Type II intersections is shown in table 112. This dataset includes the original sites in Minnesota, with additional years of accident and traffic data, the Georgia sites and the California HSIS sites. Some of the Minnesota sites experienced changes in some design feature or location information during 1990–98 and were not included in the analysis. Note that some variables are not available in the data for the Minnesota sites and California sites. The frequency column indicates the number of sites for which the information was available. Summary statistics by State are available in appendix C.

Table 112. Summary Statistics for Type II Sites

Variables	Frequency	Mean	Median	Minimum	Maximum
TOTACC per year	1106	0.9227	0.5357	0	7.13
INJACC per year	1106	0.4665	0.2500	0	4.75
AADT1	1106	5487	4245	407	38126
AADT2	1106	532	344	100	7460
RT MAJ Total 0 1	1106 911 (82.4%) 195 (17.6%)	N/A[1]			
RT MIN Total 0 1	1106 1080 (97.6%) 26 (2.4%)	N/A[1]			
LT MAJ Total 0 1	1106 883 (79.8%) 223 (20.2%)	N/A[1]			
LT MIN Total 0 1	1106 1105 (99.9%) 1 (0.1%)	N/A[1]			
MEDIAN Total 0 1	1106 1069 (96.7%) 37 (3.3%)	N/A[1]			
TERRAIN Total Flat Rolling Mountainous	856 520 (47%) 238 (21.5%) 98 (8.9%)	N/A[1]			
SPD1	355	52	55	30	55
DRWY1	358	0.83	0	0	6
HAZRAT1	358	2.45	2.00	1	6
HAU	358	0.364	0	-120	150
SHOULDER1	855	5.426	6	0	16
VCI1	358	0.43	0.05	0	8
HI1	358	0.896	0	0	14.553

[1] N/A: not available

Table 113 shows correlation statistics and *p*-values that indicate the association between crash counts and the independent variables for Type II intersections. Table 114 shows correlations between the independent variables. Only those correlations that are significant at the 90 pecent level are shown. Note that some variables are not included in the data for the Minnesota and California sites.

As expected, major and minor road AADTs correlate positively with crashes. Right-turn lanes on the major roads were negatively correlated with crashes, while right-turn lanes on the minor roads were positively correlated with crashes. Left-turn lanes on the major roads were positively correlated with crashes, however left-turn lanes on the minor roads were not significantly correlated with crashes. Again, terrain and posted speed are negatively correlated with crashes, meaning that areas with rolling or mountainous terrain experience a higher crash risk than flatter geographies and that higher speeds are associated with less crashes. Presence of a median, number of driveways, HI1, and roadside hazard rating on the major roads were all positively correlated with crashes. Intersection angle (HAU), shoulder width, and VCI1 were not significantly correlated with crashes.

Table 113. Correlation Between Crashes and Independent Variables for Type II Sites

	TOTACC per YEAR		INJACC per YEAR	
Variables	Corr.	*p*-value	Corr.	*p*-value
AADT1	0.443	0.000	0.384	0.000
AADT2	0.434	0.000	0.425	0.000
RT MAJ	-0.133	0.000	-0.126	0.000
RT MIN	0.111	0.000	0.105	0.000
LT MAJ	0.258	0.000	0.265	0.000
LT MIN	0.027	0.364	0.028	0.353
TERRAIN	-0.103	0.003	-0.115	0.001
MEDIAN	0.088	0.003	0.060	0.046
SPD1[1]	-0.246	0.000	-0.184	0.001
DRWY1[1]	0.251	0.000	0.197	0.000
HAZRAT1[1]	0.152	0.004	0.101	0.057
HAU[1]	-0.041	0.444	0.007	0.895
SHOULDER1[3]	0.008	0.821	-0.001	0.970
VCI1[1]	0.029	0.580	0.046	0.390
HI1[1]	0.086	0.106	0.123	0.020

[1] These variables are unknown for the California sites
[2] These variables are unknown for the Minnesota sites

Table 114. Summary of Correlations for Independent Variables for Type II Sites

Variable[1]	Positive Correlates[2]	Negative Correlates[2]
AADT1	AADT2, RT MIN, LT MAJ, LT MIN, MEDIAN, DRWY1, HAZRAT1, SHOULDER1	RT MAJ
AADT2	AADT1, RT MIN, LT MAJ, MEDIAN, TERRAIN, DRWY1, HAZRAT1	SPD1
RT MAJ	RT MIN, TERRAIN, SPD1, SHOULDER1	AADT1, DRWY1, HAZRAT1, VCI1, HI1
RT MIN	AADT1, AADT2, RT MAJ, LT MAJ, LT MIN	
LT MAJ	AADT1, AADT2, RT MIN, LT MIN, MEDIAN, TERRAIN, HAZRAT1, SHOULDER1, VCI1, HI1	
LT MIN	AADT1, RT MIN, LT MAJ, MEDIAN	
MEDIAN	AADT1, AADT2, LT MAJ, LT MIN, TERRAIN	SHOULDER1
TERRAIN	AADT2, RT MAJ, LT MAJ, MEDIAN, HAZRAT1, VCI1, HI1	SPD1, SHOULDER1
SPD1	RT MAJ, SHOULDER1	AADT2, TERRAIN, DRWY1, HAZRAT1, VCI1, HI1
DRWY1	AADT1, AADT2, HAZRAT1, VCI1, HI1	RT MAJ, SPD1
HAZRAT1	AADT1, AADT2, LT MAJ, TERRAIN, DRWY1, VCI1, HI1	RT MAJ, SPD1, HAU
HAU		HAZRAT1
SHOULDER1	AADT1, RT MAJ, LT MAJ, SPD1	MEDIAN, TERRAIN, HAZRAT1
VCI1	LT MAJ, TERRAIN, DRWY1, HAZRAT1, HI1	RT MAJ, SPD1
HI1	LT MAJ, TERRAIN, DRWY1, HAZRAT1, VCI	RT MAJ, SPD1

[1] Not all variables are available for Minnesota or California sites
[2] Only those correlations are shown for which *p*-values are less than 0.10

3.2.4 Type III

A summary of the full data for Type III intersections is shown in table 115. In total, 42 variables were available for model development. The HSIS California data were excluded in developing Type III full models because this data set has only a few variables (turning lanes, median, terrain, etc) of relevance. This left the California and Michigan sites from the original study, with the additional years of accident data, for inclusion in the database. Some California sites experienced changes in some design features during 1996–98. For these, only 1993–95 data were used. As before the frequency column indicates the number of sites for which the information was available.

Table 115. Summary Statistics for Type III Sites

Variables	Frequency	Mean	Median	Minimum	Maximum
TOTACC per year	136	1.35	0.80	0.00	10.60
INJACC per year	136	0.55	0.33	0.00	4.00
AADT1	136	13011	12100	2360	33333
AADT2	136	709	430	15	9490
MEDTYPE1 Total	136	N/A[1]			
No Median	69(50.7%)				
Painted	45(33.1%)				
Curbed	14(10.3%)				
Other	8(5.9%)				
MEDWIDTH1	136	12.6	6	0	63
HAU	136	1.3	0	-65	90
HAZRAT1 Total	136	N/A[1]			
1	16(11.8%)				
2	58(42.6%)				
3	26(19.1%)				
4	25(18.4%)				
5	8(5.9%)				
6	2(1.5%)				
7	1(0.7%)				
HAZRAT2 Total	52	N/A[1]			
1	0(0%)				
2	2(4.0%)				
3	20(40.0%)				
4	16(32.0%)				
5	6(12.0%)				
6	6(12.0%)				
7	2(4.0%)				
COMDRWY1	136	1.5	0	0	14
RESDRWY1	136	1.0	0	0	7
DRWY1	136	2.5	1.0	0.0	15.0
NoCOMDRWY2	52	0.4	0	0	3
RESDRWY2	52	0.6	0	0	6
DRWY2	52	1.0	1.0	0.0	6.0
SPD1	136	52.5	55	30	65
SPD2	136	33.7	35	15	55

[1] N/A: not available

Table 115. Summary Statistics for Type III Sites (Continued)

Variables	Frequency	Mean	Median	Minimum	Maximum
LIGHT Total	136				
0	97(71.3%)				
1	39(28.7%)	N/A[1]			
TERRAIN1 Total	136				
Flat	83(61.0%)				
Rolling	42(30.9%)				
Mountainous	11(8.1%)	N/A[1]			
TERRAIN2 Total	52				
Flat	24(17.6%)				
Rolling	21(15.4%)				
Mountainous	7(5.1%)	N/A[1]			
RTLN1 Total	136				
0	108(79.4%)				
1	28(20.6%)	N/A[1]			
LTLN1 Total	136				
0	48(35.3%)				
1	88(64.7%)	N/A[1]			
RTLN2 Total	136				
0	117(86.0%)				
1	19(14.0%)	N/A[1]			
LTLN2 Total	136				
0	131(96.3%)				
1	5(3.7%)	N/A[1]			
HI1	136	1.26	0.00	0	14.29
HEI1	136	2.01	0.73	0	26.63
GRADE1	136	1.0	0.7	0.0	5.9
GRADE2	52	1.5	1.2	0.0	4.7
VEI1	136	0.9	0.6	0.0	6.7
VI2	52	4.0	2.8	0.0	24.0
LEGACC1	52	0.0	0.0	0.0	1.0
LEGACC2	52	0.1	0.0	0.0	1.0
SHOULDER1	52	4.0	4.0	0.0	10.0
PKTRUCK	84	9.15	7.79	1.18	28.16
PKTURN	84	6.68	4.28	0.27	53.09
PKLEFT	84	3.28	2.16	0.13	25.97

[1] N/A: not available

Table 115. Summary Statistics for Type III Sites (Continued)

Variables	Frequency	Mean	Median	Minimum	Maximum
PKLEFT1	84	1.47	0.69	0.00	21.29
PKLEFT2	84	55.31	60.29	0.00	100.00
SD1	136	1515	2000	500	2000
SDL2	136	1418	1510	40	2000
SDR2	136	1428	1555	80	2000

Table 116 shows correlation statistics and *p*-values that indicate the association between crash counts and the independent variables for Type III intersections. Table 114 shows correlations between the independent variables. Only those correlations that are significant at the 90 percent level are shown.

Major and minor road AADTs correlate positively with crashes as expected. Peak turning movement volumes also correlate with crashes, both positively and negatively. PKTURN, PKLEFT, and PKLEFT1 correlate positively with crashes, while PKTRUCK and PKLEFT2 correlate negatively with crashes. According to table 114, PKTRUCK correlates negatively with the AADT variables. This suggests that the negative correlation of crashes with PKTRUCK may, in part, be a consequence of the positive correlation of crashes with AADT variables. PKLEFT1 and PKLEFT2 are also negatively correlated with each other. There are several variables for which the correlation results are unexpected. Roadside hazard rating on major and minor roads, number of residential driveways on major and minor roads, posted speed limits on major and minor roads, terrain on major roads, shoulder width on major roads, “LIGHT,” and the presence of left-and right-turn lane on minor roads, as well as other variables are correlated with crashes in the opposite direction to that expected, although many of these correlations are insignificant.

Table 116. Correlation Between Crashes and Independent Variables for Type III Sites

Variables	TOTACC per YEAR		INJACC per YEAR	
	Corr.	*p*-value	Corr.	*p*-value
AADT1	0.3330	0.0001	0.2943	0.0005
AADT2	0.4829	0.0000	0.3606	0.0000
MEDWDTH1	-0.0774	0.3703	-0.0051	0.9534
HAU	0.1190	0.1677	0.1917	0.0254
COMDRWY1	0.3959	0.0000	0.1765	0.0398
RESDRWY1	-0.0697	0.4201	-0.1211	0.1603
DRWY1	0.2842	0.0008	0.0854	0.3229
COMDRWY2	0.0044	0.9756	0.0486	0.7321
RESDRWY2	-0.2342	0.0947	-0.2062	0.1425
DRWY2	-0.1956	0.1647	-0.1416	0.3168
SPD1	-0.3299	0.0001	-0.1184	0.1696
SPD2	-0.0675	0.4352	0.0519	0.5483
LIGHT	0.2882	0.0007	0.1307	0.1295

Table 116. Correlation Between Crashes and Independent Variables for Type III Sites (Continued)

Variables	TOTACC per YEAR		INJACC per YEAR	
	Corr.	*p*-value	Corr.	*p*-value
L1RT	0.0118	0.8915	0.0344	0.6911
L1LT	-0.1511	0.0791	0.0192	0.8243
L3RT	0.2298	0.0071	0.1717	0.0456
L3LT	0.2025	0.0181	0.2373	0.0054
HI1	0.0309	0.7208	0.0615	0.4771
HEI1	0.0052	0.9520	0.1628	0.0583
GRADE1	0.0027	0.9748	0.0485	0.5751
GRADE2	0.0968	0.4949	0.1977	0.1601
VEI1	0.1534	0.0746	0.1247	0.1481
VI2	-0.1039	0.4633	-0.0831	0.5582
LEGACC1	-0.0721	0.6116	-0.1020	0.4719
LEGACC2	0.2099	0.1353	-0.0129	0.9278
SHOULDER1	0.1392	0.3249	-0.0140	0.9216
PKTRUCK	-0.1943	0.0766	-0.1205	0.2749
PKTURN	0.2617	0.0162	0.2527	0.0204
PKLEFT	0.2304	0.0350	0.2296	0.0357
PKLEFT1	0.2744	0.0115	0.2479	0.0230
PKLEFT2	-0.1610	0.1436	-0.0994	0.3685
SD1	-0.0752	0.3843	-0.0003	0.9970
SDL2	-0.0633	0.4642	-0.0300	0.7284
SDR2	-0.0585	0.4986	-0.0214	0.8043

Table 117. Summary of Correlations for Independent Variables for Type III Sites

Variable	Positive Correlates[1]	Negative Correlates[1]
AADT1	L1RT, L1LT	MEDTYPE2, PKTRUCK,PKLEFT2, SDL2
AADT2	L1RT, L3RT, L3LT, PKTURN, PKLEFT,PKLEFT1, SHOULDER1,	SPD1, PKTRUCK
MEDWDTH1	HAU, SPD1, SPD2, L1RT, L1LT, PKTRUCK, SHOULDER1, SDR2	COMDRWY1, RESDRWY1, DRWY1, LIGHT, TERRAIN, HI1, GRADE1, VI2,
HAU	MEDWDTH1, PKTRUCK, LEFACC2,	MEDTYPE2, RESDRWY1, DRWY2,
HAZRAT1	HAZRAT2, SPD1, SPD2, TERRAIN1, L1LT, GRADE1, VEI1	COMDRWY1, RESDRWY1, DRWY1, LIGHT, L1LT, SDR2
DRWY1	COMDRWY1, RESDRWY1, COMDRWY2, DRWY2, LIGHT, PKTURN, HI1	MEDTYPE1, MEDTYPE2, MEDTYPE3, HAZRAT1, SPD1, SPD2, L1RT, L1LT, PKTRUCK, PKLEFT2, SDL3, SDR3

Table 117. Summary of Correlations for Independent Variables for Type III Sites (Continued)

Variable	Positive Correlates[1]	Negative Correlates[1]
SPD1	MEDTYPE1,MEDTYPE3, MEDWDTH1, SPD2, TERRAIN1, L1RT, L1LT, PKTRUCK, LEGACC2, SD1, SDL2, SDR2	AADT2, COMDRWY1, RESDRWY1, DRWY1, COMDRWY2, DRWY2, LIGHT, HI1, GRADE2, VEI1
SPD2	MEDTYPE1, MEDWDTH1, HAZRAT1, SPD1, TERRAIN1, L1RT, L1LT, L3LT,	COMDRWY1, DRWY1, LIGHT
LIGHT (no=0, yes=1)	COMDRWY1, PKTURN, HI1, LEFACC1, DRWY1, PKLEFT, PKLEFT1	MEDTYPE2, MEDTYPE3, MEDWDTH1, HAZRAT1, SPD1, SPD2, L1LT, PKTRUCK, SD1, SDR2
TERRAIN1	MEDTYPE1, HAZRAT1, HAZRAT2, SPD1, SPD2, L1RT, GRADE1, GRADE2, VEI1, VI2	SD1, SDL2, SDR2
L1RT	AADT1, AADT2, MEDWDTH1, SPD1, SPD2, TERRAIN1, L1LT, L3RT, L3LT, GRADE1, LEFACC2, SHOULDER1	HAZRAT2, COMDRWY1, RESDRWY1, DRWY1, COMDRWY2, GRDE2, TERRAIN2
L1LT	AADT1, MEDTYPE1, MEDTYPE2, MEDWDTH1, HAZRAT1, SPD1, SPD2, L1RT, L3LT, SD1, SDR3	HAZRAT2, COMDRWY1, RESDRWY1, DRWY1, LIGHT, TERRAIN2
L3RT	AADT2, L1RT, L3LT, PKTURN, SHOULDER1, PKTURN, PKLEFT, PKLEFT1	HAZRAT2, TERRAIN2
L3LT	AADT2, MEDTYPE1, SPD2, L1RT, L1LT, L3RT, PKTURN, PKLEFT, PKLEFT1	HAZRAT2
PKTRUCK	MEDTYPE1, MEDTYPE3, MEDWDTH1, HAU, SPD1, SPD2, SD1, SDL2, SDR2	AADT1, AADT2, COMDRWY1, RESDRWY1, DRWY1, LIGHT, HI1, VEI1,
PKTURN	AADT2, LIGHT, L3RT, L3LT, PKLEFT, PKLEFT1	
VEI1	AADT1, HAZRAT1, TERRAIN1, HI1, GRADE1,	SPD1, PKTRUCK, SD1, SDL2, SDR2
HEI1	MEDTYPE1, HI, VI2	
GRADE1	MEDTYPE1, HAZRAT1, TERRAIN1, L1RT, HI1, VEI1	MEDWDTH1, SD1, SDL2, SDR2
SDL2	SPD1, PKTRUCK, SD1, SDR2	AADT1, RESDRWY1, DRWY1, TERRAIN1, TERRAIN2, HI1, GRADE1, GRADE2, VEI1, LEGACC2
SDR2	MEDWDTH1, SPD1, L1LT, PKTRUCK, SD1, SDL3	HAZRAT1, HAZRAT2, LIGHT, TERRAIN1, HI1, GRADE1, GRADE2, VEI1, DRWY1

[1]Only those correlations are shown for which *p*-values are less than 0.10

3.2.5 Type IV

A summary of the full data for type IV intersections is shown in table 118. In total, 53 variables were available for model development. The HSIS California data were again excluded because of a lack of sufficient variables (turning lanes, median, terrain, etc.) of relevance. Instead, the California and Michigan sites from the original study, with the additional years of accident data were included in the database. Some California sites experienced changes in some design features during 1996–98. For these, only 1993–95 data were used. As before, frequency indicates the number of sites for which the information was available.

Table 118. Summary Statistics for Type IV Sites

Variables	Frequency	Mean	Median	Minimum	Maximum
TOTACC per YEAR	124	2.0	1.4	0.0	10.8
INJACC per YEAR	124	0.9	0.5	0.0	5.7
AADT1	124	12881	11496	3150	73799
AADT2	124	621	430	21	2990
MEDTYPE on major Total	124				
0: No Median	70(56.5%)				
1: Painted	27(21.8%)				
2: Curbed	22(17.7%)				
3: Other	5(4.0%)	N/A[1]			
MEDTYPE on minor Total	52				
0: No Median	52(100%)	N/A[1]			
MEDWDTH1	124	16.1	6.5	0	60
MEDWDTH2	52	0.0	0	0	1
SHOULDER1	52	4.2	4	2	6
SHOULDER2	52	0.3	0	0	2
L1RT Total	124				
0	69(55.6%)				
1	20(16.1%)				
2	35(28.2%)	N/A[1]			
L3RT Total	124				
0	72(58.1%)				
1	13(10.5%)				
2	39(31.5%)	N/A[1]			
L3LT Total	124				
0	122(98.4%)				
1	2(1.6%)	N/A[1]			
LEGACC1 Total	52				
0	49(94.2%)				
1	3(5.8%)	N/A[1]			
LEGACC2 Total	52				
0	49(94.2%)				
1	3(5.8%)	N/A[1]			
HAZRAT1	124				
1	24(19.4%)				
2	43(34.7%)				
3	32(25.8%)				
4	21(16.9%)				
5	2(1.6%)				
6	2(1.6%)				
7	0(0%)	N/A[1]			

[1] N/A: not available

Table 118. Summary Statistics for Type IV Sites (Continued)

Variables		Frequency	Mean	Median	Minimum	Maximum
HAZRAT2		52				
1		0(0%)				
2		7(13.5%)				
3		15(28.8%)				
4		16(30.8%)				
5		12(23.1%)				
6		2(3.8%)				
7		0(0%)	N/A[1]			
COMDRWY1		124	0.6	0	0	12
RESDRWY1		124	0.7	0	0	7
DRWY1		124	1.3	0	0	15
COMDRWY2		52	0.4	0	0	4
RESDRWY2		52	0.4	0	0	3
DRWY2		52	0.8	0	0	6
LIGHT	Total	124				
0		87(70.2%)				
1		37(29.8%)	N/A[1]			
TERRAIN1	Total	124				
Flat		90(72.6%)				
Rolling		25(20.2%)				
Mountainous		9(7.3%)	N/A[1]			
TERRAIN2	Total	52				
Flat		19(36.5%)				
Rolling		27(51.9%)				
Mountainous		6(11.5%)	N/A[1]			
VEI1		124	0.87	0.35	0.00	12.50
VCEI1		124	0.63	0.00	0.00	12.50
VI1		124	0.62	0.00	0.00	12.50
VCI1		124	0.43	0.00	0.00	12.50
VEI2		52	3.05	2.84	0.32	10.18
VCEI2		52	2.97	2.31	0.00	11.36
VI2		52	2.62	2.08	0.00	9.66
VCI2		52	2.08	1.02	0.00	12.50
GRADE1		124	0.94	0.71	0.00	5.80
GRADE2		51	1.65	1.48	0.60	3.71
HI		124	0.92	0.00	0.00	7.33
HEI		124	3.28	0.60	0.00	233.33
HAU		124	1.5	0	-50	55
SPD1		124	55.6	55	25	65

[1] N/A: not available

Table 118. Summary Statistics for Type IV Sites (Continued)

Variables	Frequency	Mean	Median	Minimum	Maximum
SPD2	124	34.7	35	25	55
PKTRUCK	72	10.95	8.36	1.75	37.25
PKTHRU1	72	94.41	96.95	67.77	100.00
PKTURN	72	9.47	6.56	0.00	48.52
PKLEFT	72	4.80	3.08	0.00	25.26
PKLEFT1	72	2.78	1.51	0.00	13.96
PKTHRU2	72	15.69	10.82	0.00	68.09
PKLEFT2	72	38.89	36.66	0.00	100.00
SD1	124	1399	1332	400	2000
SDL2	124	1314	1262	324	2000
SDR2	124	1329	1354	215	2000

[1] N/A: not available

Table 119 shows correlation statistics and *p*-values that indicate the association between crash counts and the independent variables for Type IV intersections. Table 120 shows correlations between the independent variables. Only those correlations that are significant at the 90 pecent level are shown.

Major and minor road AADTs correlate positively with crashes, as expected. Peak turning movements also correlate with crashes, both positively and negatively. There are several variables for which the correlation results are contrary to expectations. Shoulder width on the road, right-and left-turn lane on minor roads, acceleration lane on major roads, residential driveway and total driveway on minor roads, light, terrain on major and minor roads, vertical curves on major and minor roads, horizontal curves on major roads, absolute grades on major and minor roads, intersection angle, posted speed limit on major roads, and others are correlated with crashes in the opposite direction than expected, although many of these correlations are insignificant. For example, median width on major road is insignificant with a counterintuitive sign. However, as table 120 shows, there is a negative correlation between median width on major roads and median types, the result of which is that median type is skewing the effect of median width at Type IV intersections.

Table 119. Correlation Between Crashes and Independent Variables for Type IV Sites

Variables	TOTACC per YEAR		INJACC per YEAR	
	Corr.	*p*-value	Corr.	*p*-value
AADT1	0.2258	0.0117	0.2285	0.0107
AADT2	0.2600	0.0035	0.1594	0.0770
MEDWDTH1	0.0314	0.7289	0.0572	0.5277
MEDWDTH2	-0.0104	0.9418	-0.0657	0.6434
SHOULDER1	-0.1631	0.2481	-0.1040	0.4633
SHOULDER2	0.2089	0.1372	0.2209	0.1155
L1RT	-0.0084	0.9267	0.0608	0.5026
L1LT	-0.0695	0.4432	0.0738	0.4152
L3RT	0.0350	0.6999	0.0995	0.2714
L3LT	0.1428	0.1137	0.1929	0.0319
LEGACC1	0.1633	0.2474	0.2323	0.0975
LEGACC2	-0.1092	0.4411	0.0000	1.0000
COMDRWY1	0.1017	0.2613	0.0942	0.2979
RESDRWY1	0.1547	0.0863	0.0015	0.9867
DRWY1	0.1569	0.0818	0.0596	0.5109
COMDRWY2	0.1900	0.1772	0.1732	0.2195
RESDRWY2	-0.2809	0.0437	-0.2474	0.0770
DRWY2	-0.0367	0.7963	-0.0283	0.8423
LIGHT	0.0592	0.5137	-0.0176	0.8459
VEI1	0.0099	0.9133	0.0373	0.6806
VCEI1	0.0765	0.3984	0.0698	0.4408
VI1	-0.0174	0.8476	0.0191	0.8332
VCI1	0.0151	0.8676	0.0490	0.5887
VEI2	-0.2156	0.1248	-0.0692	0.6257
VCEI2	-0.2626	0.0600	-0.0361	0.7994
VI2	-0.2665	0.0562	-0.0672	0.6360
VCI2	-0.2147	0.1263	-0.0506	0.7215
GRADE1	-0.0033	0.9709	0.0211	0.8161
GRADE2	-0.1825	0.1999	-0.0318	0.8245
HI1	-0.0329	0.7171	-0.0846	0.3503
HEI1	-0.0055	0.9519	-0.0581	0.5212
HAU	-0.1184	0.1905	-0.0892	0.3243
SPD1	-0.1839	0.0409	-0.0607	0.5033
SPD2	0.0301	0.7397	0.1964	0.0288
PKTRUCK	-0.3268	0.0051	-0.3369	0.0038
PKTHRU1	-0.3058	0.0090	-0.2324	0.0494
PKTURN	0.3242	0.0055	0.2544	0.0311
PKLEFT	0.3099	0.0081	0.2526	0.0323
PKLEFT1	0.3550	0.0022	0.3028	0.0097
PKTHRU2	0.1876	0.1145	0.1500	0.2086
PKLEFT2	-0.0492	0.6815	-0.0627	0.6006
SD1	-0.1331	0.1407	-0.1220	0.1770
SDL2	-0.1408	0.1187	-0.0849	0.3486
SDR2	-0.2826	0.0015	-0.1705	0.0583

Table 120. Summary of Correlations for Independent Variables for Type IV Sites

Variable	Positive Correlates[1]	Negative Correlates[1]
AADT1	MEDTYPE1, L1LT, SPD1, PKTHRU1, PKLEFT2	VCEI2, PKTRUCK, PKTURN, PKLEFT, PKLEFT1, PKTHRU2
AADT2	MEDWDTH1, MEDWDTH2, TERRAIN2, HEI1, HAU, PKTURN, PKLEFT, PKLEFT1, PKTHRU2	MEDTYPE1, GRADE1, PKTURCK, PKTHRU1, PKLEFT2
MEDWDTH1	AADT2, L1RT, L1LT, L3RT, HAZRAT1, HAU, SPD1, SPD2, PKTHRU1	MEDTYPE1, MEDTYPE2, HAZRAT2, COMDRWY1, RESDRWY1, COMDRWY2, RESDRWY2, DRWY1, DRWY2, LIGHT, TERRAIN1, VEI2, VCEI2, VI2, VCI2, PKTURN, PKLEFT, PKLEFT1
HAU	AADT2, MEDWDTH1, TERRAIN2	LIGHT
HAZRAT1	MEDTYPE1, MEDWDTH1, TERRAIN1, GRADE1, HI1,	MEDTYPE2, L1RT, L3RT, SD1, SDL2, SDR2, PKTRUCK, PKTHRU2
DRWY1	HAZRAT1, COMDRWY1, RESDRWY1, COMDRWY2, RESDRWY2, DRWY2, LIGHT, VI2, HEI1, PKTURN, PKLEFT, PKLEFT1	MEDTYPE2, MEDWDTH1, L1RT, L1LT, L3RT, SPD1, SPD2, PKTRUCK, PKTHRU1, SD1, SDL2, SDR2
SPD1	AADT1, MEDTYPE2, MEDWDTH1, SHOULDER2, L1RT, L1LT, L3RT, TERRAIN2, SPD2, PKTRUCK, PKTHRU1, SD1, SDL2, SDR2	COMDRWY1, RESDRWY1, DRWY1, COMDRWY2, DRWY2, LIGHT, HEI1, PKTURN, PKLEFT, PKLEFT1
SPD2	MEDWDTH1, L1RT, L1LT, L3RT, SPD1	HAZRAT2, COMDRWY1, RESDRWY1, DRWY1, RESDRWY2, DRWY2, LIGHT, VEI2, VCEI2, VI2, VCI2, HEI1
LIGHT (no=0,yes=1)	COMDRWY1, RESDRWY1, DRWY1, COMDRWY2, DRWY2, HEI1, PKTURN, PKLEFT, PKLEFT1	MEDTYPE2, MEDWDTH1, L1RT, L1LT, L2RT, HAU, SPD1, SPD2, PKTRUCK, PKTHRU1
TERRAIN1	MEDTYPE1, MEDWDTH2, SHOULDER2, L1LT, LEGACC1, HAZRAT1, GRADE1, HI1,	MEDWDTH1, PKTRUCK, PKTHRU2, PKLEFT2, SD1, SDL2, SDR2
L1RT	MEDTYPE2, MEDTYPE3, MEDWDTH1, L1LR, L3RT, LEGACC1, SPD1, SPD2, PKTRUCK, PKLEFT	HAZRAT1, RESDRWY1, DRWY1, LIGHT, TERRAIN2, GRADE1, GRADE2, HI1, PKTURN, PKLEFT, PKLEFT1
L1LT	AADT1, MEDTYPE1, MEDTYPE2, MEDWDTH1, L1RT, L3RT, TERRAIN1, SPD1, SPD2, PKTRUCK	COMDRWY1, RESDRWY1, DRWY1, RESDRWY2, DRWY2, LIGHT, VEI2, VCEI2, VI2, VCI2, GRADE2, HEI, PKTURN, PKLEFT, PKLEFT1
L3RT	MEDTYPE2, MEDWDTH1, SHOULDER2, L1LT, L1RT, SPD1, SPD2, PKTRUCK, PKTHRU1	MEDTYPE1, MEDTYPE3, HAZRAT1, HAZRAT2, COMDRWY1, RESDRWY2, COMDRWY2, RESDRWY2, DRWY1, DRWY2, LIGHT, VEI2, VCI2, GRADE1, GRADE2, HI1, PKTURN PKLEFT, PKLEFT1
L3LT	MEDTYPE3, PKLEFT1, PKTHRU2	

Table 120. Summary of Correlations for Independent Variables for Type IV Sites (Continued)

Variable	Positive Correlates[1]	Negative Correlates[1]
PKTRUCK	MEDTYPE2, L1RT, L1LT, L3RT, SPD1, PKTHRU2, SD1, SDL2, SDR2	AADT1, AADT2, HAZRAT1, DRWY1, LIGHT, TERRAIN1, PKTURN, PKLEFT, PKLEFT1,
PKTURN	AADT2, RESDRWY1, DRWY1, LIGHT, PKLEFT, PKLEFT1, PKLEFT2	AADT1, MEDTYPE1, MEDTYPE2, MEDWDTH1, L1RT, L1LT, L3RT, SPD1, PKTRUCK, PKTHRU1
VEI1	VI1, VCI1, GRADE1	MEDTYPE2, SD1, SDL2, SDR2
HEI1	AADT2, L1LT, RESDRWY1, DRWY1, DRWY2, LIGHT,	SHOUDLER2, L1LT, SPD1, SPD2, SD1, SDL2
GRADE1	MEDTYPE1, HAZRAT1, TERRAIN1, VEI1,VI2, HI1	AADT2, MEDTYPE2, L1RT, PKTHRU2, SD1, SDL2, SDR2
SDL2	MEDTYPE2, HAZRAT2, HAZRAT2,VCI2, SPD1, PKTRUCK, SD1, SDR2	HAZRAT1, COMDRWY1, RESDRWY1, DRWY1, TERRAIN1, VEI1, VCEI1, GRADE1, HI1, HEI1
SDR2	MEDTYPE2, SHOULDER1, LEGACC2, HAZRAT2, RESDRWY2, VCI2, SPD1, PKTRUCK, PKTHRU2, SD1, SDL2	HAZRAT1, COMDRWY1, RESDRWY1, DRWY1, TERRAIN1, VEI1, VCEI1, GRADE1, HI1

[1] Only those correlations are shown for which *p*-values are less than 0.10.

3.2.6 Type V

A summary of the full data for Type V intersections is shown in table 121. In total, 53 variables were available for model development. The HSIS California data were again excluded because only five Type V sites were available. This left the California and Michigan sites from the original study, with the additional years of accident data for inclusion in the database. Some California sites experienced changes in some design features during 1996–98 period. For these, only 1993–95 data were used. As before, the frequency column indicates the number of sites for which the information was available.

Table 121. Summary Statistics for Type V Sites

Variables	Frequency	Mean	Median	Minimum	Maximum
TOTACC per YEAR	100	5.9	5.3	0.0	26.5
INJACC per YEAR	100	1.8	1.5	0.0	6.5
AADT1	100	9126	8700	430	25132
AADT2	100	3544	3100	420	12478

Table 121. Summary Statistics for Type V Sites (Continued)

Variables	Frequency	Mean	Median	Minimum	Maximum
SIGTYPE Total	100				
0:Pre-timed	33(33%)				
1:Actuated	45(45%)				
2:Semi-actuated	22(22%)	N/A[1]			
MEDTYPE on major Total	100				
0:No Median	87(87%)				
1:Painted	12(12%)				
2:Other	1(1%)	N/A[1]			
MEDTYPE on minor Total	51				
0:No Median	48(94.1%)				
1:Painted	3(5.9%)				
2:Other	0(0%)	N/A[1]			
MEDWDTH1	100	1.3	0	0	13
MEDWDTH2	100	0.3	0	0	12
SHOULDER1	51	1.9	2	0	10
SHOULDER2	51	1.5	2	0	10
L1RT Total	100				
0	51(51%)				
1	21(21%)				
2	28(28%)	N/A[1]			
L1LT Total	100				
0	23(23%)				
1	2(2%)				
2	75(75%)	N/A[1]			
L3RT Total	100				
0	59(59%)				
1	20(20%)				
2	21(21%)	N/A[1]			
L3LT Total	100				
0	45(45%)				
1	5(5%)				
2	50(50%)	N/A[1]			
LEGACC1 Total	51				
0	46(90.2%)				
1	5(9.8%)	N/A[1]			

[1] N/A: not available

Table 121. Summary Statistics for Type V Sites (Continued)

Variables	Frequency	Mean	Median	Minimum	Maximum
LEGACC2 Total	51				
0	50(98%)				
1	1(2%)	N/A[1]			
PROTLT1 Total	100				
0	70(70%)				
1	30(30%)	N/A[1]			
PROTLT2 Total	51				
0	47(92.2%)				
1	4(7.8%)	N/A[1]			
HAZRAT1 Total	100				
1	12(12%)				
2	29(29%)				
3	27(27%)				
4	16(16%)				
5	13(13%)				
6	3(3%)				
7	0(0%)	N/A[1]			
HAZRAT2 Total	51				
1	1(2%)				
2	8(15.7%)				
3	17(33.3%)				
4	14(27.5%)				
5	8(15.7%)				
6	3(5.9%)				
7	0(0%)	N/A[1]			
COMDRWY1	100	2.64	2	0	11
RESDRWY1	100	0.52	0	0	6
DRWY1	100	3.16	3	0	15
COMDRWY2	100	2.44	2	0	10
RESDRWY2	100	0.69	0	0	8
DRWY2	100	3.13	3	0	11
LIGHT Total	100				
0	29(29%)				
1	71(715)	N/A[1]			

[1] N/A: not available

Table 121. Summary Statistics for Type V Sites (Continued)

Variables	Frequency	Mean	Median	Minimum	Maximum
TERRAIN1 Total Flat Rolling Mountainous	100 59(59%) 38(38%) 3(3%)	N/A[1]			
TERRAIN2 Total Flat Rolling Mountainous	51 18(35.3%) 31(60.8%) 2(3.9%)	N/A[1]			
SD1	100	1314	1246	235	2000
SD2	100	1213	1091	224	2000
SDL1	100	774	673	122	2000
SDL2	100	910	750	142	2000
SDR1	51	822	798	103	2000
SDR2	51	1042	934	224	2000
VEI1	100	1.45	1.19	0.00	11.97
VEI2	100	1.91	1.39	0.00	13.50
VEICOM	100	1.81	1.59	0.00	8.13
VCEI1	100	1.10	0.45	0.00	10.79
VCEI2	100	1.54	0.90	0.00	14.00
VCEICOM	100	1.32	1.03	0.00	7.00
GRADE1	100	1.20	1.00	0.00	4.98
GRADE2	100	1.50	1.28	0.00	7.79
HEI	100	3.95	0.61	0.00	94.87
HI	100	2.15	0.00	0.00	60.00
HEI2	100	2.52	0.00	0.00	36.41
HI2	100	2.58	0.00	0.00	47.44
HEICOM	100	2.56	0.58	0.00	32.54
HICOM	100	2.36	0.00	0.00	42.05
HAU	100	0.07	0.00	-45.00	40.00
SPD1	100	45.2	45	25	65
SPD2	100	40.9	40	20	55
PKTRUK	49	8.96	7.71	2.69	45.43
PKTURN	49	35.64	34.48	7.07	72.66
PKTHRU1	49	71.19	73.77	18.01	96.73
PKTHRU2	49	43.90	41.99	8.45	84.09
PKLEFT	49	18.17	17.97	4.20	37.07
PKLEFT1	49	14.99	13.15	1.78	43.23
PKLEFT2	49	28.21	24.88	2.59	75.73

[1] N/A: not available

Table 122 shows correlation statistics and *p*-values that indicate the association between crash counts and the independent variables for type V intersections. Table 123 shows correlations between the independent variables. Only those correlations that are significant at the 90 percent level are shown.

Again, as expected, major and minor road AADTs correlate positively with crashes. Peak turning movement volume also correlates with crashes, both positively and negatively. Shoulder width on major and minor roads, left-and right-lane on major and minor roads, acceleration lane on major and minor roads, protected left lane on major and minor roads, residential driveway on major and minor roads, terrains, sight distance, vertical curves, absolute grades, horizontal curves, intersection angle, and other variables are correlated with crashes in the opposite direction than expected, although many of these correlations are insignificant.

Table 122. Correlation Between Crashes and Independent Variables for Type V Sites

Variables	TOTACC per YEAR		INJACC per YEAR	
	Corr.	*p*-value	Corr.	*p*-value
AADT1	0.2581	0.0095	0.2964	0.0027
AADT2	0.4313	0.0000	0.3056	0.0020
MEDWDTH1	-0.0095	0.9251	0.0123	0.9035
MEDWDTH2	-0.0385	0.7036	-0.0942	0.3513
SHOULDER1	0.2324	0.1008	0.2826	0.0445
SHOULDER2	0.0818	0.5684	0.0557	0.6979
L1RT	0.2271	0.0231	0.1591	0.1138
L1LT	0.1516	0.1323	0.2033	0.0424
L3RT	0.2883	0.0036	0.2113	0.0348
L3LT	0.2178	0.0295	0.0771	0.4458
LEGACC1	0.3602	0.0094	0.2391	0.0911
LEGACC2	0.1079	0.4510	0.1461	0.3064
PROTLT1	0.1340	0.1837	0.1408	0.1622
PROTLT2	0.3652	0.0084	0.2452	0.0828
COMDRWY1	0.1012	0.3163	-0.1315	0.1922
RESDRWY1	-0.0130	0.8976	-0.0500	0.6212
DRWY1	0.0850	0.4004	-0.1377	0.1718
COMDRWY2	0.0015	0.9883	-0.1598	0.1122
RESDRWY2	-0.1924	0.0552	-0.0474	0.6399
DRWY2	-0.1149	0.2552	-0.1633	0.1044
LIGHT	-0.1885	0.0603	-0.2801	0.0048
SD1	0.1064	0.2919	0.1325	0.1888
SD2	0.1072	0.2886	0.1667	0.0975
SDL1	0.1692	0.0925	0.2437	0.0146
SDL2	0.1400	0.1649	0.2545	0.0106
SDR1	0.2057	0.1475	0.1938	0.1731
SDR2	0.0692	0.6296	0.1321	0.3556

Table 122. Correlation Between Crashes and Independent Variables for Type V Sites (Continued)

Variables	TOTACC per YEAR		INJACC per YEAR	
	Corr.	*p*-value	Corr.	*p*-value
VEI1	0.1228	0.2234	0.0510	0.6144
VEI2	0.0378	0.7090	0.0467	0.6443
VEICOM	0.1276	0.2059	0.1032	0.3070
VCEI1	0.1167	0.2474	0.0229	0.8208
VCEI2	0.0376	0.7103	0.0275	0.7857
VCEICOM	0.1009	0.3179	0.0367	0.7169
GRADE1	-0.0487	0.6302	-0.1739	0.0836
GRADE2	-0.0312	0.7580	-0.1208	0.2312
HEI	-0.0181	0.8578	-0.0292	0.7734
HI	-0.1541	0.1258	-0.0822	0.4162
HEI2	-0.0369	0.7155	-0.1023	0.3112
HI2	0.0222	0.8268	-0.0070	0.9450
HEICOM	-0.1692	0.0924	-0.1403	0.1639
HICOM	-0.0882	0.3829	-0.0572	0.5722
HAU	-0.1326	0.1886	-0.1988	0.0474
SPD1	0.2103	0.0357	0.4325	0.0000
SPD2	0.1837	0.0674	0.3819	0.0001
PKTRUK	0.2097	0.1482	0.2116	0.1445
PKTURN	0.1950	0.1794	-0.1203	0.4105
PKTHRU1	-0.2396	0.0973	0.0702	0.6317
PKTHRU2	0.1079	0.4604	0.1468	0.3141
PKLEFT	0.2106	0.1464	-0.0904	0.5368
PKLEFT1	0.3471	0.0145	0.1895	0.1922
PKLEFT2	-0.2983	0.0374	-0.3784	0.0073

Table 123. Summary of Correlations for Independent Variables for Type V Sites

Variable	Positive Correlates[1]	Negative Correlates[1]
AADT1	AADT2, SIGTYPE2, MEDTYPE2, L1LT, PROTLT1, RESDRWY2, LIGHT, PKTHRU1	GRADE1, PKTURN, PKTHRU2, PKLEFT
AADT2	AADT1, SIGTYPE1, L1RT, L1LT, L3RT, L3LT, LEGACC1, SDR1, HEI1, HI2, PKTURN, PKLEFT, PKLEFT1	SIGTYPE3, HAZRAT1, HAZRAT2, GRADE2, HAU, PKTHRU1
PROTLT1	AADT1, SIGTYPE2, L1RT, L1LT, LEGACC1, LEGACC2, PROTLT2, RESDRWY2, TERRAIN2, VEI2,VEICOM, VCEI1, VCEICOM, HEI, HEI2, HI2, HEICOM, HICOM	SIGTYPE1, DRWY1, COMDRWY2,

Table 123. Summary of Correlations for Independent Variables for Type V Sites (Continued)

Variable	Positive Correlates[1]	Negative Correlates[1]
MEDWDTH1	MEDTYPE1, MEDTYPE1minor, MEDWDTH2, L1LT, VEI2, VEICOM, VCEICOM, PKLEFT1	SIGTYPE1
HAU	TERRAIN1, VEI2, PKTHRU1	AADT2, METYPE1minor, MEDWDTH2, L3LT
HAZRAT1	SIGTYPE3, MEDTYPE2, HAZRAT2, TERRAIN1, VEI1, VCEI1, VCEICOM, GRADE1, GRADE2, HEICOM	AADT2, SIGTYPE1, SHOULDER1, SHOULDER2, L1RT, L1LT, L3RT, L4LT, LEGACC1, PROTLT2, SD1, SD2, SDL1, SDL2, SDR1, SDR2, SPD1, SPD2
DRWY1	COMDRWY1, RESDRWY1, COMDRWY2, DRWY2, LIGHT, PKTURN, PKLEFT, PKLEFT1	L1RT, L1LT, PRTLT1, SD2, SDL1, SDL2, SDR1, SPD1, SPD2, PKTHRU1
SPD1	SIGTYPE2, L1RT, L1LT, L3RT, L3LT, SD1, SD2, SDL1, SDL2, SDR1, SDR2, SPD2, PKTRUCK	HAZRAT1, HAZRAT2, COMDRWY1, DRWY1, COMDRWY2, DRWY2, LIGHT, VCEICOM, GRADE2, HEI1, PKTURN, PKLEFT
SPD2	L1RT, L1LT, L3RT, L3LT, SDD1, SD2, SDL1, SDL2, SDR1, SDR2, SPD1, PKTRUCK, PKTHRU2	HAZRAT1, HAZRAT2, COMDRWY1, DRWY1, COMDRWY2, RESDRWY2, DRWY2, LIGHT, GRADE2, HEI1, HEI2, HI2, HEICOM, HICOM, PKLEFT2
LIGHT (no=0,yes=1)	AADT1, SIGTYPE1, PROTLT1, COMDRWY1, DRWY1, COMDRWY2, DRWY2, PKLEFT2	SIGTYPE3, L1RT, L3RT, SDL1, SDL2, SPD1, SPD2, PKLEFT1
TERRAIN1	MEDTYPE2, HAZRAT1, TERRAIN2, VEI1, VEICOM, VCEI1, VCEICOM, GRADE1, GRADE2, HICOM, HAU	L1RT, L1LT, SD1, SD2, SDL1, SDL2, SDR2
L1RT	L1LT, L3RT, L3LT, LEGACC1, PROTLT1, SD1, SD2, SDL1, SDL2, SPD1, SPD2	HAZRAT1, COMDRWY1, DRWY1, LIGHT, TERRAIN1, VEI1, VCEI1, GRADE1, HEI1, HI1, HICOM
L1LT	AADT1, SIGTYPE2, MEDTYPE1, MEDWDTH1, L1RT, L3LT, PROTLT1, SD1, SDR2, SPD1, SPD2	SIGTYPE1, HAZRAT1, HAZRAT2, COMDRWY1, DRWY1, COMDRWY2, DRWY2, TERRAIN1, GRADE1

Table 123. Summary of Correlations for Independent Variables for Type V Sites (Continued)

Variable	Positive Correlates[1]	Negative Correlates[1]
L3RT	AADT2, SHOULDER1, L1RT, L3LT, SDL1, SDL2, SDR1, SDR2, HEI2, HI2, SPD1, SPD2, PKTHRU2	HAZRAT1, DRWY2, LIGHT, VEI2, VEICOM, PKLEFT2
L3LT	AADT2, L1RT, L3RT, LEGACC1, PROTLT1, SD2, SDL2, VEI1, SPD1, SPD2, PKTHRU2	HAZRAT1, COMDRWY1, COMDRWY2, RESDRWY2, DRWY2, HAU, PKTHRU1
PKTRUCK	PROTLT1, SPD1, SPD2	
PKTURN	AADT2, COMDRWY1, DRWY1, COMDRWY2, VEI1, VEICOM, VCEI1, VCEICOM, GRADE1, HEI1, HI2, PKLEFT, PKLEFT1	AADT1, SIGTYPE2, RESDRWY2, SPD1, PKTHRU1, PKTHRU2
VEICOM	MEDWDTH1, LEGACC2, PROTLT1, TERRAIN2, VEI1, VEI2, VCEI1, VCEI2, VCEICOM, GRADE1, GRADE2, HI1, PKTURN, PKLEFT1	L3RT, SD1, SDR1, SDR2, PKTHRU1
HEICOM	PROTLT1, HAZRAT1, HAZRAT2, VEI1, GRADE1, GRADE2, HEI1, HI1, HEI2, HI2, HICOM, PKLEFT2	SD1, SD2, SDL1, SDL2, SDR1, SPD2
GRADE1	HAZRAT1, HAZRAT2, TERRAIN1, VEI1, VEICOM, VCEI1, VCEICOM, GRADE2, HI1, HEI2, HEICOM, HICOM, PKTURN, PKLEFT	AADT1, L1RT, L1LT, SD1, SD2, SDL1, SDL2, SDR2, PKTHRU1
SDL2	SHOULDER1, L1RT, L3RT, L3LT, SD1, SD2, SDL1, SDR1, SDR2, SPD1, SPD2	HAZRAT1, HAZRAT2, COMDRWY1, DRWY1, DRWY2, LIGHT, TERRAIN1, TERRAIN2, GRADE1, GRADE2, HEI1, HI2, HEICOM, HICOM
SDR2	SHOULDER1, L1LT, L3RT, SD1, SD2, SDL1, SDL2, SDR1, SPD1, SDP2	HAZRAT1, HAZRAT2, TERRAIN1, VEI1, VEI2, VEICOM, VCEI1, VCEI2, VCEICOM, GRADE1, GRADE2

[1] Variables only significant with *p*-value of 0.1 were selected

3.3 AADT MODEL ESTIMATION RESULTS

This section discusses the development of AADT-only models. Two types of models are presented for Types I and II sites, and three types of models are given for Type III, IV, and V sites in this report. First, models were calibrated using all available data from the HSIS California database, the original sites from Minnesota and Michigan, and the Georgia validation data. This group of data is referred to as Group B. Second, Types I to IV models were developed for a subset of these sites that met specified conditions for possible use as base models in the IHSDM accident prediction algorithm. For Types III, IV, V sites, additional AADT models were calibrated from a dataset that met the base conditions of the significant variables in the full models. These AADT-only models used the data for the original sites from California and Michigan along with the Georgia validation data. This group of data is referred to as Group A. Table 124 shows the summary of the data used for AADT-only models.

Table 124. Summary of AADT Models Recalibrated and Data Used

Model Description	Site Types and Data Used			
	Types I and II	Type III	Type IV	Type V
Group B Sites: AADT Model for all sites, including California HSIS[1]	California HSIS Minnesota Georgia	California HSIS Michigan Georgia	California HSIS Michigan Georgia	California HSIS Michigan Georgia
Subset of Group B Sites: AADT Model for sties meeting base conditions for project data plus California HSIS[1]	California HSIS Minnesota Georgia	California HSIS Michigan Georgia	California HSIS Michigan Georgia	*Not calibrated*
Subset of Group A Sites: Model for sites meeting base conditions for project data	*Not calibrated*	California project Michigan Georgia	California project Michigan Georgia	California project Michigan Georgia

[1] The California project data for Types III, IV, and V were not used

Models were developed for total accidents (TOTACC) and injury (fatal + nonfatal injury) accidents (INJACC) using accidents within 76.25 m (250 ft) of the intersection center.

3.3.1 Description of Base Conditions

The accident prediction algorithm outlined in the "Red Book" provides AMFs for four variables: intersection skew angle; left-turn lanes on major approach; right-turn lanes on major approach; and the number of intersection quadrants with inadequate sight distance.(3) It was sought to develop AADT-only base models using sites which met the base condition criteria for these AMFs and for any other variables that logically and practically could provide additional AMFs.

Base conditions were defined by examining the distribution of variables and selecting the most common condition, keeping in mind that enough sites must remain to calibrate reliable models. Whether a variable exhibited an impact on safety was also considered in defining base conditions.

Group A and B Data

For type I and II intersections, the base models were developed using all of the Minnesota, Georgia, and California HSIS data, the combination of which is referred to as Group B. For Type III and IV intersections, base models were developed from two datasets. The first included the Michigan, original California, and Georgia sites (Group A). The second included the Michigan, Georgia, and California HSIS sites (Group B).

The Group B dataset has more sample sites but fewer variables than the Group A dataset for Type I to IV sites. Therefore, while the Group B dataset is more useful for the AADT model development, the Group A datasets benefit the full model development because of the large number of variables. Type III and IV considered both Group A and B sites for the full model and AADT model development. Type V base models were calibrated only for the Group A sites because only five sites could have been added from the Group B California HSIS data.

Group B Base Conditions

Intersection skew angle was not included as a base condition because the California HSIS data does not contain this variable and the skew angle at those sites where it is known is in fact highly variable. Selecting a skew angle of zero as a base condition would have left few sites for calibrating a base condition model.

For the Minnesota sites and the California HSIS sites, sight distance information is not available, and was therefore not included as a base condition. However, it is reasonable to believe that the majority of sites have adequate sight distance since roads are constructed to design standards and exceptions are made only where necessary. Thus, the base models developed could be applied assuming they represent sites with adequate sight distance, and that inadequate sight distance could be taken into account with the use of an AMF. In the event that many of the sites did, in fact, have deficient site distance, the base models calibrated with a contrary assumption would produce artificially high predictions if crashes actually increased with deficient sight distance.

The Group B nominal or base conditions and the number of sites meeting these conditions for model types I to IV are presented in table 125. For Types I and II, approximately 65 percent of all the sites met all of the specified base conditions, while for Types III and IV, the percentage of sites that met all of the base conditions was approximately 20 percent and 15 percent, respectively.

For Types I and II, no turning lanes on the major or minor road and no medians on the major road were selected as base conditions.

Table 125. Group B Base Conditions for Type I to IV AADT Models

Variable	Type I and II Base Condition	Type I Frequency (Percent)	Type II Frequency (Percent)	Type III and IV Base Condition	Type III Frequency (Percent)	Type IV Frequency (Percent)
Right turn on major	No	1563 (85.97)	911 (82.40)	No	253 (86.05)	164 (73.87)
Right turn on minor	No	1770 (97.36)	1080 (97.60)	No	268 (91.16)	176 (79.28)
Left turn on major	No	1382 (76.02)	883 (79.84)	Yes	174 (59.18)	145 (65.32)
Left turn on minor	No	1804 (99.23)	1105 (99.91)	No	292 (99.32)	219 (98.65)
Median on major	No	1738 (96.60)	1069 (96.65)	Yes	212 (73.87)	148 (66.67)
Terrain on major	N/A[1]			Flat	164 (55.78)	148 (66.67)
Total sites meeting all base conditions		1213 (66.72)	718 (64.92)		62 (21.09)	34 (15.32)
Total sites		1818 (100.00)	1106 (100.00)		294 (100.00)	222 (100.00)

[1] N/A: not available

Unlike Types I and II, terrain on major road was included as a base condition for Types III and IV because it showed a significant impact on safety. Also for Types III and IV, and unlike the cases for Types I and II, the base conditions included the presence of a left-turn lane on the major road and the presence of a median on the major road.

Group A Base Conditions

The Group A nominal or base conditions and the number of sites meeting these conditions for model Types III to V are presented in tables 126 to 131. Separate base conditions were defined for TOTACC and INJACC models. The percentage of sites meeting all of the base conditions ranged from approximately 26 percent to 54 percent.

Type III

For total accidents, vertical curves on the major road, commercial driveways on the major road, and intersection angle were selected as significant variables from the full models.

Table 126 shows the base conditions for these variables. For vertical curves, only a few sites met the "no vertical curve" condition and, therefore, a VEI less than 1 degree per 30.5 m (100 ft) (which is relatively flat) was used for the base condition. Similarly, an intersection angle between plus or minus 5 degrees was defined as the base condition representing "no skew." No commercial driveways within 76.25 m (250 ft) of the intersection center is the final base condition.

Table 126. Group A Base Conditions for Type III TOTACC AADT Models

Variable	Base Conditions	Frequency (Percent)
VEI1	Flat (≤1° per 100 ft)	88 (64.7)
COMDRWY1	0	83 (61.0)
HAU	-5° ~ 5°	89 (65.4)
Total sites meeting all base conditions		39 (28.68)
Total sites		136 (100.0)

For injury accidents, hazard rating on the major road, commercial driveways on the major road, and intersection angle were selected as significant variables from the full models. Table 127 shows base conditions for these variables. For hazard rating, values of 1 and 2 were taken as the base condition. An intersection angle between plus and minus 5 degrees and no commercial driveways within 76.25 m (250 ft) of the intersection center were the other base conditions.

Table 127. Group A Base Conditions for Type III INJACC AADT Models

Variable	Base Conditions	Frequency (Percent)
COMDRWY1	0	83 (61.0)
HAU	-5° ~ 5°	89 (65.4)
HAZRAT1	1 or 2	74 (54.4)
Total sites meeting all base conditions		36 (26.47)
Total sites		136 (100.0)

Type IV

For total accidents, "right" sight distance from minor road and median type on major road were selected as significant variables from the full models. Table 128 shows the base conditions for these variables. Adequate sight distance and no median are the base conditions. The same rule was applied to judge adequate sight distance as the rule described on page 48 of the Harwood et al. report.[3]

Table 128. Group A Base Conditions for Type IV TOTACC AADT Models

Variable	Base Conditions	Frequency (Percent)
SDR2	Adequate right sight distance	116 (96.0)
MEDTYPE	No median type	70 (56.5)
Total sites meeting all base conditions		67 (54.03)
Total sites		124 (100.0)

For injury accidents, right sight distance from minor road, median type on major roads, and posted speed limit on minor road were selected as significant variables from the full models. Table 129 shows the base conditions for these variables. Adequate sight distance, no median type, and speed limit between 48 and 56 kilometers per hour (km/h) (30 and 35 miles per hour (mi/h)) are the base conditions. As for total accidents, the same rule was applied to estimate adequate sight distance as was described on page 48 of the Harwood et al. report.[3] For posted speed limit, not enough sites with a single posted speed limit could represent a base condition. Therefore, a range with the highest frequency (48 to 56 km/h (30 to 35 mi/h)) was considered as the base condition.

Table 129. Group A Base Conditions for Type IV INJACC AADT Models

Variable	Base Conditions	Frequency (Percent)
SDR2	Adequate right sight distance	116 (96.0)
MEDTYPE1	No median type	70 (56.5)
SPD2	30 ~ 35 mi/h	84 (67.7)
Total sites meeting all base conditions		38 (30.65)
Total sites		124 (100.0)

Type V

Total accidents HEICOM for major and minor roads, median type on major roads, and posted speed limit on major roads were estimated as significant in the full models and used for base conditions. Table 130 shows the base conditions for these variables. For HEICOM, radium larger than 458 m (1500 ft) was considered as the base condition. For posted speed limit, the speed range between 72–88 km/h (45–55 mi/h) was used as the base condition since this range had the highest frequency.

Table 130. Group A Base Conditions for Type V TOTACC AADT Models

Variable	Base Conditions	Frequency (Percent)
HEICOM	≤ 3.82 (radius ≥ 1500 ft)	80 (80.0)
MEDTYPE	No median type	87 (87.0)
SPD1	72–88 km/h (45 ~ 55 mi/h)	66 (66.0)
Total sites meeting all base conditions		49 (49.00)
Total sites		100 (100.0)

For injury accidents, posted speed limit on major road and presence of lighting at intersection were selected as significant variables from the full models. Table 131 shows the base conditions for these variables. Presence of lighting and speed range between 72 and 89 km/h (45 and 55 mi/h) were considered as the base conditions.

Table 131. Group A Base Conditions for Type V INJACC AADT Models

Variable	Base Conditions	Frequency (Percent)
SPD1	72–88 km/h (45 ~ 55 mi/h)	66 (66.0)
LIGHT	Yes	71 (71.0)
Total sites meeting all base conditions		39 (39.00)
Total sites		100 (100.0)

3.3.2 Model Results

The AADT-only modeling results are discussed next. In the tables below, the data for and models calibrated using all available sites are referred to in the table headings as main models.

Type I Models

The datasets used to develop Type I AADT-only models included the Minnesota sites from the original study, with the additional years of accident data, the Georgia sites, and sites extracted from the California HSIS database. Sites with very low volume typically are not representative of sites in the general population. These low volume counts, sometimes as low as one vehicle per day, appear to be of suspect quality. With a large number of available sites, intersections with a major road AADT below 400 or a minor road AADT below 100 were removed from the data. The total number of sites and the number of Group B base condition sites are given in table 132. Summary statistics on these datasets are presented in table 133.

Table 132. Number of Sites Used for Type I Main and Group B Base AADT Models

Dataset	All Sites	Group B Base Condition Sites	Percent (Base/All Sites)
Minnesota 1985–98	270	133	49.3
Georgia 1996–97	116	107	92.2
California 1991–98	1432	973	67.9

Table 133. Summary Statistics for Type I Sites: Main and Group B Base AADT Models

Variable	All Sites				Group B Base Condition Sites			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
TOTACC/yr	0.6074	0.3750	0	6.75	0.5326	0.3750	0	6.00
INJACC/yr	0.2660	0.1250	0	4.13	0.2368	0.1250	0	4.13
AADT1	6011	4475	401	35750	4885	3800	401	20190
AADT2	492	270	100	10001	374	201	100	6480

Tables 134 and 135 report the parameter estimates for the Type I TOTACC and INJACC models calibrated using all sites as well as for those sites meeting the Group B base conditions. A unique constant term was estimated for each location to account for the differences in accident reporting and other characteristics between jurisdictions. Separate values of *K*, the overdispersion parameter, have been estimated for each location using a specially written maximum likelihood program.

Vogt and Bared did not report AADT-only models for Type I intersections, but AADT-only base models subsequently were derived by Harwood et al. by setting default values of two for HAZRAT1 and no right-turn lane on the major road in a model for predicting total intersection related accidents.[1,3] A comparison between this model applied to the recalibration data and the recalibrated model for TOTACC is given. A similar model for INJACC from the original calibration is not available for comparison. The comparison indicates the recalibrated model for total accidents is improved as measured by the GOF using the *K* value.

The CURE method described earlier was used to suggest any alternate model forms that could provide an improved fit to the data. The results indicated that the recalibrated model using the original exponential model form adequately fit the data and that the various adjustments to this model form did not improve the AADT models. Specifically, the Pearson product-moment correlation coefficient, MPB per year, and MAD per year were negligibly different. Therefore it was decided to retain the original model form. Appendix D shows the CURE plot for the Type I AADT TOTACC model.

Tables 134 and 135 indicate that the β coefficient of the log of major road AADT is about two times that for minor road AADT, which seems to be a reasonable expectation on the basis of other models reported in the literature. For the TOTACC model, the base conditions model was estimated with a lower overall K than the model using all sites. This would be expected, because the base condition sites should be more homogeneous in their design characteristics. For the INJACC model, the overall K was the same for the two AADT models.

Table 134. Parameter Estimates for Recalibrated TOTACC Type I: Main and Group B AADT Models

Variable	All Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to All Sites	Group B Base Condition Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to Base Condition Sites
Minnesota constant	-8.055 (0.225, <0.001)	-10.900 (0.148, <0.001)	-8.030 (0.294, <0.001)	-10.9 (0.148, <0.001)
Georgia constant	-7.140 (0.246, <0.001)		-7.132 (0.315, <0.001)	
California constant	-8.229 (0.232, <0.001)	N/A[2]	-8.206 (0.303, <0.001)	N/A[2]
Log of AADT1	0.6180 (0.0249, <0.001)	0.7900 (0.0630, <0.001)	0.6445 (0.0310, <0.001)	0.7900 (0.0630, <0.001)
Log of AADT2	0.3872 (0.0215, <0.001)	0.4900 (0.0680, <0.001)	0.3540 (0.0296, <0.001)	0.4900 (0.0680, <0.001)
K–all locations	0.417		0.370	
K–Minnesota	0.256		0.244	
K–Georgia	0.161		0.192	
K–California	0.476	0.540	0.400	0.540
Pearson product-moment correlation coefficient	0.668	0.658	0.600	0.584
MPB/yr	-0.001	0.280	-0.004	0.293
MAD/yr	0.368	0.394	0.321	0.367

[1] The base model published in Harwood et al., 2000, (p. 21)
[2] N/A: not available

Table 135. Parameter Estimates for Recalibrated INJACC Type I: Main and Group B AADT Models[1]

Variable	All Sites Estimate (s.e., *p*-value)	Group B Base Condition Sites Estimate (s.e., *p*-value)
Minnesota constant	-8.778 (0.275, <0.001)	-8.834 (0.376, <0.001)
Georgia constant	-7.942 (0.304, <0.001)	-8.035 (0.405, <0.001)
California constant	-8.788 (0.283, <0.001)	-8.8524 (0.388, <0.001)
Log of AADT1	0.6159 (0.0306, <0.001)	0.6426 (0.0397, <0.001)
Log of AADT2	0.3551 (0.0253, <0.001)	0.3382 (0.0364, <0.001)
K–all locations	0.435	0.435
K–Minnesota	0.263	0.227
K–Georgia	0.303	0.294
K–California	0.500	0.476
Pearson product-moment correlation coefficient	0.586	0.520
MPB/yr	-0.0001	0.0001
MAD/yr	0.195	0.182

[1]No previously calibrated AADT-only model for injury accidents exists for comparison for Type I sites

Type II Models

The datasets used to develop the Type II main and Group B base models included the Minnesota sites from the original study, with the additional years of accident data, the Georgia sites, and sites extracted from the California HSIS database. As for Type I, the large number of sites available allowed for the removal of those sites with a major road AADT less than 400 or a minor road AADT less than 100, the rationale again being that the omitted sites either have errors in AADTs or are unrepresentative of those in the general population. The total number of sites and the number of Group B base condition sites are given in table 136. Summary statistics on these datasets are presented in table 137.

Table 136. Number of Sites Used for Type II Main and Group B Base AADT Models

Dataset	All Sites	Group B Base Condition Sites	Percent (Base/All Sites)
Minnesota 1985–98	250	120	48.0
Georgia 1996–97	108	100	92.6
California 1991–98	748	498	66.6

Table 137. Summary Statistics for Type II Sites: Main and Group B Base AADT Models

Variable	All Sites				Group B Base Condition Sites			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
TOTACC/yr	0.9227	0.5357	0	7.13	0.8440	0.5000	0	7.07
INJACC/yr	0.4665	0.2500	0	4.75	0.4249	0.2500	0	3.50
AADT1	5487	4245	407	38126	4855	3907	407	28860
AADT2	532	344	100	7460	448	310	100	5801

Tables 138 and 139 report the parameter estimates for the Type II TOTACC and INJACC models, which were calibrated using all sites and those meeting the base conditions. A unique constant term was estimated for each location to account for the differences in accident reporting and other characteristics between jurisdictions. Separate values of K, the overdispersion parameter, have been estimated for each location using the specially developed maximum likelihood program.

Vogt and Bared did not report AADT-only models for Type II intersections.[1] However, AADT-only base models were subsequently derived by setting default values of "no intersection skew angle" and "no driveways within 76.25 m (250 ft) of the intersection" on the major road for a model for predicting total intersection related accidents.[3] A comparison between this model applied to the recalibration data and the recalibrated model for TOTACC is given. A similar model for INJACC for the original calibration is not available for comparison. The comparison indicates the recalibrated model for total accidents has an inferior GOF compared to the Vogt and Bared models using the *K* value for all States, both combined and individually. In particular, the model does a poorer job for the Georgia and California sites.

The CURE method was again used to suggest any alternate model forms that could provide an improved fit the data. The results indicated that the recalibrated model using the original exponential model form adequately fit the data, and the various adjustments to this model form did not improve the AADT models. Specifically, there was a negligible difference in Pearson product-moment correlation coefficient, MPB per year, and MAD per year. Therefore it was decided to retain the original model form. Appendix D shows the CURE plot for the Type II AADT TOTACC model.

Table 138 indicates that the β coefficient of the log of major road AADT is about 35 percent higher than that for minor road AADT value. Table 139 indicates that the β coefficient of the log of major road AADT is about 10 to 20 percent higher than that for minor road AADT, which is consistent with previous modeling efforts. For both the TOTACC and INJACC models, the base condition models were estimated with a lower overall *K* than the model using all sites. Again, this would be expected, because the base condition sites should be more homogeneous in their design characteristics.

Table 138. Parameter Estimates for Recalibrated TOTACC Type II: Main and Group B AADT Models

Variable	All Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to All Sites	Group B Base Condition Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to Base Condition Sites
Minnesota constant	-8.747 (0.294, <0.001)	-9.340 (0.720, <0.001)	-9.494 (0.407, <0.001)	-9.340 (0.720, <0.001)
Georgia constant	-8.299 (0.312, <0.001)	N/A[1]	-8.970 (0.424, <0.001)	N/A[1]
California constant	-8.832 (0.301, <0.001)		-9.4532 (0.415, <0.001)	
Log of AADT1	0.6723 (0.0331, <0.001)	0.6010 (0.0780, <0.001)	0.7128 (0.0423, <0.001)	0.6010 (0.0780, <0.001)
Log of AADT2	0.4873 (0.0267, <0.001)	0.6100 (0.0690, <0.001)	0.5445 (0.0361, <0.001)	0.6100 (0.0690, <0.001)
K–all locations K–Minnesota K–Georgia K–California	0.400 0.256 0.556 0.435	0.240	0.370 0.256 0.588 0.385	0.240
Pearson product-moment correlation coefficient	0.686	0.669	0.747	0.733
MPB/yr	-0.010	0.305	-0.004	0.335
MAD/yr	0.532	0.542	0.480	0.514

[1] The base model published in Harwood et al., 2000 (p. 22)
[2] N/A: not available

Table 139. Parameter Estimates for Recalibrated INJACC Type II: Main and Group B AADT Models [1]

Variable	All Sites Estimate (s.e., *p*-value)	Base Condition Sites Estimate (s.e., *p*-value)
Minnesota constant	-9.266 (0.339, <0.001)	-9.707 (0.472, <0.001)
Georgia constant	-8.636 (0.361, <0.001)	-9.071 (0.492)
California constant	-9.213 (0.347, <0.001)	-9.5611 (0.481)
Log of AADT1	0.6210 (0.0380, <0.001)	0.6282 (0.0490, <0.001)
Log of AADT2	0.5118 (0.0301, <0.001)	0.5692 (0.0411, <0.001)
K–all locations	0.417	0.385
K–Minnesota	0.294	0.303
K–Georgia	0.161	0.217
K–California	0.476	0.435
Pearson product-moment correlation coefficient	0.626	0.679
MPB/yr	-0.005	-0.001
MAD/yr	0.302	0.279

[1] No previously calibrated AADT-only model for injury accidents exists for comparison for type II sites

Type III Models

The dataset used to develop the main Type III model included the Michigan sites from the original study, with the additional years of accident data, the Georgia sites, and those extracted from the California HSIS database. Unlike the case for Types I and II models, the researchers did not have the luxury of removing sites with a minor road AADT less than 100, because as many as 87 out of the 294 available sites had an AADT on the minor road of less than 100.

Base models were calibrated using both the Group A and Group B datasets. The total number of sites and the number of Group B base condition sites are given in table 140. Summary statistics on these datasets are presented in table 141.

Table 140. Number of Sites Used for Type III Main and Group B Base Condition AADT Models

Dataset	All Sites	Group B Base Condition Sites	Percent (Base/All Sites)
Michigan 1993–97	24	0	0.0
Georgia 1996–97	52	14	27.0
California 1991–98	218	48	22.0

Table 141. Summary Statistics for Type III Sites: Main and Group B Base AADT Models

	All Sites				Group B Base Condition Sites			
Variable	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
TOTACC/yr	1.13	0.50	0.00	15.13	1.05	0.63	0	6.88
INJACC/yr	0.45	0.25	0.00	5.13	0.57	0.38	0	4.13
AADT1	17002	12909	1902	74500	18933	15433	6500	57731
AADT2	449	206	1	9490	466	325	10	2500

Tables 142 and 143 report parameter estimates for the main Type III TOTACC and INJACC models, calibrated using all sites and as well as those meeting the Group B base conditions. Unlike models for Type I and II intersections, a unique constant term was not included for each State, because the State indicator variables were insignificant.

For reference, comparisons between the Vogt AADT models applied to the recalibration data and the recalibrated models for TOTACC and INJACC are also given in tables 142, 143, and 145. The comparisons indicate the recalibrated models for TOTACC and INJACC have a better GOF measures compared to the Vogt models.

The CURE plot method proposed by Hauer was also used to suggest any alternate model forms that could provide an improved fit for the data. The results indicated that the recalibrated models using the original exponential model form adequately fit the data and that the various adjustments to this model form did not improve the AADT models. Specifically, the differences in Pearson product-moment correlation coefficient, MPB per year, and MAD per year were negligible. Therefore the original model form was retained. Appendix D shows the CURE plot for the Type III AADT TOTACC model.

Table 142 indicates that the β coefficient of the log of major road AADT is about two to three times that for minor road AADT, a reasonable expectation. Table 143 shows that β coefficient of the log of major road AADT is about three to four times that for minor road AADT, which is also consistent with previous efforts. Pearson product-moment correlation coefficients for TOTACC and INJACC models were approximately 0.65.

Table 142. Parameter Estimates for Recalibrated TOTACC Type III: Main and Group B Base AADT Models

Variable	All Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to All Sites	Group B Base Condition Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to Base Condition Sites
Constant	-9.6835 (0.6109, 0.0000)	-12.9243 (2.3682,0.0001)	-12.1332 (1.9357, 0.0000)	-12.9243 (2.3682,0.0001)
Log of AADT1	0.8238 (0.0613, 0.0000)	1.1989 (0.2477,0.0001)	1.0941 (0.1762, 0.0000)	1.1989 (0.2477,0.0001)
Log of AADT2	0.3206 (0.0317, 0.0000)	0.3027 (0.0892,0.0007)	0.2544 (0.0636, 0.0001)	0.3027 (0.0892,0.0007)
K	0.5849	0.5256	0.3125	0.5256
Pearson product-moment correlation coefficient	0.66	0.68	0.67	0.58
MPB/yr	0.03	-0.52	0.02	-0.70
MAD/yr	0.71	1.02	0.60	0.96

[1] The AADT model published in Vogt, 1999, (p. 111)

Table 143. Parameter Estimates for Recalibrated INJACC Type III: Main and Group B Base AADT Models

Variable	All Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to All Sites	Group B Base Condition Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to Base Condition Sites
Constant	-12.0590 (0.8435, 0.0000)	-13.1685 (3.0319,0.0001)	-15.2817 (2.2629, 0.0000)	-13.1685 (3.0319,0.0001)
Log of AADT1	0.9980 (0.0814, 0.0000)	1.2028 (0.3082,0.0001)	1.3316 (0.2081, 0.0000)	1.2028 (0.3082,0.0001)
Log of AADT2	0.2720 (0.0366, 0.0000)	0.1925 (0.0931,0.0388)	0.2648 (0.0717, 0.0002)	0.1925 (0.0931,0.0388)
K	0.5162	0.5649	0.3074	0.5649
Pearson product-moment correlation coefficient	0.67	0.66	0.63	0.62
MPB/yr	0.01	0.08	0.01	-0.20
MAD/yr	0.32	0.59	0.32	0.49

[1] The AADT model published in Vogt, 1999, (p.113)

Summary statistics on the Group A base condition datasets are presented in table 144.

Table 144. Summary Statistics for Type III Sites: Group A Base AADT Models

Variable	Group A Base Condition Sites TOTACC No. of Sites = 39				Group A Base Condition Sites INJACC No. of Sites = 36			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
ACC/yr	0.76	0.50	0	4.20	0.23	0.00	0	1.60
AADT1	12087	10977	2360	33333	11610	10217	4794	28000
AADT2	324	180	20	2500	359	292	15	1128

Table 145 reports the parameter estimates for the Group A Type III TOTACC and INJACC base models. The β coefficient of the log of major road AADT is about three to four times that for minor road AADT, which is reasonable. The INJACC models differed from the TOTACC models in the use of LOG (AADT1 * AADT2) rather than the individual logs of the major and minor road AADTs. For INJACC, the coefficient of the log of AADT2 was quite insignificant because of large standard error. Pearson product-moment correlation coefficients of TOTACC and INJACC AADT models were 0.65 and 0.47, respectively.

Table 145. Parameter Estimates for Type III Group A TOTACC and INJACC Base Models

Variable	TOTACC Estimate (s.e., *p*-value)	Original TOTACC AADT Model[1] Applied to Group A Sites	INJACC Estimate (s.e., *p*-value)	Original INJACC AADT Model[2] Applied to Group A Sites
Constant	-13.8087 (2.5448, 0.0000)	-12.9243 (2.3682,0.0001)	-6.3924 (2.4337, 0.0086)	-13.1685 (3.0319,0.0001)
Log of AADT1	1.2194 (0.2874, 0.0000)	1.1989 (0.2477,0.0001)	N/A[3]	1.2028 (0.3082,0.0001)
Log of AADT2	0.3693 (0.1326, 0.0054)	0.3027 (0.0892,0.0007)	N/A[3]	0.1925 (0.0931,0.0388)
Log of (AADT1*AADT2)	N/A[3]	N/A[3]	0.3280 (0.1614, 0.0421)	N/A[3]
K	0.5227	0.5256	0.7691	0.5649
K–Vogt, 1999	0.5256		0.5649	
Pearson product-moment correlation coefficient	0.65	0.58	0.47	0.64
MPB/yr	-0.01	0.05	0.00	-0.23
MAD/yr	0.55	0.58	0.25	0.35

[1] The TOTACC AADT model published in Vogt, 1999, (p. 111)
[2] The INJACC AADT model published in Vogt, 1999, (p. 113)
[3] N/A: not available

Type IV Models

The datasets used to develop the main Type IV model included the Michigan sites from the original study, with the additional years of accident data, the Georgia sites, and those extracted from the California HSIS database. Again, a large number of sites (52 out of

222) had a minor road AADT of less than 100, so, unlike the case for Types I and II, the researchers could not remove sites with a minor road AADT less than 100.

Base models were calibrated using both the Group A and Group B datasets. The total number of sites and the number of Group B base condition sites are given in table 146. Summary statistics on these datasets are presented in table 147.

Table 146. Number of Sites Used for Type IV Main and Group B Base Condition AADT Models

Dataset	All Sites	Group B Base Condition Sites	Percent (Base/All Sites)
Michigan 1993–97	18	0	0.0
Georgia 1996–97	52	1	1.9
California 1991–98	152	33	21.7

Table 147. Summary Statistics for Type IV Sites: Main and Group B Base AADT Models

Variable	All Sites				Group B Base Condition Sites			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
TOTACC/yr	1.6	1.0	0.0	10.8	1.3	0.6	0	5.4
INJACC/yr	0.7	0.4	0.0	4.5	0.7	0.4	0	3.3
AADT1	15477	12950	2192	69521	18385	13865	2367	43167
AADT2	552	420	10	7400	345	186	11	2625

Tables 148 and 149 report the parameter estimates for the main Type IV TOTACC and INJACC models, calibrated using all sites and those sites meeting the Group B base conditions. Unlike models for Type I and II intersections, a State indicator variable was insignificant. For reference, the estimated overdispersion parameter for the original full models is also given.

The CURE method was again used to suggest any alternate model forms that could provide an improved fit the data. The results indicated that the various adjustments to this model form did not improve the AADT models. Specifically, the Pearson product-moment correlation coefficient, MPB per year, and MAD per year were negligibly different. Therefore, the original model form was retrained. Appendix D shows the CURE plot for the Type IV AADT TOTACC model.

Table 148 indicates that, as expected, the β coefficient of the log of major road AADT is significantly larger than that for minor road AADT. Table 149 shows that, again, the β coefficient of the log of major road AADT for the INJACC model is also significantly larger than that for minor road AADT. Pearson product-moment correlation coefficients for TOTACC and INJACC models were 0.75 and 0.63 using all sites, and 0.90 and 0.89 for the base sites.

Comparisons between the Vogt AADT models applied to the recalibration data and the recalibrated models for TOTACC and INJACC are also given in tables 148, 149, and 151. The comparisons indicate the recalibrated models for TOTACC and INJACC have better GOF measures compared to the Vogt models.

Table 148. Parameter Estimates for Recalibrated TOTACC Type IV: Main and Group B Base AADT Models

Variable	All Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to All Sites	Group B Base Condition Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to Base Condition Sites
Constant	-8.0289 (0.8553, 0.0000)	-6.9352 (2.3767,0.0035)	-14.9469 (1.5082, 0.0000)	-6.9352 (2.3767,0.0035)
Log of AADT1	0.6136 (0.0959, 0.0000)	0.4683 (0.2330,0.0444)	1.2826 (0.1398, 0.0000)	0.4683 (0.2330,0.0444)
Log of AADT2	0.4359 (0.0360, 0.0000)	0.5135 (0.0896,0.0001)	0.4671 (0.0779, 0.0000)	0.5135 (0.0896,0.0001)
K	0.6677	0.6144	0.2070	0.6144
Pearson product-moment correlation coefficient	0.75	0.73	0.90	0.78
MPB/yr	0.03	-0.27	0.00	-0.23
MAD/yr	0.98	1.10	0.48	0.76

[1] The AADT model published in Vogt, 1999, (p. 116)

Table 149. Parameter Estimates for Recalibrated INJACC Type IV: Main and Group B Base AADT Models

Variable	All Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to All Sites	Group B Base Condition Sites Estimate (s.e., *p*-value)	Original AADT Model[1] Applied to Base Condition Sites
Constant	-8.2849 (0.9947, 0.0000)	-9.8454 (2.5675,0.0001)	-15.1858 (1.7442, 0.0000)	-9.8454 (2.5675,0.0001)
Log of AADT1	0.5844 (0.1128, 0.0000)	0.7224 (0.2591,0.0053)	1.2513 (0.1688, 0.0000)	0.7224 (0.2591,0.0053)
Log of AADT2	0.3961 (0.0445, 0.0000)	0.4778 (0.1401,0.0007)	0.4535 (0.0811, 0.0000)	0.4778 (0.1401,0.0007)
K	0.7490	0.5741	0.1486	0.5741
Pearson product-moment correlation coefficient	0.63	0.61	0.89	0.86
MPB/yr	0.02	-0.22	-0.01	-0.15
MAD/yr	0.53	0.63	0.29	0.39

[1] The AADT model published in the Vogt's report, 1999, (p. 118)

Summary statistics on the Group A base condition datasets are presented in table 150.

Table 150. Summary Statistics for Type IV Sites: Group A Base AADT Models

Variable	Group A Base Condition Sites TOTACC No. of Sites = 67				Group A Base Condition Sites INJACC No. of Sites = 38			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
ACC/year	2.39	2.00	0	10.80	0.93	0.82	0	3.33
AADT1	12444	12601	4210	25799	12417	13740	4210	25799
AADT2	764	592	21	2990	717	498	43	2990

Table 151 reports the parameter estimates for the Group A Type IV TOTACC and INJACC base models. This table indicates that the β coefficient of the log of major road AADT is about one and one half times that for minor road AADT, conforming to expectations. As was the case for Type III, the INJACC model used LOG (AADT1 * AADT2) because log of AADT2 was quite insignificant. However, even with LOG (AADT1 * AADT2), the *p*-value was not statistically significant. It appears that the sample size of 38, with a relatively low number of injury accidents, was not sufficient to provide reasonable coefficients and *p*-values for the INJACC model.

Table 151. Parameter Estimates for Type IV Group A TOTACC and INJACC Base Models

Variable	TOTACC Estimate (s.e., *p*-value)	Original TOTACC AADT Model[1] Applied to Group A Sites	INJACC Estimate (s.e., *p*-value)	Original INJACC AADT Model[2] Applied to Group A Sites
Constant	-7.2677 (2.7953, 0.0093)	-6.9352 (2.5675,0.0001)	-3.8217 (2.9225, 0.1910)	-9.8454 (2.5675,0.0001)
Log of AADT1	0.5947 (0.2712, 0.0283)	0.4683 (0.2330,0.0444)	N/A[3]	0.7224 (0.2591,0.0053)
Log of AADT2	0.3964 (0.1685, 0.0187)	0.5135 (0.0896,0.0001)	N/A[3]	0.4778 (0.1401,0.0007)
Log of (AADT1*AADT2)	N/A[3]	N/A[3]	0.2407 (0.1858, 0.1952)	N/A[3]
K	0.5771	0.6144	0.6768	0.5741
Pearson product-moment correlation coefficient	0.64	0.62	0.72	0.63
MPB/yr	-0.04	0.16	-0.03	-0.10
MAD/yr	1.63	1.63	0.73	0.75

[1] The TOTACC AADT model published in the Vogt's report, 1999, (p. 116)
[2] The INJACC AADT model published in the Vogt's report, 1999, (p. 118)
[3] N/A: not available

Type V Models

The datasets used to develop the Type V main models included the Michigan sites from the original study, the additional years of accident data, the Georgia sites, and those extracted from the California HSIS database. Only five sites were available from the California HSIS database, so it was decided not to calibrate Group B base models that would have included these data. Only Group A base models, using the Georgia data and the original sites for Michigan and California, were calibrated.

The numbers of sites comprising the dataset used for the main model are given in table152. Summary statistics are presented in table 153. As seen, for Michigan, the INJACC model used only the additional years of accident data, because injury data for the original years were not available.

Table 152. Number of Sites Used for Type V Main AADT Model

Dataset	All Sites
Michigan 1993–97 (only 1996–97 INJACC used)	18
Georgia 1996–97	51

Table 153. Summary Statistics for Type V Sites: Main AADT Model

Variable	All Sites			
	Mean	Median	Minimum	Maximum
TOTACC/yr	4.9	4.1	0.0	26.5
INJACC/yr	2.2	1.5	0.0	12.0
AADT1	9643	9000	430	26000
AADT2	2995	2700	420	10600

Tables 154 and 155 report the parameter estimates for the main Type V TOTACC and INJACC models calibrated using all sites. Unlike models for Type I and II intersections, a State indicator variable was insignificant. Both tables show that the β coefficient of the log of major road AADT is, in accord with expectations, about two to three times that for minor road AADT. Pearson product-moment correlation coefficients for TOTACC and INJACC were 0.66 and 0.44, respectively.

Unlike the case for Types III and IV, the Vogt report does not provide AADT-only models for Type V. Therefore, a comparison between the Vogt models and the newly calibrated AADT models for TOTACC and INJACC could not be done.

The CURE plot method proposed by Hauer was used to explore alternate model forms that could provide an improved fit the data. The results indicated that the recalibrated models using the original exponential model form adequately fit the data and that the various adjustments to this model form did not improve the AADT models. Specifically, the differences in Pearson product-moment correlation coefficient, MPB per year, and MAD per year were negligible. Therefore, the original model form was retained. Appendix D shows the CURE plot for the Type V AADT TOTACC model.

Table 154. Parameter Estimates for Recalibrated TOTACC Type V: Main AADT Model

Variable	All Sites Estimate (s.e., *p*-value)
Constant	-4.2638 (2.2267, 0.0555)
Log of AADT1	0.4771 (0.2285, 0.0368)
Log of AADT2	0.1970 (0.0908, 0.0300)
K	0.5776
Pearson product-moment correlation coefficient	0.66
MPB/yr	-0.01
MAD/yr	2.95

* There are no Type V AADT models for TOTACC in the Vogt report, 1999

Table 155. Parameter Estimates for Recalibrated INJACC Type V: Main AADT Model

Variable	All Sites Estimate (s.e., *p*-value)
Constant	-9.7110 (2.3118, 0.0000)
Log of AADT1	0.8599 (0.2210, 0.0001)
Log of AADT2	0.3372 (0.1547, 0.0292)
K	0.7267
Pearson product-moment correlation coefficient	0.44
MPB/yr	0.02
MAD/yr	1.64

* There are no Type V AADT models for INJACC in the Vogt report, 1999

Summary statistics on the Group A base condition datasets are presented in table 156.

Table 156. Summary Statistics for Type V Sites: Group A Base AADT Models

	Group A Base Condition Sites TOTACC No. of Sites = 49				Group A Base Condition Sites INJACC No. of Sites = 39			
Variable	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
ACC/yr	7.23	6.00	0.50	26.50	1.94	2.00	0	5.50
AADT1	9238	8700	1700	20067	10059	8750	700	25132
AADT2	3890	3459	430	10280	3772	3452	430	10280

Table 157 reports the parameter estimates for the Group A Type V TOTACC and INJACC base models. This table indicates that the β coefficient of the log of major road AADT is about two to three times greater than that for minor road AADT, which is reasonable. As was the case for Type III and IV models, the INJACC model used LOG (AADT1 * AADT2) because the individual logs for separate AADT terms were insignificant. Pearson product-moment correlation coefficients of TOTACC and INJACC AADT models were 0.70 and 0.57, respectively.

Table 157. Parameter Estimates for Type V Group A TOTACC and INJACC Base Models

Variable	TOTACC Estimate (s.e., *p*-value)	INJACC Estimate (s.e., *p*-value)
Constant	-4.0357 (1.7087, 0.0182)	-3.4199 (2.2752, 0.1328)
Log of AADT1	0.5005 (0.1966, 0.0109)	N/A[1]
Log of AADT2	0.1815 (0.1063, 0.0878)	N/A[1]
Log of (AADT1*AADT2)	N/A[1]	0.2396 (0.1350, 0.0759)
K	0.2429	0.2891
Pearson product-moment correlation coefficient	0.70	0.57
MPB/yr	-0.05	-0.08
MAD/yr	3.10	1.08

* No AADT models previously calibrated
[1] N/A: not available

3.4 FULLY PARAMETERIZED STATISTICAL MODEL ESTIMATION RESULTS

This section discusses the development of the fully parameterized statistical models. Unlike the AADT models, these models include many variables with the intent to explain as much of variation in crash occurrence as possible, given the available set of potential explanatory variables. For Types I and II, models were developed using two different datasets. Types III, IV, and V used only one dataset. Table 158 summarizes what data was used for each model.

Table 158. Summary of Models Recalibrated and Data Used

Model Description	Site Types and Data Used			
	Types I and II	Type III	Type IV	Type V
Group A Sites: Full Model with variables in project data	Minnesota Georgia	California project Michigan Georgia	California project Michigan Georgia	California project Michigan Georgia
Group B Sites: Full Model with variables from California HSIS	California HSIS Minnesota Georgia	*Not calibrated*	*Not calibrated*	*Not calibrated*

* The California project data for Types II, IV, and V were not used

As before, models for total accidents (TOTACC) and injury (fatal + nonfatal injury) accidents (INJACC) within 76.25 m (250 ft) of the intersection were developed.

3.4.1 Type I Models

Full models were developed using two groups of data. As indicated earlier, the first, Group A, was comprised of the sites from Minnesota and Georgia and consisted of many variables, including horizontal and vertical curvature. The California HSIS sites were not in this group because many of the variables were not available. The second, Group B, included the California HSIS sites, but fewer variables were available for modeling.

As was the case for the AADT-only models, sites with a major road AADT below 400 or a minor road AADT below 100 were not used. 270 sites from Minnesota and 116 sites from Georgia were used. The Group B data set contained an additional 1432 sites from the California HSIS database. Summary statistics on these datasets by State are available in appendix C.

Two model variants are reported. The first includes a State indicator term and the second does not. For reference the recalibrated models are compared to the models calibrated using data from Minnesota and recommended by Vogt and Bared.[1]

Group A

Tables 159 and 160 report the parameter estimates for the Type I TOTACC and INJACC models for the Group A data.

Table 159. Parameter Estimates for Recalibrated TOTACC Full Models: Type I Group A

Variables	Variant 1 Coeff. (s.e., *p*-value)	Variant 2 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept for Minnesota	-7.972 (0.398, <0.001)	-8.825 (0.438, <0.001)	-12.992 (1.151, 0.0001)
Intercept for Georgia	-7.086 (0.407, <0.001)		
LOG of AADT1	0.6529 (0.0416, <0.001)	0.7001 (0.0460, <0.001)	0.8052 (0.0639, 0.0001))
LOG of AADT2	0.3211 (0.0439, <0.001)	0.3785 (0.0470, <0.001)	0.5037 (0.0708, 0.0001)
HI1	0.0263 (0.0107, 0.014)	0.0314 (0.0113, 0.005)	0.0339 (0.0327, 0.3004)
RT MAJ	N/A[2]	-0.1887 (0.0841, 0.025)	0.2671 (0.1398, 0.0561)
RT MIN		0.419 (0.244, 0.086)	N/A[2]
LT MAJ		-0.155 (0.110, 0.157)	
HAZRAT1		0.1433 (0.0362, <0.001)	0.1726 (0.0677, 0.0108)
VCI1		0.1204 (0.0362, <0.001)	0.2901 (0.2935, 0.3229)
SPD1		N/A[2]	0.0285 (0.0177)
HAU			0.0045 (0.0032, 0.1578)
K–overall	0.233	0.263	0.481
K–Minnesota	0.250	N/A[2]	N/A[2]
K–Georgia	0.141		
Pearson product-moment correlation coefficients	0.742	0.726	0.726
MPB/yr	-0.010	0.048	0.026
MAD/yr	0.400	0.416	0.030

[1] Vogt and Bared, 1998, (p. 115)
[2] N/A: not available

Table 160. Parameter Estimates for Recalibrated INJACC Full Models: Type I Group A

Variables	Variant 1 Coeff. (s.e., *p*-value)	Variant 2 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept for Minnesota	-8.934 (0.523, <0.001)	-9.727 (0.566, <0.001)	-13.037 (1.791, 0.0001)
Intercept for Georgia	-8.120 (0.537, <0.001)		
LOG of AADT1	0.6809 (0.0552, <0.001)	0.7174 (0.0596, <0.001)	0.8122 (0.0973, 0.0001)
LOG of AADT2	0.2870 (0.0556, <0.001)	0.3251 (0.0569, <0.001)	0.4551 (0.0977, 0.0001)
HI1	0.0286 (0.0136, 0.035)	0.0337 (0.0139, 0.016)	0.0335 (0.0327, 0.3047)
RT MAJ		N/A[2]	0.3620 (0.1814, 0.0460)
LT MAJ		-0.258 (0.132, 0.051)	N/A[2]
HAZRAT1		0.1678 (0.0457, <0.001)	0.2065 (0.0930, 0.0263)
VCI1	N/A[2]	0.0846 (0.0557, 0.129)	0.1869 (0.3657, 0.6092)
SPD1			0.0156 (0.0269, 0.5618)
DRWY1		N/A[2]	-0.0120 (0.0714, 0.8671)
HAU			0.0051 (0.0045, 0.2594)
K–overall	0.256	0.278	0.494
K–Minnesota	0.256	N/A[2]	N/A[2]
K–Georgia	0.256		
Pearson product-moment correlation coefficients	0.691	0.690	0.660
MPB/yr	-0.001	0.003	0.002
MAD/yr	0.212	0.022	0.010

[1] Vogt and Bared, 1998, (p. 116)
[2] N/A: not available

There were similarities and differences between the recalibrated models and the Vogt and Bared models. For total accidents, posted speed on major roads and the angle variable HAU were not included in the recalibrated model, while right-turn lane on minor roads and left-turn lanes on major roads were included. For injury accidents, right-turn on major roads, posted speed on major roads, number of driveways on major roads, and the angle variable HAU were not included, while left-turn lane on major roads were included.

When a State indicator variable was used in the models in addition to the logs of AADTs, only the variable HI1 proved to be significant. Without the State indicator, more geometric variables were statistically significant. The variables RT MAJ, RT MIN, LT MAJ, HAZRAT1, HI1, and VCI1 were all estimated to be significant at the 10 percent level or better in one or both of the TOTACC and INJACC models. However, the overdispersion parameter *K* is higher for the models without the State indicator variable and with more variables.

The data summary in appendix C shows that the Georgia sites experience, on average, more accidents than sites in Minnesota and also are higher in values for HI1, VCI1, and HAZRAT1, while being less likely to have a turning lane on the major road. The question arises then, whether the significantly higher accident risk in Georgia is due to differences in these geometric features or other fundamental reasons such as reporting levels, weather, and sociodemographics. Because the models, including the State location term, have lower overdispersion parameters, it can be concluded that this model should be used. The following analysis further supports this conclusion.

Figure 21 plots the cumulative residuals (Y-axis) versus major AADT (X-axis) for the TOTACC model without the State location variable. The cumulative residuals on occasion go outside the 95 percent confidence intervals for a random walk around 0, indicating that the model is performing poorly.

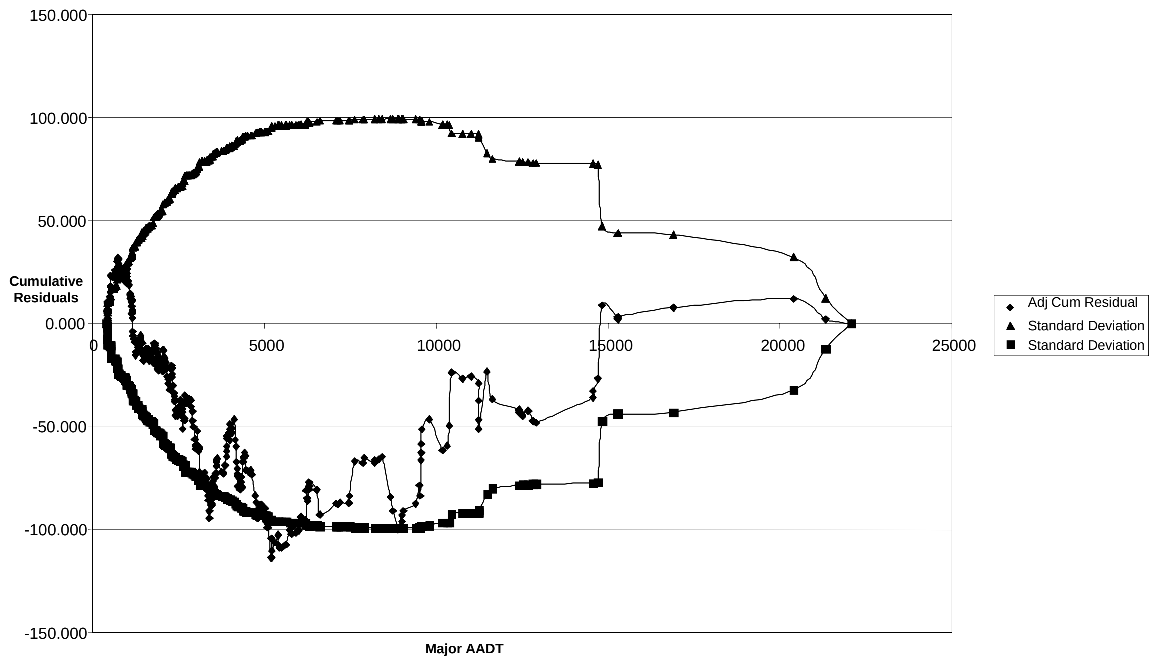

Figure 21. CURE Plot for Alternate TOTACC Type I Group A Model

Figure 22 plots the cumulative residuals (Y-axis) versus major AADT (X-axis) for the TOTACC model, including the State location variable. Although the cumulative residuals go outside the 95 percent plots for few sites at low volumes and AADTs above 15000, the results are a slight improvement over the model without the State location variable in that the oscillations tend to be closer to the x-axis.

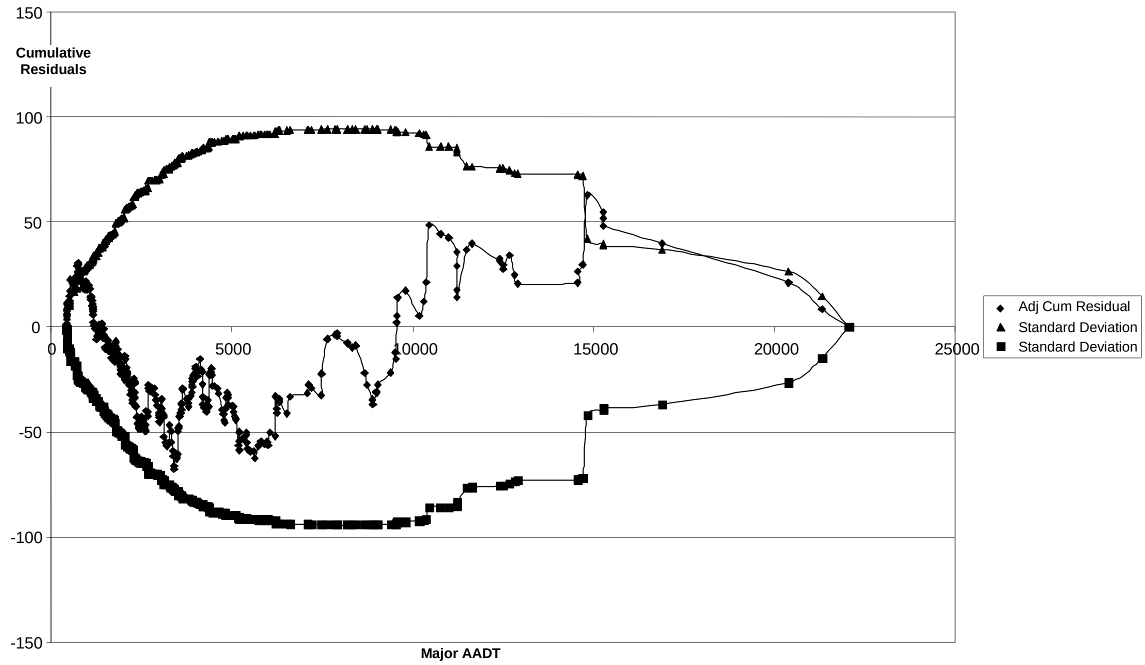

Figure 22. CURE Plot for TOTACC Type I Group A Model

The GOF as measured by *K* was improved over the Vogt and Bared models, although the measures of MPB per year and MAD per year were better for the original model with the exception of the MPB per year for the TOTACC and INJACC Variant 1 models.

Group B

Tables 161 and 162 report the parameter estimates for the Type I TOTACC and INJACC models for the Group B data.

Table 161. Parameter Estimates for Recalibrated TOTACC Full Models: Type I Group B

Variables	Variant 1	Variant 2	Original Main Model[1]
	Coeff. (s.e., *p*-value)	Coeff. (s.e., *p*-value)	Coeff. (s.e., *p*-value)
Intercept for Minnesota	-8.413 (0.244, <0.001)	-8.435 (0.250, <0.001)	-12.992 (1.151, 0.0001)
Intercept for Georgia	-7.603 (0.265, <0.001)		
Intercept for California	-8.641 (0.251, <0.001)		
LOG of AADT1	0.6557 (0.0264, <0.001)	0.6112 (0.0263, <.001)	0.8052 (0.0639, 0.0001))
LOG of AADT2	0.4128 (0.0222, <0.001)	0.4607 (0.0224, <0.001)	0.5037 (0.0708, 0.0001)
HI1[2]	N/A[3]	N/A[3]	0.0339 (0.0327, 0.3004)
RT MAJ	-0.1326 (0.0630, 0.035)	-0.0800 (0.0574, 0.164)	0.2671 (0.1398, 0.0561)
RT MIN	0.3010 (0.1140, 0.009)	0.265 (0.118, 0.024)	N/A[3]
LT MAJ	-0.2042 (0.0500, <0.001)	-0.2838 (0.0509, <.001)	
HAZRAT1[2]	N/A[3]	N/A[3]	0.1726 (0.0677, 0.0108)
VCI1[2]			0.2901 (0.2935, 0.3229)
SPD1[2]			0.0285 (0.0177)
HAU[2]			0.0045 (0.0032, 0.1578)
K–overall	0.400	0.435	0.481
K–Minnesota	0.250	N/A[3]	N/A[3]
K–Georgia	0.189		
K–California	0.455		
Pearson product-moment correlation coefficients	0.669	0.657	N/A[3]
MPB/yr	-0.003	0.021	N/A[3]
MAD/yr	0.367	0.379	N/A[3]

[1] Vogt and Bared, 1998, (p. 115)
[2] These variables area not available in the Group B data
[3] N/A: not available

Table 162. Parameter Estimates for Recalibrated INJACC Full Models: Type I Group B

Variables	Variant 1 Coeff. (s.e., *p*-value)	Variant 2 Coeff. (s.e., *p*-value)	Original Main Model[1] Coeff. (s.e., *p*-value)
Intercept for Minnesota	-9.182 (0.300, <0.001)	-9.182 (0.303, <0.001)	-13.037 (1.791, 0.0001)
Intercept for Georgia	-8.463 (0.329, <0.001)		
Intercept for California	-9.248 (0.309, <0.001)		
LOG of AADT1	0.6590 (0.0325, <0.001)	0.6402 (0.0320, <0.001))	0.8122 (0.0973, 0.0001)
LOG of AADT2	0.3820 (0.0261, <0.001)	0.4069 (0.0260, <0.001)	0.4551 (0.0977, 0.0001)
HI1[2]	N/A[3]	N/A[3]	0.0335 (0.0327, 0.3047)
RT MAJ	-0.1346 (0.0760, 0.077)	-0.1360 (0.0677, 0.045)	0.3620 (0.1814, 0.0460)
RT MIN	0.3060 (0.1330, 0.022)	0.3000 (0.1340, 0.025)	N/A[3]
LT MAJ	-0.2253 (0.0596, <0.001)	-0.2655 (0.0597, <0.001)	
HAZRAT1[2]	N/A[3]	N/A[3]	0.2065 (0.0930, 0.0263)
VCI1[2]			0.1869 (0.3657, 0.6092)
SPD1[2]			0.0156 (0.0269, 0.5618)
DRWY1[2]			-0.0120 (0.0714, 0.8671)
HAU[2]			0.0051 (0.0045, 0.2594)
K – overall	0.417	0.435	0.494
K – Minnesota	0.256	N/A[3]	N/A[3]
K – Georgia	0.345		
K – California	0.476		
Pearson product-moment correlation coefficients	0.593	0.588	N/A[3]
MPB/yr	-0.0004	0.009	N/A[3]
MAD/yr	0.194	0.195	N/A[3]

[1] Vogt and Bared, 1998, (p. 116)
[2] These variables area not available in the Group B data
[3] N/A: not available

The GOF as measured by *K* was improved over the Vogt and Bared models. In the recalibrated models, right-turn lanes on minor roads and left-turn lanes on major roads are significant in addition to right-turn lanes on major roads.

3.4.2 Type II Models

As for Type I, full models were developed using two groups of data. The first, Group A, consisted only of the sites from Minnesota and Georgia and included many variables, such as horizontal and vertical curvature. The California HSIS sites were not included in this group because many of the variables were not available. The second, Group B, included the California HSIS sites, but fewer variables were available for modeling.

As was the case for the AADT-only models, sites with a major road AADT below 400 or a minor road AADT below 100 were not included. 250 sites from Minnesota and 108 sites from Georgia were used. The Group B data contained an additional 748 sites from the California HSIS database. Summary statistics on these datasets are available in chapter 3.2, and listed by State in appendix C.

Two variants of models were calibrated. As for Type I, the first variant included a State indicator term and the second did not. For reference, the recalibrated models are compared to the models calibrated by Vogt and Bared.[(1)]

Group A

Tables 163 and 164 report the parameter estimates for the Type II TOTACC and INJACC models for the Group A data.

Table 163. Parameter Estimates for Recalibrated TOTACC Full Models: Type II Group A

Variables	Variant 1 Coeff. (s.e., *p*-value)	Variant 2 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept for Minnesota	-9.080 (0.488, <0.001)	-9.248 (0.475, <.001)	-10.426 (1.317, 0.0001)
Intercept for Georgia	-8.630 (0.499, <0.001)		
LOG of AADT1	0.6990 (0.0529, <0.001)	0.7079 (0.0537, <.001)	0.6026 (0.0836, 0.0001)
LOG of AADT2	0.4774 (0.0531, <0.001)	0.5153 (0.0529, <.001)	0.6091 (0.0694, 0.0001)
RTMAJ	0.1735 (0.0832, 0.037)	N/A[2]	N/A[2]
DRWY1	0.1219 (0.0277, <0.001)	0.1375 (0.0282, <.001)	0.1235 (0.0519, 0.0173)
HI1	N/A[2]	N/A[2]	0.0449 (0.0473, 0.3431)
SPD1			0.0187 (0.0176, 0.2875)
VCI1		0.0766 (0.0554, 0.167)	0.2885 (0.2576, 0.2628)
HAU		N/A[2]	-0.0049 (0.0033, 0.1341)
K–overall	0.256	0.278	0.206
K–Minnesota	0.227	N/A[2]	N/A[2]
K–Georgia	0.500		
Pearson product-moment correlation coefficients	0.777	0.777	0.753
MPB/yr	-0.003	0.033	0.053
MAD/yr	0.431	0.440	0.111

[1] Vogt and Bared, 1998, (p. 115)
[2] N/A: not available

Table 164. Parameter Estimates for Recalibrated INJACC Full Models: Type II Group A

Variables	Variant 1 Coeff. (s.e., *p*-value)	Variant 2 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept for Minnesota	-9.800 (0.557, <0.001)	-10.303 (0.565, <.001)	-10.783 (1.766, 0.0001)
Intercept for Georgia	-9.304 (0.570, <0.001)		
LOG of AADT1	0.6196 (0.0619, <0.001)	0.6392 (0.0638, <.001)	0.6339 (0.1055, 0.0001)
LOG of AADT2	0.5893 (0.0612, <0.001)	0.6584 (0.0614, <.001)	0.6229 (0.0870, 0.0001)
DRWY1	0.0824 (0.0328, 0.012)	0.0944 (0.0337, 0.005)	0.0857 (0.0639, 0.1799)
HI1	0.0408 (0.0266, 0.125)	0.0626 (0.0272, 0.021)	0.0729 (0.0635, 0.2513)
SPD1			0.0112 (0.0251, 0.6567)
VCI1			0.2789 (0.4623, 0.5464)
HAZRAT1	N/A[2]	N/A[2]	-0.1225 (0.0720, 0.0889)
RT MAJ			0.0451 (0.1665, 0.7865)
HAU			-0.0043 (0.0044, 0.3258)
K–overall	0.250	0.278	0.181
K–Minnesota	0.263	N/A[2]	N/A[2]
K–Georgia	0.154		
Pearson product-moment correlation coefficients	0.747	0.727	0.724
MPB/yr	-0.001	0.033	0.033
MAD/yr	0.249	0.254	0.063

[1] Vogt and Bared, 1998, (p. 117)
[2] N/A: not available

There were some similarities and differences between the recalibrated models and the Vogt and Bared models. For the recalibrated models, significant variables at approximately the 85 percent level or better for TOTACC included major and minor road AADTs, right-turn lanes on major roads, and the number of driveways for the variant that included a State indicator variable, and number of driveways and the vertical curvature variable VCI1 for the variant without the State indicator variable. The Vogt and Bared model also included the angle variable HAU, the major road posted speed, and the horizontal curvature variable HI1, although the last two were of low significance. For the INJACC models, number of driveways and horizontal curvature within 76.25 m (250 ft) of the intersection center were significant at the 10 percent level or better for both the State indicator and non-State indicator variants. The Vogt model included roadside hazard rating as a significant variable and others that were not significant. The GOF as measured by *K* was not as good as for the Vogt and Bared model.

Group B

Tables 165 and 166 report the parameter estimates for the Type II TOTACC and INJACC models using the Group B data.

Table 165. Parameter Estimates for Recalibrated TOTACC Full Models: Type II Group B

Variables	Variant 1 Coeff. (s.e., *p*-value)	Variant 2 Coeff. (s.e., *p*-value)	Original Main Model[1] Coeff. (s.e., *p*-value)
Intercept for Minnesota	-8.648 (0.296, <0.001)	-8.718 (0.321, <.001)	-10.426 (1.317, 0.0001)
Intercept for Georgia	-8.275 (0.316, <0.001)		
Intercept for California	-8.799 (0.304, <0.001)		
LOG of AADT1	0.6674 (0.0331, <0.001)	0.6483 (0.0327, <.001)	0.6026 (0.0836, 0.0001)
LOG of AADT2	0.4905 (0.0268, <0.001)	0.5200 (0.0274, <.001)	0.6091 (0.0694, 0.0001)
RTMAJ	-0.1462 (0.0686, 0.033)	-0.1070 (0.0633, 0.091)	N/A[3]
LTMAJ	N/A[3]	-0.1535 (0.0633, 0.015)	
DRWY1[2]		N/A[3]	0.1235 (0.0519, 0.0173)
HI1[2]			0.0449 (0.0473, 0.3431)
VCI1[2]			0.2885 (0.2576, 0.2628)
SPD1[2]			0..0187 (0.0176, 0.2875)
HAU[2]			-0.0049 (0.0033, 0.1341)
K–overall	0.400	0.400	0.206
K–Minnesota	0.278	N/A[3]	N/A[3]
K–Georgia	0.555		
K–California	0.435		
Pearson product-moment correlation coefficients	0.694	0.695	N/A[3]
MPB/yr	-0.008	0.009	N/A[3]
MAD/yr	0.528	0.528	N/A[3]

[1] Vogt and Bared, 1998, (p. 115)
[2] These variables area not available in the Group B data
[3] N/A: not available

Table 166. Parameter Estimates for Recalibrated INJACC Full Models: Type II Group B

Variables	Variant 1 Coeff. (s.e., *p*-value)	Variant 2 Coeff. (s.e., *p*-value)	Original Main Model[1] Coeff. (s.e., *p*-value)
Intercept for Minnesota	-9.285 (0.343, <0.001)	-9.130 (0.334, <.001)	-10.783 (1.766, 0.0001)
Intercept for Georgia	-8.729 (0.366, <0.001)		
Intercept for California	-9.298 (0.352, <0.001)		
LOG of AADT1	0.6295 (0.0382, <0.001)	0.6006 (0.0346, <.001)	0.6339 (0.1055, 0.0001)
LOG of AADT2	0.5182 (0.0299, <0.001)	0.5376 (0.0299, <.001)	0.6229 (0.0870, 0.0001)
MEDIAN	-0.3320 (0.1410, 0.019)	-0.325 (0.143, 0.023)	N/A[3]
RT MAJ	-0.1646 (0.0780, 0.035)	-0.2014 (0.0727, 0.006)	0.0451 (0.1665, 0.7865)
DRWY1[2]	N/A[3]	N/A[3]	0.0857 (0.0639, 0.1799)
HI1[2]			0.0729 (0.0635, 0.2513)
VCI1[2]			0.2789 (0.4623, 0.5464)
HAZRAT1[2]			-0.1225 (0.0720, 0.0889)
HAU[2]			-0.0043 (0.0044, 0.3258)
SPD1[2]			0.0112 (0.0251, 0.6567)
K–overall	0.400	0.417	0.181
K–Minnesota	0.303	N/A[1]	N/A[3]
K–Georgia	0.204		
K–California	0.455		
Pearson product-moment correlation coefficients	0.645	0.642	N/A[3]
MPB/yr	-0.003	0.010	N/A[3]
MAD/yr	0.299	0.0001	N/A[3]

[1] Vogt and Bared, 1998, (p. 117)
[2] These variables area not available in the Group B data
[3] N/A: not available

For TOTACC, significant variables in addition to major and minor road AADTs, include right-turn lane on major road for the variant with the State indicator variable and right-turn lane on major road and left-turn lane on major road for the variant without the State indicator variable. For INJACC, median and right-turn lane on major road were significant for both the State indicator and non-State indicator variants. The GOF as measured by *K* was not as good as that for the Vogt and Bared model.

3.4.3 Type III Models

The data used to calibrate full models consisted of the California and Michigan sites from the original study, additional years of accident data from the California and Michigan sites, and the Georgia sites. Some of the California sites experienced changes in their design features during the 1996–98 period. For such sites, accidents during the 1996–98 period were not included, and only 1993–95 accident data were used. Summary statistics on the data are provided in section 3.2.

Two models each are reported for TOTACC and INJACC. The main model was selected based on the highest Pearson product-moment correlation coefficient, lowest overdispersion, MPB per year, and MAD per year. The other model was the one judged to be next best on in terms of these measures.

For TOTACC, major and minor AADTs, vertical curve rate on major roads, intersection angle, commercial driveways on major roads, median width on major roads, and painted medians on major roads were found to be significant in the main models (15 percent level or better). State indicator variables were statistically insignificant and therefore not included in the models.

For INJACC, major and minor AADTs, roadside hazard rating on major road, intersection angle, commercial driveways on major road, peak turning percentage, and peak truck percentage were found to be significant in the main model at the 15 percent level or better. State indicator variables were again statistically insignificant.

For reference a comparison between Vogt's full models applied to the recalibration data and the newly recalibrated models for TOTACC and INJACC also is given. As expected, there were some differences between the recalibrated models and the Vogt models. For TOTACC, the recalibrated main model had the additional terms COMDRWY1, VEI1, HAU, and MEDTYPE1 compared to the Vogt model but did not include DRWY1, which was in the Vogt model. For the INJACC, the recalibrated main model had the additional terms COMDRWY1, HAZRAT1, PKTRUCK, and PKTURN compared to the Vogt model. The GOF as measured by Pearson product-moment correlation coefficients, MPB per year, and MAD per hear indicates that the recalibrated main models for TOTACC and INJACC provide better GOF than the Vogt models. However, the GOF as measured by *K* was not as good as those for the Vogt models.

Tables 167 and 168 report the model results for TOTACC and INJACC.

Table 167. Parameter Estimates for Recalibrated TOTACC Full Models: Type III

Variables	Main Model Coeff. (s.e., *p*-value)	Variant 1 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept	-10.1914 (1.5232,0.0000)	-9.9214 (1.5100,0.0000)	-12.2196 (2.3575,0.0001)
LOG of AADT1	0.8877 (0.1666,0.0000)	0.8509 (0.1665,0.0000)	1.1479 (0.2527,0.0001)
LOG of AADT2	0.3228 (0.0585,0.0000)	0.2972 (0.0590,0.0000)	0.2624 (0.0866,0.0024)
COMDRWY1	0.0681 (0.0281,0.0154)	0.0912 (0.0276,0.0010)	
VEI1	0.1081 (0.0556,0.0519)	0.1044 (0.0523,0.0461)	N/A[3]
HAU	0.0101 (0.0059,0.0861)	0.0088 (0.0054,0.1014)	
MEDWDTH1	-0.0106 (0.0060,0.0760)		-0.0546 (0.0249,0.0285)
MEDTYPE1[2]	-0.3209 (0.1771,0.0700)	N/A[3]	N/A[3]
DRWY1	N/A[3]		0.0391 (0.0239,0.1023)
K	0.4229 (0.1064,0.0001)	0.4552 (0.1109,0.0000)	0.3893 (0.1160,0.0008)
Pearson product-moment correlation coefficients	0.70	0.70	0.68
MPB/yr	0.09	-0.02	0.37
MAD/yr	0.84	0.88	0.90

[1] The main model published in Vogt, 1999, (p. 111)
[2] Median Type 1 (painted) on major roads
[3] N/A: not available

Table 168. Parameter Estimates for Recalibrated INJACC Full Models: Type III

Variables	Main Model Coeff. (s.e., *p*-value)	Variant 1 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept	-10.6443 (2.0474,0.0000)	-10.4453 (2.0845,0.0000)	-12.3246 (2.8076, 0.0001)
LOG of AADT1	0.8498 (0.2097,0.0001)	0.8260 (0.2146,0.0001)	1.1436 (0.2763,0.0001)
LOG of AADT2	0.2188 (0.0949,0.0212)	0.2460 (0.0901,0.0063)	0.1357 (0.1029,0.1872)
COMDRWY1	0.0627 (0.0353,0.0756)	0.0607 (0.0346,0.0797)	N/A[2]
HAZRAT1	0.1889 (0.0923,0.0407)	0.1897 (0.0930,0.0412)	
HAU	0.0163 (0.0053,0.0021)	0.0168 (0.0054,0.0019)	0.0230 (0.0131,0.0790)
PKTRUCK	-0.0253 (0.0135,0.0605)	-0.0331 (0.0186,0.0762)	N/A[2]
PKTURN	0.0254 (0.0135,0.0592)	N/A[2]	
PKLEFT	N/A[2]	0.0333 (0.0188,0.0758)	
K	0.5102 (0.1426,0.0003)	0.5178 (0.1437,0.0003)	0.3787 (0.1792,0.0346)
Pearson product-moment correlation coefficients	0.66	0.64	0.56
MPB/yr	-0.05	-0.14	-0.05
MAD/yr	0.43	0.47	0.47

[1] INJACC Variant 1 Model; there is no main INJACC model in Vogt, 1999
[2] N/A: not available

3.4.4 Type IV Models

The data used to calibrate full models include the California and Michigan sites from the original study, with the additional years of accident data, and the Georgia sites. Some of the California sites experienced changes in their design features during the 1996–98 period. For such sites, accidents during the 1996–98 period were ignored, and only 1993–95 accident data were used. Summary statistics on the data are provided in section 3.2.

Two models were developed for both TOTACC and INJACC. Again, the main model was selected based on the highest Pearson product-moment correlation coefficient, and lowest overdispersion, MPB per year, and MAD per year.

For TOTACC, major and minor road AADTs, peak left-turn percentages, peak through percentages on minor roads, peak truck percentages, and right-side sight distance on minor roads were found to be significant in the main model at the 10 percent level or better. State indicator variables were statistically insignificant in the main model and were therefore not included. However, Variant 1, the second best model, includes a Michigan indicator variable, which means there was more influence of the Michigan data on the model.

For INJACC, major and minor road AADTs, peak left-turn percentages on major roads, peak truck percentages, and speed limits on minor roads were selected as significant in the main model at the 10 percent level or better. State indicator variables were statistically insignificant.

For reference, a comparison between Vogt's full models applied to the recalibration data and the newly recalibrated models for TOTACC and INJACC is given. As expected, there were some differences between the recalibrated models and the Vogt's models. For TOTACC, the recalibrated main model had additional terms SDR2, PKTRUCK, PKTHRU2, and PKLEFT compared to the Vogt model, but did not include PKLEFT1 and LTLN1S, which were in the Vogt model. For the INJACC, the recalibrated main model included the additional term PKTRUCK compared to the Vogt model. The GOF as measured by Pearson product-moment correlation coefficients, MPB per year, and MAD per year indicates that the recalibrated models for TOTACC and the main model for INJACC provide better GOF than the Vogt models. However, the GOF as measured by *K* was not as good as those for the Vogt models.

Tables 169 and 170 report the model results for TOTACC and INJACC, respectively.

Table 169. Parameter Estimates for Recalibrated TOTACC Full Models: Type IV

Variables	Main Model Coeff. (s.e., *p*-value)	Variant 1 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept	-7.4713 (1.8930,0.0001)	-7.4350 (1.6933,0.0000)	-9.4631 (2.5991,0.0003)
LOG of AADT1	0.7350 (0.1849,0.0001)	0.7193 (0.1722,0.0000)	0.8503 (0.2779,0.0022)
LOG of AADT2	0.2390 (0.0926,0.0099)	0.2586 (0.0975,0.0080)	0.3294 (0.1255,0.0087)
SDR2	-0.0003 (0.0001,0.0403)	-0.0005 (0.0001,0.0018)	N/A[4]
PKTRUCK	-0.0479 (0.0110,0.0000)	N/A[4]	
PKTHRU2	0.0249 (0.0085,0.0034)	0.0154 (0.0082,0.0591)	
PKLEFT	0.0229 (0.0118,0.0525)	N/A[4]	
PKLEFT1	N/A[4]	-0.0158 (0.0083,0.0565)	0.1100 (0.0412,0.0076)
MEDTYPE1[2]		-0.4027 (0.2084,0.0533)	N/A[4]
MICHIGAN[3]		0.4823 (0.2645,0.0683)	
LTLN1S (0 or 1)		N/A[4]	-0.4841 (0.2311,0.0362)
K	0.4001 (0.0958,0.0000)	0.4382 (0.0965,0.0000)	0.4578 (0.1307,0.0005)
Pearson product-moment correlation coefficients	0.77	0.75	0.64
MPB/yr	0.12	0.28	0.48
MAD/yr	1.16	1.20	1.31

[1] The main model published in Vogt, 1999, (p. 116)
[2] Median Type 1 (painted) on major roads
[3] Indicator variable for Michigan
[4] N/A: not available

Table 170. Parameter Estimates for Recalibrated INJACC Type IV: Full Models

Variables	Main Model Coeff. (s.e., *p*-value)	Variant 1 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept	-7.3927 (2.1279,0.0005)	-7.9801 (2.0870,0.0001)	-12.5296 (2.9908,0.0001)
LOG of AADT1	0.5008 (0.2186,0.0220)	0.5670 (0.2145,0.0082)	0.9505 (0.3284,0.0038)
LOG of AADT2	0.3027 (0.1341,0.0240)	0.3452 (0.1213,0.0044)	0.3237 (0.1645,0.0491)
SPD2	0.0289 (0.0145,0.0465)	0.0262 (0.0149,0.0795)	0.0339 (0.0179,0.0577)
PKTRUCK	-0.0520 (0.0127,0.0000)	N/A[3]	N/A[3]
PKLEFT1	0.0523 (0.0128,0.0000)		0.0994 (0.0433,0.0216)
SDR2	N/A[3]	-0.0003 (0.0002,0.0420)	N/A[3]
MEDTYPE1[2]		-0.5299 (0.2560,0.0385)	
K	0.4671 (0.1296,0.0003)	0.5400 (0.1345,0.0001)	0.4308 (0.1824,0.0182)
Pearson product-moment correlation coefficients	0.71	0.70	0.60
MPB/yr	0.05	-0.05	0.14
MAD/yr	0.65	0.67	0.68

[1] INJACC Variant 1 Model; there is no main INJACC model in Vogt, 1999
[2] Median Type 1 (painted) on major roads
[3] N/A: not available

3.4.5 Type V Models

The data used to calibrate full models include the California and Michigan sites from the original study, additional years of accident data from the California and Michigan sites, and the Georgia sites. Some of California sites experienced changes in their design features during the 1996–98 period. For such sites, accidents during the 1996–98 period were ignored in the database, and only 1993–95 accident data were used. Summary statistics on the data are provided in section 3.2 of this report.

Two models were developed for both TOTACC and INJACC. Again, the main model was selected by examining the Pearson product-moment correlation coefficient, overdispersion, MPB per year, and MAD per year.

For TOTACC, major and minor AADTs, commercial driveways on major roads, speed limits on major roads, light, and horizontal curvature variables were found to be significant in the main model. Compared to the main model, Variant 1 in table 171 yields improvement in overdispersion, but not in other GOF measures. Variant 1 showed a lower Pearson product-moment correlation coefficient than the main model, but MPB per year and MAD per year were higher.

For INJACC, major and minor AADTs, presence of lighting, speed limits on major roads, and horizontal curve on minor roads within 244 m (800 ft) of intersection were significant variables in the main model. Variant 1 in table 172 was superior to the main model in terms of lower overdispersion and other GOF measures, with the exception of MPB per year. However, the model includes a Michigan indicator variable, which means more influence of the Michigan data on the model. Because the IHSDM requires the main model to be recalibrated to work in any State, the model with the State indicator was selected as a variant, not as the main model.

For reference, a comparison between the Vogt full models applied to the recalibration data and the newly recalibrated models for TOTACC and INJACC also is given. As expected, there were some differences between the recalibrated models and the Vogt models. For TOTACC, the recalibrated main model included additional terms COMDRWY1, SPD1, LIGHT, and HEICOM compared to the Vogt model but did not include PKTRUCK, PKLEFT2, PROT_LT, and VEICOM, all of which were in the Vogt model. For the INJACC model, the recalibrated main model separated the safety effect of major and minor road AADTs. The main model included LIGHT, SPD1, and HEI2 but excluded PKLEFT2, PKTRUCK, PROT_LT, and VEICOM when compared to the Vogt model. The GOF as measured by MPB per year and MAD per year indicates that the recalibrated models for TOTACC and INJACC provide better GOF than the Vogt models. Pearson product-moment correlation coefficients were also higher for INJACC but were a little lower for TOTACC. The GOF as measured by *K* was not as good as that for the Vogt models.

Tables 171 and 172 show the model results for TOTACC and INJACC, respectively.

Table 171. Parameter Estimates for Recalibrated TOTACC Full Models: Type V

Variables	Main Model Coeff. (s.e., *p*-value)	Variant 1 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept	-5.1527 (1.8653,0.0057)	-5.4718 (1.8686,0.0034)	-6.9636 (2.7911,0.0132)
LOG of AADT1	0.4499 (0.1968,0.0223)	0.4220 (0.1976,0.0327)	0.6199 (0.2504,0.0133)
LOG of AADT2	0.2699 (0.0767,0.0004)	0.2913 (0.0755,0.0001)	0.3948 (0.1737,0.0230)
COMDRWY1	0.0539 (0.0304,0.0757)	0.0494 (0.0296,0.0948)	
SPD1	0.0177 (0.0090,0.0482)	0.0229 (0.0088,0.0092)	
LIGHT	-0.2938 (0.1837,0.1098)	N/A[3]	N/A[3]
HEICOM	-0.0288 (0.0153,0.0597)		
HI		-0.0221 (0.0116,0.0571)	
MEDTYPE1[2]		-0.4941 (0.2349,0.0354)	
PKTRUCK	N/A[3]		0.0315 (0.0143,0.0275)
PKLEFT2		N/A[3]	-0.0142 (0.0047,0.0023)
PROT_LT (0=no, 1=yes)			-0.6754 (0.1824,0.0002)
VEICOM			0.1299 (0.0450,0.0039)
K	0.4019 (0.0765,0.0000)	0.3954 (0.0781,0.0000)	0.1161 (0.0323,0.0003)
Pearson product-moment correlation coefficients	0.77	0.73	0.78
MPB/yr	-0.02	-0.03	-0.79
MAD/yr	2.90	3.03	3.31

[1] The main model published in Vogt, 1999, (p. 122)
[2] Median Type 1 (painted) on major roads
[3] N/A: not available

Table 172. Parameter Estimates for Recalibrated INJACC Full Models: Type V

Variables	Main Model Coeff. (s.e., *p*-value)	Variant 1 Coeff. (s.e., *p*-value)	Original Main Model[1] Applied to Full Model Data Coeff. (s.e., *p*-value)
Intercept	-9.0707 (1.9064,0.0000)	-8.6196 (1.7838,0.0000)	-3.2562 (2.9932,0.2767)
LOG of AADT1	0.6697 (0.1899,0.0004)	0.6875 (0.1756,0.0001)	N/A[3]
LOG of AADT2	0.2509 (0.0929,0.0069)	0.1731 (0.0933,0.0636)	
Log of (AADT1*AADT2)	N/A[3]	N/A[3]	0.2358 (0.1722,0.1707)
LIGHT	-0.3985 (0.1702,0.0192)	-0.4054 (0.1641,0.0135)	N/A[3]
SPD1	0.0397 (0.0093,0.0000)	0.0370 (0.0091,0.0001)	
HEI2	-0.0284 (0.0126,0.0244)	-0.0230 (0.0124,0.0642)	
PKLEFT2	N/A[3]	N/A[3]	-0.0113 (0.0062,0.0678)
PKTRUCK			0.0323 (0.0146,0.0267)
MICHIGAN[2]		0.3499 (0.1653,0.0343)	N/A[3]
PROT_LT (0=no, 1=yes)		N/A[3]	-0.2943 (0.1864,0.1144)
VEICOM			0.0822 (0.0551,0.1358)
K	0.2360 (0.0958,0.0138)	0.2065 (0.0918,0.0244)	0.1630 (0.0662,0.0138)
Pearson product-moment correlation coefficients	0.68	0.70	0.43
MPB/yr	0.00	-0.01	-1.02
MAD/yr	0.98	0.94	1.40

[1] The main model published in Vogt, 1999, (p. 124)
[2] Indicator variable for Michigan
[3] N/A: not available

3.5 ESTIMATION OF ACCIDENT MODIFICATION FACTORS

This section discusses the derivation of AMFs for both total and injury (fatal and nonfatal injury) accidents.

FHWA and its contractors have developed a new approach that combines historical accident data, regression analysis, before-and-after studies, and expert judgment to make safety performance predictions that are better than those obtained by any of the individual approaches. A recent report documents an accident prediction algorithm for implementing the new approach for two-lane rural highway sections that include road segments and intersections.[3] Ongoing efforts aim to produce similar documents for other types of facilities.

The accident prediction algorithm has been developed for incorporation in the IHSDM as the Crash Prediction Module, but is suitable for stand-alone applications. As indicated earlier, the structure of the accident prediction algorithm for the five types of rural at-grade intersections is as follows:

$$N_{int} = N_b \, (AMF_1 \; AMF_2 \; \ldots \; AMF_n) \tag{15}$$

where
N_{int} = predicted number of total intersection-related accidents per year after application of AMFs;
N_b = predicted number of total intersection-related accidents per year for base conditions; and
AMF_1 AMF_2 … AMF_n = AMFs for various intersection features

The accident algorithm report, referred to as the "Red Book," provides AMFs for two-lane rural roads and intersections.[3] An additional report provided AMFs for turning lanes at intersections.[5] As part of this project, the available data have been used to attempt to derive AMFs for these and any other variables at rural intersections to compare and refine the current AMFs.

The AMFs provided in the "Red Book" are shown below in table 173. These AMFs apply to total intersection accidents (TOTACC). Also shown are the AMFs relevant to intersection types I, II, and V from Harwood et al.[5]

Table 173. AMFs from Previous Studies

AMF	Type I	Type II	Type V
SKEW	exp(0.004SKEW)	exp(0.0054)SKEW	1
LT MAJ	1.00 if none exist 0.78 if at least one exists (0.56 if at least one exists)	1.00 if none exist 0.76 on one approach (0.72 on one approach) 0.58 on both approaches (0.52 on both approaches)	1.00 if none exist 0.82 on one approach 0.67 on both approaches
RT MAJ	1.00 if none exist 0.95 on one approach (0.86 on one approach) 0.90 on both approaches (0.74 on both approaches)		1.00 if none exist 0.975 on one approach (0.96 on one approach) 0.95 on both approaches (0.92 on both approaches)
SIGHT DISTANCE	1.00 if sight distance is not limited 1.05 if limited in 1 quadrants 1.10 if limited in 2 quadrants 1.15 if limited in 3 quadrants 1.20 if limited in 4 quadrants		1

Derivation of AMFs in this project was attempted in two ways. First, AMFs were inferred from the parameter estimates of the full models presented in section 3.4. Second, a relatively new and untested regression procedure that relates the difference between the observed number of crashes at a site and is predicted by a base model to the nonbase condition factors was applied. This procedure is explained in detail later in this section.

3.5.1 AMFs Derived from Recalibration Full Models

One approach to deriving AMFs is to apply a model using the estimated parameter values from only statistically significant variables in accident prediction models. This approach suffers from correlation between geometric variables and traffic, and the difference in accident experience between sites is possibly due to the substantial unexplained variation resulting from omitted factors. Nevertheless, AMFs derived in this manner from the full models of section 3.4 are presented in tables 174 and 175.

Table 174. AMFs Derived from Type I and II Full Models

AMF	Type I		Type II	
	Total	Injury	Total	Injury
Group A Data				
HI1[1]	exp(0.0263HI1)	exp(0.0286HI1)	*Not calibrated*	exp(0.0408HI1)
RT MAJ	*Not calibrated*	*Not calibrated*	1.19	*Not calibrated*
DRWY1			1.13	1.09
Group B Data				
RT MAJ	0.88	0.87	0.86	0.85
RT MIN	1.35	1.36	*Not calibrated*	*Not calibrated*
LT MAJ	0.82	0.80		
MEDIAN	*Not calibrated*	*Not calibrated*		0.72

[1] As a continuous variable, the AMF for HI1 is a function and not a factor

Table 175. AMFs Derived from Type III, IV, and V Full Models

<table>
<tr><th rowspan="2">AMF</th><th colspan="2">Type III</th><th colspan="2">Type IV</th><th colspan="2">Type V</th></tr>
<tr><th>Total</th><th>Injury</th><th>Total</th><th>Injury</th><th>Total</th><th>Injury</th></tr>
<tr><td>COMDRWY1</td><td>exp (0.0681COMDRWY1)</td><td>exp (0.0627COMDRWY1)</td><td rowspan="6">Not calibrated</td><td rowspan="6">Not calibrated[2]</td><td>exp(0.0539 COMDRWY1)</td><td rowspan="12">Not calibrated</td></tr>
<tr><td>VEI1</td><td>exp(0.1081VEI1)</td><td>Not calibrated</td><td rowspan="11">Not calibrated</td></tr>
<tr><td>HAU</td><td>exp(0.0101HAU)</td><td>exp(0.0163HAU)</td></tr>
<tr><td>MEDWIDTH1</td><td>exp (-0.0106MEDWDTH1)</td><td rowspan="2">Not calibrated</td></tr>
<tr><td>MEDTYPE1[1]</td><td>0.73</td></tr>
<tr><td>HAZRAT1</td><td rowspan="10">Not calibrated</td><td>exp(0.1889HAZRAT1)</td></tr>
<tr><td>PKTRUCK</td><td>exp(-0.0253PKTRUCK)</td><td>exp(-0.0479PKTRUCK)</td><td>exp(-0.0520PKTRUCK)</td></tr>
<tr><td>PKTURN</td><td>exp(0.0254PKTURN)</td><td>Not calibrated</td><td rowspan="3">Not calibrated</td></tr>
<tr><td>PKTHRU2</td><td rowspan="7">Not calibrated</td><td>exp(0.0249PKTHRU2)</td></tr>
<tr><td>PKLEFT</td><td>exp(0.0229PKLEFT)</td></tr>
<tr><td>PKLEFT1</td><td>Not calibrated</td><td>exp(0.0523PKLEFT1)</td></tr>
<tr><td>SDR2</td><td>exp(-0.0003SDR2)</td><td rowspan="4">Not calibrated</td></tr>
<tr><td>LIGHT</td><td rowspan="3">Not calibrated</td><td>0.75</td><td>0.67</td></tr>
<tr><td>HEICOM</td><td>exp(-0.0288HEICOM)</td><td>Not calibrated</td></tr>
<tr><td>HEI2</td><td></td><td>exp(-0.0284HEI2)</td></tr>
</table>

[1] Medtype1: Painted

3.5.2 AMFs Derived from Regression Models

Recalibration of AMFs was also undertaken using a relatively untested regression analysis procedure in which the following steps were taken:

1. Suitable base conditions for qualifying the current AMFs were selected, i.e., for a turning lane AMF, the base condition is no turning lane.
2. The AADT base models that meet all of the base conditions were estimated.
3. The difference between a site's accident count per year and the expected value per year was used as an estimate of the dependent variable, *Y*.
4. Any factor (for example, left-turn lane on major road) that differs from the base conditions was specified as an independent variable.
5. The β coefficient of a factor was estimated from a simple linear regression model.
6. AMFs were estimated from the following equations:

If perfect knowledge for base models and AMFs is available, *Y* in the accident prediction algorithm should be the observed Y.

$$Y = \hat{Y} * AMFs \tag{16}$$

Equation (16) can be rewritten as:

$$AMFs = \frac{Y}{\hat{Y}} \tag{17}$$

From steps 3 and 5:

$$\hat{Y} = Y - \beta \tag{18}$$

Equations (17) and (18) can be combined to estimate an AMF:

$$AMF = \frac{Y}{Y - \beta} \tag{19}$$

7. In the case that β coefficients in equation (19) are insignificant (at the 90 percent level in this research), it was assumed that these factors have no effect on the safety of the intersection. This offered a larger sample size to re-estimate the insignificant AMFs.
8. The β coefficients of the insignificant AMFs were re-estimated by repeating step 2 and subsequent steps.
9. If the β coefficients became significant, the estimated coefficients were adopted as the relevant AMFs. If not, they were set to a value of 1.

Types I and II

For types I and II, the base conditions and base models described in section 3.3 and which were developed using the Group B dataset were used. AMFs derived from this procedure are shown in table 176. The base conditions include no turning lanes on major or minor road and no median on the major road. As mentioned, where AMFs were not estimated to be significantly different from 1, a value of 1 has been assigned.

Table 176. AMFs Estimated from Regression Procedure

	Type I		Type II	
AMF	TOTACC	INJACC	TOTACC	INJACC
RT MIN	1.48	1.56	1	1
RT MAJ	1	1	0.71	1
LT MIN	1	1	1	1
LT MAJ	1	1	0.71	0.42
MEDIAN	1	1	0.77	0.52

Few AMFs could be derived with statistically significant results. For Type I, the AMF for right-turn lane on the minor road increases the expected number of crashes from the base model. For Type II, right- and left-turn lanes on major and median on major are expected to reduce the expected number of crashes from the base model.

Type III

Unlike the case for Type I and II, for which the Group B dataset was applied, the Group A dataset was used to calibrate AMFs for Type III intersections because the Group B dataset does not provide sight distance and angle data. As a result, new base models had to be calibrated for the AMFs.

The nominal or base condition for “intersection left-turn lane” is the presence of left-lane on the major-road approach because as many as 79.4 percent of the available sites have left-turn lanes. For “right-turn lane,” the absence of right-turn lane is the base condition. The base condition for intersection sight distance is the availability of adequate intersection sight distance along the major road in all quadrants of the intersection. The same definition regarding sight distance in a quadrant as described on page 48 of the Harwood et al. report was used to define adequate sight distance.(3) The base condition for intersection skew angle was plus or minus 5 degrees of skew to have more base sites and to accommodate any possible measurement errors.

Table 177 shows the base conditions for Type III AMFs. Table 178 displays the base model estimated using the sites meeting all of the base conditions. Because the β coefficient of log of AADT1 was quite insignificant, log of (AADT1 * AADT2) was used as the traffic variable.

AMFs derived from this procedure are given in table 179. These AMFs apply to total accidents and total injury accidents.

Table 177. Base Conditions for Type III Sites

AMF	Base Condition	Frequency Meeting Base Conditions (Percent)
Left lane on major road	Presence of left lane	108 (79.4)
Right lane on major road	Absence of right lane	88 (64.7)
Sight distance	Adequate sight distance	104 (76.5)
Intersection angle	-5° ~ 5°	89 (65.4)
Total[1]	All	28 (20.6)

[1] Total means sites meeting all of the base conditions

Table 178. Base Model for Type III Sites

Variables	TOTACC	INJACC
	Coeff. (s.e., *p*-value)	Coeff. (s.e., *p*-value)
Intercept	-7.5583 (1.1313,0.0000)	-9.0573 (1.9821,0.0000)
Log (AADT1* AADT2)[1]	0.4909 (0.0740,0.0000)	0.5342 (0.1251,0.0000)
K	0.2045	0.3172

[1] Logs of AADT1 and AADT2 were combined because the β coefficient of log of AADT1 was insignificant

Table 179. AMFs for Type III Sites

AMFs	Recalibrated (TOTACC)	Recalibrated (INJACC)
Left lane on major road	0.71 (One approach)	1 (One approach)
Right lane on major road	1 (One approach)	1 (One approach)
Sight distance	1	1
Intersection angle	1+(0.016*SKEW[1])/ (0.98[2]+0.016*SKEW)	1+(0.017*SKEW[1])/ (0.52[3]+0.017*SKEW)

[1] SKEW = intersection skew angle (degrees), expressed as the absolute value of the difference between 90 degrees and the actual intersection angle

[2] 0.98 = mean of the observed TOTACC accidents per year of the sites meeting no angle, no right lane, and presence of left lane

[3] 0.52 = mean of the observed INJACC accidents per year of the sites meeting no angle, no right lane, and presence of left lane

Type IV
As was the case for Type III, the Group A dataset was used to calibrate AMFs for Type IV intersections because the Group B dataset does not provide sight distance and angle data. New base models were calibrated for the AMFs.

The base condition for “intersection left-turn lane” is the presence of left-lane on the major road approaches because as many as 72.6 percent of the available sites have left-turn lane on both approaches. For “intersection right-turn lane,” the absence of right-turn lane is the base condition. The base condition for intersection sight distance is the availability of adequate intersection sight distance along the major road in all quadrants of the intersection. As for Type III, the base condition for intersection skew angle was plus or minus 5 degrees of skew to have more base sites and to accommodate any possible measurement errors. The base conditions for Type IV AMFs are shown in table 180. Table 181 represents the base model estimated using the sites meeting all of the base conditions. Since the β coefficient of log of AADT1 was quite insignificant, log of (AADT1 * AADT2) was used as the traffic volume variable.

The AMFs derived are shown in table 182. These AMFs apply to total accidents and total injury accidents.

Table 180. Base Conditions for Type IV Sites

AMFs	Base Condition	Frequency Meeting Base Conditions (Percent)
Left-turn lane on major road	Presence of left lane (both approach)	90 (72.6)
Right-turn lane on major road	Absence of right lane	69 (55.6)
Sight distance	Adequate sight distance	81 (65.3)
Intersection angle	-5° ~ 5°	75 (60.5)
Total[1]	All	11 (8.9)

[1] Total means sites meeting all of the base conditions

Table 181. Base Model for Type IV Sites

Variables	TOTACC	INJACC
	Coeff. (s.e., *p*-value)	Coeff. (s.e., *p*-value)
Intercept	-12.1778 (6.6284,0.0662)	-14.2207 (7.1609,0.0470)
Log (AADT1* AADT2)[1]	0.8220 (0.4330,0.0576)	0.9261 (0.4677,0.0477)
K	0.5159	0.3871

[1] Logs of AADT1 and AADT2 were combined because the β coefficient of log of AADT1 was insignificant

Table 182. AMFs for Type IV Sites

AMFs	Recalibrated (TOTACC)		Recalibrated (INJACC)	
	One Approach	Both Approaches	One Approach	Both Approaches
Left-turn lane on major road	1	1	0.86	0.74
Right-turn lane on major road	1	1	1	1
Sight Distance	1		1	
Intersection Angle	1+(0.053*SKEW[1])/ (1.43[2]+0.053*SKEW)		1+(0.048*SKEW[1])/ (0.72[3]+0.048*SKEW	

[1] SKEW = intersection skew angle (degrees), expressed as the absolute value of the difference between 90 degrees and the actual intersection angle

[2] 0.43 = mean of the observed TOTACC accidents per year of the sites meeting no angle, no right lane, and presence of left lane

[3] 0.72 = mean of the observed INJACC accidents per year of the sites meeting no angle, no right lane, and presence of left lane

Type V

Because the Group B dataset does not provide sight distance and angle, the Group A dataset was used to recalibrate the current AMFs for Type V intersections, and new base models were calibrated for applying the AMFs.

As many as 75 percent of the available sites have left-turn lane on both approaches. Therefore, the base condition for "intersection left-turn lane" is the presence of left-lane on the major road approaches. For "intersection right-turn lane," the absence of right-turn lane is the base condition. The base condition for intersection skew angle was plus or minus 5 degrees of skew for the same reasons as those for Type III and IV. Sight distance was ignored for the base conditions to develop a base model because the number of sites with adequate sight distance was almost equal to the ones with sight distance limited in one or two quadrants. As a result, if one of the two sight distance levels was considered as a base condition, there would be insufficient sites for a base model. In addition, sight distance is believed to have no effect on safety because conflicting traffic movements are controlled by signals. The base conditions for Type V AMFs are shown in table 183. Table 184 represents the base model estimated using the sites meeting all of the base conditions. Because the β coefficient of log of AADT1 was insignificant, log of (AADT1 * AADT2) was used to represent the traffic volume variable.

No AMFs were statistically significant using this procedure for Type V sites. Therefore, a value of 1 was assigned, which indicates that the variable was not found to have a significant impact on the safety of the intersection.

Table 183. Base Conditions for Type V Sites

AMFs	Base Condition	Frequency Meeting Base Conditions (Percent)
Left lane on major road	Presence of left lane (both approach)	75
Right lane on major road	Absence of right lane	51
Angle	-5° ~ 5°	60
Total[1]	All	22

[1] Total means sites meeting all of the base conditions

Table 184. Base Model for Type V Sites

Variables	TOTACC	INJACC
	Coeff. (s.e., *p*-value)	Coeff. (s.e., *p*-value)
Intercept	-5.1864 (3.2780,0.1136)	-6.1265 (3.7145,0.0991)
Log (AADT1* AADT2)[1]	0.4001 (0.1969,0.0422)	0.3907 (0.2164,0.0710)
K	0.6499	0.4147

[1] Log of AADT1 was insignificant, so logs of AADT1 and AADT2 were combined

3.5.3 Summary of AMFs

This research introduced two ways of deriving AMFs. One approach is to adopt the estimated parameter values from the statistically significant variables in the accident prediction models. The other approach uses a relatively untested regression procedure. Although in general the first approach is easier to apply, the second approach is recommended. This approach aims to attribute the difference between the observed number of crashes at a site and that predicted by a base model to the presence of non-base condition factors. This difference will explain a real effect of the presence of individual design features on safety.

Tables 185 through 187 compare the AMFs from the "Red Book" and those derived here. The AMFs from Harwood et al. are also shown in brackets.(5) As mentioned, none of the variables investigated showed any significant impact on safety for Type V sites, resulting in AMFs of one for these variables.

Compared to the previous works, for Types I and II, no AMF was estimated for SKEW. For right-turn lane on major roads, AMFs greater than one and less than one were estimated for Type II sites using the Group A dataset for the former and the Group B for the latter.

Whereas the "Red Book" provides separate AMFs for right-and left-turn lanes on major roads at Type II intersections, turning lanes at most sits in this dataset were provided on both approaches and separate effects could not be detected for one versus two approaches. SKEW did not provide a significant AMF different from 1 in the new data. And very few sites had deficient sight distance so an AMF could not be estimated.

For Type III and IV intersections, intersection angle (SKEW) was estimated as significant in the regression models. Right-turn lanes on major roads provided significant AMFs for Type IV intersections. For Type V intersections, no AMFs were found to be significantly different from 1.

Table 185. Comparison of Type I–II AMFs for TOTACC

<table>
<tr><th rowspan="2">AMF</th><th colspan="2">"Red Book" and Harwood et al. (2002)</th><th colspan="2">Full Models</th><th colspan="2">Regression Models</th></tr>
<tr><th>Type I</th><th>Type II</th><th>Type I</th><th>Type II</th><th>Type I</th><th>Type II</th></tr>
<tr><td>SKEW</td><td>exp(0.004SKEW)</td><td>exp(0.0054SKEW)</td><td>Not calibrated</td><td>Not calibrated</td><td>1</td><td>1</td></tr>
<tr><td>RT MAJ</td><td colspan="2">1.00 if none exist
0.95 on one approach
(0.86 on one approach)
0.90 on both approaches
(0.74 on both approaches)</td><td>0.88</td><td>1.19,0.86[1]</td><td>1</td><td>0.71</td></tr>
<tr><td>LT MAJ</td><td>1.00 if none exist
0.78 if at least one exists
(0.56 if at least one exists)</td><td>1.00 if none exist
0.76 on one approach
(0.72 on one approach)
0.58 on both approaches
(0.52 on both approaches)</td><td>0.82</td><td></td><td>1</td><td>0.71</td></tr>
<tr><td rowspan="4">SIGHT DISTANCE</td><td colspan="2">1.05 if limited in 1 quadrants</td><td rowspan="4">Not calibrated</td><td rowspan="4">Not calibrated</td><td rowspan="4">Not calibrated</td><td rowspan="4">Not calibrated</td></tr>
<tr><td colspan="2">1.10 if limited in 2 quadrants</td></tr>
<tr><td colspan="2">1.15 if limited in 3 quadrants</td></tr>
<tr><td colspan="2">1.20 if limited in 4 quadrants</td></tr>
<tr><td>RT MIN</td><td rowspan="4">Not calibrated</td><td rowspan="4">Not calibrated</td><td>1.35</td><td rowspan="2">Not calibrated</td><td>1.48</td><td>1</td></tr>
<tr><td>HI1</td><td>exp(0.0263)</td><td rowspan="2">Not calibrated</td><td rowspan="2">Not calibrated</td></tr>
<tr><td>DRWY1</td><td rowspan="2">Not calibrated</td><td>1.13</td></tr>
<tr><td>MEDIAN</td><td>Not calibrated</td><td>1</td><td>0.77</td></tr>
</table>

[1] Group A = 1.19, Group B = 0.86

Table 186. Comparison of Type III–V AMFs for TOTACC

AMF	"Red Book" and Harwood et al. (2002)		AMFs Derived From Full Models			AMFs Derived From Regression Models		
	Type III-IV	Type V	Type III	Type IV	Type V	Type III	Type IV	Type V
SKEW	None provided	1	exp(0.010SKEW)	Not calibrated	Not calibrated	1+(0.016*SKEW)/ (0.98+0.016*SKEW)	1+(0.053*SKEW)/ (1.43+0.053*SKEW)	1
RT MAJ		1.00 if none exist 0.975 on one approach (0.96 on one approach) 0.95 on both approaches (0.92 on both approaches)	*Not calibrated*			1	1	1
LT MAJ		1.00 if none exist 0.82 on one approach 0.67 on both approaches				0.71	1	1
SIGHT DISTANCE		1				1	1	1
COMDRWY1		*Not calibrated*	exp (0.0681COMDRWY1)		exp (0.0539 COMDRWY1)	*Not calibrated*	*Not calibrated*	*Not calibrated*
VEI1			exp(0.1081VEI1)		*Not calibrated*			
MEDWIDTH1			exp (-0.0106MEDWDTH1)					
MEDTYPE1			0.73					
PKTRUCK			*Not calibrated*	exp (-0.0479PKTRUCK)				
PKTHRU2				exp (0.0249PKTHRU2)				
PKLEFT				exp (0.0229PKLEFT)				
SDR2				exp(-0.0003SDR2)				
LIGHT					0.75			
HEICOM					exp (-0.0288HEICOM)			

Table 187. Comparison of AMFs for INJACC

<table>
<tr><th rowspan="2">AMF</th><th>“Red Book”</th><th colspan="5">AMFs Derived From Full Models</th><th colspan="4">AMFs Derived From Regression Models</th></tr>
<tr><th>Type I - V</th><th>Type I</th><th>Type II</th><th>Type III</th><th>Type IV</th><th>Type V</th><th>Type I</th><th>Type II</th><th>Type III</th><th>Type IV</th></tr>
<tr><td>SKEW</td><td rowspan="16">None provided</td><td>Not calibrated</td><td>Not calibrated</td><td>exp(0.0163SKEW)</td><td rowspan="10">Not calibrated</td><td rowspan="14">Not calibrated</td><td>1</td><td>1</td><td>1+(0.017SKEW)/
(0.52+0.017SKEW)</td><td>1+(0.048SKEW)/
(0.72+0.048SKEW)</td></tr>
<tr><td>RT MAJ</td><td>0.87</td><td>0.85</td><td rowspan="7">Not calibrated</td><td>1</td><td>1</td><td>1</td><td>0.86 one approach,
0.74 both approaches</td></tr>
<tr><td>LT MAJ</td><td>0.8</td><td rowspan="3">Not calibrated</td><td>1</td><td>0.42</td><td>1</td><td>1</td></tr>
<tr><td>RT MIN</td><td>1.36</td><td>1.56</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>SIGHT DISTANCE</td><td>Not calibrated</td><td rowspan="3">Not calibrated</td><td rowspan="3">Not calibrated</td><td>1</td><td>1</td></tr>
<tr><td>HI</td><td>exp
(0.0286)</td><td>exp
(0.0408)</td><td rowspan="11">Not calibrated</td><td rowspan="11">Not calibrated</td></tr>
<tr><td>DRWY1</td><td rowspan="10">Not calibrated</td><td>1.09</td></tr>
<tr><td>MEDIAN</td><td>0.72</td><td>1</td><td>0.52</td></tr>
<tr><td>COMDRWY1</td><td rowspan="8">Not calibrated</td><td>exp
(0.0627COMDRWY1)</td><td rowspan="8">Not calibrated</td><td rowspan="8">Not calibrated</td></tr>
<tr><td>HAZRAT1</td><td>exp
(0.1889HAZRAT1)</td></tr>
<tr><td>PKTRUCK</td><td>exp
(-0.0253PKTRUCK)</td><td>exp
(-0.0520PKTRUCK)</td></tr>
<tr><td>PKTURN</td><td>exp(0.0254PKTURN)</td><td>Not calibrated</td></tr>
<tr><td>PKLEFT1</td><td rowspan="4">Not calibrated</td><td>exp
(0.0523PKLEF)</td></tr>
<tr><td>SDR2</td><td rowspan="3">Not calibrated</td></tr>
<tr><td>LIGHT</td><td>0.67</td></tr>
<tr><td>HEI2</td><td>exp
(-0.0284HEI2)</td></tr>
</table>

3.6 SENSITIVITY ANALYSIS RESULTS

A sensitivity analysis was performed to examine the estimated effect on safety of the AMFs derived from the full models and regression base models. The sensitivity analysis applies each AMF to the base model estimate for various levels of AADT.

3.6.1 Type I Intersections

The predicted TOTAL and INJURY accident frequencies per year for each AMF derived from the full models and regression base models are presented in tables 188 through 195.

Type I TOTAL Accidents

The AMFs derived for TOTAL accidents for Type I intersections are HI1, right-turn lanes on major, right-turn lane on minor, and left-turn lanes on major roads. The sensitivity test results for these AMFs are presented in tables 188 through 191.

Table 188. Sensitivity of Safety to HI1 for Type I TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	HI1			
		0	5	10	20
400	50	0.088	0.101	0.115	0.150
	100	0.113	0.129	0.147	0.191
	400	0.185	0.211	0.240	0.312
1,000	100	0.204	0.233	0.265	0.345
	500	0.361	0.411	0.469	0.610
	1,000	0.461	0.526	0.600	0.780
3,000	100	0.414	0.472	0.539	0.701
	500	0.732	0.835	0.952	1.239
	1,000	0.936	1.067	1.217	1.583
	3,000	1.380	1.574	1.796	2.336
5,000	100	0.576	0.656	0.749	0.974
	500	1.017	1.160	1.324	1.722
	1,000	1.300	1.483	1.692	2.200
	3,000	1.919	2.188	2.496	3.247
	5,000	2.299	2.622	2.990	3.890
10,000	100	0.900	1.026	1.170	1.522
	500	1.590	1.814	2.069	2.691
	1,000	2.033	2.318	2.644	3.440
	3,000	2.999	3.421	3.901	5.075
	5,000	3.594	4.099	4.675	6.081
	10,000	4.593	5.238	5.975	7.772

Note: Group B AADT base model was used.
The AMF for HI1 was derived from full models.

Table 189. Sensitivity of Safety to RT MAJ for Type I TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	RT MAJ	
		No Right-Turn Lane on Major Road	Presence of Right-Turn Lane on Major Road
400	50	0.088	0.078
	100	0.113	0.099
	400	0.185	0.162
1,000	100	0.204	0.180
	500	0.361	0.317
	1,000	0.461	0.406
3,000	100	0.414	0.364
	500	0.732	0.644
	1,000	0.936	0.823
	3,000	1.380	1.215
5,000	100	0.576	0.506
	500	1.017	0.895
	1,000	1.300	1.144
	3,000	1.919	1.688
	5,000	2.299	2.023
10,000	100	0.900	0.792
	500	1.590	1.400
	1,000	2.033	1.789
	3,000	2.999	2.639
	5,000	3.594	3.162
	10,000	4.593	4.042

Note: Group B AADT base model was used.
The AMF for RT MAJ was derived from full models.

Table 190. Sensitivity of Safety to RT MIN for Type I TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	RT MIN		
		No Right-Turn Lane on Minor Road	Presence of Right-Turn Lane on Minor Road	
			A	B
400	50	0.088	0.119	0.131
	100	0.113	0.153	0.167
	400	0.185	0.249	0.273
1,000	100	0.204	0.275	0.302
	500	0.361	0.487	0.534
	1,000	0.461	0.622	0.682
3,000	100	0.414	0.559	0.613
	500	0.732	0.988	1.083
	1,000	0.936	1.263	1.385
	3,000	1.380	1.864	2.043
5,000	100	0.576	0.777	0.852
	500	1.017	1.374	1.506
	1,000	1.300	1.756	1.925
	3,000	1.919	2.590	2.839
	5,000	2.299	3.103	3.402
10,000	100	0.900	1.215	1.332
	500	1.590	2.147	2.354
	1,000	2.033	2.744	3.099
	3,000	2.999	4.049	4.439
	5,000	3.594	4.851	5.319
	10,000	4.593	6.200	6.798

Note: Group B AADT base model was used.
A: AMF derived from full models.
B: AMF derived from regression models.

Table 191. Sensitivity of Safety to LT MAJ for Type I TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	LT MAJ: No Left-Turn Lane on Major Road	LT MAJ: Presence of Left-Turn Lane on Major Road
400	50	0.088	0.073
	100	0.113	0.093
	400	0.185	0.151
1,000	100	0.204	0.167
	500	0.361	0.296
	1,000	0.461	0.378
3,000	100	0.414	0.340
	500	0.732	0.600
	1,000	0.936	0.767
	3,000	1.380	1.132
5,000	100	0.576	0.472
	500	1.017	0.834
	1,000	1.300	1.066
	3,000	1.919	1.573
	5,000	2.299	1.885
10,000	100	0.900	0.738
	500	1.590	1.304
	1,000	2.033	1.667
	3,000	2.999	2.459
	5,000	3.594	2.947
	10,000	4.593	3.766

Note: Group B AADT base model was used.
The AMF for LT MAJ was derived from full models.

Type I INJURY Accidents

The AMFs derived for INJURY accidents for Type I intersections are HI1, right-turn lane on major, right-turn lanes on minor, and left-turn lanes on major roads. The sensitivity test results for these AMFs are presented in tables 192 through 195.

Table 192. Sensitivity of Safety to HI1 for Type I INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	HI1			
		0	5	10	20
400	50	0.036	0.042	0.048	0.064
	100	0.046	0.053	0.061	0.081
	400	0.073	0.084	0.097	0.129
1,000	100	0.082	0.095	0.109	0.145
	500	0.142	0.163	0.188	0.251
	1,000	0.179	0.206	0.238	0.317
3,000	100	0.166	0.192	0.221	0.295
	500	0.287	0.331	0.382	0.508
	1,000	0.362	0.418	0.482	0.642
	3,000	0.526	0.606	0.700	0.931
5,000	100	0.231	0.266	0.307	0.409
	500	0.398	0.459	0.530	0.705
	1,000	0.503	0.581	0.670	0.892
	3,000	0.730	0.842	0.971	1.293
	5,000	0.867	1.001	1.154	1.537
10,000	100	0.361	0.416	0.480	0.639
	500	0.621	0.717	0.827	1.101
	1,000	0.786	0.906	1.046	1.392
	3,000	1.139	1.314	1.516	2.018
	5,000	1.354	1.562	1.802	2.399
	10,000	1.712	1.975	2.278	3.033

Note: Group B AADT base model was used.
The AMF for HI1 was derived from full models.

Table 193. Sensitivity of Safety to RT MAJ for Type I INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	RT MAJ	
		No Right-Turn Lane on Major Road	Presence of Right-Turn Lane on Major Road
400	50	0.036	0.031
	100	0.046	0.040
	400	0.073	0.063
1,000	100	0.082	0.071
	500	0.142	0.123
	1,000	0.179	0.156
3,000	100	0.166	0.145
	500	0.287	0.249
	1,000	0.362	0.315
	3,000	0.526	0.457
5,000	100	0.231	0.201
	500	0.398	0.346
	1,000	0.503	0.438
	3,000	0.730	0.635
	5,000	0.867	0.755
10,000	100	0.361	0.314
	500	0.621	0.541
	1,000	0.786	0.684
	3,000	1.139	0.991
	5,000	1.354	1.178
	10,000	1.712	1.489

Note: Group B AADT base model was used.
The AMF for RT MAJ was derived from full models.

Table 194. Sensitivity of Safety to RT MIN for Type I INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	RT MIN		
		No right-turn lane on minor road	Presence of right-turn lane on minor road	
			A	B
400	50	0.036	0.049	0.056
	100	0.046	0.062	0.071
	400	0.073	0.099	0.114
1,000	100	0.082	0.112	0.128
	500	0.142	0.192	0.221
	1,000	0.179	0.243	0.279
3,000	100	0.166	0.226	0.260
	500	0.287	0.390	0.447
	1,000	0.362	0.493	0.565
	3,000	0.526	0.715	0.820
5,000	100	0.231	0.314	0.360
	500	0.398	0.541	0.621
	1,000	0.503	0.684	0.785
	3,000	0.730	0.992	1.138
	5,000	0.867	1.180	1.353
10,000	100	0.361	0.490	0.563
	500	0.621	0.845	0.970
	1,000	0.786	1.068	1.226
	3,000	1.139	1.549	1.777
	5,000	1.354	1.841	2.112
	10,000	1.712	2.328	2.670

Note: Group B AADT base model was used.
A: AMF derived from full models.
B: AMF derived from regression models.

Table 195. Sensitivity of Safety to LT MAJ for Type I INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	LT MAJ	
		No Left-Turn Lane on Major Road	Presence of Left-Turn Lane on Major Road
400	50	0.036	0.029
	100	0.046	0.036
	400	0.073	0.058
1,000	100	0.082	0.066
	500	0.142	0.113
	1,000	0.179	0.143
3,000	100	0.166	0.133
	500	0.287	0.229
	1,000	0.362	0.290
	3,000	0.526	0.420
5,000	100	0.231	0.185
	500	0.398	0.318
	1,000	0.503	0.403
	3,000	0.730	0.584
	5,000	0.867	0.694
10,000	100	0.361	0.288
	500	0.621	0.497
	1,000	0.786	0.629
	3,000	1.139	0.911
	5,000	1.354	1.083
	10,000	1.712	1.369

Note: Group B AADT base model was used.
The AMF for LT MAJ was derived from full models.

3.6.2 Type II Intersections

The predicted TOTAL and INJURY accident frequencies per year for each AMF derived from the full models and regression base models are presented in tables 196 through 204.

Type II TOTAL Accidents

The AMFs derived for TOTAL accidents for Type II intersections are ND, right-turn lanes on major, left-turn lanes on major, and median on major roads. The sensitivity test results for these AMFs are presented in tables 196 through 199.

Table 196. Sensitivity of Safety to DRWY1 for Type II TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	DRWY1		
		0	3	5
400	50	0.056	0.064	0.072
	100	0.082	0.093	0.105
	400	0.175	0.198	0.223
1,000	100	0.158	0.179	0.202
	500	0.380	0.429	0.485
	1,000	0.554	0.626	0.707
3,000	100	0.346	0.391	0.442
	500	0.831	0.939	1.061
	1,000	1.212	1.369	1.548
	3,000	2.204	2.491	2.815
5,000	100	0.498	0.563	0.636
	500	1.196	1.351	1.527
	1,000	1.744	1.971	2.227
	3,000	3.173	3.585	4.051
	5,000	4.190	4.735	5.350
10,000	100	0.816	0.922	1.042
	500	1.960	2.215	2.503
	1,000	2.859	3.230	3.650
	3,000	5.200	5.876	6.639
	5,000	6.867	7.760	8.769
	10,000	10.016	11.318	12.789

Note: Group B AADT base model was used.
The AMF for DRWY1 was derived from full models.

Table 197. Sensitivity of Safety to RT MAJ for Type II TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	RT MAJ			
		No Right-Turn Lane on Major Road	Presence of Right-Turn Lane on Major Road		
			A	B	C
400	50	0.056	0.067	0.049	0.040
	100	0.082	0.098	0.071	0.058
	400	0.175	0.208	0.151	0.124
1,000	100	0.158	0.188	0.136	0.112
	500	0.380	0.452	0.327	0.270
	1,000	0.554	0.659	0.476	0.393
3,000	100	0.346	0.412	0.297	0.246
	500	0.831	0.989	0.715	0.590
	1,000	1.212	1.442	1.042	0.860
	3,000	2.204	2.623	1.896	1.565
5,000	100	0.498	0.592	0.428	0.353
	500	1.196	1.423	1.028	0.849
	1,000	1.744	2.076	1.500	1.238
	3,000	3.173	3.775	2.728	2.252
	5,000	4.190	4.986	3.603	2.975
10,000	100	0.816	0.971	0.702	0.579
	500	1.960	2.332	1.686	1.392
	1,000	2.859	3.402	2.459	2.030
	3,000	5.200	6.188	4.472	3.692
	5,000	6.867	8.172	5.906	4.876
	10,000	10.016	11.919	8.614	7.111

Note: Group B AADT base model was used.
A: AMF derived from full models, Group A data.
B: AMF derived from full models, Group B data.
C: AMF derived from regression models

Table 198. Sensitivity of Safety to LT MAJ for Type II TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	LT MAJ	
		No Left-Turn Lane on Major Road	Presence of Left-Turn Lane on Major Road
400	50	0.056	0.040
	100	0.082	0.058
	400	0.175	0.124
1,000	100	0.158	0.112
	500	0.380	0.270
	1,000	0.554	0.393
3,000	100	0.346	0.246
	500	0.831	0.590
	1,000	1.212	0.860
	3,000	2.204	1.565
5,000	100	0.498	0.353
	500	1.196	0.8449
	1,000	1.744	1.238
	3,000	3.173	2.252
	5,000	4.190	2.975
10,000	100	0.816	0.579
	500	1.960	1.392
	1,000	2.859	2.030
	3,000	5.200	3.692
	5,000	6.867	4.876
	10,000	10.016	7.111

Note: Group B AADT base model was used.
The AMF for LT MAJ was derived from regression models.

Table 199. Sensitivity of Safety to MEDIAN for Type II TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	MEDIAN	
		No Median on Major Road	Presence of Median on Major Road
400	50	0.056	0.043
	100	0.082	0.063
	400	0.175	0.135
1,000	100	0.158	0.122
	500	0.380	0.292
	1,000	0.554	0.426
3,000	100	0.346	0.266
	500	0.831	0.640
	1,000	1.212	0.933
	3,000	2.204	1.697
5,000	100	0.498	0.383
	500	1.196	0.921
	1,000	1.744	1.343
	3,000	3.173	2.443
	5,000	4.190	3.226
10,000	100	0.816	0.628
	500	1.960	1.509
	1,000	2.859	2.201
	3,000	5.200	4.004
	5,000	6.867	5.288
	10,000	10.016	7.712

Note: Group B AADT base model was used.
The AMF for MEDIAN was derived from regression models.

Type II INJURY Accidents

The AMFs derived for INJURY accidents for Type II intersections are HI1, DRWY1, right-turn lanes on major, left-turn lanes on major, and median on major roads. The sensitivity test results for these AMFs are presented in tables 200 through 204.

Table 200. Sensitivity of Safety to HI1 for Type II INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	HI1			
		0	5	10	20
400	50	0.033	0.040	0.049	0.074
	100	0.049	0.060	0.073	0.110
	400	0.107	0.131	0.161	0.242
1,000	100	0.087	0.106	0.130	0.196
	500	0.216	0.265	0.325	0.489
	1,000	0.321	0.394	0.483	0.726
3,000	100	0.173	0.212	0.259	0.390
	500	0.431	0.529	0.649	0.975
	1,000	0.640	0.785	0.962	1.447
	3,000	1.196	1.466	1.798	2.704
5,000	100	0.238	0.292	0.358	0.538
	500	0.594	0.729	0.894	1.344
	1,000	0.882	1.082	1.326	1.995
	3,000	1.648	2.021	2.479	3.727
	5,000	2.204	2.703	3.315	4.985
10,000	100	0.368	0.451	0.553	0.831
	500	0.919	1.127	1.382	2.078
	1,000	1.363	1.672	2.050	3.083
	3,000	2.548	3.124	3.831	5.761
	5,000	3.407	4.178	5.124	7.705
	10,000	5.055	6.199	7.602	11.433

Note: Group B AADT base model was used.
The AMF for HI1 was derived from full models.

Table 201. Sensitivity of Safety to DRWY1 for Type II INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	DRWY1		
		0	3	5
400	50	0.033	0.036	0.039
	100	0.049	0.053	0.058
	400	0.107	0.117	0.127
1,000	100	0.087	0.094	0.103
	500	0.216	0.236	0.257
	1,000	0.321	0.350	0.381
3,000	100	0.173	0.188	0.205
	500	0.431	0.470	0.512
	1,000	0.640	0.697	0.760
	3,000	1.196	1.303	1.421
5,000	100	0.238	0.259	0.283
	500	0.594	0.648	0.706
	1,000	0.882	0.961	1.048
	3,000	1.648	1.797	1.958
	5,000	2.204	2.403	2.619
10,000	100	0.368	0.401	0.437
	500	0.919	1.001	1.092
	1,000	1.363	1.486	1.620
	3,000	2.548	2.777	3.027
	5,000	3.407	3.714	4.048
	10,000	5.055	5.510	6.006

Note: Group B AADT base model was used.
The AMF for DRWY1 was derived from full models.

Table 202. Sensitivity of Safety to RT MAJ for Type II INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	RT MAJ	
		No Right-Turn Lane on Major Road	Presence of Right-Turn Lane on Major Road
400	50	0.033	0.028
	100	0.049	0.041
	400	0.107	0.091
1,000	100	0.087	0.074
	500	0.216	0.184
	1,000	0.321	0.273
3,000	100	0.173	0.147
	500	0.431	0.367
	1,000	0.640	0.544
	3,000	1.196	1.016
5,000	100	0.238	0.202
	500	0.594	0.505
	1,000	0.882	0.750
	3,000	1.648	1.401
	5,000	2.204	1.874
10,000	100	0.368	0.312
	500	0.919	0.781
	1,000	1.363	1.159
	3,000	2.548	2.165
	5,000	3.407	2.896
	10,000	5.055	4.297

Note: Group B AADT base model was used.
The AMF for RT MAJ was derived from full models.

Table 203. Sensitivity of Safety to LT MAJ for Type II INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	LT MAJ	
		No Left-Turn Lane on Major Road	Presence of Left-Turn Lane on Major Road
400	50	0.033	0.014
	100	0.049	0.020
	400	0.107	0.045
1,000	100	0.087	0.036
	500	0.216	0.091
	1,000	0.321	0.135
3,000	100	0.173	0.072
	500	0.431	0.181
	1,000	0.640	0.269
	3,000	1.196	0.502
5,000	100	0.238	0.100
	500	0.594	0.250
	1,000	0.882	0.370
	3,000	1.648	0.692
	5,000	2.204	0.926
10,000	100	0.368	0.154
	500	0.919	0.386
	1,000	1.363	0.573
	3,000	2.548	1.070
	5,000	3.407	1.431
	10,000	5.055	2.123

Note: Group B AADT base model was used.
The AMF for LT MAJ was derived from regression models.

Table 204. Sensitivity of Safety to MEDIAN for Type II INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	MEDIAN		
		No Median on Major Road	Presence of Median on Major Road	
			A	B
400	50	0.033	0.024	0.017
	100	0.049	0.035	0.025
	400	0.107	0.077	0.056
1,000	100	0.087	0.062	0.045
	500	0.216	0.156	0.112
	1,000	0.321	0.231	0.167
3,000	100	0.173	0.124	0.090
	500	0.431	0.311	0.224
	1,000	0.640	0.461	0.333
	3,000	1.196	0.861	0.622
5,000	100	0.238	0.171	0.124
	500	0.594	0.428	0.309
	1,000	0.882	0.635	0.459
	3,000	1.648	1.187	0.857
	5,000	2.204	1.587	1.146
10,000	100	0.368	0.265	0.191
	500	0.919	0.662	0.478
	1,000	1.363	0.981	0.709
	3,000	2.548	1.834	1.325
	5,000	3.407	2.453	1.772
	10,000	5.055	3.640	2.629

Note: Group B AADT base model was used.
A: AMF derived from full models.
B: AMF derived from regression models.

3.6.3 Type III Intersections

The predicted TOTAL and INJURY accident frequencies per year for each AMF derived from the full models and regression base models are presented in tables 205 through 215.

Type III TOTAL Accidents

The AMFs derived for TOTAL accidents for Type III intersections are intersection SKEW angle, commercial driveways on major road, vertical curves on major road, median width on major road, painted median type on major road, and major road left-turn lane. The sensitivity test results for these AMFs are presented in tables 205 through 210.

Table 205. Sensitivity of Safety to Skew Angles for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	SKEW Angle (degrees)									
		A	B	A	B	A	B	A	B	A	B
		0		10		15		30		45	
400	50	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
	100	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
	400	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02
1,000	100	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.05
	500	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.07
	1,000	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09
3,000	100	0.11	0.11	0.12	0.13	0.13	0.13	0.15	0.15	0.17	0.16
	500	0.17	0.17	0.18	0.19	0.19	0.20	0.23	0.22	0.26	0.24
	1,000	0.20	0.20	0.22	0.23	0.23	0.24	0.27	0.26	0.31	0.28
	3,000	0.26	0.26	0.29	0.30	0.31	0.31	0.36	0.35	0.41	0.37
5,000	100	0.19	0.19	0.21	0.22	0.23	0.23	0.26	0.26	0.30	0.28
	500	0.29	0.29	0.32	0.33	0.34	0.35	0.39	0.39	0.46	0.41
	1,000	0.35	0.35	0.38	0.40	0.40	0.42	0.47	0.46	0.55	0.49
	3,000	0.46	0.46	0.51	0.52	0.53	0.55	0.62	0.61	0.72	0.65
	5,000	0.52	0.52	0.58	0.60	0.61	0.63	0.71	0.70	0.82	0.74
10,000	100	0.41	0.41	0.46	0.47	0.48	0.49	0.56	0.55	0.65	0.59
	500	0.62	0.62	0.69	0.71	0.72	0.74	0.84	0.83	0.98	0.89
	1,000	0.74	0.74	0.82	0.85	0.86	0.89	1.00	0.99	1.17	1.06
	3,000	0.98	0.98	1.09	1.12	1.14	1.17	1.33	1.30	1.55	1.40
	5,000	1.12	1.12	1.24	1.27	1.30	1.34	1.51	1.48	1.76	1.59
	10,000	1.33	1.33	1.47	1.52	1.55	1.59	1.80	1.77	2.10	1.90

Note: Group B AADT base model was used.
A: AMF derived from full models.
B: AMF derived from regression models.

Table 206. Sensitivity of Safety to Commercial Driveways on Major Road forType III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Commercial Driveways on Major Road (density)			
		0	5	10	15
400	50	0.01	0.01	0.02	0.03
	100	0.01	0.02	0.02	0.03
	400	0.02	0.02	0.03	0.05
1,000	100	0.03	0.05	0.07	0.09
	500	0.05	0.07	0.10	0.14
	1,000	0.06	0.08	0.12	0.17
3,000	100	0.11	0.16	0.22	0.31
	500	0.17	0.23	0.33	0.46
	1,000	0.20	0.28	0.39	0.55
	3,000	0.26	0.37	0.52	0.73
5,000	100	0.19	0.27	0.38	0.54
	500	0.29	0.41	0.58	0.81
	1,000	0.35	0.49	0.69	0.96
	3,000	0.46	0.65	0.91	1.28
	5,000	0.52	0.74	1.03	1.45
10,000	100	0.41	0.58	0.82	1.15
	500	0.62	0.87	1.23	1.73
	1,000	0.74	1.04	1.47	2.06
	3,000	0.98	1.38	1.94	2.72
	5,000	1.12	1.57	2.21	3.10
	10,000	1.33	1.87	2.63	3.70

Note: Group B AADT base model was used.
The AMF for CD on major road was derived from full models.

Table 207. Sensitivity of Safety to Vertical Curves on Major Road (VEI1) for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	VEI1			
		0	3	5	10
400	50	0.01	0.01	0.02	0.03
	100	0.01	0.02	0.02	0.04
	400	0.02	0.02	0.03	0.05
1,000	100	0.03	0.05	0.06	0.10
	500	0.05	0.07	0.09	0.15
	1,000	0.06	0.08	0.10	0.18
3,000	100	0.11	0.15	0.19	0.33
	500	0.17	0.23	0.29	0.49
	1,000	0.20	0.27	0.34	0.59
	3,000	0.26	0.36	0.45	0.77
5,000	100	0.19	0.27	0.33	0.57
	500	0.29	0.40	0.50	0.86
	1,000	0.35	0.48	0.60	1.02
	3,000	0.46	0.64	0.79	1.35
	5,000	0.52	0.72	0.90	1.54
10,000	100	0.41	0.57	0.71	1.22
	500	0.62	0.86	1.07	1.83
	1,000	0.74	1.03	1.27	2.19
	3,000	0.98	1.36	1.68	2.89
	5,000	1.12	1.54	1.92	3.29
	10,000	1.33	1.84	2.29	3.93

Note: Group B AADT base model was used.
The AMF for VEI1 was derived from full models.

Table 208. Sensitivity of Safety to Median Width on Major Road (MEDWIDTH1) for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	MEDWIDHT1			
		0	6	12	20
400	50	0.01	0.01	0.01	0.01
	100	0.01	0.01	0.01	0.01
	400	0.02	0.02	0.02	0.01
1,000	100	0.03	0.03	0.03	0.03
	500	0.05	0.05	0.04	0.04
	1,000	0.06	0.06	0.05	0.05
3,000	100	0.11	0.10	0.10	0.09
	500	0.17	0.16	0.15	0.13
	1,000	0.20	0.19	0.17	0.16
	3,000	0.26	0.25	0.23	0.21
5,000	100	0.19	0.18	0.17	0.16
	500	0.29	0.27	0.26	0.24
	1,000	0.35	0.33	0.31	0.28
	3,000	0.46	0.43	0.40	0.37
	5,000	0.52	0.49	0.46	0.42
10,000	100	0.41	0.39	0.36	0.33
	500	0.62	0.58	0.55	0.50
	1,000	0.74	0.70	0.65	0.60
	3,000	0.98	0.92	0.86	0.79
	5,000	1.12	1.05	0.98	0.90
	10,000	1.33	1.25	1.17	1.08

Note: Group B AADT base model was used.
The AMF for MEDWIDTH1 was derived from full models.

Table 209. Sensitivity of Safety to Painted Median Type on Major Road (MEDTYPE1) for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Median Type on Major Road	
		No Median	Painted Median
400	50	0.01	0.01
	100	0.01	0.01
	400	0.02	0.01
1,000	100	0.03	0.02
	500	0.05	0.04
	1,000	0.06	0.04
3,000	100	0.11	0.08
	500	0.17	0.12
	1,000	0.20	0.15
	3,000	0.26	0.19
5,000	100	0.19	0.14
	500	0.29	0.21
	1,000	0.35	0.25
	3,000	0.46	0.34
	5,000	0.52	0.38
10,000	100	0.41	0.30
	500	0.62	0.45
	1,000	0.74	0.54
	3,000	0.98	0.72
	5,000	1.12	0.82
	10,000	1.33	0.97

Note: Group B AADT base model was used.
The AMF for MEDTYPE1 was derived from full models.

Table 210. Sensitivity of Safety to Major Road Left-Turn Lane for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Major Road Left-Turn Lane	
		No Left-Turn Lane	One Left-Turn Lane
400	50	0.01	0.01
	100	0.01	0.01
	400	0.02	0.01
1,000	100	0.03	0.02
	500	0.05	0.04
	1,000	0.06	0.04
3,000	100	0.11	0.08
	500	0.17	0.12
	1,000	0.20	0.14
	3,000	0.26	0.19
5,000	100	0.19	0.14
	500	0.29	0.21
	1,000	0.35	0.25
	3,000	0.46	0.33
	5,000	0.52	0.37
10,000	100	0.41	0.29
	500	0.62	0.44
	1,000	0.74	0.53
	3,000	0.98	0.70
	5,000	1.12	0.79
	10,000	1.33	0.95

Note: Group B AADT base model was used.
The AMF for Major Road Left-Turn Lane was derived from regression models.

Type III INJURY Accidents

The AMFs derived for INJURY accidents for Type III intersections are intersection SKEW angle, commercial driveways on major road, hazard rating on major road, peak truck percentage on major road, and peak turning percentage. The sensitivity test results for these AMFs are presented below.

Table 211. Sensitivity of Safety to Skew Angles for Type III INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	SKEW Angle (degrees)									
		A	B	A	B	A	B	A	B	A	B
		0		10		15		30		45	
400	50	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.003
	100	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.003	0.005	0.004
	400	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.007	0.005
1,000	100	0.008	0.008	0.009	0.010	0.010	0.010	0.013	0.012	0.016	0.012
	500	0.012	0.012	0.014	0.015	0.015	0.016	0.019	0.018	0.025	0.019
	1,000	0.014	0.014	0.017	0.018	0.018	0.019	0.023	0.021	0.030	0.023
3,000	100	0.033	0.033	0.039	0.042	0.043	0.044	0.054	0.050	0.069	0.053
	500	0.051	0.051	0.060	0.064	0.065	0.068	0.083	0.076	0.106	0.081
	1,000	0.061	0.061	0.072	0.076	0.078	0.082	0.100	0.092	0.128	0.098
	3,000	0.082	0.082	0.097	0.102	0.105	0.109	0.134	0.123	0.171	0.131
5,000	100	0.066	0.066	0.077	0.082	0.084	0.087	0.107	0.098	0.137	0.105
	500	0.101	0.101	0.119	0.126	0.129	0.134	0.164	0.151	0.210	0.161
	1,000	0.121	0.121	0.143	0.151	0.155	0.161	0.197	0.181	0.252	0.193
	3,000	0.162	0.162	0.191	0.202	0.207	0.215	0.264	0.242	0.337	0.258
	5,000	0.185	0.185	0.218	0.231	0.237	0.246	0.302	0.277	0.386	0.296
10,000	100	0.166	0.166	0.195	0.206	0.212	0.220	0.270	0.248	0.345	0.264
	500	0.254	0.254	0.299	0.316	0.324	0.337	0.414	0.379	0.528	0.405
	1,000	0.305	0.305	0.359	0.380	0.389	0.405	0.497	0.456	0.635	0.486
	3,000	0.408	0.408	0.480	0.508	0.521	0.542	0.665	0.610	0.849	0.650
	5,000	0.467	0.467	0.549	0.582	0.596	0.620	0.761	0.698	0.972	0.745
	10,000	0.561	0.561	0.660	0.699	0.716	0.745	0.915	0.839	1.168	0.895

Note: Group B AADT base model was used
A: AMF derived from full models.
B: AMF derived from regression models.

Table 212. Sensitivity of Safety to Commercial Driveways on Major Road for Type III INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Commercial Driveways on Major Road (density)			
		0	5	10	15
400	50	0.002	0.003	0.004	0.005
	100	0.002	0.003	0.004	0.006
	400	0.003	0.005	0.006	0.008
1,000	100	0.008	0.011	0.014	0.020
	500	0.012	0.016	0.022	0.030
	1,000	0.014	0.019	0.027	0.036
3,000	100	0.033	0.046	0.062	0.085
	500	0.051	0.070	0.096	0.131
	1,000	0.061	0.084	0.115	0.157
	3,000	0.082	0.112	0.154	0.210
5,000	100	0.066	0.090	0.123	0.169
	500	0.101	0.138	0.189	0.258
	1,000	0.121	0.166	0.227	0.310
	3,000	0.162	0.222	0.303	0.415
	5,000	0.185	0.254	0.347	0.475
10,000	100	0.166	0.227	0.310	0.424
	500	0.254	0.347	0.475	0.650
	1,000	0.305	0.417	0.571	0.781
	3,000	0.408	0.558	0.763	1.044
	5,000	0.467	0.639	0.874	1.196
	10,000	0.561	0.767	1.050	1.436

Note: Group B AADT base model was used
The AMF for Commercial driveways on major road was derived from full models.

Table 213. Sensitivity of Safety to Hazard Rating on Major Road (HAZRAT1) for Type III INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	HAZRAT			
		1	3	5	7
400	50	0.002	0.003	0.005	0.007
	100	0.002	0.004	0.006	0.009
	400	0.003	0.006	0.008	0.012
1,000	100	0.008	0.014	0.020	0.029
	500	0.012	0.021	0.030	0.044
	1,000	0.014	0.025	0.037	0.053
3,000	100	0.033	0.059	0.086	0.125
	500	0.051	0.090	0.131	0.192
	1,000	0.061	0.108	0.158	0.230
	3,000	0.082	0.145	0.211	0.308
5,000	100	0.066	0.116	0.169	0.247
	500	0.101	0.178	0.259	0.378
	1,000	0.121	0.213	0.311	0.454
	3,000	0.162	0.286	0.417	0.608
	5,000	0.185	0.327	0.477	0.696
10,000	100	0.166	0.292	0.426	0.622
	500	0.254	0.447	0.652	0.952
	1,000	0.305	0.537	0.784	1.144
	3,000	0.408	0.719	1.049	1.530
	5,000	0.467	0.823	1.200	1.751
	10,000	0.561	0.988	1.442	2.104

Note: Group B AADT base model was used
The AMF for HAZRAT1 was derived from full models.

Table 214. Sensitivity of Safety to Peak Truck Percentage (PKTRUCK) for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	PKTURCK (percent)			
		0	5	10	15
400	50	0.002	0.002	0.001	0.001
	100	0.002	0.002	0.002	0.002
	400	0.003	0.003	0.003	0.002
1,000	100	0.008	0.007	0.006	0.005
	500	0.012	0.010	0.009	0.008
	1,000	0.014	0.013	0.011	0.010
3,000	100	0.033	0.029	0.026	0.023
	500	0.051	0.045	0.040	0.035
	1,000	0.061	0.054	0.048	0.042
	3,000	0.082	0.072	0.064	0.056
5,000	100	0.066	0.058	0.051	0.045
	500	0.101	0.089	0.078	0.069
	1,000	0.121	0.107	0.094	0.083
	3,000	0.162	0.143	0.126	0.111
	5,000	0.185	0.163	0.144	0.127
10,000	100	0.166	0.146	0.129	0.113
	500	0.254	0.224	0.197	0.174
	1,000	0.305	0.269	0.237	0.209
	3,000	0.408	0.359	0.317	0.279
	5,000	0.467	0.411	0.362	0.319
	10,000	0.561	0.494	0.435	0.384

Note: Group B AADT base model was used.
The AMF for PKTRUCK was derived from full models..

Table 215. Sensitivity of Safety to Peak Turning Percentage (PKTURN) for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	PKTURN (percent)			
		0	10	20	30
400	50	0.002	0.002	0.003	0.004
	100	0.002	0.003	0.004	0.005
	400	0.003	0.004	0.005	0.007
1,000	100	0.008	0.010	0.013	0.017
	500	0.012	0.015	0.020	0.025
	1,000	0.014	0.018	0.024	0.030
3,000	100	0.033	0.043	0.055	0.071
	500	0.051	0.066	0.085	0.109
	1,000	0.061	0.079	0.102	0.131
	3,000	0.082	0.106	0.136	0.176
5,000	100	0.066	0.085	0.109	0.141
	500	0.101	0.130	0.168	0.216
	1,000	0.121	0.156	0.201	0.259
	3,000	0.162	0.209	0.269	0.347
	5,000	0.185	0.239	0.308	0.397
10,000	100	0.166	0.214	0.275	0.355
	500	0.254	0.327	0.422	0.544
	1,000	0.305	0.393	0.507	0.653
	3,000	0.408	0.526	0.678	0.874
	5,000	0.467	0.602	0.776	1.000
	10,000	0.561	0.723	0.932	1.202

Note: Group B AADT base model was used.
The AMF for PKTURN was derived from full models.

3.6.4 Type IV Intersections

The predicted TOTAL and INJURY accident frequencies per year for each AMF derived from the full models and regression base models are presented in tables 216 through 224.

Type IV TOTAL Accidents

The AMFs derived for TOTAL accidents for Type IV intersections are intersection SKEW angle, right sight distance from minor road, peak truck percentage, peak through percentage on minor road, and peak left-turn percentage. The sensitivity test results for these AMFs are presented in tables 216 through 220.

Table 216. Sensitivity of Safety to Skew Angles for Type IV TOTAL Accidents PerYear

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	SKEW Angle (degrees)				
		0	10	15	30	45
400	50	0.01	0.01	0.01	0.01	0.01
	100	0.01	0.01	0.01	0.01	0.01
	400	0.02	0.02	0.02	0.02	0.02
1,000	100	0.02	0.03	0.03	0.04	0.04
	500	0.06	0.07	0.07	0.08	0.09
	1,000	0.08	0.10	0.11	0.12	0.13
3,000	100	0.10	0.13	0.13	0.15	0.16
	500	0.23	0.29	0.31	0.35	0.37
	1,000	0.32	0.41	0.44	0.49	0.52
	3,000	0.57	0.72	0.77	0.87	0.92
5,000	100	0.19	0.24	0.26	0.29	0.31
	500	0.44	0.55	0.59	0.66	0.71
	1,000	0.62	0.79	0.84	0.95	1.01
	3,000	1.09	1.39	1.48	1.67	1.78
	5,000	1.42	1.80	1.93	2.17	2.31
10,000	100	0.46	0.59	0.63	0.71	0.75
	500	1.06	1.35	1.44	1.62	1.72
	1,000	1.51	1.92	2.05	2.31	2.46
	3,000	2.66	3.38	3.61	4.06	4.32
	5,000	3.46	4.39	4.69	5.27	5.62
	10,000	4.93	6.27	6.69	7.53	8.02

Note: Group B AADT base model was used.
The AMF for Intersection SKEW angle was derived from regression base models.

Table 217. Sensitivity of Safety to Right Sight Distance from Minor Road (SDR2) for Type IV TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	SDR2			
		0	500	1,000	1500
400	50	0.005	0.005	0.003	0.002
	100	0.007	0.006	0.005	0.003
	400	0.015	0.013	0.010	0.006
1,000	100	0.024	0.021	0.015	0.010
	500	0.055	0.048	0.035	0.022
	1,000	0.079	0.068	0.050	0.032
3,000	100	0.099	0.085	0.063	0.040
	500	0.226	0.195	0.144	0.092
	1,000	0.323	0.278	0.206	0.131
	3,000	0.567	0.488	0.362	0.231
5,000	100	0.191	0.164	0.121	0.077
	500	0.435	0.375	0.278	0.177
	1,000	0.622	0.535	0.396	0.253
	3,000	1.093	0.940	0.697	0.444
	5,000	1.420	1.222	0.906	0.577
10,000	100	0.463	0.399	0.296	0.188
	500	1.059	0.912	0.675	0.431
	1,000	1.512	1.301	0.964	0.615
	3,000	2.658	2.288	1.695	1.081
	5,000	3.455	2.974	2.203	1.405
	10,000	4.932	4.245	3.145	2.005

Note: Group B AADT base model was used.
The AMF for SDR2 was derived from full models.

Table 218. Sensitivity of Safety to Peak Truck Percentage (PKTRUCK) for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	PKTRUCK			
		0	5	10	15
400	50	0.005	0.004	0.003	0.003
	100	0.007	0.006	0.005	0.004
	400	0.015	0.012	0.009	0.007
1,000	100	0.024	0.019	0.015	0.012
	500	0.055	0.043	0.034	0.027
	1,000	0.079	0.062	0.049	0.038
3,000	100	0.099	0.078	0.061	0.048
	500	0.226	0.178	0.140	0.110
	1,000	0.323	0.254	0.200	0.157
	3,000	0.567	0.447	0.351	0.277
5,000	100	0.191	0.150	0.118	0.093
	500	0.435	0.343	0.270	0.212
	1,000	0.622	0.489	0.385	0.303
	3,000	1.093	0.860	0.677	0.533
	5,000	1.420	1.118	0.880	0.692
10,000	100	0.463	0.365	0.287	0.226
	500	1.059	0.834	0.656	0.516
	1,000	1.512	1.190	0.937	0.737
	3,000	2.658	2.092	1.646	1.296
	5,000	3.455	2.719	2.140	1.684
	10,000	4.932	3.882	3.055	2.404

Note: Group B AADT base model was used.
The AMF for PKTRUCK was derived from full models.

Table 219. Sensitivity of Safety to Peak Through Percentage on Minor Road (PKTHRU2) for Type IV TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	PKTHRU2			
		0	10	20	30
400	50	0.005	0.007	0.009	0.011
	100	0.007	0.010	0.012	0.016
	400	0.015	0.020	0.025	0.032
1,000	100	0.024	0.031	0.040	0.051
	500	0.055	0.071	0.091	0.117
	1,000	0.079	0.101	0.130	0.166
3,000	100	0.099	0.127	0.163	0.209
	500	0.226	0.290	0.372	0.477
	1,000	0.323	0.414	0.531	0.681
	3,000	0.567	0.728	0.934	1.198
5,000	100	0.191	0.244	0.313	0.402
	500	0.435	0.558	0.716	0.919
	1,000	0.622	0.797	1.023	1.312
	3,000	1.093	1.401	1.798	2.306
	5,000	1.420	1.822	2.337	2.998
10,000	100	0.463	0.595	0.763	0.978
	500	1.059	1. 359	1.743	2.236
	1,000	1.512	1.939	2.488	3.191
	3,000	2.658	3.409	4.373	5.610
	5,000	3.455	4.432	5.685	7.293
	10,000	4.932	6.327	8.116	10.410

Note: Group B AADT base model was used.
The AMF for PKTHRU2 was derived from full models.

Table 220. Sensitivity of Safety to Peak Left-Turn Percentage (PKLEFT) for Type IV TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	PKLEFT			
		0	10	20	30
400	50	0.005	0.007	0.008	0.010
	100	0.007	0.009	0.012	0.015
	400	0.015	0.019	0.024	0.030
1,000	100	0.024	0.030	0.038	0.048
	500	0.055	0.069	0.087	0.110
	1,000	0.079	0.099	0.125	0.157
3,000	100	0.099	0.124	0.156	0.197
	500	0.226	0.284	0.357	0.449
	1,000	0.323	0.406	0.510	0.642
	3,000	0.567	0.713	0.897	1.128
5,000	100	0.191	0.240	0.301	0.379
	500	0.435	0.547	0.688	0.865
	1,000	0.622	0.781	0.983	1.235
	3,000	1.093	1.374	1.727	2.172
	5,000	1.420	1.786	2.245	2.823
10,000	100	0.463	0.583	0.733	0.921
	500	1.059	1.332	1.674	2.105
	1,000	1.512	1.901	2.390	3.005
	3,000	2.658	3.342	4.202	5.283
	5,000	3.455	4.344	5.462	6.868
	10,000	4.932	6.202	7.797	9.804

Note: Group B AADT base model was used.
The AMF for PKLEFT was derived from full models.

Type IV INJURY Accidents

The AMFs derived for INJURY accidents for Type IV intersections are intersection SKEW angle, major right-turn lane, peak truck percentage, and peak left-turn percentage. The sensitivity test results for these AMFs are presented in tables 221 through 224.

Table 221. Sensitivity of Safety to Skew Angles for Type IV INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	SKEW Angle (degrees)				
		0	10	15	30	45
400	50	0.003	0.004	0.004	0.004	0.005
	100	0.004	0.005	0.006	0.006	0.006
	400	0.007	0.010	0.010	0.012	0.012
1,000	100	0.012	0.016	0.017	0.019	0.020
	500	0.024	0.034	0.036	0.040	0.042
	1,000	0.033	0.046	0.050	0.055	0.058
3,000	100	0.046	0.064	0.069	0.077	0.081
	500	0.095	0.134	0.143	0.159	0.167
	1,000	0.131	0.183	0.196	0.218	0.229
	3,000	0.215	0.301	0.323	0.359	0.376
5,000	100	0.087	0.122	0.131	0.145	0.153
	500	0.181	0.253	0.271	0.301	0.317
	1,000	0.248	0.347	0.372	0.413	0.433
	3,000	0.408	0.571	0.611	0.679	0.713
	5,000	0.514	0.719	0.771	0.857	0.899
10,000	100	0.208	0.291	0.311	0.346	0.363
	500	0.431	0.603	0.646	0.718	0.754
	1,000	0.590	0.826	0.884	0.983	1.032
	3,000	0.970	1.359	1.456	1.617	1.698
	5,000	1.223	1.713	1.835	2.039	2.141
	10,000	1.675	2.345	2.513	2.792	2.932

Note: Group B AADT base model was used.
The AMF for Intersection SKEW angle was derived from regression base models.

Table 222. Sensitivity of Safety to Major Right-Turn Lane for Type IV INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Right-Turn Lane on Major Road		
		No Right Turn	Right-Turn Lane on One Approach	Right-Turn Lane on Two Approaches
400	50	0.003	0.002	0.002
	100	0.004	0.003	0.003
	400	0.007	0.006	0.005
1,000	100	0.012	0.010	0.009
	500	0.024	0.021	0.018
	1,000	0.033	0.028	0.024
3,000	100	0.046	0.040	0.034
	500	0.095	0.082	0.071
	1,000	0.131	0.112	0.097
	3,000	0.215	0.185	0.159
5,000	100	0.087	0.075	0.065
	500	0.181	0.156	0.134
	1,000	0.248	0.213	0.183
	3,000	0.408	0.351	0.302
	5,000	0.514	0.442	0.380
10,000	100	0.208	0.178	0.154
	500	0.431	0.370	0.319
	1,000	0.590	0.507	0.436
	3,000	0.970	0.835	0.718
	5,000	1.223	1.052	0.905
	10,000	1.675	1.441	1.240

Note: Group B AADT base model was used.
The AMF for Major Right-Turn Lane was derived from full models.

Table 223. Sensitivity of Safety to Peak Truck Percentage (PKTRUCK) for Type IV INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	PKTRUCK			
		0	5	10	15
400	50	0.003	0.002	0.002	0.001
	100	0.004	0.003	0.002	0.002
	400	0.007	0.005	0.004	0.003
1,000	100	0.012	0.009	0.007	0.005
	500	0.024	0.019	0.014	0.011
	1,000	0.033	0.025	0.020	0.015
3,000	100	0.046	0.035	0.027	0.021
	500	0.095	0.074	0.057	0.044
	1,000	0.131	0.101	0.078	0.060
	3,000	0.215	0.166	0.128	0.099
5,000	100	0.087	0.067	0.052	0.040
	500	0.181	0.139	0.108	0.083
	1,000	0.248	0.191	0.147	0.114
	3,000	0.408	0.314	0.242	0.187
	5,000	0.514	0.396	0.306	0.236
10,000	100	0.208	0.160	0.123	0.095
	500	0.431	0.332	0.256	0.197
	1,000	0.590	0.455	0.351	0.270
	3,000	0.970	0.748	0.577	0.445
	5,000	1.223	0.943	0.727	0.561
	10,000	1.675	1.292	0.996	0.768

Note: Group B AADT base model was used.
The AMF for PKTRUCK was derived from full models.

Table 224. Sensitivity of Safety to Peak Left-Turn Percentage (PKLEFT) for Type IV INJURY Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	PKLEFT			
		0	10	20	30
400	50	0.003	0.005	0.008	0.013
	100	0.004	0.006	0.011	0.018
	400	0.007	0.012	0.020	0.033
1,000	100	0.012	0.020	0.033	0.056
	500	0.024	0.041	0.069	0.116
	1,000	0.033	0.056	0.094	0.159
3,000	100	0.046	0.078	0.131	0.221
	500	0.095	0.161	0.272	0.458
	1,000	0.131	0.221	0.372	0.628
	3,000	0.215	0.363	0.612	1.033
5,000	100	0.087	0.147	0.248	0.419
	500	0.181	0.305	0.515	0.869
	1,000	0.248	0.418	0.705	1.189
	3,000	0.408	0.688	1.160	1.957
	5,000	0.514	0.867	1.463	2.468
10,000	100	0.208	0.350	0.591	0.997
	500	0.431	0.726	1.226	2.068
	1,000	0.590	0.995	1.678	2.831
	3,000	0.970	1.637	2.762	4.660
	5,000	1.223	2.064	3.482	5.875
	10,000	1.675	2.826	4.768	8.044

Note: Group B AADT base model was used.
The AMF for PKLEFT was derived from full model

3.6.5 Type V Intersections

The predicted TOTAL and INJURY accident frequencies per year for each AMF derived from the full models and regression base models are presented in tables 225 through 229.

Type V TOTAL Accidents

The AMFs derived for TOTAL accidents for Type IV intersections are commercial driveways on major road, horizontal curve combinations on major and minor roads, and light. The sensitivity test results for these AMFs are presented in tables 225 through 227.

Table 225. Sensitivity of Safety to Commercial Driveways on Major Road for Type V TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Commercial Driveways on Major Road (density)			
		0	5	10	15
400	50	0.72	0.94	1.24	1.62
	100	0.82	1.07	1.40	1.84
	400	1.05	1.38	1.80	2.36
1,000	100	1.29	1.69	2.22	2.90
	500	1.73	2.27	2.97	3.89
	1,000	1.96	2.57	3.37	4.41
3,000	100	2.24	2.94	3.84	5.03
	500	3.00	3.93	5.15	6.74
	1,000	3.40	4.46	5.84	7.64
	3,000	4.16	5.44	7.13	9.33
5,000	100	2.90	3.79	4.96	6.50
	500	3.88	5.08	6.65	8.70
	1,000	4.40	5.76	7.54	9.87
	3,000	5.37	7.03	9.20	12.05
	5,000	5.89	7.71	10.09	13.22
10,000	100	4.10	5.36	7.02	9.19
	500	5.49	7.18	9.40	12.31
	1,000	6.22	8.14	10.66	13.96
	3,000	7.59	9.94	13.02	17.04
	5,000	8.33	10.91	14.28	18.70
	10,000	9.45	12.37	16.20	21.21

Note: Group A AADT base model was used.
The AMF for Commercial driveways on major road was derived from full models.

Table 226. Sensitivity of Safety to Horizontal Curve Combinations on Major and Minor Roads (HEICOM) for Type III TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	HEICOM			
		0	3	5	10
400	50	0.72	0.66	0.62	0.54
	100	0.82	0.75	0.71	0.61
	400	1.05	0.96	0.91	0.79
1,000	100	1.29	1.19	1.12	0.97
	500	1.73	1.59	1.50	1.30
	1,000	1.96	1.80	1.70	1.47
3,000	100	2.24	2.06	1.94	1.68
	500	3.00	2.75	2.60	2.25
	1,000	3.40	3.12	2.95	2.55
	3,000	4.16	3.81	3.60	3.12
5,000	100	2.90	2.66	2.51	2.17
	500	3.88	3.56	3.36	2.91
	1,000	4.40	4.03	3.81	3.30
	3,000	5.37	4.92	4.65	4.02
	5,000	5.89	5.40	5.10	4.42
10,000	100	4.10	3.76	3.55	3.07
	500	5.49	5.03	4.75	4.11
	1,000	6.22	5.71	5.39	4.66
	3,000	7.59	6.96	6.57	5.69
	5,000	8.33	7.64	7.21	6.25
	10,000	9.45	8.67	8.18	7.08

Note: Group A AADT base model was used.
The AMF for HEICOM was derived from full models.

Table 227. Sensitivity of Safety to Light for Type IV TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Presence of Light	
		No	Yes
400	50	0.72	0.54
	100	0.82	0.61
	400	1.05	0.79
1,000	100	1.29	0.97
	500	1.73	1.30
	1,000	1.96	1.47
3,000	100	2.24	1.68
	500	3.00	2.25
	1,000	3.40	2.55
	3,000	4.16	3.12
5,000	100	2.90	2.17
	500	3.88	2.91
	1,000	4.40	3.30
	3,000	5.37	4.03
	5,000	5.89	4.42
10,000	100	4.10	3.07
	500	5.49	4.11
	1,000	6.22	4.67
	3,000	7.59	5.69
	5,000	8.33	6.25
	10,000	9.45	7.09

Note: Group A AADT base model was used.
The AMF for LIGHT was derived from full models.

Type V INJURY Accidents

The AMFs derived for INJURY accidents for Type V intersections are horizontal curves on minor roads and light on intersections. The sensitivity test results for these AMFs are presented in tables 228 to 229.

Table 228. Sensitivity of Safety to Horizontal Curves on Minor Road (HEI2) for Type IV TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	HEI2			
		0	3	5	10
400	50	0.35	0.32	0.30	0.26
	100	0.41	0.38	0.36	0.31
	400	0.58	0.53	0.50	0.43
1,000	100	0.52	0.47	0.45	0.39
	500	0.76	0.70	0.66	0.57
	1,000	0.90	0.82	0.78	0.67
3,000	100	0.67	0.62	0.58	0.51
	500	0.99	0.91	0.86	0.74
	1,000	1.17	1.07	1.01	0.88
	3,000	1.52	1.39	1.32	1.14
5,000	100	0.76	0.70	0.66	0.57
	500	1.12	1.02	0.97	0.84
	1,000	1.32	1.21	1.14	0.99
	3,000	1.71	1.57	1.49	1.29
	5,000	1.94	1.78	1.68	1.46
10,000	100	0.90	0.82	0.78	0.67
	500	1.32	1.21	1.14	0.99
	1,000	1.56	1.43	1.35	1.17
	3,000	2.02	1.86	1.76	1.52
	5,000	2.29	2.10	1.98	1.72
	10,000	2.70	2.48	2.34	2.03

Note: Group A AADT base model was used.
The AMF for HEI2 was derived from full models.

Table 229. Sensitivity of Safety to Light for Type IV TOTAL Accidents Per Year

Major Road AADT (veh/day)	Minor Road AADT (veh/day)	Presence of Light	
		No	Yes
400	50	0.35	0.24
	100	0.41	0.28
	400	0.58	0.39
1,000	100	0.52	0.35
	500	0.76	0.51
	1,000	0.90	0.60
3,000	100	0.67	0.45
	500	0.99	0.66
	1,000	1.17	0.78
	3,000	1.52	1.02
5,000	100	0.76	0.51
	500	1.12	0.75
	1,000	1.32	0.88
	3,000	1.71	1.15
	5,000	1.94	1.30
10,000	100	0.90	0.60
	500	1.32	0.88
	1,000	1.56	1.04
	3,000	2.02	1.36
	5,000	2.29	1.53
	10,000	2.70	1.81

Note: Group A AADT base model was used.
The AMF for LIGHT was derived from full models.

3.7 SUMMARY, DISCUSSION, AND CONCLUSIONS

In summarizing and discussing the model recalibration exercise, it is important not to lose sight of the fundamental purpose of the statistical models that are the focus of this research. Because the models are required for use in the IHSDM accident prediction algorithm, the recalibration efforts were focused on this application. In this sense, the research reflected here represents a different perspective from the original calibration by Vogt since, at that time, the algorithm was not developed and the calibration philosophy was somewhat different. Models with a comprehensive set of regression parameters were to be used directly for predicting the expected number of accidents at intersections and for deriving AMFs for the five types of intersection crash models examined in this research. To remind the reader, the five intersection types examined are:

- Type I: Three-legged stop controlled intersections of two-lane roads.
- Type II: Four-legged stop controlled intersections of two-lane roads.
- Type III: Three-legged stop controlled intersections with two lanes on the minor and four lanes on major roads.
- Type IV: Four-legged stop controlled intersections with two lanes on the minor and four lanes on major roads.
- Type V: Signalized intersections of two-lane roads.

The accident prediction algorithm enables the number of total intersection-related accidents per year to be estimated by multiplying the predicted number of such accidents for base conditions by AMFs for various features specific to an intersection. The Harwood et al. "Red Book" presented base models and AMFs for three- and four-legged intersections of two-lane rural roads with STOP control, and four-legged signalized intersections of two-lane roads. These base models were the best of available accident prediction models developed in the earlier Vogt FHWA projects and included only variables that were statistically significant at the 15 percent level. Those projects also developed full models with additional variables with the intention of using the variable coefficients to estimate AMFs for use in IHSDM. The full models, along with several variants, are presented in two FHWA reports. Vogt and Bared present models for three- and four-legged intersections of two-lane roads, while Vogt documents models for three other types of rural intersections: three- and four-legged stop controlled with four lanes on the major and two on the minor, and signalized intersections of two-lane roads.(1,2)

Understanding what was required for the recalibration effort is an improvement of the base models and AMFs to be used in the IHSDM accident prediction algorithm—including possible enhancements to model functional forms, addition or exclusion of variables, and updated parameter estimates. This requirement guided the approach. At the same time, full models were developed in keeping with the original intent of the project and with the expectation that it may be possible to derive AMFs similar to what were accomplished in the earlier FHWA work.

The discussion provided here focuses primarily on summarizing and briefly discussing the results of the recalibration detailed in the body of this report, and translating these results into meaningful observations and conclusions. The reader interested in additional details, such as sources of published results for the earlier models and comparison tables, should refer to the earlier sections of this report. Descriptions of all variable abbreviations and definitions used in this report can be found at the beginning of this document.

3.7.1 Model Recalibration

For the five intersection types previously described, statistical models were developed for total accidents (TOTACC) and injury (fatal + nonfatal injury) accidents (INJACC) within 76.25 m (250 ft) of the intersection center. For each intersection type, two fundamental classes of statistical models were developed—models using AADT as the sole predictor of crashes (referred as base or AADT models) and models containing a fairly comprehensive set of predictor variables (referred as full models). There are two levels for each class. Not all levels were calibrated for all model Types (I to V). These details of the models calibrated and data used are summarized in table 230.

Table 230. Summary of Models Recalibrated and Data Used

Model Description	Site Types and Data Used			
	Types I and II	Type III	Type IV	Type V
Group A Sites: Full Model with variables in project data	Minnesota Georgia	California project Michigan Georgia	California project Michigan Georgia	California project Michigan Georgia
Group B Sites: AADT Model for all sites, including California HSIS*	California HSIS Minnesota Georgia	California HSIS Michigan Georgia	California HSIS Michigan Georgia	California HSIS Michigan Georgia
Group B Sites: Full Model with variables from California HSIS	California HSIS Minnesota Georgia	*Not calibrated*	*Not calibrated*	*Not calibrated*
Subset of Group B Sites: AADT Model for sties meeting base conditions for project data plus California HSIS*	California HSIS Minnesota Georgia	California HSIS Michigan Georgia	California HSIS Michigan Georgia	*Not calibrated*
Subset of Group A Sites: AADT Model for sites meeting base conditions for project data	*Not calibrated*	California project Michigan Georgia	California project Michigan Georgia	California project Michigan Georgia

* The California project data for Types II, IV, and V were not used.

AADT Models Overview

The AADT statistical models include AADT as the sole predictor variable and are proposed for consideration as base models to be used in IHSDM. The reasoning behind this apparently simplistic approach is that models with AADT as the only predictor are more likely to be transferable across jurisdictions than models that include other variables. This is an appealing feature, considering that the models are calibrated on data from three States within the United States; however, the likely application is to apply them for forecasting crashes across the entire country. This research strongly supported their use.

Two types of AADT models are presented for Type I and II sites, and three types for Type III, IV, and V sites. First, models were calibrated using all available data from the HSIS California database, original sites from Minnesota and Michigan, and Georgia validation data. Second, models were developed for a subset of these sites that met specified conditions for possible use as base models in the IHSDM accident prediction algorithm. For Types III, IV, and V sites, additional AADT models were calibrated from a dataset that met the base conditions of the significant variables in the full models. These AADT-only models were calibrated on data from the original sites (intersections) from California, Michigan, and the sites used for the Georgia validation data.

Full Models Overview

Statistical models with relatively comprehensive sets of predictor variables were also developed. Unlike their AADT counterparts, these models include many variables, with the intent to explain as much of variation in crash occurrence as possible, given the available set of potential explanatory variables.

For Types I and II, full models were developed using two groups of data. The first, Group A, was comprised of the sites from Minnesota and Georgia and consisted of many variables, including horizontal and vertical curvature. The California sites were not in this group because many of the variables were not available. Group B consisted of the Minnesota, Georgia, and California HSIS sites, but fewer variables were available for modeling.

For Types III, IV, and V, the data used to calibrate full models consisted of the California and Michigan sites from the original study, including the additional years of accident data, and the Georgia sites. There was no equivalent to Group B of the Types I and II models because there were very few HSIS sites, and these had almost no variables of interest.

Type I Model Results

Type I AADT Models (see table 134 and table 135)

The recalibrated models for total accidents represent improvements to the one reported in Harwood et al. (such a model was not presented in the Vogt reports).[3] The β coefficient of the log of major road AADT is about two times that for minor road AADT, which seems to be a reasonable expectation on the basis of other models reported in the literature. The CURE plots confirmed the superiority of the chosen model form, which testifies to the reasonableness of the calibrated models. For the TOTACC model, the base condition model (calibrated from data that met specified base conditions) was estimated with a lower overall overdispersion parameter than the model using all sites. This was expected, because the base condition sites should be more homogeneous in their design characteristics. For the INJACC model the overdispersion was similar for the two AADT models.

Type I Full Models (see table 160, table 161, and table 162)

Full models were developed using two groups of data. The first, Group A, was comprised of the sites from Minnesota and Georgia and consisted of many variables, including horizontal and vertical curvature. The second, Group B, added California HSIS sites, which resulted in fewer variables being available for modeling. Two model variants are reported. One includes a State indicator term and the other does not.

For the Group A models, when a State indicator variable was used in the models, the only geometric variable that proved to be significant was HI1. Without the State indicator, more geometric variables were statistically significant. This effect suggests that geometric variables are correlated with State of origin, with certain States possessing intersections that systematically share geometric traits. There were some similarities and differences between the recalibrated models and the Vogt and Bared models. For total accidents, posted speed limit on major roads and the angle variable HAU were not included in the recalibrated model, while right-turn lanes on minor roads and left-turn lanes on major roads were included. For injury accidents, right-turns on major roads, posted speed on major, number of driveways on major roads, and the angle variable HAU were not included while left-turn lanes on major roads was included. The GOF as measured by the overdispersion parameter was improved over the Vogt and Bared models, just one of numerous GOF measures.

For both of the Group B models, with and without the State indicator variable, right-turn lanes on minor roads and left-turn lanes on major roads are significant in addition to right-turn lanes on major roads.

Type II Model Results

Type II AADT Models (see table 135 and table 139)

Unlike the case for Type I models, the recalibrated Type II models for total accidents have more overdispersion than models reported in Harwood et al. (such a model was not presented in the Vogt reports).(3) In particular, the models do a poorer job for the Georgia and California sites. Nevertheless, the β coefficient of the log of major road AADT is about 20–30 percent higher than that for minor road AADT, which appears to be reasonable. For both the TOTACC and INJACC models, the base condition models were estimated with a lower overdispersion than the model using all sites, again not surprising, because the base condition sites should be more homogeneous in their design characteristics.

Type II Full Models (see table 163, table 164, table 165, and table 166)

As was the case for Type I, full models were developed using two groups of data. The first, Group A, was comprised of sites from Minnesota and Georgia and included variables such as horizontal and vertical curvature. The second, Group B, added California HSIS sites, which resulted in fewer variables being available for modeling. Two model variants were reported. As for Type I, one included a State indicator term and the other did not.

For the Group A models, there were some similarities and differences between the recalibrated models and the Vogt and Bared models. For the recalibrated models, significant geometric variables at approximately the 10 percent level of significance or better for TOTACC included right-turn lane on major roads and the number of driveways for the model l variant, including a State indicator variable, and number of driveways and the vertical curvature variable VCI1 for the variant without the State indicator variable. The Vogt and Bared model also included the angle variable HAU, the major road posted speed, and the horizontal curvature variable HI1, although these last two were of low significance. For the INJACC models, number of driveways and horizontal curvature within 76.25 m (250 ft) of the intersection center were significant at the 10 percent level or better for both the State indicator and non-State indicator variants. The Vogt model included roadside hazard rating as a significant variable and others that were not significant. The GOF as measured by the overdispersion parameter was not as good as that for the Vogt and Bared model.

In the case of the Group B models, for TOTACC, significant variables (in addition to major and minor road AADTs) include right-turn lanes on major roads for the variant with the State indicator variable, and right- and left-turn lanes on major roads for the variant without the State indicator variable. For INJACC, medians and right-turn lanes on major roads were significant for both the State indicator and non-State indicator variants. Again, the GOF for all of the Group B models, as measured by the overdispersion parameter, was not as good as that for the Vogt and Bared model.

Type III Model Results

Type III AADT Models (see table 142, table 143, and table 145)
Unlike models for Type I and II intersections, a State indicator variable was insignificant for all models. The recalibrated models for TOTACC and INJACC generally have better GOF measures than comparable models from the earlier FHWA research. As expected, the GOF statistics were better for the models using base condition sites than for models using all sites.

For the Group A models, for TOTACC, the β coefficient of the log of major road AADT is about three to four times that for minor road AADT, which, once again, is reasonable. For INJACC, the AADT variable effect was captured as the product of the major and minor AADTs as opposed to the TOTACC model, which specified these variables as separate terms.

In the case of the Group B models, for both TOTACC and INJACC, the β coefficient of the log of major road AADT is significantly larger than that for minor road AADT, which is in accord with reasonable expectations.

Type III Full Models (see table 167 and table 168)
Two models each are reported for TOTACC and INJACC. The main model was selected based on the highest Pearson product-moment correlation coefficient, lowest overdispersion, MPB per year, and MAD per year. The other model was the one judged to be next best in terms of these measures.

For TOTACC, major and minor AADTs, crest curve rates on major roads, intersection angle, commercial driveways on major roads, median width on major roads, and painted medians on major roads were found to be significant in the main model. Of these, only median widths on major roads and the AAADT variables were included in the Vogt model, but that model did have a driveway variable DRWY1 instead of COMDRWY1. State indicator variables were statistically insignificant in the recalibration.

For INJACC, major and minor AADTs, roadside hazard ratings on major roads, intersection angles, commercial driveways on major roads, peak turning percentages, and peak truck percentages were found to be significant in the main model. None of these were included in the Vogt model, which had an angle variable HAU as the only geometric variable. Like TOTACC, State indicator variables were again statistically insignificant in the recalibration.

The recalibrated models for both TOTACC and INJACC produce better GOF measures than the Vogt's models, except for the overdispersion parameter.

Type IV Model Results

Type IV AADT Models (see table 148, table 149, and table 151)

Unlike models for Type I and II intersections, a State indicator variable was not statistically significant for all models. The recalibrated models for TOTACC and INJACC resulted in generally improved GOF measures than comparable models from the previous FHWA research.

For the Group A models, the small sample size was insufficient to provide good coefficients and *p*-values for a model with specified base conditions. For the TOTACC model using all sites, the β coefficient of the log of major road AADT is about one and one half times that for minor road AADT, conforming to expectations. The AADT variable effect for the INJACC model was captured as the product of the major and minor AADTs, as opposed to the TOTACC model, which specified these variables as separate terms.

In the case of the Group B models, as seems reasonable, the β coefficient of the log of major road AADT is significantly larger than that for minor road AADT for both TOTACC and INJACC. As expected, the GOF statistics were improved for the models using base condition sites compared to models using all sites.

Type IV Full Models (see table 170)

Two models were presented for both TOTACC and INJACC. Again, the main model was selected based on the highest Pearson product-moment correlation coefficient, lowest overdispersion, MPB per year, and MAD per year.

For TOTACC, major and minor road AADTs, peak left-turn percentages, peak through percentages on minor roads, peak truck percentages, and right-side sight distances on minor roads were found to be significant in the main model. By contrast, the Vogt main model included only a peak left-turn percentage on major road variable PKLEFT1 and a left-turn lane on major road variable LTN1S in addition to the AADT variables. The main model showed the lowest overdispersion among candidate models and indicated the best GOF results. The State indicator variable was statistically insignificant in the main model, but for the variant model, a Michigan indicator variable was found to be significant, indicating more influence of the Michigan data on the model.

For INJACC, major and minor road AADTs, peak left-turn percentages on major roads, peak truck percentages, and speed limits on minor roads were significant in the main model. The Vogt model contained a speed limit on minor road variable SPD2 and a peak left-turn percentage on major road variable PKLEFT1 in addition to the AADT variables. The variant model yields an improvement in overdispersion and Pearson product-moment correlation coefficient, but not in MPB per year and MAD per year. State indicator variables were statistically insignificant.

The recalibrated models for TOTACC and INJACC generally provide better GOF measures than Vogt's models. The overdispersion values of the recalibrated models were lower than Vogt's for TOTACC but slightly higher for INJACC.

Type V Model Results

Type V AADT Models (see table 154, table 155, and table 156)

Statistical models could not be calibrated for specified base conditions due to lack of data. Unlike the case for the other model types, the Vogt report does not provide AADT-only models for Type V. Therefore, a comparison between the Vogt models and the newly calibrated AADT models for TOTACC and INJACC could not be done.

For the Group A models, for TOTACC, the β coefficient of the log of major road AADT is about two to three times greater than that for minor road AADT, which is reasonable. As was the case for the Type III and IV models, for the INJACC model, the AADT variable effect was captured as the product of the major and minor AADTs as opposed to the TOTACC model, which specified these variables as separate terms.

In the case of the Group B models, the main Type V TOTACC and INJACC models calibrated using all sites have a β coefficient of the log of major road AADT, in accord with expectations, about two to three times that for minor road AADT.

Type V Full Models (see table 171 and table 172)

Two models were developed for both TOTACC and INJACC. Again, the main model was selected based on the highest Pearson product-moment correlation coefficient, lowest overdispersion, MPB per year, and MAD per year.

For TOTACC, major and minor AADTs, commercial driveways on major roads, speed limits on major roads, presence of lighting, and horizontal curvature variables were found to be significant in the main model. By contrast, the Vogt main model included a completely different set of non-AADT variables: peak truck percentage PKTRUCK, peak left-turn percentage on minor road PKLEFT2, protected left lane PROT_LT, and vertical curvature VEICOM. The variant model provides an improvement over the main model in overdispersion and Pearson product-moment correlation, but not in MPB per year and MAD per year.

For INJACC, major and minor AADTs, peak left-turn percentages on minor roads, peak truck percentages, presence of lighting, and speed limits on major roads were significant variables in the main model. Again, the Vogt main model had a completely different set of non-AADT variables: peak left-turn percentage on minor road PKLEFT2, peak truck percentage PKTRUCK, protected left lane PROT_LT, and vertical curvature VEICOM. In addition, the AADT variable effect was captured as the product of the major minor AADTs, as opposed to specifying these variables as separate terms in the recalibrated model. Although the recalibrated model variant was superior to the main model in terms of lower overdispersion and better fit to the data, it does include a Michigan indicator variable, which means more influence of the Michigan data on the model. Because the IHSDM requires the main model to be recalibrated to work in any State, the model with the State indicator was selected as a variant and not as the main model, similar to what was done for Types I and II.

The recalibrated models for both TOTACC and INJACC provide a better GOF measures than Vogt's models, except for the overdispersion parameter.

3.7.2 Summary of AMFs

Several strategies for assessing and recalibrating the AMFs corresponding with the five intersection models were explored, including:

1. An attempt, similar to the technique used by Vogt, to infer AMFs from full models.
2. Implementation of a relatively untested regression analysis procedure. The dependent variable was the difference between a site's observed accident count and its AADT-based model prediction. Independent variables were factors at the site that differed from conditions assumed in base or AADT model.

Tables 231, 232, 233, and 234 compare the AMFs from the "Red Book," those from Harwood et al.'s 2002 report, and those derived during the course of this research. None of the variables used showed any significant impacts on safety for Type V sites. In general, the AMF estimates developed were of the same direction of effect and reasonably close in magnitude to those provided by Harwood et al. in 2000 and 2002.

Whereas the "Red Book" provides separate AMFs for major road right-and left-turn lanes at Type II intersections, sites in this dataset had turning lanes on both approaches, and separate effects could not be detected for one versus two approaches. It is believed that a SKEW AMF significantly different than 1 was not supported by the data. There were only few sites with deficient sight distance, so an AMF could not be estimated for the effect of this variable.

For Type III and IV intersections, SKEW was estimated as statistically significant in the regression models. Right-turn lanes on major roads provided statistically significant AMFs for Type IV intersections. For Type V intersections, no variables showed any statistically significant impacts on safety in the regression model.

Table 231. Comparison of Type III–V AMFs for TOTACC

AMF	"Red Book" Type III-IV	"Red Book" Type V	AMFs Derived From Full Models Type III	AMFs Derived From Full Models Type IV	AMFs Derived From Full Models Type V	AMFs Derived From Regression Models Type III	AMFs Derived From Regression Models Type IV	AMFs Derived From Regression Models Type V
SKEW		1	exp(0.0101SKEW)			1+(0.016*SKEW)/ (0.98+0.016*SKEW)	1+(0.053*SKEW)/ (1.43+0.053*SKEW)	1
RT MAJ		1.00 if none exist 0.975 on one approach (0.96 on one approach) 0.95 on both approaches (0.92 on both approaches)	*Not calibrated*	*Not calibrated*	*Not calibrated*	1	1	1
LT MAJ		1.00 if none exist 0.82 on one approach 0.67 on both approaches				0.71	1	1
SIGHT DISTANCE		1				1	1	1
COMDRWY1			exp (0.0681COMDRWY1)		exp (0.0539 COMDRWY1)			
VEI1			exp(0.1081VEI1)	*Not calibrated*				
MEDWIDTH1			exp (-0.0106MEDWDTH1)					
MEDTYPE1	None provided		0.73					
PKTRUCK		*Not calibrated*		exp (-0.0479PKTRUCK)	*Not calibrated*	*Not calibrated*		
PKTHRU2				exp (0.0249PKTHRU2)				
PKLEFT			*Not calibrated*	exp (0.0229PKLEFT)				
SDR2				exp(-0.0003SDR2)				
LIGHT				*Not calibrated*	0.75			
HEICOM					exp (-0.0288HEICOM)			

Table 232. Comparison of Type I–II AMFs for TOTACC

AMF	"Red Book"		Full Models		Regression Models	
	Type I	Type II	Type I	Type II	Type I	Type II
SKEW	exp(0.004SKEW)	exp(0.0054SKEW)	*Not calibrated*	*Not calibrated*	1	1
RT MAJ	1.00 if none exist 0.95 on one approach (0.86 on one approach) 0.90 on both approaches (0.74 on both approaches)		0.88	1.19,0.86[1]	1	0.71
LT MAJ	1.00 if none exist 0.78 if at least one exists (0.56 if at least one exists)	1.00 if none exist 0.76 on one approach (0.72 on one approach) 0.58 on both approaches (0.52 on both approaches)	0.82	*Not calibrated*	1	0.71
SIGHT DISTANCE	1.05 if limited in 1 quadrants 1.10 if limited in 2 quadrants 1.15 if limited in 3 quadrants 1.20 if limited in 4 quadrants		*Not calibrated*	*Not calibrated*	*Not calibrated*	*Not calibrated*
RT MIN	*Not calibrated*	*Not calibrated*	1.35	*Not calibrated*	1.48	1
HI1	*Not calibrated*	*Not calibrated*	exp(0.0263)	*Not calibrated*	*Not calibrated*	*Not calibrated*
DRWY1	*Not calibrated*	*Not calibrated*	*Not calibrated*	1.13	*Not calibrated*	*Not calibrated*
MEDIAN	*Not calibrated*	*Not calibrated*	*Not calibrated*	*Not calibrated*	1	0.77

[1] Group A = 1.19, Group B = 0.86

Table 233. Comparison of Type III–V AMFs for TOTACC

AMF	"Red Book"		AMFs Derived From Full Models			AMFs Derived From Regression Models		
	Type III-IV	Type V	Type III	Type IV	Type V	Type III	Type IV	Type V
SKEW	None provided	1	exp(0.0101SKEW)	*Not calibrated*	*Not calibrated*	1+(0.016*SKEW)/ (0.98+0.016*SKEW)	1+(0.053*SKEW)/ (1.43+0.053*SKEW)	1
RT MAJ		1.00 if none exist 0.975 on one approach (0.96 on one approach) 0.95 on both approaches (0.92 on both approaches)	*Not calibrated*			1	1	1
LT MAJ		1.00 if none exist 0.82 on one approach 0.67 on both approaches				0.71	1	1
SIGHT DISTANCE		1				1	1	1
COMDRWY1		*Not calibrated*	exp (0.0681COMDRWY1)	*Not calibrated*	exp (0.0539 COMDRWY1)	*Not calibrated*		
VEI1			exp(0.1081VEI1)		*Not calibrated*			
MEDWIDTH1			exp (-0.0106MEDWDTH1)					
MEDTYPE1			0.73					
PKTRUCK			*Not calibrated*	exp (-0.0479PKTRUCK)				
PKTHRU2				exp (0.0249PKTHRU2)				
PKLEFT				exp (0.0229PKLEFT)				
SDR2				exp(-0.0003SDR2)				
LIGHT				*Not calibrated*	0.75			
HEICOM					exp (-0.0288HEICOM)			

Table 234. Comparison of AMFs for INJACC

AMF	"Red Book"	AMFs Derived From Full Models					AMFs Derived From Regression Models				
	Type I-V	Type I	Type II	Type III	Type IV	Type V	Type I	Type II	Type III	Type IV	Type V
SKEW		*Not calibrated*	*Not calibrated*	exp(0.0163SKEW)			1	1	1+(0.017SKEW)/ (0.52+0.017SKEW)	1+(0.048SKEW)/ (0.72+0.048SKEW)	1
RT MAJ		0.87	0.85				1	1	1	0.86 one approach, 0.74 both approaches	1
LT MAJ		0.8					1	0.42	1	1	1
RT MIN		1.36	*Not calibrated*				1.56	1	1	1	1
SIGHT DISTANCE		*Not calibrated*		*Not calibrated*	*Not calibrated*	*Not calibrated*			1	1	1
HI1		exp (0.0286)	exp (0.0408)				*Not calibrated*	*Not calibrated*			
DRWY1			1.09								
MEDIAN			0.72				1	0.52			
COMDRWY1				exp (0.0627COMDRWY1)							
HAZRAT1	None provided			exp (0.1889HAZRAT1)					*Not calibrated*	*Not calibrated*	*Not calibrated*
PKTRUCK		*Not calibrated*		exp (-0.0253PKTRUCK)	exp (-0.0520PKTRUCK)						
PKTURN			*Not calibrated*	exp(0.0254PKTURN)	*Not calibrated*		*Not calibrated*	*Not calibrated*			
PKLEFT1					exp (0.0523PKLEFT1)						
SDR2				*Not calibrated*	*Not calibrated*						
LIGHT						0.67					
HEI2						exp (-0.0284HEI2)					

3.7.3 Conclusions and Recommendations

Extensive work was conducted as part of this effort to examine the appropriateness and defensibility of various models in the IHSDM. Numerous GOF indices were used to assess the models, as described in previous sections. Based on these extensive analyses, and practical issues of concern, several conclusions and recommendations can be drawn with respect to full models, AADT models, and AMFs. These are made in the context of IHSDM and general applications.

IHSDM Application

For IHSDM model development, it is recommended that there be a continuation of the current approach whereby AMFs are applied to base model accident predictions to account for factors for intersections under consideration that are different from the base condition.

For base models, those calibrated with AADT as the only explanatory variable are recommended. For these models, the main considerations for recommendation surround the issues of variable selection, GOF, and the most defensible and representative data set from which models were estimated. Because previous AADT models were not directly calibrated as AADT-only, and instead were created by substituting constants for the non-AADT variables in the calibrated models, models estimated in previous efforts should be replaced with improved versions described in this report. Two sets of AADT models are recommended for both total and injury accidents. The first were calibrated using all available data and the second for a subset of sites meeting base condition criteria. If these base condition criterion are not known, or the appropriate AMFs not available, the models calibrated using all sites should be used. Specifically, the models shown in table 235 are recommended for use in the IHSDM:

Table 235. AADT Models Recommended for Use in IHSDM

Model	Table Numbers	Further Notes on Selection
Type I	134, 135	Only Group B data models available.
Type II	138, 139	Only Group B data models available.
Type III	142, 143	Group B selected due to larger sample size.
Type IV	148, 149	Group B selected due to larger sample size.
Type V	154, 155, 157	Only Group A data models available.

For AMFs, the main consideration is logical appeal. It is important to recognize that AMFs derived from expert opinion lack the conventional statistical variability measures associated with statistically derived AMFs. Also important is that expert derived AMFs were borne out of a perceived need among respected safety professionals that statistical information on empirically derived AMFs is unreliable. Combined with the fact that the research team had difficulty producing sufficient sample sizes for testing and/or validating AMFs, the following recommendations regarding AMFs are made:

1. Expert opinion derived AMFs should be used in the IHSDM in the short term.

2. Continued studies should be undertaken to: a) develop analytical methods for obtaining AMFs under observational study conditions; and b) accrue data to help validate and/or recalibrate and refine AMFs in support of the IHSDM.

General Applications of Full Models

Although this research was focused on IHSDM applications, useful byproducts are the full crash prediction models that have been calibrated. These models are appropriate for crash prediction applications such as network screening and safety treatment evaluation. In these applications, crash prediction models are most relevant to ongoing and planned *Highway Safety Manual* projects and to the FHWA initiative known as SafetyAnalyst that consists of software tools to help manage site-specific safety improvements.

The overriding concerns for full models surround the selection of variables in the models, the intuitive appeal and agreement with engineering expectations, and the GOF criterion. Some of the main considerations in this regard include whether or not to include indicator variables for individual State effects (as opposed to a single constant term) and the appeal of individual model variables. It is generally believed that individual State effect models should be used if the individual States (e.g., California) were the target of crash forecasts. If crashes in States other than those identified are to be forecast, then models without State effects should be applied. Considering these factors, the full models shown in table 236 are recommended as "best available" statistical models:

Table 236. Full Models Recommended for Use in Crash Prediction

Model	Table Numbers	Further Notes on Selection
Type I	159, 160	Group B not selected due to few available variables.
Type II	163, 164	Group B not selected due to few available variables.
Type III	167 main model, 168 main model	Only Group A available.
Type IV	169 main model, 170 main model	Only Group A available.
Type V	171 main model, 172 main model	Only Group A available.

APPENDIX A: ALL MODELS IN THE REPORTS OF RELEVANCE

Table 237. All Models in the Reports of Relevance

Validation Number (V)	Model Reference	Reference	Equation/Table	Dependent Variable[1]	Remarks
1, 5	1	1	Table 35, p. 115	A (TOT)	Final Model
2	1	1	Table 36, p. 116	A (INJ)	Final Model
3	1	1	Table 31, p. 111	A (TOT)	Interim Model
4	1	1	Table 34, p. 114	A (TOT)	Interim Model
5, 1	1	3	Eq. 52, p. 134	A (TOT)	Full Model
6	1	3	Eq. 53, p. 136	A (TOT)	Recommended Base Model
7	1	3	Eq. 54, p. 137	B (TOT)	Full Model
8	1	3	Eq. 55, p. 138	B (TOT)	Alternative Base Model
9, 14	2	1	Table 35, p. 115	A (TOT)	Final Model
10	2	1	Table 37, p. 117	A (INJ)	Final Model
11	2	1	Table 32, p. 112	A (TOT)	Interim Model
12	2	1	Table 34, p. 114	A (TOT)	Interim Model
13	2	1	Table 34, p. 114	A (TOT)	Interim Model
14, 9	2	3	Eq. 58, p. 140	A (TOT)	Full Model
15	2	3	Eq. 59, p. 141	A (TOT)	Alternative Base Model
16	2	3	Eq. 60, p. 142	B (TOT)	Full Model
17	2	3	Eq. 61, p. 143	B (TOT)	Base Model Recommended
18	3	2	Table 28, p. 111	C (TOT)	ADT ONLY
19	3	2	Table 28, p. 111	C (TOT)	Main Model
20	3	2	Table 28, p. 111	C (TOT)	Variant
21	3	2	Table 30, p. 113	C (INJ)	ADT ONLY
22	3	2	Table 30, p. 113	C (INJ)	Variant 1
23	3	2	Table 30, p. 113	C (INJ)	Variant 2
24	3	2	Table 29, p. 112	B (TOT)	ADT ONLY
25	3	2	Table 29, p. 112	B (TOT)	Main Model
26	3	2	Table 29, p. 112	B (TOT)	Variant 1
27	3	2	Table 29, p. 112	B (TOT)	Variant 2
28	3	2	Table 29, p. 112	B (TOT)	Variant 3

Table 237. All Models in the Reports of Relevance (Continued)

Validation Number (V)	Model Reference	Reference	Equation/Table	Dependent Variable[1]	Remarks
29	4	2	Table 32, p. 116	C (TOT)	ADT ONLY
30	4	2	Table 32, p. 116	C (TOT)	Main Model
31	4	2	Table 32, p. 116	C (TOT)	Variant 1
32	4	2	Table 32, p. 116	C (TOT)	Variant 2
33	4	2	Table 32, p. 116	C (TOT)	Variant 3
34	4	2	Table 34, p. 118	C (INJ)	ADT ONLY
35	4	2	Table 34, p. 118	C (INJ)	Variant 1
36	4	2	Table 33, p. 117	B (TOT)	ADT ONLY
37	4	2	Table 33, p. 117	B (TOT)	Main Model
38	4	2	Table 33, p. 117	B (TOT)	Variant 1
39	4	2	Table 33, p. 117	B (TOT)	Variant 2
40	4	2	Table 33, p. 117	B (TOT)	Variant 3
41	4	2	Table 34, p. 118	B (INJ)	ADT only
42	4	2	Table 34, p. 118	B (INJ)	Variant 1
43, 54	5	2	Table 35, p. 122	C (TOT)	Main
44, 53	5	2	Table 35, p. 122	C (TOT)	Variant 1
45	5	2	Table 35, p. 122	C (TOT)	Variant 2
46	5	2	Table 35, p. 122	C (TOT)	Variant 3
47	5	2	Table 37, p. 124	C (INJ)	Main
48, 56	5	2	Table 36, p. 123	B (TOT)	Main
49, 55	5	2	Table 36, p. 123	B (TOT)	Variant 1
50, 57	5	2	Table 36, p. 123	B (TOT)	Variant 2
51, 58	5	2	Table 36, p. 123	B (TOT)	Variant 3
52	5	2	Table 36, p. 123	B (INJ)	Main
53, 44	5	3	Eq. 63, p. 145	C(TOT)	Full
54, 43	5	3	Eq. 64, p. 146	C(TOT)	Full
55, 49	5	3	Eq. 65, p. 146	B (TOT)	Full
56, 48	5	3	Eq. 66, p. 146	B (TOT)	Full
57, 50	5	3	Eq. 67, p. 146	B (TOT)	Full
58, 51	5	3	Eq. 68, p. 148	B (TOT)	Full Recommended

[1]A = Police definition of intersection related; B = Accidents generally considered to be intersection-related (BMI); C = Total number occurring at intersection

APPENDIX B: MODELS VALIDATED

Table 238. Models Validated

Validation Number (V)	Model Reference	Reference	Equation/Table	Dependent Variable	Validation Tasks	Remarks
1, 5	1	1	Table 35, p. 115	A (TOT)	All	Final Model
2	1	1	Table 36, p. 116	A (INJ)	All	Final Model
5, 1	1	3	Eq. 52, p. 134	A (TOT)	See V1	Full Model
6	1	3	Eq. 53, p. 136	A (TOT)	Algo.	Recommended Base Model
9, 14	2	1	Table 35, p. 115	A (TOT)	All	Final Model
10	2	1	Table 37, p. 117	A (INJ)	All	Final Model
14, 9	2	3	Eq. 58, p. 140	A (TOT)	See V9	Full Model
17	2	3	Eq. 61, p. 143	B (TOT)	Algo.	Base Model Recommended
19	3	2	Table 28, p. 111	C (TOT)	All	Main Model
22	3	2	Table 30, p. 113	C (INJ)	All	Variant 1
23	3	2	Table 30, p. 113	C (INJ)	All	Variant 2
25	3	2	Table 29, p. 112	B (TOT)	All	Main Model
30	4	2	Table 32, p. 116	C (TOT)	All	Main Model
35	4	2	Table 34, p. 118	C (INJ)	All	Variant 1
37	4	2	Table 33, p. 117	B (TOT)	All	Main Model
42	4	2	Table 34, p. 118	B (INJ)	All	Variant 1
43, 54	5	2	Table 35, p. 122	C (TOT)	All	Main
44, 53	5	2	Table 35, p. 122	C (TOT)	All	Variant 1
47	5	2	Table 37, p. 124	C (INJ)	All	Main
48, 56	5	2	Table 36, p. 123	B (TOT)	All	Main
51, 58	5	2	Table 36, p. 123	B (TOT)	See V58	Variant 3
52	5	2	Table 36, p. 123	B (INJ)	All	Main
58, 51	5	3	Eq. 68, p. 148	B (TOT)	Algo.	Full Recommended

APPENDIX C: DESCRIPTIVE STATISTICS FOR FULL DATASETS BY STATE

TYPE I

Table 239. Summary Statistics for Type I Sites by State

Variables		Number of Sites	Mean	Median	Minimum	Maximum
TOTACC per year	Minnesota	270	0.5368	0.3571	0	3.86
	Georgia	116	1.2716	1.0000	0	6.00
	California	1432	0.5669	0.3750	0	6.75
INJACC per year	Minnesota	270	0.2085	0.1429	0	1.57
	Georgia	116	0.4741	0.5000	0	2.50
	California	1432	0.2600	0.1250	0	4.13
AADT1	Minnesota	270	3981	2611	401	22067
	Georgia	116	3593	2950	420	16900
	California	1432	6590	5097	450	35750
AADT2	Minnesota	270	536	339	101	4608
	Georgia	116	639	430	300	6480
	California	1432	472	210	100	10001
RT MAJ	Minnesota	270	139 (51.5%)			
	Georgia	116	3 (2.6%)			
	California	1432	121 (8.4%)			
RT MIN	Minnesota	270	4 (1.5%)			
	Georgia	116	4 (3.4%)			
	California	1432	40 (2.8%)			
LT MAJ	Minnesota	270	45 (16.7%)			
	Georgia	116	3 (2.6%)			
	California	1432	388 (27.1%)			
LT MIN	Minnesota	270	0 (0%)			
	Georgia	116	1 (0.9%)			
	California	1432	13 (0.9%)			
MEDIAN	Minnesota	270	0 (0%)			
	Georgia	116	3 (2.6%)			
	California	1432	77 (5.4%)			
TERRAIN	Minnesota	270	unknown			
	Georgia	116	flat 48 (41.4%) rolling 58 (50%) mountainous 10 (8.6%)			
	California	1432	flat 520 (36.3%) rolling 489 (34.1%) mountainous 423 (29.5%)			

Table 239. Summary Statistics for Type I Sites by State (Continued)

Variables		Number of Sites	Mean	Median	Minimum	Maximum
SPD1	Minnesota	270	52.54	55.00	25	55
	Georgia	116	46.89	45.00	25	55
	California	1432	unknown			
DRWY1	Minnesota	270	1.29	1.00	0	8
	Georgia	116	1.57	1.00	0	7
	California	1432	unknown			
HAZRAT1	Minnesota	270	2.13	2.00	1.00	4.00
	Georgia	116	3.56	3.50	1.50	7.00
	California	1432	unknown			
HAU	Minnesota	270	-0.80	0.00	-90	85
	Georgia	116	-2.97	0.00	-65	60
	California	1432	unknown			
SHOULDER1	Minnesota	270	unknown			
	Georgia	116	1.02	0.35	0.00	7.00
	California	1432	5.05	4.50	0.00	16.00
VCI1	Minnesota	270	0.1088	0.0000	0.0000	1.0200
	Georgia	116	1.3337	0.8855	0.0000	14.0000
	California	1432	unknown			
HI1	Minnesota	270	1.2689	0.0000	0.0000	29.0000
	Georgia	116	2.5545	0.6435	0.0000	23.2900
	California	1432	unknown			

TYPE II

Table 240. Summary Statistics for Type II Sites by State

Variable and Abbreviation		Number of Sites	Mean	Median	Minimum	Maximum
TOTACC per year	Minnesota	250	0.5406	0.3571	0	7.07
	Georgia	108	1.1806	0.5000	0	6.00
	California	748	1.0132	0.6250	0	7.13
INJACC per year	Minnesota	250	0.2509	0.1429	0	3.14
	Georgia	108	0.6574	0.5000	0	3.50
	California	748	0.5110	0.3750	0	4.75
AADT1	Minnesota	250	2605	1983	419	14141
	Georgia	108	3181	2100	420	12300
	California	748	6784	5620	407	38126
AADT2	Minnesota	250	395	258	100	3209
	Georgia	108	644	430	100	7460
	California	748	562	310	100	6700
RT MAJ	Minnesota	250	130 (52%)			
	Georgia	108	3 (2.8%)			
	California	748	62 (8.3%)			
RT MIN	Minnesota	250	1 (0.4%)			
	Georgia	108	2 (1.9%)			
	California	748	23 (3.1%)			
LT MAJ	Minnesota	250	0 (0%)			
	Georgia	108	6 (5.6%)			
	California	748	217 (29%)			
LT MIN	Minnesota	250	0 (0%)			
	Georgia	108	0 (0%)			
	California	748	1 (0.1%)			
MEDIAN	Minnesota	250	0 (0%)			
	Georgia	108	1 (0.9%)			
	California	748	36 (4.8%)			

Table 240. Summary Statistics for Type II Sites by State (Continued)

Variable and Abbreviation		Number of Sites	Mean	Median	Minimum	Maximum
TERRAIN	Minnesota	250	unknown			
	Georgia	108	flat 52 (48.1%) rolling 52 (48.1%) mountainous (3.7%)			
	California	748	flat 468 (62.6%) rolling 186 (24.9%) mountainous (12.6%)			
SPD1	Minnesota	250	53.75	55.00	30	55
	Georgia	108	49.17	55.00	30	55
	California	748	unknown			
DRWY1	Minnesota	250	0.66	0.00	0	6
	Georgia	108	1.21	1.00	0	6
	California	748	unknown			
HAZRAT1	Minnesota	250	2.04	2.00	1	6
	Georgia	108	3.41	3.00	1	6
	California	748	unknown			
HAU	Minnesota	250	0.75	0.00	-120	150
	Georgia	108	-0.52	-0.25	-58	50
	California	748	unknown			
SHOULDER1	Minnesota	250	unknown			
	Georgia	108	0.73	0.50	0.00	2.30
	California	748	6.10	6.00	0.00	16.00
VCI1	Minnesota	250	0.1350	0.0300	0.0000	2.1000
	Georgia	108	1.1089	0.9045	0.0000	7.5000
	California	748	unknown			
HI1	Minnesota	250	0.55	0.00	0.00	9.00
	Georgia	108	1.69	0.58	0.00	14.60
	California	748	unknown			

TYPE III

Table 241. Summary Statistics for Type III Sites by State: California (CA), Michigan (MI), and Georgia (GA)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
TOTACC per Year		CA	60	1.2	0.7	0.0	4.5
		MI	24	2.1	1.2	0.2	10.6
		GA	52	1.2	0.8	0.0	6.0
		Total	136	1.4	0.8	0.0	10.6
INJACC per Year		CA	60	0.6	0.3	0.0	3.7
		MI	24	0.5	0.4	0.0	2.0
		GA	52	0.5	0.5	0.0	4.0
		Total	136	0.6	0.3	0.0	4.0
AADT1		CA	60	13484	12082	2360	33333
		MI	24	11635	11958	6817	23716
		GA	52	13100	12200	6500	28601
		Total	136	13011	12100	2360	33333
AADT2		CA	60	500	190	20	3001
		MI	24	835	779	15	2957
		GA	52	892	430	80	9490
		Total	136	709	430	15	9490
MEDTYPE	Total		136				
	No Median	CA	21(15.4%)				
		MI	24(17.6%)				
		GA	24(17.6%)				
		Total	69(50.7%)				
	Painted	CA	24(17.6%)				
		MI	0(0%)				
		GA	21(15.4%)				
		Total	45(33.1%)				
	Curbed	CA	9(6.6%)				
		MI	0(0%)				
		GA	5(3.7%)				
		Total	14(10.3%)				
	Other	CA	6(4.4%)				
		MI	0(0%)				
		GA	2(1.5%)				
		Total	8(5.9%)				
MEDWDTH1		CA	60	5.2	2.5	0.0	36.0
		MI	24	0.0		0.0	0.0
		GA	52	27.0	20.0	0.0	63.0
		Total	136	12.6	6.0	0.0	63.0
HAU		CA	60	-2.0	0.0	-45.0	55.0
		MI	24	3.8	0.0	0.0	50.0
		GA	52	4.1	0.0	-65.0	90.0
		Total	136	1.3	0.0	-65.0	90.0

Table 241. Summary Statistics for Type III Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
HAZRAT1	Total		136				
	1	CA	2(1.5%)				
		MI	14(10.3%)				
		GA	0(0.0%)				
		Total	16(11.8%)				
	2	CA	29(21.3%)				
		MI	8(5.9%)				
		GA	21(15.4%)				
		Total	58(42.6%)				
	3	CA	12 (8.8%)				
		MI	1(0.7%)				
		GA	13(9.6%)				
		Total	26(19.1%)				
	4	CA	9(6.6%)				
		MI	1(0.7%)				
		GA	15(11.0%)				
		Total	25(18.4%)				
	5	CA	6(4.4%)				
		MI	0(0.0%)				
		GA	2(1.5%)				
		Total	8(5.9%)				
	6	CA	1(0.7%)				
		MI	0(0.0%)				
		GA	1(0.7%)				
		Total	2(1.5%)				
	7	CA	1(0.7%)				
		MI	0(0.0%)				
		GA	0(0.0%)				
		Total	1(0.7%)				
		MI	unknown				
		GA	2(4.0%)				
COMDRWY1		CA	60	1.5	0.0	0.0	14.0
		MI	24	2.9	2.0	0.0	11.0
		GA	52	0.7	0.0	0.0	9.0
		Total	136	1.5	0.0	0.0	14.0
RESDRWY1		CA	60	1.0	0.0	0.0	6.0
		MI	24	1.7	1.0	0.0	7.0
		GA	52	0.8	0.0	0.0	5.0
		Total	136	1.0	0.0	0.0	7.0
DRWY1		CA	60	2.5	0.0	0.0	15.0
		MI	24	4.6	5.0	0.0	11.0
		GA	52	1.5	1.0	0.0	9.0
		Total	136	2.5	1.0	0.0	15.0

Table 241. Summary Statistics for Type III Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
SPD1		CA	60	53.3	55.0	30.0	65.0
		MI	24	43.1	40.0	30.0	55.0
		GA	52	55.8	55.0	45.0	65.0
		Total	136	52.5	55.0	30.0	65.0
SPD2		CA	60	34.2	35.0	15.0	35.0
		MI	24	25.0	25.0	15.0	35.0
		GA	52	37.1	35.0	25.0	55.0
		Total	136	33.7	35.0	15.0	55.0
LIGHT	Total		136				
	0	CA	43(31.6%)				
		MI	9(6.6%)				
		GA	45(33.1%)				
		Total	97(71.3%)				
	1	CA	17(12.5%)				
		MI	15(11.0%)				
		GA	7(5.1%)				
		Total	39(28.7%)				
TERRAIN1	Total		136				
	Flat	CA	24(17.6%)				
		MI	24(17.6%)				
		GA	35(25.7%)				
		Total	83(61.0%)				
	Rolling	CA	29(21.3%)				
		MI	0(0.0%)				
		GA	13(9.6%)				
		Total	42(30.9%)				
	Mountainous	CA	7(5.1%)				
		MI	0(0.0%)				
		GA	4(2.9%)				
		Total	11(8.1%)				
TERRAIN2	Total		52				
	Flat	CA	unknown				
		MI	unknown				
		GA	24(17.6%)				
	Rolling	CA	unknown				
		MI	unknown				
		GA	21(15.4%)				
	Mountainous	CA	unknown				
		MI	unknown				
		GA	7(5.1%)				

Table 241. Summary Statistics for Type III Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
RTLN1	Total		136				
	0	CA	44(32.4%)				
		MI	24(17.6%)				
		GA	40(29.4%)				
		Total	108(79.4%)				
	1	CA	16(11.8%)				
		MI	0(0.0%)				
		GA	12(8.8%)				
		Total	28(20.6%)				
LTLN1	Total		136				
	0	CA	15(11.0%)				
		MI	24(17.6%)				
		GA	9(6.6%)				
		Total	48(35.3%)				
	1	CA	45(33.1%)				
		MI	0(0.0%)				
		GA	43(31.6%)				
		Total	88(64.7%)				
RTLN2	Total		136				
	0	CA	55(40.4%)				
		MI	19(14.0%)				
		GA	43(31.6%)				
		Total	117(86.0%)				
	1	CA	5(3.7%)				
		MI	5(3.7%)				
		GA	9(6.6%)				
		Total	19(14.0%)				
LTLN2	Total		136				
	0	CA	57(41.9%)				
		MI	24(17.6%)				
		GA	50(36.8%)				
		Total	131(96.3%)				
	1	CA	3(2.2%)				
		MI	0(0.0%)				
		GA	2(1.5%)				
		Total	5(3.7%)				
HI1		CA	60	1.52	0.00	0.00	14.29
		MI	24	1.36	0.00	0.00	9.15
		GA	52	0.90	0.00	0.00	6.30
		Total	136	1.26	0.00	0.00	14.29
HEI1		CA	60	2.17	0.00	0.00	14.29
		MI	24	3.21	0.00	0.00	26.63
		GA	52	1.28	0.88	0.00	6.30
		Total	136	2.01	0.73	0.00	26.63

Table 241. Summary Statistics for Type III Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables	State	No. of Sites	Mean	Median	Minimum	Maximum
GRADE1	CA	60	1.35	0.85	0.00	5.85
	MI	24	0.51	0.48	0.00	1.37
	GA	52	0.76	0.85	0.00	2.75
	Total	136	1.00	0.70	0.00	5.90
VEI1	CA	60	0.88	0.14	0.00	6.71
	MI	24	0.78	0.00	0.00	5.83
	GA	52	1.03	1.12	0.00	2.83
	Total	136	0.90	0.60	0.00	6.70
PKTRUCK	CA	60	9.53	7.91	1.18	28.16
	MI	24	8.21	7.59	2.93	16.63
	GA	unknown				
	Total	84	9.15	7.79	1.18	28.16
PKTURN	CA	60	6.55	3.50	0.46	53.09
	MI	24	6.99	5.87	0.27	18.87
	GA	unknown				
	Total	84	6.68	4.28	0.27	53.09
PKLEFT	CA	60	3.15	1.73	0.23	25.97
	MI	24	3.59	3.20	0.13	11.17
	GA	unknown				
	Total	84	3.28	2.16	0.13	25.97
PKLEFT1	CA	60	1.44	0.62	0.00	21.29
	MI	24	1.54	0.97	0.00	5.95
	GA	unknown				
	Total	84	1.47	0.69	0.00	21.29
PKLEFT2	CA	60	55.44	60.77	0.00	100.00
	MI	24	54.97	58.70	0.00	100.00
	GA	unknown				
	Total	84	55.31	60.29	0.00	100.00
SD1	CA	60	1553	2000	500	2000
	MI	24	1519	2000	600	2000
	GA	52	1470	1715	560	2000
	Total	136	1515	2000	500	2000
SDL2	CA	60	1364	1365	40	2000
	MI	24	1486	1800	400	2000
	GA	52	1448	1533	170	2000
	Total	136	1418	1510	40	2000
SDR2	CA	60	1380	1424	80	2000
	MI	24	1408	1350	500	2000
	GA	52	1493	1865	510	2000
	Total	136	1428	1555	80	2000

TYPE IV

Table 242. Summary Statistics for Type IV Sites by State: California (CA), Michigan (MI), and Georgia (GA)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
TOTACC per year		CA	54	1.4	0.8	0.0	7.2
		MI	18	3.1	2.2	0.0	10.8
		GA	52	2.1	2.0	0.0	6.5
		Total	124	2.0	1.4	0.0	10.8
INJACC per year		CA	54	0.8	0.5	0.0	5.7
		MI	18	1.0	0.9	0.0	3.2
		GA	52	1.0	1.0	0.0	4.5
		Total	124	0.9	0.5	0.0	5.7
AADT1		CA	54	13847	11199	3150	73799
		MI	18	10707	10550	5967	19384
		GA	52	12631	12850	5300	25799
		Total	124	12881	11496	3150	73799
AADT2		CA	54	441	301	21	1850
		MI	18	913	733	254	2018
		GA	52	706	463	300	2990
		Total	124	621	430	21	2990
MEDTYPE	Total		124				
	No Median	CA	13(10.5%)				
		MI	18(14.5%)				
		GA	39(31.5%)				
		Total	70(56.5%)				
	Painted	CA	17(13.7%)				
		MI	0(0.0%)				
		GA	10(8.1%)				
		Total	27(21.8%)				
	Curbed	CA	22(17.7%)				
		MI	0(0.0%)				
		GA	3(2.4%)				
		Total	22(17.7%)				
	Other	CA	2(1.6%)				
		MI	0(0.0%)				
		GA	0(0.0%)				
		Total	5(4.0%)				

Table 242. Summary Statistics for Type IV Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
MEDWDTH1		CA	54	5.0	4.6	0.0	36
		MI	18	0	0	0	0
		GA	52	33.1	40.0	0.0	60
		Total	124	16.1	6.5	0	60
HAU		CA	54	0.8	0.0	-20.0	22.5
		MI	18	1.1	0.0	-20.0	30.0
		GA	52	2.40	1.25	-50.0	55.0
		Total	124	1.5	0.0	-50.0	55.0
HAZRAT1	Total		124				
	1	CA	13(10.5%)				
		MI	8(6.5%)				
		GA	3(2.4%)				
		Total	24(19.4%)				
	2	CA	20(16.1%)				
		MI	9(7.3%)				
		GA	14(11.3%)				
		Total	43(34.7%)				
	3	CA	11(8.9%)				
		MI	1(0.8%)				
		GA	20(16.1%)				
		Total	32(25.8%)				
	4	CA	8(6.5%)				
		MI	0(0.0%)				
		GA	13(10.5%)				
		Total	21(16.9%)				
	5	CA	1(0.8%)				
		MI	0(0.0%)				
		GA	1(0.8%)				
		Total	2(1.6%)				
	6	CA	1(0.8%)				
		MI	0(0.0%)				
		GA	1(0.8%)				
		Total	2(1.6%)				
	7	CA	0(0.0%)				
		MI	0(0.0%)				
		GA	0(0.0%)				
		Total	0(0.0%)				
COMDRWY1		CA	54	0.7	0.0	0.0	12.0
		MI	18	1.3	0.5	0.0	7.0
		GA	52	0.3	0.0	0.0	2.0
		Total	124	0.6	0	0	12

Table 242. Summary Statistics for Type IV Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
RESDRWY1		CA	54	0.6	0.0	0.0	6.0
		MI	18	2.5	2	0	7
		GA	52	0.2	0.0	0.0	2.0
		Total	124	0.7	0	0	7
DRWY1		CA	54	1.3	0.0	0.0	15.0
		MI	18	3.8	4.0	0.0	9.0
		GA	52	0.4	0.0	0.0	3.0
		Total	124	1.3	0	0	15
SPD1		CA	54	56.4	55.0	25	65
		MI	18	45.3	42.5	35	55
		GA	52	58.4	55.0	45	65
		Total	124	55.6	55	25	65
SPD2		CA	54	35.0	35.0	25	50
		MI	18	28.2	25.0	25	45
		GA	52	36.6	35.0	25	55
		Total	124	34.7	35.0	25	55
LIGHT	Total		124				
	0	CA	36(29.0%)				
		MI	4(3.2%)				
		GA	47(37.9%)				
		Total	87(70.2%)				
	1	CA	18(14.5%)				
		MI	14(11.3%)				
		GA	5(4.0%)				
		Total	37(29.8%)				
TERRAIN1	Total		124				
	Flat	CA	32(25.8%)				
		MI	18(14.5%)				
		GA	40(32.3%)				
		Total	90(72.6%)				
	Rolling	CA	13(10.5%)				
		MI	0(0.0%)				
		GA	12(9.7%)				
		Total	25(20.2%)				
	Mountainous	CA	9(7.3%)				
		MI	0(0.0%)				
		GA	0(0.0%)				
		Total	9(7.3%)				

Table 242. Summary Statistics for Type IV Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
RTLN1	Total		124				
	0	CA	27(21.8%)				
		MI	18(14.5%)				
		GA	24(19.4%)				
		Total	69(55.6%)				
	1	CA	7(5.6%)				
		MI	0(0.0%)				
		GA	13(10.5%)				
		Total	20(16.1%)				
	2	CA	20(16.1%)				
		MI	0(0.0%)				
		GA	15(12.1%)				
		Total	35(28.2%)				
LTLN1	Total		124				
	0	CA	4(3.2%)				
		MI	18(14.5%)				
		GA	7(5.6%)				
		Total	29(23.4%)				
	1	CA	4(3.2%)				
		MI	0(0.0%)				
		GA	1(0.8%)				
		Total	5(4.0%)				
	2	CA	46(37.1%)				
		MI	0(0.0%)				
		GA	44(35.5%)				
		Total	90(72.6%)				
RTLN2	Total		124				
	0	CA	33(26.6%)				
		MI	12(9.7%)				
		GA	27(21.8%)				
		Total	72(58.1%)				
	1	CA	7(5.6%)				
		MI	3(2.4%)				
		GA	3(2.4%)				
		Total	13(10.5%)				
	2	CA	14(11.3%)				
		MI	3(2.4%)				
		GA	22(17.7%)				
		Total	39(31.5%)				

Table 242. Summary Statistics for Type IV Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
LTLN2	Total		124				
	0	CA	52(41.9%)				
		MI	18(14.5%)				
		GA	52(41.9%)				
		Total	122(98.4%)				
	1	CA	2(1.6%)				
		MI	0(0.0%)				
		GA	0(0.0%)				
		Total	2(1.6%)				
	2	CA	0(0.0%)				
		MI	0(0.0%)				
		GA	0(0.0%)				
		Total	0(0.0%)				
HI1		CA	54	1.24	0.00	0.00	7.07
		MI	18	0.83	0.00	0.00	7.33
		GA	52	0.62	0.29	0.00	2.50
		Total	124	0.92	0	0	7.33
HEI1		CA	54	1.47	0.00	0.00	7.07
		MI	18	15.65	0.00	0.00	233.33
		GA	52	0.88	0.72	0.00	3.49
		Total	124	3.28	0.6	0	233.33
GRADE1		CA	54	1.19	0.67	0.00	5.80
		MI	18	0.32	0.00	0.00	2.25
		GA	52	0.89	0.85	0.00	2.30
		Total	124	0.94	0.71	0.00	5.80
VEI1		CA	54	0.5	0.0	0.0	3.7
		MI	18	1.3	0.0	0.0	12.5
		GA	52	1.09	1.05	0.00	2.79
		Total	124	0.87	0.35	0	12.5
VI1		CA	54	0.4	0.0	0.0	3.1
		MI	18	1.1	0.0	0.0	12.5
		GA	52	0.71	0.45	0.00	3.23
		Total	124	0.62	0	0	12.5
VCI1		CA	54	0.1	0.0	0.0	3.1
		MI	18	1.04	0.00	0.00	12.50
		GA	52	0.50	0.00	0.00	2.57
		Total	124	0.43	0	0	12.5

Table 242. Summary Statistics for Type IV Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables	State	No. of Sites	Mean	Median	Minimum	Maximum
VCEI1	CA	54	0.3	0.0	0.0	3.2
	MI	18	1.12	0.00	0.00	12.50
	GA	52	0.80	0.56	0.00	2.57
	Total	124	0.63	0	0	12.5
PKTRUCK	CA	54	11.99	8.92	2.22	37.25
	MI	18	7.83	7.94	1.75	13.13
	GA	unknown				
	Total	72	10.95	8.36	1.75	37.25
PKTURN	CA	54	7.93	4.87	0.00	48.52
	MI	18	14.10	9.53	4.54	32.55
	GA	unknown				
	Total	72	9.47	6.56	0	48.52
PKLEFT	CA	54	4.05	2.54	0.00	25.26
	MI	18	7.04	4.75	2.14	16.76
	GA	unknown				
	Total	72	4.8	3.08	0	25.26
PKLEFT1	CA	54	2.25	1.02	0.00	13.96
	MI	18	4.36	3.10	0.83	11.56
	GA	unknown				
	Total	72	2.78	1.51	0	13.96
PKLEFT2	CA	54	39.78	37.12	0.00	100.00
	MI	18	36.22	34.10	13.61	58.65
	GA	unknown				
	Total	72	38.89	36.66	0	100
PKTHRU1	CA	54	95.27	97.71	67.77	100.00
	MI	18	91.85	94.51	79.20	98.26
	GA	unknown				
	Total	72	94.41	96.95	67.77	100
PKTHRU2	CA	54	15.44	8.26	0.00	68.09
	MI	18	16.45	18.19	0.96	39.39
	GA	unknown				
	Total	72	15.69	10.82	0	68.09
SD1	CA	54	1431	1519	400	2000
	MI	18	1430	1310	580	2000
	GA	52	1356	1301	639	2000
	Total	124	1399	1332	400	2000

Table 242. Summary Statistics for Type IV Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables	State	No. of Sites	Mean	Median	Minimum	Maximum
SDL2	CA	54	1382	1470	324	2000
	MI	18	1286	1203	394	2000
	GA	52	1254	1182	579	2000
	Total	124	1314	1262	324	2000
SDR2	CA	54	1384	1470	215	2000
	MI	18	1356	1255	479	2000
	GA	52	1263	1206	540	2000
	Total	124	1329	1354	215	2000

TYPE V

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
TOTACC per year		CA	18	5.2	5.3	1.3	10.7
		MI	31	8.1	8.0	2.0	14.8
		GA	51	4.8	3.5	0.0	26.5
		Total	100	5.9	5.3	0	26.5
INJACC per year		CA	18	2.0	1.8	0.3	4.0
		MI	31	2.6	2.5	0.0	6.5
		GA	51	1.2	0.5	0.0	6.5
		Total	100	1.8	1.5	0	6.5
AADT1		CA	18	13095	12650	7340	25132
		MI	31	9007	8435	4917	17483
		GA	51	7798	7400	430	15200
		Total	100	9126	8700	430	25132
AADT2		CA	18	3642	3026	940	10280
		MI	31	4796	4434	1961	12478
		GA	51	2749	2200	420	10400
		Total	100	3544	3100	420	12478
SIGTYPE	Total		100				
	Pretimed	CA	0				
		MI	22				
		GA	11				
		Total	33				
	Actuated	CA	17				
		MI	4				
		GA	24				
		Total	45				
	Semiactuated	CA	1				
		MI	5				
		GA	16				
		Total	22				

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
MEDTYPE	Total		100				
	No Median	CA	12				
		MI	31				
		GA	44				
		Total	87				
	Painted	CA	5				
		MI	0				
		GA	7				
		Total	12				
	Other	CA	1				
		MI	0				
		GA	0				
		Total	1				
MEDWIDTH1		CA	18	3	0	0	13
		MI	31	0	0	0	0
		GA	51	1.5	0	0	13
		Total	100	1.3	0	0	13
HAU		CA	18	3.33	0	-10	30
		MI	31	-3.06	0	-45	40
		GA	51	0.82	0	-45	35
		Total	100	0.07	0	-45	40
HAZRAT1	Total		100				
	1	CA	3				
		MI	7				
		GA	2				
		Total	12				
	2	CA	5				
		MI	15				
		GA	9				
		Total	29				
	3	CA	6				
		MI	8				
		GA	13				
		Total	27				
	4	CA	2				
		MI	1				
		GA	13				
		Total	16				
	5	CA	1				
		MI	0				
		GA	12				
		Total	13				

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
HAZRAT1	6	CA	1				
		MI	0				
		GA	2				
		Total	3				
	7	CA	0				
		MI	0				
		GA	0				
		Total	0				
COMDRWY1		CA	18	1.6	1	0	6
		MI	31	2.9	3	0	11
		GA	51	2.9	2	0	9
		Total	100	2.6	2	0	11
RESDRWY1		CA	18	0.3	0	0	5
		MI	31	0.9	0	0	6
		GA	51	0.4	0	0	4
		Total	100	0.5	0	0	6
DRWY1		CA	18	1.9	1	0	7
		MI	31	3.8	3	0	15
		GA	51	3.2	3	0	9
		Total	100	3.2	3	0	15
SPD1		CA	18	50.8	55	35	65
		MI	31	47.4	50	30	55
		GA	51	41.8	45	25	55
		Total	100	45.2	45	25	65
SPD2		CA	18	45	45	30	55
		MI	31	43.1	45	25	55
		GA	51	38.1	35	20	55
		Total	100	40.9	40	20	55
LIGHT		Total	100				
	0	CA	1				
		MI	9				
		GA	19				
		Total	29				
	1	CA	17				
		MI	22				
		GA	32				
		Total	71				

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
TERRAIN1	Total		100				
	Flat	CA	11				
		MI	25				
		GA	23				
		Total	59				
	Rolling	CA	5				
		MI	6				
		GA	27				
		Total	38				
	Mountainous	CA	2				
		MI	0				
		GA	1				
		Total	3				
PROTLT1	Total		100				
	0	CA	1				
		MI	27				
		GA	42				
		Total	70				
	1	CA	17				
		MI	4				
		GA	9				
		Total	30				
RTLN1	Total		100				
	0	CA	7				
		MI	14				
		GA	30				
		Total	51				
	1	CA	3				
		MI	5				
		GA	13				
		Total	21				
	2	CA	8				
		MI	12				
		GA	8				
		Total	28				

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables		State	No. of Sites	Mean	Median	Minimum	Maximum
LTLN1	Total		100				
	0	CA	0				
		MI	7				
		GA	16				
		Total	23				
	1	CA	0				
		MI	1				
		GA	1				
		Total	2				
	2	CA	18				
		MI	23				
		GA	34				
		Total	75				
RTLN2	Total		100				
	0	CA	12				
		MI	14				
		GA	33				
		Total	59				
	1	CA	3				
		MI	7				
		GA	10				
		Total	20				
	2	CA	3				
		MI	10				
		GA	8				
		Total	21				
LTLN2	Total		100				
	0	CA	8				
		MI	9				
		GA	28				
		Total	45				
	1	CA	0				
		MI	3				
		GA	2				
		Total	5				
	2	CA	10				
		MI	19				
		GA	21				
		Total	50				

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables	State	No. of Sites	Mean	Median	Minimum	Maximum
HEI	CA	18	2.10	1.65	0.00	9.82
	MI	31	6.38	0.00	0.00	94.87
	GA	51	3.13	0.65	0.00	49.90
	Total	100	3.95	0.61	0.00	94.87
HEI2	CA	18	4.40	0.00	0.00	36.41
	MI	31	0.89	0.00	0.00	12.22
	GA	51	2.85	0.00	0.00	19.00
	Total	100	2.52	0.00	0.00	36.41
HI1	CA	18	1.22	0.00	0.00	9.82
	MI	31	3.31	0.00	0.00	60.00
	GA	51	1.78	0.00	0.00	49.90
	Total	100	2.15	0.00	0.00	60.00
HI2	CA	18	3.25	1.48	0.00	19.16
	MI	31	3.63	0.00	0.00	47.44
	GA	51	1.70	0.00	0.00	27.05
	Total	100	2.58	0.00	0.00	47.44
HEICOM	CA	18	2.46	0.00	0.00	18.72
	MI	31	1.93	0.00	0.00	30.00
	GA	51	2.99	1.09	0.00	32.54
	Total	100	2.56	0.58	0.00	32.54
HICOM	CA	18	2.23	0.79	0.00	10.72
	MI	31	3.47	0.00	0.00	42.05
	GA	51	1.74	0.00	0.00	32.54
	Total	100	2.36	0	0	42.05
GRADE1	CA	18	0.88	0.58	0.00	3.45
	MI	31	0.80	0.83	0.00	3.31
	GA	51	1.56	1.45	0.00	4.98
	Total	100	1.20	1.00	0.00	4.98
GRADE2	CA	18	1.01	0.59	0.00	5.30
	MI	31	1.00	0.71	0.00	4.00
	GA	51	1.99	1.65	0.00	7.79
	Total	100	1.50	1.28	0.00	7.79
VEI1	CA	18	1.40	0.46	0.00	11.97
	MI	31	1.43	0.94	0.00	6.83
	GA	51	1.48	1.45	0.00	4.98
	Total	100	1.45	1.19	0.00	11.97

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables	State	No. of Sites	Mean	Median	Minimum	Maximum
VEI2	CA	18	2.41	0.71	0.00	11.53
	MI	31	1.65	0.65	0.00	13.50
	GA	51	1.90	1.65	0.00	7.79
	Total	100	1.91	1.39	0.00	13.50
VEICOM	CA	18	2.03	1.33	0.00	8.13
	MI	31	1.87	1.62	0.00	6.75
	GA	51	1.69	1.60	0.00	4.79
	Total	100	1.81	1.59	0.00	8.13
VCEI1	CA	18	1.38	0.00	0.00	10.79
	MI	31	0.66	0.00	0.00	4.77
	GA	51	1.26	1.15	0.00	5.18
	Total	100	1.10	0.45	0.00	10.79
VCEI2	CA	18	1.72	0.17	0.00	12.13
	MI	31	1.24	0.31	0.00	14.00
	GA	51	1.66	1.41	0.00	8.40
	Total	100	1.54	0.90	0.00	14.00
VCEICOM	CA	18	1.55	0.82	0.00	6.07
	MI	31	0.95	0.47	0.00	7.00
	GA	51	1.46	1.30	0.00	5.08
	Total	100	1.32	1.03	0.00	7.00
PKTRUCK	CA	18	7.36	6.43	2.69	15.45
	MI	31	9.89	8.37	2.97	45.43
	GA	unknown				
	Total	49	8.96	7.71	2.69	45.43
PKTURN	CA	18	30.74	29.90	7.07	72.66
	MI	31	38.48	35.29	26.00	61.03
	GA	unknown				
	Total	49	35.64	34.48	7.07	72.66
PKLEFT	CA	18	15.80	14.51	4.20	37.07
	MI	31	19.54	19.09	11.88	31.58
	GA	unknown				
	Total	49	18.17	17.97	4.2	37.07
PKLEFT1	CA	18	13.83	11.36	1.78	43.23
	MI	31	15.66	16.32	4.60	36.67
	GA	unknown				
	Total	49	14.99	13.15	1.78	43.23

Table 243. Summary Statistics for Type V Sites by State: California (CA), Michigan (MI), and Georgia (GA) (Continued)

Variables	State	No. of Sites	Mean	Median	Minimum	Maximum
PKLEFT2	CA	18	28.90	25.21	2.59	68.57
	MI	31	27.80	24.88	9.91	75.73
	GA	unknown				
	Total	49	28.21	24.88	2.59	75.73
PKTHRU1	CA	18	74.49	80.83	18.01	96.73
	MI	31	69.27	70.37	44.40	85.33
	GA	unknown				
	Total	49	71.19	73.77	18.01	96.73
PKTHRU2	CA	18	44.68	39.17	9.34	84.09
	MI	31	43.44	45.78	8.45	73.14
	GA	unknown				
	Total	49	43.9	41.99	8.45	84.09
SD1	CA	18	1482	2000	267	2000
	MI	31	1447	1500	522	2000
	GA	51	1175	1086	235	2000
	Total	100	1314	1246	235	2000
SD2	CA	18	1420	1750	390	2000
	MI	31	1389	1212	509	2000
	GA	51	1033	961	224	2000
	Total	100	1213	1091	224	2000
SDL1	CA	18	815	454	188	2000
	MI	31	814	615	200	2000
	GA	51	735	709	122	2000
	Total	100	774	673	122	2000
SDL2	CA	18	1011	787	269	2000
	MI	31	1041	850	253	2000
	GA	51	794	739	142	2000
	Total	100	910	750	142	2000

APPENDIX D: CURE PLOTS FOR TYPE I, II, III, IV, AND V AADT MODELS

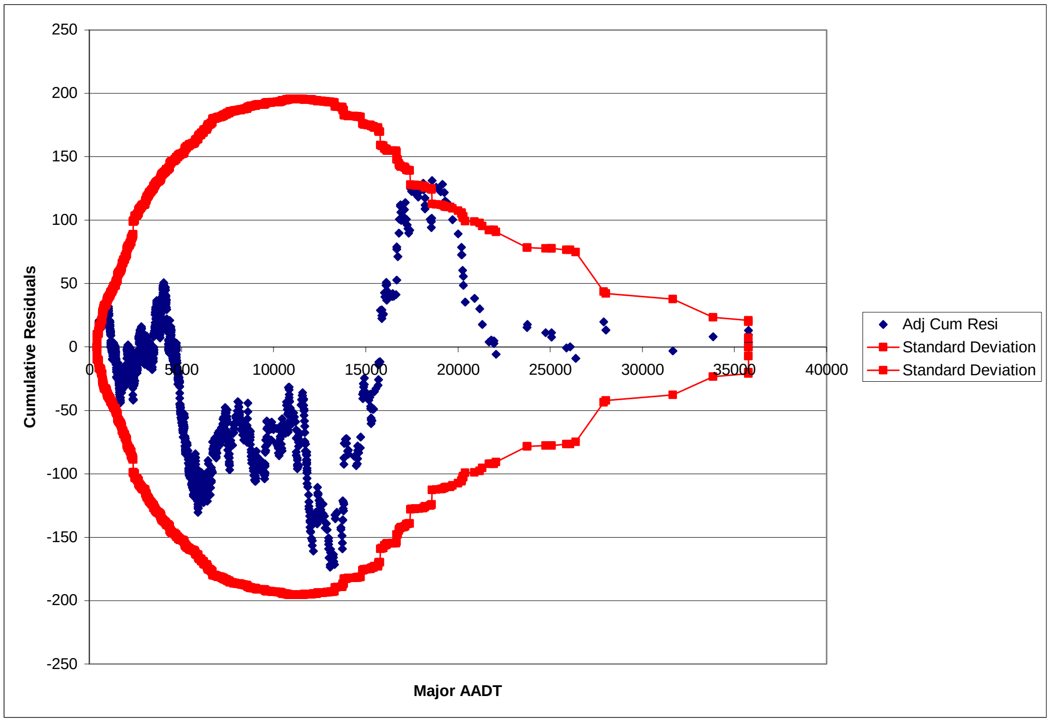

Figure 23. CURE Plot for Type I TOTACC AADT Model

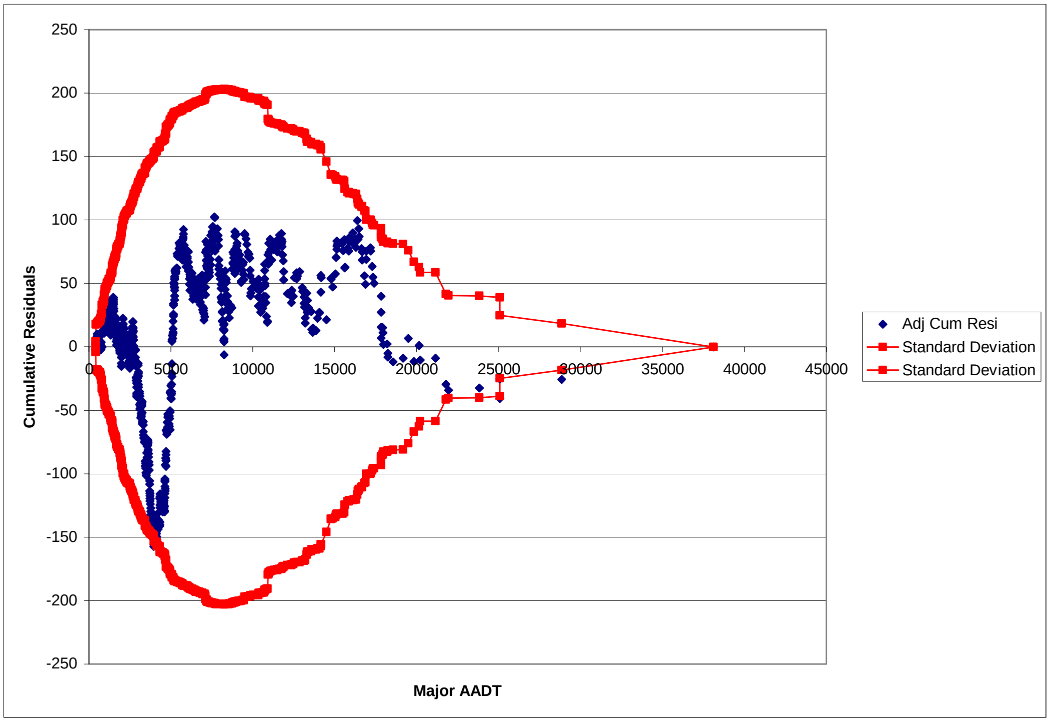

Figure 24. CURE Plot for Type II TOTACC AADT Model

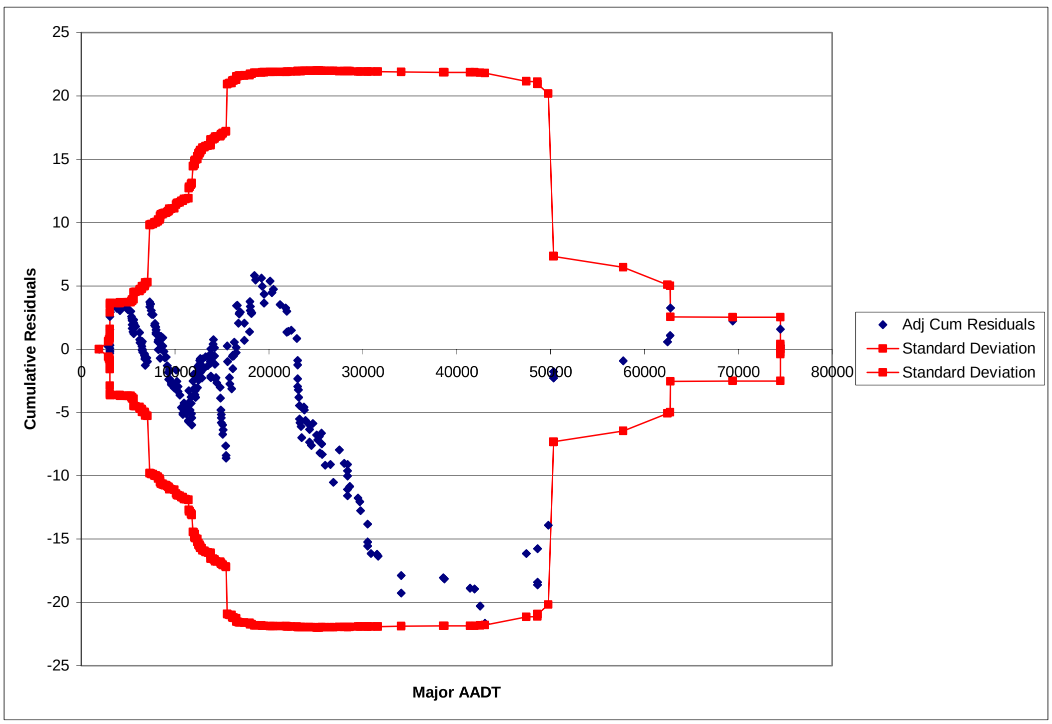

Figure 25. CURE Plot for Type III TOTACC AADT Model

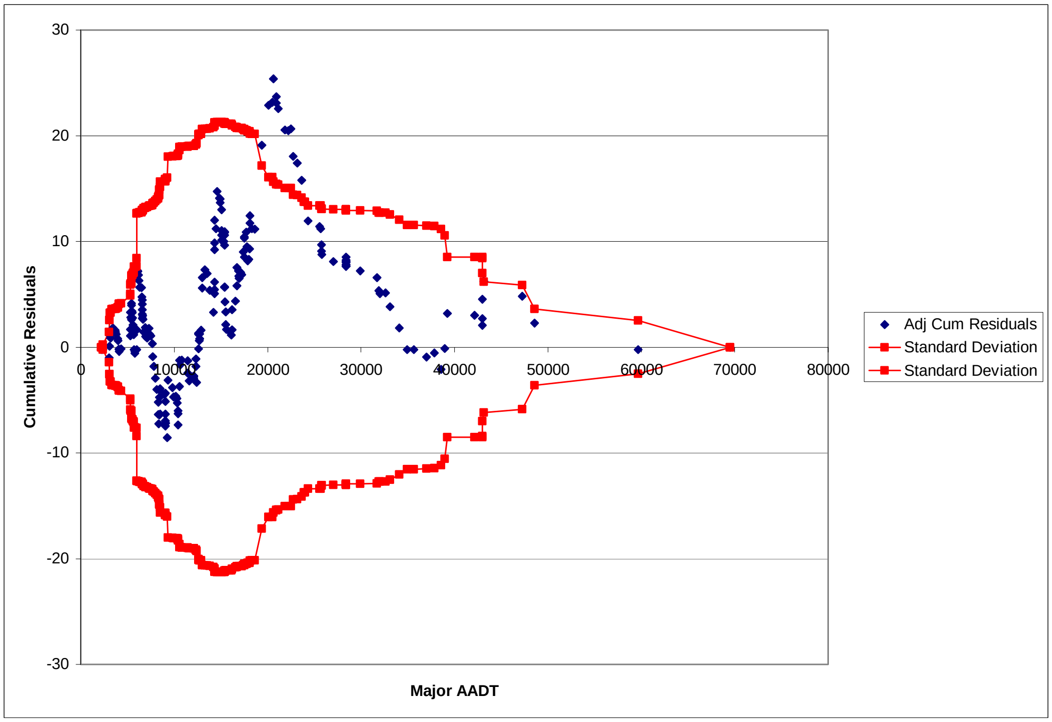

Figure 26. CURE Plot for Type IV TOTACC AADT Model

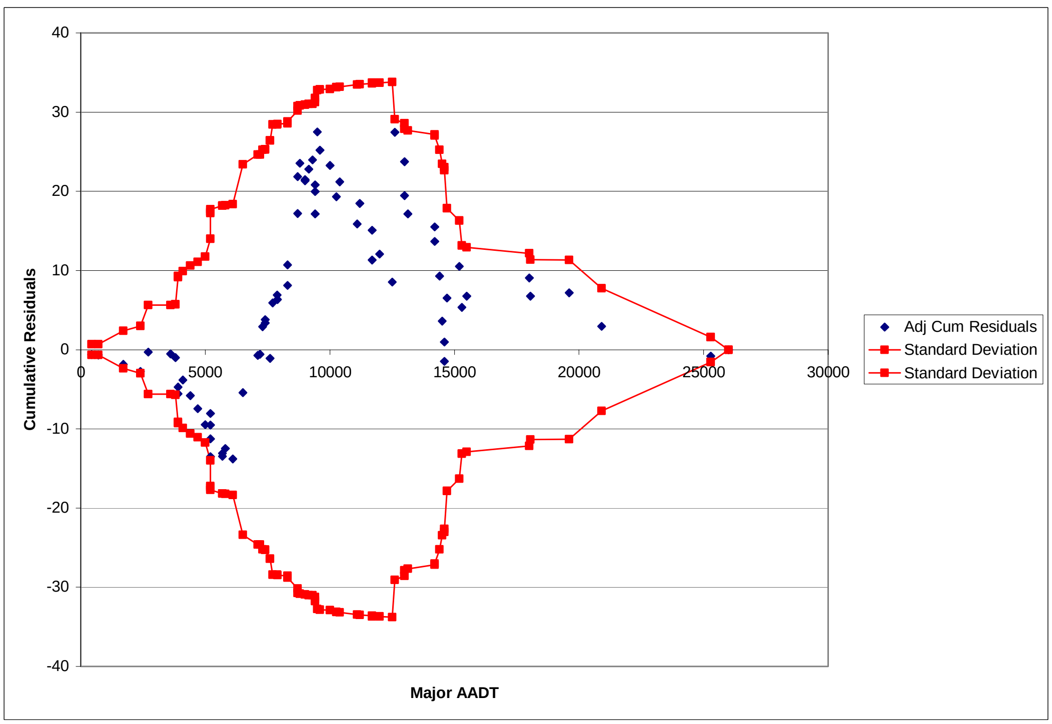

Figure 27. CURE Plot for Type V TOTACC AADT Model

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