Research & Technology Transfer

Alaska Department of Transportation & Public Facilities

CALIBRATION OF THE HIGHWAY SAFETY MANUAL FOR THE STATE OF ALASKA

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The American Association of State Highway and Transportation Officials Highway Safety Manual provides a system to quantitatively analyze the safety of existing roadways and identify which geometric characteristics of current sites are correlated with high crash rates. To raise awareness about the frequency, severity, and locations of crashes and provide a tool to mitigate the occurrence of crashes, the Highway Safety Manual was calibrated specifically for Alaska. This research determined the local calibration for several main roadway facilities in the state, including four-way signalized intersections, unsignalized intersections, and two-lane rural highways. The research showed that calibration of most unsignalized intersections and two-lane rural highways provided consistent results. Calibration of four-way stop-controlled intersections in Central Region and four-way signalized intersections statewide showed results that varied based on annual average daily traffic (AADT). This finding is an indication that a Safety Performance Function (SPF) for this facility type should be determined to provide consistent results, independent of AADT.

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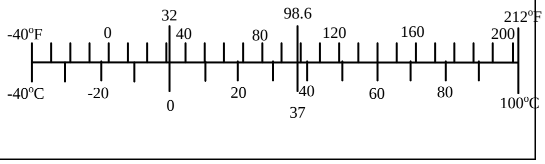
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.4		mm	mm	millimeters	0.039	inches	in
ft	feet	0.3048		m	m	meters	3.28	feet	ft
yd	yards	0.914		m	m	meters	1.09	yards	yd
mi	Miles (statute)	1.61		km	km	kilometers	0.621	Miles (statute)	mi
		AREA					AREA		
in^2	square inches	645.2	millimeters squared	cm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.0929	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	km^2	kilometers squared	0.39	square miles	mi^2
mi^2	square miles	2.59	kilometers squared	km^2	ha	hectares (10,000 m^2)	2.471	acres	ac
ac	acres	0.4046	hectares	ha					
		MASS (weight)					MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g	g	grams	0.0353	Ounces (avdp)	oz
lb	Pounds (avdp)	0.454	kilograms	kg	kg	kilograms	2.205	Pounds (avdp)	lb
T	Short tons (2000 lb)	0.907	megagrams	mg	mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME					VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces (US)	fl oz
gal	Gallons (liq)	3.785	liters	liters	liters	liters	0.264	Gallons (liq)	gal
ft^3	cubic feet	0.0283	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
Note: Volumes greater than 1000 L shall be shown in m^3									
		TEMPERATURE (exact)					TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (°F-32)	Celsius temperature	°C	°C	Celsius temperature	9/5 °C+32	Fahrenheit temperature	°F
		ILLUMINATION					ILLUMINATION		
fc	Foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2	cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi
These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements									

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Abstract

The American Association of State Highway and Transportation Officials Highway Safety Manual provides a system to quantitatively analyze the safety of existing roadways and identify which geometric characteristics of current sites are correlated with high crash rates. To raise awareness about the frequency, severity, and locations of crashes and provide a tool to mitigate the occurrence of crashes, the Highway Safety Manual was calibrated specifically for Alaska. This research determined the local calibration for several main roadway facilities in the state, including four-way signalized intersections, unsignalized intersections, and two-lane rural highways. The research showed that calibration of most unsignalized intersections and two-lane rural highways provided consistent results. Calibration of four-way stop-controlled intersections in Central Region and four-way signalized intersections statewide showed results that varied based on annual average daily traffic (AADT). This finding is an indication that a Safety Performance Function (SPF) for this facility type should be determined to provide consistent results by adding more variables in addition to AADT.

Summary of Findings

Calibration factor (CF) values were found for three different categories—four-way signalized intersections (4SG), unsignalized intersections (ST), and two-lane rural highway segments. For 4SG intersections, a CF was found per region, and these were then combined into one value that can be used to represent the entire state. These values are shown in Table A.

Table A – CF Values for 4SG Intersections

Region	CF Value	Combined CF Values
Northern	3.29	3.54
Central	3.66	
Southcoast	1.84	–

(For use with HSM Equation 12-5)

For unsignalized intersections, a CF was found per facility type per region. Some of these calibration values were combined to create a more general value if calibration values between regions where similar, or if there was insufficient data for a particular regional facility. These calibration results are summarized in Table B.

Table B – CF Values for Unsignalized Intersections

Region	Facility Type	Facility Abbreviation	CF Value
Northern	Rural Two-lane Three-way	R23ST	1.10
	Rural Two-lane Four-way	R24ST	
	Urban Three-way	U3ST	
	Urban Four-way	U4ST	
Central	Rural Two-lane Three-way	R23ST	0.81
	Rural Two-lane Four-way	R24ST	
	Urban Three-way	U3ST	1.72
	Urban Four-way	U4ST	2.37
Southcoast	Urban Three-way	U3ST	1.60
	Urban Four-way	U4ST	1.04

(For use with HSM Equations 10-3 and 12-5)

For two-lane rural highways, a CF was found for Central and Northern regions. A combined statewide CF was also calculated, as summarized in Table C.

Table C – CF Values for Two-Lane Two-Way Rural Highways

Region	CF Value	Combined CF Value
Central	1.25	1.25
Northern	1.22	
Southcoast	-	

(For use with HSM Equation 10-2)

CHAPTER 1 – INTRODUCTION AND RESEARCH APPROACH

Introduction

The American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) (2010) provides crash prediction models, which include safety performance functions (SPFs), crash modification factors (CMFs), and calibration factors (CFs), all of which have been developed for specific roadway segment and intersection types. The stated purpose of the HSM is to provide "safety, knowledge and tools in a useful form to facilitate improved decision-making based on safety performance" (Highway Safety Manual, 2010). The value of the HSM lies in its ability to assign quantitative crash values to road segments, intersections, and entire road systems based on the physical attributes and surrounding characteristics of a specific roadway. By providing a quantitative value, the HSM acts as a predictive tool for designers, engineers, and planners in selecting countermeasures and prioritizing projects, comparing alternatives, and quantifying and predicting the safety performance of roadway elements considered in planning, design, construction, maintenance, and operation. The HSM was originally published in 2010; it now incorporates a 2014 supplement. Efforts are underway by the National Cooperative Highway Research Program (NCHRP) and the Transportation Research Board (TRB) to expand the HSM to include other facilities and create a mechanism to make it more user-friendly for professionals and practicing engineers.

The ability to measure and predict roadway safety is an important component of local agency and community efforts to maintain and enhance the safety of road systems. The methods advocated by the HSM have proven useful across the United States in determining the safety impacts of geometric design elements. However, some areas of the United States, such as Alaska, have features and characteristics that are notably different from locations where the models were originally developed.

In order to effectively apply the HSM in Alaska, the SPFs given in the HSM have been calibrated to match local conditions.

Problem Statement

Alaska's current Highway Safety Improvement Program (HSIP) practice and design procedures use previous crash experience to identify locations for implementing safety countermeasures. However, previous crash experience does not necessarily predict future crash events. The Federal Highway Administration (FHWA) encourages states to adopt "a more comprehensive and proactive approach to prevent the most severe crashes by using risk analysis techniques within a data driven process to identify sites for potential safety improvement" (FHWA, 2013). The HSM is one of the tools available to help analyze risk factors and evaluate various countermeasures to maximize safety performance. However, as with any tool used for scientific purposes, the HSM and its SPFs require calibration. The Alaska Department of Transportation and Public Facilities (DOT&PF) contracted with the University of Alaska Anchorage (UAA) to conduct this work.

Regional Differences

Alaska covers approximately 375 million acres, a vast area that contains many different climate and population zones. DOT&PF has created regional boundaries in part to account for the differences. These regional boundaries, shown in Figure 1.1, are used throughout this report. Regional characteristic variations may cause disparity among the calibrated numbers for Northern, Central, and Southcoast regions. Regional differences include driver behavior, congestion, average annual daily traffic (AADT), wildlife, daylight hours, and weather conditions.

Figure 1.1 – DOT&PF's regional boundaries

Although wildlife is not expected to vary greatly between DOT&PF's three regions, there may be differences in population density among various species. For example, Southcoast Region contains fewer moose and, therefore, experiences fewer moose vehicle collisions (MVC), while the Glenn Highway in Central and Northern Regions continues to have one of highest crash rates for MVC in the state.

Daylight hours may also have an effect on driver sight distance and behavior. For instance, in comparison with major cities in other regions, Fairbanks in Northern Region receives the least amount of daylight during winter, with an average of 7.5 hours from October to March, and the most daylight in the summer, with an average of 17.5 hours from April to September. Anchorage in Central Region is second in this respect, with an average of 8.33 hours in the winter months, and an average of 16.5 hours in the summer months. Meanwhile, Southcoast Region receives the most daylight of any region during winter, with an average of nearly 9 hours, and the least light in the summer, with an average of 15.75 hours.

Weather conditions also play a role in varying calibration numbers. Typically, Southcoast Region receives more precipitation, while Northern Region is the driest.

Scope of Study

This study focused on the calibration of the HSM for the following facility types in the state:

1) Four-way signalized intersections
2) Unsignalized intersections
3) Two-lane rural highways

Project Description

Development of calibration factors included analyses of infrastructure features (segment length, lane width, shoulder width, grade, lighting, composition, and driveway frequency), traffic volumes, and historical crash experience in relation to standardized safety performance functions. Infrastructure and operational conditions were assessed to develop calibration factors for the various facility and intersection types. This effort required regional calibration factors, some of which were combined to create statewide values if all DOT&PF regions for that facility agreed or if data were insufficient for regional calibration.

The use of HSM methods enables the comparison of multiple design options to establish the most safety-enhancing and cost-effective combinations of countermeasures. HSM methods utilize objective reasoning for countermeasures that can be communicated to departmental decision-makers and the public. HSM analysis can be applied to facilities lacking crash records, which may lead to more HSIP projects, including systemic treatment projects and analysis of delivery of HSIP funding. Using HSM methods may enhance the HSIP by enabling objective prioritization of virtually all proposed HSIP projects.

Research Approach

The methods and procedures described in this section are based on the HSM methodology for determining local calibration factors.

Step 1 – Identify Facility Types for Which the Applicable SPFs Are to be Calibrated

For the purposes of this study, only four-way signalized intersections, all unsignalized intersections, and two-lane rural highways will be included. Other facility types are not addressed here, but could be considered for future research if enough sample sites are available.

Step 2 – Select Sites for Calibration of the SPF for Each Facility Type

For the calibration process, the HSM suggests a minimum sample size of 30–50 sites for each facility type, with at least 100 crashes per year of historical crash data. The HSM also suggests breaking the analysis up by region to provide a more accurate calibration factor. This was done by first determining the total number of samples available and then selecting the samples to be used in the calibration process. It was found that all types of rural multi-lane intersections in all regions, and rural two-lane intersections and highways in Southcoast Region lacked the required number of samples and/or crashes for the calibration factor to be determined.

The total sample size available and the number of samples selected are shown in Table 1.1. In the case of the four-way signalized intersections, an effort was made to include a representative sample of low, medium, and high AADT intersections in the calibration process.

Table 1.1 – Total Samples and Number of Samples Selected

Facility Type	Region	Total Samples Available	Number of Samples Selected to be used in the Calibration
Four-way Signalized Intersections	Northern	49	49
	Central	118	68
	Southcoast	13	13
Rural Two-lane Three-way Unsignalized Intersections	Northern	23	18
	Central	81	46
Rural Two-lane Four-way Unsignalized Intersections	Northern	13	9
	Central	15	10
Urban Three-way Unsignalized Intersections	Northern	95	80
	Central	225	69
	Southcoast	44	31
Urban Four-way Unsignalized Intersections	Northern	94	84
	Central	129	34
	Southcoast	17	11
Rural Two-lane Highway	Northern	333	30
	Central	371	30

The rural two-lane highway samples presented a problem, in that following the recommended sample selection method provided far fewer than 100 crashes per year. This is because most rural two-lane highways in Alaska experience relatively low traffic volumes, hence, sparse historical crashes. Since the HSM is designed for facilities where crashes from various contiguous segments can be added together, an alternative sample selection method was devised. Instead of using single homogenous segments as samples, 5-mile sections of the road were sampled and the various homogenous segments within each section were added together to produce a total crash number. This method allowed a larger number of crashes to be included using a smaller sample size.

Step 3 – Obtain Data for Each Sample Site

The data required for the sites varied for differing facility types. Table 1.2 is a summary of the data needed and the sources used to obtain the information.

In several cases for unsignalized intersections, AADT was unavailable for one or more legs of the intersection. Each leg missing AADT data was visually inspected using Google Earth and then assigned a qualitative traffic volume value—very low, low, medium, or high—based on location and proximity to high traffic attractions. To estimate actual AADT based on these quantitative values, the maximum, median, and minimum AADT values for each intersection type in each region were found using the data available.

Table 1.2 – Data Needs and Sources

Facility	Data Needed	Data Source
Intersections	AADT for the major/minor roads	DOT&PF/MOA/estimated
	Number of approaches with left turn lanes	Google Earth/site visit
	Number of approaches with right turn lanes	Google Earth/site visit
	Presence of lighting	Google Earth/site visit
	Presence of left-turn phasing	Google Earth/site visit
	Type of left-turn phasing	Google Earth/site visit
	Use of right-turn-on-red signal operation	Google Earth/site visit
	Use of red-light cameras	None used in Alaska
	Pedestrian volume	Assumed to be med-high
	Maximum number of lanes crossed by pedestrians	Google Earth/site visit
	Presence of bus stops within 1,000 ft	Bus maps/Google Earth
	Presence of schools within 1,000 ft	Google Earth/site visit
	Presence of alcohol sales establishments within 1,000 ft	Google Earth/site visit
	Historical crash data (2008–2012)	DOT&PF
Highways	AADT	DOT&PF
	Lengths of curves and tangents	Historical as-builts
	Radii of horizontal curves	Historical as-builts
	Percent grade	Assumed to be level
	Lane width	Historical as-builts
	Shoulder type	Historical as-builts
	Shoulder width	Historical as-builts
	Roadside hazard rating	Google Earth
	Presence of lighting	Google Earth
	Driveway density	Google Earth
	Presence of passing lane	Google Earth
	Presence of short four-lane section	Google Earth
	Presence of TWLTL	Google Earth
	Presence of centerline rumble strip	Google Earth
	Use of automated enforcement	None used in Alaska
	Historical crash data (2008–2012)	DOT&PF

It is important to note crash-reporting procedures for the state of Alaska. Alaska state law (AS 28.35.080) requires the reporting of any motor vehicle crash that results in the death or injury of one or more persons, or that causes total property damage of $2,000 or more. Alaska state law also requires that drivers or vehicle owners involved in a motor vehicle crash on public property that involves injury, death, or total property damage exceeding $501 (AS28.22.021) must provide proof of motor vehicle liability insurance to the Division of

Motor Vehicles in the Alaska Department of Administration. Studies in other locations have been conducted on reporting rates for crashes involving property damage only (PDO). In an Oregon study, 1 out of every 5 crashes went unreported (Malik et al., 2002). Most of these unreported crashes were PDO, such as fender benders, where drivers determined no substantial damage occurred and agreed not to report the accident. If 20% of crashes go unreported, as suggested by the Oregon study, the calibration factors resulting from the predictive method may be inaccurate. It should be acknowledged that the data provided in this report only reflect reported crashes.

Step 4 – Apply the Applicable Predictive Method to Predict Total Crash Frequency for Each Site during the Calibration Period

HSM predictive methods, which are shown in Appendix A, vary depending on the facility type. As suggested in the HSM, these methods were applied to selected sites without the use of the Empirical Bayes Method or any calibration factor. A total predicted crash value was determined for each site for a 5-year period.

Step 5 – Compute Calibration Factors

Based on the HSM methodology, the calibration factor was calculated. This was done for each facility type and region by taking the ratio of observed historical crashes, over predicted crashes for each type of facility (refer to Appendix A for the equation used).

Step 6 – Validation of Computed Calibration Factors

For Four-way signalized intersections and some unsignalized intersections, an additional step was taken of applying the computed calibration factor to a validation data set to see if it could adequately predict crashes compared with the historical crash data. This comparison demonstrated whether the model could be accurately used in cold regions.

CHAPTER 2 – FINDINGS

State-of-the-Art Summary

As part of the calibration research project, a state-of-the-art review was conducted to find published research and statistical reports or articles relevant to the project. Databases used for the review include the Journal of Traffic Safety, Traffic Injury Prevention and other relevant journals, as well as publications from state DOTs, the Federal Highway Administration (FHWA), the Transportation Research Board (TRB), the American Association of State and Highway Transportation Officials (AASHTO), the National Cooperative Highway Research Program (NCHRP), the National Highway Traffic Safety Administration (NHTSA), and other national and international organizations interested in highway and traffic safety. Databases such as the Transportation Research Information Services (TRIS), and the National Transportation Information Service (NTIS) were also reviewed.

For this project, the following issues were studied:

- Methodologies used to establish crash prediction models for specific roadway types
- Techniques performed in other states for developing local calibration
- Changes other studies made to the calibration methodology given in the HSM, and new methodologies that may be considered based on this information

For details of the literature review, see Appendix B.

The literature review provided emphasis on the following key aspects, which are critical for this research project: existing methodologies, outcomes, and recommendations for new methodologies because of said outcomes. The gathered literature made it apparent that:

1. Google Earth, the DOT&PF GIS database, and project as-builts will be used in acquiring geometrical data for the facilities under consideration.
2. Some roadway segments and intersections considered statistical outliers in the state will be excluded.
3. Other than the omissions addressed above, the sample set will be chosen at random.
4. Assumptions on typical values will be made if information, like pedestrian volume at intersections, is missing.
5. The fact that some crashes go unreported will be considered in the development of the calibration factors.
6. At least five years of crash data, 2007–2012, available through DOT&PF, will be considered.
7. Crashes within 250 feet of the intersection are considered intersection crashes.
8. Only segments covered in the HSM will be considered (for example, one-way streets will not be considered).
9. All values used in the HSM local calibration will be used, unless information is missing or there is no possibility of using typical values.
10. Local calibration values will be developed for each of the three DOT&PF regions addressed by the project. In case of a lack of information, adequate sample size, or insignificant differences in the outcome, a representative sample will be taken from each region to be considered in the development of local calibration.
11. For stop-controlled intersections, a mix of urban and rural samples will be considered.

12. Other issues may be identified based on feedback from the project technical advisory committee.

Four-way Signalized Intersection Results

The results of the calibration process for four-way signalized intersections are shown in Table 2.1.

Table 2.1 – Calculated CF Values for four-way Signalized Intersections

Region	CF Value
Northern	3.29
Central	3.66
Southcoast	1.84

(For use with HSM Equation 12-5)

The calibration factor was then applied to the prediction of the validation data set. The statistical comparison between the predicted crash rates of the intersections in the validation set and the historical crashes at those intersections showed no significant differences, at a 95% confidence level. Table 2.2 gives further details on the statistical analysis. Comparing the two samples as a pair, the data are significant; therefore, the conclusion is that the data sets are comparable.

Table 2.2 – Statistical Analysis for Calibrated vs. Validated Data

***t*-Test: Paired Two Sample for Means**		
	N predicted	***N observed***
Mean	68.81	56.67
Variance	1260.67	2405.09
Observations	45	45
Pearson Correlation	0.67010693	-
Df	44	-
t Stat	2.232	-
P (T ≤ *t*) two-tail	0.031	**< .05 so significant**
t Critical two-tail	2.015	**< t stat so significant**

Unsignalized Intersection Results

The results of the calibration process for unsignalized intersections are shown in Table 2.3.

Table 2.3 – Calibration Factors Found in Alaska: Stop-controlled Intersections

Region	Facility Type	Facility Abbreviation	CF Value
Northern	Rural 2-lane 3-way	R23ST	1.11
	Rural 2-lane 4-way	R24ST	0.93
	Urban 3-way	U3ST	1.33
	Urban 4-way	U4ST	0.99
Central	Rural 2-lane 3-way	R23ST	0.82
	Rural 2-lane 4-way	R24ST	0.80
	Urban 3-way	U3ST	1.72
	Urban 4-way	U4ST	2.37
Southcoast	Rural 2-lane 3-way	R23ST	---
	Rural 2-lane 4-way	R24ST	---
	Urban 3-way	U3ST	1.60
	Urban 4-way	U4ST	1.04

(For use with HSM Equations 10-2 and 12-5)

Many of the facility types follow the national data with CF close to 1.00, however both Central Region urban-type facilities have higher CF values than the rest of the state. This finding can be explained by city driving behavior and by the high urban traffic flow. Central Region includes Anchorage, the largest city in Alaska. Due to much heavier congestion, drivers may be forced to accept smaller gaps in traffic flow. This may lead to aggressive driving behaviors, which, in turn, may lead to a greater number of crashes per intersection.

While the Central Region U4ST CF value, 2.37, is relatively high, it is not unreasonable. It is lower than the value calculated in the previous Alaska study, which was 3.46 (Bowie et al., 2014). This difference is to be expected, as the previous study took into account only Anchorage, rather than the entirety of Central Region. Including the other places in Central Region served to moderate the value, due to the somewhat calmer driving conditions and, thus, lower CF values in the rest of Central Region.

The values for U3ST in both Northern and Southcoast regions are higher than their U4ST counterparts. Many of the higher values compare with other studies as well. A study from Regina, Canada, indicates comparable values: Regina's CF was 1.47 (Young and Park, 2012), which is similar to both Southcoast Region's value, 1.60, and Northern Region's value, 1.33. The Saskatchewan area has similar climate and driving conditions to Alaska, so these similar values are to be expected.

The validation process was performed on only Central Region U3ST and U4ST because other region and facility types did contain a large enough sample size. The values from the validation process are included in Table 2.4.

Table 2.4 – Central Alaska Validation Values

Facility Abbreviation	Validation CF Value
U3ST	1.85
U4ST	1.83

Two-Lane Rural Highway Results

The calibration values for two-lane rural highways were calculated using the SPFs presented in the HSM. The models are listed in Appendix A. The CF values resulting from this study are summarized in Table 2.5.

Table 2.5 – Calculated CF Values for Two-lane Two-way Rural Roads

Region	Calculated CF Value
Central	1.25
Northern	1.22
Combined	1.25

(For use with HSM Equation 10-2)

Overall, the calibration values for all three regions were fairly consistent. Unlike other calibration factors, the two-lane, two-way rural road calibration factor appears to be consistent across both various AADT as well as the different regions analyzed.

When looking at calibration factors found in other locations, the value for Alaska is higher than most, but not extreme, as shown in Table 2.6.

Table 2.6 – Calculated CF Values for Two-lane Two-way Rural Roads in Various Locations

Location	CF Value	Reference
Oregon	0.74	Xie et al. (2011)
Missouri	0.82	Sun et al. (2013)
Idaho	1.115	Sipple (2014)
Utah	1.16	Saito et al. (2012)
Alaska	1.25	-
Illinois	1.40	Williamson and Zhou (2012)

A validation process was not performed for the two-lane rural highways. This is due to the large effort in collecting the samples for this type of facility and that it is not required by the HSM process.

CHAPTER 3 – INTERPRETATION, APPRAISAL, AND APPLICATIONS

General Recommendations

Calibration factor (CF) values vary significantly across the state of Alaska. For this reason, blanketing the entire state with one value is not possible. This study recommends that DOT&PF use the region-specific CFs developed in this research for use in Alaska. If a region-specific CF is not available, then a combined CF may still provide accurate results. The validation results show that these CFs can reliably predict crash frequency when used with the HSM methods.

The HSM suggests recalculating CFs every two to three years. This may not be needed currently; however, if DOT&PF starts implementing the HSM as a planning and design tool, then this time interval should be considered. If few changes were found following several iterations of recalculations, perhaps a longer time between recalculations would be justified.

To assist with future HSM calibration efforts, it is recommended that DOT&PF maintain a single statewide database of crash data, roadway inventory, and traffic volume data. Although creating this database could be challenging, it would make determining CFs far more efficient in the future. Additionally, such a database could be used both for planning and safety analysis.

CHAPTER 4 – CONCLUSIONS AND SUGGESTED RESEARCH

Conclusions

While many of the calibration factor (CF) values found in this study are higher than average, the Highway Safety Manual (HSM) prediction models are still accurate. Some of the CF values found were markedly high, such as for urban four-way signalized intersections. However, even in these cases the validation procedure showed that CF values produce accurate results. The values developed in this study can be used for the following facilities:

- Urban four-way Signalized Intersections
- Northern and Central Region Unsignalized Intersections
- Rural Two-lane Highways

The CF values found in this study allow DOT&PF to apply quantitative estimates of crash frequency in planning, system-wide analysis, and all phases of the design process.

This practice will increase the efficiency of spending on safety improvements and lead to improved safety of the roadway system in general.

Suggested Research

The HSM suggests recalculating CFs every two to three years. This time interval may not be needed currently, but if DOT&PF begins using the HSM as a planning and design tool, this timing should be considered. If few changes are found following several iterations of recalculations, then perhaps a longer time between recalculations would be justified.

Although this study assists in accurate prediction of crash frequency, crash severity is not addressed. A study of crash severity distribution at various facility types in Alaska would fill this knowledge gap and increase the usefulness of the HSM.

DOT&PF should also consider what additional types of facilities they would like to apply the HSM to and perform a similar calibration procedure to determine CF values.

For several of the facilities analyzed, the HSM supplied SPFs produced predictions that varied in accuracy based on AADT. To increase the reliability of HSM crash prediction, development of jurisdictional SPFs, as prescribed in the HSM, is suggested for the following facility types:

- Urban four-way Signalized Intersections
- Northern and Central Region Unsignalized Intersections

Finally, a study concerning crash-reporting procedures in Alaska compared with other jurisdictions could ascertain the percentage of crash reporting in other states to further validate the calibration accuracy.

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APPENDIX A – HSM Predictive Models and Procedures

Four-Way Signalized Intersection Predictive Model

The predictive model used to determine crash frequency at four-way signalized intersections, as discussed in Chapter 12 of the HSM, is shown in HSM Equations 12-5, 12-6, and 12-7:

$$N_{predicted\ int} = C_i \times (N_{bi} + N_{pedi} + N_{bikei}) \qquad \textbf{(HSM Eq 12-5)}$$

where:

$N_{predicted\ int}$ = predicted average crash frequency for an individual intersection for the selected year
N_{bi} = predicted average crash frequency of an intersection (only vehicle-vehicle collisions)
N_{pedi} = predicted average crash frequency of vehicle-pedestrian collisions
N_{bikei} = predicted average crash frequency of vehicle-bicycle collisions
C_i = calibration factor for intersections developed for use for a particular jurisdiction or geographical area.

$$N_{bi} = N_{spf\ int} \times (CMF_{1i} \times CMF_{2i} \times \ldots CMF_{6i}) \qquad \textbf{(HSM Eq 12-6)}$$

where:

$N_{spf\ int}$ = predicted average crash frequency for an intersection with base conditions (only vehicle-vehicle collisions)
CMF_{Ii} = crash modification factors for intersections

$$N_{spf\ int} = N_{pimv} + N_{pisv} \qquad \textbf{(HSM Eq 12-7)}$$

where:

$\mathrm{N_{pimv}}$ = predicted average number of multiple-vehicle collisions for base conditions
$\mathrm{N_{pisv}}$ = predicted average number of single-vehicle collisions for base conditions

The SPF for multiple-vehicle collisions is shown in HSM Equation 12-21:

$$N_{pimv} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})] \qquad \textbf{(HSM Eq 12-21)}$$

where:

$AADT_{maj}$ = AADT(vehicles per day) on the major road
$AADT_{min}$ = AADT(vehicles per day) on the minor road
a, b, c = regression coefficients

For four-way signalized intersections, a = -10.99, b = 1.07, c = 0.23, and the overdispersion parameter is 0.39. The SPF for single-vehicle collisions is shown in HSM Equation 12-24:

$$N_{pisv} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})] \qquad \textbf{(HSM Eq 12-24)}$$

For four-way signalized intersections, a = -10.21, b = 0.68, c = 0.27, and the overdispersion parameter is 0.36. The predicted number of vehicle-pedestrian collisions is shown in HSM Equation 12-28:

$$N_{pedi} = N_{pedbase} \times CMF_{1p} \times CMF_{2p} \times CMF_{3p} \qquad \textbf{(HSM Eq 12-28)}$$

where:

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

$CMF_{1p} \ldots CMF_{3p}$ = crash modification factors for intersections

The SPF for vehicle-pedestrian collisions is shown in HSM Equation 12-29:

$$N_{pedbase} = exp[a + b \times ln(AADT_{total}) + c \times ln(AADT_{min} / AADT_{maj}) + d \times ln(PedVol) + e \times \mathrm{n}_{\mathrm{lanesx}}] \qquad \textbf{(HSM Eq 12-29)}$$

where:

$AADT_{total}$ = sum of the 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

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

The regression coefficients for four-way signalized intersections are: a = -9.53, b = 0.40, c = 0.26, d = 0.45, e = 0.04, and the overdispersion parameter is 0.24. The predicted number of vehicle-bicycle collisions is shown in HSM Equation 12-31:

$$N_{pedi} = N_{bi} + f_{bikei} \qquad \textbf{(HSM Eq 12-31)}$$

where:

f_{bikei} = bicycle crash adjustment factor (3ST = 0.016, 4ST = 0.018)

Rural Two-Lane Two-Way Unsignalized Intersection Predictive Model

The predictive model used to determine crash frequency at two-lane two-way unsignalized intersections, as discussed in Chapter 10 of the HSM, is shown in HSM Equation 10-3:

$$N_{predicted\ int} = N_{spf\ int} \times C_i \times (CMF_{1i} \times CMF_{2i} \times \ldots\ CMF_{4i}) \qquad \textbf{(HSM Eq 10-3)}$$

where:

$N_{predicted\ int}$ = predicted average crash frequency for an individual intersection for the selected year

$N_{spf\ int}$ = predicted average crash frequency for an intersection with base conditions

CMF_{1i} ..CMF_{4i} = crash modification factors for intersections

C_i = calibration factor for intersections of a specific type developed for use for a particular jurisdiction or geographical area.

There are two subcategories for this facility type: three-way stop-controlled and four-way stop-controlled. The HSM offers slightly different SPFs for each. The SPF for three-way stop-controlled intersections is shown in HSM Equation 10-8:

$$N_{spf\ 3ST} = exp[-9.86 + 0.79 \times ln(AADT_{maj}) + 0.49 \times ln(AADT_{min})] \qquad \textbf{(HSM Eq 10-8)}$$

where:

$N_{spf\ 3ST}$ = estimate of intersection-related predicted average crash frequency for base conditions

$AADT_{maj}$ = AADT(vehicles per day) on the major road

$AADT_{min}$ = AADT(vehicles per day) on the minor road

The overdispersion parameter (k) for this SPF is 0.54. The equation works for an $AADT_{maj}$ between 0 and 19,500, and an $AADT_{min}$ between 0 and 4,300. The SPF for four-way stop-controlled intersections is shown in HSM Equation 10-9:

$$N_{spf\ 4ST} = exp[-8.56 + 0.60 \times ln(AADT_{maj}) + 0.61 \times ln(AADT_{min})] \qquad \textbf{(HSM Eq 10-9)}$$

where:

$N_{spf\ 4ST}$ = estimate of intersection-related predicted average crash frequency for base conditions

$AADT_{maj}$ = AADT(vehicles per day) on the major road

$AADT_{min}$ = AADT(vehicles per day) on the minor road

The overdispersion parameter (k) for this SPF is 0.24. This equation works for an $AADT_{maj}$ between 0 and 14,700, and an $AADT_{min}$ between 0 and 3,500.

Urban and Suburban Arterial Unsignalized Intersection Predictive Model

The predictive model used to determine crash frequency at urban and suburban unsignalized intersections, as discussed in Chapter 12 of the HSM, is shown in HSM Equations 12-5, 12-6, and 12-7:

$$N_{predicted\ int} = C_i \times (N_{bi} + N_{pedi} + N_{bikei}) \qquad \textbf{(HSM Eq 12-5)}$$

where:

$N_{predicted\ int}$ = predicted average crash frequency for an individual intersection for the selected year
N_{bi} = predicted average crash frequency of an intersection (only vehicle-vehicle collisions)
N_{pedi} = predicted average crash frequency of vehicle-pedestrian collisions
N_{bikei} = predicted average crash frequency of vehicle-bicycle collisions
C_i = calibration factor for intersections developed for use for a particular jurisdiction or geographical area.

$$N_{bi} = N_{spf\ int} \times (CMF_{1i} \times CMF_{2i} \times \ldots CMF_{6i}) \qquad \textbf{(HSM Eq 12-6)}$$

where:

$N_{spf\ int}$ = predicted average crash frequency for an intersection with base conditions (only vehicle-vehicle collisions)
CMF_{Ii} = crash modification factors for intersections

$$N_{spf\ int} = N_{pimv} + N_{pisv} \qquad \textbf{(HSM Eq 12-7)}$$

where:

$\mathrm{N_{pimv}}$ = predicted average number of multiple-vehicle collisions for base conditions
$\mathrm{N_{pisv}}$ = predicted average number of single-vehicle collisions for base conditions

The SPF for multiple-vehicle collisions is shown in HSM Equation 12-21:

$$N_{pimv} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})] \qquad \textbf{(HSM Eq 12-21)}$$

where:

$AADT_{maj}$ = AADT(vehicles per day) on the major road
$AADT_{min}$ = AADT(vehicles per day) on the minor road
a, b, c = regression coefficients

For three-way unsignalized intersections, a = -6.81, b = 0.16, c = 0.51, and the overdispersion parameter is 1.14. For four-way unsignalized intersections, a = -5.33, b = 0.33, c = 0.12, and the overdispersion parameter is 0.65. The SPF for single-vehicle collisions is shown in HSM Equation 12-24:

$$N_{pisv} = exp[a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min})] \qquad \textbf{(HSM Eq 12-24)}$$

For three-way unsignalized intersections, a = -13.36, b = 1.11, c = 0.41, and the overdispersion parameter is 0.80. For four-way unsignalized intersections, a = -8.90, b = 0.82, c = 0.25, and the overdispersion parameter is 0.40. The predicted number of vehicle-pedestrian collisions is shown in HSM Equation 12-30:

$$N_{pedi} = N_{bi} + f_{pedi} \qquad \textbf{(HSM Eq 12-30)}$$

where:

f_{pedi} = pedestrian crash adjustment factor (3ST = 0.021, 4ST = 0.022)

The predicted number of vehicle-bicycle collisions is shown in HSM Equation 12-31:

$$N_{pedi} = N_{bi} + f_{bikei} \qquad \textbf{(HSM Eq 12-31)}$$

where:

f_{bikei} = bicycle crash adjustment factor (3ST = 0.016, 4ST = 0.018)

Two-Lane Two-Way Rural Highway Predictive Model

The predictive model used to determine crash frequency on two-lane two-way rural highways, as discussed in Chapter 10 of the HSM, is shown in HSM Equation 10-2:

$$N_{predicted\ rs} = N_{spf\ rs} \times C_r \times (CMF_{1r} \times CMF_{2r} \times \ldots\ CMF_{12r}) \qquad \textbf{(HSM Eq 10-2)}$$

where:

$N_{predicted\ rs}$ = predicted avg. crash frequency for an individual roadway segment for a specific year

$N_{spf\ rs}$ = predicted avg. crash frequency for base conditions for an individual roadway segment;

C_r = calibration factor for roadway segments of a specific type developed for a particular jurisdiction or geographical area; and

$CMF_{1r}..CMF_{12r}$ = crash modification factors for rural two-lane, two-way roadway segments.

The SPF for two-lane two-way rural roads is shown in HSM Equation 10-6:

$$N_{spf\ rs} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)} \qquad \textbf{(HSM Eq 10-6)}$$

where:

$N_{spf\ rs}$ = predicted average crash frequency for base conditions for an individual roadway segment;

$AADT$ = average annual daily traffic volume (vehicles per day); and

L = length of the roadway segment (miles).

The overdispersion parameter for this SPF is shown in HSM Equation 10-7:

$$k = 0.236 / L \qquad \textbf{(HSM Eq 10-7)}$$

where:

k = overdispersion parameter; and

L = length of the roadway segment (miles).

Calibration Procedure

The local calibration factor is determined, as discussed in Appendix A of the HSM, using HSM Equation A-1:

$$C_r \text{ (or } C_i) = (\sum \text{observed crashes}) / (\sum \text{predicted crashes}) \qquad \textbf{(HSM Eq A-1)}$$

APPENDIX B – Literature Review

B.1 Introduction

The following is an overview of the HSM calibration methods utilized both within the United States and in other countries, which was gleaned from a review of various studies. These methods will be presented and their modifications analyzed for applicability to the state of Alaska, in order to provide insight into how the HSM may be calibrated for Alaska's unique geographical and weather conditions. Studies included in this review were conducted in the states of Illinois (Williamson and Zhou, 2012), Louisiana (Sun et al., 2006), Missouri (Sun et al., 2013), North Carolina (Srinivasan and Carter, 2011), Oregon (Xie et al., 2011), Idaho (Sipple, 2014), Kansas (Lubliner, 2011), Alabama (Mehta and Lou, 2013), Maryland (Shin, Lee, and Dadvar, 2014), as well as Regina (Young and Park, 2012) and Québec, Canada (Barber, 2014). Additional relevant topics were reviewed to better understand the HSM function, problems encountered, limitations, and calibration process.

B.2 HSM Calibration in the United States

B.2.1 HSM Calibration in North Carolina

Srinivasan and Carter (2011) detailed the safety performance functions (SPFs) for nine crash types in North Carolina, using data compiled from several sources.

Methods for Collecting Data
The Highway Safety Information System (HSIS) was used to collect roadway inventory, traffic volumes, and crash data. This system includes the Traffic Engineering Accident Analysis System (TEAAS), which collects crash data for the North Carolina Department of Transportation (NCDOT). Years 2007–2009 were used for this study. Aerial and street views came from Google Maps and NCDOT GIS files. The study classified road segments by their geographical characteristics: coast, piedmont, and mountain. The piedmont is a plateau region located in the eastern United States between the Atlantic Coastal Plain and the main Appalachian Mountains, stretching from New Jersey in the north to central Alabama in the south.

Scope of Calibration
Four intersection site types were not calibrated due to a lack of data. This study limited crashes to vehicle-vehicle and vehicle-bicycle, omitting pedestrian crashes to avoid the collection of detailed data on bus stops, schools, and alcohol sales.

Methods of Sampling
The study initially attempted to follow the sampling suggestions proposed in the HSM, but instead decided to select entire routes, using all segments and intersections from a route to increase efficiency. To minimize the bias that might be introduced by using this method, all routes were chosen from either a single county or adjacent counties. This allowed for a mix of road classes in the samples. Roughly the same numbers of groups were selected from each of the three geographic areas.

Intersections were extended 250 feet in both directions from the center. The smallest sample size was rural two-lane signalized four-way intersections (R24SG), with 19 samples, and the largest was rural two-lane minor road stop-controlled three-way intersections (R23ST), with 133 samples. Half of the intersection types met the HSM-recommended minimum of 100 crashes per year.

Results and Calibration Factors
The data from each of the three years analyzed did not differ significantly as shown in table B.1. It was theorized that the higher calibration values might be caused by North Carolina's fatal crash rate, as it was 50% higher than Washington's, which was one of the states used in the original HSM model.

Table B.1 – Calibration Results for North Carolina Facilities

Facility Abbreviation	2007	2008	2009	3-Year Average
R23ST	0.57	0.58	0.57	0.57
R24SG	1.14	1.13	0.84	1.04
R24ST	0.77	0.64	0.65	0.68
RM4SG	0.55	0.47	0.46	0.49
U3SG	2.86	2.46	2.09	2.47
U3ST	1.75	2.03	1.38	1.72
U4SG	3.01	2.85	2.51	2.79
U4ST	1.61	1.13	1.22	1.32
R4D	0.96	0.95	0.99	0.97
U2U	1.58	1.66	1.36	1.54
U3T	4.30	3.65	2.90	3.62
U4D	3.90	4.25	3.45	3.87
U4U	4.10	4.45	3.57	4.04
U5T	1.75	1.72	1.68	1.72

B.2.2 HSM Calibration in Utah

Saito et al. (2012) calibrated rural, two-lane highways in Utah.

Methods for Collecting Data
The Road View Explorer of the Utah Department of Transportation (UDOT) was used to collect road information and visual data, and to choose segments. UDOT also provided data concerning crash history and AADT. Google Earth was used for geometric measurements. Since curvature data were limited, tangent segments were adopted as a new variable in their model.

Scope of Calibration
This study used 426 crashes on 157 segments of rural, two-lane two-way roads to develop the SPFs. Only 14 of these segments met the HSM base conditions. All segments were local, federally sponsored roads, so that data were easily accessible. The researchers chose to remove segments with AADT values greater than 10,000 vehicles/day, justifying the procedure because these roads were outliers when compared to the rest of Utah's rural, two-

lane highways. Eight segments were removed through this process. Four segments were removed for having a speed limit of 40 or 45 mph, for the same reasons. The calibration included three years of data, from 2005 to 2007.

Methods of Sampling
Other than the obvious omissions above, the sample set was chosen at random, with an original size of 169 sites. The UDOT Construction Database was used to verify that the samples chosen had not been involved in any construction from 2005–2007.

Results and Calibration Factors
The calibration factor of rural, two-lane highways was 1.16. This model predicted 368 crashes for the years 2005–2007. The study also developed jurisdiction-specific SPFs. They developed a new model using negative binomial regression and an over-dispersion parameter to improve these specific SPFs. Four SPFs were developed: two conventional models, and two transformed models using the natural log of the AADT. The over-dispersion parameters were 1.20 (75% confidence level) and 1.24 (95% confidence level) for the conventional models, and 1.14 (75% confidence level) and 1.19 (95% confidence level) for the transformed models. Bayesian information criterion (BIC) was used to select the preferred model, as shown in Table B.2. The model that produced the lowest value, the transformed method, was preferred.

Table B.2 – BIC Values for Utah HSM Study

Types of Calibration	BIC Value
Calibrated HSM SPF	1095.6
Conventional method (75%)	607.4
Conventional method (95%)	601.5
Transformed method (75%)	596.7
Transformed method (95%)	583.7

B.2.3 HSM Calibration in Oregon

Xie et al. (2011) calibrated several facility types in Oregon, with data compiled from several sources.

Methods for Collecting Data
Three years of crash data (2004–2006) were collected from the Statewide Crash Data System of the Oregon Department of Transportation (ODOT). In keeping with standard procedure in the HSM, crashes were credited to intersections if they were within 250 ft. All other crashes were considered segment crashes. The study did not use default values, as the researchers were concerned that the level of precision would be impacted. Digital volume logs and aerial photos via Google Earth were used to find local characteristics.

Due to lack of information, medium pedestrian volume at intersections was assumed. Signal phasing was determined by assuming minor roads had the same phasing as major roads if there were dedicated left-turn lanes. Models were developed to estimate missing AADT values for some minor roads and their intersections. Equation B.1 gives the model used for unsignalized intersections.

$$\begin{aligned}\text{Log}_{10}\ \text{AADT} = {} & 2.0281 - 0.112\ (\log_{10} \text{Distance} - 1.174634) + 0.68\ (\text{MIA}) \\ & + 0.4148\ (\text{MAC}) + 0.1391\ (\text{CityLimit}) + 0.1761\ (\text{Right}) \\ & + 0.2060\ (\text{RightCross}) + 0.2125\ (\text{LandUse}) + 0.3028\ (\text{Centerline}) \\ & + 0.1268\ (\text{Edgeline})\end{aligned} \qquad \text{(Equation B.1)}$$

Scope of Calibration

Three facility types described in the HSM were calibrated: segments and intersections on rural two-lane highways, rural multi-lane highways, and urban and suburban arterials, as well as intersections shown in Table B.3. A total of 18 factors were calibrated.

Methods of Sampling

This study followed the general site selection guidelines in the HSM, with a few modifications. Instead of a sample size of 50–70, a sample size of 100 was chosen where possible. For stop-controlled intersections with few crashes, this was necessary to achieve an accurate sample. State-maintained roads were chosen first, with roads outside this limit selected if the sample size was too small.

Results and Calibration Factors

The calibration results are shown in Table B.3. These results show that most of the calibration factors were less than 1.00, implying that both roads and intersections in Oregon are safer than the national average. Urban four-lane divided segments (U4D) and urban four-lane signalized intersections (U4SG) both had calibration factors above 1.00.

The researchers found possible explanations for the low calibration values, noting that the threshold level for crash reports was higher (minimum of $1,500 damage) than in some of the states used in the HSM. They also found that the ratio of fatal and injury crashes to property damage crashes was higher in Oregon. When they adjusted for this difference, their calibration values increased and were closer to the national average. They also noted that the AADT was a variable that seemed to greatly influence their calibration factors.

Table B.3 – Estimated Calibration Factors for Oregon Intersection Types

	CALIBRATION FACTOR			
Rural Two-Lane Two-Way				
SEGMENT TYPE	2004	2005	2006	2004-2006
R2	.68	.79	.75	.74
Rural Multilane				
SEGMENT TYPE	2004	2005	2006	2004-2006
MRU	0.33	0.42	0.34	0.36
MRD	0.69	0.60	1.03	0.78
Urban and Suburban Arterials				
SEGMENT TYPE	2004	2005	2006	2004-2006
U2U	0.63	0.49	0.76	0.63
U3T	0.83	0.81	0.81	0.82
U4D	1.16	1.60	1.53	1.43
U4U	0.58	0.64	0.73	0.65
U5T	0.68	0.64	0.60	0.64
Rural Two-lane Two-way				
INTERSECTION TYPE	2004	2005	2006	2004-2006
R3ST	.68	.79	.75	.74
R4ST	0.31	0.27	0.36	0.31
R4SG	0.38	0.51	0.52	0.47
Rural Multilane				
INTERSECTION TYPE	2004	2005	2006	2004-2006
MR3ST	0.20	0.13	0.14	0.16
MR4ST	0.32	0.39	0.49	0.40
MR4SG	0.14	0.14	0.16	0.15
Urban and Suburban Arterials				
INTERSECTION TYPE	2004	2005	2006	2004-2006
U3ST	0.41	0.32	0.31	0.35
U4ST	0.48	0.38	0.46	0.44
U3SG	0.76	0.72	0.78	0.75
U4SG	1.11	1.13	1.08	1.10

B.2.4 HSM Calibration in Illinois

Williamson and Zhou (2012) calibrated rural two-lane highways in Illinois.

Methods for Collecting Data
The researchers used a traditional approach, similar to the HSM collection process, to gather their data. This included an inspection of roadways, reviewing crash reports, and meeting with stakeholders and citizens.

Scope of Calibration
In accordance with the HSM, crashes within 250 feet of an intersection were classified as intersection crashes. Both the HSM SPF and the Illinois SPF were used in the study. Three years of data (2005–2007) were analyzed with a total of 165 crashes. These years were specifically chosen due to a crash recording policy in late 2009.

Methods of Sampling
Five segments were randomly selected from six randomly selected counties. This was done to ensure the prediction would be representative of the state.

Results and Calibration Factor
The HSM SPF predicted 22.1 crashes total, while the Illinois SPF predicted 19.6. These results were used to find calibration factors of 1.40 and 1.58, showing that the number of crashes on rural two-lane segments in Illinois is higher than the national average. The results were confirmed with a validation process including 10 randomly selected segments in similar counties. Both SPFs were found, and their results indicated a 53% and 59% correlation between actual and predicted crashes.

As mentioned above, there was a change in crash reporting policy in Illinois in 2009. The reporting threshold increased from $500 to $1,500, a significant jump, which resulted in a significant decrease in crash reports. The total number dropped from 422,778 reports (2007) and 408,258 reports (2008) to 292,106 reports (2009). It was noted it would likely be necessary to adjust for the introduced bias.

B.2.5 HSM Calibration in Florida

Alluri et al. (2012) conducted a study to identify and prioritize calibration variables that most influence the calibration of the HSM in individual locations.

Methods for Collecting Data
Data were collected on the required variables in the HSM through the Roadway Characteristics Inventory (RCI) or aerial images from Google Earth. The RCI database includes segments that are part of, or are soon to be included in, the state highway system. The Visual Roadway Collection System (VRICS) was used to collect information on the variables that the RCI database did not have. There were not enough three-way and four-way signalized and unsignalized intersections identified, so a map was overlaid with the known signalized intersections to identify intersections without signals. Using this method, 1555 intersections were found. Three years of crash data (2009–2011) were analyzed.

Scope of Calibration
Initially, all the segment and intersection subtypes in the HSM, including the unsignalized intersections focused on in this report, were calibrated. It was later found that certain site types had sample sizes of less than 100 intersections, and these types were excluded from analysis.

Methods of Sampling
Only segments that were recorded as "active on the state highway system" were chosen, as they had recent crash data. One-way segments were excluded, as they are not specifically covered in the HSM. Due to lack of data, several site types were not analyzed, but none of them were the unsignalized intersections of interest for this review.

Results and Calibration Factor
As previously assumed, it was found that certain variables were more influential in predicting crashes than others. The study ranked the variables according to their IncNodePurity values, which were found using the random forest technique. An example of one of their rankings is shown in Table B.4

Table B.4 – Florida Ranking of Variables: R23ST

Variables	IncNodePurity	Rank[1]	Comments[2]
Major road AADT	49.9	1	Variables of primary importance
Minor road AADT	48.0	2	
Number of approaches with right-turn lanes	6.2	3	Variables of secondary importance
Number of approaches with left-turn lanes	5.5	4	
Presence of skewness	3.9	5	
Presence of lighting	3.8	6	

[1] Mean of squared residuals: 0.457; Percent of variance explained: 16.90%

[2] Variables of primary importance: Variables having *IncNodePurity* value relatively greater than that of the other variables; Variables of secondary importance: Variables having *IncNodePurity* value within 15% of 6.2 (≥ 0.9); Variables of lesser importance: Variables having *IncNodePurity* value below 15% threshold (< 0.9).

The study also summarized the differences between Florida-specific and HSM-default crash distributions. This summary is presented in Tables B.5–B.7.

Table B.5 – Nighttime Crash Proportions for Unlighted Intersections

Facility Type	Site Subtype	Florida-Specific Values	HSM-Default Values
Rural Two-lane Intersections	Three-way Stop-controlled	0.346	0.260
	Four-way Stop-controlled	0.188	0.244
	Four-way Signalized	0.104	0.286
Rural Four-lane Intersections	Three-way Stop-controlled	0.198	0.276
	Four-way Signalized	0.138	0.273
Urban and Suburban Intersections	Three-way Stop-controlled	0.155	0.238
	Four-way Stop-controlled	0.057	0.229
	Three-way Signalized	0.094	0.235
	Four-way Signalized	0.091	0.235

Table B.6 – Pedestrian and Bicycle Adjustment Factors for Urban and Suburban Intersections

Adjustment Factor	Site Subtype	Florida-Specific Values	HSM-Default
Pedestrian Adjustment Factor	Three-way Stop-controlled	0.012	0.021
	Four-way Stop-controlled	0.020	0.022
Bicycle Adjustment Factor	Three-way Stop-controlled	0.020	0.016
	Four-way Stop-controlled	0.033	0.011
	Three-way Signalized	0.014	0.018
	Four-way Signalized	0.012	0.015

Table B.7 – Proportion of Specific Crashes on Florida Urban and Suburban Signalized Intersections

Crash Type	Number of Intersection Legs	2009	2010	2011	HSM-Default Values
Multiple-vehicle F+I crashes represented by right-angle collisions	Three-way	0.023	0.037	0.026	0.280
	Four-way	0.013	0.013	0.008	0.347
Multiple-vehicle PDO crashes represented by right-angle collisions	Three-way	0.027	0.033	0.030	0.204
	Four-way	0.033	0.027	0.018	0.244
Multiple-vehicle F+I crashes represented by rear-end collisions	Three-way	0.538	0.622	0.614	0.549
	Four-way	0.512	0.505	0.541	0.450
Multiple-vehicle PDO crashes represented by rear-end collisions	Three-way	0.423	0.489	0.533	0.546
	Four-way	0.438	0.452	0.502	0.483

B.2.6 HSM Calibration in Missouri

Sun et al. (2013) calibrated several facilities in Missouri.

Methods for Collecting Data

Data were collected from various sources, including the MoDOT Transportation Management System (TMS) database, Google Earth, and methods developed during the project. Along with providing basic information about roadways, the TMS also contains statewide Automated Road Analyzer video, which was used to visually collect data. The Statewide Traffic Accident Records System, which computerizes crash reports, was also used to collect crash data. Both Google Earth and the Center for Applied Research and Environmental Systems provided aerial maps, which included data on the number of turn lanes and the number of schools near a site. No geometric database was available, so AutoCAD was used to estimate the horizontal curve data.

Scope of Calibration

This study was all-inclusive, recording calibration values for all the main site types in the HSM. For the purposes of our review, we will focus primarily on the unsignalized intersections section of the report. These intersections were defined in the exact manner written in the HSM.

Methods of Sampling

The sampling procedures for this study were based on the guidelines presented by the HSM, with 30–50 sites for every type. Missouri is divided into seven MoDOT districts, and five random samples were selected from each district, producing 35 samples per type. Some samples were excluded due to location or inadequate data. Samples from Colombia, Missouri, were all excluded due to inaccurate crash data resulting from a difference in crash recording. Stop-control verification was impossible for rural areas, as no aerial images existed, so these sites were excluded. The final sample size was 420 unsignalized intersections.

Results and Calibration Factors
The calibration factors for rural two-lane unsignalized intersections were 0.77 and 0.49 for three-way and four-way intersections (R24ST), respectively. The factors for rural multi-lane unsignalized intersections were 0.28 for three-way intersections (RM3ST) and 0.39 for four-way intersections (RM4ST). In contrast, the factors for urban unsignalized intersections were 1.06 for three-way intersections (U3ST) and 1.30 for four-way intersections (U4ST). The study's final results led them to conclude that the number of crashes predicted by the HSM was generally consistent with the data in Missouri, but the intersections that were of interest in the study had notably lower calibration factors. The researchers did not discuss why this might be possible, but the crash report threshold can be ruled out as a cause, as Missouri’s threshold is comparable to that of other states whose data were used for the HSM. Table B.8 summarizes Missouri’s results.

Table B.8 – Calibration Results for Missouri Segments and Intersections

Site Type	Calibration Factor
Rural Two-lane Undivided Highway Segments	0.82
Rural Multilane Divided Highway Segments	0.98
Urban Two-lane Undivided Arterial Segments	0.84
Urban Four-lane Divided Arterial Segments	0.98
Urban Five-lane Undivided Arterial Segments	0.73
Rural Four-lane Freeway Segments (PDO SV)	1.51
Rural Four-lane Freeway Segments (PDO MV)	1.98
Rural Four-lane Freeway Segments (FI SV)	0.77
Rural Four-lane Freeway Segments (FI MV)	0.91
Urban Four-lane Freeway Segments (PDO SV)	1.62
Urban Four-lane Freeway Segments (PDO MV)	3.59
Urban Four-lane Freeway Segments (FI SV)	0.70
Urban Four-lane Freeway Segments (FI MV)	1.40
Urban Six-lane Freeway Segments (PDO SV)	0.88
Urban Six-lane Freeway Segments (PDO MV)	1.63
Urban Six-lane Freeway Segments (FI SV)	1.01
Urban Six-lane Freeway Segments (FI MV)	1.20
Urban Three-way Signalized Intersections	3.03
Urban Four-way Signalized Intersections	4.91
Urban Three-way Stop-controlled Intersections	1.06
Urban Four-way Stop-controlled Intersections	1.30

Site Type	Calibration Factor
Rural Two-lane Three-way Stop-controlled Intersections	0.77
Rural Two-lane Four-way Stop-controlled Intersections	0.49
Rural Multilane Three-way Stop-controlled Intersections	0.28
Rural Multilane Four-way Stop-controlled Intersections	0.39

B.2.7 HSM Calibration in Alaska

Bowie et al. (2014) calculated the calibration factors for four intersection site types in Anchorage, Alaska.

Methods for Collecting Data

The researchers reviewed data for the intersections, as well as the Sterling Highway, from 2000–2010. The Interactive Highway Safety Design Model (IHSDM) software was used to predict crash frequencies through 2040.

Scope of Calibration

This study focused on four types of urban and suburban arterials:

- Unsignalized three-way intersections, with stop-control on the minor road approaches (U3ST)
- Signalized three-way intersections (U3SG)
- Unsignalized four-way intersections, with stop-control on the minor road approaches (U4ST)
- Signalized four-way intersections (U4SG)

In order to simplify the data collection process, only intersections that met specific criteria were chosen. They all had to be located within the Municipality of Anchorage with two-way approaches, and had to have available AADT. Intersections that fit these criteria were chosen for calibration.

Methods of Sampling

After it was determined which intersections fit the above criteria, these intersections were randomly sampled to produce a set for calibration. Table B.9 shows the total number of intersections and crashes per facility type used in this study.

Table B.9 – Data set for Alaska HSM Calibration

	U3ST	U3SG	U4ST	U4SG
Number of Intersections	30	22	30	30
Total Number of Crashes (2010)	34	241	135	421

Results and Calibration Factors
In this study, the calibration factors for three-way and four-way signalized intersections were 3.94 and 4.65, respectively. In contrast, the calibration factors for three-way and four-way unsignalized intersections were 1.48 and 3.46, respectively. The researchers in this study concluded that, under some conditions, signal control increases crash frequency over stop control. This study does not offer a reason as to why this may be; rather, a paper by Wang and Abdel-Aty is mentioned which gives some explanation to the cause.

B.2.8 HSM Calibration in Idaho

Sipple calibrated and developed safety performance functions (SPFs) for rural highway facilities in the state of Idaho.

Scope of Calibration
The scope of the thesis paper by Sipple includes calibrating existing HSM SPFs for the following three types of facilities: rural two-lane/two-way highways, rural three-way stop-controlled intersections, and rural four-way stop-controlled intersections. Sipple also focuses on developing new SPFs for each facility using the binomial regression and Idaho crash data.

Methodology
The methodology used by Sipple includes data collection, site selection, model variation, calibration of HSM SPFs, and developing jurisdiction-specific SPFs. Sipple used data describing roadway geometry, traffic conditions, crash data, and AADT, and pathway data, including pathway geometrics. Crash data were obtained from ITD's online Web Crash Analysis Reporting System (WebCARS), using 10 years of crash data to obtain representative crash data.

Site were selected at random from an Excel file provided by the ITD. Data were collected and divided into homogenous roadway segments, with longer segments divided into shorter segments.

For model validation, segments were randomly split 70/30 to fit the models, then further randomly sampled ten times from the full data set to test the variability in each of the calibration factors and regression coefficients. This was only performed for two-lane highway segments as a test. For the calibration of HSM SPFs, this study by Sipple uses 313 segments for rural two-lane/two-way highways, 79 segments for three-way intersections, and 85 segments for four-way intersections. Based on the methods presented in the HSM, calibration factors for the entire state of Idaho were developed. Results are presented in Table B.10.

Table B.10 – Calibration Factors for State of Idaho

Facility Type	Predicted Crashes	Observed Crashes	Calibration Factor
Two-lane, Two-way Highways	168.95	188.40	1.115
Three-way Stop-controlled Intersections	52.10	13.20	0.253
Four-way Stop-controlled Intersections	69.40	29.60	0.427

B.2.9 HSM Calibration in Alabama

Mehta and Lou calibrated and developed safety performance functions for Alabama. This study aimed to evaluate the applicability of HSM predictive methods, and develop models for two-lane/two-way rural roads and four-lane divided highways. For calibration of HSM base SPFs, SPF predictions for two-lane, two-way rural roads and four-lane divided highways were included. This study had three tasks: 1) to calibrate the base SPF model following the HSM, 2) to estimate the calibration factor by estimating a NB regression model, and 3) to develop state-specific SPFs for Alabama. Data used were obtained from the Critical Analysis Reporting Environment, a roadway inventory that holds crash data from the Alabama Department of Public Safety.

The authors state, “To correctly apply the HSM methods, the roadways needed to be divided into homogeneous sections or sites.” In order to do this, the major geometric and traffic characteristics of the road need to remain the same within each site. Major characteristics included type of facility, number and width of lanes, shoulder and median width, speed limit, and AADT. When any of the characteristics changed, a new segment was created. Horizontal and vertical curve variables were not considered in this study due to the accuracy of available data.

Two approaches were taken to estimate the calibration factor: a NB regression model and the software NLOGIT. A discussion of estimation of SPF was also included, with SPFs estimated by using SPSS for two-lane/two-way rural roads and four-lane divided highways.

B.2.10 HSM Calibration in Maryland

Shin, Lee, and Dadvar developed local calibration factors for implementing the HSM in Maryland. The primary goal of this study was the determination of Local Calibration Factors (LCFs) for the state of Maryland’s application of the HSM. Specific objectives of this study were to review available studies that apply, and evaluate the suggested methodologies in the HSM, to collect and compile all required data for the selected State Highway Administration (SHA) maintained roadway segments and intersections, to estimate crash frequencies, severity, and types of crashes for roadway segments and intersections by different roadway facility types, and to develop LCFs for Maryland by comparing crash frequencies predicted by HSM methods to observed crashes. The methodology used in this study is as follows: initial data collection, creation of homogeneous data sets, site selection, additional data collection for samples, application of SPFs and computation of LCFs, and analysis and comparison of scenarios.

Data collected included historical crash data, AADT, and roadway geometry. After completing sample site selection for local calibration, additional data were collected by counting features on aerial photos. LCFs are calculated for rural two-lane two-way highways at C=0.6956; for 3-way stop-controlled intersections at C=0.1788; and for 4-way stop-controlled intersections, C=0.3667. LCFs for 18 facility types were calculated.

B.2.11 HSM Calibration in Missouri

Carlos, Henry, and Edara calibrated the HSM for Missouri. Missouri DOT-calibrated models for this study included five segments and eight intersection site types, and three freeway segment types that will be a part of the next edition of the HSM. This paper provides a chapter structure of introduction and scope, HSM methodology, sampling considerations, data collection, results, and discussion for each segment type, and includes chapters on rural two-lane undivided segments, rural multi-lane divided segments, urban signalized intersections, and unsignalized intersections.

Using the SPF based on AADT and the length of the segment,

$$N_{spf\ rs} = AADT \times L \times 365 \times 10\text{-}6 \times e^{(-0.312)}. \qquad \textbf{(Equation B.2)}$$

where:

$N_{spf\ rs}$ = predicted total crash frequency for roadway segment base conditions,

AADT = annual average daily traffic volume (vehicles per day), and

L = length of roadway segment (miles).

A random sample of five sites from each district of Missouri DOT was selected for analysis, making sure that each site met selection criteria for HSM analysis.

Data collection included the following items: AADT, lane and shoulder width, shoulder type, horizontal curve radius and length, super elevation variance, presence of spirals, vertical grade, driveway density, presence of centerline rumble strips, presence of passing lanes, presence of two-way left turn lanes, roadside hazard rating, presence of lighting, presence of automated speed enforcement, and number of crashes.

The calibration factor for rural two-lane undivided roadway segments in Missouri is C=0.82.

B.3 HSM Calibration Outside the United States

B.3.1 HSM Calibration in Québec

The Ministére des Transports du Québec calibrated rural two-lane roads in the territorial branches of Quebec, Canada (Barber, 2014).

Methods for Collecting Data

Various highway database systems maintained by the Ministry of Transport in Québec (MTQ) provided a list of potential sites and their data from 2006–2008. Certain variables not available through the MTQ database, including lighting and access density, were determined with video surveys. Geometry and traffic characteristics were reviewed by the territorial branches to ensure correct data and to ensure that no changes had occurred within the three-year span.

Scope of Calibration

This study focuses on three kinds of rural intersections: unsignalized three-way with stop control on the minor-road approaches, unsignalized four-way with stop control on minor-road approaches, and signalized four-way intersections. “Rural” was defined by roads with a posted speed limit of 80–90 km/h. The proportion of crashes involving animals varied greatly between territorial branches, as well as within branches. Road safety experts determined that the calibration would be more accurate if these crashes were not included.

Methods of Sampling

A sample of approximately 50 sites was picked randomly for each category. These samples were reviewed to verify that their distribution was representative of the territorial branches. If later data collection proved impossible for a site, an alternate site within the same territory was chosen.

Results and Calibration Factors

The study found that the resulting calibration factors for Québec were between .76 and 1.07. These numbers confirmed their assumption that the HSM is also valid for safety research in the Canadian provinces. Tables B.11 and B.12 show the distribution for unsignalized intersections with stop control on minor road approaches.

Table B.11 – Distribution of 4ST Intersections by Territorial Branch

Territorial Branch	Sample		Overall Distribution
	Number of Sites	%	
Abitibi-Témiscamingue	5	10%	9%
Bas-Saint-Laurent-Gaspésie-Iles-de-la-	8	16%	14%
Chaudière-Appalaches	5	10%	12%
Côte-Nord	0	0%	1%
Capitale-Nationale	1	2%	3%
Estrie	5	10%	10%
Est-de-la-Montérégie	7	14%	10%
Laurentides-Lanaudière	5	10%	11%
Laval-Mille-Iles	0	0%	< 1%
Mauricie-Centre-du-Québec	5	10%	11%
Outaouais	2	4%	7%

Territorial Branch	Sample		Overall Distribution
	Number of Sites	%	
Ouest-de-la-Montérégie	3	6%	6%
Saguenay-Lac-Saint-Jean-Chibougamau	4	8%	7%
TOTAL	50	100%	100%

Table B.12 – Distribution of 3ST Intersections by Territorial Branch

Territorial Branch	Sample		Overall Distribution
	Number of Sites	%	
Abitibi-Témiscamingue	3	6%	7%
Bas-Saint-Laurent-Gaspésie-Iles-de-la-Madeleine	4	8%	14%
Chaudière-Appalaches	6	12%	9%
Côte-Nord	2	4%	2%
Capitale-Nationale	1	2%	4%
Estrie	4	8%	11%
Est-de-la-Montérégie	5	10%	7%
Laurentides-Lanaudière	9	17%	18%
Laval-Mille-Iles	0	0%	1%
Mauricie-Centre-du-Québec	8	15%	10%
Outaouais	4	8%	7%
Ouest-de-la-Montérégie	4	8%	6%
Saguenay-Lac-Saint-Jean-Chibougamau	2	4%	6%
TOTAL	52	100%	100%

B.3.2 HSM Calibration in Regina

Young and Park (2012) calibrated HSM SPFs and compared them to jurisdiction-specific SPFs in Regina, Saskatchewan, Canada.

Methods for Collecting Data

Data for traffic counts and road information were retrieved from the city of Regina's database. This data were from a three-year span (2005–2009). Data were interpolated for segments or intersections with missing information. Saskatchewan Government Insurance supplied collision information.

Scope of Calibration

This study focused on three intersection categories: three-way unsignalized, four-way unsignalized, and four-way signalized. The study was limited to vehicle-vehicle crashes.

Methods of Sampling

The number of three-way signalized intersections (28) was low, so three-way signalized intersections were combined with four-way signalized intersections to create a sufficiently large sample size. The site types were divided randomly into two subsections: 70% to data and 30% to validation.

Results and Calibration Factors

The researchers found that the HSM's SPFs under-predicted collisions at three- and four-way signalized intersections, and over-predicted collisions at three- and four-way unsignalized intersections. They determined that the jurisdiction-specific SPFs predicted collisions better than the calibrated HSM SPFs, but only slightly. The calibrated values are shown in Table B.13.

Table B.13 – Calibration Factors for the City of Regina

Category	**Severity**	**Calibration Factor**					
		2005	**2006**	**2007**	**2008**	**2009**	**Avg**
Three-way Unsignalized	Total	1.67	1.28	1.37	1.46	1.54	1.47
	FI	0.60	0.62	0.72	0.64	0.68	0.65
	PDO	2.14	1.57	1.65	1.80	1.87	1.81
Four-way Unsignalized	Total	1.57	1.47	1.43	1.65	1.97	1.63
	FI	0.61	0.69	0.58	0.79	0.63	0.66
	PDO	2.12	1.92	1.91	2.14	2.73	2.17
Three- and Four-way Signalized	Total	2.27	1.90	2.16	2.32	2.56	2.25
	FI	1.68	1.18	1.44	1.32	1.26	1.37
	PDO	2.67	2.34	2.63	2.94	3.33	2.79

B.4 Other Related Research

Some Limitations of the Models in the Highway Safety Manual to Predict Run-Off-Road Crashes (Miaou, 2013)

This paper is a review of state models in HSM focusing on SPFs. The objective of this article was to identify the limitations of the prediction models in estimating single vehicle and run-off-road crashes for roadside safety analyses, and to suggest needed changes and developments. Miaou highlights areas of limitations of SPFs including assumptions involved in development, variables that are potentially important to design but not considered, and statistical bias and uncertainty of the models.

Miaou reports that “for rural two-lane and multi-lane highways, frequencies of single vehicle crashes at a site are estimated as fixed percentages of some estimated totals from SPF equations, regardless of the AADT level,” and cautions that “the assumption is not likely to work for other collision types. Thus, there needs to be some reexamination of the treatment for estimating crashes of various combinations of collision types.”

Variables that are important to design, but not considered when developing SPFs, are posted speed limit, vehicle type, and truck volume or percentage of large trucks. Miaou suggests that these components should be taken into consideration when developing future editions of the HSM.

Miaou points out that, by adopting the SPF equations for single vehicle run-off-road crashes, there is going to be a reduction in statistical quality, and suggests that a larger sample taken over a longer period is needed to achieve a higher statistical quality.

Development of Adjustment Functions to Assess Combined Safety Effects of Multiple Treatments on Rural Two-Lane Roadways (Park and Abdel-Aty, 2014)

This journal article addresses using more than one treatment for a roadway, and addresses issues with combining multiple treatments including over/under-estimating CMFs. The main objectives of this research were

1. to estimate CMFs and crash modification functions for two single treatments, both individually and combined using the observational before-after with the EB method; and
2. to develop adjustment factors and functions to evaluate the combined safety effects of two or more treatments.

These tasks were based on the accuracy of the combined CMFs for multiple treatments, as estimated by the existing combining method. Roadway geometry data from 2004 through 2011 were identified, and crash data were obtained for 2 years (2004 through 2005) and another 2 years (2010 through 2011). The crash data and roadway geometric data were provided by the Florida Department of Transportation. SPFs were developed for four different crash types and different severities, and the results of four full SPFs show that the crash frequency is higher for the roadway segments longer in length with higher AADT. The study evaluated CMFs for shoulder rumble strips (SRS) + widening shoulder width (WSW), and calculated combined CMFs using the HSM procedure. The results of the estimated CMFs show that SRS, WSW, and SRS + WSW have a reduction in crash frequencies.

Finding A New Safety Performance Function For Two-Way, Two-Lane Highways in Rural Areas (Bornheimer, 2011)

This study investigates finding the best model for rural, two-lane highways in Kansas. The objective was to create a SPF, compare that SPF to previous methods, and determine best methods for engineers at KDOT. Data collection from the CANSYS database maintained by the Kansas DOT was utilized in this project. Data collected include crash data, location of the crash, type of crash, and the severity of the crash. Geometric data were also obtained using existing plans, video logs, and aerial photography. This paper features a section on creating new SPFs for rural two-way two-lane highways, and the data were run though SPSS to create equations. The study found a SPF model for the state of Kansas, shown in Equations B.3 and B.4.

$$C_{county} = 1.13\ (ACR_{county}) + 0.635 \qquad \textbf{(Equation B.3)}$$

and

$$N_{predicted\ rs} = N_{spf\ rs} \times C_r \times (CMF_{1r} \times CMF_{2r} \times \ldots \times CMF_{12r}) \qquad \textbf{(Equation B.4)}$$

B.5 Outcomes of Literature Review

In summary, we found several challenges to the HSM calibration efforts by other states, which helped in calibrating roadway facilities in Alaska. These challenges are summarized below.

The North Carolina calibration study showed that it may be necessary to consider grouping areas by geographical characteristics. It also showed that a more efficient sampling method can be chosen without damaging the validity of results. This helped our research efforts to be less burdened by unnecessarily complicated procedures.

The Utah calibration study introduced the need to be careful when considering the speed limits of the roads chosen. The researchers noted that speed limits could potentially skew results. They also mentioned the impact of construction during the period evaluated on the results of the study. This was an important consideration for our study, with Alaska's appreciable regular road maintenance during the summer.

The Oregon calibration study provided a tested model for estimating AADT values for minor roads if no data have been collected previously. This study proved that estimating AADT can still be an effective way to calibrate the HSM. It was noted in the study that AADT is an important variable, and that changes in crash report minimums can affect the data. The Illinois calibration study confirmed the need to recognize the bias that changes in crash reporting thresholds can cause.

The Florida calibration study introduced a creative way to find unsignalized intersections when a database is lacking. The study indicated which variables are the most important to consider, in the event that not all are possible to collect. Interestingly, their conclusion agreed with the Oregon study; the AADT values are the most important variables in crash prediction. The Florida study found that not all variables have the same impact on estimating crashes, as the HSM assumes. In urban and suburban intersections, the nighttime crash proportions are significantly lower than the HSM's default values, as are some of the crash type proportions. Multiple-vehicle F&I and PDO crashes with right-angle collisions were extremely overestimated in the HSM's default values.

The Missouri calibration study was all-inclusive, and offered CAD as another way to estimate horizontal curve data. The researchers excluded certain samples due to differences in crash recording, a variable taken into consideration in this Alaska study. They also validated the previously suggested effect that crash-reporting thresholds have on calibration values.

The Québec calibration study also made sure to check construction in their proposed site samples, and defined set speed limit maximums and minimums for the sites. Their most important contribution was the necessity of removing crashes involving animals from their data set to make the SPFs valid in different territorial branches.

The Regina, Saskatchewan, study focused on the specific site types of interest for this review and, therefore, was helpful in our calibration efforts. The researchers chose to limit their sample size to vehicle-vehicle, mirroring the Québec study's choice to exclude animal crash data. They also performed a validation with a portion of their chosen sites, a method this study adopted to ensure valid calibration factors.