Report No. K-TRAN: KSU-17-3 P1 ▪ FINAL REPORT ▪ November 2020

Calibrating the Highway Safety Manual Crash Prediction Models for Urban and Suburban Arterial Intersections in Kansas

Sunanda Dissanayake, Ph.D., P.E., F.ASCE
Rijesh Karmacharya

Kansas State University Transportation Center

Kansas Department of Transportation

1 Report No. K-TRAN: KSU-17-3 P1	**2 Government Accession No.**	**3 Recipient Catalog No.**

4 Title and Subtitle
Calibrating the Highway Safety Manual Crash Prediction Models for Urban and Suburban Arterial Intersections in Kansas

5 Report Date
November 2020

6 Performing Organization Code

7 Author(s)
Sunanda Dissanayake, Ph.D., P.E., F.ASCE
Rijesh Karmacharya

8 Performing Organization Report No.

9 Performing Organization Name and Address
Kansas State University Transportation Center
Department of Civil Engineering
2118 Fiedler Hall
Manhattan, Kansas 66506-5000

10 Work Unit No. (TRAIS)

11 Contract or Grant No.
C2100

12 Sponsoring Agency Name and Address
Kansas Department of Transportation
Bureau of Research
2300 SW Van Buren
Topeka, Kansas 66611-1195

13 Type of Report and Period Covered
Final Report
November 2016–December 2019

14 Sponsoring Agency Code
RE-0712-01

15 Supplementary Notes
See also K-TRAN: KSU-17-3 P2 for a companion report titled *Calibration of Highway Safety Manual Prediction Models for Freeway Segments, Speed-Change Lanes, Ramp Segments, and Crossroad Ramp Terminals in Kansas.*
For more information write to address in block 9.

16 Abstract

Kansas experienced about 60,000 crashes annually from 2013 to 2016, 25% of which occurred at urban intersections. Hence, urban intersections in Kansas are one of the critical locations in terms of frequency of crashes. Therefore, an accurate prediction of crashes at these locations would help identify critical intersections with a higher probability of an occurrence of crash, which would help in selecting appropriate countermeasures to reduce those crashes. The crash prediction models provided in the Highway Safety Manual (HSM) predict crashes using traffic and geometric data for various roadway facilities, which are incorporated through Safety Performance Functions (SPFs) and Crash Modification Factors.

The primary objective of this study was to estimate calibration factors for different types of urban intersections in Kansas. This study followed the crash prediction method and calibration procedure provided in the HSM to estimate calibration factors for four different urban intersection types in Kansas: 3-leg unsignalized intersections with stop control on the minor approach (3ST), 3-leg signalized intersections (3SG), 4-leg unsignalized intersections with stop control on the minor approach (4ST), and 4-leg signalized intersections (4SG). Following the HSM methodology, the required data elements were collected from various sources. The Annual Average Daily Traffic (AADT) data were extracted from the Kansas Crash Analysis & Reporting System (KCARS) database and GIS Shapefiles were downloaded from the Federal Highway Administration website. For some of the 3ST and 3SG intersections, minor-street AADT was not available. Hence, multiple linear regression models were developed for the estimation of minor-street AADT. Crash data were extracted from the KCARS database, and other geometric data were extracted using Google Earth. The HSM requirement for sample size is 30 to 50 sites, with at least 100 crashes per year for the study period for the combined set of sites.

In this study, 2013 to 2015 was chosen as the study period for 3ST, 3SG, and 4SG intersections, and 2014 to 2016 was chosen for 4ST intersections, based on the availability of recent crash data at the beginning of the calibration procedure for each facility type. The sample size considered for calibration was 234 for 3ST, 89 for 3SG, 167 for 4ST, and 198 for 4SG intersections. Out of the 234 3ST intersections, minor-street AADT was estimated using multiple linear regression models for 106 intersections. For 3SG intersections, minor-street AADT was estimated for 21 out of the 89 intersections. The calibration factors for these facility types were estimated to be 0.64 for 3SG, 0.51 for 3ST, 1.17 for 4SG, and 0.61 for 4ST when considering crashes of all severities. Considering only the fatal and injury crashes, the calibration factors were estimated as 0.52 for 3SG, 0.40 for 3ST, 2.00 for 4SG, and 0.73 for 4ST. The calibration factors show that the HSM methodology underpredicted crashes for 4SG intersections, and overpredicted crashes for the other three intersection types. The reliability of the calibration factors was assessed with the help of Cumulative Residual plots and coefficient of variation. The results from the goodness-of-fit tests showed that the calibration factors were not reliable and showed bias in the prediction of crashes. Hence, calibration functions were developed, and their reliability was examined. The results showed that calibration functions had better reliability as compared to calibration factors, with more accuracy in crash prediction. The findings from this study can be used to identify intersections with a higher probability of having crashes in the future. Suitable countermeasures can be applied at critical locations which would help reduce the number of crashes at urban intersections in Kansas, thus increasing the safety.

17 Key Words
Traffic Crashes, Crash Avoidance Systems, Signalized Intersections, Unsignalized Intersections, Calibration

18 Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service www.ntis.gov.

19 Security Classification (of this report) Unclassified	**20 Security Classification (of this page)** Unclassified	**21 No. of pages** 129	**22 Price**

Form DOT F 1700.7 (8-72)

This page intentionally left blank.

Calibrating the Highway Safety Manual Crash Prediction Models for Urban and Suburban Arterial Intersections in Kansas

Final Report

Prepared By

Sunanda Dissanayake, Ph.D., P.E., F.ASCE
Rijesh Karmacharya

Kansas State University Transportation Center

A Report on Research Sponsored By

THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

and

KANSAS STATE UNIVERSITY TRANSPORTATION CENTER
MANHATTAN, KANSAS

November 2020

PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

NOTICE

The authors and the state of Kansas do not endorse products or manufacturers. Trade and manufacturers names appear herein solely because they are considered essential to the object of this report.

This information is available in alternative accessible formats. To obtain an alternative format, contact the Office of Public Affairs, Kansas Department of Transportation, 700 SW Harrison, 2nd Floor – West Wing, Topeka, Kansas 66603-3745 or phone (785) 296-3585 (Voice) (TDD).

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or the policies of the state of Kansas. This report does not constitute a standard, specification or regulation.

Abstract

Kansas experienced about 60,000 crashes annually from 2013 to 2016, 25% of which occurred at urban intersections. Hence, urban intersections in Kansas are one of the critical locations in terms of frequency of crashes. Therefore, an accurate prediction of crashes at these locations would help identify critical intersections with a higher probability of an occurrence of crash, which would help in selecting appropriate countermeasures to reduce those crashes. The crash prediction models provided in the Highway Safety Manual (HSM) predict crashes using traffic and geometric data for various roadway facilities, which are incorporated through Safety Performance Functions (SPFs) and Crash Modification Factors.

The primary objective of this study was to estimate calibration factors for different types of urban intersections in Kansas. This study followed the crash prediction method and calibration procedure provided in the HSM to estimate calibration factors for four different urban intersection types in Kansas: 3-leg unsignalized intersections with stop control on the minor approach (3ST), 3-leg signalized intersections (3SG), 4-leg unsignalized intersections with stop control on the minor approach (4ST), and 4-leg signalized intersections (4SG). Following the HSM methodology, the required data elements were collected from various sources. The Annual Average Daily Traffic (AADT) data were extracted from the Kansas Crash Analysis & Reporting System (KCARS) database and GIS Shapefiles were downloaded from the Federal Highway Administration website. For some of the 3ST and 3SG intersections, minor-street AADT was not available. Hence, multiple linear regression models were developed for the estimation of minor-street AADT. Crash data were extracted from the KCARS database, and other geometric data were extracted using Google Earth. The HSM requirement for sample size is 30 to 50 sites, with at least 100 crashes per year for the study period for the combined set of sites.

In this study, 2013 to 2015 was chosen as the study period for 3ST, 3SG, and 4SG intersections, and 2014 to 2016 was chosen for 4ST intersections, based on the availability of recent crash data at the beginning of the calibration procedure for each facility type. The sample size considered for calibration was 234 for 3ST, 89 for 3SG, 167 for 4ST, and 198 for 4SG intersections. Out of the 234 3ST intersections, minor-street AADT was estimated using multiple linear regression models for 106 intersections. For 3SG intersections, minor-street AADT was estimated for 21 out of the 89 intersections. The calibration factors for these facility types were estimated to be 0.64 for 3SG, 0.51 for 3ST, 1.17 for 4SG, and 0.61 for 4ST when considering crashes of all severities. Considering only the fatal and injury crashes, the calibration factors were estimated as 0.52 for 3SG, 0.40 for 3ST, 2.00 for 4SG, and 0.73 for 4ST. The calibration factors show that the HSM methodology underpredicted crashes for 4SG intersections, and overpredicted crashes for the other three intersection types. The reliability of the calibration factors was assessed with the help of Cumulative Residual plots and coefficient of variation. The results from the goodness-of-fit tests showed that the calibration factors were not reliable and showed bias in the prediction of crashes. Hence, calibration functions were developed, and their reliability was examined. The results showed that calibration functions had better reliability as compared to calibration factors, with more accuracy in crash prediction. The findings from this study can be used to identify intersections with a higher probability of having crashes in the future. Suitable countermeasures can be applied at critical locations which would help reduce the number of crashes at urban intersections in Kansas, thus increasing the safety.

Acknowledgements

The authors thank the Kansas Department of Transportation for providing financial support for this research. The support and assistance provided by the project monitors, Mr. Benjamin Ware and Ms. Carla Anderson, are greatly appreciated.

Abbreviations

AASHTO	-	American Association of State Highway and Transportation Officials
CMFs	-	Crash Modification Factors
CURE	-	Cumulative Residual
FHWA	-	Federal Highway Administration
FI	-	Fatal and Injury crashes
GOF	-	Goodness-of-Fit
HSM	-	Highway Safety Manual
KCARS	-	Kansas Crash Analysis and Reporting System
KDOT	-	Kansas Department of Transportation
NHTSA	-	National Highway Traffic Safety Administration
PDO	-	Property Damage Only crashes
SPFs	-	Safety Performance Functions

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background

Accidents or unintentional injuries have been one of the top 10 causes for fatalities in the United States in recent years. According to the National Center for Health Statistics, fatalities due to accidents per 100,000 US population was 47.4 in 2016, an increase of 9.7% from the fatality rate in 2015, and the top three leading causes of accident-related deaths are unintentional falls, motor vehicle crashes, and unintentional poisoning (Kochanek, Murphy, Xu, & Arias, 2017). According to crash data from the National Highway Traffic Safety Administration (NHTSA), 37,461 people were killed in traffic crashes in 2016, compared to 35,485 in 2015, and 32,744 in 2014 (NHTSA, 2017). The number of fatalities due to motor vehicle crashes in the United States and in Kansas for the period of 2011 to 2016 is shown in Figure 1.1. The number of fatalities in Kansas accounts for approximately 1% of total fatalities due to motor vehicle crashes in the United States.

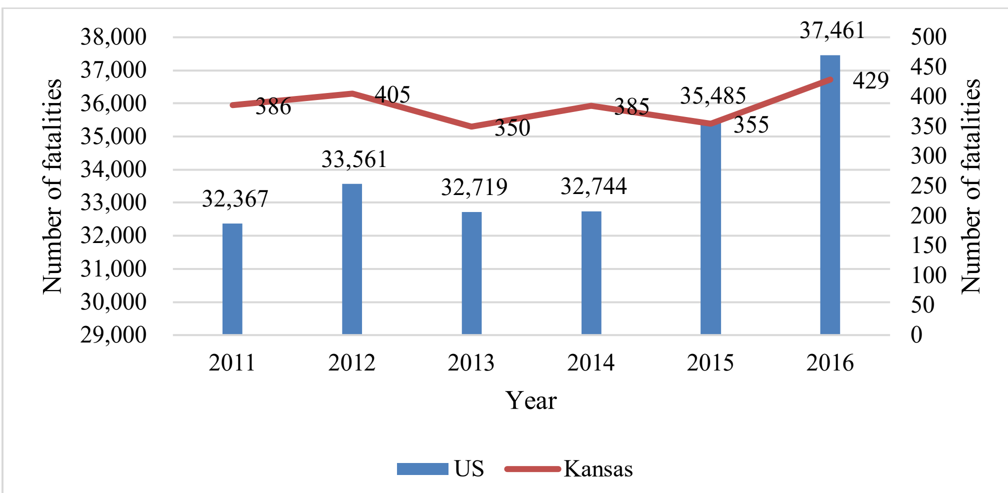


Figure 1.1: Number of fatalities due to motor vehicle crashes in the US and Kansas (2011–2016)
Source: KDOT (n.d.)

Although the number of fatalities in Kansas accounted for only a small percentage of national fatalities from 2011 to 2016, the fatality rate per 100,000 population was higher in Kansas than throughout the United States (Figure 1.2). This high motor vehicle crash fatality rate reveals prevalent traffic safety concerns for the state.

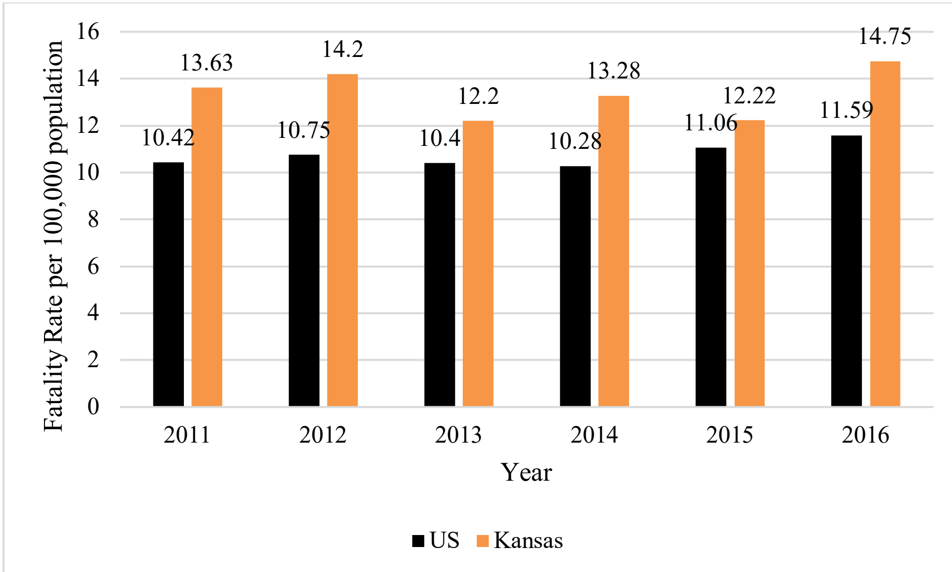


Figure 1.2: Fatality rate per 100,000 population in the US and Kansas (2011–2016)

In addition to lives lost, crashes also negatively impact the economy. The economic cost due to crashes in the United States in 2016 was $242 billion, and the comprehensive cost was $836 billion (NHTSA, 2017). In 2016, crashes in Kansas resulted in an economic loss of $10.14 billion (KDOT, 2017).

According to Kansas Crash Facts, maintained by the Kansas Department of Transportation (KDOT), Kansas experienced approximately 60,000 crashes per year (for years 2013–2016). For example, Kansas had 61,844 crashes resulting in 429 fatalities in the year 2016 (KDOT, 2017). Distribution of crashes in Kansas by area type (rural or urban) and crash percentages for the years 2013–2016 are listed in Table 1.1.

Table 1.1 shows that more than 65% of crashes in Kansas occurred in urban locations and that the total number of crashes and the number of crashes in urban locations in Kansas increased each year during the four-year period. The data, however, shows that rural areas had higher numbers of fatal crashes than urban areas, potentially due to higher speed limits and longer emergency service response times in rural locations.

Table 1.1: Distribution of crashes by area type in Kansas (2013–2016)

Year	Rural Location			Urban Location			Total	
	Fatal Crashes	All Crashes	% of Total	Fatal Crashes	All Crashes	% of Total	Fatal Crashes	All Crashes
2013	231	21,265	36.37	96	37,207	63.63	327	58,472
2014	233	21,015	35.29	108	38,518	64.68	341	59,553
2015	215	20,780	34.36	107	39,693	65.64	322	60,473
2016	239	20,094	32.49	142	41,747	67.50	381	61,844
Total	918	83,154	34.61	453	157,165	65.39	1,371	240,342

Source: KDOT (n.d.)

Furthermore, as shown in Table 1.2, classification based on crash location shows that crashes at intersections and intersection-related crashes accounted for more than 30% of total crashes in Kansas for the four-year period.

Table 1.2: Crashes by crash location in Kansas (2013–2016)

Year	Non-Intersection		Intersection/ Intersection Related		Other Locations		Total
	# of Crashes	% Total	# of Crashes	% Total	# of Crashes	% Total	
2013	26,204	44.81	17,699	30.27	14,569	24.91	58,472
2014	22,308	37.46	18,549	31.14	18,696	31.39	59,553
2015	21,228	35.10	18,302	30.26	20,943	34.63	60,473
2016	23,258	37.61	19,336	31.26	19,250	31.13	61,844
Total	92,998	38.69	73,886	30.74	73,458	30.56	240,342

Because Kansas has had a high percentage of crashes in urban locations and at intersections, urban intersections have the greatest possibility of having motor vehicle crashes. Based on the Kansas Crash Analysis and Reporting System (KCARS) database, the numbers of crashes at urban intersections in Kansas were 16,116, 16,068, and 16,401 for the years 2014, 2015, and 2016, respectively. Crashes at urban intersections accounted for more than 25% of total crashes (KCARS, n.d.). Therefore, urban intersections in Kansas are critical roadway facility types that require increased safety measures to prevent crashes.

1.2 Highway Safety Manual

In 2010, the American Association of State Highway and Transportation Officials (AASHTO) published the Highway Safety Manual (HSM), which contains crash predictive methodologies for various types of roadway facilities. The HSM also allows users to develop calibration factors for these methodologies and provides guidelines for an agency to develop agency-specific Safety Performance Functions (SPFs) to increase predictive model accuracy (AASHTO, 2010).

Chapter 12 of the HSM covers the following four facility types:

1. Unsignalized three-legged intersection with stop control on minor-road approaches (3ST),
2. Signalized three-legged intersections (3SG),
3. Unsignalized four-legged intersection with stop control on minor-road approaches (4ST), and
4. Signalized four-legged intersections (4SG).

HSM methodology allows users to predict crashes using SPFs and the Crash Modification Factors (CMFs). SPFs account for traffic characteristics that affect crashes and CMFs help incorporate geometric characteristics and traffic control features. Since data used to develop the crash prediction models in the HSM were from select states only, calibration using agency-specific data would increase crash prediction accuracy. In addition, developing local SPFs would also increase the prediction accuracy for individual states. Part C, Appendix A of the HSM describes the calibration methodology.

1.3 Study Objectives

The objectives of this research were as follows:

1. To estimate the calibration factors for urban and suburban intersections in Kansas using the predictive methodology and calibration procedure provided in Chapter 12 and Appendix A, Part C of the first edition of the HSM;

2. To assess the quality of the estimated calibration factors for the four facility types: 3ST, 3SG, 4ST, and 4SG;
3. To develop calibration functions to increase crash prediction reliability; and
4. To provide recommendations regarding recalibration based on the study findings.

1.4 Organization of the Report

This report consists of five chapters and an appendix. Chapter 1 describes the rationale behind this study and study objectives. Chapter 2 summarizes research relevant to this study, and Chapter 3 describes the methodology and data elements used during the research. Results of the estimated calibration factors and developed calibration functions are provided in Chapter 4. Chapter 5 provides the conclusions and recommendations based on research findings.

Chapter 2: Literature Review

This chapter briefly reviews HSM calibration studies for various facility types throughout the United States. This chapter also summarizes studies related to the development of regression models used for the estimation of minor-street average annual daily traffic (AADT). In addition, this chapter reviews sample size guidelines and calibration functions.

2.1 Relevant Calibration Studies

Several studies have been conducted regarding the calibration of SPFs provided in the first edition of the HSM and its supplement. Shin, Lee, and Dadvar (2014) estimated 18 Local Calibration Factors (LCFs) for 18 facility types (eight roadway segments and 10 intersection types) in Maryland. The study calculated LCFs for roadway facilities in rural and urban locations based on observed crashes obtained from the Maryland State Police database for a three-year period (2008–2010). Predicted crashes were estimated following the prediction methodology in the HSM and other required data elements were obtained using aerial maps, Google Earth, the Maryland State Highway Administration database, and manual collection. LCFs were calculated for different crash severities for all facility types, with LCFs ranging from 0.1562 to 0.4782 for urban and suburban intersections. Results showed that HSM methodology overpredicted crashes in Maryland. The study recommended determination of a reliable sampling procedure since sample size affects confidence levels and errors. The study also recommended that a procedure be developed to determine minimum segment length. The study mentioned that a single LCF for a certain facility type may not be applicable to an entire state due to variations in climatic conditions, population, and other factors within the state. Hence, the study recommended developing LCFs specific to sub-regions.

Sun, Edara, Brown, Claros, and Nam (2013) calibrated five roadway segment types, eight intersection types, and three freeway segment types in Missouri. Calibration was carried out using crash data for a three-year period (2009–2011). AADT and crash data were obtained from the Missouri Department of Transportation's Transportation Management System database, and aerial photographs, AutoCAD, and other sources and software were used to collect required data elements. Estimated calibration factors varied from 0.28 to 4.91 for various facilities, showing that the HSM methodology overpredicted and underpredicted the total number of crashes for different facility types in the same state. Calibration factors were estimated as 1.06 for 3ST, 3.03 for 3SG, 1.30 for 4ST, and 4.91 for 4SG, demonstrating that HSM methodology underpredicted the number of crashes at urban intersections in Missouri. The study recommended a sensitivity analysis of various data levels and modeling details on HSM calibration, as well as development of jurisdiction-specific SPFs for the state of Missouri.

Xie and Chen (2016) calculated calibration factors for four intersection types at urban locations in Massachusetts. Required data elements were collected from 2009 to 2012. Results showed that calibration factors were significantly greater than 1.00, so the study developed jurisdiction-specific SPFs. However, the developed SPFs were meaningful only for multiple-vehicle crashes. The calibration factors calculated using the jurisdiction-specific SPFs had a value closer to 1.00 as compared to the calibration factors calculated using the HSM model.

Troyer, Bradbury, and Juliano (2015) developed calibration factors for 18 facility types in Ohio. Crash data from 2009 to 2011 were obtained from the crash database maintained by the Ohio Department of Public Safety. Google Maps, Bing Maps, Ohio DOT Pathway Video Logs, and GIS were used to obtain traffic and geometric characteristics. Estimated calibration factors for intersections at urban and suburban locations ranged from 1.34 to 3.71, showing that HSM methodology underpredicted the number of crashes in Ohio. Cumulative Residual (CURE) plots were used to verify reliability of the calibration factors. Residuals in the CURE plots tightly fit around zero, which showed that the developed factors were reliable. Results also showed that a larger sample size would not have as much of an impact of the outliers on the overall trend of the CURE plots as compared to that of a smaller sample size. The study stated that the estimation of calibration factors aided in the identification and prioritization of facility types when investigating jurisdiction-specific SPFs.

Srinivasan et al. (2011) estimated calibration factors for various facility types in Florida for the years 2005–2009. For signalized intersections at urban locations, calibration factors were developed for individual years, with all estimated calibration factors having a value greater than 1.00, showing that HSM methodology underpredicted the number of crashes. Calibration factors were not developed for unsignalized intersections at urban and suburban intersections due to lack of sufficient data. Sensitivity analyses were performed on the calibration factors estimated for roadway segments to assess the impact of inputs for which actual data were not available. The study recommended caution in using calibration factors estimated for the intersections since the sample size was small.

Dixon, Monsere, Xie, and Gladhill (2012) estimated calibration factors for various roadway facility types in rural and urban locations in Oregon using data from 2004 to 2006. Crashes predicted using HSM default proportions were compared to locally derived proportions. Calibration factors for urban intersections ranged from 0.35 to 1.10, showing that HSM methodology underpredicted, as well as overpredicted, crashes at different types of urban and suburban intersections in Oregon. The study recommended modification of data inventories to include data required for calibration efforts. Recommendations were also made regarding use of local crash proportions instead of HSM default proportions.

Srinivasan and Carter (2011) calibrated HSM predictive models for roadway segments and intersections at rural and urban locations in North Carolina using crash data from 2007 to 2009. The study also developed SPFs for roadway facility types for nine crash types. Calibration factors for urban intersections showed that HSM methodology underpredicted the number of crashes in North Carolina.

Smith, Carter, and Srinivasan (2017) estimated calibration factors for freeway models, in addition to the facility types in the first edition of the HSM in North Carolina. Using roadway and crash data from 2010 to 2015, this study estimated calibration factors for facilities that had not previously been calibrated for North Carolina, while also updating previously estimated calibration factors. Calibration factors for urban intersections showed that the HSM methodology underpredicted the number of crashes as in previous calibration.

Estimated calibration factors showed that the HSM crash prediction methodology underpredicts and overpredicts crashes for the same facility type in different states. This is because the predictive models were developed using data from select states only, and traffic and geometric characteristics of these states may differ significantly from state to state. Therefore, calibration of HSM methodology using local data would increase crash prediction accuracy. Table 2.1 shows estimated calibration factors from the summarized studies.

Table 2.1: Calibration results by state

State	Study Year/s	3ST		3SG		4ST		4SG	
		Obs. Crashes	C.F.	Obs. Crashes	C.F.	Obs. Crashes	C.F.	Obs. Crashes	C.F.
Maryland	2008–2010	103	0.1562	789	0.3982	173	0.3824	1763	0.4782
Missouri	2009–2011	52	1.06	531	3.03	179	1.3	1347	4.91
Massachusetts	2009–2012	310	0.77	767	1.5	339	1.03	2426	1.49
Ohio	2009–2011	-	1.34	-	3.35	-	1.6	-	3.71
Florida	2005	-	-	113	1.98	-	-	815	2.05
	2006	-	-	112	1.9	-	-	756	1.91
	2007	-	-	123	2.1	-	-	715	1.82
	2008	-	-	109	1.87	-	-	698	1.79
	2009	-	-	80	1.41	-	-	700	1.84
Oregon	2004–2006	103	0.35	321	0.75	105	0.44	690	1.1
North Carolina	2007–2009	-	1.72	-	2.47	-	1.32	-	2.79
North Carolina	2010–2015	-	1.61	-	2.17	-	1.79	-	3.07

Obs. Crashes = Observed crashes for the study period, C.F. = Calibration Factor

In addition to these studies that calibrated HSM prediction models for urban and suburban intersections, several studies conducted calibration on various roadway facilities. Results demonstrated a wide range of estimated calibration factors, values smaller or greater than 1.00, showing overprediction and underprediction of crashes by the HSM predictive methodologies (Kim, Anderson, & Gholston, 2015; Colety, Crowther, Farmen, Bahar, & Srinivasan, 2016; Dissanayake & Aziz, 2016).

2.2 Sample Size Selection

The HSM recommends a sample size of 30–50 with a minimum of 100 crashes per year for calibration (AASHTO, 2010). However, studies have shown that a larger sample size results in greater accuracy of the estimated calibration factor. Shirazi, Lord, and Geedipally (2016) suggested a range of sample sizes related to the crash data's coefficient of variance (CV), with sample sizes ranging from 30 to 1,500 for three levels of confidence (70%, 80%, and 90%). The study validated the suggested sample size guidelines using two observed datasets: crash data from 868 4SG intersections for the year 1995 in Toronto, Ontario, and crash data from 4,265 roadway segments of four-lane divided urban arterials in Texas for the years 2012–2014. Results showed that HSM recommendations may not be sufficient to achieve high confidence levels.

Trieu, Park, and McFadden (2014) conducted a sensitivity analysis using Monte-Carlo simulation for different calibration sample sets to re-sample the sites. Roadway geometry, traffic volume, and crash data for 372 roadway segments for the period from 2009 to 2011 were used for the simulation. Study results showed that reliability was attained only after using 30% of the sites. The study recommended use of percentage as a requirement for minimum sample size instead of an absolute number. Furthermore, study findings revealed that the 100 crashes per year criteria could lead to a bias; therefore, a larger sample size would increase reliability and remove bias for site selection.

Shin et al. (2014) conducted a study in Maryland regarding the development of local calibration factors. The study selected 30 sites initially, in case of intersections, and then increased the sample size for a desired 90% confidence level. The final sample sizes for 3ST, 4ST, 3SG, and 4SG were 152, 90, 167, and 244, respectively. A higher level of confidence would require a larger sample size, which may not be feasible given the time constraint.

Banihashemi (2012) assessed the quality of estimated calibration factors for rural and urban highway segments in Washington. Results showed that the sample size of 30–50 sites recommended by the HSM was not sufficient for all facility types in a roadway network because it was unable to generate satisfactory results for all calibration factors in the study.

Alluri, Saha, and Gan (2016) assessed calibration factors for 10 sites using 50 sites for each facility type. Of the 10 calibration factors, seven had less than 50% probability that the estimated calibration factor would fall within 10% of the true value. The study concluded that the sample size of 30–50 is not sufficient to estimate a reliable calibration factor.

Several studies have conducted calibration of HSM methodology for urban intersections using various sample sizes. Table 2.2 lists sample sizes adopted in other studies.

In summary, many studies have proven that the HSM recommendation of 30–50 sites is insufficient and that a larger sample size is required to estimate a reliable calibration factor. Increasing the sample size increases the reliability and the probability that the estimated calibration factor is close to its true value.

Table 2.2: Sample sizes for relevant calibration studies of urban intersections

State	Sample size			
	3ST	3SG	4ST	4SG
Maryland	152	167	90	244
Missouri	70	35	70	35
Massachusetts	86	48	59	52
Ohio	50	50	125	50
Florida	-	45	-	121
Oregon	73	49	48	57

2.3 Minor-Street AADT Estimation Models

AADT is a required data element for the minor approach in the HSM predictive methodology. However, minor-street AADT is not always readily available for all selected intersections. Several studies have used different methods for estimating minor-street AADT, with multiple linear regression modeling being the most common method.

Pan (2008) developed linear regression models to estimate AADT by creating a separate database for AADT values in Florida. The socio-economic data were collected for 67 counties from 1995 to 2005, and the roadway characteristics database was formed by combining GIS layers provided by the Florida Department of Transportation (FDOT). The dependent variable was the AADT on a particular roadway segment, with seven socio-economic variables and five roadway characteristic variables initially included as independent variables in the model. The seven socio-economic variables were: population in a county, total lane mileage of the highways, number of registered vehicles in a county, per capita income, yearly retail sales in a county, municipalities, and labor force. Roadway characteristic variables initially included during model development were divided/undivided (based on median). These include the number of lanes, location, land use, and accessibility to freeways. The study used 26,721 traffic counts provided by FDOT to develop six AADT prediction models using the stepwise selection method for variable selection. A 90% level of confidence was used to develop the model, yielding adjusted R^2 values ranging from 0.186 to 0.418. Although multicollinearity was checked, correlated independent variables were included in the models. Mean Absolute Percentage Error (MAPE), which measures the error between predicted AADT values and values obtained from traffic count stations, was used to validate the developed regression models. A total of 1,149 traffic counts were used for validation, yielding MAPE values ranging from 31.99% to 159.49%.

Zhao and Chung (2001) developed four regression models to estimate AADT, including variables of functional class, number of lanes, direct access from a count station to expressway access points, accessibility to regional employment, employment in a variable-sized buffer, and population in a variable-sized buffer around a count station. A total of 898 data points, 816 to develop models and 82 for validation, were obtained from average quarterly traffic counts from the Broward County Metropolitan Planning Organization for 1998. The R^2 values ranged from 0.66 to 0.82 for the developed models. The study compared the percent error of predicted AADT values to validate the models. The maximum error for the four models ranged from 155.67% to 185.40%. The study found that the largest errors occurred on low-volume roads.

Shin et al. (2014) developed multiple regression models to estimate minor street AADT in Maryland. The dependent variable was the AADT for the minor approach, and the independent variables were traffic, geometric, and demographic characteristics, as well as land use and socio-economic characteristics. R-squared, adjusted R-squared, leaps and bounds, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) were used for model selection. The R-squared values exceeded 0.70 for signalized intersections, and the R-squared values for stop-controlled intersections were greater than 0.50, although one model with an R-squared value of 0.3253 was considered a weak fit. Models with R-squared values greater than 0.50 were deemed a good fit.

In Oregon, Dixon et al. (2012) developed multiple linear regression models to estimate AADT, with independent variables such as geometric characteristics of the intersection and area, population, functional class of the road, and traffic characteristics. To reduce the effect of unequal variances, $\log_{10}$ transformation of the continuous variables was applied. The R-squared values for the two final models were greater than 0.60, which were acceptable. After removing the highly correlated variables, the independent variables that were significant and included in the final model were: the location of the intersection from the nearest freeway, the functional class, location of the intersection within the city limit, presence of right turn lanes, centerlines, edge lines, and land use.

Mohamad, Sinha, Kuczek, and Scholer (1998) developed AADT prediction models for county roads in Indiana, with the most common transformation of $\log_{10}$ for AADT. Cross validation of actual and predicted data was done for model validation, with errors of 16.78% on average. Hauer (2016) provided guidance about developing regression models, along with detailed steps regarding interpretation of results obtained from developing regression models.

Hauer, Council, and Mohammedshah (2004) developed statistical models to estimate crashes for urban four-lane undivided road segments in Washington. Maximum likelihood function based on a negative multinomial model was used for parameter estimation. The study also estimated the overdispersion parameter. Results showed that AADT and speed limit strongly influenced the fit of the model, and variables such as vertical alignment or lane and shoulder width had a weaker influence. Furthermore, results obtained for one facility potentially did not justify for another facility type, showing that relationships between significant variables may differ for each facility type, even within the same jurisdiction.

These studies demonstrated use of a wide range of variables for developing regression models to estimate the AADT for the minor approach. The developed models also had a wide range of R-squared values, and several methods were used for model validation. Based on cross validation, even a model with a low R-squared value can provide satisfactory results if the errors are low. Multiple linear regression models with the log transformation of continuous variables were shown to reliably estimate minor-street AADT.

2.4 Calibration Functions

Srinivasan, Carter, and Bauer (2013) proposed a procedure for deciding between calibrating SPFs or developing jurisdiction-specific SPFs. Calibration of SPFs is the first step, followed by the assessment of the calibration factors and developing SPFs. The study also provided methods for assessing the developed calibration factors. Similarly, Srinivasan and Bauer (2013) provided a guide for developing jurisdiction-specific SPFs, and other studies have developed jurisdiction-specific SPFs for various states (Garber & Rivera, 2010; Tegge, Jo, & Ouyang, 2010; Srinivasan & Carter, 2011; Brimley, Saito, & Schultz, 2012; Savolainen et al., 2015; Shankar & Madanat, 2015; Dissanayake & Aziz, 2016; Qin, Chen, & Shaon, 2018). These studies showed that developing SPFs requires extensive data and a significant amount of time. Therefore, calibration functions, which can perform better than the calibration factors, could be developed instead of SPFs.

Srinivasan, Colety, Bahar, Crowther, and Farmen (2016) developed calibration functions to predict crashes in Arizona. Six calibration functions were developed using three methods: Ordinary Least Squares, Poisson Regression, and Negative Binomial (NB) Regression. The concern regarding the calibration function is that the selected sample size was originally for estimating calibration factors; hence, the effect of this sample size on calibration functions is unknown.

Claros, Sun, and Edara (2018) conducted a comparative analysis of calibration factors, calibration functions, and jurisdiction-specific models. CURE plots, overdispersion parameter, and log-likelihood were used to analyze the developed functions. Results showed that calibration functions did not perform better than calibration factors by ranges. Also, the developed SPFs had a similar goodness-of-fit (GOF) to the calibration factor and calibration function by ranges.

Hauer (2016) provided a detailed procedure for developing calibration functions, including various methods for developing calibration functions using the Solver add-in in Excel. The book also provided actual examples of calculations in Excel worksheets.

CURE plots and CV have been shown to help assess the quality of developed calibration functions and estimated calibration factors. If the trendline of a CURE plot falls within the threshold of two standard deviations or if the CV is less than 0.15, the calibration factors and calibration functions are reliable (Lyon, Persaud, & Gross, 2016). Several studies have used CURE plots to assess estimated calibration factors and interpret results (Troyer et al., 2015; Claros et al., 2018; Persaud and Lyon Inc., & Felsburg Holt & Ullevig, 2009; Smith et al., 2017).

In summary, estimated calibration factors should be assessed to verify reliability; this assessment can be done using CURE plots and CV values. Furthermore, calibration functions can be developed to increase crash prediction accuracy. Reliable calibration functions can provide an alternative to developing SPFs.

Chapter 3: Data and Methodology

3.1 Data Elements and Data Collection

Data elements required for the predictive method and the calibration procedure were identified from the HSM Part C, Chapter 12 predictive methodology and Part C, Appendix A calibration methodology. The data elements identified are described below in the following sections.

3.1.1 Average Annual Daily Traffic (AADT)

AADT is a required data element for the predictive and calibration procedures, as crashes are predicted based on the AADT. Therefore, for this study, AADT data for sample intersections were taken from the KCARS database maintained by KDOT and the Federal Highway Administration (FHWA, 2016). ArcGIS shape files, which can be downloaded from the FHWA website, are part of the federal Highway Performance Monitoring System (HPMS). The HPMS is an information system that includes data associated with the highways in the United States.

3.1.2 Study Period

The study period for 3SG, 3ST, and 4SG intersections was 2013–2015 and for 4ST was 2014–2016 based on the availability of recent crash data at the beginning of the calibration procedure for each facility type.

3.1.3 Crash Data

Crash data for the study period were extracted from the KCARS database, which contains information from the Kansas Motor Vehicle Accident Report, presented in Appendix A. The KCARS database contains Microsoft Access files with details about all police-reported crashes in Kansas. The KCARS database consists of several tables, including ACCIDENT_CANSYS, ACCIDENT_SUMMARY, ACCIDENTS, CITY, CITY_COUNTY, COUNTY, and TRAFFIC_CONTROLS, which are used to collect data from the database. Queries were made in Microsoft Access to include required fields from the various tables and the data were extracted to

Microsoft Excel worksheets. A screenshot of a query, which links various tables in Access, is shown in Figure 3.1.

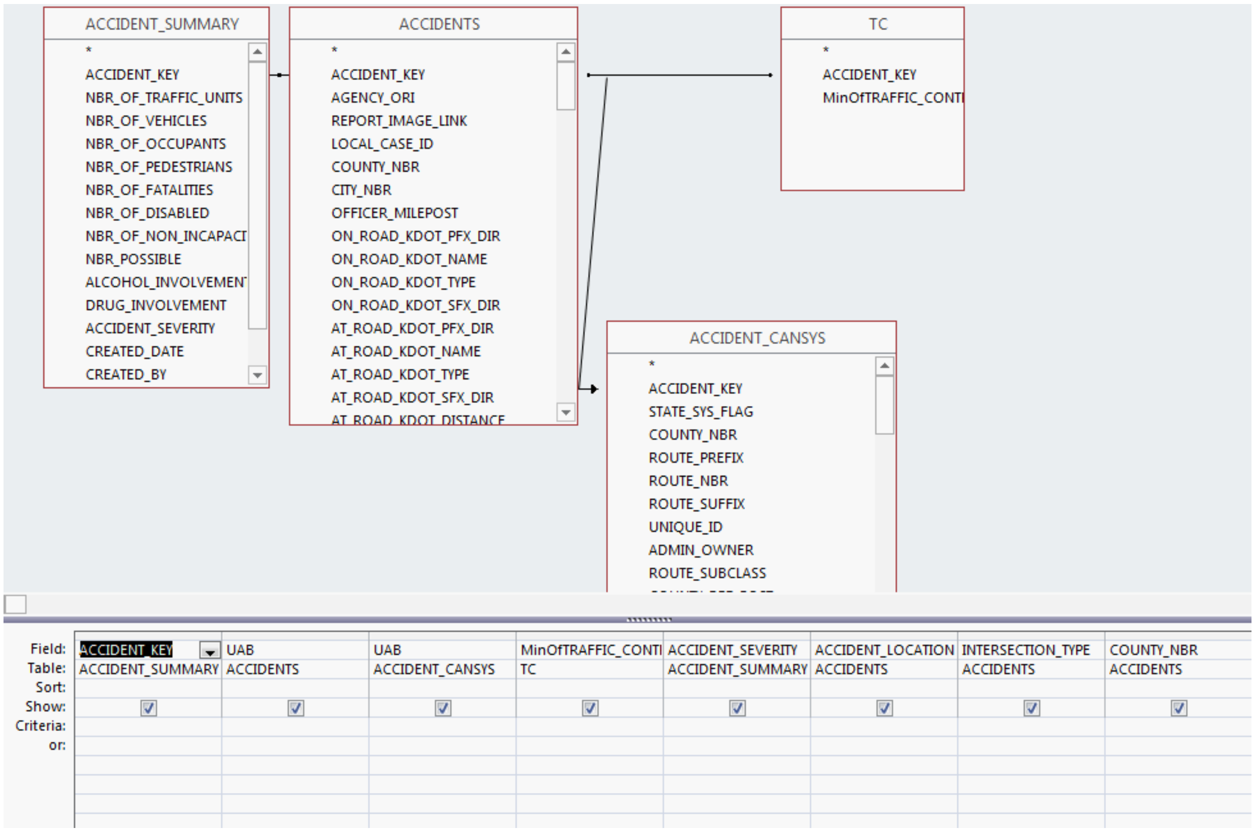


Figure 3.1: Query for crash data extraction from the KCARS database for the year 2013

The field "UAB" in the table ACCIDENT_SUMMARY helps identify urban and rural locations. A rural location is coded "999" in the "UAB" field, and all other codes indicate urban location; used to assign crashes at urban and rural locations in this study.

3.1.3.1 Accident Key

The field ACCIDENT_KEY present in all the available tables in the KCARS database helps to connect various tables for a query. The accident key is a unique number assigned to individual crashes that combines details from different tables in the KCARS database to obtain crash characteristics, AADT, geometric characteristics, and other required data elements.

3.1.3.2 Accident Location

The table ACCIDENTS contains the field ACCIDENT_LOCATION, which gives crash locations that can be identified according to the coding provided in the Kansas Motor Vehicle Coding Manual. For example, code number "12" in the ACCIDENT_LOCATION field indicates the crash location as an intersection and the number "13" indicates that the crash is intersection-related (KCARS, n.d.). All crashes that occurred at intersections can be identified using these two code numbers. Crashes that occurred within 250 feet of the intersection were only considered as crashes related to the specific intersection (Harwood et al., 2002).

3.1.3.3 Intersection Type

The ACCIDENTS table also contains the field INTERSECTION_TYPE, in which the code "01" refers to a four-way intersection, code "03" refers to a T-intersection, and "04" indicates a Y-intersection. This field was used to distinguish four-legged and three-legged intersections in Kansas.

3.1.3.4 Traffic Control Type

Coding in the table TRAFFIC_CONTROLS helps identify the type of traffic signals installed at the selected intersection. A code of "02" represents use of traffic signals at an intersection, and code "03" indicates the presence of STOP signs, meaning the intersection is unsignalized. This coding system was used to distinguish signalized and unsignalized intersections.

3.1.3.5 Crash Severity

Three main categories of crash severity (fatal, injury, and property-damage-only) can be extracted from the ACCIDENT_SEVERITY field in the table ACCIDENT_SUMMARY. The injury category can be further divided into three sub-categories: possible injury, non-incapacitating injury, and incapacitating injury. An injury that leads to death within 30 days of the crash is identified as a fatal crash. If the death occurs after the 30-day period, the crash is identified as an injury crash. For a PDO crash, the reporting threshold is set at damage worth $1,000 with no injuries; damage less than $1,000 is not recorded in the crash database.

3.1.4 Roadway and Physical Characteristics

Roadway characteristics data required for CMFs were taken from Google Earth and Google Maps. These include data elements such as: number of approaches in an intersection with left-turn lanes and right-turn lanes, the type of traffic control, the type of left turn signal at a signalized intersection, the presence of lighting at an intersection, and the right-turn-on-red. KML Circle Generator, an online software that allows users to create a circular area on Google Earth, was used to identify bus stops, schools, and alcohol sales establishments within 1,000 feet of an intersection (KML Circle Generator). After the circle was generated in Google Earth, physical attributes within the area were identified using the street and aerial views. Use of Google Earth is shown in Figure 3.2 and Figure 3.3, and the use of KML Circle Generator is shown in Figure 3.4.

Figure 3.2: Google Earth being used to identify lanes in a 4SG intersection

Figure 3.3: Google Earth being used to identify the type of left turn signal, the presence of RTOR, and lighting in one approach of a 4SG intersection

Figure 3.4: Circles of radius 1,000 feet generated from KML Circle Generator in Google Earth

3.2 Sample Sites

According to the HSM definition, a location within a boundary with population more than 5,000 is an urban area, based on which urban cities in Kansas were identified (AASHTO, 2010). Intersections for sampling were selected from these identified urban areas. The HSM recommends 30–50 sites with the combined set of sites experiencing at least 100 crashes per year (AASHTO, 2010). However, several studies have shown that a larger sample size is required for higher accuracy of the estimated calibration factor (Banihashemi, 2012; Shirazi et al., 2016; Alluri et al., 2016). Therefore, the sample size selected for each facility type in this study was determined using Equation 3.1 (Shin et al., 2014).

$$n = (z^* \sigma/ME)^2$$ **Equation 3.1**

Where:

n = desired sample size,

z = z-score,

σ = standard deviation for the sample, and

ME = margin of error.

Since the total population of each of the facility types was unknown, a few sites were selected to calculate the standard deviation of crashes; this calculated standard deviation was assumed to be true for the entire population. The initial selected number of sites used to calculate the standard deviation, the confidence level, the margin of error, and the desired sample size for the four facility types are shown in Table 3.1.

Table 3.1: Initial desired sample size for urban intersections in Kansas

Facility Type	Initial Sample	Standard Deviation	Confidence Level	Margin of Error	Desired Sample Size
3ST	40	0.79	90%	10%	178
3SG	40	6.25	90%	10%	181
4ST	40	1.19	90%	10%	112
4SG	40	3.40	90%	10%	184

To incorporate all possible traffic characteristics throughout Kansas, the number of intersections selected from each urban city was determined using Equation 3.2.

$$\text{Ni} = \frac{Pi}{\sum Pi} * X$$ **Equation 3.2**

Where:

N_i = number of intersections selected from city i,

P_i = population of city i,

$\sum P_i$ = total population of 60 urban cities in the state of Kansas, and

X = total sample size considered initially, calculated from Equation 3.1.

For signalized intersections, the approach with a higher functional class was assumed as the major approach. In cases where the functional class were the same for both approaches, the approach with higher AADT was assumed as the major approach. In the case of unsignalized intersections, all-way stop controlled intersections were discarded. The approach with the stop-control was taken as the minor approach for unsignalized intersections.

Intersections that were not considered sample sites had at least one of the following criteria:

1. Any of the approaches is a one-way street.
2. For unsignalized intersections, a stop sign is present on the major approach.
3. For three-legged intersections, a fourth leg is present that does not have a traffic sign but is an access to a local road or a parking lot.
4. Intersections with both traffic signals and stop signs.
5. Another intersection is within 300 feet of the considered intersection.

The list of all intersections used in the calibration procedure are presented in Appendix B.

3.3 Crash Prediction Methodology

The crash prediction model for intersections at urban and suburban locations is included in Part C, Chapter 12 of the HSM. In addition to the predictive models, this chapter also provides a detailed 18-step procedure for crash prediction, as well as the SPFs and CMFs used in the prediction methodology. The predictive model for an intersection at urban and suburban locations is as shown in the following equations:

$$N_{predictedint} = C_i \times (N_{bi} + N_{pedi} + N_{bikei}) \qquad \textbf{Equation 3.3}$$

$$N_{bi} = N_{spfint} \times (CMF_{1i} \times CMF_{2i} \times \ldots \times CMF_{6i}) \qquad \textbf{Equation 3.4}$$

Where:

$N_{predictedint}$ = predicted average crash frequency of an intersection for the selected year,

N_{bi} = predicted average crash frequency of an intersection (excluding vehicle pedestrian and vehicle-bicycle collisions),

N_{spfint} = predicted total average crash frequency of intersection-related crashes for base conditions (excluding vehicle-pedestrian and vehicle-bicycle collisions),

N_{pedi} = predicted average crash frequency of vehicle-pedestrian collisions,

N_{bikei} = predicted average crash frequency of vehicle-bicycle collisions,

$CMF_{1i} \ldots CMF_{6i}$ = crash modification factors for intersections, and

Ci = calibration factor for the intersection.

$$N_{spfint} = N_{bimv} + N_{bisv} \qquad \textbf{Equation 3.5}$$

Where:

N_{bimv} = predicted average number of multiple-vehicle collisions for base conditions, and

N_{bisv} = predicted average number of single-vehicle collisions for base conditions.

The 18-step crash prediction methodology in the HSM uses traffic and geometric characteristics of a particular site, including SPFs and CMFs, to predict crashes at an intersection. Calibration factor (C_i) is taken as 1.00 in Equation 3.3 since this study intended to develop the calibration factor. The 18-step crash prediction procedure is as follows (AASHTO, 2010):

1. Define the limits of roadway and facility types in the study network, facility, or site for which the expected average crash frequency, severity, and collision types are to be estimated.
2. Define the period of interest.
3. For the study period, determine the availability of AADT volumes, pedestrian crossing volumes, and, for an existing roadway network, the availability of observed crash data.
4. Determine geometric design features, traffic control features, and site characteristics for all sites in the study network.
5. Divide the roadway facility into homogenous intersections, referred to as sites.
6. Assign observed crashes to the individual sites (if applicable).
7. Select the first or next individual site in the study network.
8. For the selected site, select the first or next year in the period of interest.
9. For the selected site, determine and apply the appropriate SPF for the site's facility type and traffic control features.
10. Multiply the result obtained by CMFs to adjust base conditions to site-specific geometric design and traffic control features.
11. Use the calibration factor.
12. Repeat steps 8 to 11 for another year present.
13. Apply site-specific EB Method (if applicable).
14. If there is another site, repeat steps 7 to 13.
15. Apply the project-level EB Method (if site level is not applicable).
16. Sum all sites and years in the study to estimate total crash frequency.
17. Determine if there is an alternative design, treatment, or forecast AADT to be evaluated.
18. Evaluate and compare results.

3.3.1 Safety Performance Functions

SPFs are regression equations that predict an average number of crashes at a location based on traffic characteristics and AADT. Part C, Chapter 12 of the HSM provides four SPF equations for four collision types: multiple-vehicle collision, single-vehicle crashes, vehicle-pedestrian collision, and vehicle-bicycle collision. SPFs for multiple-vehicle intersection-related collisions and single vehicle crashes are:

$$N_{bimv} = \exp(a + b \times \ln(AADT_{maj}) + c \times \ln(AADT_{min})) \qquad \textbf{Equation 3.6}$$

Where:

$AADT_{maj}$ = average daily traffic volume (vehicles/day) for major road (both directions of travel combined),

$AADT_{min}$ = average daily traffic volume (vehicles/day) for minor road (both directions of travel combined), and

a, b, c = regression coefficients.

SPFs for vehicle-pedestrian collisions at signalized intersections are applied as:

$$N_{pedi} = N_{pedbase} \times CMF_{1p} \times CMF_{2p} \times CMF_{3p} \qquad \textbf{Equation 3.7}$$

Where:

$N_{pedbase}$ = predicted number of vehicle-pedestrian collisions per year for base conditions at signalized intersections, and

$CMF_{1p} \ldots CMF_{3p}$ = crash modification factors for vehicle-pedestrian collisions at 4SG.

$$N_{pedbase} = \exp\left(a + b * \ln(AADT_{total}) + c * \ln\left(\frac{AADT_{maj}}{AADT_{min}}\right) + d * \ln(PedVol) + e * n_{lanesx}\right)$$

Equation 3.8

Where:

$AADT_{total}$ = sum of average daily traffic volumes (vehicles per day) for the major and minor roads (= $AADT_{maj}$ + $AADT_{min}$),

PedVol = sum of daily pedestrian volumes (pedestrians/day) crossing all intersection legs,

n_{lanesx} = maximum number of traffic lanes crossed by a pedestrian in any crossing maneuver at the intersection considering the presence of refuge islands, and

a, b, c, d, e = regression coefficients.

SPFs for vehicle-pedestrian collisions for unsignalized intersections are:

$$N_{pedi} = N_{bi} * f_{pedi}$$ **Equation 3.9**

Where:

N_{bi} = N_{spfint} * $(CMF_{1i} * .... * CMF_{6i})$

f_{pedi} = pedestrian crash adjustment factor.

$$f_{pedi} = K_{ped} / K_{non}$$ **Equation 3.10**

Where:

K_{ped} = observed vehicle-pedestrian crash frequency, and

K_{non} = observed frequency for all crashes not including vehicle-pedestrian and vehicle-bicycle crash.

SPFs for vehicle-bicycle collisions are:

$$N_{bikei} = N_{bi} \times f_{bikei}$$ **Equation 3.11**

Where,

N_{bi} = N_{spfint}* $(CMF_{1i} * .... * CMF_{6i})$

f_{bikei} = bicycle crash adjustment factor.

$$f_{bikei} = K_{bike} / K_{non}$$ **Equation 3.12**

Where:

K_{bike} = observed vehicle-bicycle crash frequency, and

K_{non} = observed frequency for all crashes not including vehicle-pedestrian and vehicle-bicycle crash.

3.3.2 Crash Modification Factors

Chapter 12 of the HSM provides nine CMFs that were used for crash prediction, as shown in Equation 3.4 and Equation 3.7. CMFs account for the effects of geometric design and traffic controls on an intersection. The nine CMFs are described in the following sections.

3.3.2.1 CMF_{1i} – Intersection Left-Turn Lanes

The base condition for left-turn lanes in intersections is the absence of left-turn lanes on intersection approaches. A CMF of 1.00 is used when no left-turn lanes are present, and the values of CMF_{1i} depend on the number of approaches with dedicated left-turn lanes. For stop-controlled intersections, however, the minor approach with the stop control is not considered in the number of approaches with left-turn lanes.

3.3.2.2 CMF_{2i} – Intersection Left-Turn Signal Phasing

The types of left-turn signal phasing include permissive, protected, protected/permissive, and permissive/protected. Protected/permissive operation is also referred to as a leading left-turn signal phase and permissive/protected is also known as a lagging left-turn signal phasing. CMF values are given below:

Permissive – 1.00

Protected/permissive or permissive/protected – 0.99

Protected – 0.94

If several approaches to a signalized intersection have left-turn phasing, CMF_{2i} values for each approach are multiplied together.

3.3.2.3 CMF_{3i} – Intersection Right-Turn Lanes

The base condition for right-turn lanes in intersections is the absence of right-turn lanes on intersection approaches. A CMF of 1.00 is used when no right-turn lanes are present and the values of CMF_{3i} depend on the number of approaches with dedicated right-turn lanes. For stop-controlled intersections, however, the minor approach with the stop control is not considered in the number of approaches with right-turn lanes.

3.3.2.4 CMF_{4i} – Right-Turn-On-Red

The base condition for CMF_{4i} is permitting a right-turn-on-red at all approaches. The CMF for prohibiting right-turn-on-red on one or more approaches is determined by:

$$CMF_{4i} = 0.98^{(n_{prohib})} \qquad \textbf{Equation 3.13}$$

Where:

CMF_{4i} = crash modification factor for the effect of prohibiting right turns on red for total crashes, and

n_{prohib} = number of signalized intersection approaches for which right-turn on-red is prohibited.

3.3.2.5 CMF_{5i} – Lighting

The base condition for lighting is the absence of intersection lighting. The value for CMF_{5i} is calculated using Equation 3.14.

$$CMF_{5i} = 1 - 0.38 \times p_{ni} \qquad \text{Equation 3.14}$$

Where:

CMF_{5i} = crash modification factor for the effect of intersection lighting on total crashes, and

p_{ni} = proportion of total crashes for unlighted intersections at night.

3.3.2.6 CMF_{6i} – Red-Light Cameras

The base condition for red-light cameras is their absence. The CMF for red-light camera installation is 0.74 for right-angle collisions and 1.18 for rear-end collisions. Since Kansas has no laws regarding red-light camera installations, the value of CMF_{6i} is taken as 1.00 considering base condition.

3.3.2.7 CMFs for Vehicle-Pedestrians Collisions

CMF_{1p} – Bus Stops

The base condition for bus stops is the absence of bus stops near the intersections. The CMFs for the number of bus stops within 1,000 feet of the center of the intersection are listed in Table 3.2.

Table 3.2: CMFs for presence of bus stops

Number of Bus Stops	CMF_{1p}
0	1.00
1 or 2	2.78
3 or more	4.15

CMF_{2p} – Schools

The base condition for schools is the absence of schools near the intersections. The CMFs for the number of schools within 1,000 feet of the center of the intersection are listed in Table 3.3.

Table 3.3: CMFs for presence of schools

Presence of schools	CMF_{2p}
No school present	1.00
School present	1.35

CMF_{3p} – Alcohol Sales Establishment

The base condition for alcohol sales establishments is the absence of these establishments near the intersections. The CMFs for the number of alcohol sales establishments within 1,000 feet of the center of the intersection are listed in Table 3.4.

Table 3.4: CMFs for presence of alcohol sales establishments

Number of alcohol sales establishments	CMF_{3p}
0	1.00
1 or-8	1.12
9 or more	1.56

3.4 Highway Safety Manual Calibration Procedure

The calibration procedure described in Part C, Appendix A of the HSM consists of the following five steps:

1. Identify facility type.
2. Select sites for the calibration.
3. Obtain data for the facility type for the study period.
4. Apply the predictive methodology to predict the total crash frequency.
5. Compute the calibration factor.

The calibration factor is calculated as

$$C_i = \frac{\Sigma observed\ crashes}{\Sigma predicted\ crashes} \quad \textbf{Equation 3.15}$$

To predict crashes using the 18-step predictive methodology, this study collected observed crashes from the KCARS database for the study period for the sites selected. A calibration factor value greater than 1.00 means that the predictive model underpredicts the crash frequency, and the calibration factor of less than 1.00 means that the predictive methodology overpredicts the crash frequency.

3.5 Minor-Street AADT Estimation Models

Minor-street AADT is a required data element for calibration. After selecting all intersections with available minor AADT values, the HSM criteria of at least 100 crashes per year for each facility type was not attained for 3SG and 3ST intersections; therefore, multiple linear regression models were developed.

3.5.1 Multiple Linear Regression

Multiple linear regression is a predictive analysis that explains the relationship between a dependent variable and two or more independent variables. The general form of a multiple regression equation is shown in Equation 3.16.

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \qquad \textbf{Equation 3.16}$$

Where:
Y = dependent variable,
$X_1 \ldots X_n$ = independent variables,
$\beta_o \ldots \beta_n$ = parameter estimates, and
ε = error.

Statistical software SAS 9.4 was used to develop multiple linear regression models in this study (SAS Institute Inc.). Features of SAS 9.4 are described in the following sections.

3.5.1.1 Test for Multi-Collinearity

The test for multi-collinearity of the independent variables was done using the Pearson Correlation Coefficient. The range of the coefficient is -1 to 1, with -1 showing a strong negative relationship, 0 showing no relationship, and 1 showing a very strong positive relationship. In terms of the strength and direct relationship between two variables, the Pearson correlation coefficient is the extent to which one variable can be guessed with the help of another variable. The correlation value greater than 0.7 can be interpreted as having a strong relationship between variables (Moore, Notz, & Fligner, 2013). In this study, variables with Pearson Correlation Coefficient of values greater than absolute value of 0.7 were considered strongly correlated and their influence on the model was checked.

3.5.1.2 Variable Selection

Although many factors may influence dependent variable estimates when developing a multiple regression model, all independent variables initially included in the model may not significantly impact dependent variable prediction. Therefore, the following variable selection methods were used to include only significant variables.

3.5.1.2.1 Forward Selection

In forward selection, a significance level is set, as required by research, that determines which variables are included one at a time in the final model. When no more variables meet the cut-off criteria (significance level), no variables are added to the model. The initial model begins with the most significant variable in the initial analysis, and variables are added until none of the remaining variables are significant. The primary drawback of this method is that the already included variable may be insignificant after the addition of other variables. The level of significance used for this research for the selection of variables was 5%.

3.5.1.2.2 Stepwise Selection

Stepwise selection requires two distinct significance levels, one for entering the variable in the model and the other for a variable to stay in the model once other variables are added. In the selection process of this method, the least significant variable is dropped and, except for this variable, all other variables are reconsidered for re-introduction into the model. For this research, the significance level for both cases, variables to enter the model and variables to stay in the model, was set at 5%.

3.5.1.2.3 Backward Selection

Contrary to forward selection, backward selection enters all initially considered variables into the model. At each step, the least significant variable is removed from the model until all remaining variables are statistically significant. The level of significance used in the research for this selection method was 5%.

3.5.1.3 Model Validation

Model validation for regression models determines whether the numerical values that quantify the relationship between the variables are acceptable. The validation process can be done with GOF tests of the regression, graphical analysis of the residuals, and cross validation using data not previously used for model development. The various tests considered for model validation in this study are described in the following section.

3.5.1.3.1 R-squared and Adjusted R-squared Values

The coefficient of determination (R^2) value is the percentage of the variation of the response variable explained by the developed model. The R-squared value ranges from 0 to 1, with higher values usually indicating a more accurate fit of the model to the data. However, a low value for R-squared does not necessarily mean an inaccurate model. Whenever the response variable is difficult to predict, such as with human behavior, the R-squared value can be below 50% and the model would still be a good fit since conclusions can be made based on statistically significant predictors. However, the R-squared value cannot determine the bias between estimated coefficients and predictions.

Adjusted R-squared, the modified version of the R-squared value, is affected only if the new added variable improves the model. The adjusted R-squared value is either equal to or less than the R-squared value.

3.5.1.3.2 Akaike Information Criterion

Akaike Information Criterion (AIC) is a measure of the relative quality between developed models for a given set of data; AIC estimates the quality of a given model with respect to other models. However, the AIC value does not reveal the absolute quality of a single model. For a set of models, the lower the AIC value, the better the model. AIC is calculated by:

$$AIC = 2k - 2Ln(L) \qquad \textbf{Equation 3.17}$$

Where:

Ln (L) = model log-likelihood, and

k = number of predictors.

3.5.1.3.3 Akaike Information Criterion Corrected

Akaike Information Criterion Corrected (AICc), a modified version of AIC, depends on the sample size. The lower the AICc value, the better the model. AICc is calculated as:

$$AICc = AIC + \frac{2k(k+1)}{n-k-1} \qquad \textbf{Equation 3.18}$$

Where:

n = sample size.

3.5.1.3.4 Bayesian Information Criterion/Schwarz Criterion

The BIC/Schwarz Criterion (SBC) is a model selection method based on likelihood function. The BIC accounts for overfitting that can be caused by the addition of parameters and resulting penalty terms when too many variables are used. As with AIC, BIC/SBC also measures the relative quality between various models for a given data set. Similar to AIC, lower value of BIC means a better model. BIC is calculated by:

$$BIC = kLn(n) - 2Ln(L) \qquad \textbf{Equation 3.19}$$

Where:

Ln (L) = model log-likelihood,

k = number of predictors, and

n = number of model observations.

3.5.1.3.5 Graphical Analysis of Residuals

Although graphical analysis of residuals is not a quantitative method, it relates to visual interpretation of scatter plots to check residual randomness. Plots that can be visually interpreted could be scatter plots of residuals and predictors, histograms, or normal probability plots. If a relationship between residuals and predictors is suspected, tests can be performed to confirm or reject that notion. However, the interpretation of graphs can vary from individual to individual.

3.5.1.3.6 Cross Validation

Mean absolute percentage error (MAPE), which measures the error between estimated minor AADT values and actual AADT values, was used for cross validation in this study. The MAPE value is calculated as:

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{|AADTpi - AADTai|}{AADTai} \qquad \textbf{Equation 3.20}$$

Where:

AADTpi = predicted AADT for i^{th} observation,

AADTai = actual AADT for i^{th} observation, and

n = sample size.

MAPE value was calculated using two datasets for validation. The first dataset included minor AADT data for the year 2012, while the models were developed using data from 2013 to 2015. The second dataset was one-third data from the total data from 2013 to 2015, which were randomly selected using the random generator in Microsoft Excel.

3.5.1.4 Outliers and Cook's Distance

In multiple regression, outliers are extreme observations that generally do not fit the rest of the data. An observation that exceeds three to four times the standard deviation is considered an outlier. However, an outlier can be influential on the regression as well. Cook's Distance, which measures the effect of deleting a given observation, can be used to identify influential outliers.

3.5.1.5 Developed Regression Models

This study used SAS 9.4 to develop regression models using combinations of independent variables to estimate minor-street AADT for 3SG and 3ST intersections (SAS Institute Inc.). The dependent variable for the regression model was the AADT for the minor approach, and the independent variables were the AADT for the major approach, the area of the city and county, the population, per capita income, median age, and population per household of the city. In addition to the demographic data, other independent variables included the number of left- and right-turn lanes in the major and minor approaches, left-turn signal phasing for 3SG intersections, the number of through lanes in the major approach, and the speed and functional class of the major and minor approaches. Several regression models were developed using variables without transformation and natural log and $\log_{10}$ transformation of the continuous variables. The final model was selected based on the various model validation methods. The regression model used to estimate minor street AADT for 3SG intersections is given by:

$$\mathbf{Ln(minorAADT) = 1.40 + 0.70\ ln(majorAADT) + 0.26\ LtMinor + 0.52\ RTmajor - 0.41\ LtSigMaj + 0.33\ LtSigMin - 0.03\ SLmajor + 0.02\ SLminor + 0.57\ FcMajAr + 0.90\ FcMajCl}$$

Equation 3.21

Where:

minorAADT = AADT of the minor approach (dependent variable),
majorAADT = AADT of the major approach,
RTmajor = number of right turn lanes in the major approach,
LTminor = number of left turn lanes in the minor approach,
LtSigMaj = type of left turn signal in the major approach,
LtSigMin = type of left turn signal in the minor approach,
SLmajor = speed limit of the major approach in mph,
SLminor = speed limit of the minor approach in mph,
FcMajAr = value of 1 if the major approach is an arterial; otherwise 0, and
FcMajCl = value of 1 if the major approach is a collector; otherwise 0.

Forward, backward, and stepwise selection methods were used at a significance level of 5% to select independent variables in the model. From the models developed using the same data and same set of variables, the best model was selected based on R-squared value, AIC, BIC, and Mallow's C_p. The R-squared value for the regression model in Equation 3.21 was 0.5314, indicating that the model is acceptable. Multiple regression models were developed to estimate minor-street AADT for 3SG intersections using a combination of independent variables and log transformation of the continuous variables. Cross validation was used to select the best performing model from the developed models, in which data from the year 2012 for the same set of intersections used for developing the model were used. The mean error between the real and predicted minor AADT were assessed. For the final selected regression model, given by Equation 3.21, the mean error was found to be 43.95%.

The regression model (Equation 3.22) was used to estimate AADT on the minor approach for 3ST intersections.

$$\log_{10}(minorAADT) = -1.73 + 0.55 \log_{10}(majorAADT) + 0.96 \log_{10}(PcInc) - 0.86\log_{10}(MedAge) + 0.96 \log_{10}(PplHH) + 0.07\, LTmajor - 0.15\, ThLanes + 0.14\, Mi\_fc\_ar - 0.26\, Mi\_fc\_cl$$

Equation 3.22

Where:

minorAADT = AADT of the minor approach (veh/day),

majorAADT = AADT of the major approach (veh/day),

PcInc = per capita income of the city (in dollars),

MedAge = median Age of the city (years),

PplHH = number of people in a household,

LTmajor = number of left turn lanes in the major approach,

ThLanes = number of through lanes in the major approach,

Mi_fc_ar = functional class of minor approach: 1 if arterial, otherwise 0, and

Mi_fc_cl = functional class of minor approach: 1 if collector, otherwise 0.

Similar variable selection, model selection, and cross validation methods were applied as regression models for minor-street AADT for 3SG. The R-squared value for the regression model in Equation 3.22 was 0.3218. Although the model had a lower R-squared value than the R-squared value of the regression model developed for 3SG intersections, this model had low errors for cross validation. The mean error for the model given by Equation 3.22 was 59.74%, which was the least error among the several developed regression models.

Given the results from the two regression models, shown in Equation 3.21 and Equation 3.22, a conclusion was made that although R-squared value is a good measure for model selection, models with low R-squared value can also demonstrate minimal prediction errors. One reason for prediction errors is the presence of outliers; however, even though removal of outliers from the dataset increased accuracy, the outliers were actual data in the field and therefore not removed from the dataset. For some of the outliers, the minor-street AADT was greater than the major-street AADT, which contributed to error in the prediction.

The SAS outputs for the two regression models (Equation 3.21 and Equation 3.22) are presented in Appendix C.

3.6 Cumulative Residual Plots and Coefficient of Variance

CURE plots and CV can be a reliable measure of GOF tests when verifying the reliability of estimated calibration factors. Lyon et al. (2016) developed a guide for analysis that helps assess estimated calibration factors. The guide provides the following two criteria which helps determine the reliability of the estimated calibration factors:

1. The total CURE deviation, in terms of percentage, is not more than 5% from the two standard deviation thresholds; and
2. The calibration factors for which the CV value is 0.15 or less are acceptable.

3.7 Calibration Functions

CURE deviation higher than the acceptable limit shows bias in calibration factor prediction. Therefore, calibration functions can be developed for which the CURE deviation can be within the acceptable limit. The general form of the calibration function is given by:

$$N_{predicted} = a*(HSM_{pred})^{b} \qquad \textbf{Equation 3.23}$$

Where:

$N_{predicted}$ = predicted number of crashes using calibration functions,

HSM_{pred} = number of predicted crashes using HSM predictive methodology, and

a, b = constants, calculated from iteration.

Calibration functions were developed using the Solver add-in in Microsoft Excel, by setting the criteria of the maximum value of log-likelihood for a given facility type. The log-likelihood function was calculated as:

$$LL_{NB} = \ln\Gamma(X+1/k) - 1/k*\ln(1/k) + X\ln(y) - (1/k+X)\ln(1/k+y) \qquad \textbf{Equation 3.24}$$

Where:

k = over-dispersion parameter,

X = observed crashes, and

y = fitted predicted crashes.

The dispersion parameter in Equation 3.24 was calculated using Equation 3.25:

$$\mathbf{Var\ (m) = E(m) + k{*}E(m)^2} \qquad \textbf{Equation 3.25}$$

Where:

k = dispersion parameter,

Var (m) = variance of the crashes, and

E(m) = mean crash.

Chapter 4: Results and Discussions

4.1 Kansas-Specific Crash Proportions

The Highway Safety Manual provides crash proportions to categorize multiple-vehicle crashes by manner of collision and single-vehicle crashes by crash type. However, the HSM suggests that these default values may be replaced with jurisdiction-specific crash proportions. The HSM also mentions that a total of at least 200 crashes should be used for each facility type to develop crash proportions to replace the default values given in the HSM. Table 4.1 provides crash proportions for multiple-vehicle collisions distributed by manner of collision for Kansas.

Table 4.1: Distribution of multiple vehicle collisions at urban intersections in Kansas

Manner of Collision	3ST		3SG		4ST		4SG	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	0.235	0.253	0.543	0.553	0.114	0.150	0.416	0.489
Head-on collision	0.036	0.027	0.049	0.028	0.044	0.030	0.042	0.025
Angle collision	0.702	0.637	0.390	0.321	0.825	0.785	0.520	0.395
Sideswipe	0.023	0.067	0.012	0.085	0.020	0.054	0.020	0.074
Other multiple-vehicle collisions	0.004	0.016	0.006	0.013	0.003	0.025	0.002	0.017

The crash proportions in Table 4.1 show that rear-end collisions and angle collisions are the types of multiple-vehicle crashes which have the highest frequency in all the four types of intersections in urban locations in Kansas. These two types of crashes account for around 90% of the total multiple-vehicle crashes for all four intersection types in Kansas. Crash proportions for single-vehicle crashes categorized by crash type for Kansas are given in Table 4.2. The sample size used to develop crash proportions for 3-legged signalized intersections and crash proportion for fatal and injury (FI) crashes for 4-legged unsignalized intersections were less than the HSM recommended sample size of 200. Hence, the use of these crash proportions should be done with caution. However, these crash proportions show similar characteristics to other intersection types since collision with fixed object is the type of single-vehicle crash with the highest frequency as shown in Table 4.2. For FI crashes at 3ST and 4SG intersections, non-collision also contributed to a higher number of crashes.

Table 4.2: Distribution of single vehicle crashes at urban intersections in Kansas

Crash Type	3ST		3SG		4ST		4SG	
	FI	PDO	FI*	PDO*	FI*	PDO	FI	PDO
Collision with parked vehicle	0.049	0.165	0.000	0.083	0.029	0.167	0.038	0.225
Collision with animal	0.010	0.039	0.000	0.021	0.006	0.040	0.012	0.065
Collision with fixed object	0.527	0.688	0.706	0.740	0.356	0.641	0.382	0.506
Collision with other object	0.025	0.014	0.029	0.052	0.011	0.013	0.037	0.010
Other single-vehicle collision	0	0.004	0.000	0.021	0.017	0.002	0	0.017
Non-collision	0.389	0.090	0.265	0.083	0.580	0.136	0.531	0.177

* Indicates the total number of crashes were less than 200, which is a criterion for replacing HSM default values (AASHTO, 2010).

In addition, the HSM provides crash adjustment factors for crashes involving pedestrians and bicycles. These adjustment factors are used in predicting crashes that involve pedestrians and bicycles. The default values for these adjustment factors given in the HSM can be replaced with jurisdiction-specific values as described in Section 3.3.1. The HSM criteria for replacing the default values states that there should be at least 20 vehicle-pedestrian crashes and 20 vehicle-bicycle crashes to develop jurisdiction-specific crash adjustment factors. Kansas-specific pedestrian and bicycle crash adjustment factors are given in Table 4.3.

Table 4.3: Kansas-specific crash adjustment factors

Facility Type	Pedestrian crash adjustment factor	Bicycle crash adjustment factor
3ST	0.008	0.009
3SG	Not applicable	0.011
4ST	0.009	0.015
4SG	Not applicable	0.015

The crash proportions presented in Tables 4.1 and 4.2 and crash adjustment factors given in Table 4.3 were developed using data from Kansas. These values would increase crash prediction for Kansas compared to the use of default values given in the HSM.

4.2 Estimated Calibration Factors for Urban and Suburban Intersections in Kansas

Table 4.4 shows the estimated calibration factors for the four facility types considered in this study (3ST, 3SG, 4ST, and 4SG) at urban and suburban locations in Kansas.

Table 4.4: Estimated calibration factors for urban and suburban intersections in Kansas

Facility Type	Observed Crashes	Predicted crashes	HSM Calibration Factor
3ST (FI crashes)	95	234.58	0.40
3ST (all crashes)	321	625.07	0.51
3SG (FI crashes)	89	170.56	0.52
3SG (all crashes)	310	481.36	0.64
4ST (FI crashes)	153	211.73	0.73
4ST (all crashes)	352	577.74	0.61
4SG (FI crashes)	956	475.88	2.00
4SG (all crashes)	1644	1400.49	1.17

The calibration factors in Table 4.4 show that HSM predictive methodology overpredicted the number of crashes for 3ST, 3SG, and 4ST when considering fatal-and-injury (FI) crashes only and all crashes. A calibration factor less than 1.00 indicates overprediction of crashes and a calibration factor greater than 1.00 indicates underprediction. When considering FI crashes, the number of actual crashes at urban 3ST intersections in Kansas was 0.40 times the predicted number of crashes that were estimated using HSM methodology. When considering all crash severities, the actual number of crashes was almost half the predicted number of crashes in Kansas. Similarly, the predicted number of crashes at 3SG and 4ST intersections were significantly more than the actual number of crashes in Kansas. However, as shown in Table 4.4, the number of crashes at 4SG intersections were underpredicted by HSM methodology. When considering FI crashes only, the actual number of crashes was two times the predicted number of crashes at 4SG intersections in Kansas. Considering all crashes, the number of observed crashes was 1.17 times the predicted number of crashes in Kansas.

Intersection sample sites were selected from urban cities in Kansas. The major approach for these intersections were principal arterials, with some arterials on the state highway system. Table 4.5 shows calibration factors for the four facility types when considering only intersections on state highways, as well as all the intersections used as sample sites for calibration. Arterials on US or K routes are considered part of the state highway system. Even when selecting only intersections on the state route, HSM methodology still overpredicted crashes at 3ST, 3SG, and 4ST intersections, and underpredicted crashes at 4SG intersections. However, calibration factors for intersections on the state routes differed from overall calibration factors possibly due to higher AADT values and higher speed limits for intersections on the state highway system. In addition, the number of intersections on state highways is relatively low, with subsequent low numbers of crashes compared to the overall sample size potentially affecting the accuracy of the estimated calibration factors.

Table 4.5: Calibration factors for urban intersections on the state routes (US- and K-routes) in Kansas

Facility Type	Description	Sample Size	FI			Total		
			Observed crashes	Predicted crashes	CF	Observed crashes	Predicted crashes	CF
3ST	Intersections on state highway system	40	14	49.73	0.22	66	133.52	0.49
	Total selected intersections	234	95	234.58	0.40	321	625.07	0.51
3SG	Intersections on state highway system	20	29	45.57	0.64	97	130.78	0.74
	Total selected intersections	89	89	170.56	0.52	310	481.36	0.64
4ST	Intersections on state highway system	44	50	51.293	0.97	108	138.66	0.78
	Total selected intersections	167	153	211.73	0.73	352	577.74	0.61
4SG	Intersections on state highway system	38	162	92.44	1.75	289	265.76	1.09
	Total selected intersections	198	956	475.88	2.01	1,644	1,400.49	1.17

For the prediction of crashes using the HSM predictive methodology, minor AADT is one of the required data elements. All 4SG and 4ST intersections had the minor-street AADT data for the intersections selected as sample sites. However, the minor AADT for all 3SG and 3ST intersections considered for calibration were not available, so the minor-street AADT for these intersections were estimated using regression models developed in Equation 3.21 and Equation 3.22. Table 4.6 shows the number of intersections with actual AADT data, intersections with estimated minor-street AADT, and calibration factors.

Table 4.6: Calibration factors for intersections with actual and estimated minor street AADT

Facility Type	Description	Number of Intersections	Observed Crashes	Predicted crashes	Calibration Factor
3ST	Intersections with actual data (FI)	128	57	115.60	0.49
	Intersections with estimated data (FI)	106	38	118.98	0.32
	Intersections with actual data (all crashes)	128	180	319.93	0.56
	Intersections with estimated data (all crashes)	106	141	305.13	0.46
3SG	Intersections with actual data (FI)	68	75	133.11	0.56
	Intersections with estimated data (FI)	21	14	37.45	0.37
	Intersections with actual data (all crashes)	68	256	376.12	0.68
	Intersections with estimated data (all crashes)	21	54	105.24	0.51

The calibration factors in Table 4.6 show that the calibration factor for the set of intersections with actual minor-street AADT was greater than the calibration factor for the set of intersections with estimated minor-street AADT considering FI crashes only and all crashes. This discrepancy could be a result of prediction errors made by the regression models. Nonetheless, HSM methodology overpredicted the number of crashes for both sets intersection types.

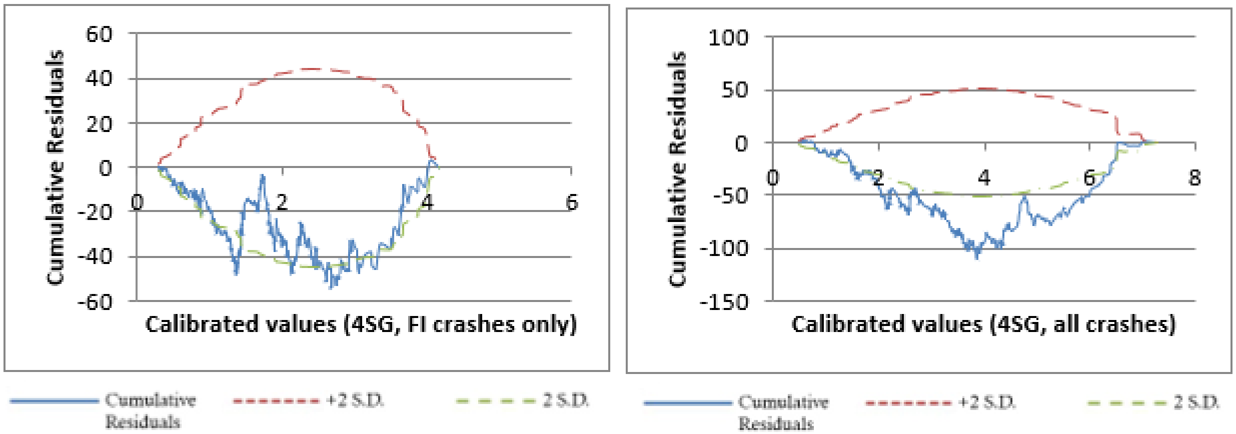
4.3 Calibration Functions and Estimated Calibration Factors

This study initially assessed the reliability of the estimated calibration factors using CURE plots and CV values. Based on the two criteria of assessment described in Section 3.6, calibration functions were developed for the four intersection types, and reliability of the calibration functions was checked. The functional form of the calibration functions is given by Equation 3.23. Overall results are presented in Table 4.7.

Table 4.7: Constants of calibration functions, CURE values, and CV values for calibration factors and calibration functions

Facility Type (crashes)	Calibration Factor			Calibration Functions (developed using NB Regression)			
	C.F.	CV	% CURE deviation	a	b	k	% CURE deviation
3ST (FI)	0.40	0.15	61 %	0.24	0.47	0.01	0 %
3ST (all)	0.51	0.08	93 %	0.51	0.46	0.01	0 %
3SG (FI)	0.52	0.16	3 %	0.52	0.97	0.01	3 %
3SG (all)	0.64	0.11	15 %	0.77	0.76	0.11	3 %
4ST (FI)	0.73	0.12	17 %	0.60	0.77	0.01	13 %
4ST (all)	0.61	0.08	75 %	0.66	0.58	0.01	0 %
4SG (FI)	2.00	0.08	15 %	2.00	0.93	0.54	4 %
4SG (all)	1.17	0.06	80%	0.94	1.22	0.16	5 %

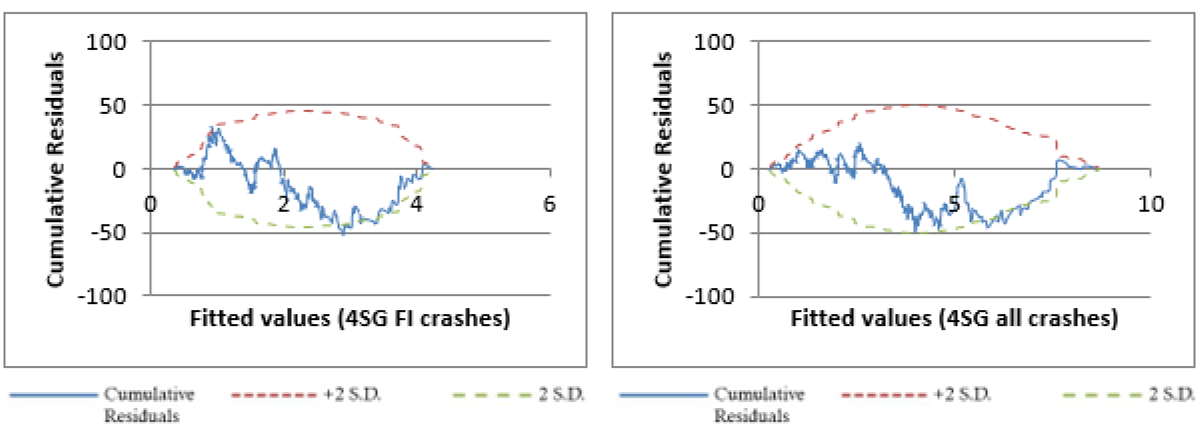
Table 4.7 shows that although CV values for the estimated calibration factors were within acceptable limit of 0.15, except for 3SG when considering FI crashes, the percent CURE deviation was not within 5%. This percentage refers to the CURE deviation outside the two standard deviation thresholds and shows that the calibrated SPFs were not sufficiently reliable. Therefore, calibration functions were developed using NB regression. CV values for the calibration functions are equal to the calibration factors of the respective facility type. However, the calibration functions showed increased accuracy, with the percent CURE deviation for all considered facility types being within the acceptable limit of 5%. GOF tests for the calibration functions showed that the developed functions were reliable, with an increase in crash prediction accuracy. CURE plots for the 4SG facility type are shown in Figure 4.1 and Figure 4.2. CURE plots for the other facility types are presented in Appendix D.



(a) (b)

Figure 4.1: CURE plots for calibration factors for 4SG intersections: (a) FI crashes only, and (b) all crashes

Figure 4.1(a) shows a small portion of the CURE plot outside the threshold, which is 14% but a majority of the curve is outside the threshold when considering all crashes for 4SG intersections as shown in Figure 4.1(b). For the same set of intersections, CURE plots for calibration functions show improved performance, with most of the curve sections inside the two-standard deviation threshold as shown in Figure 4.2(a) and Figure 4.2(b). This shows that the developed calibration functions have better reliability than the estimated calibration factors.



(a) (b)

Figure 4.2: CURE plots for calibration functions for 4SG intersections: (a) FI crashes only, and (b) all crashes

Chapter 5: Conclusions and Recommendations

5.1 Summary and Conclusions

The study estimated calibration factors and calibration functions for four types of intersections (3ST, 3SG, 4ST, and 4SG) at urban and suburban locations in Kansas. Crash data used for the calibration procedure was from 2013–2015 for 3ST, 3SG, and 4SG intersections, and 2014–2016 for 4ST, based on the availability of recent data at the beginning of calibration of each facility type. AADT data were collected from the GIS shapefiles downloaded from FHWA (2016) and the KCARS database. Crash data were collected from the KCARS database, and other geometric and physical data were collected from Google Earth. ArcGIS was used to create layers of AADT and crashes for all considered intersection types (Esri, 2012).

Two-hundred thirty-four 3ST intersections, 89 3SG intersections, 167 4ST intersections, and 198 4SG intersections were selected as sample sites for calibration. The calibration effort, which followed HSM crash predictive methodology and calibration procedure (AASHTO, 2010), yielded a calibration factor of 0.40 for 3ST intersections when considering only FI crashes, and 0.51 when considering all crashes. Calibration factors for 3ST showed that the HSM methodology overpredicted the number of crashes at urban 3ST intersections in Kansas. Similarly, calibration factors for 3SG intersections were estimated at 0.52 for FI crashes and 0.64 for all crashes, and calibration factors for 4ST were 0.73 for FI crashes and 0.61 when considering all crashes. HSM methodology overpredicted the total number of crashes for these intersection types. However, HSM methodology underpredicted the crashes for 4SG intersections, with estimated calibration factors of 2.00 for FI crashes and 1.17 for all crashes. This shows that HSM methodology can overpredict and underpredict crashes for different facility types in the same jurisdiction. One reason for this discrepancy could be differences in traffic and geometric characteristics between Kansas and the states used to develop HSM crash prediction models. Another reason could be the differences in PDO crash reporting thresholds for each state.

The reliability of the estimated calibration factors was checked using CURE plots and CV values. GOF tests showed that the calibration factors were not reliable, so calibration functions were developed for the four intersection types using NB regression. GOF tests for the calibration functions showed that these functions had greater reliability than the estimated calibration factors.

Crash prediction accuracy increased with use of the developed calibration functions. Values of the estimated calibration factors and calibration functions justified the calibration effort of this study.

5.2 Recommendations

SPFs can be developed using Kansas-specific data to further increase the crash prediction accuracy. However, developing SPFs requires extensive data and is time consuming. The estimated calibration factors and the developed calibration functions can be used to predict crashes. Because the calibration functions showed good reliability, it is recommended that these functions be used to predict crashes.

HSM predicted models are recommended for recalibration every 2–3 years (AASHTO, 2010). Intersections used in this study should be checked for any changes in physical attributes for recalibration, and more intersections should be added during recalibration to further increase reliability of the calibration factors and calibration functions. Regression models were developed to estimate minor-street AADT for 3SG and 3ST intersections, which could have also affected the final value of the calibration factor. Actual data should be used to increase the accuracy of the calibration factors and calibration functions.

Crash prediction helps identify critical locations, or intersections with a higher probability of being a crash location, allowing countermeasures to be applied to prevent crash occurrences. The use of calibration factors and calibration functions helps to predict crashes at existing intersections, alternatives to existing intersections, and new intersections. The distribution of multiple-vehicle collisions and single-vehicle crashes at urban intersections in Kansas, presented in Section 4.1, helps in identifying the types of crashes that occur more frequently in Kansas.

Crash proportions in Table 4.1 and Table 4.2 were developed using historical crash data from Kansas. Although the HSM provides crash proportions for multiple-vehicle collisions and single-vehicle crashes, it recommends replacing these values using jurisdiction-specific data, given that there are at least 200 crashes for a facility type (AASHTO, 2010). Crash proportions for multiple-vehicle collisions show that a majority of multiple-vehicle crashes at urban intersections in Kansas are rear-end collisions and angle collisions. Similarly, crash proportions for single-vehicle crashes show that collision with a fixed object is the primary type of single-vehicle crashes at urban intersections in Kansas. Therefore, it is recommended that Kansas-specific crash proportions should be used to identify the type of crash that could occur at intersections so that necessary countermeasures can be applied.

References

Alluri, P., Saha, D., & Gan, A. (2016). Minimum sample sizes for estimating reliable Highway Safety Manual (HSM) calibration factors. *Journal of Transportation Safety & Security, 8*(1), 56–74.

American Association of State Highway and Transportation Officials (AASHTO). (2010). *Highway safety manual* (1st ed.). Washington, DC: Author.

Banihashemi, M. (2012). Sensitivity analysis of data set sizes for Highway Safety Manual calibration factors. *Transportation Research Record, 2279*, 75–81.

Brimley, B. K., Saito, M., & Schultz, G. G. (2012). Calibration of Highway Safety Manual safety performance function: Development of new models for rural two-lane two-way highways. *Transportation Research Record, 2279*, 82–89.

Claros, B., Sun, C., & Edara, P. (2018). HSM calibration factor, calibration function, or jurisdiction-specific safety model – A comparative analysis. *Journal of Transportation Safety & Security, 12*(2), 309–328.

Colety, M., Crowther, B., Farmen, M., Bahar, G., & Srinivasan, R. (2016). *ADOT state-specific crash prediction models: An Arizona needs study* (Report No. FHWA-AZ-16-704). Phoenix, AZ: Arizona Department of Transportation.

Dissanayake, S., & Aziz, S. R. (2016). *Calibration of the Highway Safety Manual and development of new safety performance functions for rural multilane highways in Kansas* (Report No. K-TRAN: KSU-14-3). Topeka, KS: Kansas Department of Transportation.

Dixon, K., Monsere, C. M., Xie, F., & Gladhill, K. (2012). *Calibrating the HSM predictive methods for Oregon highways* (Report No. FHWA-OR-RD-12-07). Salem, OR: Oregon Department of Transportation Research Section.

Esri. (2012). *ArcGIS Desktop* (Version 10.1). Redlands, CA: Environmental Systems Research Institute.

Federal Highway Administration (FHWA). (2016). *HPMS public release of geospatial data in Shapefile format*. Retrieved July 2017 from https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm

Garber, N. J., & Rivera, G. (2010). *Safety performance functions for intersections on highways maintained by the Virginia Department of Transportation* (Report No. FHWA/VTRC 11-CR1). Richmond, VA: Virginia Department of Transportation.

Harwood, D. W., Bauer, K. M., Potts, I. B., Torbic, D. J., Richard, K. R., Kohlman Rabbani, E. R., Hauer, E., & Elefteriadou, L. (2002). *Safety effectiveness of intersection left- and right-turn lanes* (Report No. FHWA-RD-02-089). McLean, VA: Federal Highway Administration.

Hauer, E. (2016). *The art of regression modeling in road safety*. New York, NY: Springer.

Hauer, E., Council, F. M., & Mohammedshah, Y. (2004). Safety models for urban four-lane undivided road segments. *Transportation Research Record, 1897*, 96–105.

Kansas Department of Transportation (KDOT). (n.d.). *Crash statistics*. Retrieved from https://kdotapp.ksdot.org/AccidentStatistics/

Kansas Department of Transportation (KDOT). (2017). *2016 Kansas traffic crash facts book*. Retrieved from https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burTransPlan/prodinfo/accstat/2016FactsBook.pdf

KCARS (Kansas Crash Analysis and Reporting System). (n.d.). [Database]. Retrieved from https://www.ksdot.org/bureaus/offchiefcoun/openrecords.asp

Kim, J., Anderson, M., & Gholston, S. (2015). Modeling safety performance functions for Alabama's urban and suburban arterials. *International Journal of Traffic and Transportation Engineering, 4*(3), 84–93.

KML Circle Generator. (n.d.). Retrieved May 2017 from http://kml4earth.appspot.com/circlegen.html

Kochanek, K. D., Murphy, S. L., Xu, J., & Arias, E. (2017, December). *Mortality in the United States, 2016* (NCHS Data Brief No. 293). Retrieved from https://www.cdc.gov/nchs/data/databriefs/db293.pdf

Lyon, C., Persaud, B., & Gross, F. (2016). *The Calibrator—An SPF calibration and assessment tool, User guide* (Report No. FHWA-SA-17-016). Washington, DC: Federal Highway Administration.

Mohamad, D., Sinha, K. C., Kuczek, T., & Scholer, C. F. (1998). Annual average daily traffic prediction model for county roads. *Transportation Research Record, 1617*, 69–77.

Moore, D. S., Notz, W. I., & Fligner, M. A. (2013). *The basic practice of statistics* (6th ed.). New York, NY: W.H. Freeman.

National Highway Traffic Safety Administration (NHTSA). (2017). *2016 Quick facts*. Retrieved from https://www.nhtsa.gov/press-releases/usdot-releases-2016-fatal-traffic-crash-data

Pan, T. (2008). *Assignment of estimated average annual daily traffic volumes on all roads in Florida* (Master's thesis). Retrieved from https://scholarcommons.usf.edu/etd/442/

Persaud and Lyon Inc., & Felsburg Holt & Ullevig. (2009). *Safety performance functions for intersections* (Report No. CDOT-2009-10). Denver, CO: Colorado Department of Transportation.

Qin, X., Chen, Z., & Shaon, R. R. (2018). Developing jurisdiction-specific SPFs and crash severity portion functions for rural two-lane, two-way intersections. *Journal of Transportation Safety & Security, 11*(6), 629–641.

SAS (Version 9.4) [Software]. (2013). Cary, NC: SAS Institute Inc.

Savolainen, P. T., Gates, T., Lord, D., Geedipally, S., Rista, E., Barrette, T., Russo, B. J., & Hamzeie, R. (2015). *Michigan urban trunkline intersections safety performance functions (SPFs) development and support* (Report No. RC-1628). Lansing, MI: Michigan Department of Transportation.

Shankar, V., & Madanat, S. (2015). *Methods for identifying high collision concentrations for identifying potential safety improvements: Development of safety performance functions for California* (Report No. CA15-2317). Sacramento, CA: California Department of Transportation.

Shin, H., Lee, Y.-J., & Dadvar, S. (2014). *The development of local calibration factors for implementing the Highway Safety Manual in Maryland* (Report No. MD-14-SP209B4J). Baltimore, MD: Maryland State Highway Administration.

Shirazi, M., Lord, D., & Geedipally, S. R. (2016). Sample-size guidelines for recalibrating crash prediction models: Recommendations for the Highway Safety Manual. *Accident Analysis & Prevention, 93*, 160–168.

Smith, S., Carter, D., & Srinivasan, R. (2017). *Updated and regional calibration factors for Highway Safety Manual crash prediction models* (Report No. FHWA/NC/2016-09). Raleigh, NC: North Carolina Department of Transportation.

Srinivasan, R., & Bauer, K. (2013). *Safety performance function development guide: Developing jurisdiction specific SPFs* (Report No. FHWA-SA-14-005). Washington, DC: Federal Highway Administration.

Srinivasan, R., & Carter, D. (2011). *Development of safety performance functions for North Carolina* (FHWA/NC/2010-09). Raleigh, NC: North Carolina Department of Transportation.

Srinivasan, R., Carter, D., & Bauer, K. (2013). *Safety performance function decision guide: SPF calibration vs SPF development* (Report No. FHWA-SA-14-004). Washington, DC: Federal Highway Administration.

Srinivasan, R., Colety, M., Bahar, G., Crowther, B., & Farmen, M. (2016). Estimation of calibration functions for predicting crashes on rural two-lane roads in Arizona. *Transportation Research Record, 2583*, 17–24.

Srinivasan, S., Haas, P., Dhakar, N. S., Hormel, R., Torbic, D., & Harwood, D. (2011). *Development and calibration of Highway Safety Manual equations for Florida conditions* (Report No. TRC-FDOT-82013-2011). Tallahassee, FL: Florida Department of Transportation.

Sun, C., Edara, P., Brown, H., Claros, B., & Nam, K. (2013). *Calibration of the Highway Safety Manual for Missouri* (Report No. cmr14-007). Jefferson City, MO: Missouri Department of Transportation.

Tegge, R. A., Jo, J.-H., & Ouyang, Y. (2010). *Development and application of safety performance functions for Illinois* (Report No. FHWA-ICT-10-066). Springfield, IL: Illinois Department of Transportation.

Trieu, V., Park, S., & McFadden, J. (2014). Use of Monte Carlo simulation for a sensitivity analysis of Highway Safety Manual calibration factors. *Transportation Research Board, 2435*, 1–10.

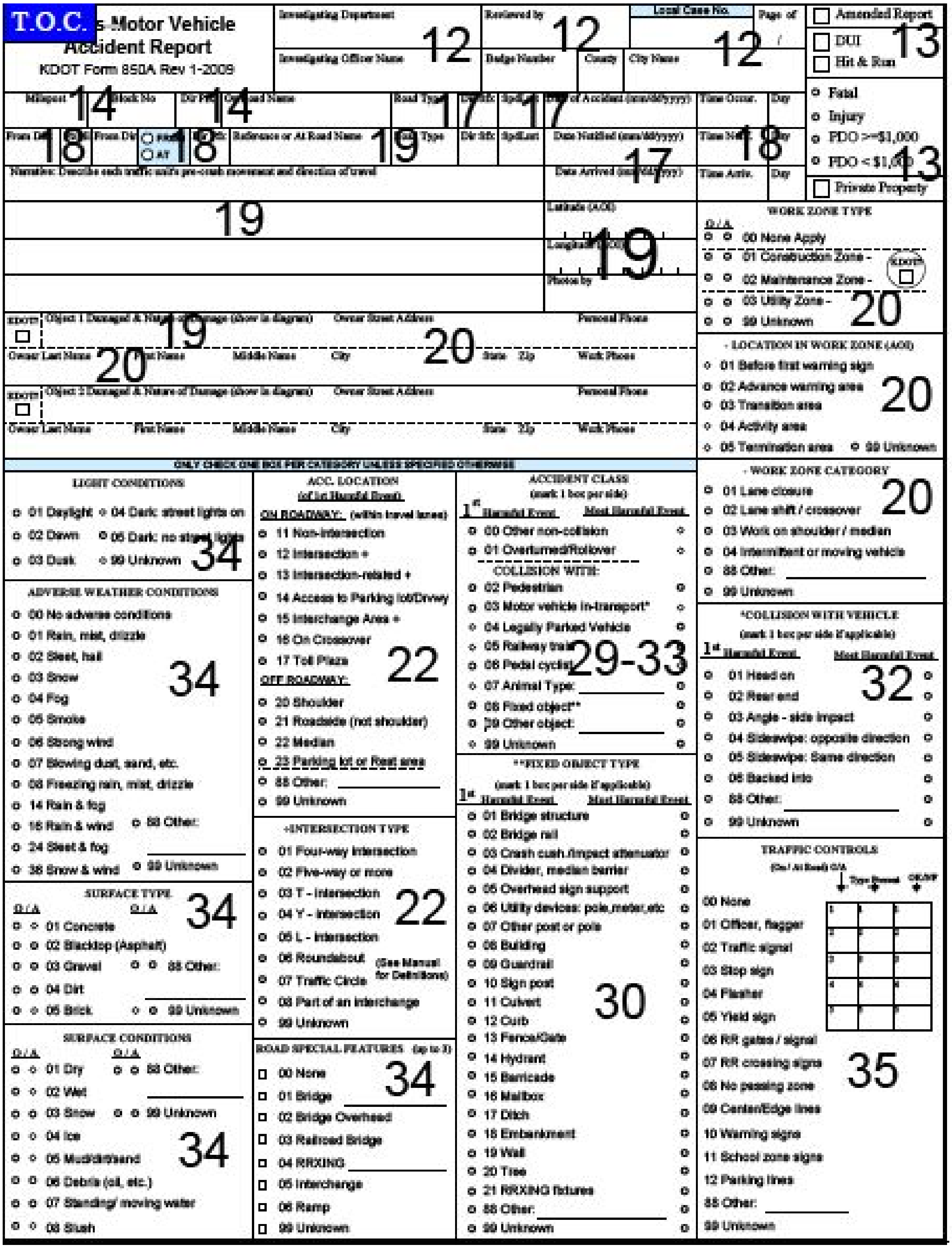
Troyer, D., Bradbury, K., & Juliano, C. (2015). Strength of the variable: Calculating and evaluating safety performance function calibration factors for the state of Ohio. *Transportation Research Record, 2515*, 86–93.

Xie, Y., & Chen, C. (2016). *Calibration of safety performance functions for Massachusetts urban and suburban intersections* (Report No. UMTC 16.01). Boston, MA: Massachusetts Department of Transportation.

Zhao, F., & Chung, S. (2011). Contributing factors of annual average daily traffic in a Florida county exploration with geographic information system and regression models. *Transportation Research Record, 1769*, 113–122.

Appendix A: Kansas Motor Vehicle Accident Report

See next page.


T.O.C.

Kansas Motor Vehicle Accident Report
KDOT Form 850A Rev 1-2009

Investigating Department — 12
Investigating Officer Name
Reviewed by — 12
Badge Number | County | City Name
Local Case No. — 12
Page of /
Amended Report
DUI — 13
Hit & Run

Milepost — 14 | Block No | Dir Pfx | On Road Name — 14 | Road Type — 17 | Dir Sfx | Spd Lmt — 17 | Date of Accident (mm/dd/yyyy) | Time Occur. | Day

From Dist — 18 | Unit | From Dir | ○ Feet ○ At — 18 | Dir Pfx | Reference or At Road Name — 19 | Road Type | Dir Sfx | Spd Lmt | Date Notified (mm/dd/yyyy) | Time Notif. — 18 | Day

Date Arrived (mm/dd/yyyy) — 17 | Time Arriv. | Day

- Fatal
- Injury
- PDO >=$1,000
- PDO < $1,000 — 13
- Private Property

Narrative: Describe each traffic unit's pre-crash movement and direction of travel — 19

Latitude (AOI)
Longitude — 19
Photos by

WORK ZONE TYPE (O / A)
- 00 None Apply
- 01 Construction Zone -
- 02 Maintenance Zone - (KDOT?)
- 03 Utility Zone -
- 99 Unknown

20

KDOT? Object 1 Damaged & Nature of Damage (show in diagram) — 19 | Owner Street Address — 20 | Personal Phone
Owner Last Name — 20 | First Name | Middle Name | City | State | Zip | Work Phone

KDOT? Object 2 Damaged & Nature of Damage (show in diagram) | Owner Street Address | Personal Phone
Owner Last Name | First Name | Middle Name | City | State | Zip | Work Phone

- LOCATION IN WORK ZONE (AOI) — 20
- 01 Before first warning sign
- 02 Advance warning area
- 03 Transition area
- 04 Activity area
- 05 Termination area
- 99 Unknown

ONLY CHECK ONE BOX PER CATEGORY UNLESS SPECIFIED OTHERWISE

LIGHT CONDITIONS — 34
- 01 Daylight
- 02 Dawn
- 03 Dusk
- 04 Dark: street lights on
- 05 Dark: no street lights
- 99 Unknown

ADVERSE WEATHER CONDITIONS — 34
- 00 No adverse conditions
- 01 Rain, mist, drizzle
- 02 Sleet, hail
- 03 Snow
- 04 Fog
- 05 Smoke
- 06 Strong wind
- 07 Blowing dust, sand, etc.
- 08 Freezing rain, mist, drizzle
- 14 Rain & fog
- 16 Rain & wind
- 24 Sleet & fog
- 36 Snow & wind
- 88 Other:
- 99 Unknown

SURFACE TYPE (O / A) — 34
- 01 Concrete
- 02 Blacktop (Asphalt)
- 03 Gravel
- 04 Dirt
- 05 Brick
- 88 Other:
- 99 Unknown

SURFACE CONDITIONS (O / A) — 34
- 01 Dry
- 02 Wet
- 03 Snow
- 04 Ice
- 05 Mud/dirt/sand
- 06 Debris (oil, etc.)
- 07 Standing/ moving water
- 08 Slush
- 88 Other:
- 99 Unknown

ACC. LOCATION (of 1st Harmful Event) — 22
ON ROADWAY: (within travel lanes)
- 11 Non-intersection
- 12 Intersection +
- 13 Intersection-related +
- 14 Access to Parking lot/Drvwy
- 15 Interchange Area +
- 16 On Crossover
- 17 Toll Plaza

OFF ROADWAY:
- 20 Shoulder
- 21 Roadside (not shoulder)
- 22 Median
- 23 Parking lot or Rest area
- 88 Other:
- 99 Unknown

+INTERSECTION TYPE — 22
- 01 Four-way intersection
- 02 Five-way or more
- 03 T - intersection
- 04 Y - intersection
- 05 L - intersection
- 06 Roundabout (See Manual for Definitions)
- 07 Traffic Circle
- 08 Part of an interchange
- 99 Unknown

ROAD SPECIAL FEATURES (up to 3) — 34
- 00 None
- 01 Bridge
- 02 Bridge Overhead
- 03 Railroad Bridge
- 04 RRXING
- 05 Interchange
- 06 Ramp
- 99 Unknown

ACCIDENT CLASS (mark 1 box per side) — 29-33
1st Harmful Event | Most Harmful Event
- 00 Other non-collision
- 01 Overturned/Rollover

COLLISION WITH:
- 02 Pedestrian
- 03 Motor vehicle in-transport*
- 04 Legally Parked Vehicle
- 05 Railway train
- 06 Pedal cyclist
- 07 Animal Type:
- 08 Fixed object**
- 09 Other object:
- 99 Unknown

****FIXED OBJECT TYPE** (mark 1 box per side if applicable) — 30
1st Harmful Event | Most Harmful Event
- 01 Bridge structure
- 02 Bridge rail
- 03 Crash cush./impact attenuator
- 04 Divider, median barrier
- 05 Overhead sign support
- 06 Utility devices: pole,meter,etc
- 07 Other post or pole
- 08 Building
- 09 Guardrail
- 10 Sign post
- 11 Culvert
- 12 Curb
- 13 Fence/Gate
- 14 Hydrant
- 15 Barricade
- 16 Mailbox
- 17 Ditch
- 18 Embankment
- 19 Wall
- 20 Tree
- 21 RRXING fixtures
- 88 Other:
- 99 Unknown

- WORK ZONE CATEGORY — 20
- 01 Lane closure
- 02 Lane shift / crossover
- 03 Work on shoulder / median
- 04 Intermittent or moving vehicle
- 88 Other:
- 99 Unknown

***COLLISION WITH VEHICLE** (mark 1 box per side if applicable) — 32
1st Harmful Event | Most Harmful Event
- 01 Head on
- 02 Rear end
- 03 Angle - side impact
- 04 Sideswipe: opposite direction
- 05 Sideswipe: Same direction
- 06 Backed into
- 88 Other:
- 99 Unknown

TRAFFIC CONTROLS (On / At Road) O/A — 35
Type | Present | OK/NF
- 00 None
- 01 Officer, flagger
- 02 Traffic signal
- 03 Stop sign
- 04 Flasher
- 05 Yield sign
- 06 RR gates / signal
- 07 RR crossing signs
- 08 No passing zone
- 09 Center/Edge lines
- 10 Warning signs
- 11 School zone signs
- 12 Parking lines
- 88 Other:
- 99 Unknown

T.O.C. t Diagram continued

SPECIAL EVENT 36 SPECIAL DATA

Local Case No. | Page of /

ROADWAY NUMBER OF LANES	ROAD CHARACTER	SPECIAL JURISDICTION
O / A	O / A	
01 One	01 Straight & Level	00 Normal Jurisdiction (Not Special)
02 Two	02 Straight on grade/slope	01 National Park Service
03 Three	03 Straight on hillcrest	02 Military
04 Four to Six	04 Curved & level	03 Indian Reservation
05 Seven or more	05 Curved on grade/slope	04 College / University Campus
88 Other:	06 Curved on hillcrest	05 Other Federal property
99 Unknown	88 Other:	88 Other:
	99 Unknown	99 Unknown

37 37 37

A basic diagram is required for all state reportable accidents showing movements, direction, and positions of all traffic units in relationship to the trafficway. Identify (label) the street(s) and traffic unit(s) along with the area of impact (AOI) where possible. Refer to vehicles and pedestrians by unique numbers assigned in this report.

36

Indicate North Direction

Draw scene as observed or recreate per statements and evidence available

36

Note: The above line scale is 1"=20'. 5 feet squares. If another scale is used, please specify.

Appendix B: List of Intersections Used for Calibration

See next page.

Table B.1: List of urban 3-leg unsignalized intersections with stop control on the minor approach used in calibration

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
021-010-3ST-001	38.92983	−97.21861	Abilene	Dickinson	Mulberry St	14th St
021-010-3ST-002	38.92191	−97.22341	Abilene	Dickinson	Vine St	7th St
008-623-3ST-003	37.69401	−97.13046	Andover	Butler	Shay Rd	Central Ave
018-030-3ST-004	37.08545	−97.05818	Arkansas City	Cowley	15th St	Radio Lane
018-030-3ST-005	37.0781	−97.04161	Arkansas City	Cowley	2nd St	Kansas Ave
003-040-3ST-006	39.57193	−95.11517	Atchison	Atchison	2nd St	Division St
008-050-3ST-007	37.67928	−96.96234	Augusta	Butler	Cluster Ln	7th Ave
087-644-3ST-008	37.76622	−97.26776	Bel Aire	Sedgwick	Farmstead St	45th St
105-064-3ST-009	39.06236	−94.87064	Bonner Springs	Wyandotte	Morse Ave	Kaw Dr
067-100-3ST-010	37.69301	−95.45266	Chanute	Neosho	Santa Fe Ave	Spruce Ave
063-130-3ST-011	37.02879	−95.61578	Coffeyville	Montgomery	Walnut St	14th St
097-134-3ST-012	39.38693	−101.0365	Colby	Thomas	Country Club Dr	Pine St
046-141-3ST-013	38.97823	−94.95575	De Soto	Johnson	Kill Creek Rd	83rd St
087-139-3ST-014	37.56615	−97.27127	Derby	Sedgwick	Buckner St	Red Powell Dr
087-139-3ST-015	37.53271	−97.26169	Derby	Sedgwick	Woodlawn Blvd	Chet Smith Ave
087-139-3ST-016	37.55571	−97.25655	Derby	Sedgwick	Brook Forest Rd	James St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
029-170-3ST-017	37.75267	−100.017	Dodge City	Ford	Central Ave	Wyatt Earp Blvd
029-170-3ST-018	37.7522	−99.99666	Dodge City	Ford	Avenue P	Wyatt Earp Blvd
029-170-3ST-019	37.76916	−100.0165	Dodge City	Ford	Central Ave	Morgan Blvd
008-180-3ST-020	37.8211	−96.84841	El Dorado	Butler	Vine St	3rd Ave
008-180-3ST-021	37.82478	−96.85899	El Dorado	Butler	Topeka St	6th St
056-190-3ST-022	38.42686	−96.22617	Emporia	Lyon	Graphics Arts Rd	24th Ave
056-190-3ST-023	38.41961	−96.19834	Emporia	Lyon	Lincoln St	18th Ave
056-190-3ST-024	38.41958	−96.20773	Emporia	Lyon	Prairie St	18th Ave
006-210-3ST-025	37.84704	−94.70737	Fort Scott	Bourbon	National Ave	Humboltd St
046-202-3ST-027	38.82548	−94.90904	Gardner	Johnson	Moonlight Rd	167th St
005-280-3ST-028	38.37066	−98.79283	Great Bend	Barton	McKinley St	19th St
005-280-3ST-029	38.35546	−98.76508	Great Bend	Barton	Main St	Railroad Ave
026-290-3ST-030	38.86286	−99.31801	Hays	Ellis	Vine St	6th St
026-290-3ST-031	38.86391	−99.31803	Hays	Ellis	Vine St	7th St
026-290-3ST-032	38.86474	−99.33548	Hays	Ellis	Main St	Elm St
087-244-3ST-033	37.57052	−97.33403	Haysville	Sedgwick	Broadway St	Kay St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-244-3ST-034	37.56439	−97.34411	Haysville	Sedgwick	Jane St	Grand Ave
078-350-3ST-035	38.04868	−97.90379	Hutchinson	Reno	Loraine St	Carey Blvd
078-350-3ST-036	38.07226	−97.8791	Hutchinson	Reno	Apple Ln	17th Ave
078-350-3ST-037	38.06844	−97.9131	Hutchinson	Reno	Severance St	14th St
078-350-3ST-038	38.08646	−97.87903	Hutchinson	Reno	Apple Ln	30th Ave
063-360-3ST-039	37.21878	−95.69293	Independence	Montgomery	Cement St	Poplar St
001-370-3ST-040	37.92837	−95.40903	Iola	Allen	State St	Lincoln St
031-380-3ST-041	39.03003	−96.85418	Junction City	Geary	Rucker Rd	8th St
031-380-3ST-042	39.01572	−96.83145	Junction City	Geary	Jefferson St	Ash St
031-380-3ST-043	39.01111	−96.83504	Junction City	Geary	Madison St	Skyline Dr
105-390-3ST-044	39.10943	−94.67414	Kansas City	Wyandotte	38th St	Orville Ave
023-420-3ST-045	38.92812	−95.27346	Lawrence	Douglas	Lawrence Ave	31st St
023-420-3ST-046	38.92866	−95.27866	Lawrence	Douglas	Lawrence Trfwy Trail	31st St
023-420-3ST-047	38.98104	−95.31187	Lawrence	Douglas	Dole Dr	Wakarusa Dr
023-420-3ST-048	38.97355	−95.29763	Lawrence	Douglas	Folks Rd	Overland Dr
023-420-3ST-049	38.98608	−95.26052	Lawrence	Douglas	Iowa St	Peterson Rd

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
023-420-3ST-050	38.97693	−95.26079	Lawrence	Douglas	McDonald Dr	4th St
052-430-3ST-051	39.29601	−94.90897	Leavenworth	Leavenworth	4th St	Thornton St
052-430-3ST-053	39.29516	−94.90407	Leavenworth	Leavenworth	2nd St	Marion St
052-430-3ST-054	39.32849	−94.91758	Leavenworth	Leavenworth	5th St	Metropolitan Ave
046-299-3ST-055	38.92211	−94.65779	Leawood	Johnson	Lamar Ave	115th St
088-440-3ST-056	37.07207	−100.9202	Liberal	Seward	Kansas Ave	US-83
088-440-3ST-057	37.05377	−100.9043	Liberal	Seward	US-83	15th St
081-460-3ST-058	39.19288	−96.60749	Manhattan	Riley	Browning Ave	Claflin Rd
081-460-3ST-059	39.19661	−96.59814	Manhattan	Riley	College Ave	Dickens Ave
081-460-3ST-060	39.17962	−96.58899	Manhattan	Riley	Sunset Ave	Poyntz Ave
081-460-3ST-061	39.19531	−96.56183	Manhattan	Riley	Tuttle Creek Blvd	Ehlers Rd
081-460-3ST-062	39.18365	−96.57824	Manhattan	Riley	14th St	Fremont St
059-480-3ST-063	38.36217	−97.6582	McPherson	McPherson	Hartup St	Avenue A
059-480-3ST-064	38.37675	−97.63983	McPherson	McPherson	Baer St	1st St
087-391-3ST-065	37.48996	−97.24456	Mulvane	Sedgwick	Rock Rd	111th St
040-500-3ST-066	38.05005	−97.31836	Newton	Harvey	Spencer Rd	Broadway St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
040-500-3ST-067	38.04278	−97.3593	Newton	Harvey	Grandview Ave	1st St
046-520-3ST-068	38.92728	−94.86084	Olathe	Johnson	Valley Pkwy	College Blvd
046-520-3ST-069	38.91289	−94.81607	Olathe	Johnson	Woodland Rd	119th St
046-520-3ST-070	38.9119	−94.80793	Olathe	Johnson	Nelson Rd	Northgate Ave
046-520-3ST-071	38.88358	−94.81601	Olathe	Johnson	Woodland Rd	Santa Fe St
046-520-3ST-072	38.87894	−94.77955	Olathe	Johnson	Mur-Len Rd	Willow Dr
030-540-3ST-073	38.59386	−95.27701	Ottawa	Franklin	Ash St	15th St
030-540-3ST-074	38.59025	−95.27256	Ottawa	Franklin	Elm St	17th St
046-614-3ST-075	38.96314	−94.68631	Overland Park	Johnson	Antoich Rd	91st Terrace
050-560-3ST-076	37.33453	−95.28557	Parsons	Labette	32nd St	Appleton St
019-570-3ST-077	37.45152	−94.70507	Pittsburg	Crawford	Parkview Dr	Leighton St
019-570-3ST-078	37.39999	−94.68687	Pittsburg	Crawford	Rouse St	Jefferson St
046-457-3ST-079	38.98533	−94.60986	Prairie Village	Johnson	Cambridge St	Somerset Dr
076-580-3ST-080	37.64582	−98.72128	Pratt	Pratt	Country Club Rd	1st St
046-482-3ST-081	39.03972	−94.63837	Roeland Park	Johnson	Roe Ln	Elledge Dr
085-600-3ST-082	38.82718	−97.5785	Salina	Saline	Seitz Dr	Crawford St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
085-600-3ST-083	38.78944	−97.59432	Salina	Saline	Ohio St	Neal Ave
085-600-3ST-084	38.79863	−97.60334	Salina	Saline	Quincy St	Belmont Blvd
085-600-3ST-085	38.81057	−97.61283	Salina	Saline	9th St	Charlotte Ave
085-600-3ST-086	38.81993	−97.63115	Salina	Saline	Cherokee Dr	Republic Ave
046-513-3ST-087	39.01482	−94.74249	Shawnee	Johnson	Pflumm Rd	63rd St
089-610-3ST-088	39.0434	−95.78021	Topeka	Shawnee	SW Urish Rd	SW Huntoon St
089-610-3ST-089	39.01451	−95.77371	Topeka	Shawnee	SW Kingsrow Rd	SW 29th St
089-610-3ST-090	39.01463	−95.7575	Topeka	Shawnee	SW Westport Dr	SW 29th St
089-610-3ST-091	39.01814	−95.72502	Topeka	Shawnee	SW Gage Blvd	SW Shunga Dr
089-610-3ST-092	39.01179	−95.72816	Topeka	Shawnee	SW Gage Blvd	SW Twilight Dr
089-610-3ST-093	39.01506	−95.71158	Topeka	Shawnee	SW Randolph Ave	SW 29th St
089-610-3ST-094	39.025	−95.71099	Topeka	Shawnee	SW Randolph Ave	SW Shunga Dr
089-610-3ST-095	39.02467	−95.69692	Topeka	Shawnee	SW Washburn Ave	SW Shunga Dr
089-610-3ST-096	39.05489	−95.7247	Topeka	Shawnee	SW Gage Blvd	SW 8th Ave
089-610-3ST-097	39.06374	−95.70619	Topeka	Shawnee	NW MacVicar Ave	NW 1st Ave
089-610-3ST-098	39.02978	−95.6442	Topeka	Shawnee	SE Golden Ave	SE 21st St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
089-610-3ST-099	39.02976	−95.64187	Topeka	Shawnee	SE Highland Ave	SE 21st St
034-555-3ST-100	37.58372	−101.3453	Ulysses	Grant	Stubbs St	Nebraska Ave
087-558-3ST-101	37.82499	−97.37199	Valley Center	Sedgwick	Meridian Ave	77th St
096-620-3ST-102	37.25308	−97.40366	Wellington	Sumner	Hoover Rd	Botkin St
018-640-3ST-103	37.24379	−96.96923	Winfield	Cowley	Viking Blvd	9th Ave
018-640-3ST-104	37.22884	−96.96965	Winfield	Cowley	Wheat Rd	19th Ave
087-630-3ST-105	37.59362	−97.31586	Wichita	Sedgwick	Hydraulic St	55th St
087-630-3ST-106	37.64052	−97.29879	Wichita	Sedgwick	Hillside St	Ross Pkwy
087-630-3ST-107	37.6448	−97.29876	Wichita	Sedgwick	Hillside St	Roseberry St
087-630-3ST-108	37.63504	−97.31712	Wichita	Sedgwick	Hydraulic St	31st St
087-630-3ST-109	37.65031	−97.34329	Wichita	Sedgwick	Palisade St	Pawnee St
087-630-3ST-110	37.65878	−97.35275	Wichita	Sedgwick	Seneca St	May St
087-630-3ST-111	37.66958	−97.34528	Wichita	Sedgwick	McLean Blvd	Walker St
087-630-3ST-112	37.72285	−97.36709	Wichita	Sedgwick	Sweetbriar St	21st St
087-630-3ST-113	37.72276	−97.35391	Wichita	Sedgwick	Hood St	21st St
087-630-3ST-114	37.73021	−97.28065	Wichita	Sedgwick	Oliver St	25th St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-630-3ST-115	37.73344	−97.28065	Wichita	Sedgwick	Oliver St	Greenbriar Ln
087-630-3ST-116	37.70836	−97.27259	Wichita	Sedgwick	Edgemoor St	13th St
087-630-3ST-117	37.65736	−97.26214	Wichita	Sedgwick	Woodlawn St	Mt Vernon St
089-610-3ST-118	39.00732	−95.70159	Topeka	Shawnee	SW Burlingame Rd	SW 33rd St
008-623-3ST-119	37.7029	−97.13515	Andover	Butler	Andover Rd	10th St
015-150-3ST-120	39.56055	−97.64834	Concordia	Cloud	Hill St	E 17th St
023-178-3ST-121	38.94231	−95.11177	Eudora	Douglas	Winchester Rd	N 1400th Rd
028-240-3ST-122	37.98944	−100.8527	Garden City	Finney	Pearly Jane Ave	Mary St
028-240-3ST-123	37.97492	−100.8507	Garden City	Finney	Nelson St	Kansas Ave
046-202-3ST-124	38.82209	−94.909	Gardner	Johnson	Moonlight Rd	Parma way
046-202-3ST-125	38.81645	−94.91382	Gardner	Johnson	Alder St	Madison St
005-280-3ST-126	38.37632	−98.77198	Great Bend	Barton	Odell St	24th St
105-390-3ST-127	39.11115	−94.62679	Kansas City	Wyandotte	7th St	Sandusky Ave
105-390-3ST-128	39.10769	−94.62681	Kansas City	Wyandotte	7th St	Ohio Ave
105-390-3ST-129	39.10033	−94.62618	Kansas City	Wyandotte	7th St	Sumner Ave
105-390-3ST-130	39.10315	−94.64184	Kansas City	Wyandotte	S Valley St	Central Ave

Table B.1 Continued						
Intersection ID	**Latitude**	**Longitude**	**City**	**County**	**North/ Southbound**	**East/ Westbound**
105-390-3ST-131	39.14291	−94.68723	Kansas City	Wyandotte	47th St	Leavenworth Rd
105-390-3ST-132	39.14289	−94.69569	Kansas City	Wyandotte	Welborn St	Leavenworth Rd
105-390-3ST-133	39.14293	−94.66258	Kansas City	Wyandotte	30th St	Brown Ave
105-390-3ST-134	39.14007	−94.65805	Kansas City	Wyandotte	26th St	Quindaro Blvd
105-390-3ST-135	39.13645	−94.65928	Kansas City	Wyandotte	27th St	Longwood Ave
105-390-3ST-136	39.13096	−94.65949	Kansas City	Wyandotte	27th St	Waverly Ave
105-390-3ST-137	39.13746	−94.6461	Kansas City	Wyandotte	16th St	Quindaro Blvd
105-390-3ST-138	39.08744	−94.6295	Kansas City	Wyandotte	8th St	Kansas Ave
105-390-3ST-139	39.08056	−94.6399	Kansas City	Wyandotte	12th St	Cheyenne Ave
105-390-3ST-140	39.079	−94.63989	Kansas City	Wyandotte	12th St	Pawnee St
052-622-3ST-141	39.25215	−94.91896	Lansing	Leavenworth	Desoto Rd	Ida St
052-622-3ST-142	39.24165	−94.90024	Lansing	Leavenworth	Main St	Olive St
023-420-3ST-143	38.96379	−95.23472	Lawrence	Douglas	New Hampshire St	11th St
023-420-3ST-144	38.94823	−95.2418	Lawrence	Douglas	Louisiana St	20th St
023-420-3ST-145	38.96066	−95.26043	Lawrence	Douglas	Iowa St	University Dr
046-299-3ST-146	38.91293	−94.62541	Leawood	Johnson	Wenonga Ln	119th St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-299-3ST-147	38.91293	−94.61282	Leawood	Johnson	High Dr	119th St
046-299-3ST-148	38.89831	−94.63054	Leawood	Johnson	Mission Rd	127th St
046-305-3ST-149	38.96334	−94.72359	Lenexa	Johnson	Quivira Rd	91st Ter
046-305-3ST-150	38.96016	−94.72358	Lenexa	Johnson	Quivira Rd	93rd St
046-305-3ST-151	38.9638	−94.71743	Lenexa	Johnson	Flint St	91st St
046-305-3ST-152	38.95821	−94.74626	Lenexa	Johnson	Widmer Rd	Santa Fe Trail Dr
046-305-3ST-153	38.95921	−94.74459	Lenexa	Johnson	Park St	Santa Fe Trail Dr
046-363-3ST-154	39.0186	−94.68645	Merriam	Johnson	Antoich Rd	61st St
046-363-3ST-155	39.01494	−94.68809	Merriam	Johnson	Slater St	Shawnee Mission Pkwy
046-372-3ST-156	39.02216	−94.65741	Mission	Johnson	Horton St	Johnson Dr
046-520-3ST-157	38.88355	−94.82544	Olathe	Johnson	Iowa St	Santa Fe St
046-520-3ST-158	38.87914	−94.83447	Olathe	Johnson	Parker St	Cedar St
046-520-3ST-159	38.87276	−94.83446	Olathe	Johnson	Parker St	Sheridan St
046-520-3ST-160	38.86916	−94.82667	Olathe	Johnson	Grant St	Dennis Ave
046-520-3ST-161	38.8836	−94.80928	Olathe	Johnson	Cooper St	Santa Fe St
046-520-3ST-162	38.88624	−94.79724	Olathe	Johnson	Ridgeview Rd	Prairie St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-520-3ST-163	38.90583	−94.78217	Olathe	Johnson	Kansas City Rd	123rd St
046-520-3ST-164	38.89818	−94.79479	Olathe	Johnson	Jan-Mar Dr	Harold St
046-614-3ST-165	38.99673	−94.66769	Overland Park	Johnson	Metcalf Ave	73rd St
046-614-3ST-166	38.99311	−94.67006	Overland Park	Johnson	Marty St	75th St
046-614-3ST-167	38.98906	−94.68639	Overland Park	Johnson	Antoich Rd	77th St
046-614-3ST-168	38.97854	−94.66591	Overland Park	Johnson	Broadmoor Ln	83rd St
046-614-3ST-169	38.98581	−94.65041	Overland Park	Johnson	Maple St	79th St
046-614-3ST-170	38.98401	−94.64903	Overland Park	Johnson	Nall Ave	80th St
046-614-3ST-171	38.98177	−94.64903	Overland Park	Johnson	Nall Ave	81st Ter
046-614-3ST-172	38.99311	−94.66358	Overland Park	Johnson	Glenwood Ln	75th St
046-614-3ST-173	38.97491	−94.66767	Overland Park	Johnson	Metcalf Ave	85th St
046-614-3ST-174	38.97126	−94.67583	Overland Park	Johnson	Robinson St	87th St
046-614-3ST-175	38.94015	−94.68626	Overland Park	Johnson	Antoich Rd	104th St
046-614-3ST-176	38.94193	−94.66499	Overland Park	Johnson	Barkely St	103rd St
046-614-3ST-177	38.95666	−94.69078	Overland Park	Johnson	Kessler Ln	95th St
046-614-3ST-178	38.96393	−94.70031	Overland Park	Johnson	Farley St	91st St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-614-3ST-179	38.97407	−94.649	Overland Park	Johnson	Nall Ave	85th Ter
046-614-3ST-180	38.96929	−94.67703	Overland Park	Johnson	Lowell St	88th St
061-550-3ST-181	38.57647	−94.87811	Paola	Miami	Silver St	2nd St
087-645-3ST-182	37.7959	−97.3057	Park City	Sedgwick	Upchurch Ave	61st St
046-457-3ST-183	38.98294	−94.62487	Prairie Village	Johnson	Windsor St	Somerset Dr
046-513-3ST-184	39.02197	−94.73088	Shawnee	Johnson	Long Ave	Johnson Dr
046-513-3ST-185	39.02927	−94.72976	Shawnee	Johnson	Caenen St	55th St
046-513-3ST-186	39.02272	−94.70813	Shawnee	Johnson	Melrose Ln	Johnson Dr
046-513-3ST-187	39.02211	−94.70294	Shawnee	Johnson	Mastin St	Johnson Dr
046-513-3ST-188	39.03306	−94.71459	Shawnee	Johnson	Nieman Rd	53rd St
046-524-3ST-189	38.74782	−94.82561	Spring Hill	Johnson	Webster St	King St
087-630-3ST-190	37.6729	−97.24446	Wichita	Sedgwick	Rock Rd	Watson Rd
087-630-3ST-191	37.65009	−97.2839	Wichita	Sedgwick	Terrace Dr	Pawnee St
087-630-3ST-192	37.65736	−97.28392	Wichita	Sedgwick	Terrace Dr	Vernon St
087-630-3ST-193	37.66466	−97.27815	Wichita	Sedgwick	Elpyco St	Harry St
087-630-3ST-194	37.66102	−97.28044	Wichita	Sedgwick	Oliver St	Funston St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-630-3ST-195	37.69375	−97.29096	Wichita	Sedgwick	Quentin St	Central Ave
087-630-3ST-196	37.7083	−97.28983	Wichita	Sedgwick	Vest Dr	13th St
087-630-3ST-197	37.72458	−97.29906	Wichita	Sedgwick	Hillside St	22nd St
087-630-3ST-198	37.7226	−97.35613	Wichita	Sedgwick	Somerset St	21st St
087-630-3ST-199	37.7234	−97.35165	Wichita	Sedgwick	Salina Ave	21st St
087-630-3ST-200	37.72804	−97.33588	Wichita	Sedgwick	Broadway St	24th St
087-630-3ST-201	37.70866	−97.35506	Wichita	Sedgwick	Garland St	13th St
087-630-3ST-202	37.64969	−97.33941	Wichita	Sedgwick	Water St	Pawnee St
087-630-3ST-203	37.64997	−97.3039	Wichita	Sedgwick	Volutsia St	Pawnee St
087-630-3ST-204	37.71134	−97.26229	Wichita	Sedgwick	Woodlawn St	Abbotstord St
087-630-3ST-205	37.69987	−97.2446	Wichita	Sedgwick	Rock Rd	Kilarney St
087-630-3ST-206	37.68789	−97.44433	Wichita	Sedgwick	Tyler Rd	Rolling Hills Rd
087-630-3ST-207	37.68685	−97.44432	Wichita	Sedgwick	Tyler Rd	2nd St
087-630-3ST-208	37.67955	−97.44248	Wichita	Sedgwick	Robin Rd	Maple St
087-630-3ST-209	37.6867	−97.42606	Wichita	Sedgwick	Ridge Rd	O'Niel St
087-630-3ST-210	37.68715	−97.42609	Wichita	Sedgwick	Ridge Rd	2nd St

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-630-3ST-211	37.68837	−97.42611	Wichita	Sedgwick	Ridge Rd	Shade Ln
081-460-3ST-212	39.18788	−96.59826	Manhattan	Riley	Anderson Ave	Bellhaven Rd
081-460-3ST-213	39.18607	−96.58075	Manhattan	Riley	16th St	Anderson Ave
085-600-3ST-214	38.83738	−97.59406	Salina	Saline	Ohio St	The Midway St
026-290-3ST-215	38.88548	−99.31618	Hays	Ellis	General Hays Rd	27th St
078-350-3ST-216	38.0674	−97.92206	Hutchinson	Reno	Plum Rd	13th St
029-170-3ST-217	37.74707	−99.98843	Dodge City	Ford	Underpass Rd	Trail St
063-360-3ST-218	37.23637	−95.71694	Independence	Montgomery	Oakhurst Pl	Oak St
018-030-3ST-219	37.10774	−97.03697	Arkansas City	Cowley	Summit St/ US-77	US-77
031-380-3ST-220	39.01281	−96.83126	Junction City	Geary	Washington St	Dreiling Rd
105-390-3ST-221	39.11555	−94.65173	Kansas City	Wyandotte	Minnesota Dr	Hoel Pkwy
023-420-3ST-222	38.97155	−95.27901	Lawrence	Douglas	Frontier Rd	6th St
023-420-3ST-223	38.98319	−95.26047	Lawrence	Douglas	Iowa St	Kingston Dr
052-430-3ST-224	39.29685	−94.90893	Leavenworth	Leavenworth	4th St	Apache St
052-622-3ST-225	39.25839	−94.89999	Lansing	Leavenworth	Main St	Plaza Ln
052-622-3ST-226	39.25922	−94.89998	Lansing	Leavenworth	Main St	Holiday Dr

Table B.1 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
081-460-3ST-227	39.17412	−96.55182	Manhattan	Riley	McDowell Creek Rd	K-18
081-460-3ST-228	39.24716	−96.62298	Manhattan	Riley	Seth Child Rd	Tuttle Creek Blvd
081-460-3ST-229	39.20632	−96.56969	Manhattan	Riley	Tuttle Creek Blvd	Griffith Dr
076-580-3ST-230	37.65413	−98.73936	Pratt	Pratt	Main St/ US-281	Pitzer St
026-290-3ST-231	38.88193	−99.31782	Hays	Ellis	Vine St	Centennial Blvd
018-640-3ST-232	37.24061	−96.97948	Winfield	Cowley	High St	9th Ave
008-180-3ST-233	37.81101	−96.84984	El Dorado	Butler	US-77	Kansas Ave
008-180-3ST-234	37.84639	−96.84974	El Dorado	Butler	US-77	McCollum Rd

Table B.2: List of urban 3-leg signalized intersections used in calibration

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
018-030-3SG-001	37.09989	−97.04034	Arkansas City	Cowley	Summit St	Skyline Rd
067-100-3SG-002	37.68804	−95.45266	Chanute	Neosho	Santa Fe Ave	Cherry St
029-170-3SG-003	37.7874	−100.0241	Dodge City	Ford	6th Ave	Ross Blvd
029-170-3SG-004	37.7526	−100.0192	Dodge City	Ford	2nd Ave	Wyatt Earp Blvd
008-180-3SG-005	37.83191	−96.84944	El Dorado	Butler	Main St	12th Ave
046-202-3SG-006	38.8131	−94.90374	Gardner	Johnson	Old 56 Highway	Main St
026-290-3SG-007	38.8741	−99.31789	Hays	Ellis	Vine St	18th St
026-290-3SG-008	38.88928	−99.31772	Hays	Ellis	Vine St	29th St
078-350-3SG-009	38.06492	−97.89927	Hutchinson	Reno	Porter St	11th Ave
105-390-3SG-010	39.12844	−94.69674	Kansas City	Wyandotte	51st St	Parallel Pkwy
105-390-3SG-011	39.12473	−94.67496	Kansas City	Wyandotte	Praun Lane	Victory Dr
105-390-3SG-012	39.12405	−94.67341	Kansas City	Wyandotte	38th St	Wood Ave
105-390-3SG-013	39.12872	−94.6614	Kansas City	Wyandotte	29th St	Parallel Pkwy
023-420-3SG-014	38.95701	−95.28834	Lawrence	Douglas	Monterey Way	Bob Billings Pkwy
023-420-3SG-015	38.97284	−95.26072	Lawrence	Douglas	Iowa St	6th St
052-430-3SG-016	39.28918	−94.91389	Leavenworth	Leavenworth	2nd Ave	Limit St

Table B.2 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-614-3SG-017	38.92231	−94.66738	Overland Park	Johnson	Metcalf Ave	112th St
046-299-3SG-018	38.9056	−94.63053	Leawood	Johnson	Mission Rd	123rd St
046-299-3SG-019	38.90563	−94.60803	Leawood	Johnson	State Line Rd	123rd St
046-299-3SG-020	38.92023	−94.63973	Leawood	Johnson	Roe Ave	115th St
081-460-3SG-021	39.20647	−96.57624	Manhattan	Riley	Manhattan Ave	Kimball Ave
081-460-3SG-022	39.20384	−96.56729	Manhattan	Riley	Tuttle Creek Blvd	Allen Rd
081-460-3SG-023	39.19772	−96.56256	Manhattan	Riley	Tuttle Creek Blvd	Casement Rd
081-460-3SG-024	39.17431	−96.58435	Manhattan	Riley	17th St	Fort Riley Blvd
081-460-3SG-025	39.17648	−96.60457	Manhattan	Riley	Seth Child Rd	Farm Bureau Rd
046-363-3SG-026	39.00768	−94.68643	Merriam	Johnson	Antioch Rd	67th St
046-363-3SG-027	39.02954	−94.69233	Merriam	Johnson	Merriam Dr	55th St
087-391-3SG-028	37.47907	−97.23387	Mulvane	Sedgwick	KS-15	Lisa Ln
040-500-3SG-029	38.02708	−97.33663	Newton	Harvey	Kansas Ave	US-50 Ramp
046-520-3SG-030	38.88359	−94.81266	Olathe	Johnson	Kansas City Rd	Santa Fe St
046-614-3SG-031	38.96396	−94.68631	Overland Park	Johnson	Antioch Rd	91st St
046-614-3SG-032	38.97152	−94.69066	Overland Park	Johnson	Santa Fe Dr	87th St
046-614-3SG-033	38.97939	−94.67739	Overland Park	Johnson	Santa Fe Dr	83rd St

Table B.2 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-614-3SG-034	39.0004	−94.68643	Overland Park	Johnson	Antioch Rd	71st St
046-614-3SG-035	38.94207	−94.67689	Overland Park	Johnson	Lowell St	103rd St
019-570-3SG-036	37.43313	−94.70493	Pittsburg	Crawford	Broadway St	27th St
019-570-3SG-037	37.38185	−94.70052	Pittsburg	Crawford	Joplin St	Centennial Dr
046-457-3SG-038	38.98418	−94.61643	Prairie Village	Johnson	Belinder Rd	Somerset Dr
085-600-3SG-039	38.80492	−97.61278	Salina	Saline	9th St	Otto Ave
085-600-3SG-040	38.8074	−97.61265	Salina	Saline	9th St	Broadway Blvd
085-600-3SG-041	38.7983	−97.63436	Salina	Saline	Centennial Rd	Magnolia Rd
046-513-3SG-042	39.01482	−94.70389	Shawnee	Johnson	Mastin St	Shawnee Mission Pkwy
089-610-3SG-043	39.01516	−95.63298	Topeka	Shawnee	West Edge Rd	29th St
089-610-3SG-044	38.98531	−95.68766	Topeka	Shawnee	SW Topeka Blvd	SW 45th St
018-640-3SG-045	37.22512	−96.99559	Winfield	Cowley	US-77	KS-360
018-640-3SG-046	37.24065	−96.97831	Winfield	Cowley	College St	9th Ave
087-630-3SG-047	37.73759	−97.28062	Wichita	Sedgwick	Oliver St	29th St
087-630-3SG-048	37.71566	−97.28064	Wichita	Sedgwick	Oliver St	17th St
087-630-3SG-049	37.68656	−97.22618	Wichita	Sedgwick	Webb Rd	Douglas Ave

Table B.2 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-630-3SG-050	37.67197	−97.24445	Wichita	Sedgwick	Rock Rd	Lincoln St
087-630-3SG-051	37.63509	−97.29883	Wichita	Sedgwick	Hillside St	31st St
087-630-3SG-052	37.72265	−97.35956	Wichita	Sedgwick	Woodrow Ave	21st St
087-630-3SG-053	37.72257	−97.34201	Wichita	Sedgwick	Waco St	21st St
087-630-3SG-054	37.72264	−97.32768	Wichita	Sedgwick	Mosley St	21st St
087-630-3SG-055	37.71704	−97.40308	Wichita	Sedgwick	Zoo Blvd	Windmill Rd
087-630-3SG-056	37.69323	−97.35278	Wichita	Sedgwick	Seneca St	Museum Blvd
087-630-3SG-057	37.63714	−97.33438	Wichita	Sedgwick	Broadway St	31st St
089-610-3SG-058	39.00936	−95.69948	Topeka	Shawnee	SW Burlingame Rd	SW Clontarf St
089-610-3SG-059	39.00816	−95.70076	Topeka	Shawnee	SW Burlingame Rd	SW 33rd St
089-610-3SG-060	39.02936	−95.73573	Topeka	Shawnee	SW Eveningside Dr	SW 21st St
089-610-3SG-061	39.0292	−95.74783	Topeka	Shawnee	SW Chelsea Dr	SW 21st St
089-610-3SG-062	39.04853	−95.68574	Topeka	Shawnee	SW Taylor St	SW 10th Ave
089-610-3SG-063	39.05133	−95.67184	Topeka	Shawnee	SE Quincy Ave	SE 6th St
105-064-4SG-064	39.05608	−94.88076	Bonner Springs	Wyandotte	E Front St	Cedar St
029-170-3SG-065	37.75272	−100.0215	Dodge City	Ford	4th Ave	Wyatt Earp Blvd
028-240-3SG-066	37.98943	−100.8414	Garden City	Finney	Buffalo Way Blvd	Mary St

Table B.2 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
026-290-3SG-067	38.89277	−99.31768	Hays	Ellis	Vine St	33rd St
078-350-3SG-068	38.07205	−97.91786	Hutchinson	Reno	Cleveland St	17th Ave
105-390-3SG-069	39.11457	−94.62684	Kansas City	Wyandotte	7th St	Armstrong Ave
105-390-3SG-070	39.10255	−94.64011	Kansas City	Wyandotte	12th St	Central Ave
105-390-3SG-071	39.1401	−94.65911	Kansas City	Wyandotte	27th St	Quindaro Blvd
105-390-3SG-072	39.11534	−94.67323	Kansas City	Wyandotte	38th St	Minnesota Ave
105-390-3SG-073	39.08543	−94.7053	Kansas City	Wyandotte	55th St	Inland Dr
105-390-3SG-074	39.08943	−94.69599	Kansas City	Wyandotte	51st St	Kansas Ave
105-390-3SG-075	39.07513	−94.66367	Kansas City	Wyandotte	30th St	Strong Ave
105-390-3SG-076	39.07311	−94.65706	Kansas City	Wyandotte	24th St	Metropolitan Ave
023-420-3SG-077	38.96751	−95.25117	Lawrence	Douglas	Emery St	9th St
046-305-3SG-078	38.97104	−94.73873	Lenexa	Johnson	Hauser Ct	87th St Pkwy
046-305-3SG-079	38.97105	−94.77219	Lenexa	Johnson	Maurer Rd	87th St Pkwy
046-520-3SG-080	38.87184	−94.83449	Olathe	Johnson	Parker St	Virginia Lane
046-520-3SG-081	38.88203	−94.82069	Olathe	Johnson	Kansas Ave	Park St
046-520-3SG-082	38.86768	−94.81318	Olathe	Johnson	Public Safety	Old 56 Highway
046-520-3SG-083	38.91288	−94.7832	Olathe	Johnson	Barney Blvd	199th St

Table B.2 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-520-3SG-084	38.90919	−94.77458	Olathe	Johnson	Strang Line Rd	121st Ter
046-520-3SG-085	38.90358	−94.77967	Olathe	Johnson	Strang Line Rd	Rogers Rd
096-620-3SG-086	37.27162	−97.38516	Wellington	Sumner	Woodlawn St	Crusader St
031-380-3SG-087	39.09218	−96.8648	Junction City	Geary	US-77	Old Highway 77
081-460-3SG-088	39.17346	−96.59057	Manhattan	Riley	Westwood Dr	Fort Riley Blvd
081-460-3SG-089	39.1892	−96.54456	Manhattan	Riley	Poyntz Ave	McCall Ave

Table B.3: List of 4-leg unsignalized intersections with stop control on the minor approach used in calibration

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
021-010-4ST-001	38.92981	−97.21661	Abilene	Dickinson	Cedar St	14th St
021-010-4ST-002	38.92161	−97.21657	Abilene	Dickinson	Cedar St	7th St
008-623-4ST-003	37.66492	−97.13535	Andover	Butler	Andover Rd	Harry St
008-623-4ST-004	37.65031	−97.13535	Andover	Butler	Butler Rd	120th St
018-030-4ST-005	37.05639	−97.03771	Arkansas City	Cowley	A St	Madison Ave
018-030-4ST-006	37.05635	−97.04888	Arkansas City	Cowley	8th St	Madison Ave
003-040-4ST-007	39.57194	−95.11904	Atchison	Atchison	5th St	Division St
008-050-4ST-008	37.68027	−96.97403	Augusta	Butler	Dearborn St	Main St
052-636-4ST-009	39.12867	−94.93854	Basehor	Leavenworth	155th St	Parallel Rd
087-644-4ST-010	37.78142	−97.24507	Bel Aire	Sedgwick	Rock Rd	53rd St
105-064-4ST-011	39.07246	−94.90055	Bonner Springs	Wyandotte	138th St	Metropolitan Ave
067-100-4ST-012	37.68812	−95.45671	Chanute	Neosho	Steuben Ave	Cherry St
063-130-4ST-013	37.02888	−95.62073	Coffeyville	Montgomery	Old Willow St	14th St
097-134-4ST-014	39.37975	−101.0366	Colby	Thomas	Country Club Dr	College Dr
015-150-4ST-015	39.57263	−97.6648	Concordia	Cloud	Cedar St	5th St

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-141-4ST-016	38.97814	−94.9651	De Soto	Johnson	Wyandotte St	83rd St
087-139-4ST-017	37.57012	−97.27122	Derby	Sedgwick	Buckner St	Tall Tree Rd
087-139-4ST-018	37.54791	−97.26878	Derby	Sedgwick	Georgie Ave	Madison Ave
087-139-4ST-019	37.54427	−97.26213	Derby	Sedgwick	Woodlawn Blvd	Market St
029-170-4ST-020	37.75388	−99.99662	Dodge City	Ford	Avenue P	Military Ave
029-170-4ST-021	37.77141	−100.0521	Dodge City	Ford	US-50	Matt Down Ln
029-170-4ST-022	37.77964	−99.97911	Dodge City	Ford	113 Rd	US-50
008-180-4ST-023	37.81742	−96.87031	El Dorado	Butler	Arthur St	Central Ave
008-180-4ST-024	37.81739	−96.86843	El Dorado	Butler	Orchard St	Central Ave
056-190-4ST-025	38.40502	−96.18525	Emporia	Lyon	State St	6th Ave
056-190-4ST-026	38.4001	−96.17889	Emporia	Lyon	Mechanic St	2nd Ave
056-190-4ST-027	38.3977	−96.17098	Emporia	Lyon	East St	South Ave
023-178-4ST-028	38.92649	−95.09351	Eudora	Douglas	Church St	20th St
006-210-4ST-029	37.84192	−94.69821	Fort Scott	Bourbon	Margrave St	Wall St
028-240-4ST-030	37.9677	−100.8545	Garden City	Finney	Fleming St	Spruce St
028-240-4ST-031	37.98952	−100.8694	Garden City	Finney	Main St	Mary St
028-240-4ST-032	37.96772	−100.8682	Garden City	Finney	4th St	Pine St

Table B.3 Continued						
Intersection ID	**Latitude**	**Longitude**	**City**	**County**	**North/ Southbound**	**East/ Westbound**
046-202-4ST-033	38.8256	−94.92764	Gardner	Johnson	Center St	167th St
046-202-4ST-034	38.82572	−94.94586	Gardner	Johnson	Waverly St	167th St
005-280-4ST-035	38.36644	−98.78359	Great Bend	Barton	Harrison St	Broadway Ave
005-280-4ST-036	38.36652	−98.76923	Great Bend	Barton	Morton St	Broadway Ave
026-290-4ST-037	38.87159	−99.3247	Hays	Ellis	Allen St	13th St
026-290-4ST-038	38.86861	−99.32675	Hays	Ellis	Allen St	8th St
026-290-4ST-039	38.88547	−99.32213	Hays	Ellis	Main St	27th St
087-244-4ST-040	37.54986	−97.33394	Haysville	Sedgwick	79th St	Broadway St
087-244-4ST-041	37.56439	−97.33978	Haysville	Sedgwick	Marlen Dr	Grand Ave
078-350-4ST-042	38.051	−97.91302	Hutchinson	Reno	Severance St	Avenue A
078-350-4ST-043	38.04306	−97.90375	Hutchinson	Reno	Lorraine St	Avenue G
078-350-4ST-044	38.10106	−97.92205	Hutchinson	Reno	Plum St	43rd Ave
078-350-4ST-045	38.0716	−97.95898	Hutchinson	Reno	Hendricks St	17th Ave
063-360-4ST-046	37.21891	−95.71085	Independence	Montgomery	10th St	Poplar St
001-370-4ST-047	37.94399	−95.409	Iola	Allen	State St	Miller Rd
031-380-4ST-048	39.04453	−96.86926	Junction City	Geary	US-77	Rucker Rd
031-380-4ST-049	39.01572	−96.83906	Junction City	Geary	Webster St	Ash St

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
031-380-4ST-050	39.04159	−96.83143	Junction City	Geary	Jefferson St	18th St
105-390-4ST-051	39.07276	−94.66644	Kansas City	Wyandotte	Woodland Blvd	Silver Ave
105-390-4ST-052	39.17236	−94.90053	Kansas City	Wyandotte	139th St	Hollingsworth Rd
105-390-4ST-053	39.15785	−94.90068	Kansas City	Wyandotte	139th St	Donahoo Rd
105-390-4ST-054	39.17225	−94.82669	Kansas City	Wyandotte	107th St	Hollingsworth Rd
105-390-4ST-055	39.11609	−94.87238	Kansas City	Wyandotte	126th St	State Ave
105-390-4ST-056	39.11035	−94.85241	Kansas City	Wyandotte	118th St	Speedway Blvd
105-390-4ST-057	39.14311	−94.77104	Kansas City	Wyandotte	83rd St	Leavenworth Rd
052-622-4ST-058	39.23768	−94.91904	Lansing	Leavenworth	147th St	4-H Rd
052-622-4ST-059	39.23065	−94.90014	Lansing	Leavenworth	Main St	Gilman Rd
023-420-4ST-060	38.97516	−95.31636	Lawrence	Douglas	Queens Rd	Overland Dr
023-420-4ST-061	38.92247	−95.27876	Lawrence	Douglas	1200 Rd	1260 Rd
023-420-4ST-062	38.93531	−95.22343	Lawrence	Douglas	Haskell Ave	27th St
023-420-4ST-063	38.94644	−95.2359	Lawrence	Douglas	Massachusetts St	21st St
023-420-4ST-064	38.95699	−95.23588	Lawrence	Douglas	Massachusetts St	15th St
023-420-4ST-065	38.98238	−95.22388	Lawrence	Douglas	7th St	Lyon St
023-420-4ST-066	38.98602	−95.22393	Lawrence	Douglas	7th St	North St

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
023-420-4ST-067	38.96431	−95.24756	Lawrence	Douglas	Maine St	Fambrough Dr
052-430-4ST-068	39.31751	−94.95069	Leavenworth	Leavenworth	20th St	Shawnee St
052-430-4ST-069	39.32238	−94.95063	Leavenworth	Leavenworth	20th St	Ottawa St
052-430-4ST-070	39.30079	−94.91761	Leavenworth	Leavenworth	5th Ave	Pennsylvania Ave
052-430-4ST-071	39.29586	−94.91838	Leavenworth	Leavenworth	Maple Ave	Thornton St
088-440-4ST-072	37.06853	−100.9061	Liberal	Seward	Country Estates Rd	Tucker Rd
081-460-4ST-073	39.20358	−96.62819	Manhattan	Riley	Plymouth Rd	Kimball Ave
081-460-4ST-074	39.19278	−96.61674	Manhattan	Riley	Wreath Ave	Claflin Rd
081-460-4ST-075	39.21183	−96.57494	Manhattan	Riley	Tuttle Creek Blvd	Northfield Rd
081-460-4ST-076	39.20356	−96.63136	Manhattan	Riley	Little Kitten Ave	Kimball Ave
081-460-4ST-077	39.17531	−96.57673	Manhattan	Riley	Manhattan Ave	Yuma St
059-480-4ST-078	38.39108	−97.66163	McPherson	McPherson	Grimes St	Northview Rd
059-480-4ST-079	38.36939	−97.67605	McPherson	McPherson	Hickory St	Kansas Ave
087-391-4ST-080	37.47477	−97.23869	Mulvane	Sedgwick	College Ave	Main St
040-500-4ST-081	38.07179	−97.34524	Newton	Harvey	Main St	24th St
040-500-4ST-082	38.04993	−97.33531	Newton	Harvey	High St	Broadway St
030-540-4ST-083	38.60475	−95.26592	Ottawa	Franklin	Cedar St	9th St

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
030-540-4ST-084	38.60849	−95.26589	Ottawa	Franklin	Cedar St	7th St
030-540-4ST-085	38.6085	−95.27712	Ottawa	Franklin	Ash St	7th St
061-550-4ST-086	38.5634	−94.85443	Paola	Miami	Hedge Ln	311 Rd
087-645-4ST-087	37.7959	−97.2992	Park City	Sedgwick	Hillside St	61st St
050-560-4ST-088	37.32555	−95.28571	Parsons	Labette	Ness Rd	Southern Ave
019-570-4ST-089	37.41689	−94.68668	Pittsburg	Crawford	Rouse St	10th St
019-570-4ST-090	37.41118	−94.71868	Pittsburg	Crawford	Georgia St	4th St
076-580-4ST-091	37.64608	−98.74603	Pratt	Pratt	Mound St	1st St
076-580-4ST-092	37.64599	−98.73684	Pratt	Pratt	Oak St	1st St
085-600-4ST-093	38.82719	−97.62107	Salina	Saline	Montrose St	Crawford St
085-600-4ST-094	38.84895	−97.60903	Salina	Saline	Santa Fe Ave	North St
085-600-4ST-095	38.84289	−97.61986	Salina	Saline	College Ave	Ash St
085-600-4ST-096	38.84038	−97.5759	Salina	Saline	Marymount Rd	Iron Ave
085-600-4ST-097	38.84282	−97.59399	Salina	Saline	Ohio St	Ash St
034-555-4ST-098	37.58372	−101.3543	Ulysses	Grant	Missouri St	Nebraska Ave
034-555-4ST-099	37.59101	−101.3453	Ulysses	Grant	Rock Rd	Patterson Ave
087-558-4ST-100	37.83901	−97.35396	Valley Center	Sedgwick	Seneca St	85th St

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
096-620-4ST-101	37.26467	−97.39797	Wellington	Sumner	Washington Ave	Lincoln Ave
018-640-4ST-102	37.24167	−96.97833	Winfield	Cowley	College St	8th Ave
018-640-4ST-103	37.24476	−96.95085	Winfield	Cowley	JP Brant Rd	9th Ave
089-610-4ST-104	38.97153	−95.68769	Topeka	Shawnee	Topeka Blvd	53rd St
089-610-4ST-105	39.01439	−95.8167	Topeka	Shawnee	Auburn Rd	29th St
089-610-4ST-106	39.02885	−95.81667	Topeka	Shawnee	Auburn Rd	21st St
089-610-4ST-107	39.10229	−95.66466	Topeka	Shawnee	Topeka Blvd	Menninger Rd
089-610-4ST-108	39.10943	−95.6732	Topeka	Shawnee	Rochester Rd	35th St
089-610-4ST-109	39.02242	−95.68534	Topeka	Shawnee	Topeka Blvd	27th St
089-610-4ST-110	39.05883	−95.67024	Topeka	Shawnee	Kansas Ave	1st Ave
089-610-4ST-111	39.06616	−95.64092	Topeka	Shawnee	Chester Ave	Sardou Ave
089-610-4ST-112	39.06252	−95.64106	Topeka	Shawnee	Chester Ave	Division St
089-610-4ST-113	39.0458	−95.65067	Topeka	Shawnee	California Ave	6th Ave
089-610-4ST-114	39.04893	−95.64376	Topeka	Shawnee	Golden Ave	4th St
089-610-4ST-115	39.00406	−95.67042	Topeka	Shawnee	Adams St	35th St
087-630-4ST-116	37.74486	−97.33596	Wichita	Sedgwick	Broadway St	33rd St N
087-630-4ST-117	37.73345	−97.34483	Wichita	Sedgwick	Arkansas Ave	27th St N

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-630-4ST-118	37.7298	−97.35168	Wichita	Sedgwick	Salina St	25th St N
087-630-4ST-119	37.71714	−97.33558	Wichita	Sedgwick	Broadway St	18th St N
087-630-4ST-120	37.73004	−97.29907	Wichita	Sedgwick	Hillside St	25th St N
087-630-4ST-121	37.70834	−97.28291	Wichita	Sedgwick	Pershing St	13th St N
087-630-4ST-122	37.70108	−97.28055	Wichita	Sedgwick	Oliver St	9th St N
087-630-4ST-123	37.7011	−97.26221	Wichita	Sedgwick	Woodlawn St	9th St N
087-630-4ST-124	37.68271	−97.29891	Wichita	Sedgwick	Hillside St	Waterman St
087-630-4ST-125	37.66426	−97.34324	Wichita	Sedgwick	Palisade St	Harry St
087-630-4ST-126	37.75143	−97.48081	Wichita	Sedgwick	119th St W	37th St N
087-630-4ST-127	37.66909	−97.422119	Wichita	Sedgwick	Airport Rd	Pueblo Dr
087-630-4ST-128	37.64634	−97.4618	Wichita	Sedgwick	Maize Rd	Yosemite Dr
087-630-4ST-129	37.65001	−97.48081	Wichita	Sedgwick	119th St W	Pawnee St
087-630-4ST-130	37.69303	−97.53498	Wichita	Sedgwick	167th St W	4th St N
087-630-4ST-131	37.69458	−97.40775	Wichita	Sedgwick	Hoover Rd	Central Ave
087-630-4ST-132	37.69461	−97.4048	Wichita	Sedgwick	Elder St	Central Ave
087-630-4ST-133	37.6947	−97.3986	Wichita	Sedgwick	Anna St	Central Ave
087-630-4ST-134	37.71601	−97.38971	Wichita	Sedgwick	West St	17th St N

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-630-4ST-135	37.72118	−97.4074	Wichita	Sedgwick	Hoover Rd	Zoo Blvd
087-630-4ST-136	37.72306	−97.37555	Wichita	Sedgwick	Hyacinth Ln	21st St N
087-630-4ST-137	37.66975	−97.35287	Wichita	Sedgwick	Seneca St	Walker St
087-630-4ST-138	37.66948	−97.37107	Wichita	Sedgwick	Meridian Ave	Walker St
087-630-4ST-139	37.63692	−97.36194	Wichita	Sedgwick	Glenn Ave	31st St W
087-630-4ST-140	37.64421	−97.35263	Wichita	Sedgwick	Seneca St	27th St S
087-630-4ST-141	37.63334	−97.35259	Wichita	Sedgwick	Seneca St	33rd St S
087-630-4ST-142	37.61157	−97.35232	Wichita	Sedgwick	Seneca St	45th St S
087-630-4ST-143	37.59151	−97.28468	Wichita	Sedgwick	KS-15	55th St S
087-630-4ST-144	37.78133	−97.35423	Wichita	Sedgwick	Seneca St	53rd St N
087-630-4ST-145	37.64415	−97.37086	Wichita	Sedgwick	Meridian Ave	27th St S
087-630-4ST-146	37.70107	−97.27141	Wichita	Sedgwick	Edgemoor St	9th St N
081-460-4ST-147	39.20408	−96.55735	Manhattan	Riley	Casement Rd	Allen Rd
081-460-4ST-148	39.1964	−96.60748	Manhattan	Riley	Browning Ave	Dickens Ave
018-030-4ST-149	37.05632	−97.02773	Arkansas City	Cowley	US-77	Madison Ave
018-030-4ST-150	37.06351	−97.02789	Arkansas City	Cowley	US-77	Chestnut Ave
003-040-4ST-151	39.54707	−95.12952	Atchison	Atchison	US-73	Green St

Table B.3 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
003-040-4ST-152	39.55432	−95.15294	Atchison	Atchison	US-73	US-59
008-050-4ST-153	37.67756	−96.98019	Augusta	Butler	US-77/Walnut St	6th Ave
087-644-4ST-154	37.79602	−97.24508	Bel Aire	Sedgwick	Rock Road	K-254
087-644-4ST-155	37.7961	−97.22673	Bel Aire	Sedgwick	Webb Rd	K-254
063-130-4ST-156	37.03591	−95.60015	Coffeyville	Montgomery	US-166	8th St
029-170-4ST-157	37.72934	−99.97921	Dodge City	Ford	US-283	Lariat Way
005-280-4ST-158	38.37444	−98.81096	Great Bend	Barton	Patton Rd	K-96
063-360-4ST-159	37.22336	−95.71996	Independence	Montgomery	17th St	Main St/US-160
031-380-4ST-160	39.00225	−96.86302	Junction City	Geary	US-77	Golden Belt Blvd
052-430-4ST-161	39.32699	−94.91565	Leavenworth	Leavenworth	4th St/US-73	Pawnee St
081-460-4ST-162	39.24739	−96.60542	Manhattan	Riley	K-13	US-24
081-460-4ST-163	39.22183	−96.61851	Manhattan	Riley	Seth Child Rd/K-113	Marlatt Ave
019-570-4ST-164	37.36755	−94.70923	Pittsburg	Crawford	US-69	520th Ave
076-580-4ST-165	37.64591	−98.72703	Pratt	Pratt	Howard St	1st St/US-400
018-640-4ST-166	37.21544	−96.99579	Winfield	Cowley	US-77	33rd Ave
087-630-4ST-167	37.61659	−97.29339	Wichita	Sedgwick	K-15	Clinton St

Table B.4: List of 4-leg signalized intersections used for calibration

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
021-010-4SG-001	38.92979	−97.21399	Abilene	Dickinson	Buckeye Ave	14th St
008-623-4SG-002	37.69401	−97.13518	Andover	Butler	Andover Rd	Central Ave
018-030-4SG-003	37.0564	−97.03897	Arkansas City	Cowley	Summit St	Madison Ave
003-040-4SG-004	39.56089	−95.13551	Atchison	Atchison	14th St	Main St
008-050-4SG-005	37.69027	−96.97146	Augusta	Butler	Ohio St	Kelly Ave
105-064-4SG-006	39.05789	−94.88491	Bonner Springs	Wyandotte	Nettleton Ave	Kump Ave
067-100-4SG-007	37.67474	−95.47089	Chanute	Neosho	Plummer Ave	7th St
063-130-4SG-008	37.03299	−95.62065	Coffeyville	Montgomery	Old Willow St	11th St
097-134-4SG-009	39.37973	−101.0549	Colby	Thomas	KS-25	College Dr
015-150-4SG-010	39.56651	−97.65746	Concordia	Cloud	Lincoln St	11th St
087-139-4SG-011	37.54791	−97.26217	Derby	Sedgwick	Woodlawn Blvd	Madison Ave
087-139-4SG-012	37.55589	−97.24433	Derby	Sedgwick	Rock Rd	James St
029-170-4SG-013	37.76548	−100.0176	Dodge City	Ford	1st Ave	Comanche St
029-170-4SG-014	37.77277	−100.0239	Dodge City	Ford	6th Ave	Soule St
008-180-4SG-015	37.81741	−96.86369	El Dorado	Butler	Summit St	Central Ave

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
056-190-4SG-016	38.41231	−96.20783	Emporia	Lyon	Prairie St	12th Ave
056-190-4SG-017	38.40738	−96.18014	Emporia	Lyon	Commercial St	8th Ave
006-210-4SG-018	37.83568	−94.70732	Fort Scott	Bourbon	National Ave	6th St
028-240-4SG-019	37.98945	−100.8542	Garden City	Finney	Fleming St	Mary St
028-240-4SG-020	37.97213	−100.8751	Garden City	Finney	8th St	Buffalo Jones Ave
046-202-4SG-021	38.79649	−94.9275	Gardner	Johnson	Center St	183rd St
046-202-4SG-022	38.81663	−94.92763	Gardner	Johnson	Center St	Madison St
005-280-4SG-023	38.36655	−98.76658	Great Bend	Barton	Williams St	Broadway Ave
026-290-4SG-024	38.88548	−99.33634	Hays	Ellis	Hall St	27th St
026-290-4SG-025	38.87098	−99.29936	Hays	Ellis	Canterbury Dr	13th St
087-244-4SG-026	37.56436	−97.35225	Haysville	Sedgwick	Turkle Ave	Grand Ave
078-350-4SG-027	38.05757	−97.91305	Hutchinson	Reno	Severance St	4th Ave
078-350-4SG-028	38.06504	−97.92825	Hutchinson	Reno	Poplar St	11th Ave
078-350-4SG-029	38.05154	−97.93183	Hutchinson	Reno	Main St	Avenue A
063-360-4SG-030	37.23632	−95.70643	Independence	Montgomery	US-75	Oak St
001-370-4SG-031	37.92141	−95.40552	Iola	Allen	Washington Ave	Madison Ave
031-380-4SG-032	39.02827	−96.83914	Junction City	Geary	Webster St	6th St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
031-380-4SG-033	39.02824	−96.82951	Junction City	Geary	Washington St	6th St
105-390-4SG-034	39.12423	−94.62141	Kansas City	Wyandotte	5th St	Parallel Pkwy
105-390-4SG-035	39.11852	−94.62683	Kansas City	Wyandotte	7th St Trfy	Washington Blvd
105-390-4SG-036	39.11652	−94.63512	Kansas City	Wyandotte	10th St	State Ave
105-390-4SG-037	39.13473	−94.63503	Kansas City	Wyandotte	10th St	Quindaro Blvd
105-390-4SG-038	39.07305	−94.70526	Kansas City	Wyandotte	55th St	Metropolitan Ave
105-390-4SG-039	39.12856	−94.71528	Kansas City	Wyandotte	59th St	Parallel Pkwy
105-390-4SG-040	39.08743	−94.63534	Kansas City	Wyandotte	10th St	Kansas Ave
105-390-4SG-041	39.11671	−94.67326	Kansas City	Wyandotte	38th St	State Ave
052-622-4SG-042	39.25179	−94.9	Lansing	Leavenworth	Main St	Ida St
023-420-4SG-043	38.95701	−95.27906	Lawrence	Douglas	Kasold Dr	Bob Billings Pkwy
023-420-4SG-044	38.9427	−95.22344	Lawrence	Douglas	Haskell Ave	23rd St
023-420-4SG-045	38.95	−95.2359	Lawrence	Douglas	Massachusetts St	19th St
023-420-4SG-046	38.96753	−95.24757	Lawrence	Douglas	Maine St	9th St
023-420-4SG-047	38.94267	−95.29787	Lawrence	Douglas	Inverness Dr	Clinton Pkwy
052-430-4SG-048	39.31036	−94.92791	Leavenworth	Leavenworth	10th Ave	Spruce St
052-430-4SG-049	39.31845	−94.91863	Leavenworth	Leavenworth	7th St	Shawnee St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-299-4SG-050	38.92754	−94.63964	Leawood	Johnson	Roe Ave	College Blvd
046-299-4SG-051	38.89831	−94.64921	Leawood	Johnson	Nall Ave	127th St
046-305-4SG-052	38.95206	−94.72352	Lenexa	Johnson	Quivira Rd	103rd St
046-305-4SG-053	38.97111	−94.74234	Lenexa	Johnson	Pflumm Rd	87th St
046-305-4SG-054	38.98559	−94.76108	Lenexa	Johnson	Lackman Rd	79th St
088-440-4SG-055	37.05416	−100.9223	Liberal	Seward	Kansas Ave	15th St
088-440-4SG-056	37.04533	−100.9315	Liberal	Seward	Clay Ave	7th St
081-460-4SG-057	39.17939	−96.56677	Manhattan	Riley	Juliette Ave	Poyntz Ave
081-460-4SG-058	39.18596	−96.58883	Manhattan	Riley	Sunset Ave	Anderson Ave
081-460-4SG-059	39.20388	−96.59818	Manhattan	Riley	College Ave	Kimball Ave
059-480-4SG-060	38.36936	−97.6669	McPherson	McPherson	Main St	Kansas Ave
046-363-4SG-061	39.02226	−94.68646	Merriam	Johnson	Antoich Rd	Johnson Dr
046-372-4SG-062	39.02213	−94.65835	Mission	Johnson	Lamar Ave	Johnson Dr
087-391-4SG-063	37.4873	−97.2446	Mulvane	Sedgwick	2nd Ave	KS-15
040-500-4SG-064	38.04989	−97.34511	Newton	Harvey	Main St	Broadway St
046-520-4SG-065	38.86911	−94.77956	Olathe	Johnson	Mur-Len Rd	143rd St
046-520-4SG-066	38.91274	−94.77967	Olathe	Johnson	Renner Blvd	119th St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-520-4SG-067	38.89821	−94.81849	Olathe	Johnson	Northgate	Harold St
046-520-4SG-068	38.92723	−94.79755	Olathe	Johnson	Ridgeview Rd	College Blvd
046-520-4SG-069	38.9273	−94.83458	Olathe	Johnson	Lone Elm Rd	College Blvd
046-520-4SG-070	38.8677	−94.81583	Olathe	Johnson	Harrison St	Old US 56
046-520-4SG-071	38.84	−94.81593	Olathe	Johnson	US 169	159th St
030-540-4SG-072	38.6085	−95.26869	Ottawa	Franklin	Main St	7th St
046-614-4SG-073	38.84002	−94.6864	Overland Park	Johnson	Antioch Rd	159th St
046-614-4SG-074	38.99287	−94.71441	Overland Park	Johnson	Neiman Rd	75th St
046-614-4SG-075	38.86915	−94.6678	Overland Park	Johnson	Metcalf Ave	143rd St
046-614-4SG-076	38.88377	−94.64924	Overland Park	Johnson	Nall Ave	135th St
046-614-4SG-077	38.88367	−94.7237	Overland Park	Johnson	Quivara Rd	135th St
046-614-4SG-078	38.89835	−94.6678	Overland Park	Johnson	Metcalf Ave	127th Ave
046-614-4SG-079	38.91286	−94.68638	Overland Park	Johnson	Antioch Rd	119th St
046-614-4SG-080	38.99321	−94.649	Overland Park	Johnson	Nall Ave	75th St
046-614-4SG-081	38.97123	−94.6863	Overland Park	Johnson	Antioch Rd	87th St
046-614-4SG-082	38.95669	−94.66764	Overland Park	Johnson	Metcalf Ave	95th St
061-550-4SG-083	38.57282	−94.87896	Paola	Miami	Silver St	Peoria St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-645-4SG-084	37.79589	−97.31739	Park City	Sedgwick	Hydraulic Ave	61st St N
050-560-4SG-085	37.3405	−95.25921	Parsons	Labette	16th St	Main St
019-570-4SG-086	37.411	−94.70486	Pittsburg	Crawford	Broadway St	4th St
019-570-4SG-087	37.42575	−94.70489	Pittsburg	Crawford	Broadway St	20th St
046-457-4SG-088	38.99324	−94.6304	Prairie Village	Johnson	Mission Rd	75th St
046-457-4SG-089	38.99321	−94.61648	Prairie Village	Johnson	Belinder Ave	75th St
076-580-4SG-090	37.646	−98.73948	Pratt	Pratt	Main St	1st St
046-482-4SG-091	39.0376	−94.63969	Roeland Park	Johnson	Roe Blvd	50th Terrace
085-600-4SG-092	38.82718	−97.625	Salina	Saline	Broadway Blvd	Crawford St
085-600-4SG-093	38.84053	−97.594	Salina	Saline	Ohio St	Iron Ave
085-600-4SG-094	38.82714	−97.576	Salina	Saline	Marymount Rd	Crawford St
046-513-4SG-095	39.01475	−94.72386	Shawnee	Johnson	Quivira Rd	Shawnee Mission Pkwy
046-513-4SG-096	39.02934	−94.7146	Shawnee	Johnson	Nieman Rd	55th St
046-513-4SG-097	39.022	−94.74251	Shawnee	Johnson	Pflumm Rd	Johnson Dr
046-513-4SG-098	39.00739	−94.72378	Shawnee	Johnson	Quivira Rd	67th St
089-610-4SG-099	39.01513	−95.61423	Topeka	Shawnee	SE Croco Rd	SE 29th St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
089-610-4SG-100	39.05849	−95.72469	Topeka	Shawnee	SW Gage Blvd	SW 6th Ave
089-610-4SG-101	39.05171	−95.67328	Topeka	Shawnee	Kansas Ave	SW 6th Ave
089-610-4SG-102	39.03646	−95.74335	Topeka	Shawnee	Fairlawn Rd	SW 17th St
089-610-4SG-103	39.01513	−95.697	Topeka	Shawnee	SW Burlingame Rd	SW 29th St
089-610-4SG-104	39.01522	−95.67023	Topeka	Shawnee	SE Adams St	SE 29th St
089-610-4SG-105	39.03696	−95.70615	Topeka	Shawnee	SW MacVicar Ave	SW 17th St
034-555-4SG-106	37.57652	−101.3634	Ulysses	Grant	Colorado St	Oklahoma Ave
087-558-4SG-107	37.83953	−97.372	Valley Center	Sedgwick	Meridian Ave	5th St
096-620-4SG-108	37.26782	−97.39807	Wellington	Sumner	Washington Ave	8th St
087-630-4SG-109	37.70842	−97.2623	Wichita	Sedgwick	Woodlawn Blvd	13th St N
087-630-4SG-110	37.70828	−97.29905	Wichita	Sedgwick	Hillside St	13th St N
087-630-4SG-111	37.75222	−97.26239	Wichita	Sedgwick	Woodlawn St	37th St N
087-630-4SG-112	37.69071	−97.35308	Wichita	Sedgwick	Seneca St	McLean Blvd
087-630-4SG-113	37.65155	−97.35268	Wichita	Sedgwick	Seneca St	Pawnee St
087-630-4SG-114	37.66474	−97.20787	Wichita	Sedgwick	Greenwich Rd	Harry St
087-630-4SG-115	37.65008	−97.22619	Wichita	Sedgwick	Webb Rd	Pawnee St
087-630-4SG-116	37.7232	−97.4262	Wichita	Sedgwick	Ridge Rd	21st St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
087-630-4SG-117	37.75172	−97.46291	Wichita	Sedgwick	Maize Rd	37th St N
087-630-4SG-118	37.72276	−97.46257	Wichita	Sedgwick	Maize Rd	21st St
087-630-4SG-119	37.75226	−97.29947	Wichita	Sedgwick	Hillside St	37th St N
087-630-4SG-120	37.66466	−97.28042	Wichita	Sedgwick	Oliver St	Harry St
087-630-4SG-121	37.65038	−97.46193	Wichita	Sedgwick	Maize Rd	Pawnee St
087-630-4SG-122	37.70854	−97.18958	Wichita	Sedgwick	127th St E	13th St N
087-630-4SG-123	37.72306	−97.18958	Wichita	Sedgwick	127thSt E	21st St N
087-630-4SG-124	37.70844	−97.20794	Wichita	Sedgwick	Greenwich Rd	13th St N
087-630-4SG-125	37.73747	−97.33593	Wichita	Sedgwick	Broadway St	29th St N
087-630-4SG-126	37.72999	−97.36308	Wichita	Sedgwick	Amidon St	25th St N
087-630-4SG-127	37.67665	−97.38936	Wichita	Sedgwick	West St	Taft
087-630-4SG-128	37.68632	−97.29897	Wichita	Sedgwick	Hillside St	Douglas Ave
018-640-4SG-129	37.24031	−96.99723	Winfield	Cowley	Main St	9th Ave
008-623-4SG-130	37.6868	−97.1353	Andover	Butler	Andover Rd	Douglas Ave
018-030-4SG-131	37.0695	−97.0391	Arkansas City	Cowley	Summit St	Maple Ave
087-139-4SG-132	37.5479	−97.2702	Derby	Sedgwick	Baltimore Ave	Madison Ave
029-170-4SG-133	37.7727	−100.0164	Dodge City	Ford	Central Ave	Soule St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
008-180-4SG-134	37.8174	−96.8498	El Dorado	Butler	Main St	Central Ave
056-190-4SG-135	38.4123	−96.1815	Emporia	Lyon	Merchant St	12th Ave
028-240-4SG-136	37.9677	−100.8474	Garden City	Finney	Campus Dr	Spruce St
046-202-4SG-137	38.8110	−94.9275	Gardner	Johnson	Center St	Main St
005-280-4SG-138	38.3708	−98.7744	Great Bend	Barton	Washington St	19th St
026-290-4SG-139	38.8783	−99.3179	Hays	Ellis	Vine St	22nd St
087-244-4SG-140	37.5645	−97.3339	Haysville	Sedgwick	US-81	Grand Ave
078-350-4SG-141	38.0722	−97.9039	Hutchinson	Reno	Lorraine St	17th Ave
031-380-4SG-142	39.0367	−96.8372	Junction City	Geary	Jackson St	14th St
105-390-4SG-143	39.1289	−94.6497	Kansas City	Wyandotte	18th St	Parallel Pkwy
105-390-4SG-144	39.0875	−94.6260	Kansas City	Wyandotte	7th St	Kansas Ave
105-390-4SG-145	39.1008	−94.6355	Kansas City	Wyandotte	10th St	Central Ave
105-390-4SG-146	39.1156	−94.6493	Kansas City	Wyandotte	18th St	Minnesota Ave
105-390-4SG-147	39.1284	−94.6736	Kansas City	Wyandotte	38th St	Parallel Pkwy
105-390-4SG-148	39.1387	−94.6513	Kansas City	Wyandotte	18th St	Quindaro Blvd
052-622-4SG-149	39.2670	−94.8999	Lansing	Leavenworth	4th St	Eisenhower Rd
023-420-4SG-150	38.9715	−95.3070	Lawrence	Douglas	Wakarusa Dr	6th St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
023-420-4SG-151	38.9282	−95.2606	Lawrence	Douglas	Iowa St	31st St
023-420-4SG-152	38.9500	−95.2605	Lawrence	Douglas	Iowa St	19th St
023-420-4SG-153	38.9570	−95.3069	Lawrence	Douglas	Wakarusa Dr	Bob Billings Pkwy
052-430-4SG-154	39.3103	−94.9508	Leavenworth	Leavenworth	20th St Trfy	Spruce St
052-430-4SG-155	39.2959	−94.9138	Leavenworth	Leavenworth	2nd St	Thornton St
046-299-4SG-156	38.9129	−94.6398	Leawood	Johnson	Roe Ave	119th St
046-299-4SG-157	38.9205	−94.6490	Leawood	Johnson	Nall Ave	115th St
046-305-4SG-158	38.9565	−94.7236	Lenexa	Johnson	Quivira Rd	95th St
046-305-4SG-159	38.9273	−94.7608	Lenexa	Johnson	Lackman Rd	College Blvd
081-460-4SG-160	39.1895	−96.5549	Manhattan	Riley	Hayes Dr	McCall Rd
081-460-4SG-161	39.2042	−96.5855	Manhattan	Riley	Denison Ave	Kimball Ave
059-480-4SG-162	38.37657	−97.6669	McPherson	McPherson	Main St	1st St
046-363-4SG-163	39.02217	−94.69422	Merriam	Johnson	Merriam Dr	Johnson Dr
040-500-4SG-164	38.04293	−97.37194	Newton	Harvey	Meridian Rd	1st St
046-520-4SG-165	38.88368	−94.79724	Olathe	Johnson	Ridgeview Rd	Santa Fe St
046-520-4SG-166	38.88352	−94.82069	Olathe	Johnson	Kansas Ave	Santa Fe St
046-520-4SG-167	38.88374	−94.83461	Olathe	Johnson	Parker St	Santa Fe St

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
046-520-4SG-168	38.89827	−94.77954	Olathe	Johnson	Mur-Len Rd	127th St
046-520-4SG-169	38.89815	−94.79737	Olathe	Johnson	Ridgeview Rd	Harold St
046-520-4SG-170	38.88369	−94.7795	Olathe	Johnson	Mur-Len Rd	Santa Fe St
030-540-4SG-171	38.59387	−95.26882	Ottawa	Franklin	Main St	15th St
046-614-4SG-172	38.99314	−94.66771	Overland Park	Johnson	Metcalf Ave	75th St
046-614-4SG-173	38.9567	−94.67698	Overland Park	Johnson	Lowell Ave	95th St
046-614-4SG-174	38.94174	−94.66755	Overland Park	Johnson	Metcalf Ave	103rd St
046-614-4SG-175	38.94893	−94.68626	Overland Park	Johnson	Antioch Rd	99th St
046-614-4SG-176	38.984	−94.66769	Overland Park	Johnson	Metcalf Ave	80th St
046-614-4SG-177	38.9568	−94.63912	Overland Park	Johnson	Roe Ave	95th St
046-614-4SG-178	38.96403	−94.65834	Overland Park	Johnson	Lamar Ave	91st St
085-600-4SG-179	38.79813	−97.61282	Salina	Saline	9th St	Magnolia Rd
085-600-4SG-180	38.78366	−97.63223	Salina	Saline	Centennial Rd	Schilling Rd
046-513-4SG-181	39.00743	−94.74245	Shawnee	Johnson	Pflumm Rd	67th St
046-513-4SG-182	39.02293	−94.71459	Shawnee	Johnson	Nieman Rd	Johnson Dr
018-640-4SG-183	37.23519	−96.99708	Winfield	Cowley	Main St	14th Ave
089-610-4SG-184	39.04419	−95.66525	Topeka	Shawnee	Branner Trfwy	10th Ave

Table B.4 Continued

Intersection ID	Latitude	Longitude	City	County	North/ Southbound	East/ Westbound
089-610-4SG-185	39.0723	−95.67078	Topeka	Shawnee	NW Topeka Blvd	NW Morse St
089-610-4SG-186	39.02243	−95.65139	Topeka	Shawnee	SE California Ave	SE 25th St
089-610-4SG-187	39.0297	−95.68297	Topeka	Shawnee	SW Topeka Blvd	SW 21st St
089-610-4SG-188	39.01458	−95.76238	Topeka	Shawnee	SW Wanamaker Rd	SW 29th St
087-630-4SG-189	37.68609	−97.32639	Wichita	Sedgwick	Washington St	Douglas Ave
087-630-4SG-190	37.69754	−97.33558	Wichita	Sedgwick	Broadway St	Murdock St
087-630-4SG-191	37.70797	−97.34818	Wichita	Sedgwick	Jeanette St	13th St N
087-630-4SG-192	37.70878	−97.376	Wichita	Sedgwick	St Paul St	13th St N
087-630-4SG-193	37.69471	−97.38948	Wichita	Sedgwick	West St	Central Ave
087-630-4SG-194	37.66589	−97.37106	Wichita	Sedgwick	Meridian Ave	Harry St
087-630-4SG-195	37.65701	−97.33552	Wichita	Sedgwick	Broadway St	Mt Vernon St
087-630-4SG-196	37.63697	−97.3526	Wichita	Sedgwick	Seneca St	31st St
087-630-4SG-197	37.63686	−97.38921	Wichita	Sedgwick	West St	31st St
087-630-4SG-198	37.65	−97.29874	Wichita	Sedgwick	Hillside St	Pawnee St

Appendix C: Statistical Outputs for Regression Models

See next page.

Table C.1: Descriptive statistics of AADT and crashes for 3ST, 3SG, and 4SG urban intersections in Kansas

Facility Type	Description	2013				2014				2015			
		Min	Max	Avg	S.D.	Min	Max	Avg	S.D.	Min	Max	Avg	S.D.
3ST	AADT major	155	36,900	10,403	6,803	320	37,400	10,441	6,829	330	41,500	10,458	6,872
	AADT minor	100	7,625	2,218	1,473	100	7,790	2,271	1,524	105	8,080	2,324	1,593
	Crashes	0	2	0.44	0.55	0	2	0.49	0.58	0	2	0.44	0.56
3SG	AADT major	2,555	43,840	14,879	7,998	2,610	43,890	14,931	8,087	2,940	45,650	15,248	8,130
	AADT minor	55	13,365	4,910	2,974	55	13,765	4,988	3,034	145	13,975	5,042	3,045
	Crashes	0	6	1.19	1.14	0	6	1.11	1.15	0	8	1.16	1.65
4SG	AADT major	2,710	36,840	14,186	7,416	1,502	37,000	14,131	7,553	2,825	37,720	14,370	7,625
	AADT minor	425	23,000	7,757	4,951	1,010	23,133	7,648	4,826	1,045	23,425	7,795	4,896
	Crashes	0	14	2.72	2.78	0	14	2.87	2.80	0	17	2.72	2.82

Table C.2: Descriptive statistics of AADT and crashes for 4ST urban intersections in Kansas

Facility Type	Description	2014				2015				2016			
		Min	Max	Avg	S.D.	Min	Max	Avg	S.D.	Min	Max	Avg	S.D.
4ST	AADT major	615	35,100	8,225	5,635	640	27,000	8,367	5,557	825	27,490	8,492	5,636
	AADT minor	85	5,465	1,852	1,080	245	5,580	1,877	1,083	160	5,680	1,904	1,114
	Crashes	0	4	0.74	0.70	0	5	0.69	0.71	0	2	0.68	0.60

Table C.3: Statistics of minor AADT estimation regression models

Description	3SG	3ST
Mean Square Error	0.2761	0.0885
R-Square	0.5314	0.3281
Adjusted R-Square	0.4904	0.3124
Akaike Information Criterion	−135.9	−842.2
Bayesian Information Criterion	−132	−839.8
Mallow’s C_p	10	9

Table C.4: Correlation matrix for variables used in developing minor AADT estimation regression models for 3SG intersections in Kansas

Pearson Correlation Coefficients, N = 171
Prob > |r| under H0: Rho=0

	minorAADT	MajorAADT	CityPop	CityAr	CountyAr	PCinc	MedAge	pplHH
minorAADT	1.00000	0.41752 <.0001	0.27503 0.0003	0.19356 0.0112	0.14004 0.0677	0.20503 0.0071	0.07391 0.3367	0.05099 0.5078
MajorAADT	0.41752 <.0001	1.00000	0.16416 0.0319	0.10317 0.1793	-0.08377 0.2760	0.29911 <.0001	-0.03197 0.6781	0.07112 0.3553
CityPop	0.27503 0.0003	0.16416 0.0319	1.00000	**0.96062** <.0001	0.26572 0.0004	-0.12926 0.0920	0.02228 0.7724	0.06249 0.4168
CityAr	0.19356 0.0112	0.10317 0.1793	**0.96062** <.0001	1.00000	0.12749 0.0966	-0.18633 0.0147	0.02782 0.7179	0.16084 0.0356
CountyAr	0.14004 0.0677	-0.08377 0.2760	0.26572 0.0004	0.12749 0.0966	1.00000	-0.28158 0.0002	-0.07878 0.3057	-0.01893 0.8059
PCinc	0.20503 0.0071	0.29911 <.0001	-0.12926 0.0920	-0.18633 0.0147	-0.28158 0.0002	1.00000	0.67148 <.0001	0.10957 0.1537
MedAge	0.07391 0.3367	-0.03197 0.6781	0.02228 0.7724	0.02782 0.7179	-0.07878 0.3057	0.67148 <.0001	1.00000	0.07431 0.3340
pplHH	0.05099 0.5078	0.07112 0.3553	0.06249 0.4168	0.16084 0.0356	-0.01893 0.8059	0.10957 0.1537	0.07431 0.3340	1.00000
LTmajor	0.14534 0.0579	0.27071 0.0003	-0.12804 0.0951	-0.10352 0.1778	-0.21463 0.0048	-0.01466 0.8491	-0.18305 0.0166	0.00774 0.9200
LTminor	0.18109 0.0178	0.18341 0.0163	-0.28921 0.0001	-0.32197 <.0001	-0.25149 0.0009	0.03960 0.6071	-0.08224 0.2849	-0.24531 0.0012
Thlanes	0.19697 0.0098	0.58523 <.0001	0.08532 0.2672	0.01377 0.8581	0.13718 0.0736	0.12392 0.1064	-0.10822 0.1589	0.08176 0.2877

Pearson Correlation Coefficients, N = 171 Prob > |r| under H0: Rho=0								
	minorAADT	**MajorAADT**	**CityPop**	**CityAr**	**CountyAr**	**PCinc**	**MedAge**	**pplHH**
RTmajor	0.25242 0.0009	0.10034 0.1916	-0.08422 0.2734	-0.10976 0.1530	0.05687 0.4600	0.15356 0.0449	0.00853 0.9118	0.13561 0.0770
RTminor	-0.00714 0.9262	0.12118 0.1144	-0.25583 0.0007	-0.27309 0.0003	-0.09155 0.2337	-0.27948 0.0002	-0.22586 0.0030	-0.27234 0.0003
LTsigmajor	0.17878 0.0193	0.50522 <.0001	-0.14667 0.0556	-0.17022 0.0260	-0.12234 0.1109	-0.04445 0.5638	-0.21102 0.0056	0.05810 0.4503
LTsigmin	0.27970 0.0002	0.31437 <.0001	-0.10586 0.1682	-0.15840 0.0385	0.09270 0.2278	-0.16705 0.0290	-0.45371 <.0001	-0.05018 0.5145
SLmajor	0.03264 0.6717	0.42166 <.0001	-0.11130 0.1473	-0.16523 0.0308	0.09719 0.2060	0.10653 0.1655	-0.12525 0.1026	-0.07749 0.3138
SLminor	0.35408 <.0001	0.16509 0.0309	0.19820 0.0094	0.14825 0.0530	0.28505 0.0002	-0.13425 0.0800	-0.01257 0.8704	-0.18647 0.0146
Ma_fc_pa	0.01419 0.8539	0.30965 <.0001	-0.35567 <.0001	-0.40001 <.0001	0.06257 0.4162	0.10419 0.1750	-0.23994 0.0016	-0.13174 0.0859
Ma_fc_ar	-0.07570 0.3251	-0.15656 0.0409	0.09534 0.2148	0.16366 0.0324	-0.24478 0.0013	-0.07605 0.3229	0.13448 0.0795	0.18999 0.0128
Ma_fc_cl	0.09782 0.2031	-0.19084 0.0124	0.35061 <.0001	0.30654 <.0001	0.29289 0.0001	-0.02788 0.7173	0.12742 0.0968	-0.11068 0.1496
Mi_fc_ar	0.08177 0.2877	-0.10362 0.1774	-0.27522 0.0003	-0.28403 0.0002	-0.10611 0.1672	-0.19063 0.0125	-0.13223 0.0847	-0.11758 0.1256
Mi_fc_cl	-0.17596 0.0213	-0.12594 0.1007	0.45814 <.0001	0.47390 <.0001	0.14300 0.0621	-0.28176 0.0002	-0.14148 0.0649	-0.09805 0.2020
Mi_fc_lc	0.14219 0.0636	0.27089 0.0003	-0.30520 <.0001	-0.31638 <.0001	-0.07420 0.3348	0.56310 <.0001	0.32083 <.0001	0.24940 0.0010

Pearson Correlation Coefficients, N = 171 Prob > |r| under H0: Rho=0								
	LTmajor	**LTminor**	**Thlanes**	**RTmajor**	**RTminor**	**LTsigmajor**	**LTsigmin**	**SLmajor**
minorAADT	0.14534 0.0579	0.18109 0.0178	0.19697 0.0098	0.25242 0.0009	-0.00714 0.9262	0.17878 0.0193	0.27970 0.0002	0.03264 0.6717
MajorAADT	0.27071 0.0003	0.18341 0.0163	0.58523 <.0001	0.10034 0.1916	0.12118 0.1144	0.50522 <.0001	0.31437 <.0001	0.42166 <.0001
CityPop	-0.12804 0.0951	-0.28921 0.0001	0.08532 0.2672	-0.08422 0.2734	-0.25583 0.0007	-0.14667 0.0556	-0.10586 0.1682	-0.11130 0.1473

Pearson Correlation Coefficients, N = 171 Prob > |r| under H0: Rho=0								
	LTmajor	**LTminor**	**Thlanes**	**RTmajor**	**RTminor**	**LTsigmajor**	**LTsigmin**	**SLmajor**
CityAr	-0.10352 0.1778	-0.32197 <.0001	0.01377 0.8581	-0.10976 0.1530	-0.27309 0.0003	-0.17022 0.0260	-0.15840 0.0385	-0.16523 0.0308
CountyAr	-0.21463 0.0048	-0.25149 0.0009	0.13718 0.0736	0.05687 0.4600	-0.09155 0.2337	-0.12234 0.1109	0.09270 0.2278	0.09719 0.2060
PCinc	-0.01466 0.8491	0.03960 0.6071	0.12392 0.1064	0.15356 0.0449	-0.27948 0.0002	-0.04445 0.5638	-0.16705 0.0290	0.10653 0.1655
MedAge	-0.18305 0.0166	-0.08224 0.2849	-0.10822 0.1589	0.00853 0.9118	-0.22586 0.0030	-0.21102 0.0056	-0.45371 <.0001	-0.12525 0.1026
pplHH	0.00774 0.9200	-0.24531 0.0012	0.08176 0.2877	0.13561 0.0770	-0.27234 0.0003	0.05810 0.4503	-0.05018 0.5145	-0.07749 0.3138
LTmajor	1.00000	0.49843 <.0001	0.03891 0.6133	0.26100 0.0006	0.42985 <.0001	0.58909 <.0001	0.30608 <.0001	0.28122 0.0002
LTminor	0.49843 <.0001	1.00000	-0.00897 0.9073	0.16153 0.0348	**0.78764** <.0001	0.46949 <.0001	0.44053 <.0001	0.26320 0.0005
Thlanes	0.03891 0.6133	-0.00897 0.9073	1.00000	-0.18418 0.0159	-0.08161 0.2886	0.36044 <.0001	0.22990 0.0025	0.44095 <.0001
RTmajor	0.26100 0.0006	0.16153 0.0348	-0.18418 0.0159	1.00000	0.05583 0.4683	0.35144 <.0001	0.09318 0.2254	0.22773 0.0027
RTminor	0.42985 <.0001	**0.78764** <.0001	-0.08161 0.2886	0.05583 0.4683	1.00000	0.40971 <.0001	0.31298 <.0001	0.20521 0.0071
LTsigmajor	0.58909 <.0001	0.46949 <.0001	0.36044 <.0001	0.35144 <.0001	0.40971 <.0001	1.00000	0.49369 <.0001	0.54192 <.0001
LTsigmin	0.30608 <.0001	0.44053 <.0001	0.22990 0.0025	0.09318 0.2254	0.31298 <.0001	0.49369 <.0001	1.00000	0.31031 <.0001
SLmajor	0.28122 0.0002	0.26320 0.0005	0.44095 <.0001	0.22773 0.0027	0.20521 0.0071	0.54192 <.0001	0.31031 <.0001	1.00000
SLminor	0.19137 0.0122	0.25994 0.0006	0.11064 0.1497	0.25574 0.0007	0.22283 0.0034	0.14079 0.0662	0.11020 0.1513	0.29243 0.0001
Ma_fc_pa	0.16849 0.0276	0.19563 0.0103	0.27299 0.0003	0.23488 0.0020	0.12469 0.1042	0.36190 <.0001	0.36679 <.0001	0.50372 <.0001
Ma_fc_ar	0.01493 0.8464	-0.00106 0.9890	-0.22798 0.0027	-0.09098 0.2366	0.03628 0.6376	-0.12802 0.0952	-0.20322 0.0077	-0.39660 <.0001
Ma_fc_cl	-0.25954 0.0006	-0.27275 0.0003	-0.02836 0.7127	-0.18797 0.0138	-0.23132 0.0023	-0.30851 <.0001	-0.19844 0.0093	-0.08977 0.2429
Mi_fc_ar	0.13620 0.0757	0.41881 <.0001	-0.18308 0.0165	0.33595 <.0001	0.32322 <.0001	0.23191 0.0023	0.18384 0.0161	0.09591 0.2121

Pearson Correlation Coefficients, N = 171 Prob > |r| under H0: Rho=0								
	LTmajor	**LTminor**	**Thlanes**	**RTmajor**	**RTminor**	**LTsigmajor**	**LTsigmin**	**SLmajor**
Mi_fc_cl	-0.20880 0.0061	-0.34759 <.0001	-0.04385 0.5690	-0.35000 <.0001	-0.13957 0.0687	-0.22831 0.0027	-0.09091 0.2370	-0.08225 0.2848
Mi_fc_lc	0.12786 0.0956	0.01252 0.8709	0.24766 0.0011	0.10206 0.1841	-0.15670 0.0407	0.05326 0.4890	-0.07423 0.3346	0.00630 0.9349

Pearson Correlation Coefficients, N = 171 Prob > |r| under H0: Rho=0							
	SLminor	**Ma_fc_pa**	**Ma_fc_ar**	**Ma_fc_cl**	**Mi_fc_ar**	**Mi_fc_cl**	**Mi_fc_lc**
minorAADT	0.35408 <.0001	0.01419 0.8539	-0.07570 0.3251	0.09782 0.2031	0.08177 0.2877	-0.17596 0.0213	0.14219 0.0636
MajorAADT	0.16509 0.0309	0.30965 <.0001	-0.15656 0.0409	-0.19084 0.0124	-0.10362 0.1774	-0.12594 0.1007	0.27089 0.0003
CityPop	0.19820 0.0094	-0.35567 <.0001	0.09534 0.2148	0.35061 <.0001	-0.27522 0.0003	0.45814 <.0001	-0.30520 <.0001
CityAr	0.14825 0.0530	-0.40001 <.0001	0.16366 0.0324	0.30654 <.0001	-0.28403 0.0002	0.47390 <.0001	-0.31638 <.0001
CountyAr	0.28505 0.0002	0.06257 0.4162	-0.24478 0.0013	0.29289 0.0001	-0.10611 0.1672	0.14300 0.0621	-0.07420 0.3348
PCinc	-0.13425 0.0800	0.10419 0.1750	-0.07605 0.3229	-0.02788 0.7173	-0.19063 0.0125	-0.28176 0.0002	0.56310 <.0001
MedAge	-0.01257 0.8704	-0.23994 0.0016	0.13448 0.0795	0.12742 0.0968	-0.13223 0.0847	-0.14148 0.0649	0.32083 <.0001
pplHH	-0.18647 0.0146	-0.13174 0.0859	0.18999 0.0128	-0.11068 0.1496	-0.11758 0.1256	-0.09805 0.2020	0.24940 0.0010
LTmajor	0.19137 0.0122	0.16849 0.0276	0.01493 0.8464	-0.25954 0.0006	0.13620 0.0757	-0.20880 0.0061	0.12786 0.0956
LTminor	0.25994 0.0006	0.19563 0.0103	-0.00106 0.9890	-0.27275 0.0003	0.41881 <.0001	-0.34759 <.0001	0.01252 0.8709
Thlanes	0.11064 0.1497	0.27299 0.0003	-0.22798 0.0027	-0.02836 0.7127	-0.18308 0.0165	-0.04385 0.5690	0.24766 0.0011
RTmajor	0.25574 0.0007	0.23488 0.0020	-0.09098 0.2366	-0.18797 0.0138	0.33595 <.0001	-0.35000 <.0001	0.10206 0.1841
RTminor	0.22283 0.0034	0.12469 0.1042	0.03628 0.6376	-0.23132 0.0023	0.32322 <.0001	-0.13957 0.0687	-0.15670 0.0407

Pearson Correlation Coefficients, N = 171
Prob > |r| under H0: Rho=0

	SLminor	Ma_fc_pa	Ma_fc_ar	Ma_fc_cl	Mi_fc_ar	Mi_fc_cl	Mi_fc_lc
LTsigmajor	0.14079 0.0662	0.36190 <.0001	-0.12802 0.0952	-0.30851 <.0001	0.23191 0.0023	-0.22831 0.0027	0.05326 0.4890
LTsigmin	0.11020 0.1513	0.36679 <.0001	-0.20322 0.0077	-0.19844 0.0093	0.18384 0.0161	-0.09091 0.2370	-0.07423 0.3346
SLmajor	0.29243 0.0001	0.50372 <.0001	-0.39660 <.0001	-0.08977 0.2429	0.09591 0.2121	-0.08225 0.2848	0.00630 0.9349
SLminor	1.00000	0.14826 0.0530	-0.22441 0.0032	0.14102 0.0658	0.39730 <.0001	-0.17739 0.0203	-0.18508 0.0154
Ma_fc_pa	0.14826 0.0530	1.00000	**-0.77610** <.0001	-0.19571 0.0103	0.27260 0.0003	-0.37465 <.0001	0.20001 0.0087
Ma_fc_ar	-0.22441 0.0032	**-0.77610** <.0001	1.00000	-0.46653 <.0001	-0.14413 0.0600	0.18196 0.0172	-0.08490 0.2696
Ma_fc_cl	0.14102 0.0658	-0.19571 0.0103	-0.46653 <.0001	1.00000	-0.15821 0.0388	0.24254 0.0014	-0.14852 0.0525
Mi_fc_ar	0.39730 <.0001	0.27260 0.0003	-0.14413 0.0600	-0.15821 0.0388	1.00000	-0.65233 <.0001	-0.19973 0.0088
Mi_fc_cl	-0.17739 0.0203	-0.37465 <.0001	0.18196 0.0172	0.24254 0.0014	-0.65233 <.0001	1.00000	-0.61237 <.0001
Mi_fc_lc	-0.18508 0.0154	0.20001 0.0087	-0.08490 0.2696	-0.14852 0.0525	-0.19973 0.0088	-0.61237 <.0001	1.00000

Table C.5: Correlation matrix for variables used in developing minor AADT estimation regression models for 3ST intersections in Kansas

Pearson Correlation Coefficients, N = 351
Prob > |r| under H0: Rho=0

	minorAADT	majorAADT	CityPop	CityAr	CountyAr	PCInc	MedAge	PplHH
minorAADT	1.00000	0.31781 <.0001	0.15096 0.0046	0.10970 0.0400	-0.08795 0.1000	0.20825 <.0001	-0.10356 0.0526	0.11616 0.0296
majorAADT	0.31781 <.0001	1.00000	0.42537 <.0001	0.40935 <.0001	-0.02115 0.6930	0.19221 0.0003	-0.05182 0.3330	0.06326 0.2372
CityPop	0.15096 0.0046	0.42537 <.0001	1.00000	**0.96576** <.0001	-0.08393 0.1165	0.17853 0.0008	-0.11503 0.0312	-0.07271 0.1741
CityAr	0.10970 0.0400	0.40935 <.0001	**0.96576** <.0001	1.00000	-0.12146 0.0229	0.11665 0.0289	-0.00575 0.9146	-0.04037 0.4509
CountyAr	-0.08795 0.1000	-0.02115 0.6930	-0.08393 0.1165	-0.12146 0.0229	1.00000	-0.13342 0.0124	0.15952 0.0027	-0.02318 0.6652
PCInc	0.20825 <.0001	0.19221 0.0003	0.17853 0.0008	0.11665 0.0289	-0.13342 0.0124	1.00000	0.31068 <.0001	0.03863 0.4707
MedAge	-0.10356 0.0526	-0.05182 0.3330	-0.11503 0.0312	-0.00575 0.9146	0.15952 0.0027	0.31068 <.0001	1.00000	-0.13321 0.0125
PplHH	0.11616 0.0296	0.06326 0.2372	-0.07271 0.1741	-0.04037 0.4509	-0.02318 0.6652	0.03863 0.4707	-0.13321 0.0125	1.00000
LTmajor	0.21222 <.0001	0.21267 <.0001	0.20637 <.0001	0.21724 <.0001	-0.06007 0.2617	0.16409 0.0020	-0.02614 0.6254	0.07850 0.1422
LTminor	0.15473 0.0037	0.07590 0.1559	-0.05069 0.3437	-0.10035 0.0604	0.09531 0.0745	0.21332 <.0001	-0.09198 0.0853	0.27892 <.0001
RTmajor	-0.02369 0.6583	0.00953 0.8587	-0.10934 0.0406	-0.06052 0.2581	-0.16419 0.0020	0.01113 0.8354	0.00839 0.8755	0.15005 0.0048
RTminor	0.15473 0.0037	0.07590 0.1559	-0.05069 0.3437	-0.10035 0.0604	0.09531 0.0745	0.21332 <.0001	-0.09198 0.0853	0.27892 <.0001
THlanes	-0.02649 0.6208	0.64930 <.0001	0.39972 <.0001	0.40606 <.0001	-0.06718 0.2093	0.11850 0.0264	-0.08800 0.0998	0.14176 0.0078
SLmajor	0.13012 0.0147	0.26415 <.0001	0.00828 0.8772	0.04693 0.3808	0.03694 0.4902	-0.05977 0.2641	0.05309 0.3213	0.12281 0.0214
SLminor	0.19505 0.0002	0.16469 0.0020	0.16972 0.0014	0.17970 0.0007	-0.09343 0.0805	0.08577 0.1087	-0.00207 0.9691	0.17955 0.0007
Ma_fc_pa	0.13883 0.0092	0.20135 0.0001	-0.16792 0.0016	-0.15540 0.0035	-0.09866 0.0648	-0.12066 0.0238	-0.18409 0.0005	0.08319 0.1198
Ma_fc_ar	0.07034 0.1886	0.26185 <.0001	0.07570 0.1570	0.09258 0.0833	-0.05927 0.2681	-0.06096 0.2546	0.08528 0.1107	-0.12200 0.0223

Pearson Correlation Coefficients, N = 351 Prob > |r| under H0: Rho=0								
	minorAADT	**majorAADT**	**CityPop**	**CityAr**	**CountyAr**	**PCInc**	**MedAge**	**PplHH**
Ma_fc_cl	-0.15885 0.0028	-0.39459 <.0001	0.02694 0.6150	0.00179 0.9734	0.12242 0.0218	0.13788 0.0097	0.02719 0.6117	0.07346 0.1697
Mi_fc_ar	0.18592 0.0005	0.00735 0.8909	-0.24743 <.0001	-0.19728 0.0002	-0.08975 0.0932	-0.23063 <.0001	-0.04767 0.3732	0.18006 0.0007
Mi_fc_cl	-0.05953 0.2660	-0.02458 0.6463	0.22904 <.0001	0.16688 0.0017	-0.02488 0.6422	0.16054 0.0026	-0.04398 0.4114	-0.20053 0.0002
Mi_fc_lc	-0.18934 0.0004	0.03199 0.5503	-0.01415 0.7917	0.01668 0.7554	0.18666 0.0004	0.08089 0.1304	0.15380 0.0039	0.07044 0.1880

Pearson Correlation Coefficients, N = 351 Prob > |r| under H0: Rho=0								
	LTmajor	**LTminor**	**RTmajor**	**RTminor**	**THlanes**	**SLmajor**	**SLminor**	**Ma_fc_pa**
minorAADT	0.21222 <.0001	0.15473 0.0037	-0.02369 0.6583	0.15473 0.0037	-0.02649 0.6208	0.13012 0.0147	0.19505 0.0002	0.13883 0.0092
majorAADT	0.21267 <.0001	0.07590 0.1559	0.00953 0.8587	0.07590 0.1559	0.64930 <.0001	0.26415 <.0001	0.16469 0.0020	0.20135 0.0001
CityPop	0.20637 <.0001	-0.05069 0.3437	-0.10934 0.0406	-0.05069 0.3437	0.39972 <.0001	0.00828 0.8772	0.16972 0.0014	-0.16792 0.0016
CityAr	0.21724 <.0001	-0.10035 0.0604	-0.06052 0.2581	-0.10035 0.0604	0.40606 <.0001	0.04693 0.3808	0.17970 0.0007	-0.15540 0.0035
CountyAr	-0.06007 0.2617	0.09531 0.0745	-0.16419 0.0020	0.09531 0.0745	-0.06718 0.2093	0.03694 0.4902	-0.09343 0.0805	-0.09866 0.0648
PCInc	0.16409 0.0020	0.21332 <.0001	0.01113 0.8354	0.21332 <.0001	0.11850 0.0264	-0.05977 0.2641	0.08577 0.1087	-0.12066 0.0238
MedAge	-0.02614 0.6254	-0.09198 0.0853	0.00839 0.8755	-0.09198 0.0853	-0.08800 0.0998	0.05309 0.3213	-0.00207 0.9691	-0.18409 0.0005
PplHH	0.07850 0.1422	0.27892 <.0001	0.15005 0.0048	0.27892 <.0001	0.14176 0.0078	0.12281 0.0214	0.17955 0.0007	0.08319 0.1198
LTmajor	1.00000	0.26615 <.0001	0.11685 0.0286	0.26615 <.0001	0.18293 0.0006	0.15399 0.0038	0.17637 0.0009	0.16503 0.0019
LTminor	0.26615 <.0001	1.00000	0.09946 0.0627	**1.00000** <.0001	0.04773 0.3727	0.13655 0.0104	0.36087 <.0001	-0.00496 0.9262
RTmajor	0.11685 0.0286	0.09946 0.0627	1.00000	0.09946 0.0627	0.00592 0.9120	0.40803 <.0001	0.06609 0.2168	0.15229 0.0042

Pearson Correlation Coefficients, N = 351 Prob > |r| under H0: Rho=0								
	LTmajor	**LTminor**	**RTmajor**	**RTminor**	**THlanes**	**SLmajor**	**SLminor**	**Ma_fc_pa**
RTminor	0.26615 <.0001	**1.00000** <.0001	0.09946 0.0627	1.00000	0.04773 0.3727	0.13655 0.0104	0.36087 <.0001	-0.00496 0.9262
THlanes	0.18293 0.0006	0.04773 0.3727	0.00592 0.9120	0.04773 0.3727	1.00000	0.16876 0.0015	0.07511 0.1603	0.18707 0.0004
SLmajor	0.15399 0.0038	0.13655 0.0104	0.40803 <.0001	0.13655 0.0104	0.16876 0.0015	1.00000	0.36120 <.0001	0.25482 <.0001
SLminor	0.17637 0.0009	0.36087 <.0001	0.06609 0.2168	0.36087 <.0001	0.07511 0.1603	0.36120 <.0001	1.00000	0.10877 0.0417
Ma_fc_pa	0.16503 0.0019	-0.00496 0.9262	0.15229 0.0042	-0.00496 0.9262	0.18707 0.0004	0.25482 <.0001	0.10877 0.0417	1.00000
Ma_fc_ar	0.07076 0.1859	-0.09338 0.0806	-0.04252 0.4271	-0.09338 0.0806	0.10069 0.0595	-0.03949 0.4608	-0.07757 0.1470	-0.34684 <.0001
Ma_fc_cl	-0.17562 0.0010	0.09904 0.0638	-0.05128 0.3381	0.09904 0.0638	-0.22011 <.0001	-0.11834 0.0266	0.01187 0.8246	-0.26726 <.0001
Mi_fc_ar	-0.00041 0.9939	-0.00667 0.9010	0.07691 0.1505	-0.00667 0.9010	-0.10090 0.0590	0.19080 0.0003	0.09862 0.0650	0.37033 <.0001
Mi_fc_cl	0.10466 0.0501	0.04288 0.4232	-0.03290 0.5390	0.04288 0.4232	0.08682 0.1044	-0.19715 0.0002	-0.04895 0.3605	-0.28289 <.0001
Mi_fc_lc	-0.18528 0.0005	-0.06560 0.2202	-0.06364 0.2344	-0.06560 0.2202	0.00592 0.9120	0.04739 0.3760	-0.06957 0.1935	-0.08528 0.1107

Pearson Correlation Coefficients, N = 351 Prob > |r| under H0: Rho=0					
	Ma_fc_ar	**Ma_fc_cl**	**Mi_fc_ar**	**Mi_fc_cl**	**Mi_fc_lc**
minorAADT	0.07034 0.1886	-0.15885 0.0028	0.18592 0.0005	-0.05953 0.2660	-0.18934 0.0004
majorAADT	0.26185 <.0001	-0.39459 <.0001	0.00735 0.8909	-0.02458 0.6463	0.03199 0.5503
CityPop	0.07570 0.1570	0.02694 0.6150	-0.24743 <.0001	0.22904 <.0001	-0.01415 0.7917
CityAr	0.09258 0.0833	0.00179 0.9734	-0.19728 0.0002	0.16688 0.0017	0.01668 0.7554
CountyAr	-0.05927 0.2681	0.12242 0.0218	-0.08975 0.0932	-0.02488 0.6422	0.18666 0.0004

Pearson Correlation Coefficients, N = 351 Prob > |r| under H0: Rho=0					
	Ma_fc_ar	**Ma_fc_cl**	**Mi_fc_ar**	**Mi_fc_cl**	**Mi_fc_lc**
PCInc	-0.06096 0.2546	0.13788 0.0097	-0.23063 <.0001	0.16054 0.0026	0.08089 0.1304
MedAge	0.08528 0.1107	0.02719 0.6117	-0.04767 0.3732	-0.04398 0.4114	0.15380 0.0039
PplHH	-0.12200 0.0223	0.07346 0.1697	0.18006 0.0007	-0.20053 0.0002	0.07044 0.1880
LTmajor	0.07076 0.1859	-0.17562 0.0010	-0.00041 0.9939	0.10466 0.0501	-0.18528 0.0005
LTminor	-0.09338 0.0806	0.09904 0.0638	-0.00667 0.9010	0.04288 0.4232	-0.06560 0.2202
RTmajor	-0.04252 0.4271	-0.05128 0.3381	0.07691 0.1505	-0.03290 0.5390	-0.06364 0.2344
RTminor	-0.09338 0.0806	0.09904 0.0638	-0.00667 0.9010	0.04288 0.4232	-0.06560 0.2202
THlanes	0.10069 0.0595	-0.22011 <.0001	-0.10090 0.0590	0.08682 0.1044	0.00592 0.9120
SLmajor	-0.03949 0.4608	-0.11834 0.0266	0.19080 0.0003	-0.19715 0.0002	0.04739 0.3760
SLminor	-0.07757 0.1470	0.01187 0.8246	0.09862 0.0650	-0.04895 0.3605	-0.06957 0.1935
Ma_fc_pa	-0.34684 <.0001	-0.26726 <.0001	0.37033 <.0001	-0.28289 <.0001	-0.08528 0.1107
Ma_fc_ar	1.00000	**-0.81111** <.0001	0.12462 0.0195	0.03434 0.5213	-0.25882 <.0001
Ma_fc_cl	**-0.81111** <.0001	1.00000	-0.35898 <.0001	0.14113 0.0081	0.31909 <.0001
Mi_fc_ar	0.12462 0.0195	-0.35898 <.0001	1.00000	**-0.82903** <.0001	-0.11455 0.0319
Mi_fc_cl	0.03434 0.5213	0.14113 0.0081	-0.82903 <.0001	1.00000	-0.46057 <.0001
Mi_fc_lc	-0.25882 <.0001	0.31909 <.0001	-0.11455 0.0319	-0.46057 <.0001	1.00000

Table C.6: Descriptive statistics of variables used to develop minor street AADT estimation models for 3SG intersections in Kansas

Variables	Minimum	Maximum	Average	Standard Deviation
Minor street AADT	55	13,975	5,109	2,933
Major street AADT	2,555	45,650	15,844	8,478
City Population	6,294	389,060	128,967	137,754
City Area (sq. mi.)	4.32	159.29	59.00	58.59
County Area (sq. mi.)	151.60	1,429.86	696.00	301.45
Per Capita Income	17,692	81,743	29,364	14,780
Median Age	23.80	45.00	34.00	5.20
Number of people per Household	2.21	3.12	2.00	0.19
Number of through lanes	2	6	4	0.85
Speed Limit (Major Street)	30	55	38	6.00
Speed Limit (Minor Street)	20	60	32	6.30

Table C.7: Descriptive statistics of variables used to develop minor street AADT estimation models for 3ST intersections in Kansas

Variables	Minimum	Maximum	Average	Standard Deviation
Minor street AADT	100	8,080	2,187	1,532
Major street AADT	500	24,700	8,408	5,252
City Population	5,361	389,060	85,116	115,764
City Area (sq. mi.)	1.62	159.29	38.00	47.53
County Area (sq. mi.)	151.60	1,429.86	757.00	290.93
Per Capita Income	17,668	81,743	24,906	6,637
Median Age	23.80	45.00	34.00	4.22
Number of people per Household	2.15	3.12	2.00	0.21
Number of through lanes	2	4	3	1.00
Speed Limit (Major Street)	20	65	36	8.00
Speed Limit (Minor Street)	20	45	30	4.00

Appendix D: CURE Plots

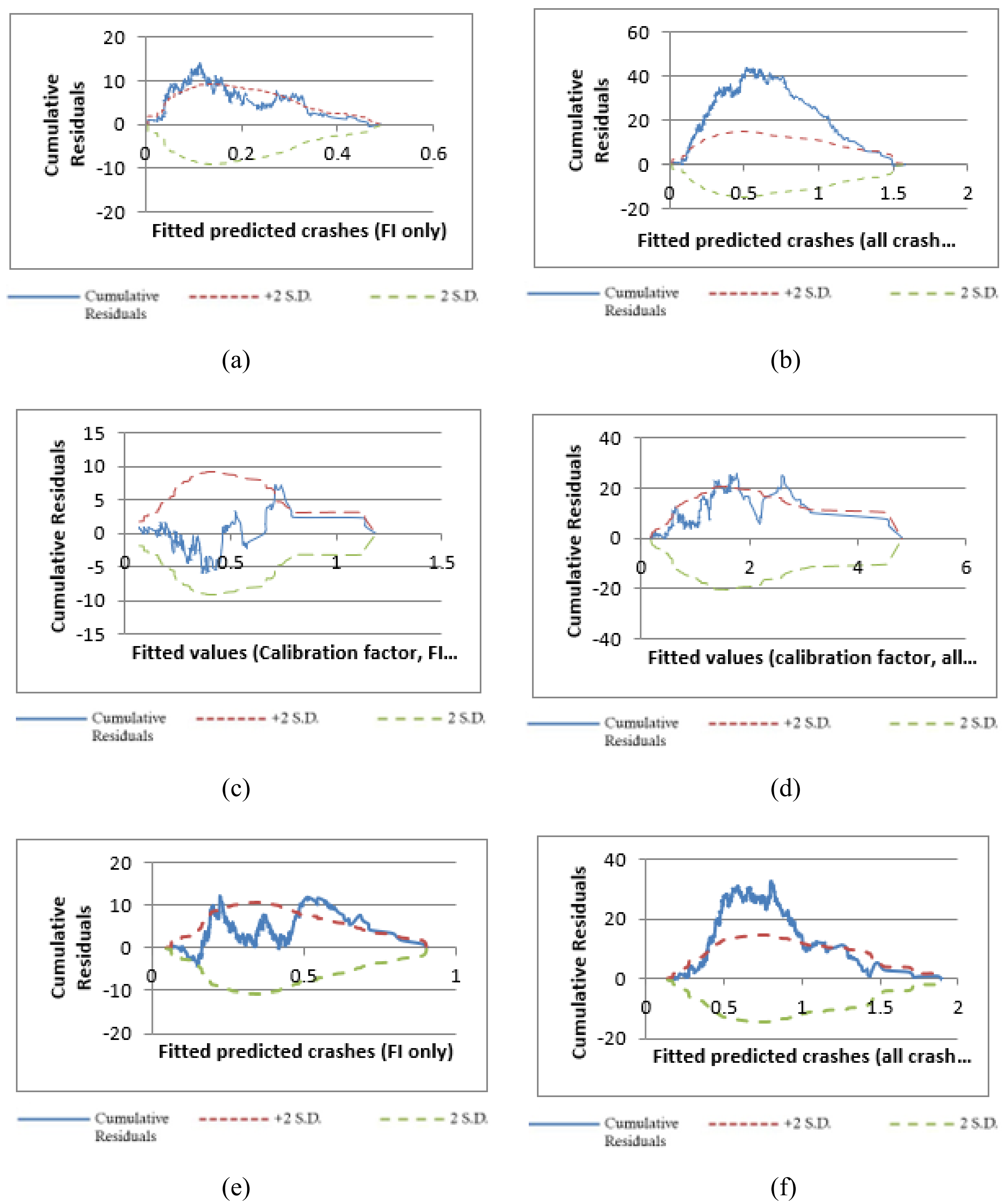
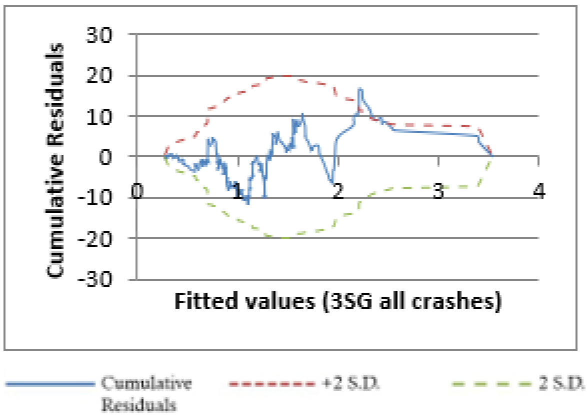
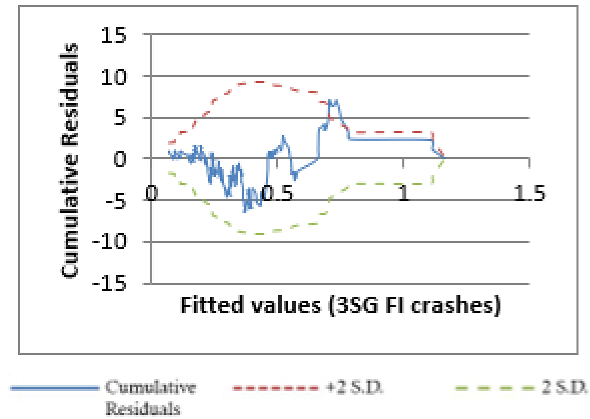


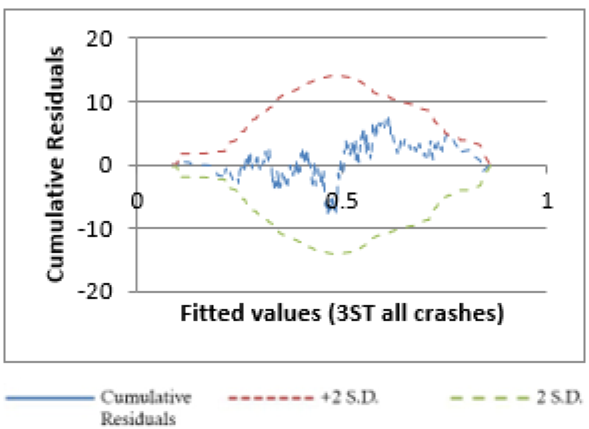
Figure D.1: CURE plots for fitted values estimated using calibration factors for: (a) 3SG, FI, (b) 3SG, all crashes, (c) 3ST, FI, (d) 3ST, all crashes, (e) 4ST, FI, and (f) 4ST, all crashes



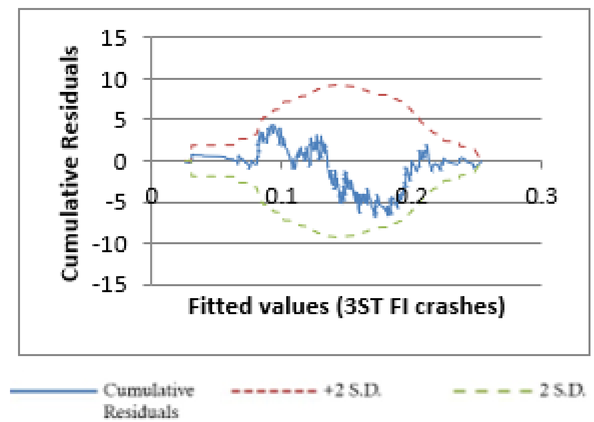
(a)



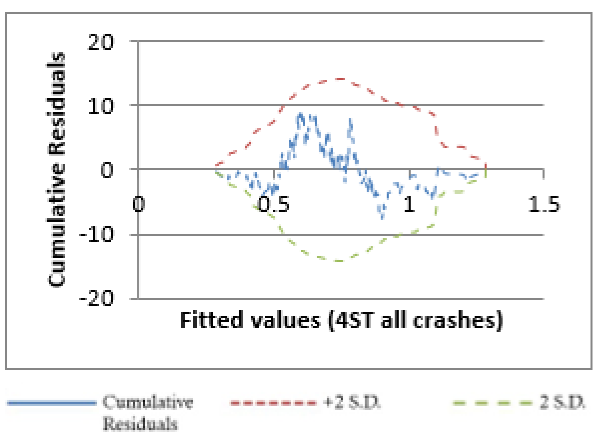
(b)



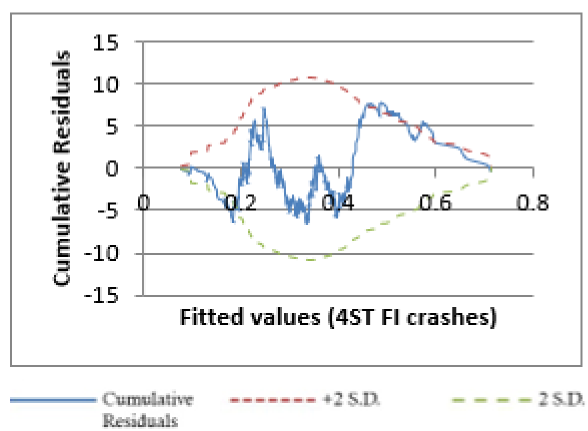
(c)



(d)



(e)



(f)

Figure D.2: CURE plots for fitted values estimated using calibration functions for: (a) 3SG, all crashes, (b) 3SG, FI, (c) 3ST, all crashes, (d) 3ST, FI, (e) 4ST, all crashes, and (f) 4ST, FI

K-TRAN

KANSAS TRANSPORTATION RESEARCH AND NEW-DEVELOPMENT PROGRAM

AD ASTRA PER ASPERA

Kansas

Department of Transportation