# Missouri Highway Safety Manual Recalibration

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**16. Abstract**

The Highway Safety Manual (HSM) is a national manual for analyzing the highway safety of various facilities, including rural roads, urban arterials, freeways, and intersections. The HSM was first published in 2010, and a supplement was published in 2014 that addressed freeway interchanges. The HSM incorporated the safety modeling results from several National Cooperative Highway Research Projects that used data from various states across the nation. The HSM recommends that individual states calibrate the HSM to local conditions on a regular basis. An initial statewide calibration for Missouri was finalized in 2013. The current recalibration effort builds upon the previous calibration and keeps the calibration values up-to-date with the most current crash data and calibration methodology. The current effort also involves the development of crash severity distributions functions so that crash frequencies can be estimated according to the severities of fatal, severe injury, minor injury, and property damage only. HSM calibration is a labor intensive effort that requires the derivation and use of detailed data such as road geometrics, traffic volumes, traffic signalization, land-use, and crash frequency and severity. This report documents the details of the methodology employed for facility site selection, data collection, data processing, calibration, and severity assignment. A total of 16 facility types were calibrated. These include rural 2-lane segments with the related 3-leg and 4-leg intersections; rural multilane segments with the related 3-leg and 4-leg intersections; urban 2-, 4- and 5-lane arterial segments; urban and rural 4-lane and urban 6-lane freeway segments; urban 3- and 4-leg signalized intersections; and urban 3- and 4-leg unsignalized intersections. The calibration results indicated that the HSM predicted Missouri crashes reasonably well, with the exception of a few site types for which it may be desirable for Missouri to develop its own safety performance functions in the future.

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# MISSOURI HIGHWAY SAFETY MANUAL RECALIBRATION

**Final Report**
**December 2017**

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# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

**ACKNOWLEDGMENTS**

# ABBREVIATIONS AND ACRONYMS

The following is a list of common acronyms and abbreviations used in this report.

| Name | Description |
|---|---|
| AADT | Average Annual Daily Traffic |
| AASHTO | American Association of State Highway and Transportation Officials |
| ARAN | Automated Road Analyzer |
| CMF | Crash Modification Factor |
| EB | Empirical Bayes |
| FHWA | Federal Highway Administration |
| IHSDM | Interactive Highway Safety Design Model |
| HCM | Highway Capacity Manual |
| HSIP | Highway Safety Improvement Program |
| HSM | Highway Safety Manual |
| KABCO | K – fatality, A – disabling injury, B – evident injury, C – possible injury, O - PDO |
| MoDOT | Missouri Department of Transportation |
| MU | University of Missouri |
| MUTCD | Manual on Uniform Traffic Control Devices |
| NCHRP | National Cooperative Highway Research Program |
| ODBC | Open Database Connectivity |
| PDO | Property Damage Only |
| SPF | Safety Performance Function |
| TMS | Transportation Management Systems |
| TRB | Transportation Research Board |
| USDOT | United States Department of Transportation |

## EXECUTIVE SUMMARY

The new Highway Safety Manual (HSM) is a national manual that facilitates the quantitative evaluation of safety. HSM contains models that need to be calibrated in order to reflect local driver populations, conditions and environments such as driver behavior, geometric design, signage, traffic control devices, signal timing practices, climate, and animal population. A systematic calibration of HSM freeway models to account for such conditions in Missouri was previously performed by the University of Missouri (MU) using 2009 to 2011 data. MU produced 25 calibration values for 16 different types of transportation facilities including rural undivided and divided highways, urban undivided and divided highways, rural and urban freeway segments, rural stop-controlled intersections, and urban stop-controlled and signalized intersections. These calibration values were published in the MoDOT Engineering Policy Guide for use in all MoDOT districts.

Even though the HSM accounts for exposure variables such as AADT and other safety variables, such as geometrics, signalization, land-use, and lighting, there are other safety-related variables that can change over time. For example, driver behavior could change, with the prevalence of mobile device use while driving being a prime example. Another example is the increase in automotive electronics which, on the one hand, improves safety with features such as object detection and video monitors, but on the other, could overload driver attention. Therefore, HSM recommends that calibration values be updated at least every two to three years. The Missouri recalibration used three years of data from 2012 to 2014.

The following four step recalibration process was followed: (1) identification of calibration samples/sites, (2) verification/collection of relevant site data, (3) prediction of HSM crash frequencies and (4) fine-tuning calibration parameters by comparing predicted with actual crash frequencies. Steps (1) through (4) were performed for 25 values and 16 facilities. HSM freeway models were subdivided by severity and by single or multi-vehicle crashes, thus three freeway facilities required 12 separate values. The 16 facilities are:
- Rural 2-Lane Undivided Highway Segments
- Rural Multilane Divided Highway Segments
- Urban 2-Lane Undivided Arterial Segments
- Urban 4-Lane Divided Arterial Segments
- Urban 5-Lane Undivided Arterial Segments
- Rural 4-Lane Freeway Segments
- Urban 4-Lane Freeway Segments
- Urban 6-Lane Freeway Segments
- Urban 3-Leg Signalized Intersections
- Urban 4-Leg Signalized Intersections
- Urban 3-Leg Stop-Controlled Intersections
- Urban 4-Leg Stop-Controlled Intersections
- Rural 2-Lane 3-Leg Stop-Controlled Intersections
- Rural 2-Lane 4-Leg Stop-Controlled Intersections
- Rural Multilane 3-Leg Stop-Controlled Intersections
- Rural Multilane 4-Leg Stop-Controlled Intersections

In step (1), the necessary samples required for HSM calibration were selected. Whenever possible, the random samples from the previous calibration were reused. By reusing previous sites, a sensitivity analysis of the calibration value to an increase in the number of data years could be conducted. However, samples were replaced if they had undergone changes in geometric design or other configuration. The HSM recommended sample sizes were followed unless Missouri lacked the number of samples or characteristics, or it was inefficient to oversample the number of sites. HSM recommends at least 30 sites per facility and a crash frequency of at least 100 crashes per year over all the sites of the particular facility type. Step (2) involved the verification of site characteristics to ensure that the site could still be used for recalibration. A changed site requires a replacement and the collection of necessary data associated with the replacement site. The data necessary could include traffic volumes, geometric data, pavement type, and signal control. Steps (3) and (4) were completed using the FHWA Interactive Highway Safety Design Model (IHSDM) software. Table ES1 summarizes the recalibration results. Not unexpectedly, the calibration value for some facilities changed from the previous calibration. These changes are due to natural data variability, driver behavior changes, changes in crash reporting, and, in a few facilities, a modification in how data was collected. Reasons specific to each facility are discussed in more detail in the facility-specific chapters. The two highest calibration values, urban three-leg and four-leg intersections, continue to be high following the previous calibration values. The development of Missouri-specific safety performance functions is recommended for these two facilities.

**Table ES1. Summary of HSM recalibration results for Missouri**

| Site type | Number of Sites | Observed Crashes | Previous Factor | Current Factor |
|---|---|---|---|---|
| Rural Two-Lane Undivided Highway Segments | 194 | 281 | 0.82 | 0.97 |
| Rural Multilane Divided Highway Segments | 37 | 697 | 0.98 | 0.74 |
| Urban Two-Lane Undivided Arterial Segments | 75 | 365 | 0.84 | 1.48 |
| Urban Four-Lane Divided Arterial Segments | 66 | 403 | 0.98 | 0.91 |
| Urban Five-Lane Undivided Arterial Segments | 59 | 721 | 0.73 | 0.84 |
| Rural Four-Lane Freeway Segments (PDO SV) | 45 | 631 | 1.51 | 1.29 |
| Rural Four-Lane Freeway Segments (PDO MV) | 45 | 302 | 1.98 | 2.14 |
| Rural Four-Lane Freeway Segments (FI SV) | 45 | 110 | 0.77 | 0.50 |
| Rural Four-Lane Freeway Segments (FI MV) | 45 | 70 | 0.91 | 0.84 |
| Urban Four-Lane Freeway Segments (PDO SV) | 41 | 434 | 1.62 | 1.20 |
| Urban Four-Lane Freeway Segments (PDO MV) | 41 | 363 | 3.59 | 1.46 |
| Urban Four-Lane Freeway Segments (FI SV) | 41 | 95 | 0.70 | 0.60 |
| Urban Four-Lane Freeway Segments (FI MV) | 41 | 100 | 1.40 | 0.71 |
| Urban Six-Lane Freeway Segments (PDO SV) | 54 | 443 | 0.88 | 0.85 |
| Urban Six-Lane Freeway Segments (PDO MV) | 54 | 1,281 | 1.63 | 1.22 |
| Urban Six-Lane Freeway Segments(FI SV) | 54 | 189 | 1.01 | 0.96 |
| Urban Six-Lane Freeway Segments (FI MV) | 54 | 411 | 1.20 | 0.85 |
| Urban Three-Leg Signalized Intersections | 35 | 1,372 | 3.03 | 2.95 |
| Urban Four-Leg Signalized Intersections | 35 | 529 | 4.91 | 5.21 |
| Urban Three-Leg Stop-Controlled Intersections | 70 | 57 | 1.06 | 1.28 |
| Urban Four-Leg Stop-Controlled Intersections | 70 | 172 | 1.30 | 1.27 |
| Rural Two-Lane Three-Leg Stop-Controlled Intersections | 70 | 22 | 0.77 | 0.69 |
| Rural Two-Lane Four-Leg Stop-Controlled Intersections | 70 | 44 | 0.49 | 0.41 |
| Rural Multilane Three-Leg Stop-Controlled Intersections | 70 | 169 | 1.08 | 0.95 |
| Rural Multilane Four-Leg Stop-Controlled Intersections | 66 | 144 | 0.73 | 0.65 |

In order to develop crash severity distributions, the crash severity of every crash in a particular type of facility in Missouri was tabulated. These sites were not limited to the calibration sites but were developed from every possible site in Missouri. The severity levels of interest are fatal, severe injury, minor injury, and PDO. Table ES2 summarizes the severity distribution factors for Missouri. The facility types with the highest FI (fatal plus injury) crash proportions include rural two-lane undivided highways, rural two-lane four-leg stop-controlled intersections, and rural multilane three- and four-leg stop controlled intersections. By using Table ES2, crash frequency by severity can be derived by multiplying the severity distribution factor values by the predicted total crash frequency obtained from the calibrated HSM.

**Table ES2. Summary of severity distribution factors for Missouri**

| Site type | Fatal | Severe Injury | Minor Injury | PDO | FI |
|---|---|---|---|---|---|
| Rural Two-Lane Undivided Highway Segments | 0.020 | 0.084 | 0.266 | 0.630 | 0.37 |
| Rural Multilane Divided Highway Segments | 0.014 | 0.043 | 0.245 | 0.699 | 0.301 |
| Urban Two-Lane Undivided Arterial Segments | 0.008 | 0.039 | 0.235 | 0.718 | 0.282 |
| Urban Four-Lane Divided Arterial Segments | 0.003 | 0.024 | 0.228 | 0.745 | 0.255 |
| Urban Five-Lane Undivided Arterial Segments | 0.003 | 0.021 | 0.250 | 0.726 | 0.274 |
| Rural Four-Lane Freeway Segments | 0.009 | 0.035 | 0.148 | 0.808 | 0.192 |
| Urban Four and Six-Lane Freeway Segments | 0.004 | 0.022 | 0.216 | 0.759 | 0.241 |
| Urban Three-Leg Signalized Intersections | 0.002 | 0.020 | 0.264 | 0.714 | 0.286 |
| Urban Four-Leg Signalized Intersections | 0.002 | 0.021 | 0.228 | 0.749 | 0.251 |
| Urban Three-Leg Stop-Controlled Intersections | 0.003 | 0.028 | 0.250 | 0.719 | 0.281 |
| Urban Four-Leg Stop-Controlled Intersections | 0.004 | 0.026 | 0.255 | 0.716 | 0.284 |
| Rural Two-Lane Three-Leg Stop-Controlled Intersections | 0.005 | 0.039 | 0.197 | 0.759 | 0.241 |
| Rural Two-Lane Four-Leg Stop-Controlled Intersections | 0.014 | 0.063 | 0.262 | 0.661 | 0.339 |
| Rural Multilane Three-Leg Stop-Controlled Intersections | 0.013 | 0.070 | 0.289 | 0.627 | 0.373 |
| Rural Multilane Four-Leg Stop-Controlled Intersections | 0.007 | 0.066 | 0.253 | 0.674 | 0.326 |

# CHAPTER 1. INTRODUCTION

## 1.1 Missouri HSM Calibration Efforts

The state of Missouri has been one of the 10-12 lead states in improving transportation safety analysis nationwide and in promoting the use of the national Highway Safety Manual (HSM). The state actively participates in the National Cooperative Highway Research Program (NCHRP) 17-50, "Lead States Initiative for Implementing the Highway Safety Manual," the Highway Safety Performance Committee (ABN25) of the Transportation Research Board (TRB), and in peer exchanges with other states. These efforts are important for furthering the goals of reducing traffic injuries and fatalities, and improving highway safety for all Missourians.

The new Highway Safety Manual (HSM) (AASHTO, 2010) is a national manual that facilitates the quantitative evaluation of safety. HSM contains models that need to be calibrated in order to reflect local driver populations, conditions and environments such as driver behavior, geometric design, signage, traffic control devices, signal timing practices, climate, and animal population. A systematic calibration of HSM freeway models to account for such conditions in Missouri was performed by the University of Missouri (MU) using 2009 to 2011 data (Sun et al., 2013). MU produced 25 calibration values for 16 different types of transportation facilities, including rural undivided and divided highways, urban undivided and divided highways, rural and urban freeway segments, rural stop-controlled intersections, and urban stop-controlled and signalized intersections. These calibration values were published in the MoDOT Engineering Policy Guide for use in all MoDOT districts.

In a 2014 supplement, freeway facilities were added to the original HSM manual which allows the modeling of highway interchanges. The most vital freeway interchange facility types in Missouri were calibrated and reported in 2016 (Sun et al., 2016a). These facility types include nine freeway interchange terminals, including diamond, partial cloverleaf, and full cloverleaf interchanges. The non-terminal facilities included entrance and exit speed-change lanes, and entrance and exit ramps. The calibrated facilities applied to both rural and urban locations. For each facility type, sample sites were randomly selected from an exhaustive master list. Four types of data were collected for each site: geometric, AADT, traffic control, and crash. Crash data was especially noteworthy because of the crash landing problem, i.e. crashes were not located on the proper interchange facility. A significant companion crash correction project (Sun et al., 2016b) was undertaken involving the review of 12,409 crash reports, and the detailed review of 9,169 crash reports. Using the corrected data, 44 calibration values were derived for freeway terminal and non-terminal facilities. These values were the first reported freeway interchange calibration values since the release of the 2014 HSM supplement.

This project involves the recalibration of the HSM for Missouri. All 25 HSM values (16 facilities) that were previously calibrated were recalibrated using additional data since 2011. These facilities are:

- Rural 2-Lane Undivided Highway Segments
- Rural Multilane Divided Highway Segments

- Urban 2-Lane Undivided Arterial Segments
- Urban 4-Lane Divided Arterial Segments
- Urban 5-Lane Undivided Arterial Segments
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- Rural Multilane 4-Leg Stop-Controlled Intersections

The recalibration of freeway interchange facilities was not undertaken as they were just recently calibrated. By keeping HSM calibration values up-to-date, changes in driver behavior, crash reporting, and other safety-influencing factors can be taken into account when applying the HSM. In addition, this project produced severity distribution factors for all corresponding road facilities. These factors allows the estimation of crash frequency by the severities of fatal, severe injury, minor injury, and property damage only.

## 1.2 General Goals

The calibration of the HSM for Missouri and the application of the HSM directly support all four key focus areas of USDOT and MoDOT: enhancing safety, improving the state of good repair, improving economic competiveness, and improving environmental sustainability of the U.S. surface transportation system. The most obvious area is enhancing safety. The HSM can be used in DOT planning, design, operations, and maintenance. For example, HSM analysis is required for safety-related road design exceptions such as lane width, shoulder type, turn lanes, and geometric alignment. HSM can be used to analyze projects that are funded by the Highway Safety Improvement Program and for the development and repair of infrastructure. Because of the elevated risks associated with work zones during construction, it is important to include safety in implementing construction and rehabilitation work. HSM also supports the goal of economic competiveness because the HSM facilitates the economic estimation of crash reduction benefits, design alternatives, and project improvements. Lastly, the HSM can be a useful tool during the NEPA (National Environmental and Policy Act) process by quantifying the safety impacts of various alternatives.

## 1.3 Organization of the Report

Chapter 2 summarizes the calibration efforts across the U.S. and even internationally. Chapter 3 presents the overall calibration methodology. Each facility type has its own set of unique characteristics, thus there are unique methodological components to each facility. The calibration

of individual facilities is discussed in Chapters 4-9 for rural two-lane undivided roadway segments, rural multilane divided segments, urban arterial segments, freeway segments, urban signalized intersections, and unsignalized intersections. Each chapter, involving a specific facility type, includes scope, data requirements, HSM methodology, sampling, data description, and results. These chapter subsections could be similar among the various facilities; however, some do have significant differences. In order to improve readability, each of these chapters was written in a way where it could be read independently. The repetition of some material was purposeful to aid the reader.

# CHAPTER 2. NATIONAL CALIBRATION EFFORTS

Since the publication of the HSM, several states have started to calibrate the manual to local conditions. The most common type of facility to be calibrated has been rural two-lane highway segments. The reason for this is probably due to the relative ease of modeling this facility as compared to other facilities and the prevalence of such facilities. This chapter surveys the nationwide effort on HSM calibration of non-interchange facilities. Interchange facilities are outside the scope of this report. The state efforts are presented in an alphabetical order. There are several on-going calibration projects, so more states are expected to report on their calibration results.

## 2.1 Alabama

Mehta and Lou (2013) described both the calibration and development of safety performance functions for two-lane, two-way rural roads and four-lane divided highways in Alabama. The calibration results were 1.392 for two-lane roads and 1.103 for four-lane roads. The authors described an alternate calibration approach by using negative binomial regression. The alternate approach produced slightly different results of 1.522 for two-lane roads and 1.863 for four-lane roads.

## 2.2 Arizona

Srinivasan et al. (2016) calibrated rural two-lane roads in Arizona. The authors also discussed the option of developing calibration functions in addition to calibration factors. Instead of a constant calibration factor, the use of functions allows the calibration values to vary according to different variable values.

## 2.3 Florida

Sivaramakrishnan et al. (2011) produced calibration factors for Florida. The facility types were rural two-lane and multilane segments, and urban and suburban arterial segments and intersections. The authors produced calibration factors by year and focused on fatal and injury crashes. Most calibration values were much less than 2.0, but urban three- and four-leg intersections had higher calibration factors values of around 2.0 for most years.

## 2.4 Illinois

One Illinois calibration involved rural two-lane highways (Williamson and Zhou 2012). Three years of data was used from 2005 to 2007. The sample contained 165 total crashes. Five random segments were selected from each of six counties. The property damage threshold was significantly increased in 2009 from $500 to $1,500. Thus future calibrations would result in lower calibration values because of the decrease in the number of property damage only crash reports.

## 2.5 Kansas

Dissanayake and Aziz (2016) calibrated rural four-lane divided and undivided highways in Kansas. They found that that the HSM underpredicted crashes by 48% and 64% for four-lane divided and undivided highways, respectively. The authors also developed Kansas-specific SPFs and found them to be more accurate than the calibrated HSM SPFs.

## 2.6 Louisiana

Sun et al. (2006) calibrated rural two-lane facilities in Louisiana. Three years of data were used from 1999 to 2001. Sampling of sites was divided into two groups of 26 and 16 samples. The calibration result for the first group was 1.1, and the result for the second group was 2.5 times higher than the state average.

## 2.7 Maryland

Maryland (Shin et al. 2014) calibrated 18 facility types, including 8 segment and 10 intersection types. For segments, they included rural two-lane and four-lane undivided, and urban two, three, four, and five-lane undivided and divided. The intersection types included both stop control and signalized intersections for both rural and urban. Other than a calibration value of 2.26 for rural four-lane undivided, the rest of segment values were near or less than 1.0. The intersection values were all much smaller than 1.0.

## 2.8 North Carolina

One North Carolina calibration (Srinivasan and Carter 2011) included the six segment types of rural four-lane divided, urban two-lane undivided, urban two-lane with two-way left-turn lane, urban four-lane divided, and urban four-lane with two-way left-turn lane roadways. The eight intersection facility types included rural two-lane three- and four-leg stop control, rural two-lane three- and four-leg signalized, urban arterial three- and four-leg signalized, and urban arterial three- and four-leg stop control intersections. In order to maximize sampling efficiency, entire routes were used for segments. For intersections, the sampling varied from 19 samples for rural two-lane four-leg signalized intersections to the 133 for rural two-lane three-leg stop control intersections. Half of the intersection types did not reach the 100 crashes per year recommended by the HSM. Several of the North Carolina segment types resulted in high calibration values. For example, the calibration value for urban two-lane with two-way left-turn was 3.62, urban four-lane divided was 3.87, and urban four-lane undivided was 4.04. Intersection values were closer to 1.0 except for the calibration values of 2.45 for urban arterial signalized three-leg intersection and 2.79 for urban arterial signalized four-leg intersection.

## 2.9 Ohio

Troyer et al. (2015) calibrated 18 facility types in Ohio. These facilities, both rural and urban, included 8 segment types with two being divided. The ten intersection types included rural and

urban intersections with stop control and signals, and with three and four legs. The urban three-leg and four-leg arterials had the highest calibration values of 3.35 and 3.71, respectively. Urban four-lane arterials and five-lane arterials with two-way left-turn lane had the lowest calibration values of 0.24 and 0.36, respectively.

## 2.10 Oregon

Xie et al. (2011) calibrated several Oregon facilities. The segment facilities included rural two-lane and multilane, and urban two to five lane arterials. The intersection types included both stop control and signalized for rural two-lane, rural multilane, and urban arterial roadways. None of the calibration values were very high, and most were under the value of 1.0. One reason for the low calibration factors could have been the higher crash reporting threshold of $1,500 for property damage. In contrast, Missouri uses a much lower property damage threshold of $500.

## 2.11 Utah

One Utah calibration (Brimley et al. 2012) involved rural two-lane highways. The sample sites were limited to AADTs of less than 10,000 and speed limits of higher than 55 mph. The calibration factor was 1.16. In addition to calibration, Utah also developed jurisdiction-specific SPFs using 157 segments.

## 2.12 Virginia

Kweon et al. (2014) published guidance for the state of Virginia on not just calibration but also on customizing HSM procedures and on SPF development. The calibration was limited to divided segments and four-leg signalized intersections of rural multilane highways. District-specific calibration factors were derived. For four-leg signalized intersections, the number of sites in each district was limited, and a multiplication scheme was devised to rectify this issue. The district-specific calibration factors for four-lane divided segments were all close to the value of 1.0 with some districts being slightly under and others being slightly over.

## 2.13 Washington

Banihashemi (2011) compared new models versus calibration for rural two-lane segments in the state of Washington. The author used over 5,000 miles of data and half were used for comparing the Washington-specific SPF against the calibrated HSM SPF. The performance of Washington-specific SPF was comparable the calibrated HSM models.

## 2.14 International Efforts

There have been HSM calibration efforts even outside the U.S. Martinelli et al. (2009) calibrated rural two-lane highways in Arezzo, Italy. The calibration factor value was 0.17. The authors explained that this factor was partly due to the fact that many sections of roadways did not have

crash records. Young and Park (2012) compared the use of HSM with locally developed models in Regina, Canada. Al Kaaf and Abdel-Aty (2015) calibrated urban four-lane divided highways in Riyadh, Saudi Arabia.

# CHAPTER 3. OVERVIEW OF CALIBRATION METHDOLOGY

This chapter presents an overview of the calibration methodology for all facility types. HSM calibration follows the following general steps:
- identification and sampling of facility sites
- collection of relevant site data
- modeling and prediction using HSM methodology
- derivation of calibration factors

Each specific facility type will have unique characteristics for each of these steps. Chapters 4-9 will cover the aspects of the methodology that are particular to each facility.

## 3.1 Site Identification and Sampling

There are several objectives when compiling a list of sites for calibrating a facility type. One objective is to obtain a random set of samples. This objective is important for performing statistical inference. Inference refers to the use of a set of sample data in order to explain the characteristics of the general population of interest. Here, population, as used in a statistical sense, refers to a particular type of facility in Missouri. For example, a population could be all urban four-leg signalized intersections in Missouri, and the sample could be a set of thirty five intersections in Missouri. If the sample is not a random set of facilities, then the inference would be biased towards the characteristics of the sample. In other words, the safety would be more reflective of the sample than the population. Random sampling was performed in the 2013 Missouri calibration and is continued with this current calibration.

A second objective is to obtain a sample size that will result in conclusions that are statistically significant. Unfortunately, there is a chicken and egg problem related to sample size determination. The required sample size is not known until a significant sample has been obtained and can be analyzed for its distributional properties. The HSM recommends that at least 30 to 50 sites be used for calibration, and that the selected sites include a total of at least 100 crashes per year. This recommendation is a practical recommendation; otherwise, sampling becomes a very elaborate exercise of sampling until the sample set meets certain distribution characteristics, some of which relate to data variability. In the current calibration effort, the HSM recommendation is followed unless it becomes prohibitive. For example, due to the low volumes and the low number of crashes on rural roads, meeting the 100 crashes per year criteria is difficult.

Another objective is geographic representation throughout the state. The state of Missouri is divided into seven MoDOT districts. These districts cover a wide range of driving population, terrain, weather, and population areas. For example, St. Louis and Kansas City are major metropolitan areas while other districts are mostly rural. For most facility types, five random samples were selected from each MoDOT district, resulting in at least 35 samples per facility type. This was not possible for all facility types due to the lack of a particular facility in certain districts. For example, urban six-lane freeway segments were located mostly in St. Louis and Kansas City.

A fourth objective is to exclude any anomalous samples that could bias the calibration result. For example, the Columbia Police Department does not follow the $500 property damage threshold; thus, PDO crashes are underrepresented in Columbia. Columbia sites were therefore excluded.

In contrast to intersections, the sampling of segments requires an additional step of deciding how to segment. The most important aspect of this step is to ensure that each segment is homogeneous with respect to characteristics such as volume, geometric design, and speed limit. For the sake of efficiency, a minimum segment length is applied to sampling, as short segments have very few crashes. Generally, a minimum segment length of 0.5 miles was used, although there were some exceptions due to difficulty in obtaining samples. This threshold is longer than the minimum of 0.1 mile recommended by the HSM.

The last objective is to maintain the same list of sites used in the previous Missouri calibration effort. This allows the comparison of results across multiple calibration cycles and reveals the sensitivity of calibration over time. Some sites had to be replaced due to site changes or other issues.

After the initial samples were determined, there was visual verification via the use of aerial photographs. This was necessary because there are sometimes coding errors and other data issues with electronic databases. For example, a segment coded as a five-lane segment with a two-way left-turn lane might actually be a four-lane divided road for a portion of the road. Another example is signalized driveways that should be included as an intersection leg according to the HSM.

## 3.2 Data Collection

A primary source of data is the MoDOT Transportation Management System (TMS). The TMS provides several databases for obtaining various types of data, including crash data, geometric design, pavement, functional classification, and traffic. Examples of geometric design data include lane widths, shoulder widths, median type, and left-turn lanes. TMS also provides videos collected from Automated Road Analyzer (ARAN) vehicles. These are useful for identifying items such as roadside components, the number of driveways, the distance to fixed objects, and type of parking. The ARAN video is indexed to the roadway log mile making locating objects and road distances easy. One issue with ARAN video is that sometimes frames are skipped, so the video footage is not continuous.

Another primary source of data involves photographs, both aerial street view. Aerial photographs present a bird's eye view, while street view photographs present a driver's eye view. These sources of information along with the TMS databases and ARAN videos are complementary. Thus these sources could be used for cross-checking. Aerial images were used to collect data, such as the number of turn lanes, median type, skew angle, maximum number of lanes crossed by pedestrians, and the number of schools, bus stops, and alcohol sales establishments within 1,000 feet of a signalized intersection. Aerial images are also imported into CAD to derive the horizontal radius of curves and ramps. Street view photographs were utilized to identify the

number of legs at a signalized intersection, type of parking, posted speed limit, median barrier type, and to verify that the intersection was signalized.

## 3.3 HSM Modeling/Prediction

In general, HSM prediction involves the multiplication of the base SPF with several CMFs and the calibration factor.

$$N_{predicted} = N_{spf} \times C \times (CMF_1 \times CMF_2 \times \ldots \times CMF_n) \tag{3.1}$$

where $N_{predicted}$ is the predicted average crash frequency of an individual facility for the selected year, $N_{spf}$ is the predicted average crash frequency of an individual facility with given base conditions, $C$ is the calibration factor for a specific facility type developed for use in Missouri, and $CMF_1 \ldots CMF_n$ are various crash modification factors, such as lane width, horizontal curve radius, driveway density, and lighting. Each facility type has a SPF or multiple SPFs specific to that facility. The number and types of CMFs vary depending on the complexity of the facility. Freeway segments, for example, have over 20 different CMFs.

## 3.4 Calibration Factor Derivation

The Interactive Highway Safety Design Model (IHSDM) is used for performing HSM prediction and calibration. The SPFs and CMFs related to various facility types are coded into the IHSDM. The IHSDM is developed through the FHWA Every Day Counts program. The software and technical support are provided by FHWA free of charge. All crash, geometric, traffic, and land-use data are entered into IHSDM, and IHSDM outputs the overall calibration factor. The observed and predicted number of crashes can also be derived for each individual site to check for outliers.

# CHAPTER 4. RURAL TWO-LANE UNDIVIDED ROADWAY SEGMENTS

## 4.1 Introduction and Scope

Chapter 10 of the HSM describes the methodology for crash prediction on rural two-lane undivided roadway segments. Rural two-lane undivided highways are common across all Missouri districts and is a facility type that has been calibrated in many states.

## 4.2 Calibration Data Requirements

The input data in the IHSDM is divided into required and desired data. The required data consists of site, crash, and traffic data. The desired data is optional and includes variables such as superelevation variance, presence of lighting, and automated speed enforcement.

### 4.2.1 Required Site Data

#### 4.2.1.1 Area Type

The classification of areas depends on the roadway characteristics, surrounding population, and land use. Based on the FHWA guidelines, the HSM defines "urban" areas as regions that contain a population greater than 5,000 people. "Rural" areas are designated as regions outside urban areas and which contain a population fewer than 5,000 people. Although the terms metropolitan, urbanized, or suburban refer to urban subcategories, the HSM does not make a distinction among these subgroups and considers all as urban (AASHTO 2010). MoDOT uses the same area classification.

#### 4.2.1.2 Segment Length

The roadway segment length for rural two-lane undivided segments consists of the total length in miles over a homogenous segment with no significant changes in travelway cross-section geometry and speed limit. In addition, rural two-lane undivided segments should not intersect or have interchange facilities as part of the segment. The HSM recommends a minimum of 0.1 miles to reduce calculation efforts. In the previous MoDOT HSM calibration, a minimum of 0.5 mile was specified in order to obtain a more efficient segment length. Very short segments have a relatively small likelihood of experiencing crashes while requiring a similar level of coding effort as longer segments. The present calibration no longer uses the 0.5 mile minimum although only one rural two-lane undivided segment was shorter than 0.5 mile, being 0.36 mile.

#### 4.2.1.3 Left/Right Side Lane Width

The IHSDM input for rural two-lane undivided segments requires the lane width for the roadway in each direction. It was decided that the right side lane was in the direction of increasing milepost, and the left side was in the opposing direction. If different lane width values are

observed by direction, an average value should be used. The input value should be in feet and larger than zero.

## 4.2.1.4 Left/Right Side Shoulder Width and Type

The IHSDM input for rural two-lane undivided segments requires the shoulder width for the roadway in each direction. If different shoulder width values are observed by direction, an average value should be used. The input value should be in feet and larger than zero. The particular shoulder types, as described by the HSM, are paved, gravel, and turf, according to their safety effectiveness.

## 4.2.1.5 Curve Radius and Length

In the case that a segment contains a curved section of roadway, the radius of the curve should be measured in feet along the inside edge of the curved roadway. The input value should be greater than or equal to zero. The length of curvature should be measured in miles and should be greater than or equal to zero.

## 4.2.1.6 Presence of TWLT Lane

Special attention should be paid if a portion of the segment contains a two-way left-turn (TWLT) lane because it is necessary that each segment be considered homogenous. The presence of a TWLT lane should be introduced as a "yes" or a "no". Figure 4.1 is an example of a segment with a TWLT lane present.



**Figure 4.1. Segment containing two-way left-turn lane (Google 2016)**

## 4.2.2 Required Crash and Traffic Data

## 4.2.2.1 Years of Crash Data

The years associated with the calibration should be specified. The IHSDM considers up to three years for the input data.

4.2.2.2 Observed Number of Crashes

On rural two-lane roadways, observed crashes are assigned to either segments or intersections depending on the geometric, traffic control, and operational characteristics. Intersection influence areas should not be included as part of segments. This is because the contributory circumstances of intersection crashes generally differ from those of segment crashes. MoDOT assigns crashes to an intersection if it is located within 132 feet of the intersection. For this calibration, intersection-related crashes were removed based on the intersection identification number that was designated in the crash data. Figure 4.2 illustrates the intersection influence area graphically. Crashes in area A are all classified as intersection crashes as they occur physically within the intersection area. Crashes in area B need to be classified as either segment or intersection related depending on the specific crash characteristics.
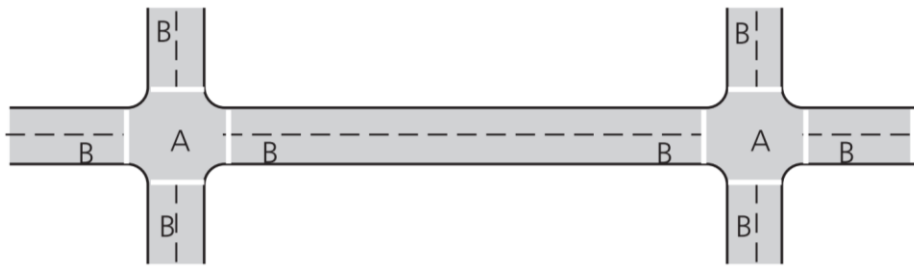


**Figure 4.2. HSM definition of segment and intersection crashes (AASHTO 2010)**

4.2.2.3 Segment AADT

The total segment AADT, in both directions, should be collected for all years of analysis. The HSM-recommended AADT range for rural-two lane highway segments is 0 to 17,800 vehicles per day. AADT data can be obtained using the MoDOT TMS system. Note that AADT data might not be actual counted traffic volumes but estimates based on historical or nearby counts. In rural areas, traffic volumes are counted less frequently.

*4.2.3 Desired Site Data*

4.2.3.1 Presence of Spirals

Any spiral transitions for horizontal curves within the segment should be noted. MoDOT indicated that most existing horizontal curves on Missouri roadways do not contain spirals. Therefore, it was assumed that no curved segments contained spirals.

4.2.3.2 Superelevation Variance

This is the percent difference between actual superelevation and the superelevation identified by AASHTO policy. It was reasonable to assume that all horizontal curves were designed to the

appropriate superelevation rate. Therefore, the base condition of zero percent variance was assumed for all curved samples.

4.2.3.3 Grade

The vertical grade of the segments could not be accurately determined from databases and were therefore assumed as the base condition of zero percent. This value correlated to the level terrain category in the HSM that included grades between +/- 3 percent. It was indicated by MoDOT that although vertical grade was collected by ARAN, it was not readily available through TMS. MoDOT has recently made available grade information that could be used in future calibrations.

4.2.3.4 Driveway Density

The driveway density, combined for both sides of the roadway, is given as the number of driveways per mile.

4.2.3.5 Presence of Centerline Rumble Strip

This input indicates the presence of rumble strips along the centerline of the roadway segment. The IHSDM data input only requires specifying whether or not rumble strips exist along the segment (i.e. yes or no).

4.2.3.6 Presence of Passing Lanes

In some cases, short sections of certain rural two-lane undivided highway segments may contain additional lanes that serve exclusively to increase passing opportunities through side-by-side passing lanes. It should be noted if the presence of passing lanes exists on one or both sides of the roadway or does not exist at all. Special consideration should be made if passing lanes exist for a long stretch of roadway, as this situation would no longer be considered a two-lane facility.

4.2.3.7 Roadside Hazard Rating

The roadside hazard rating (RHR) is a common ranking system from 1 (best) to 7 (worst) (Zegeer et al. 1981). Pictures and quantitative definitions of the rating categories are listed in the HSM (2010) in Appendix 13A. The RHR is used to estimate the potential for accidents to occur on rural two-lane highways. The ranking involves the clear zone, side slope, guardrail presence, presence of obstacles, and other attributes of the roadway segment.

4.2.3.8 Presence of Lighting

The presence of lighting along the segment is considered in the crash prediction process. The IHSDM data input only requires specifying the presence of lighting along the segment (i.e. yes or no).

4.2.3.9 Automated Speed Enforcement

Automated speed enforcement may use video or photographic identification in combination with radar or laser to detect vehicles exceeding the posted speed limit of the segment. The system automatically records the vehicle information when at fault. The IHSDM data input only requires specifying the presence of automated speed enforcement along the segment (i.e. yes or no). Figure 4.3 illustrates examples of speed enforcement cameras and signs.
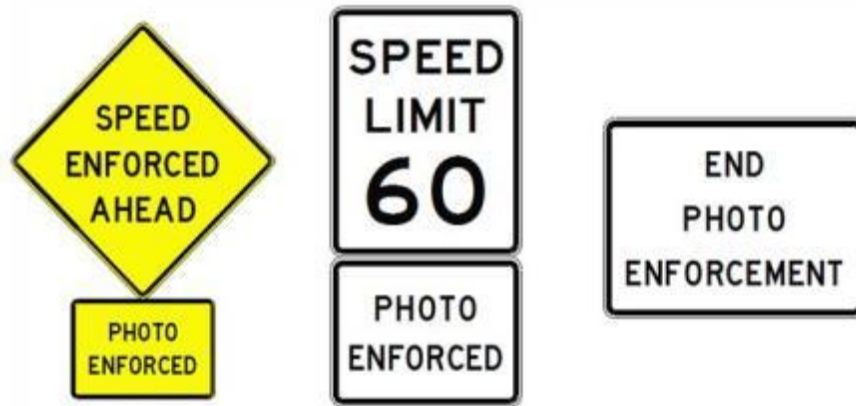


**Figure 4.3 Automated speed enforcement camera (Seat Pleasant 2017, MoDOT 2017)**

**4.3 HSM Methodology**

As described in Chapter 10 of the HSM, the SPFs for rural two-lane undivided segments predict the number of total crashes on a segment per year for base conditions. The SPF is obtained through equations 4.1-4.2, with the base conditions listed in Table 4.1:

$$N_{predicted\,rs} = N_{spf\,rs} \times C_r \times (CMF_{1r} \times CMF_{2r} \times \ldots \times CMF_{12r}) \tag{4.1}$$

where $N_{predicted,rs}$ is the predicted average crash frequency of an individual roadway segment for a selected year, $N_{spf\,rs}$ is the predicted average crash frequency of an individual roadway segment with given base conditions, $C_r$ is the calibration factor for roadway segments of a specific type developed for use in Missouri, and $CMF_{1r} \dots CMF_{12r}$ are various crash modification factors such as lane width, horizontal curve radius, driveway density, and lighting.

$$N_{spf\,rs} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)} \qquad \textbf{(4.2)}$$

where $N_{spf\,rs}$ is the predicted average crash frequency of an individual roadway segment with given base conditions, $AADT$ is the annual average daily traffic (vehicles/day) on roadway segment, and $L$ is the length of roadway (miles). Table 4.1 shows the base conditions applicable to $N_{spf\,rs}$. Deviations from the base conditions are addressed by the corresponding CMF. For example, a lane width narrower than 12 feet is taken into account by multiplying by a CMF that is greater than 1.0. In other words, safety decreased slightly from the base conditions with the reduction in lane width.

**Table 4.1 Base conditions in HSM for SPF for rural two-lane undivided segments**

| Description | Base Condition |
|---|---|
| Lane Width | 12 ft |
| Shoulder Width | 6 ft |
| Shoulder Type | Paved |
| Roadside Hazard Rating | 3 |
| Driveway Density | 5 driveways/mile |
| Horizontal Curvature | None |
| Vertical Curvature | None |
| Centerline Rumble Strips | None |
| Passing Lanes | None |
| Two-way Left-turn Lanes | None |
| Lighting | None |
| Automated Speed Enforcement | None |
| Grade Level | 0% |

## 4.4 Sampling Considerations

For this calibration effort, it was desirable to reuse the same sites that were used in the previous calibration project (Sun et al. 2013). The sampling process for the previous calibration of rural two-lane undivided segments included a random sample of five sites from each MoDOT district based on a minimum length of 0.5 miles per site. TMS was used to generate database queries with a list of candidate rural two-lane sites for each district. The criteria used to generate the queries are shown in Table 4.2. Column 1 is the table or a particular TMS database. Two separate databases were used for rural two-lane undivided segments. Column 2 is the specific

data field. Column 3 is the query criterion, often a limitation on the data sought. For example, the field DRVD_TRFRNGINFO_YEAR was used to specify the query for 2012 data since TMS contained AADT data for each year. The AADT data for other years were later obtained using other queries in a similar fashion. A separate query was run for each MoDOT district using the BEG_DISTRICT_ABBR field. The DRVD_TRF_INFO_NAME field was used to specify that AADT is needed. The BEG_OVERLAPPING_INDICATOR field was used to exclude secondary routes that overlapped with primary routes. The BEG_URBAN_RURAL_CLASS field was used to limit the query to rural segments. The query was limited to two-lane segments by using the NUMBER_OF_LANES field.

**Table 4.2 Query criteria for rural two-lane undivided segments**

| Table | Field | Criterion |
|---|---|---|
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRFRNGINFO_YEAR | 2012 |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DISTRICT_ABBR | Varies |
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRF_INFO_NAME | AADT |
| TMS_TRF_INFO_SEGMENT_VW | BEG_OVERLAPPING_INDICATOR | not S |
| TMS_TRF_INFO_SEGMENT_VW | BEG_URBAN_RURAL_CLASS | RURAL |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DIVIDED_UNDIVIDED | UNDIVIDED |
| TMS_SS_PAVEMENT | NUMBER_OF_LANES | 2 |

In order to eliminate data errors, each site was individually reviewed and verified for this calibration process. During the site verification, each segment was inspected to ensure there were no apparent changes to the roadway facility from the time of the previous calibration. Special attention was paid to ensure that each site satisfied the necessary criteria to be considered a valid sample for this facility type. The sampled sites were also reviewed to ensure that ARAN data were available for the sites, and to verify that the sites were of the proper site type and were homogeneous with respect to the cross section. Some sampled sites were discarded and replaced because they did not contain adequate ARAN data. The replacement sampling was performed in the same fashion as the original sampling. For a particular district, a random number generator selected a specific site from a list of all possible rural two-lane segments in the district. The END_URBAN_RURAL_CLASS field was also checked in TMS to confirm that the value of the field was rural. If the value of this field was not rural, the sample site verified using ARAN video to determine whether the site was rural or urban based upon surrounding land use characteristics. The list of sampled sites is shown in Table 4.3. Most of the sites were Missouri state highways, although there were a few sites that were US highways. The sample set included sites from 24 Missouri counties.

**Table 4.3 List of sites for rural two-lane undivided segments**

| Site ID | District | Description | Primary Direction | Primary Begin Log | Primary End Log | County | Length (mi) |
|---|---|---|---|---|---|---|---|
| 1 | CD | MO 185 | S | 39.54 | 44.00 | Washington | 4.46 |
| 2 | CD | MO 5 | S | 220.91 | 222.15 | Camden | 1.24 |
| 3 | CD | MO 17 | N | 156.57 | 160.31 | Miller | 3.74 |
| 4 | CD | MO 5 | N | 222.80 | 226.89 | Howard | 4.09 |
| 5 | CD | MO 124 | W | 23.24 | 25.06 | Howard | 1.82 |
| 6 | KC | MO 13 | S | 127.13 | 130.91 | Johnson | 3.78 |
| 7 | KC | MO 45 | N | 9.29 | 15.80 | Platte | 6.51 |
| 8 | KC | MO 210 | E | 25.32 | 26.63 | Ray | 1.31 |
| 9 | KC | MO 273 | S | 19.16 | 22.94 | Platte | 3.78 |
| 10 | KC | MO 58 | E | 47.62 | 49.39 | Johnson | 1.77 |
| 11 | NE | MO 47 | S | 49.97 | 52.87 | Warren | 2.89 |
| 12 | NE | MO 19 | S | 21.55 | 22.05 | Ralls | 0.50 |
| 13 | NE | MO 6 | E | 168.84 | 176.65 | Knox | 7.81 |
| 14 | NE | MO 94 | W | 61.00 | 61.69 | Warren | 0.72 |
| 15 | NE | MO 15 | N | 112.45 | 115.65 | Scotland | 3.20 |
| 16 | NW | MO 5 | S | 87.90 | 95.61 | Chariton | 7.71 |
| 17 | NW | US 24 | E | 109.73 | 111.92 | Chariton | 2.19 |
| 18 | NW | MO 139 | N | 9.26 | 14.23 | Carroll | 4.97 |
| 19 | NW | US 136 | W | 92.50 | 94.62 | Putnam | 2.12 |
| 20 | NW | US 169 | N | 27.46 | 28.46 | Clinton | 1.00 |
| 21 | SE | MO 25 | S | 32.32 | 32.86 | Stoddard | 0.54 |
| 22 | SE | US 160 | W | 107.55 | 110.25 | Howell | 2.70 |
| 23 | SE | MO 137 | S | 39.02 | 41.86 | Howell | 2.84 |
| 24 | SE | MO 91 | S | 17.92 | 18.87 | Stoddard | 0.95 |
| 25 | SE | MO 34 | E | 71.46 | 73.68 | Bollinger | 2.22 |
| 26 | SL | MO 100 | E | 56.23 | 57.12 | Franklin | 0.89 |
| 27 | SL | MO 110 | W | 1.34 | 2.93 | Jefferson | 1.59 |
| 28 | SL | RT H | E | 4.22 | 10.77 | Jefferson | 6.55 |
| 29 | SL | RT C | S | 13.52 | 14.35 | Franklin | 0.83 |
| 30 | SL | RT B | N | 6.00 | 6.56 | Jefferson | 0.56 |
| 31 | SW | MO 73 | S | 4.26 | 6.18 | Dallas | 1.92 |
| 32 | SW | RT H | S | 15.83 | 20.33 | Greene | 4.50 |
| 33 | SW | MO 76 | W | 179.95 | 184.74 | McDonald | 4.79 |
| 34 | SW | MO 76 | E | 133.06 | 138.20 | Taney | 5.14 |
| 35 | SW | MO 125 | S | 18.92 | 20.87 | Greene | 1.95 |
| 36 | SW | MO 125 | S | 20.95 | 21.41 | Greene | 0.46 |

Since the HSM methodology contained a CMF for horizontal curvature, it was necessary to subdivide these 36 sites further based on horizontal curvature. Each site was subdivided into curve and tangent sections. The limits of the curve and tangent sections were determined based on aerial imagery. For future calibrations, the new MoDOT curves list can also be used. A separate segment was created for each section of each horizontal curve. All of the tangent sections from a given site were combined into one segment since they were homogeneous with respect to cross section and horizontal curvature. The calibration data set consisted of 194 segments, of which 158 segments were horizontal curves.

## 4.5 Data Collection

A list of the data types collected for rural two-lane undivided highways and their sources is shown in Table 4.4. All data, except for horizontal curve data, were collected before the sites in Table 4.3 were subdivided based on horizontal curvature. This method of data collection was used to help ensure that bias created by short segments (i.e. due to horizontal curvature) was not introduced. Lane width and outside paved shoulder width were assumed to be the same in each direction. This assumption was reasonable since most rural two-lane highways were symmetric with respect to cross section. The relationship between the TMS shoulder type and the HSM shoulder type is shown in Table 4.5. ARAN was used to determine driveway density, presence of centerline rumble strips, presence of passing lanes, presence of a two-way left-turn lane, roadside hazard rating, and the presence of lighting.

**Table 4.2 Data sources for rural two-lane undivided segments**

| Data Description | Source |
|---|---|
| AADT | TMS |
| Lane Width | TMS |
| Shoulder Width | TMS |
| Shoulder Type | TMS |
| Horizontal Curve Radius | Aerial Imagery/CAD |
| Horizontal Curve Length | Aerial Imagery/CAD |
| Superelevation Variance | Assumed to be 0 percent |
| Presence of Spirals | Assumed not present |
| Vertical Grade | Assumed to be 0 percent |
| Driveway Density | ARAN, Aerial Imagery |
| Presence of Centerline Rumble Strips | ARAN, Aerial Imagery |
| Presence of Passing Lanes | ARAN, Aerial Imagery |
| Presence of TWLT | ARAN, Aerial Imagery |
| Roadside Hazard Rating | ARAN |
| Presence of Lighting | ARAN, Aerial Imagery |
| Presence of Automated Speed Enforcement | ARAN, Aerial Imagery |
| Number of Crashes | Accident Browser (TMS) |

**Table 4.5 Relationship between TMS shoulder type and HSM shoulder type**

| HSM Shoulder Type | TMS Shoulder Type | TMS Shoulder Description |
|---|---|---|
| Paved | AC | Asphaltic Concrete |
| | BM | Bituminous Mat |
| | BRK | Brick |
| | LC | Asphalt leveling course |
| | PC | Concrete Unknown Reinforcement |
| | PCN | Concrete Non-Reinforced |
| | PCR | Concrete Reinforced |
| | SLC | Superpave Leveling Course |
| | SP | Superpave |
| | UTA | Ultra-Thin Bonded A |
| | UTB | Ultra-Thin Bonded B |
| | UTC | Ultra-Thin Bonded C |
| Gravel | AG | Aggregate |
| | OA | Oil Aggregate |
| | TP1 | Type 1 Aggregate |
| | TP2 | Type 2 Aggregate |
| | TP3 | Type 3 Aggregate |
| | TP4 | Type 4 Aggregate |
| | TP5 | Type 5 Aggregate |
| Turf | ERT | Earth |

The horizontal curve data were measured using aerial imagery of the segments in conjunction with a computer-aided design (CAD) program. One concern relating to the curve data for rural two-lane undivided highway segments was the creation of too many short segments due to subdivisions for horizontal curves. To help alleviate this concern, curves that visually appeared to be straight in the aerial photographs were treated as tangents. In addition, all of the tangent sections on a given site were treated as one segment in the calibration since they were homogeneous with respect to horizontal alignment, AADT, and cross section.

The following data were not readily available: superelevation variance, presence of spirals, and grade. Based on discussions with MoDOT, it was reasonable to assume that all horizontal curves were designed to the appropriate superelevation rate. Therefore, the superelevation variance was assumed to have a value of zero. According to EPG 230.1.5, spiral curves are to be used on all roadways with design traffic greater than 400 vehicles per day, an anticipated posted speed greater than 50 mph, and a curve radius less than 2,865 feet. However, MoDOT indicated that most existing horizontal curves on Missouri highways did not have spirals. Therefore, it was assumed, for calibration purposes, that no horizontal curves contained spirals. A grade value of zero percent was also assumed. This value correlated to the level terrain category in the HSM

that includes grades between -3 percent and 3 percent. MoDOT explained that, though grade was collected by ARAN, it was not available through TMS. The assumptions made regarding superelevation variance, the presence of spirals, and grade corresponded to the base conditions in the HSM for these factors.

4.5.1 Summary Statistics for Rural Two-lane Undivided Roadway Segments

Descriptive statistics for segments are shown in Table 4.6. The average length of the sampled segments was 0.54 miles. The segments ranged in length between 0.02 miles and 7.52 miles. The length standard deviation was 1.12 miles. Many of the segment lengths were short due to the presence of horizontal curves. The minimum length for segments with no horizontal curves was 0.36 miles. The segments were relatively uniform with respect to lane width, but showed some variation with respect to shoulder width. The average values for the driveway density and Roadside Hazard Rating were greater than the values that corresponded to the base conditions in the HSM. A majority of the segments contained paved shoulders. Three of the segments had centerline rumble strips, and one of the segments had a two-way left-turn lane. Nine of the segments had lighting, and no segments contained automated speed enforcement. The segments with horizontal curves had an average curve radius of 1,680 feet and an average curve length of 0.16 miles. The radii of the curve segments varied between 208 feet and 8,483 feet, with a standard deviation of 1,462 feet. The average number of observed crashes was 1.4, and ranged between zero and 48 crashes. The standard deviation of observed crashes was 4.4. The total number of crashes for the segments was 281 (93.7 per year), which is close to the HSM sampling recommendation of having 100 total crashes per year for a specific facility type.

**Table 4.6 Descriptive statistics for rural two-lane undivided segment samples**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| Segment Length | 0.54 | 0.02 | 7.52 | 1.12 |
| AADT (bidirectional) | 2,621 | 265 | 10,939 | 1,982 |
| Lane Width (ft) | 11.1 | 10.0 | 12.5 | 0.8 |
| Shoulder Width (ft) | 3.7 | 2.0 | 10.0 | 2.6 |
| Driveway Density (drives/mi) | 9.5 | 0.8 | 35.6 | 5.1 |
| Roadside Hazard Rating | 4.3 | 1.0 | 6.0 | 1.0 |
| Horizontal Curve Radius (ft) | 1,690 | 208 | 8,483 | 1,462 |
| Horizontal Curve Length (mi) | 0.16 | 0.02 | 0.64 | 0.10 |
| Presence of Spirals | 0 | 0 | 0 | 0 |
| Superelevation Variance | 0 | 0 | 0 | 0 |
| Grade | 0 | 0 | 0 | 0 |
| Number of Observed Crashes | 1.4 | 0.0 | 48.0 | 4.4 |

| Description | No. of Segments |
|---|---|
| Shoulder Type = Paved | 17 |
| Shoulder Type = Gravel | 7 |
| Shoulder Type = Turf | 12 |
| Tangent Segments | 36 |
| Curve Segments | 158 |
| Centerline Rumble Strips | 3 |
| Passing Lanes | 0 |
| Two-way Left-turn Lane | 1 |
| Lighting | 9 |
| Automated Speed Enforcement | 0 |

## 4.6 Results and Discussion

4.6.1 Calibration Factor

The calibration factor for rural two-lane undivided roadway segments in Missouri yielded a calibration factor value of 0.97. The IHSDM output is shown in Figure 4.4. The observed and predicted crash frequencies for each segment are presented in Table 4.7 which is consistent with the IHSDM output. These results indicate that the number of crashes observed in Missouri was slightly less than the number of crashes predicted by the un-calibrated HSM for this site type. The un-calibrated HSM models were obtained using data from two states: Minnesota and Washington. The base models were developed by Vogt and Bared (1998). The model was developed with data from 619 rural two-lane highway segments in Minnesota and 712 roadway

segments in Washington obtained from the FHWA HSIS. These roadway segments included approximately 1,130 km (700 mi) of two-lane roadway in Minnesota and 850 km (530 mi) of roadway in Washington. The database available for model development included five years of crash data (1985-1989) for each roadway segment in Minnesota and three years of crash data (1993-1995) for each roadway segment in Washington.

The calibration factor value of 0.97 is higher than the previous Missouri calibration value of 0.82. In addition to natural variability, a major reason for the increase is an improvement in crash data processing. The previous calibration removed all crashes that were identified as intersection crashes. After analyzing intersection crashes associated with rural two-lane segments, the research team realized that TMS designates some larger driveways with an intersection node identification number, some being stop-controlled and others being signalized. To be consistent with the HSM, these driveways are now included in the current calibration, whereas they were excluded from the previous calibration. There are also other possible reasons for the increase, including driver behavior changes, changes in crash reporting, and changes in the calibration sample.
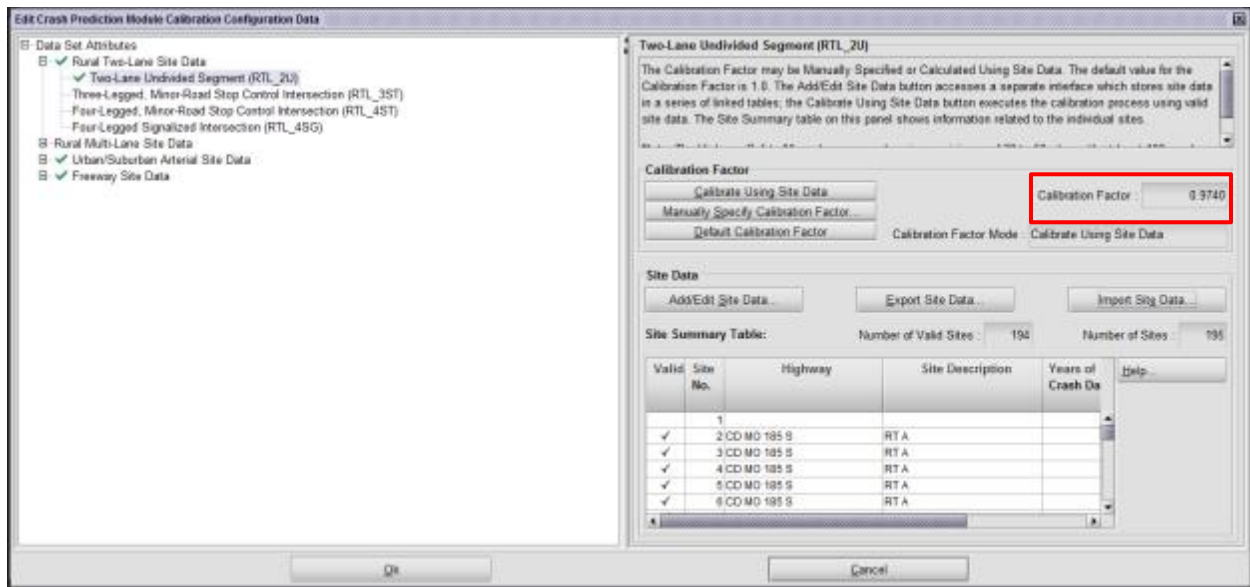


**Figure 4.4 Calibration output for rural two-lane undivided roadway segments**

**Table 4.7 Calibration results for rural two-lane undivided roadway segments**

| No. | District | Segment | Begin Log | Length (mi) | All Crashes | |
|---|---|---|---|---|---|---|
| | | | | | Observed | Predicted |
| 1 | CD | MO 185 S | 39.54 | 44.00 | 14 | 8 |
| 2 | CD | MO 5 S | 220.91 | 222.15 | 1 | 11 |
| 3 | CD | MO 17 N | 156.57 | 160.31 | 9 | 13 |
| 4 | CD | MO 5 N | 222.80 | 226.89 | 3 | 10 |
| 5 | CD | MO 124 W | 23.24 | 25.06 | 4 | 3 |
| 6 | KC | MO 13 S | 127.13 | 130.91 | 10 | 14 |
| 7 | KC | MO 45 N | 9.29 | 15.80 | 51 | 19 |
| 8 | KC | MO 210 E | 25.32 | 26.63 | 6 | 0 |
| 9 | KC | MO 273 S | 19.16 | 22.94 | 22 | 23 |
| 10 | KC | MO 58 E | 47.62 | 49.39 | 12 | 7 |
| 11 | NE | MO 47 S | 49.97 | 52.87 | 5 | 7 |
| 12 | NE | MO 19 S | 21.55 | 22.05 | 0 | 1 |
| 13 | NE | MO 6 E | 168.84 | 176.65 | 8 | 16 |
| 14 | NE | MO 94 W | 61.00 | 61.69 | 4 | 9 |
| 15 | NE | MO 15 N | 112.45 | 115.65 | 4 | 6 |
| 16 | NW | MO 5 S | 87.90 | 95.61 | 5 | 5 |
| 17 | NW | US 24 E | 109.73 | 111.92 | 0 | 5 |
| 18 | NW | MO 139 N | 9.26 | 14.23 | 0 | 1 |
| 19 | NW | US 136 W | 92.50 | 94.62 | 2 | 5 |
| 20 | NW | US 169 N | 27.46 | 28.46 | 4 | 5 |
| 21 | SE | MO 25 S | 32.32 | 32.86 | 1 | 2 |
| 22 | SE | US 160 W | 107.55 | 110.25 | 11 | 13 |
| 23 | SE | MO 137 S | 39.02 | 41.86 | 3 | 2 |
| 24 | SE | MO 91 S | 17.92 | 18.87 | 1 | 1 |
| 25 | SE | MO 34 E | 71.46 | 73.68 | 10 | 8 |
| 26 | SL | MO 100 E | 56.23 | 57.12 | 11 | 7 |
| 27 | SL | MO 110 W | 1.34 | 2.93 | 7 | 14 |
| 28 | SL | RT H E | 4.22 | 10.77 | 41 | 19 |
| 29 | SL | RT C S | 13.52 | 14.35 | 1 | 1 |
| 30 | SL | RT B N | 6.00 | 6.56 | 3 | 3 |
| 31 | SW | MO 73 S | 4.26 | 6.18 | 1 | 5 |
| 32 | SW | RT H S | 15.83 | 20.33 | 14 | 19 |
| 33 | SW | MO 76 W | 179.95 | 184.74 | 7 | 8 |
| 34 | SW | MO 76 E | 133.06 | 138.20 | 3 | 4 |
| 35 | SW | MO 125 S | 18.92 | 20.87 | 1 | 11 |
| 36 | SW | MO 125 S | 20.95 | 21.41 | 2 | 2 |
| **Sum** | | | | | **281** | **289** |
| **Calibration Factor** | | | | | **0.97** | |

4.6.2 Severity Distribution Factors

Using data from the calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 4.8 shows the obtained SDFs for rural two-lane undivided segments. MV refers to multi-vehicle and SV refers to single vehicle crashes.

**Table 4.8 Severity distribution factors for rural two-lane undivided segments**

| Severity | MV | | SV | |
|---|---|---|---|---|
| | Crashes | SDF | Crashes | SDF |
| Fatal | 3 | 0.041 | 6 | 0.029 |
| Disabling Injury | 6 | 0.082 | 17 | 0.081 |
| Minor Injury | 17 | 0.233 | 51 | 0.243 |
| Property Damage Only | 47 | 0.644 | 136 | 0.648 |

4.6.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of predicted crashes according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since Missouri crash type categories differ from the HSM. Therefore, different categories were aggregated to provide similar classifications to those recommended by the HSM. The crash types were estimated for total crashes in correspondence to the calibration factor severity. Based on the classification of crash types in Missouri, Table 4.9 provides the CDFs for rural two-lane undivided roadway segments.

**Table 4.9 Crash type distribution factors for rural two-lane undivided segments**

| Multiple-Vehicle | | |
|---|---|---|
| Collision Type | Crashes | CDF |
| Rear-end | 30 | 0.106 |
| Head-on | 6 | 0.021 |
| Right-angle | 8 | 0.028 |
| Sideswipe | 20 | 0.071 |
| Other | 8 | 0.028 |
| Single-Vehicle | | |
| Collision Type | Crashes | CDF |
| Crash with Animal | 49 | 0.173 |
| Crash with Fixed Object | 4 | 0.014 |
| Out of Control | 134 | 0.473 |
| Other | 24 | 0.085 |

**CHAPTER 5. RURAL MULTILANE DIVIDED SEGMENTS**

**5.1 Introduction and Scope**

Chapter 11 of the HSM describes the methodology for crash prediction on rural multilane highways, including both divided and undivided segments. Rural multilane divided segments were calibrated as part of this project. Rural multilane undivided segments were not calibrated because they were not common in Missouri. The HSM crash prediction models for this site type applied only to segments with four through lanes.

**5.2 Calibration Data Requirements**

The input data in the IHSDM is divided into required and desired data. The required data consist of site, crash, and traffic data. The desired data is optional and includes variables such as lighting and automated speed enforcement.

5.2.1 Required Site Data

5.2.1.1 Area Type and Functional Classification

The classification of areas depends on the roadway characteristics, surrounding population, and land use. Based on the FHWA guidelines, the HSM defines "urban" areas as regions that contain a population greater than 5,000 people. "Rural" areas are designated as regions outside urban areas and which contain a population of fewer than 5,000 people. Although the terms metropolitan, urbanized, or suburban refer to urban subcategories, the HSM does not make a distinction among these subgroups and considers all as urban (AASHTO 2010). MoDOT uses the same area classification. The arterial roadway segment functional classification should include facilities designated as arterial or expressways.

5.2.1.2 Segment Length

The roadway segment length for rural multilane divided segments consists of the total length in miles over a homogenous segment with no significant changes in travelway, cross-section geometry, and speed limit. In addition, rural multilane segments should not intersect or have interchanges facilities as part of the segment. The HSM recommends a minimum segment length of 0.1 miles to reduce calculation efforts. The rural multilane divided segments used for calibration were all longer than 1 mile.

5.2.1.3 Left/Right Side Lane Width

The IHSDM input for rural multilane divided segments requires the lane width for the left and right side lanes of the road in each direction. If different lane width values are observed by direction, an average value should be used. The input value should be introduced in feet and be

larger than zero. Figure 5.1 illustrates the location and lane width convention used in specifying input data.

5.2.1.4 Left/Right Side Paved Shoulder Width

For the right side, the shoulder width should be measured from the outside continuous travelway white marking up to the edge of the shoulder. For the left (median) side, the shoulder should be measured from the yellow continuous line at the edge of the travel way up to the end of the inside shoulder. If the shoulder widths for each direction are different, the average should be calculated. Figure 5.1 illustrates the measurement and location of lane, median, and shoulder widths.



**Figure 5.1 Lane, shoulder, and median width illustration**

5.2.1.5 Effective Median Width

The effective median width is measured between the inside edges of the travelway (through lanes) in the opposing direction of travel. Therefore, inside shoulders and turning lanes are

included in the median width if present. Figure 5.1 illustrates the measurement of the effective median.

5.2.2 Required Crash and Traffic Data

5.2.2.1 Years of Crash Data

The years associated with the calibration should be specified. The IHSDM considers up to three years for the input data.

5.2.2.2 Observed Number of Crashes

The HSM predictive method estimates crash frequency of rural multilane divided segment related crashes. Crash assignment to segments and intersections are based on geometric, traffic control, and operations characteristics. Stop-controlled and signalized intersections may be present along rural multilane segments; however, intersection related crashes should be removed. In the case of Missouri, intersection related crashes were removed based on the intersection identification number that was designated in the crash data. MoDOT assigns crashes to an intersection if it is located within 132 feet of the intersection.

5.2.2.3 Segment AADT

The total segment AADT (both directions) should be collected for all years of analysis.

5.2.3 Desired Data

5.2.3.1 Lighting

Presence of illumination along the segment is considered as lighting. The IHSDM data input only requires specifying the presence of lighting along the segment (i.e. yes or no).

5.2.3.2 Automated Speed Enforcement

Automated speed enforcement of rural multilane segments may use video or photographic identification in combination with radar or laser to detect driver exceeding the posted speed limit of the segment. The system automatically records the vehicle information when at fault. The IHSDM data input only requires specifying the presence of automated speed enforcement along the segment (i.e. yes or no).

### 5.3 HSM Methodology

As described in chapter 11 of the HSM, the SPF for rural multilane divided highway segments predicts the number of total crashes on the segment per year for base conditions. The SPF is based on the AADT and length of the segment, and is given by the equation:

$$N_{spf,rd} = e^{[a+b\times ln(AADT)+ln(L)]}$$
(5.1)

where $N_{spf,rd}$ is the base total number of roadway segment crashes per year, $AADT$ is the annual average daily traffic (vehicles/day) on roadway segment, $L$ is the length of roadway segment (miles); and $a$ and $b$ are regression coefficients.

The base conditions for the SPF are shown in Table 5.1. Crash modification factors were applied when the conditions deviated from the base condition.

**Table 5.1 SPF base conditions for rural multilane divided segments**

| Description | Base Condition |
|---|---|
| Lane Width | 12 ft |
| Right Paved Shoulder Width | 8 ft |
| Median Width | 30 ft |
| Lighting | None |
| Automated Speed Enforcement | None |

### 5.4 Sampling Considerations

For rural multilane divided highways, a random sample of five segments from each MoDOT district was created. TMS was used to generate database queries with a list of candidate rural multilane divided segments for each district. The criteria used to generate the queries are shown in Table 5.2. The field DRVD_TRFRNGINFO_YEAR was used to limit the query to an individual year, e.g., 2012, since TMS contained AADT data for each year. The AADT data for other years were later obtained using other queries. A separate query was run for each MoDOT district using the BEG_DISTRICT_ABBR field. The DRVD_TRF_INFO_NAME field was used to specify AADT in the query output. The BEG_OVERLAPPING_INDICATOR field was used to exclude secondary routes that overlapped with primary routes. The BEG_URBAN_RURAL_CLASS field was used to limit the query to rural segments. The query was limited to rural multilane segments by using the BEG_DIVIDED_UNDIVIDED and NUMBER_OF_LANES fields.

**Table 5.2 Query criteria for rural multilane divided segments**

| Table | Field | Criteria |
|---|---|---|
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRFRNGINFO_YEAR | 2012 |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DISTRICT_ABBR | Varies |
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRF_INFO_NAME | AADT |
| TMS_TRF_INFO_SEGMENT_VW | BEG_OVERLAPPING_INDICATOR | not S |
| TMS_TRF_INFO_SEGMENT_VW | BEG_URBAN_RURAL_CLASS | RURAL |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DIVIDED_UNDIVIDED | DIVIDED |
| TMS_SS_PAVEMENT | NUMBER_OF_LANES | > 2 |

During the sampling process, the functional class of each segment was verified using TMS State of the System, and the segment was discarded if it was a freeway segment. The sample segments were also observed with the ARAN viewer to ensure that ARAN data were available for the segments and that the segments were homogeneous and represented the correct site type. Some sample segments were discarded and replaced with another random sample segment because they did not have adequate ARAN data. The END_URBAN_RURAL_CLASS field was also checked in TMS to confirm that the value of the field was rural. If the value of this field was not rural, the sample segment was also checked in ARAN to determine whether the segment was rural or urban based upon surrounding land use characteristics.

The limits of interchanges within the segment were determined using the MoDOT TMS Maps application, since interchanges were not included in the HSM methodology for rural multilane facilities. The interchange limits were defined as spanning the beginning of the deceleration lane for the exit ramp to the end of the acceleration lane for the entrance ramp. If the interchange contained only an entrance or exit ramp, the end of the gore area was taken as the other interchange limit.

If a segment contained two types of medians: a traversable median and a median barrier, it was classified as heterogeneous. These segments were subdivided based on median type to ensure that each segment had a homogeneous cross section. The final sample for the calibration of rural multilane divided highways consisted of 37 segments. The list of the sample segments is shown in Table 5.3. Twenty-six segments were US numbered highways, and eleven were Missouri numbered highways. No single highway contributed more than four segments. The highways with four segments in the sample were MO-13, US-50, and US-61. The total length of the segments in the sample was approximately 93 miles. Segment lengths will be discussed in detail in the next section. As shown in Table 5.3, the segments from each district came from three to five different counties, with four being the most common. There were 29 counties represented in the samples out of a total of 114 Missouri counties, or, 25%. The sample, therefore, had representation from all MoDOT districts and many counties within each district.

**Table 5.3 List of samples for rural multilane divided segments**

| No. | City | County | Dist. | Description | Primary Dir. | Primary Begin Log | Primary End Log | Length (mi.) |
|-----|------|--------|-------|-------------|------|-----------|---------|--------------|
| 1 | Centertown | Cole | CD | US 50 | W | 134.43 | 136.61 | 2.18 |
| 2 | Loose Creek | Osage | CD | US 50 | E | 154.56 | 156.08 | 1.53 |
| 3 | Linn Creek | Camden | CD | US 54 | W | 156.26 | 157.56 | 1.30 |
| 4 | Clark | Boone | CD | US 63 | S | 99.70 | 101.58 | 1.88 |
| 5 | Camdenton | Camden | CD | MO 5 | S | 226.78 | 227.84 | 1.06 |
| 6 | Elm | Johnson | KC | US 50 | E | 28.90 | 31.27 | 2.37 |
| 7 | Henrietta | Ray | KC | MO 13 | N | 212.04 | 213.64 | 1.60 |
| 8 | Lexington | Ray | KC | MO 13 | N | 208.31 | 209.32 | 1.01 |
| 9 | Garden City | Cass | KC | MO 7 | N | 137.92 | 140.69 | 2.76 |
| 10 | Spring Fork | Pettis | KC | US 65 | N | 154.42 | 157.63 | 3.20 |
| 11 | Knob Noster | Johnson | KC | US 50 | W | 202.90 | 206.43 | 3.52 |
| 12 | La Grande | Lewis | NE | US 61 | S | 34.47 | 37.61 | 3.14 |
| 13 | Winchester | Clark | NE | US 61 | S | 9.24 | 11.21 | 1.98 |
| 14 | Ely | Marion | NE | US 24 | E | 186.28 | 187.96 | 1.69 |
| 15 | Eolia | Pike | NE | US 61 | N | 291.34 | 294.18 | 2.85 |
| 16 | Millard | Adair | NE | US 63 | S | 35.75 | 39.28 | 3.53 |
| 17 | Savannah | Andrew | NW | US 59 | S | 68.99 | 70.77 | 1.78 |
| 18 | Pumpkin Center | Nodaway | NW | US 71 | N | 283.65 | 286.98 | 3.33 |
| 19 | Amazonia | Andrew | NW | US 59 | N | 33.86 | 35.37 | 1.51 |
| 20 | Meadville | Linn | NW | US 36 | W | 107.75 | 109.84 | 2.09 |
| 21 | Cameron | Dekalb | NW | US 36 | E | 31.40 | 32.79 | 1.39 |
| 22 | Halifax | St. Francois | SE | US 67 | S | 77.01 | 84.45 | 7.44 |
| 23 | Wilby | Butler | SE | US 67 | N | 27.82 | 31.81 | 3.98 |
| 24 | Mountain Grove | Wright | SE | US 60 | W | 198.09 | 204.03 | 5.95 |
| 25 | Willow Springs | Howell | SE | US 63 | S | 292.25 | 294.71 | 2.46 |
| 26 | Cabool | Texas | SE | US 60 | W | 186.22 | 188.14 | 1.93 |
| 27 | Goldman | Jefferson | SL | MO 21 | N | 173.01 | 174.78 | 1.77 |
| 28 | Wentzville | St. Charles | SL | US 61 | S | 130.67 | 132.56 | 1.89 |
| 29 | Villa Ridge | Franklin | SL | MO 100 | W | 44.40 | 47.69 | 3.28 |
| 30 | Villa Ridge | Franklin | SL | MO 100 | W | 42.20 | 44.16 | 1.95 |
| 31 | Olympian Village | Jefferson | SL | US 67 | N | 130.21 | 133.46 | 3.25 |
| 32 | Goldman | Jefferson | SL | MO 21 | S | 21.98 | 24.22 | 2.24 |
| 33 | Ridgedale | Taney | SW | US 65 | S | 310.42 | 312.39 | 1.97 |
| 34 | Hartwell | Henry | SW | MO 7 | N | 119.88 | 123.45 | 3.57 |
| 35 | Osceola | St. Clair | SW | MO 13 | S | 171.07 | 172.42 | 1.35 |
| 36 | Seymour | Webster | SW | US 60 | W | 227.07 | 229.70 | 2.64 |
| 37 | Osceola | St. Clair | SW | MO 13 | N | 122.92 | 124.35 | 1.43 |

## 5.5 Data Collection

A list of the data types collected for rural multilane divided highways and their sources is shown in Table 5.4. Lane width and outside paved shoulder width were determined separately for each direction. The ARAN viewer and Google maps street view were used to determine whether the segment had a median barrier or a traversable median. For segments with a traversable median, the median width was measured from aerial images in Google Maps. The median width was measured from the edge of the through lanes in the opposing directions. Therefore, the median width included both median turn lanes and median shoulders. Segment length was calculated in both directions using beginning and end log miles. As previously discussed, sampling was done so that there were no interchanges within the segments. A list of automated enforced locations was provided by MoDOT.

**Table 5.4 Data sources for rural multilane divided segments**

| Data Description | Source |
|---|---|
| AADT | State of the System (TMS) |
| Lane Width | State of the System (TMS) |
| Shoulder Width | State of the System (TMS) |
| Median Type | ARAN |
| Effective Median Width | Aerials |
| Presence of Lighting | ARAN |
| Presence of Automated Speed Enforcement | MoDOT |
| Number of Crashes | Accident Browser (TMS) |

Descriptive statistics for the segments are shown in Table 5.5. The average length of the sampled segments was well above 0.5 mile. The segments ranged in length between 1.01 and 7.44 miles, with the average length being 2.51 miles and the median being 2.09 miles. The length standard deviation was 1.30 miles. The volumes averaged 12,719 AADT, with a maximum of 43,421. The segments were relatively uniform with respect to lane and shoulder width, but showed some variation with respect to effective median width. The average number of crashes was 13.97, and ranged between 1 and 98 crashes. The standard deviation of crashes was 18.14, which was larger than the average. The total number of crashes was 516, which easily exceeded the HSM recommended of 100 crashes per year. Most of the segments had traversable medians. None of the segments had lighting or automated speed enforcement.

**Table 5.5 Descriptive statistics for rural multilane divided samples**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| Length (mi) | 2.51 | 1.01 | 7.44 | 1.30 |
| AADT (2012-2014) | 12,719 | 4,705 | 43,421 | 7,294 |
| Left lane width (ft) | 12.00 | 12.00 | 12.00 | 0.00 |
| Right lane width (ft) | 12.00 | 12.00 | 12.00 | 0.00 |
| Left outside paved shoulder width (ft) | 4.68 | 4.00 | 8.00 | 1.11 |
| Right outside paved shoulder. width (ft) | 9.84 | 8.00 | 10.00 | 0.55 |
| Effective median width (ft) | 68.24 | 15.00 | 120.00 | 24.13 |
| Number of crashes | 13.97 | 1.00 | 98.00 | 18.14 |
| **Description** | | | | **No. of Segments** |
| Non-traversable median | | | | 4 |
| Lighting | | | | 0 |
| Automated speed enforcement | | | | 0 |

## 5.6 Results and Discussion

The original models were developed using data from Texas, California, New York, and Washington. (Lord et al. 2008). Some of the summary statistics for the data used as the basis for model development are shown in Table 5.6. Even though four states were sampled, Texas and California accounted for 92.4% of the segments and 87.1% of the total length. In summary, HSM rural multilane divided highway data consisted of 3,052 segments covering 2,604 miles in four different states. Even though none of the states was in the Midwest, the dataset was a large national dataset that should reflect design and behavior in a large number of U.S. states.

**Table 5.6 Descriptive statistics for HSM model data for rural multilane divided highways**

| State | Number of Segments | Total Length (mi) | Minimum AADT (vpd) | Maximum AADT (vpd) |
|---|---|---|---|---|
| Texas | 1,733 | 1,750 | 160 | 90,000 |
| California | 1,087 | 519 | 1,300 | 61,000 |
| New York | 197 | 139 | 1,082 | 46,717 |
| Washington | 35 | 196 | 3,187 | 61,947 |

The calibration factor for rural multilane divided highways in Missouri yielded a value of 0.74. The IHSDM output is shown in Figure 5.2. Table 5.7 provides detailed results of predictions and observations by facility. These results indicate that the number of crashes observed in Missouri were lower than the crashes predicted by the HSM for this facility type.
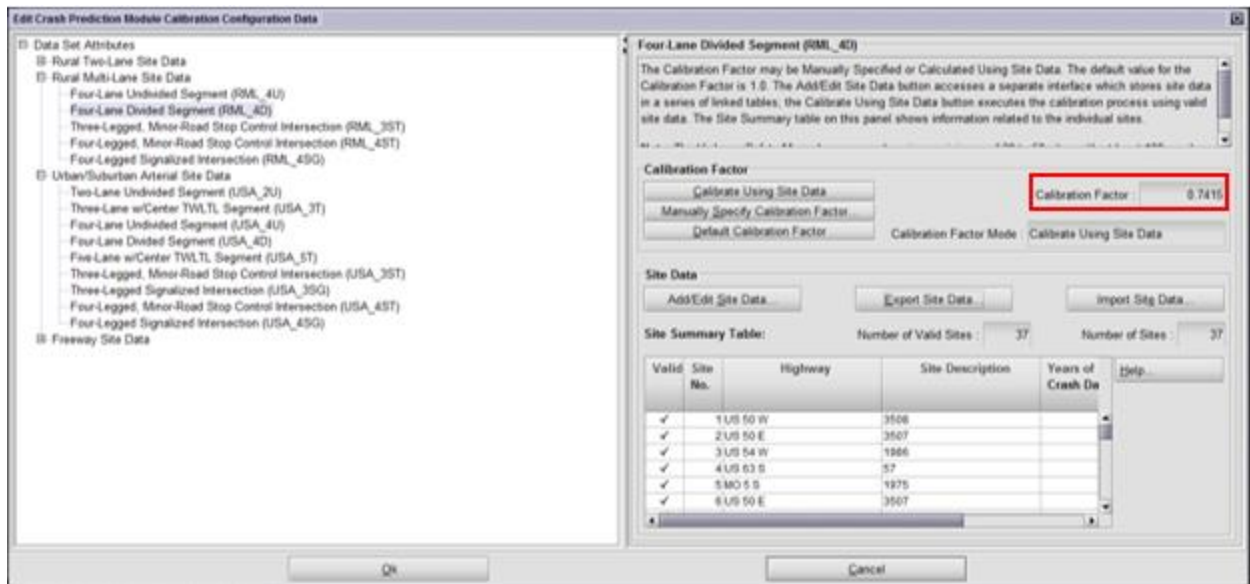
**Figure 5.2 Calibration output for rural multiline divided segments**

**Table 5.7 Calibration results for rural multilane divided segments**

| No. | District | Segment | Begin Log | Length (mi.) | All Crashes | |
|---|---|---|---|---|---|---|
| | | | | | Observed | Predicted |
| 1 | CD | US 50 W | 134.43 | 2.18 | 9 | 10 |
| 2 | CD | US 50 E | 154.56 | 1.53 | 3 | 8 |
| 3 | CD | US 54 W | 156.26 | 1.30 | 8 | 22 |
| 4 | CD | US 63 S | 99.70 | 1.88 | 8 | 14 |
| 5 | CD | MO 5 S | 226.78 | 1.06 | 1 | 9 |
| 6 | KC | US 50 E | 28.90 | 2.37 | 17 | 20 |
| 7 | KC | MO 13 N | 212.04 | 1.60 | 1 | 4 |
| 8 | KC | MO 13 N | 208.31 | 1.01 | 2 | 3 |
| 9 | KC | MO 7 N | 137.92 | 2.76 | 15 | 19 |
| 10 | KC | US 65 N | 154.42 | 3.20 | 26 | 17 |
| 11 | KC | US 50 W | 202.90 | 3.52 | 27 | 29 |
| 12 | NE | US 61 S | 34.47 | 3.14 | 12 | 13 |
| 13 | NE | US 61 S | 9.24 | 1.98 | 3 | 8 |
| 14 | NE | US 24 E | 186.28 | 1.69 | 4 | 9 |
| 15 | NE | US 61 N | 291.34 | 2.85 | 13 | 19 |
| 16 | NE | US 63 S | 35.75 | 3.53 | 10 | 13 |
| 17 | NW | US 59 S | 68.99 | 1.78 | 1 | 7 |
| 18 | NW | US 71 N | 283.65 | 3.33 | 4 | 11 |
| 19 | NW | US 59 N | 33.86 | 1.51 | 2 | 8 |
| 20 | NW | US 36 W | 107.75 | 2.09 | 9 | 9 |
| 21 | NW | US 36 E | 31.40 | 1.39 | 6 | 8 |
| 22 | SE | US 67 S | 77.01 | 7.44 | 98 | 79 |
| 23 | SE | US 67 N | 27.82 | 3.98 | 14 | 15 |
| 24 | SE | US 60 W | 198.09 | 5.95 | 19 | 46 |
| 25 | SE | US 63 S | 292.25 | 2.46 | 8 | 14 |
| 26 | SE | US 60 W | 186.22 | 1.93 | 7 | 14 |
| 27 | SL | MO 21 N | 173.01 | 1.77 | 14 | 15 |
| 28 | SL | US 61 S | 130.67 | 1.89 | 34 | 42 |
| 29 | SL | MO 100 W | 44.40 | 3.28 | 21 | 31 |
| 30 | SL | MO 100 W | 42.20 | 1.95 | 8 | 19 |
| 31 | SL | US 67 N | 130.21 | 3.25 | 59 | 69 |
| 32 | SL | MO 21 S | 21.98 | 2.24 | 19 | 19 |
| 33 | SW | US 65 S | 310.42 | 1.97 | 5 | 16 |
| 34 | SW | MO 7 N | 119.88 | 3.57 | 15 | 22 |
| 35 | SW | MO 13 S | 171.07 | 1.35 | 3 | 5 |
| 36 | SW | US 60 W | 227.07 | 2.64 | 11 | 23 |
| 37 | SW | MO 13 N | 122.92 | 1.43 | 1 | 9 |
| Sum | | | | | 517 | 697 |
| Calibration Factor | | | | | 0.741 | |

The result of the recalibration in this project is different from the previous calibration performed for the period of 2009-2012. The previous calibration factor was 0.98. The main differences were due to crash data processing and effective segment length determination. The previous calibration queried for all crashes within a segment. The crash query included intersections, interchanges, and other inconsistent sections. The segment length and crashes were later processed by removing sections of the segment to omit interchanges and inconsistent sections. In the case of intersections, all intersection related crashes were removed from the query. The resulting segment length in the previous HSM calibration was an effective length that was a combination of multiple sections along the queried segment. Although this practice is common, the capability and precision to consistently remove crashes and sections within segments was not possible because of data characteristics. Missouri crash data is sometimes landed inaccurately close to interchanges since the interchange polygon defined by MoDOT may extend further down the approaching segments or assign crossroad crashes to the mainline. Therefore, the samples in the new recalibration were readjusted so the segments were not a combination of separate sections. In other words, the new samples were adjusted to establish continuous segments away from interchanges. As a result, the new samples had fewer crashes across the board because the queries were consistent and continuous along the segments without including other crashes corresponding to interchanges or inconsistent sections.

5.6.1 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 5.8 shows the obtained SDFs for rural multilane segments.

**Table 5.8 Severity distribution factors for rural multilane divided segments**

| Severity | Crashes | SDF |
|---|---|---|
| Fatal | 6 | 0.012 |
| Disabling Injury | 20 | 0.039 |
| Minor Injury | 118 | 0.228 |
| Property Damage Only | 373 | 0.721 |

5.6.2 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of predicted crashes according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since Missouri crash type categories were different than the HSM. Therefore, different Missouri categories were aggregated to provide similar classifications as those recommended by the HSM. The crash types were estimated for total crashes in correspondence to the calibration factor severity. Table 5.9 provides the CDFs for rural multilane divided segments.

**Table 5.9 Crash type distribution factors rural multilane divided segments**

| Collision Type | Crashes | CDF |
|---|---|---|
| Head-on | 1 | 0.002 |
| Sideswipe | 33 | 0.064 |
| Rear-end | 58 | 0.112 |
| Angle collision | 7 | 0.014 |
| Collision with animal | 111 | 0.215 |
| Collision with fixed object | 11 | 0.021 |
| Collision with parked vehicle | 5 | 0.010 |
| Out of control | 234 | 0.453 |
| Other | 57 | 0.110 |

**CHAPTER 6 URBAN ARTERIAL SEGMENTS**

**6.1 Introduction and Scope**

Chapter 12 of the HSM describes the methodology for crash prediction on urban arterial segments including two-lane and four-lane undivided segments, four-lane divided segments, and three-lane and five-lane undivided segments with two-way left-turn lanes. Because some of these site types were not common in Missouri, the calibration of urban arterial segments in this project was only performed for two-lane undivided segments, four-lane divided segments, and five-lane undivided segments with a two-way left-turn lane.

**6.2 Calibration Data Requirements**

The input data in the IHSDM is divided into required and desired data. The required data consists of site, crash, and traffic data. The desired data is optional and includes variables such as fixed objects, lighting, and automated speed enforcement.

6.2.1 Required Site Data

6.2.1.1 Area Type

The classification of areas depends on the roadway characteristics, surrounding population, and land use. Based on the FHWA guidelines, the HSM defines "urban" areas as regions that containe a population greater than 5,000 people. "Rural" areas are designated as regions outside urban areas and which contain a population less than 5,000 people. Although the terms metropolitan, urbanized, or suburban refer to urban subcategories, the HSM does not make a distinction among these subgroups and considers all as urban (AASHTO 2010). MoDOT uses the same area classification.

6.2.1.2 Segment Length

The roadway segment length for urban arterials consists of the total length in miles over a homogenous segment with no significant changes in travelway, cross-section, geometry, and speed limit. The HSM recommends a minimum of 0.1 miles to reduce calculation efforts. Due to the urban environment, long segments were not as plentiful as other facility types. There were 19 out of the 75 four lane divided arterial segments and 32 out of the 59 for four lane undivided arterial segments that were shorter than 0.5 miles. Figure 6.1 illustrates a homogenous segment including a horizontal curve that was limited by two stop-controlled intersections.

**Figure 6.1 Segment length of a homogenous segment (Google Earth 2016)**

6.2.1.3 Number of Driveways

Driveways are defined as frontage access along an establishment property with the road segment arterial. The driveway designation is restricted to unsignalized driveways only. The number of driveways counted should be within the roadway segment including all driveways on both sides of the road. Driveways are categorized by commercial, industrial/institutional, residential, and other driveways. Commercial driveways are facilities that provide access to retail establishments. Commercial driveways with no restriction of access along an entire property frontage can be counted as two driveways. Figure 6.2 shows an example of a commercial driveway that leads to a fast food drive-through.



**Figure 6.2 Commercial driveway at an urban arterial segment (Google Earth 2016)**

Industrial/institutional driveways are designated as facilities that provide access to factories, warehouses, schools, hospitals, churches, offices, public facilities, and other places of employment. Figure 6.3 shows examples of institutional driveways of a hospital complex. Note that the signalized driveway in Figure 6.3 should be considered as an intersection.



**Figure 6.3 Institutional driveways example at an arterial segment (Google Earth 2016)**

Residential driveways provide access to single and multiple family homes. A residential driveway could be a driveway directly connecting a home to the arterial segment or a driveway that connects to a network of homes. Figure 6.4 provides an example of a major residential driveway that provides access to a neighborhood without cutting-through to a city street. A residential driveway should not include public streets that serve additional traffic than a specific residential complex. Thus, public streets should be designated as intersections according to their control type. Driveways are further divided into major and minor driveways based on the estimated number of parking spaces that the driveway connects to. Major driveways accommodate 50 or more parking spaces, and minor driveways serve fewer than 50 parking spaces (AASHTO 2010).

**Figure 6.4 Residential driveway at an urban arterial (Google Earth 2016)**

6.2.1.4 Type of Parking and Land Use

Parking is designated according to the type of on-street parking allowed, including parallel, angle, or no parking. In addition, the land use of the adjacent establishment in which parking is located is designated as commercial/industrial/institutional or residential/other. The type of parking and land-used is further designated as left or right side. The left side parking designation is present at divided road segments with wide medians capable of accommodating parked vehicles. Figure 6.5 provides an example of angle parking and Figure 6.6 illustrates parallel parking on one side of the roadway.
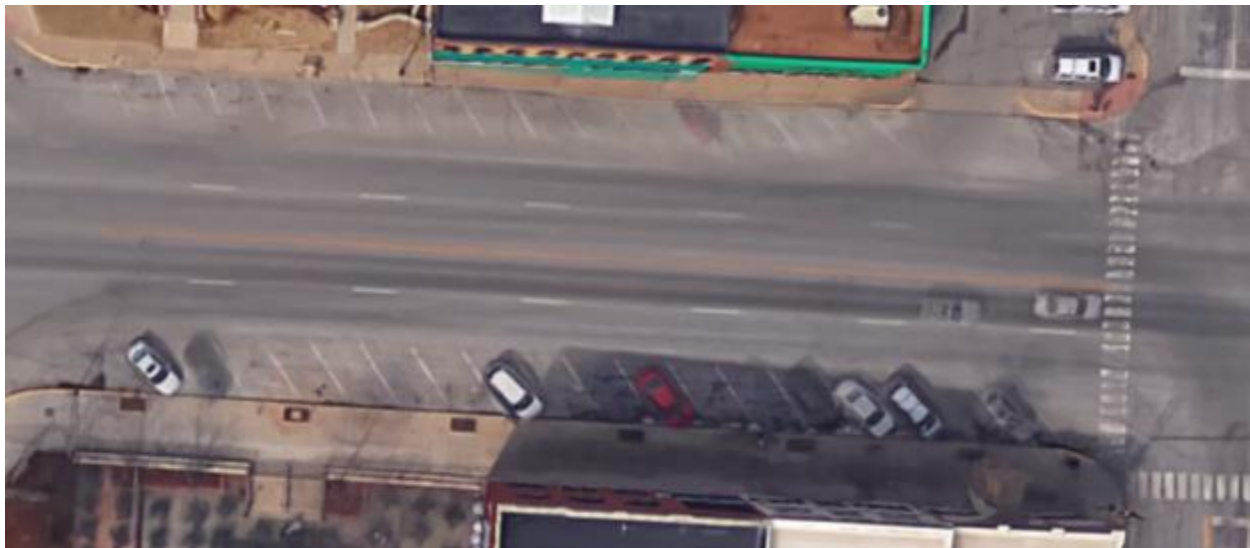


**Figure 6.5 Angle parking on right side of the road (Google Earth 2016)**

**Figure 6.6 Parallel parking on one side of the road only (right side) (Google Earth 2016)**

6.2.1.5 Proportion of Curb Length with Parking

The proportion of the curb length with on-street parking represents the portion of the road segment that contains parking and should include parking that is available on either side of the roadway. The left side parking would primarily be present at divided road segments that allow parked vehicles on the left side on one-way segments.

6.2.1.6 Speed Category

Pedestrians and bicycle crashes are part of the prediction methodology based on posted speed limit categories. Two speed categories are considered: 1) Low (30 mph or lower) and 2) Intermediate/High (more than 30 mph). Street view images were used to verify the posted speed limits within the segments.

6.2.1.7 Effective Median Width and Type

This section applies to divided segments only. The effective median width is the total length of median that remains constant throughout the segment delineated by the edges of travelway, including inside shoulders, if present. The median width is measured in feet. If there are significant variations of median width within a segment, the segment should be divided into different sections or a weighted average width should be used. There are several possible median configurations. Arterials with no physical separation (i.e., painted median) are considered undivided facilities. The HSM defines two types of median: 1) traversable and 2) non-traversable. Figure 6.7 shows examples of various types of medians.

**(a) Painted median**



**(b) Median concrete barrier**



**(c) Median W-beam barrier**



**(d) Median cable barrier**



**(e) Depressed median**



**(f) Flush paved median**



**(g) Rapid transit median**



**(h) Railroad median**

**Figure 6.7 Examples of different median types (Google 2016)**

6.2.2 Required Crash and Traffic Data

6.2.2.1 Years of Crash Data

The IHSDM considers up to three years for the input data. The years associated with the calibration were specified as 2012 to 2014.

6.2.2.2 Observed Number of Crashes

The HSM predictive method estimates crash frequency of urban arterial segment crashes. Crash assignment to segments or intersections is based on geometric, traffic control, and operations characteristics. It is common to find urban arterial segments limited by intersections; thus, intersection related crashes should not be considered as segment related crashes. In the case of Missouri, intersection related crashes were removed based on the intersection identification number that was designated in the crash data. MoDOT assigns crashes to an intersection if it is located within 132 feet of the intersection. Note that some driveways are assigned intersection node numbers on the TMS system, and crashes associated with these driveways should not be excluded. All segment related crashes should be included with no additional separation by severity or single/multiple vehicle designation as is done in Chapter 7 for freeway segments. Figure 6.8 provides the definition from the HSM for segmentation and crash assignment for segments and intersections.
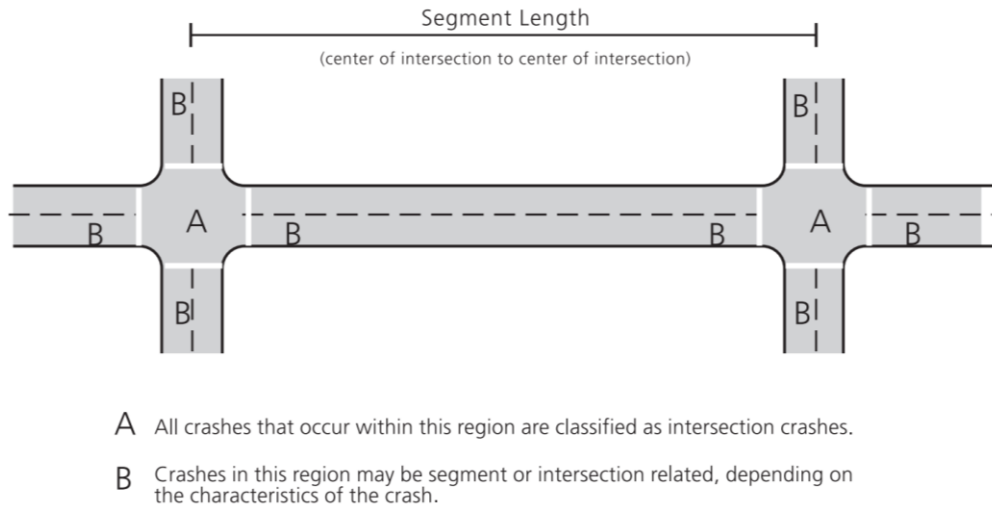


**Figure 6.8 HSM definition of segment and intersection crashes (AASHTO 2010)**

6.2.2.3 Segment AADT

The total segment AADT (in both directions) was collected for all years of analysis.

6.2.3 Desired Data

6.2.3.1 Offset to Fixed Objects

Fixed objects that are 4 inches or more in diameter and do not have breakaway design are applicable. The average offset of objects (from the edge of the travelway) within a segment on the right side of the roadway in each direction of travel were considered; fixed objects in the roadway median on divided arterials were not considered (AASHTO 2010). Figure 6.9 shows an example of an offset to a commercial sign.



**Figure 6.9. Offset to fixed object example (Google 2016)**

6.2.3.2 Fixed Object Density

According to the HSM, "point objects that are within 70 feet of one another longitudinally along the road are counted as a single object. Continuous objects that are not behind point objects are counted as one point object for each 70 feet of length." (AASHTO 2010). Fixed object density for both sides of the road are considered in units of fix object per mile. Figure 6.10 illustrates utility posts along one side of the road at a constant spacing (considered as one object for every 70 feet).

**Figure 6.10. Utility posts on side of the road**

6.2.3.3 Lighting

Lighting is defined as the presence of illumination along a segment. The IHSDM data input only requires specifying whether or not there is lighting along the segment (i.e. yes or no). Figure 6.11 shows common lighting configuration on both sides of the road on an urban arterial.



**Figure 6.11. Illumination on both sides of the road**

6.2.3.4 Automated Speed Enforcement

Automated speed enforcement of arterial segments may use video or photographic identification in combination with radar or laser to detect driver going over the posted speed limit of the

segment. The system automatically records the vehicle information when at fault. The IHSDM data input only requires specifying whether or not there is automated speed enforcement along the segment (i.e. yes or no). Figure 6.12 illustrates common configurations and signs for automated speed enforcement.



**Figure 6.12. Automated speed enforcement camera (Google 2016)**

## 6.3 HSM Methodology

As described in chapter 12 of the HSM, the SPFs for urban arterial segments predict the number of total crashes on a segment per year for the base conditions. The SPF is a function of the AADT and length of the segment, and is obtained through equations 6.1-6.8 below. The vehicular and non-vehicular (pedestrian and bicycle) related crashes are added together to obtain the total number of crashes on a segment. The base conditions are listed in Table 6.1.

$$N_{predicted,rs} = C_r \times (N_{br} + N_{pedr} + N_{biker}) \tag{6.1}$$

where $N_{predicted,rs}$ is the predicted average crash frequency of an individual roadway segment for the selected year, $C_r$ is the calibration factor for roadway segments of a specific type developed for use for a particular geographical area, $N_{br}$ is the predicted average crash frequency of an individual roadway segment (excluding vehicle-pedestrian and vehicle-bicycle collisions), $N_{pedr}$ is the predicted average crash frequency of vehicle-pedestrian collisions for an individual roadway segment, and $N_{biker}$ is the predicted average crash frequency of vehicle-bicycle collisions for an individual roadway segment.

$$N_{br} = N_{spf,rs} \times (CMF_{lr} \times CMF_{2lr} \times ... \times CMF_{nr}) \tag{6.2}$$

where $N_{spf,rs}$ is the predicted total average crash frequency of an individual roadway segment for base conditions (excluding vehicle-pedestrian and vehicle-bicycle collisions) and $CMF_{lr} \times ... \times CMF_{nr}$ are the crash modification factors for roadway segments. The vehicular related crashes are the sum of multi-vehicle, single-vehicle, and driveway crashes.

$$N_{spf,rs} = N_{brmv} + N_{brsv} + N_{brdwy} \tag{6.3}$$

47

where $N_{brmv}$ is the predicted average crash frequency of multiple-vehicle non-driveway crashes for base conditions, $N_{brsv}$ is the predicted average crash frequency of single-vehicle crashes for base conditions, and $N_{brdwy}$ is the predicted average crash frequency of multiple-vehicle driveway-related collisions.

$$N_{brmv} = e^{(a+b\times\ln(AADT)+\ln(L))} \tag{6.4}$$

$$N_{brsv} = e^{(a+b\times\ln(AADT)+\ln(L))} \tag{6.5}$$

$$N_{brdwy} = \sum_{\substack{all \\ driveway \\ types}} n_j \times N_j \times \left(\frac{AADT}{15,000}\right)^{(t)} \tag{6.6}$$

where $a + b$ are the regression coefficients, $AADT$ is the annual average daily traffic volume (vehicles/day) on roadway segment, $L$ is the length of roadway segment (mi), $n_j$ is the number of driveways within roadway segment of driveway type $j$ including all driveways on both sides of the road, $N_j$ is the number of driveway-related collisions per driveway per year for driveway type $j$, and $t$ is the coefficient of traffic volume adjustment. Even though the model forms are the same for multi-vehicle and single vehicle equations (i.e., 6.4 and 6.5), the coefficients, a and b, are different.

$$N_{pedr} = N_{br} \times f_{pedr} \tag{6.7}$$

$$N_{biker} = N_{br} \times f_{biker} \tag{6.8}$$

where $f_{pedr}$ is the pedestrian crash adjustment factor and $f_{biker}$ is the bicycle crash adjustment factor.

**Table 6.1 Base conditions in HSM for SPF for urban arterial segments**

| Description | Base Condition |
|---|---|
| On-Street Parking | None |
| Roadside Fixed Objects | None |
| Median Width | 15 ft |
| Lighting | None |
| Automated Speed Enforcement | None |

## 6.4 Sampling Considerations

In order to select sample urban arterial segments, a list of all segments for each district and each site type was generated using TMS database queries. Duplicate samples were filtered out using a

spreadsheet. During the sampling process, an attempt was made to obtain 10 samples from each district with a minimum segment length of 0.25 miles. A greater number of samples were used for urban arterials as the segments were shorter. However, it was not possible to meet this goal for all of the site types due to a lack of a sufficient number of samples. The urban two-lane arterial segments were subdivided if the speed limit changed from 30 mph and below to over 30 mph, since the CMF for speed category was based upon these speed limit ranges. Variations of 5 to 10 mph in the posted speed limit were tolerated. Significant variations in speed limits were not considered as homogenous segments. The segments were not subdivided based on minor changes in cross section. The urban four-lane divided arterial segments were subdivided based on changes in median type or significant changes in median width. Major signalized intersections were avoided within the segments. In addition, the proximity to interchange facilities was avoided. The specific considerations for each site type are described below.

6.4.1 Sampling for Urban Two-Lane Undivided Arterial Segments

The query criteria used to generate the master list of urban two-lane arterial undivided segments are shown in Table 6.2. The query utilized the ROADWAY_TYPE_NAME field in the TMS table TMS_SS_PAVEMENT to obtain segments that were classified as either TWO_LANE or SUPER 2-LANE. The BEG_OVERLAPPING_INDICATOR field was used to exclude secondary routes that overlapped with primary routes. The BEG_URBAN_RURAL_CLASS field was used to limit the query to urban segments. The query was limited to undivided segments by using the BEG_DIVIDED_UNDIVIDED and END_DIVIDED_UNDIVIDED fields.

**Table 6.2 Query criteria for urban two-lane undivided arterial segments**

| Table | Field | Criteria |
|---|---|---|
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRFRNGINFO_YEAR | 2012 |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DISTRICT_ABBR | Varies |
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRF_INFO_NAME | AADT |
| TMS_TRF_INFO_SEGMENT_VW | BEG_OVERLAPPING_INDICATOR | not S |
| TMS_TRF_INFO_SEGMENT_VW | BEG_URBAN_RURAL_CLASS | URBAN |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DIVIDED_UNDIVIDED | UNDIVIDED |
| TMS_TRF_INFO_SEGMENT_VW | END_DIVIDED_UNDIVIDED | UNDIVIDED |
| TMS_SS_PAVEMENT | ROADWAY_TYPE_NAME | TWO-LANE or SUPER 2-LANE |

Sampling for urban two-lane undivided arterial segments was performed based on the master list generated from the database queries. All data requirements were reviewed along the segments using ARAN video, TMS information, and Google Maps. At least nine random samples from each district were generated. Therefore, the sample set for calibration included 75 sites.

A list of samples for urban two-lane undivided arterial segments is shown in Table 6.3. The samples were distributed among the seven MoDOT districts as follows:

- 11 samples from the Central District
- 9 samples from the Kansas City District
- 10 samples from the Northeast District
- 9 samples from the Northwest District
- 12 samples from the Southeast District
- 9 samples from the Saint Louis District
- 13 samples from the Southwest District

The samples represent geographic diversity from around the state of Missouri. The samples included US highways and Missouri highways, as well as segments from 34 counties in Missouri, including large counties such as Jackson and small counties such as Pike.

**Table 6.3 List of sites for urban two-lane undivided arterial segments**

| No. | City | County | Dist. | Description | Primary Dir. | Begin Log | End Log | Length (mi.) |
|-----|------|--------|-------|-------------|------|-----------|---------|--------------|
| 1 | Fulton | Callaway | CD | RT F | E | 7.58 | 9.03 | 1.45 |
| 2 | Fulton | Callaway | CD | RT O | E | 0.25 | 0.93 | 0.68 |
| 3 | Boonville | Cooper | CD | US 40 | E | 105.74 | 106.14 | 0.40 |
| 4 | Boonville | Cooper | CD | MO 87 | S | 22.69 | 23.28 | 0.59 |
| 5 | Waynesville | Pulaski | CD | MO 17 | N | 136.31 | 136.86 | 0.55 |
| 6 | New Franklin | Howard | CD | MO 5 | N | 210.76 | 211.61 | 0.85 |
| 7 | Boonville | Cooper | CD | RT B | N | 23.39 | 24.10 | 0.71 |
| 8 | Salem | Dent | CD | RT J | E | 1.03 | 1.76 | 0.74 |
| 9 | Salem | Dent | CD | RT HH | S | 0.00 | 0.45 | 0.45 |
| 10 | Fulton | Callaway | CD | BU 54 | E | 4.48 | 4.86 | 0.38 |
| 11 | Eldon | Howard | CD | MO 87 | S | 75.57 | 75.97 | 0.40 |
| 12 | Sedalia | Pettis | KC | US 50 | E | 83.46 | 84.51 | 1.05 |
| 13 | Marshall | Saline | KC | MO 240 | E | 0.65 | 1.46 | 0.81 |
| 14 | Marshall | Saline | KC | US 65 | N | 194.14 | 194.78 | 0.64 |
| 15 | Marshall | Saline | KC | RT WW | E | 0.70 | 1.65 | 0.95 |
| 16 | Marshall | Saline | KC | RT WW | W | 2.78 | 3.39 | 0.61 |
| 17 | Marshall | Saline | KC | BU 65 | S | 2.27 | 2.52 | 0.25 |
| 18 | Excelsior Springs | Clay | KC | SP 10 | E | 0.07 | 0.60 | 0.53 |
| 19 | Oak Grove | Jackson | KC | RT F | S | 2.07 | 2.49 | 0.42 |
| 20 | Excelsior Springs | Clay | KC | RT N | S | 0.54 | 1.10 | 0.56 |
| 21 | Oak Grove | Jackson | KC | RT F | S | 0.99 | 2.07 | 1.08 |
| 22 | Sedalia | Pettis | KC | US 50 | E | 82.50 | 83.33 | 0.83 |
| 23 | Mexico | Audrain | NE | MO 15 | N | 2.38 | 2.75 | 0.37 |
| 24 | Mexico | Audrain | NE | MO 15 | N | 2.87 | 3.22 | 0.35 |
| 25 | Mexico | Audrain | NE | MO 22 | E | 22.96 | 23.86 | 0.90 |
| 26 | Bowling Green | Pike | NE | MO 161 | S | 0.46 | 1.07 | 0.61 |
| 27 | Moberly | Randolph | NE | RT M | W | 23.71 | 24.73 | 1.02 |
| 28 | Bowling Green | Pike | NE | BU 61 | S | 1.96 | 2.46 | 0.50 |
| 29 | Troy | Lincoln | NE | RT J | S | 0.63 | 1.43 | 0.80 |
| 30 | Moberly | Randolph | NE | BU 63 | N | 5.29 | 6.30 | 1.01 |
| 31 | Kirksville | Adair | NE | RT P | E | 0.24 | 0.68 | 0.43 |
| 32 | Kirksville | Adair | NE | RT B | S | 11.69 | 12.58 | 0.89 |
| 33 | Cameron | Dekalb | NW | BU 36 | W | 0.59 | 1.40 | 0.81 |
| 34 | Blake | Daviess | NW | RT V | N | 0.59 | 1.00 | 0.40 |
| 35 | Trenton | Grundy | NW | MO 6 | E | 79.82 | 80.46 | 0.64 |
| 36 | Maryville | Nodaway | NW | BU 71 | N | 3.23 | 4.42 | 1.18 |

**Table 6.3 Continued**

| No. | City | County | Dist. | Description | Primary | | | Length (mi.) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Dir. | Begin Log | End Log | |
| 37 | Cameron | Dekalb | NW | US 69 | S | 67.65 | 67.99 | 0.34 |
| 38 | Maryville | Nodaway | NW | MO 46 | E | 27.11 | 27.46 | 0.34 |
| 39 | Trenton | Grundy | NW | RT AA | N | 0.00 | 0.57 | 0.57 |
| 40 | Cameron | Clinton | NW | RT A | N | 15.78 | 16.30 | 0.51 |
| 41 | Maryville | Nodaway | NW | RT V | E | 11.75 | 12.18 | 0.43 |
| 42 | Cape Girardeau | Cape Girardeau | SE | RT W | S | 5.89 | 7.19 | 1.30 |
| 43 | Cape Girardeau | Cape Girardeau | SE | RT W | S | 7.68 | 8.47 | 0.79 |
| 44 | Cape Girardeau | Cape Girardeau | SE | RT W | S | 8.97 | 9.55 | 0.59 |
| 45 | Perryville | Perry | SE | RT B | S | 0.08 | 0.45 | 0.37 |
| 46 | Miner | Scott | SE | US 62 | E | 62.72 | 63.24 | 0.52 |
| 47 | Jackson | Cape Girardeau | SE | RT PP | S | 0.06 | 1.03 | 0.97 |
| 48 | Desloge | St. Francois | SE | MO 8 | E | 70.74 | 71.16 | 0.42 |
| 49 | Perryville | Perry | SE | MO 51 | S | 15.20 | 15.54 | 0.34 |
| 50 | Malden | Dunklin | SE | RT J | E | 10.94 | 11.42 | 0.48 |
| 51 | Cape Girardeau | Scott | SE | RT AB | W | 4.08 | 5.73 | 1.65 |
| 52 | Dexter | Stoddard | SE | MO 114 | E | 0.28 | 0.78 | 0.50 |
| 53 | Kennett | Dunklin | SE | RT E | E | 0.16 | 2.20 | 2.04 |
| 54 | De Soto | Jefferson | SL | RT E | N | 14.83 | 15.92 | 1.09 |
| 55 | Saint Clair | Franklin | SL | MO 47 | N | 49.14 | 49.83 | 0.69 |
| 56 | Sullivan | Franklin | SL | MO 185 | N | 37.12 | 37.71 | 0.59 |
| 57 | Sullivan | Franklin | SL | MO 185 | S | 30.24 | 30.85 | 0.61 |
| 58 | Cedar Hill | Jefferson | SL | RT NN | N | 0.07 | 1.13 | 1.06 |
| 59 | Union | Franklin | SL | MO 47 | S | 65.02 | 66.65 | 1.64 |
| 60 | Saint Clair | Franklin | SL | MO 47 | N | 47.14 | 47.58 | 0.44 |
| 61 | Sullivan | Crawford | SL | RT D | S | 0.64 | 1.32 | 0.68 |
| 62 | Sullivan | Crawford | SL | RT D | S | 1.42 | 2.41 | 1.00 |
| 63 | Hollister | Taney | SW | RT BB | S | 0.03 | 1.37 | 1.34 |
| 64 | Hollister | Taney | SW | BU 65 | N | 1.30 | 1.86 | 0.55 |
| 65 | Hollister | Taney | SW | BU 65 | N | 2.02 | 2.36 | 0.34 |
| 66 | Aurora | Lawrence | SW | BU 60 | E | 6.51 | 7.24 | 0.73 |
| 67 | Forsyth | Taney | SW | US 160 | W | 177.11 | 177.94 | 0.83 |
| 68 | Forsyth | Taney | SW | US 160 | W | 178.19 | 179.08 | 0.89 |
| 69 | Aurora | Lawrence | SW | BU 60 | E | 4.80 | 5.66 | 0.86 |
| 70 | Marshfield | Webster | SW | RT CC | S | 16.61 | 17.49 | 0.88 |
| 71 | Marshfield | Webster | SW | RT CC | N | 0.11 | 0.74 | 0.63 |

**Table 6.3 Continued**

| No. | City | County | Dist. | Description | Primary Dir. | Primary Begin Log | Primary End Log | Length (mi.) |
|-----|------|--------|-------|-------------|------|-----------|---------|--------------|
| 72 | Clinton | Henry | SW | BU 13 | S | 0.12 | 1.10 | 0.98 |
| 73 | Nevada | Vernon | SW | RT BB | S | 0.08 | 0.90 | 0.82 |
| 74 | Nevada | Vernon | SW | RT BB | S | 0.95 | 1.55 | 0.60 |
| 75 | Carthage | Jasper | SW | MO 96 | E | 14.92 | 15.80 | 0.88 |

6.4.2 Sampling for Urban Four-Lane Divided Arterial Segments

The query criteria used to generate the master list of urban four-lane divided arterial segments are shown in Table 6.4. These criteria were similar to the criteria used for urban two-lane undivided segments, with a few differences. The query utilized the BEG_DIVIDED_UNDIVIDED field to obtain segments that were classified as DIVIDED. The query also excluded interstate segments by using the field BEG_FUNCTIONAL CLASS.

**Table 6.4 Query criteria for urban four-lane divided arterial segments**

| Table | Field | Criteria |
|-------|-------|----------|
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRFRNGINFO_YEAR | 2012 |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DISTRICT_ABBR | Varies |
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRF_INFO_NAME | AADT |
| TMS_TRF_INFO_SEGMENT_VW | BEG_OVERLAPPING_INDICATOR | not S |
| TMS_TRF_INFO_SEGMENT_VW | BEG_URBAN_RURAL_CLASS | URBAN |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DIVIDED_UNDIVIDED | DIVIDED |
| TMS_TRF_INFO_SEGMENT_VW | BEG_FUNCTIONAL CLASS | not INTERSTATE |

Samples were selected from the aforementioned master list. Freeway segments were removed from the list of candidate segments using spreadsheet filtering. In some cases, the limits of the segments were revised after viewing them in ARAN because a portion of the segment was located within the limits of an interchange, was not urban, or was not of the proper site type. For this site type, it was not possible to obtain 10 random samples from each district due to a lack of a sufficient number of samples. At-large samples were taken from the entire state in order to obtain as many samples as possible. One segment from the Central District was subdivided into three segments due to significant changes in median width. One segment from the Northeast District was subdivided into two segments because a portion of the segment contained median cable barrier. The sample set for calibration included 66 sites.

A list of samples for urban four-lane undivided arterial segments is shown in Table 6.5. The samples were distributed among the seven MoDOT districts as follows:

- 1 sample from the Central District
- 7 samples from the Kansas City District
- 7 samples from the Northeast District
- 2 samples from the Northwest District
- 19 samples from the Southeast District
- 22 samples from the Saint Louis District
- 8 samples from the Southwest District

The sample set included arterial segments that represented geographic diversity from around the state of Missouri, although approximately one-third of the samples were from the Saint Louis District. The sample set included segments from 22 counties in Missouri, including large counties such as Jefferson and small counties such as Scott. The majority of the segments were on Missouri highways, while the remaining segments were on US highways.

**Table 6.5 List of sites for urban four-lane divided arterial segments**

| Segment ID | District | Description | Primary Direction | Primary Begin Log | Primary End Log | Length | County |
|---|---|---|---|---|---|---|---|
| 1 | CD | LP 44 | E | 7.62 | 7.92 | 0.30 | Jackson |
| 2 | KC | US 50 | E | 61.26 | 61.70 | 0.44 | Johnson |
| 3 | NE | US 61 | S | 63.95 | 64.62 | 0.66 | Ralls |
| 4 | NE | US 61 | S | 88.81 | 89.19 | 0.38 | Pike |
| 5 | NE | US 61 | S | 120.25 | 120.74 | 0.49 | Lincoln |
| 6 | NE | US 61 | S | 123.47 | 124.06 | 0.59 | Lincoln |
| 7 | NE | US 63 | N | 252.78 | 253.35 | 0.58 | Randolph |
| 8 | NE | US 63 | N | 250.75 | 251.48 | 0.73 | Randolph |
| 9 | NE | US 36 | E | 131.64 | 132.52 | 0.87 | Macon |
| 10 | NW | US 36 | E | 71.99 | 72.41 | 0.42 | Livingston |
| 11 | NW | US 36 | E | 73.31 | 73.81 | 0.50 | Livingston |
| 12 | SE | US 61 | S | 285.52 | 286.00 | 0.48 | Cape Girardeau |
| 13 | SE | US 67 | N | 99.50 | 99.97 | 0.48 | St. Francois |
| 14 | KC | MO 291 | S | 14.89 | 15.47 | 0.57 | Jackson |
| 15 | KC | MO 291 | S | 16.86 | 17.12 | 0.27 | Jackson |
| 16 | SE | US 67 | N | 106.81 | 107.22 | 0.41 | St. Francois |
| 17 | SE | US 67 | N | 108.17 | 108.99 | 0.82 | St. Francois |
| 18 | SE | US 67 | N | 109.59 | 111.65 | 2.06 | St. Francois |
| 19 | KC | MO 291 | S | 17.27 | 17.58 | 0.31 | Jackson |
| 20 | SE | MO 25 | S | 47.77 | 48.13 | 0.36 | Stoddard |
| 21 | SE | MO 25 | S | 49.02 | 49.42 | 0.40 | Stoddard |
| 22 | KC | MO 291 | S | 19.77 | 20.21 | 0.44 | Jackson |
| 23 | KC | US 69 | N | 8.38 | 8.65 | 0.27 | Clay |
| 24 | SE | MO 34 | E | 101.25 | 102.04 | 0.79 | Cape Girardeau |
| 25 | SE | MO 34 | E | 102.27 | 102.63 | 0.36 | Cape Girardeau |
| 26 | SE | MO 74 | E | 7.78 | 8.19 | 0.42 | Cape Girardeau |
| 27 | SE | MO 32 | E | 247.21 | 248.02 | 0.81 | St. Francois |
| 28 | SE | MO 232 | E | 248.78 | 249.70 | 0.92 | St. Francois |
| 29 | SE | MO 32 | E | 254.38 | 254.63 | 0.26 | St. Francois |
| 30 | SE | MO 412 | W | 25.95 | 26.35 | 0.40 | Dunklin |
| 31 | SE | US 61 | N | 101.36 | 101.99 | 0.63 | Cape Girardeau |
| 32 | SE | US 60 | E | 290.88 | 291.80 | 0.91 | Stoddard |
| 33 | SE | US 60 | E | 314.49 | 315.88 | 1.39 | New Madrid |
| 34 | SE | US 60 | E | 316.20 | 316.54 | 0.34 | Scott |
| 35 | SE | BU 67 | S | 4.70 | 5.01 | 0.32 | Butler |
| 36 | SL | MO 30 | E | 21.02 | 21.69 | 0.67 | Jefferson |
| 37 | SL | MO 30 | E | 22.26 | 22.62 | 0.36 | Jefferson |

**Table 6.5 Continued**

| Segment ID | District | Description | Primary Direction | Primary Begin Log | Primary End Log | Length | County |
|---|---|---|---|---|---|---|---|
| 38 | SL | MO 30 | E | 22.79 | 23.10 | 0.30 | Jefferson |
| 39 | SL | MO 30 | E | 23.47 | 23.78 | 0.31 | Jefferson |
| 40 | SL | MO 30 | E | 24.62 | 25.33 | 0.71 | Jefferson |
| 41 | SL | MO 30 | E | 25.48 | 26.43 | 0.95 | Jefferson |
| 42 | SL | MO 30 | E | 26.96 | 27.33 | 0.37 | Jefferson |
| 43 | SL | MO 30 | E | 28.03 | 29.26 | 1.23 | Jefferson |
| 44 | SL | MO 30 | E | 30.18 | 30.50 | 0.32 | Jefferson |
| 45 | SL | MO 30 | E | 31.57 | 32.07 | 0.50 | Jefferson |
| 46 | SL | MO 30 | E | 32.33 | 32.87 | 0.54 | Jefferson |
| 47 | SL | MO 30 | E | 33.58 | 34.19 | 0.55 | Jefferson |
| 48 | KC | US 40 | E | 15.48 | 15.85 | 0.37 | Jackson |
| 49 | SL | MO 30 | E | 39.98 | 40.35 | 0.37 | St. Louis |
| 50 | SL | MO 30 | E | 41.11 | 41.37 | 0.29 | St. Louis |
| 51 | SW | MO 13 | S | 147.27 | 147.74 | 0.48 | Henry |
| 52 | SW | RT D | E | 0.18 | 1.27 | 1.08 | Newton |
| 53 | SW | MO 59 | S | 19.66 | 19.93 | 0.28 | Newton |
| 54 | SW | MO 59 | S | 20.07 | 20.70 | 0.63 | Newton |
| 55 | SW | MO 59 | S | 21.45 | 22.25 | 0.80 | Newton |
| 56 | SW | MO 59 | S | 22.37 | 22.77 | 0.40 | Newton |
| 57 | SW | US 60 | E | 75.70 | 76.64 | 0.94 | Greene |
| 58 | SW | US 60 | E | 77.12 | 77.40 | 0.28 | Greene |
| 59 | SL | MO 94 | E | 100.68 | 101.12 | 0.44 | St. Charles |
| 60 | SL | MO 94 | E | 101.32 | 102.02 | 0.70 | St. Charles |
| 61 | SL | MO 141 | S | 29.28 | 29.90 | 0.62 | Jefferson |
| 62 | SL | MO 141 | S | 28.21 | 28.93 | 0.73 | Jefferson |
| 63 | SL | MO 141 | S | 27.52 | 27.96 | 0.44 | Jefferson |
| 64 | SL | MO 141 | S | 26.03 | 26.46 | 0.43 | Jefferson |
| 65 | SL | MO 141 | S | 24.66 | 25.26 | 0.60 | Jefferson |
| 66 | SL | Midland Blvd. | E | 2.93 | 3.40 | 0.47 | St. Louis |

6.4.3 Sampling for Urban Five-Lane Undivided Arterial Segments

The query criteria used to generate the master list of urban five-lane arterial undivided segments are shown in Table 6.6. These criteria were similar to the criteria used for urban two-lane undivided segments, with a few differences. The query did not use the fields BEG_DIVIDED_UNDIVIDED or END_DIVIDED_UNDIVIDED. Instead, the query utilized

the ROADWAY_TYPE_NAME field in the TMS table TMS_SS_PAVEMENT to obtain segments that were classified as 5 LANE SECTION.

**Table 6.6 Query criteria for urban five-lane undivided arterial segments**

| Table | Field | Criteria |
|---|---|---|
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRFRNGINFO_YEAR | 2012 |
| TMS_TRF_INFO_SEGMENT_VW | BEG_DISTRICT_ABBR | Varies |
| TMS_TRF_INFO_SEGMENT_VW | DRVD_TRF_INFO_NAME | AADT |
| TMS_TRF_INFO_SEGMENT_VW | BEG_OVERLAPPING_INDICATOR | P |
| TMS_TRF_INFO_SEGMENT_VW | BEG_URBAN_RURAL_CLASS | URBAN |
| TMS_SS_PAVEMENT | ROADWAY_TYPE_NAME | 5 LANE SECTION |

A master list from a database query was used to generate the samples. In some cases, the limits of the segments were revised after viewing them in ARAN because a portion of the segment was not urban or of the proper site type. For this site type, it was not possible to obtain 10 random samples from each district due to lack of a sufficient number of samples. At-large samples were taken from the entire state in order to obtain as many samples as possible. The sample set for calibration included 59 sites.

A list of samples for urban five-lane undivided arterial segments is shown in Table 6.7. The samples were distributed among the seven MoDOT districts as follows:

- 13 samples from the Central District
- 9 samples from the Kansas City District
- 6 samples from the Northeast District
- 6 samples from the Northwest District
- 10 samples from the Southeast District
- 5 samples from the Saint Louis District
- 10 samples from the Southwest District

The samples were representative of geographic diversity from around the state of Missouri. The sample set included segments from 20 counties in Missouri, including more populous counties such as Greene and less populous counties such as Livingston. US highways and Missouri highways were represented nearly equally.

**Table 6.7 List of sites for urban five-lane undivided arterial segments**

| Segment ID | District | Description | Primary Direction | Primary Begin Log | Primary End Log | County | Length (mi) |
|---|---|---|---|---|---|---|---|
| 1 | CD | US 63 | N | 123.10 | 124.18 | Phelps | 1.08 |
| 2 | CD | MO 72 | E | 0.08 | 0.59 | Phelps | 0.50 |
| 3 | CD | MO 72 | E | 0.59 | 1.75 | Phelps | 1.16 |
| 4 | CD | MO 72 | E | 1.75 | 2.34 | Phelps | 0.59 |
| 5 | CD | MO 5 | S | 248.31 | 249.06 | Laclede | 0.75 |
| 6 | CD | MO 5 | S | 249.06 | 249.54 | Laclede | 0.48 |
| 7 | CD | MO 5 | S | 249.54 | 250.01 | Laclede | 0.47 |
| 8 | CD | MO 5 | S | 250.64 | 250.90 | Laclede | 0.26 |
| 9 | CD | MO 5 | S | 251.01 | 251.51 | Laclede | 0.50 |
| 10 | CD | MO 5 | S | 251.83 | 252.13 | Laclede | 0.31 |
| 11 | CD | LP 44 | E | 0.29 | 1.17 | Laclede | 0.88 |
| 12 | CD | LP 44 | E | 1.17 | 1.88 | Laclede | 0.70 |
| 13 | CD | LP 44 | E | 2.59 | 3.02 | Laclede | 0.42 |
| 14 | KC | US 65 | S | 150.28 | 151.20 | Pettis | 0.92 |
| 15 | KC | US 65 | S | 151.20 | 152.11 | Pettis | 0.91 |
| 16 | KC | US 50 | E | 77.78 | 78.20 | Pettis | 0.42 |
| 17 | KC | US 50 | E | 78.55 | 78.80 | Pettis | 0.25 |
| 18 | KC | US 50 | E | 79.16 | 79.53 | Pettis | 0.38 |
| 19 | KC | US 50 | E | 80.66 | 80.97 | Pettis | 0.31 |
| 20 | KC | US 50 | E | 81.09 | 81.38 | Pettis | 0.29 |
| 21 | KC | US 50 | E | 81.38 | 82.01 | Pettis | 0.63 |
| 22 | KC | MO 58 | E | 6.55 | 7.01 | Cass | 0.47 |
| 23 | NW | US 65 | S | 55.50 | 56.69 | Livingston | 1.18 |
| 24 | NW | US 65 | S | 56.69 | 57.32 | Livingston | 0.63 |
| 25 | NW | US 65 | S | 57.68 | 58.16 | Livingston | 0.48 |
| 26 | NW | US 65 | S | 58.75 | 59.02 | Livingston | 0.28 |
| 27 | NW | US 65 | S | 59.02 | 59.72 | Livingston | 0.70 |
| 28 | NW | US 69 | N | 55.80 | 56.08 | Dekalb | 0.29 |
| 29 | SE | US 63 | N | 30.34 | 30.92 | Howell | 0.58 |
| 30 | SE | US 63 | N | 30.93 | 33.15 | Howell | 2.23 |
| 31 | SE | BU 67 | S | 3.90 | 4.27 | Butler | 0.37 |
| 32 | SE | BU 60 | W | 5.45 | 5.71 | Butler | 0.26 |
| 33 | SE | BU 60 | W | 5.71 | 6.40 | Butler | 0.69 |
| 34 | SE | BU 60 | W | 6.40 | 7.06 | Butler | 0.66 |

**Table 6.7 Continued**

| Segment ID | District | Description | Primary Direction | Primary Begin Log | Primary End Log | County | Length (mi) |
|---|---|---|---|---|---|---|---|
| 35 | SE | MO 32 | E | 254.84 | 255.24 | St. Francois | 0.40 |
| 36 | SE | MO 32 | E | 255.43 | 256.01 | St. Francois | 0.58 |
| 37 | SE | MO 32 | E | 256.01 | 256.26 | St. Francois | 0.25 |
| 38 | SE | MO 32 | E | 256.26 | 256.56 | St. Francois | 0.30 |
| 39 | SL | LP 44 | E | 3.08 | 3.40 | Franklin | 0.33 |
| 40 | SL | US 67 | N | 137.18 | 137.55 | Jefferson | 0.38 |
| 41 | SL | MO 47 | S | 70.65 | 70.97 | Franklin | 0.31 |
| 42 | SL | US 50 | E | 216.15 | 216.90 | Franklin | 0.76 |
| 43 | SL | US 50 | E | 215.67 | 216.15 | Franklin | 0.48 |
| 44 | SW | MO 7 | N | 107.24 | 107.49 | Henry | 0.25 |
| 45 | SW | MO 7 | N | 111.01 | 111.75 | Henry | 0.74 |
| 46 | SW | MO 96 | E | 13.44 | 13.69 | Jasper | 0.25 |
| 47 | SW | US 54 | E | 14.07 | 14.49 | Vernon | 0.42 |
| 48 | SW | MO 376 | W | 0.00 | 1.00 | Taney | 1.00 |
| 49 | SW | MO 86 | W | 91.45 | 92.95 | Newton | 1.50 |
| 50 | SW | MO 248 | E | 53.90 | 55.56 | Taney | 1.66 |
| 51 | SW | BU 65 | S | 3.31 | 3.74 | Taney | 0.44 |
| 52 | SW | US 60 | E | 72.62 | 73.08 | Greene | 0.45 |
| 53 | SW | US 60 | E | 71.98 | 72.45 | Greene | 0.47 |
| 54 | NE | US 61 | S | 60.76 | 61.03 | Marion | 0.27 |
| 55 | NE | US 61 | S | 60.05 | 60.49 | Marion | 0.44 |
| 56 | NE | US 24 | E | 135.46 | 135.80 | Randolph | 0.34 |
| 57 | NE | MO 47 | S | 33.69 | 34.04 | Warren | 0.35 |
| 58 | NE | BU 63 | N | 7.51 | 8.34 | Randolph | 0.83 |
| 59 | NE | US 24 | E | 136.07 | 136.32 | Randolph | 0.25 |

## 6.5 Data Collection

A list of the data types collected for urban arterial segments and their sources is shown in Table 6.8. The number of driveways of each type was counted. The HSM defines major driveways as connecting to 50 or more parking spaces and minor as connecting to fewer than 50 parking spaces. The driveways were classified using the HSM definition by viewing ARAN, Google street view, and aerial photographs. The number of fixed objects and offset for the fixed objects

were estimated visually from street view and aerial images. It should be noted that the HSM defines fixed objects as objects that are four inches or greater in diameter and not breakaway. The type of land use, type of parking, and proportion of curb length with parking were determined separately for each side of the roadway using street view and aerial images. In most cases, the road segments did not contain parking. Because IHSDM requires a value to be set for the type of parking, regardless of the existence of parking, the type of parking was arbitrarily set as parallel if there was no parking on the segment. Using the arbitrary parallel type was inconsequential, since the proportion of curb length with parking was coded with a value of zero for segments with no parking. Speed limit values at the beginning and end of each segment were retrieved from the TMS database and validated through street view images, Street view was also used to determine whether lighting was present on the segment. MoDOT provided information regarding locations with automated speed enforcement.

**Table 6.8 List of data sources for urban arterial segments**

| Data Description | Source |
|---|---|
| AADT | ODBC |
| No. of Major Commercial Driveways | ARAN/Aerials |
| No. of Minor Commercial Driveways | ARAN/Aerials |
| No. of Major Industrial/Institutional Driveways | ARAN/Aerials |
| No. of Minor Industrial/Institutional Driveways | ARAN/Aerials |
| No. of Major Residential Driveways | ARAN/Aerials |
| No. of Minor Residential Driveways | ARAN/Aerials |
| No. of Other Driveways | ARAN/Aerials |
| Type of Parking | ARAN/Aerials |
| Land Use | ARAN/Aerials |
| Proportion of Curb Length with Parking | ARAN/Aerials |
| Speed Category | TMS/Street View |
| Offset to Fixed Objects | Aerial/Street View |
| Fixed Object Density | Aerial/Street View |
| Presence of Lighting | Aerial/Street View |
| Presence of Automated Speed Enforcement | MoDOT |
| Number of Crashes | TMS |

6.5.1 Summary Statistics for Urban Two-Lane Undivided Arterial Segments

Descriptive statistics for urban two-lane undivided arterial segments are shown in Table 6.9. The average AADT was 5,232 vpd, and the standard deviation was 3,685 vpd. Thus, the sample set contained a wide range of AADT values. The average segment length was 0.75 miles, which was greater than the minimum segment length of 0.25 miles. The most common driveway types for the sample set were minor residential driveways, minor industrial/institutional driveways, and minor commercial driveways. The presence of parking on the segments was not common. The

average offset to fixed objects was 20.20 feet, and the average fixed object density was 48.635 fixed objects per mile. The standard deviation of the fixed object density was 20.18 fixed objects per mile, indicating the segments had a wide variation in fixed object density. A total of 50 sites out of the 75 segments had lighting. None of the segments had automated speed enforcement. Only 14 of the segments fell under the low speed category. The average number of crashes was 4.87. The standard deviation for the number of crashes was 6.85, indicating that the number of crashes on these segments varied considerably. The total number of crashes on these segments, from 2012 to 2014, was 349 (116.33 per year), which was more than the value of 100 crashes per year recommended by the HSM.

**Table 6.9 Sample descriptive statistics for urban two-lane undivided arterial segments**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| AADT (2012-2014) | 5,232 | 450 | 15,762 | 3,685 |
| Length | 0.75 | 0.25 | 2.04 | 0.34 |
| No. of Major Commercial Driveways | 0.05 | 0.00 | 2.00 | 0.28 |
| No. of Minor Commercial Driveways | 2.51 | 0.00 | 31.00 | 5.36 |
| No. of Major Industrial/Institutional Driveways | 1.00 | 0.00 | 10.00 | 1.98 |
| No. of Minor Industrial/Institutional Driveways | 7.28 | 0.00 | 30.00 | 8.10 |
| No. of Major Residential Driveways | 0.28 | 0.00 | 9.00 | 1.20 |
| No. of Minor Residential Driveways | 9.93 | 0.00 | 48.00 | 9.48 |
| Proportion of Right Curb Length with Parking | 0.00 | 0.00 | 0.08 | 0.01 |
| Offset to Fixed Objects (ft) | 20.20 | 5.00 | 30.00 | 7.71 |
| Fixed Object Density (per mi) | 48.64 | 13.10 | 98.40 | 20.18 |
| No. of Observed Crashes | 4.87 | 0.00 | 40.00 | 6.85 |

| Description | No. of Segments |
|---|---|
| All Samples | 75 |
| Speed Category = Low | 14 |
| Speed Category = Intermediate/High | 61 |
| Presence of Street Lighting | 50 |
| Presence of Automated Speed Enforcement | 0 |

6.5.2 Summary Statistics for Urban Four-Lane Divided Arterial Segments

Descriptive statistics for urban four-lane divided arterial segments are shown in Table 6.10. The average AADT was 19,880 vpd, meaning the average urban four-lane AADT was around two-and-a-half times that of the urban two-lane. The standard deviation was 11,230 vpd. Thus, the sample set contained a wide range of AADT values. The average segment length was 0.57 miles. The segments in the sample set did not contain many driveways. Minor commercial driveways were the most common driveway type for the sample set. None of the segments had parking or automated speed enforcement. The average offset to fixed objects was 55.5 feet, and the average fixed object density was 23.1 fixed objects per mile. The four-lane offset was approximately 2.6 times longer than that of the two-lane, but the density was only 37% of the two-lane. The

standard deviation of the fixed object density was 18.5 fixed objects per mile, indicating the segments displayed a wide variability in fixed object density. Like two-lane segments, residential land use was slightly more predominant than commercial land use. Lighting was present on 12 of the segments. None of the segments fell under the low speed category. The average number of crashes was 6.3. The standard deviation for the number of crashes was 6.9, indicating that the number of crashes on these segments varied considerably. The total number of crashes on these segments from 2012 to 2014 was 567 (189 per year), which was greater than the 100 crashes per year recommended by the HSM.

**Table 6.10 Sample descriptive statistics for urban four-lane divided arterial segments**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| AADT (2014) | 19,880 | 5,418 | 51,640 | 11,230 |
| Length | 0.57 | 0.26 | 2.06 | 0.31 |
| No. of Major Commercial Driveways | 0.3 | 0.0 | 11.0 | 1.4 |
| No. of Minor Commercial Driveways | 0.4 | 0.0 | 4.0 | 0.9 |
| No. of Major Industrial/Institutional Driveways | 0.3 | 0.0 | 4.0 | 0.8 |
| No. of Minor Industrial/Institutional Driveways | 0.3 | 0.0 | 8.0 | 1.1 |
| No. of Major Residential Driveways | 0.1 | 0.0 | 1.0 | 0.3 |
| No. of Minor Residential Driveways | 1.3 | 0.0 | 36.0 | 4.7 |
| No. of Other Driveways | 0.2 | 0.0 | 3.0 | 0.6 |
| Proportion of Right Curb Length with Parking | 0.00 | 0.00 | 0.00 | 0.00 |
| Proportion of Left Curb Length with Parking | 0.00 | 0.00 | 0.00 | 0.00 |
| Offset to Fixed Objects (ft) | 55.5 | 0.0 | 120 | 29.6 |
| Fixed Object Density (per mi) | 23.1 | 0.0 | 76.1 | 18.5 |
| Number of Crashes | 6.3 | 0.0 | 35.0 | 6.9 |

| Description | No. of Segments |
|---|---|
| All Samples | 66 |
| Speed Category = Low | 0 |
| Parking Type (Right) = Parallel | 1 |
| Parking Type (Left) = Parallel | 0 |
| Land Use (Right) = Residential | 1 |
| Land Use (Left) = Residential | 0 |
| Presence of Lighting | 7 |
| Presence of Automated Speed Enforcement | 0 |

### 6.5.3. Summary Statistics for Urban Five-Lane Undivided Arterial Segments

Descriptive statistics for urban five-lane undivided arterial segments are shown in Table 6.11. The AADT data contained an average of 15,613 vpd, minimum of 3,622 vpd, maximum of 32,058, and standard deviation of 5,823 vpd. Thus, the sample set AADT values were slightly skewed towards the higher values. The average segment length was 0.58 miles, and all segments met the minimum segment length criteria of 0.25 miles. The most common driveway types for the sample set were minor commercial driveways and minor residential driveways. None of the sites contained any curbside parking facilities. The average fixed object density was 38.94 fixed objects per mile at an average offset of 20.04 feet. The standard deviation of the fixed object density was 24.96 fixed objects per mile, indicating the presence of fixed objects varied widely across the samples. A total of 53 sites out of the 59 segments contained street lighting. None of the segments had automated speed enforcement. Only one of the segments was classified in the low speed category. The average number of crashes was 12.22 with a standard deviation of 16.66, indicating that the number of crashes on these segments varied considerably. The total number of crashes across all segments from 2012 to 2014 was 721 (240.33 per year), which was more than the value of 100 crashes per year recommended by the HSM methodology.

**Table 6.11 Sample descriptive statistics for urban five-lane undivided arterial segments**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| AADT (2012-2014) | 15,613 | 3,622 | 32,058 | 5,823 |
| Segment Length | 0.58 | 0.25 | 2.23 | 0.38 |
| No. of Major Commercial Driveways | 1.80 | 0 | 10 | 2.31 |
| No. of Minor Commercial Driveways | 11.81 | 0 | 42 | 10.00 |
| No. of Major Industrial/Institutional Driveways | 0.69 | 0 | 10 | 1.58 |
| No. of Minor Industrial/Institutional Driveways | 1.24 | 0 | 7 | 1.73 |
| No. of Major Residential Driveways | 0.17 | 0 | 4 | 0.62 |
| No. of Minor Residential Driveways | 3.29 | 0 | 33 | 6.25 |
| Proportion of Right Curb Length with Parking | 0.00 | 0 | 0 | 0.00 |
| Proportion of Left Curb Length with Parking | 0.00 | 0 | 0 | 0.00 |
| Offset to Fixed Objects (ft) | 20.04 | 0 | 43.86 | 8.37 |
| Fixed Object Density (per mi) | 38.94 | 0 | 151.39 | 24.96 |
| No. of Observed Crashes | 12.22 | 0 | 88 | 16.66 |

| Description | No. of Segments |
|---|---|
| All Samples | 59 |
| Speed Category = Low | 1 |
| Speed Category = Intermediate/High | 58 |
| Presence of Street Lighting | 53 |
| Presence of Automated Speed Enforcement | 0 |

## 6.6 Results and Discussion

The original HSM models were developed using data from Minnesota, Michigan, and Washington. The data from Minnesota and Michigan were used to develop the HSM methodology, while the data from Washington were used in validating the methodology (Harwood et al. 2007). The database used for urban and suburban segment model development was divided into individual blocks, where each block began and ended at a public intersection of the arterial segment being studied. The database included 4,255 blocks: 2,436 in Minnesota and 1,819 in Michigan. Blocks ranged in length from 0.04 to 1.42 mi. The total length of all blocks was 553.3 mi: 303.9 mi from Minnesota with an average block length of 0.12 mi, and 294.4 mi from Michigan with an average block length of 0.14 mi. Most of the data collected from Minnesota were located in the Twin Cities metropolitan area, while the data collected in Michigan were primarily from Oakland County, Michigan. Even though these states were located in the northern part of the country, data were collected at a variety of sites to develop a database that should reflect national design and behavior.

6.6.1 Results for Urban Two-Lane Undivided Arterial Segments

6.6.1.1 Calibration Factor

The calibration factor for urban two-lane undivided arterial segments in Missouri yielded a value of 1.48. The IHSDM output is shown in Figure 6.13, and the summary of crash prediction versus observation by sites is presented in Table 6.12. These results indicate that the number of crashes observed in Missouri was higher than the number of crashes predicted by the HSM for this site type. The result of the recalibration in this project is different from the previous calibration performed for the period of 2009-2012. The previous calibration factor was 0.84. The main differences were identified in the crash data processing, fixed objects count, and AADTs. The previous calibration removed all crashes that had intersection identification. Some major driveways have intersection identification numbers (not minor road stop or signalized intersections), so these driveway-related crashes were removed in the previous calibration reducing the number of observed crashes. In the previous calibration, fixed objects were counted using the ARAN viewer, which was not ideal since image frames are skipped on a regular basis, and many sections are not visualized. This issue was solved using Google street view along the segments for the recalibration. In addition, light posts along segments were predominantly without breakaway since lighting was installed on wood posts. Another difference in data collection was the AADTs. The AADTs were previously collected from the state of the system and resulted in higher AADTs (on average 400 vpd). For the recalibration, the AADTs were collected through ODBC using TMS intersections node numbers along the segments. Thus, the AADT values were improved from the previous calibration.

**Figure 6.13 Calibration output for urban two-lane undivided arterial segments**

**Table 6.12 Calibration results for urban two-lane undivided arterial segments**

| No. | District | Segment | Begin Log | Length (mi) | All Crashes | |
|---|---|---|---|---|---|---|
| | | | | | Observed | Predicted |
| 1 | CD | RT F E | 7.58 | 1.45 | 11 | 5 |
| 2 | CD | RT O E | 0.25 | 0.68 | 5 | 5 |
| 3 | CD | US 40 E | 105.74 | 0.40 | 1 | 4 |
| 4 | CD | MO 87 S | 22.69 | 0.59 | 2 | 2 |
| 5 | CD | MO 17 N | 136.31 | 0.55 | 24 | 4 |
| 6 | CD | MO 5 N | 210.76 | 0.85 | 1 | 2 |
| 7 | CD | RT B N | 23.39 | 0.71 | 4 | 4 |
| 8 | CD | RT J E | 1.03 | 0.74 | 0 | 3 |
| 9 | CD | RT HH S | 0.00 | 0.45 | 3 | 0 |
| 10 | CD | BU 54 E | 4.48 | 0.38 | 12 | 2 |
| 11 | CD | MO 87 S | 75.57 | 0.40 | 2 | 2 |
| 12 | KC | US 50 E | 83.46 | 1.05 | 10 | 7 |
| 13 | KC | MO 240 | 0.65 | 0.81 | 0 | 2 |
| 14 | KC | US 65 N | 194.14 | 0.64 | 2 | 2 |
| 15 | KC | RT WW E | 0.70 | 0.95 | 0 | 0 |
| 16 | KC | RT WW W | 2.78 | 0.61 | 0 | 1 |
| 17 | KC | BU 65 S | 2.27 | 0.25 | 0 | 3 |
| 18 | KC | SP 10 E | 0.07 | 0.53 | 0 | 1 |
| 19 | KC | RT F S | 2.07 | 0.42 | 4 | 2 |
| 20 | KC | RT N S | 0.54 | 0.56 | 0 | 0 |
| 21 | KC | RT F S | 0.99 | 1.08 | 25 | 14 |
| 22 | KC | US 50 E | 82.50 | 0.83 | 10 | 6 |
| 23 | NE | MO 15 N | 2.38 | 0.37 | 4 | 3 |
| 24 | NE | MO 15 N | 2.87 | 0.35 | 6 | 4 |
| 25 | NE | MO 22 E | 22.96 | 0.90 | 4 | 3 |
| 26 | NE | MO 161 | 0.46 | 0.61 | 9 | 4 |
| 27 | NE | RT M W | 23.71 | 1.02 | 6 | 3 |
| 28 | NE | BU 61 S | 1.96 | 0.50 | 2 | 2 |
| 29 | NE | RT J S | 0.63 | 0.80 | 7 | 2 |
| 30 | NE | BU 63 N | 5.29 | 1.01 | 12 | 5 |
| 31 | NE | RT P E | 0.24 | 0.43 | 0 | 1 |
| 32 | NE | RT B S | 11.69 | 0.89 | 0 | 1 |
| 33 | NW | BU 36 W | 0.59 | 0.81 | 3 | 2 |
| 34 | NW | RT V N | 0.59 | 0.40 | 0 | 0 |
| 35 | NW | MO 6 E | 79.82 | 0.64 | 1 | 1 |
| 36 | NW | BU 71 N | 3.23 | 1.18 | 4 | 2 |
| 37 | NW | US 69 S | 67.65 | 0.34 | 0 | 1 |
| 38 | NW | MO 46 E | 27.11 | 0.34 | 0 | 2 |
| 39 | NW | RT AA N | 0.00 | 0.57 | 1 | 1 |

**Table 6.12 Continued**

| No. | District | Segment | Begin Log | Length (mi) | All Crashes | |
|---|---|---|---|---|---|---|
| | | | | | Observed | Predicted |
| 40 | NW | RT A N | 15.78 | 0.51 | 0 | 1 |
| 41 | NW | RT V E | 11.75 | 0.43 | 0 | 1 |
| 42 | SE | RT W S | 5.89 | 1.30 | 7 | 2 |
| 43 | SE | RT W S | 7.68 | 0.79 | 3 | 1 |
| 44 | SE | RT W S | 8.97 | 0.59 | 2 | 2 |
| 45 | SE | RT B S | 0.08 | 0.37 | 3 | 3 |
| 46 | SE | US 62 E | 62.72 | 0.52 | 1 | 2 |
| 47 | SE | RT PP S | 0.06 | 0.97 | 4 | 2 |
| 48 | SE | MO 8 E | 70.74 | 0.42 | 0 | 5 |
| 49 | SE | MO 51 S | 15.20 | 0.34 | 1 | 3 |
| 50 | SE | RT J E | 10.94 | 0.48 | 0 | 1 |
| 51 | SE | RT AB W | 4.08 | 1.65 | 10 | 2 |
| 52 | SE | MO 114 | 0.28 | 0.50 | 0 | 1 |
| 53 | SE | RT E E | 0.16 | 2.04 | 5 | 8 |
| 54 | SL | RT E N | 14.83 | 1.09 | 5 | 4 |
| 55 | SL | MO 47 N | 49.14 | 0.69 | 12 | 6 |
| 56 | SL | MO 185 | 37.12 | 0.59 | 4 | 1 |
| 57 | SL | MO 185 | 30.24 | 0.61 | 2 | 2 |
| 58 | SL | RT NN N | 0.07 | 1.06 | 5 | 1 |
| 59 | SL | MO 47 S | 65.02 | 1.64 | 40 | 21 |
| 60 | SL | MO 47 N | 47.14 | 0.44 | 13 | 5 |
| 61 | SL | RT D S | 0.64 | 0.68 | 0 | 1 |
| 62 | SL | RT D S | 1.42 | 1.00 | 1 | 0 |
| 63 | SW | RT BB S | 0.03 | 1.34 | 19 | 3 |
| 64 | SW | BU 65 N | 1.30 | 0.55 | 5 | 7 |
| 65 | SW | BU 65 N | 2.02 | 0.34 | 2 | 3 |
| 66 | SW | BU 60 E | 6.51 | 0.73 | 2 | 3 |
| 67 | SW | US 160 | 177.11 | 0.83 | 13 | 16 |
| 68 | SW | US 160 | 178.19 | 0.89 | 17 | 11 |
| 69 | SW | BU 60 E | 4.80 | 0.86 | 1 | 2 |
| 70 | SW | RT CC S | 16.61 | 0.88 | 1 | 2 |
| 71 | SW | RT CC N | 0.11 | 0.63 | 2 | 2 |
| 72 | SW | BU 13 S | 0.12 | 0.98 | 5 | 7 |
| 73 | SW | RT BB S | 0.08 | 0.82 | 2 | 2 |
| 74 | SW | RT BB S | 0.95 | 0.60 | 0 | 1 |
| 75 | SW | MO 96 E | 14.92 | 0.88 | 3 | 3 |
| **Sum** | | | | | **365** | **247** |
| **Calibration Factor** | | | | | **1.478** | |

6.6.1.2 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 6.13 shows the SDFs for urban two-lane undivided segments.

**Table 6.13 Severity distribution factors urban two-lane undivided arterial segments**

| Severity | MV | | SV | |
|---|---|---|---|---|
| | Crashes | SDF | Crashes | SDF |
| Fatal | 3 | 0.023 | 1 | 0.008 |
| Disabling Injury | 3 | 0.023 | 2 | 0.015 |
| Minor Injury | 34 | 0.258 | 53 | 0.402 |
| Property Damage Only | 92 | 0.697 | 178 | 1.348 |

6.6.1.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of predicted crashes according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since Missouri crash types categories differed from the HSM. Therefore, different categories were aggregated to provide similar classifications than those recommended by the HSM. The crash types were estimated for all severities only. Table 6.14 provides the CDFs for two-lane undivided arterials based on the classification of crash types in Missouri.

**Table 6.14 Crash type distribution factors for urban two-lane undivided arterial segments**

| Multiple-Vehicle | | |
|---|---|---|
| Collision Type | Crashes | CDF |
| Rear-end | 147 | 0.665 |
| Head-on | 9 | 0.041 |
| Angle | 45 | 0.204 |
| Sideswipe | 13 | 0.059 |
| Other | 7 | 0.032 |
| Single-Vehicle | | |
| Collision Type | Crashes | CDF |
| Collision with Animal | 34 | 0.248 |
| Collision with Fixed Object | 5 | 0.036 |
| Collision with Parked Vehicle | 5 | 0.036 |
| Out of Control | 83 | 0.606 |
| Other | 10 | 0.073 |

## 6.6.2 Results for Urban Four-Lane Divided Arterial Segments

### 6.6.2.1 Calibration Factor

The calibration factor for urban four-lane divided arterial segments in Missouri yielded a calibration factor value of 0.91. The IHSDM output is shown in Figure 6.14, and the summary of crash prediction versus observation by sites is presented in Table 6.15. These results indicate that the number of crashes observed in Missouri was fairly consistent with the number of crashes predicted by the HSM for this site type.
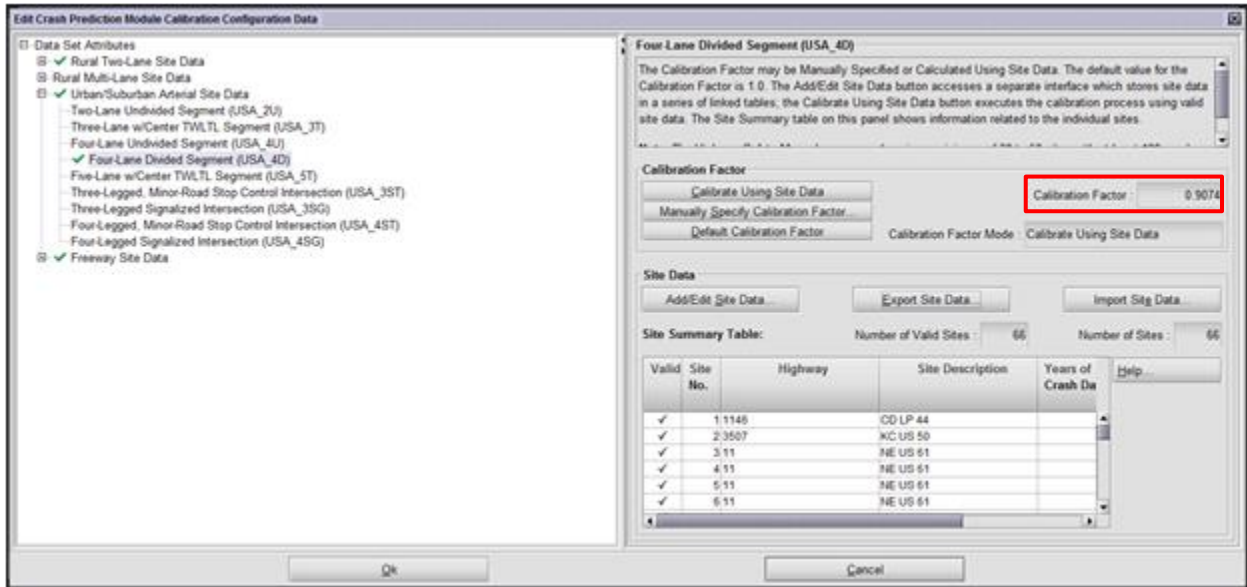


**Figure 6.14 Calibration output for urban four-lane divided arterial segments**

**Table 6.15 Calibration results for urban four-lane divided arterial segments**

| No. | District | Segment | Begin Log | Length (mi) | All Crashes | |
|---|---|---|---|---|---|---|
| | | | | | Observed | Predicted |
| 1 | CD | LP 44 E | 7.621 | 0.301 | 15 | 4.18 |
| 2 | KC | US 50 E | 61.261 | 0.442 | 2 | 2.68 |
| 3 | KC | MO 291 S | 14.894 | 0.573 | 4 | 5.07 |
| 4 | KC | MO 291 S | 16.855 | 0.268 | 3 | 6.58 |
| 5 | KC | MO 291 S | 17.27 | 0.309 | 1 | 7.03 |
| 6 | KC | MO 291 S | 19.769 | 0.44 | 22 | 18.15 |
| 7 | KC | US 69 N | 8.379 | 0.267 | 0 | 1.34 |
| 8 | KC | US 40 E | 15.48 | 0.365 | 5 | 4.6 |
| 9 | NE | US 61 S | 63.954 | 0.664 | 6 | 6.84 |
| 10 | NE | US 61 S | 88.81 | 0.38 | 1 | 2.04 |
| 11 | NE | US 61 S | 120.253 | 0.49 | 1 | 5.03 |
| 12 | NE | US 61 S | 123.471 | 0.591 | 8 | 12.21 |
| 13 | NE | US 63 N | 252.775 | 0.575 | 3 | 3.81 |
| 14 | NE | US 63 N | 250.748 | 0.733 | 6 | 5.18 |
| 15 | NE | US 36 E | 131.644 | 0.873 | 6 | 3.04 |
| 16 | NW | US 36 E | 71.99 | 0.42 | 0 | 2.09 |
| 17 | NW | US 36 E | 73.31 | 0.495 | 6 | 2.07 |
| 18 | SE | US 61 S | 285.517 | 0.484 | 13 | 4.76 |
| 19 | SE | US 67 N | 99.496 | 0.475 | 2 | 2.87 |
| 20 | SE | US 67 N | 106.811 | 0.407 | 13 | 5.22 |
| 21 | SE | US 67 N | 108.169 | 0.82 | 9 | 11.33 |
| 22 | SE | US 67 N | 109.589 | 2.061 | 35 | 26.98 |
| 23 | SE | MO 25 S | 47.771 | 0.359 | 1 | 1.3 |
| 24 | SE | MO 25 S | 49.02 | 0.404 | 7 | 2.19 |
| 25 | SE | MO 34 E | 101.253 | 0.789 | 3 | 9.75 |
| 26 | SE | MO 34 E | 102.271 | 0.361 | 3 | 3.62 |
| 27 | SE | MO 74 E | 7.777 | 0.417 | 2 | 2.25 |
| 28 | SE | MO 32 E | 247.211 | 0.812 | 1 | 2.26 |
| 29 | SE | MO 232 E | 248.783 | 0.92 | 2 | 4.63 |
| 30 | SE | MO 32 E | 254.376 | 0.256 | 9 | 3.43 |
| 31 | SE | MO 412 W | 25.952 | 0.4 | 2 | 2.09 |
| 32 | SE | US 61 N | 101.358 | 0.631 | 4 | 4 |
| 33 | SE | US 60 E | 290.883 | 0.913 | 2 | 4.85 |
| 34 | SE | US 60 E | 314.489 | 1.391 | 5 | 9.34 |
| 35 | SE | US 60 E | 316.203 | 0.335 | 1 | 1.43 |
| 36 | SE | BU 67 S | 4.698 | 0.316 | 5 | 2.27 |
| 37 | SL | MO 30 E | 21.023 | 0.665 | 1 | 4.25 |

**Table 6.15 Continued**

| No. | District | Segment | Begin Log | Length (mi) | All Crashes | |
|-----|----------|---------|-----------|-------------|-------------|-------------|
| | | | | | Observed | Predicted |
| 38 | SL | MO 30 E | 22.262 | 0.355 | 4 | 3.81 |
| 39 | SL | MO 30 E | 22.792 | 0.303 | 1 | 3.25 |
| 40 | SL | MO 30 E | 23.472 | 0.311 | 5 | 3.25 |
| 41 | SL | MO 30 E | 24.618 | 0.709 | 0 | 7.35 |
| 42 | SL | MO 30 E | 25.481 | 0.953 | 6 | 10 |
| 43 | SL | MO 30 E | 26.957 | 0.373 | 4 | 3.76 |
| 44 | SL | MO 30 E | 28.029 | 1.23 | 3 | 18.36 |
| 45 | SL | MO 30 E | 30.177 | 0.322 | 1 | 4.56 |
| 46 | SL | MO 30 E | 31.566 | 0.5 | 6 | 14.02 |
| 47 | SL | MO 30 E | 32.333 | 0.536 | 11 | 13.28 |
| 48 | SL | MO 30 E | 33.583 | 0.545 | 9 | 13.5 |
| 49 | SL | MO 30 E | 39.982 | 0.367 | 13 | 12.86 |
| 50 | SL | MO 30 E | 41.108 | 0.258 | 3 | 4.52 |
| 51 | SL | MO 94 E | 100.682 | 0.439 | 13 | 12.76 |
| 52 | SL | MO 94 E | 101.316 | 0.702 | 33 | 21.44 |
| 53 | SL | MO 141 S | 29.281 | 0.619 | 7 | 12.81 |
| 54 | SL | MO 141 S | 28.206 | 0.728 | 13 | 14.01 |
| 55 | SL | MO 141 S | 27.515 | 0.441 | 9 | 9.31 |
| 56 | SL | MO 141 S | 26.025 | 0.432 | 13 | 9.57 |
| 57 | SL | MO 141 S | 24.662 | 0.598 | 11 | 13.06 |
| 58 | SL | CST MIDLAND BLVD E | 2.931 | 0.473 | 1 | 2.95 |
| 59 | SW | MO 13 S | 147.266 | 0.478 | 1 | 3.17 |
| 60 | SW | RT D E | 0.183 | 1.082 | 4 | 2.96 |
| 61 | SW | MO 59 S | 19.655 | 0.276 | 3 | 1.28 |
| 62 | SW | MO 59 S | 20.067 | 0.633 | 0 | 4.08 |
| 63 | SW | MO 59 S | 21.45 | 0.8 | 2 | 3.64 |
| 64 | SW | MO 59 S | 22.37 | 0.397 | 1 | 1.78 |
| 65 | SW | US 60 E | 75.702 | 0.937 | 15 | 13.01 |
| 66 | SW | US 60 E | 77.122 | 0.277 | 2 | 4.99 |
| Sum | | | | | 403 | 444.1 |
| Calibration Factor | | | | | 0.907453276 | |

6.6.2.2 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 6.16 shows the obtained SDFs for urban four-lane divided segments.

**Table 6.16 Severity distribution factors for urban four-lane divided segments**

| | MV | | SV | |
|---|---|---|---|---|
| **Severity** | **Crashes** | **SDF** | **Crashes** | **SDF** |
| Fatal | 0 | 0 | 7 | 0.042 |
| Disabling Injury | 9 | 0.038 | 6 | 0.036 |
| Minor Injury | 65 | 0.273 | 36 | 0.218 |
| Property Damage Only | 164 | 0.689 | 116 | 0.703 |

6.6.2.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of crashes from the prediction according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since there are multiple crash type categories. Therefore, different categories were aggregated to provide similar classifications than those recommended by the HSM. The crash types were also divided by multiple and single vehicle crashes. Table 6.17 shows the CDFs for urban four-lane divided segments.

**Table 6.17 Crash type distribution factors for urban four-lane divided segments**

| Multiple-Vehicle | | |
|---|---|---|
| **Collision Type** | **Crashes** | **CDF** |
| Rear-end | 161 | 0.399 |
| Head-on | 2 | 0.005 |
| Angle | 12 | 0.029 |
| Sideswipe | 43 | 0.107 |
| Other | 16 | 0.039 |
| **Single-Vehicle** | | |
| **Collision Type** | **Crashes** | **CDF** |
| Collision with Animal | 47 | 0.117 |
| Collision with Fixed Object | 3 | 0.007 |
| Collision with Parked Vehicle | 4 | 0.009 |
| Out of Control | 85 | 0.211 |
| Other | 30 | 0.074 |

6.6.3 Results for Urban Five-Lane Undivided Arterial Segments

6.6.3.1 Calibration Factor

The calibration factor for urban five-lane undivided arterial segments in Missouri yielded a value of 0.84. The IHSDM output is shown in Figure 6.15, and the summary of crash prediction versus observation by site is presented in Table 6.18. These results indicate that the number of crashes

observed in Missouri was lower than the number of crashes predicted by the HSM for this facility type. The result of the recalibration in this project is different from the previous calibration performed for the period of 2009-2012. The previous calibration factor was 0.73. The main differences were identified in the crash data processing, fixed object offset and density, and segment AADTs. The previous calibration removed all crashes that had intersection identification. TMS designates some larger driveways with intersection node identification numbers (some that are stop-controlled and others that are signalized). All intersection crashes were removed in the previous calibration reducing the number of observed crashes. The intersection nodes in each segment were analyzed, and crashes that were assigned to driveways were included in this calibration effort. In the previous calibration, fixed objects were counted using ARAN viewer, which may not have provided an accurate representation since the viewer can skip several frames along the segment. This issue was solved using Google street view along each segment for the recalibration. Another difference in data collection was the AADTs. The AADTs were collected from the current state of the system feature using TMS and resulted in higher AADTs (286 vpd on average). For the recalibration, the AADTs were collected through ODBC using TMS intersections node numbers along the segments. Thus, the AADTs were more accurate than before.
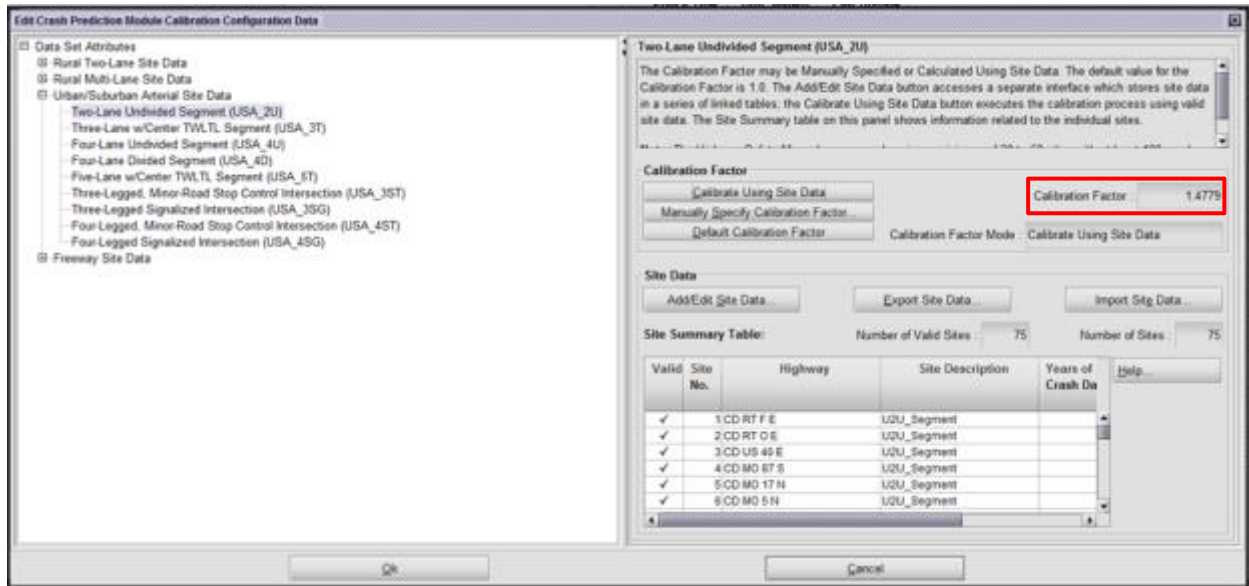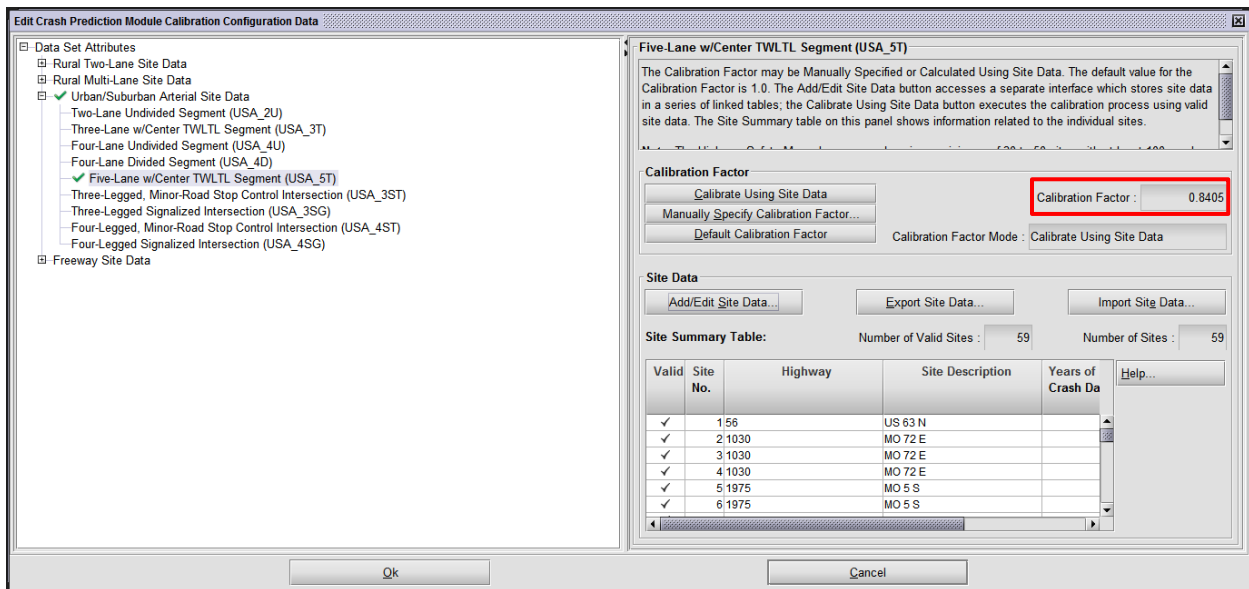


**Figure 6.15 Calibration output for urban five-lane undivided arterial segments**

**Table 6.18 Calibration results for five-lane undivided arterial segments**

| No. | District | Segment | Begin Log | Length (mi) | All Crashes Observed | All Crashes Predicted |
|-----|----------|---------|-----------|-------------|----------------------|----------------------|
| 1 | CD | US 63 N | 123.10 | 1.08 | 33 | 40 |
| 2 | CD | MO 72 E | 0.08 | 0.50 | 4 | 11 |
| 3 | CD | MO 72 E | 0.59 | 1.16 | 15 | 24 |
| 4 | CD | MO 72 E | 1.75 | 0.59 | 1 | 6 |
| 5 | CD | MO 5 S | 248.31 | 0.75 | 8 | 14 |
| 6 | CD | MO 5 S | 249.06 | 0.48 | 2 | 7 |
| 7 | CD | MO 5 S | 249.54 | 0.47 | 4 | 10 |
| 8 | CD | MO 5 S | 250.64 | 0.26 | 5 | 9 |
| 9 | CD | MO 5 S | 251.01 | 0.50 | 34 | 29 |
| 10 | CD | MO 5 S | 251.83 | 0.31 | 5 | 10 |
| 11 | CD | LP 44 E | 0.29 | 0.88 | 4 | 14 |
| 12 | CD | LP 44 E | 1.17 | 0.70 | 2 | 12 |
| 13 | CD | LP 44 E | 2.59 | 0.42 | 0 | 6 |
| 14 | KC | US 65 S | 150.28 | 0.92 | 48 | 30 |
| 15 | KC | US 65 S | 151.20 | 0.91 | 29 | 30 |
| 16 | KC | US 50 E | 77.78 | 0.42 | 41 | 10 |
| 17 | KC | US 50 E | 78.55 | 0.25 | 16 | 15 |
| 18 | KC | US 50 E | 79.16 | 0.38 | 0 | 10 |
| 19 | KC | US 50 E | 80.66 | 0.31 | 1 | 8 |
| 20 | KC | US 50 E | 81.09 | 0.29 | 1 | 6 |
| 21 | KC | US 50 E | 81.38 | 0.63 | 0 | 11 |
| 22 | KC | MO 58 E | 6.55 | 0.47 | 2 | 8 |
| 23 | NW | US 65 S | 55.50 | 1.18 | 3 | 6 |
| 24 | NW | US 65 S | 56.69 | 0.63 | 3 | 9 |
| 25 | NW | US 65 S | 57.68 | 0.48 | 5 | 10 |
| 26 | NW | US 65 S | 58.75 | 0.28 | 0 | 9 |
| 27 | NW | US 65 S | 59.02 | 0.70 | 9 | 25 |
| 28 | NW | US 69 N | 55.80 | 0.29 | 1 | 7 |
| 29 | SE | US 63 N | 30.34 | 0.58 | 2 | 11 |
| 30 | SE | US 63 N | 30.93 | 2.23 | 6 | 49 |
| 31 | SE | BU 67 S | 3.90 | 0.37 | 13 | 15 |
| 32 | SE | BU 60 W | 5.45 | 0.26 | 39 | 13 |
| 33 | SE | BU 60 W | 5.71 | 0.69 | 88 | 20 |
| 34 | SE | BU 60 W | 6.40 | 0.66 | 31 | 23 |

**Table 6.18 Continued**

| No. | District | Segment | Begin Log | Length (mi) | All Crashes Observed | All Crashes Predicted |
|---|---|---|---|---|---|---|
| 35 | SE | MO 32 E | 254.84 | 0.40 | 8 | 18 |
| 36 | SE | MO 32 E | 255.43 | 0.58 | 5 | 16 |
| 37 | SE | MO 32 E | 256.01 | 0.25 | 1 | 5 |
| 38 | SE | MO 32 E | 256.26 | 0.30 | 4 | 6 |
| 39 | SL | LP 44 E | 3.08 | 0.33 | 4 | 6 |
| 40 | SL | US 67 N | 137.18 | 0.38 | 7 | 13 |
| 41 | SL | MO 47 S | 70.65 | 0.31 | 7 | 5 |
| 42 | SL | US 50 E | 216.15 | 0.76 | 7 | 23 |
| 43 | SL | US 50 E | 215.67 | 0.48 | 8 | 15 |
| 44 | SW | MO 7 N | 107.24 | 0.25 | 28 | 6 |
| 45 | SW | MO 7 N | 111.01 | 0.74 | 3 | 12 |
| 46 | SW | MO 96 E | 13.44 | 0.25 | 4 | 7 |
| 47 | SW | US 54 E | 14.07 | 0.42 | 6 | 9 |
| 48 | SW | MO 376 W | 0.00 | 1.00 | 11 | 7 |
| 49 | SW | MO 86 W | 91.45 | 1.50 | 13 | 26 |
| 50 | SW | MO 248 E | 53.90 | 1.66 | 59 | 49 |
| 51 | SW | BU 65 S | 3.31 | 0.44 | 3 | 5 |
| 52 | SW | US 60 E | 72.62 | 0.45 | 6 | 18 |
| 53 | SW | US 60 E | 71.98 | 0.47 | 3 | 17 |
| 54 | NE | US 61 S | 60.76 | 0.27 | 24 | 13 |
| 55 | NE | US 61 S | 60.05 | 0.44 | 25 | 18 |
| 56 | NE | US 24 E | 135.46 | 0.34 | 19 | 8 |
| 57 | NE | MO 47 S | 33.69 | 0.35 | 2 | 11 |
| 58 | NE | BU 63 N | 7.51 | 0.83 | 3 | 26 |
| 59 | NE | US 24 E | 136.07 | 0.25 | 6 | 5 |
| **Sum** | | | | | **721** | **858** |
| **Calibration Factor** | | | | | **0.841** | |

6.6.3.2 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 6.19 shows the obtained SDFs for urban five-lane undivided arterial segments.

**Table 6.19 Severity distribution factors urban five-lane undivided arterial segments**

| Severity | MV | | SV | |
|---|---|---|---|---|
| | **Crashes** | **SDF** | **Crashes** | **SDF** |
| Fatal | 1 | 0.002 | 1 | 0.016 |
| Disabling Injury | 9 | 0.014 | 2 | 0.031 |
| Minor Injury | 177 | 0.269 | 20 | 0.313 |
| Property Damage Only | 470 | 0.715 | 41 | 0.641 |

6.6.3.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of predicted crashes according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since there are multiple crash type categories. Therefore, different categories were aggregated to provide similar classifications than those recommended by the HSM. The crash types were estimated for total crashes in correspondence to the calibration factor severity. Table 6.20 provides the CDFs for five-lane undivided arterials based on the classification of crash types in Missouri.

**Table 6.20 Crash type distribution factors for urban five-lane undivided arterial segments**

| Multiple-Vehicle | | |
|---|---|---|
| **Collision Type** | **Crashes** | **CDF** |
| Rear-end | 257 | 0.394 |
| Head-on | 20 | 0.031 |
| Angle | 252 | 0.386 |
| Sideswipe | 102 | 0.156 |
| Other | 22 | 0.034 |
| **Single-Vehicle** | | |
| **Collision Type** | **Crashes** | **CDF** |
| Collision with Animal | 9 | 0.132 |
| Collision with Fixed Object | 4 | 0.059 |
| Collision with Parked Vehicle | 4 | 0.059 |
| Out of Control | 43 | 0.632 |
| Other | 8 | 0.118 |

# CHAPTER 7. FREEWAY SEGMENTS

## 7.1 Introduction and Scope

Freeway segments require data involving facility-specific population designations, geometric design, operations, protective devices, and surrounding land use. The prediction methodology for freeways is in the HSM Supplement, in Chapter 18 (Bonneson et al. 2012). This chapter contains a detailed description of the data requirements and the HSM prediction methodology for freeway segments. Because some of these freeway segment types are not common in Missouri, this calibration contains only the most relevant freeway types utilized across the state. New updated calibration factors were obtained for freeway segments for four-lane rural, four-lane urban, and six-lane urban freeway segments.

## 7.2 Calibration Data Requirements

The IHSDM input data is divided into required and desired data. The required data consists of site, crash, and traffic data. The desired data is optional and includes variables such as inside/outside rumble strips, clear zone, and geometric curve data.

### 7.2.1. Required Site Data

#### 7.2.1.1. Area Type

The classification of areas depends on the roadway characteristics, surrounding population, and land use. Based on the FHWA guidelines, the HSM defines "urban" areas as regions that contain a population greater than 5,000 people. "Rural" areas are designated as regions outside urban areas and which contain a population fewer than 5,000 people. Although the terms metropolitan, urbanized, or suburban refer to urban subcategories, the HSM does not make a distinction among these subgroups and considers all as urban (AASHTO 2010). MoDOT uses the same area classification.

#### 7.2.1.2 Number of Through Lanes

IHSDM calibration requires the total number of through lanes in both directions for urban freeway segments. Add and drop lanes are considered as through lanes after the downstream taper. Figure 7.1 shows an example of through lane counting with add and drop lanes. If auxiliary lanes exceed 4,500 ft, the auxiliary lane is treated as a through lane. If entrance speed change lanes exceed 1,600 ft, the speed change lane is treated as a through lane that begins at the ramp entrance gore point and ends at the taper (the same applies to exit speed change lanes) (AASHTO 2010).
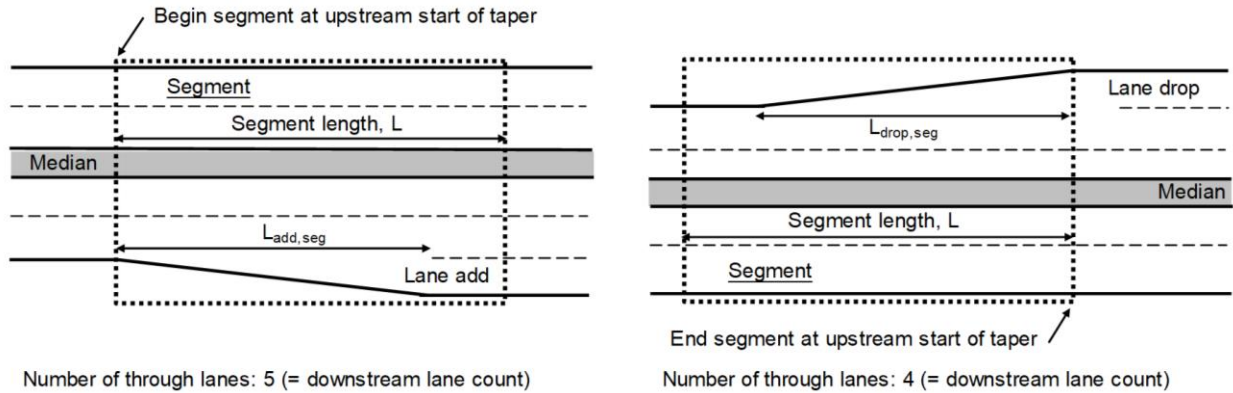
**Figure 7.1 Freeway through lanes count with add and drop lanes (AASHTO, 2010)**

7.2.1.3 Segment Length

The segment length is the distance from the beginning to the end of a freeway segment, including the different components that may be part of the segment such as speed change lanes, add and drop lanes, and auxiliary lanes, if they meet the previously mentioned criteria. The units used for the segment length is in miles. No rural or urban four-lane freeway segment sampled was shorter than 0.5 miles. There were 7 out of 54 urban six-lane freeway segments that were slightly shorter than 0.5 mile.

7.2.1.4 Effective Segment Length

The effective segment length is the segment length without the speed change lanes in miles. Figure 7.2 shows how freeway segments are treated within interchanges. In Figure 7.2, the segment length is equal to $L_{fs1} + L_{fs2} + L_{fs3}$. Figure 7.2 contains one exit and one entrance speed change lane in one direction of travel of the freeway segment. Thus, the effective length is the total segment minus the speed change lane distance from gore to taper point—note that the speed change lanes distances are divided by two to consider a homogenous segment in both directions (AASHTO 2010). Figure 7.3 illustrates the process of segmentation and calculation of the effective length.

**PLAN VIEW**
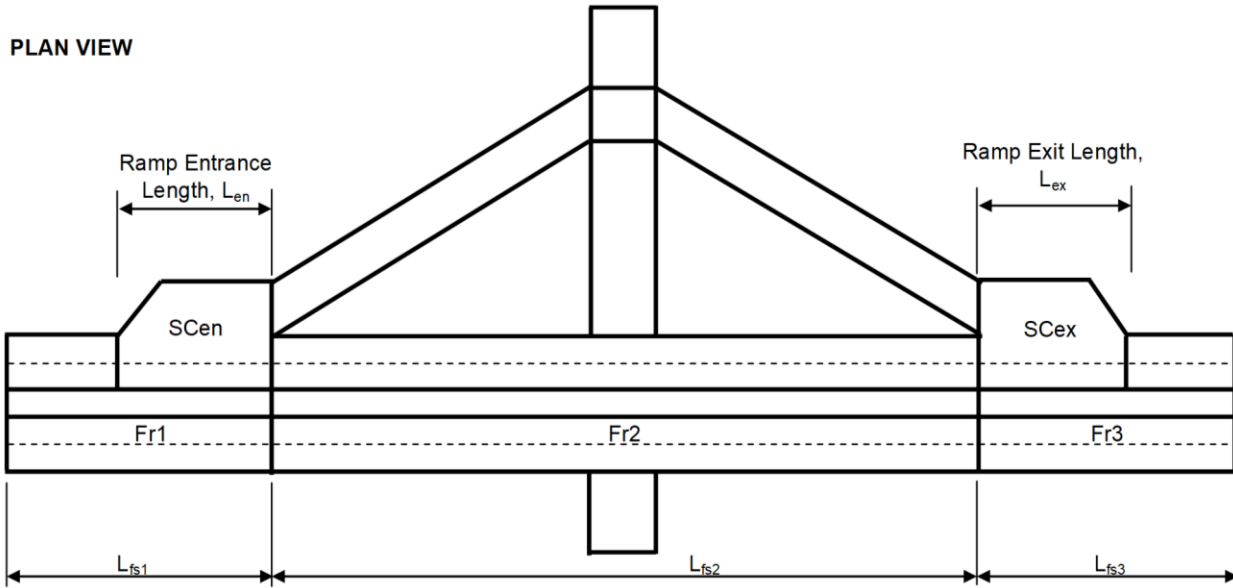


**Figure 7.2. Illustration of segment length with speed change lanes (AASHTO, 2010)**

**COMPONENT PARTS**



Speed-Change Lane
  Type: ramp entrance
  Seg. length = $L_{en}$
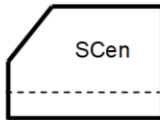
Speed-Change Lane
  Type: ramp exit
  Seg. length = $L_{ex}$

Freeway Segment
  Effective segment length, $L^* = L_{fs} - L_{en}/2 - L_{ex}/2$

  (note: freeway segment length does not include the length of speed-change lanes, if these lanes are adjacent to the segment)
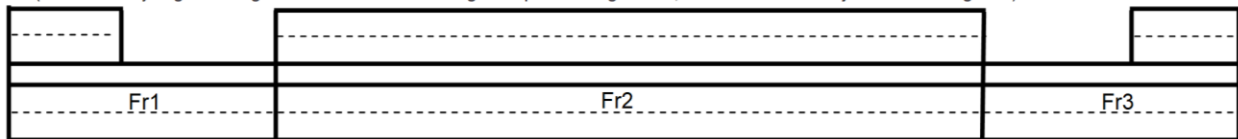
**Figure 7.3. Effective segment length example (AASHTO 2010)**

7.2.1.5 Average Lane Width

The average lane width is to be computed by measuring the lane width at different points throughout the freeway segment to compute the average. If necessary, the average lane width is to be rounded to the nearest 0.5 ft. If there are significant changes in lane width throughout the segment, it should be divided into separate freeway segments (AASHTO 2010).

7.2.1.6 Effective Median Width

The effective median width is the distance between the inside edges of the travelway in both directions (in feet). The edge of the travelway for median width determination is the left edge in

each direction of travel. Thus, the effective median includes the inside shoulders. This distance should be measured at different points in the segment to compute the average. Figure 7.4(a) illustrates how to measure the median width. If there are significant changes in the effective median width, the segment should be divided into separate segments (AASHTO 2010). Figure 7.4(b) shows an example of a freeway segment divided into five different segments due to the variation of median width.
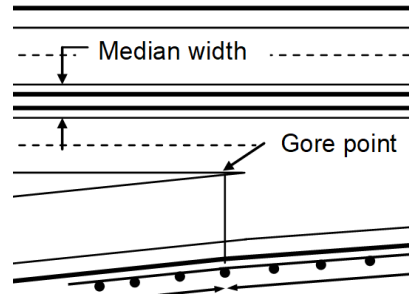


**(a) Median width**
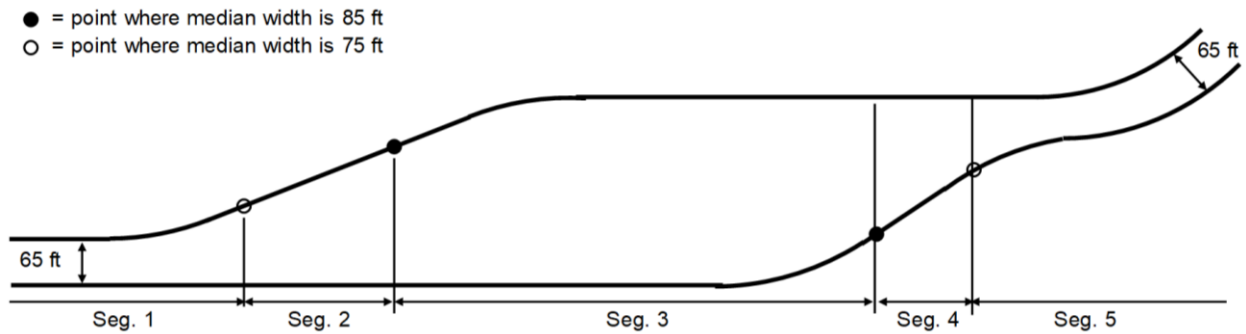


**(b) Median width variation and segmentation**

**Figure 7.4. Median width and variations (AASHTO 2010)**

7.2.1.7 Proportion of Segment Length with Median Barrier

The length of a barrier is measured along a reference line (in one direction). If the median barrier is present along the entire segment (i.e. cable or concrete), the proportion of the segment with median barrier is equal to one. In the case that a protective barrier is present along part of the segment, each barrier element should be measured following the reference line. The proportion of the segment with the protective median barrier is then calculated, and it should be between zero and one. If no median barrier is present, then the proportion is equal to 0. Therefore, the proportion of segment with median barrier must have a value between 0 and 1.

### 7.2.1.8 Average Median Barrier Offset

The offset is measured from the nearest edge of the travelway (including inside shoulder) to the face of the barrier along the reference line (in feet). There may be different barrier components along the segment with different offset lengths, so the average is found appropriate when there are not overlapping barriers in the median in both directions of travel (i.e. bridge columns). Figure 7.5 illustrates the case in which barriers in both directions are overlapped and shows how they can be categorized.
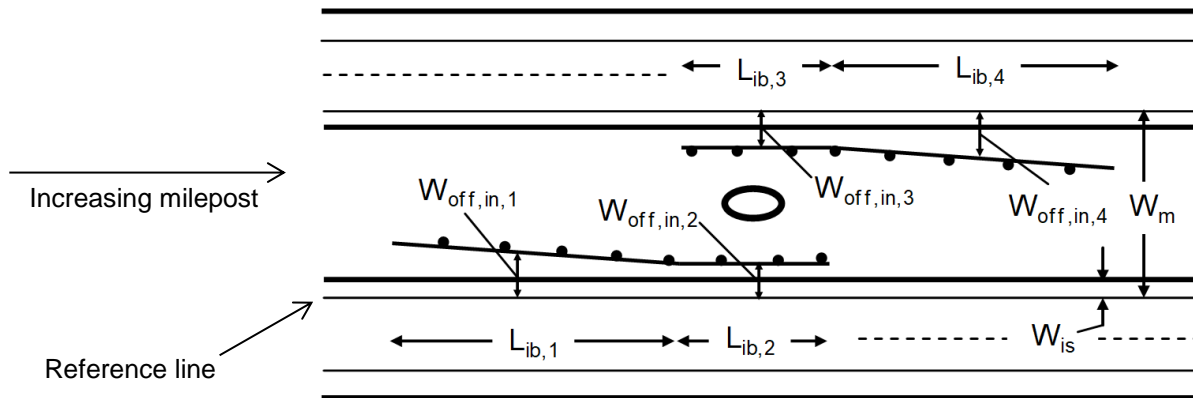


**Figure 7.5. Median barrier length and offset (AASHTO 2010)**

### 7.2.1.9 Proportion of Segment Length with Outside Barrier

A barrier on the roadside is noted if the offset from the near edge of the travelway is 30 ft or less. The proportion is calculated similar to the inside median barrier proportion. The proportion should be equal to 1 if the roadside barrier is along the entire segment and 0 when it is not present at all.

### 7.2.1.10 Average Outside Barrier Offset

The offset of outside barriers is measured form the outside edge of the travelway along the reference line in feet. Because there may be different sections of the segment with outside barriers, the offset distance should be measured at different points along the segment to obtain an average outside barrier offset.

### 7.2.1.11 Average Inside/Outside Shoulder Width

IHSDM methodology requires both inside and outside shoulder widths. Only paved shoulders (inside and outside) in both directions should be considered. The width of both inside and outside shoulders should be measured throughout the segment and averaged (in feet). The width should

be measured for sections in which the width is constant. If the shoulder width varies significantly along the segments, a weighted average of the widths should be computed.

7.2.1.12 Type B Weaving Section Characteristics

A Type B weaving section has the following defining characteristics (AASHTO 2010):
1) one of the two weaving movements can be made without making any lane changes
2) the other weaving movement requires at most one lane change
3) the exit and entrance ramps associated with the weaving section are located on the right side of the road.

Figure 7.6 shows typical Type B weaving sections.



a. Major Weave with Lane Balance at Exit Gore

b. Major Weave with Merge at Entry Gore

c. Major Weave with Merge at Entry Gore and Lane Balance at Exit Gore
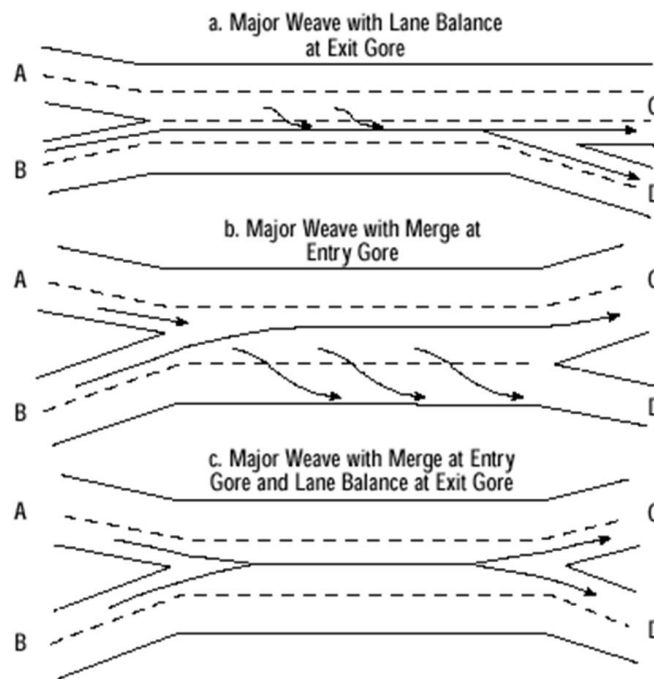
**Figure 7.6 Typical Type B weaving sections (AASHTO 2010)**

7.2.1.13 Length of Weaving Section

The length of weaving section on the segment is measured along the edge of the travelway from the gore point of the exit ramp to the gore point of the entrance ramp in feet. This length is measured by direction of travel, so two measurements are made. The gore point is the location where the edge markings of the ramp and the freeway meet and are 2 ft apart. It should be noted that the weaving length might exceed the length of the segment under study, so the segment length should be considered as the boundary.

Figure 7.7 shows an example of a weaving section on the increasing milepost with an entrance ramp followed by an exit ramp. If the length of the weaving section exceeds 0.85 mi (4,500 ft),

then the section should no longer be treated as a weaving section. Instead, add/drop lanes should be designated according to the situation (AASHTO 2010).
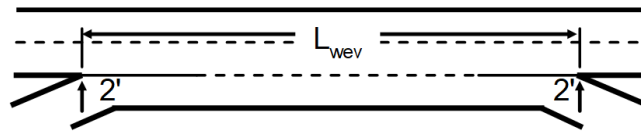


$L_{wev}$ = weaving section length

**Figure 7.7 Weaving section length (AASHTO 2010)**

7.2.1.14 Distance from Segment Beginning/End to Ramps

The segment distances are measured in both directions of travel (increasing or decreasing milepost) and in feet. Figure 7.8(a) shows a segment with spacing to ramps. For the increasing milepost, the distance from the beginning of the segment to the upstream entrance ramp is measured ($X_{b,ent}$), and the distance from the end of the segment to the downstream exit ramp ($X_{e,ext}$). For the decreasing milepost the same criteria applies, keeping the designated beginning and end of the segment designation. Note that speed change lanes are treated as separate segments. For the entrance ramp, Figure 7.8(b) shows an add lane from the gore point of the entrance ramp to the taper. For the exit ramp, Figure 7.8(b) shows the speed change lane from the taper point to the gore point.
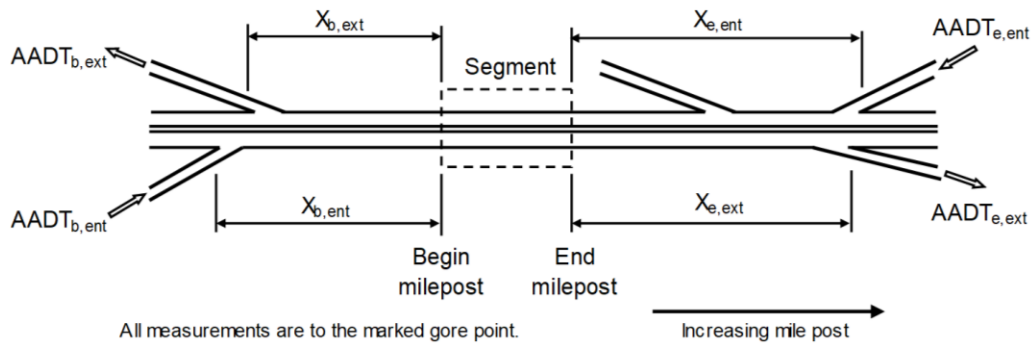


**(a) Distances from a segment with spacing to ramps**
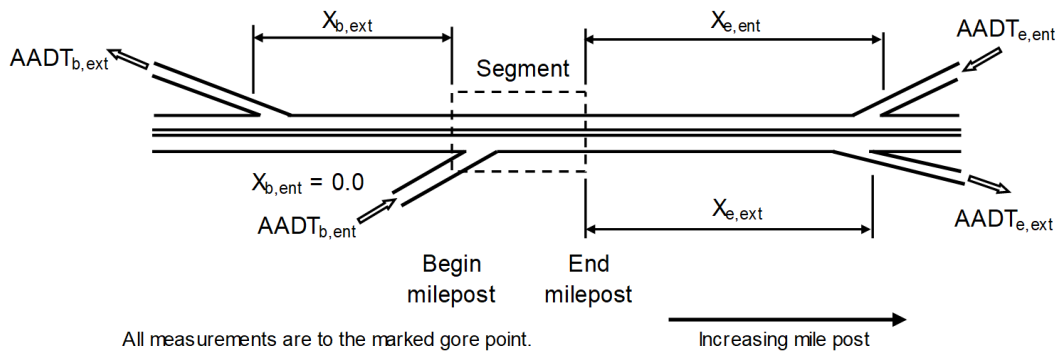
**(b) Distances from a segment starting at the gore point of an entrance ramp**

**Figure 7.8 Ramp AADTs and distances to beginning/end of segment (AASHTO 2010)**

7.2.2 Required Crash and Traffic Data

7.2.2.1 Years of Crash Data

The years associated with the calibration needs to be specified in IHSDM. The IHSDM considers up to three years of input data.

7.2.2.2 Observed Number of Crashes

Freeway related crashes involve collisions occurring within the boundaries of a segment. Because freeways often contain speed change lanes near interchange facilities, it is important to distinguish the difference between speed change lane and freeway segment related crashes. Figure 7.9 shows an example of crash assignment on freeways with speed change lanes. As illustrated in Figure 7.9, crashes within the taper and gore point of speed change lanes are considered speed change related crashes (A), and crashes occurring outside these boundaries are freeway segment related crashes (B). The assignment of crashes based on physical location was used as the crash landing criterion for simplicity. In theory with the criterion, there could be speed change related crashes that are incorrectly landed on mainline freeway segments. But in practice, the vicinity of interchanges was avoided in the sampling of freeway segments, so the crash landing problem was avoided in practice.

**Entrance Ramp with Parallel Design**

Ramp Entrance Length

B

A

Taper point

**Exit Ramp with Taper Design**

Ramp Exit Length

B

A

B

Taper point

\* Point where marked gore is 2 ft wide (gore point)
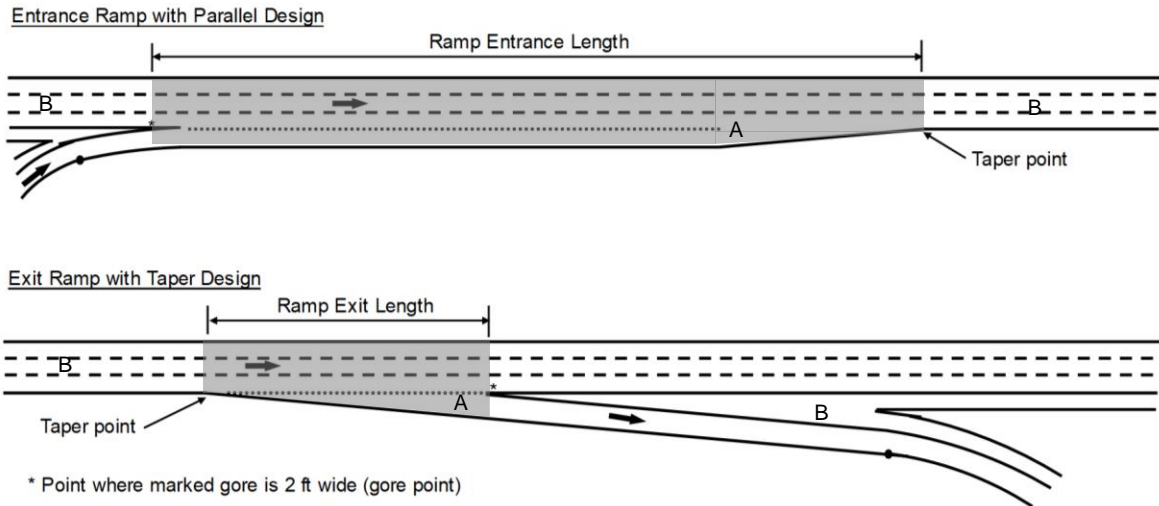
**Figure 7.9 Freeway crashes assignment (AASHTO 2010)**

7.2.2.3 Freeway AADT

The total AADT in both directions should be collected for all years of analysis.

7.2.2.4 Ramps AADT

The AADT of the nearest ramps, both upstream and downstream of the freeway segment, should be collected for all years of analysis. Similar to Figure 7.8, the AADTs are designated based on the beginning/end of the segment and the increasing/decreasing milepost.

7.2.2.5 Proportion of High Volume

The proportion of high volume introduces the influence of volume concentration in crash frequency prediction. Past research shows that as volume nears capacity, average speed decreases and headway is reduced (Bonneson et al. 2012). Thus, these variations have some influence on freeway segment crashes. IHSDM defines the proportion of high volume as the proportion of AADT during which the volume exceeds 1,000 veh/h/ln. Using data from three different states, the proportion of volume statistic was modeled using regression (Bonneson et al. 2012). Figure 7.10 illustrates data and trend distribution. This CMF was not applied in the previous calibration.
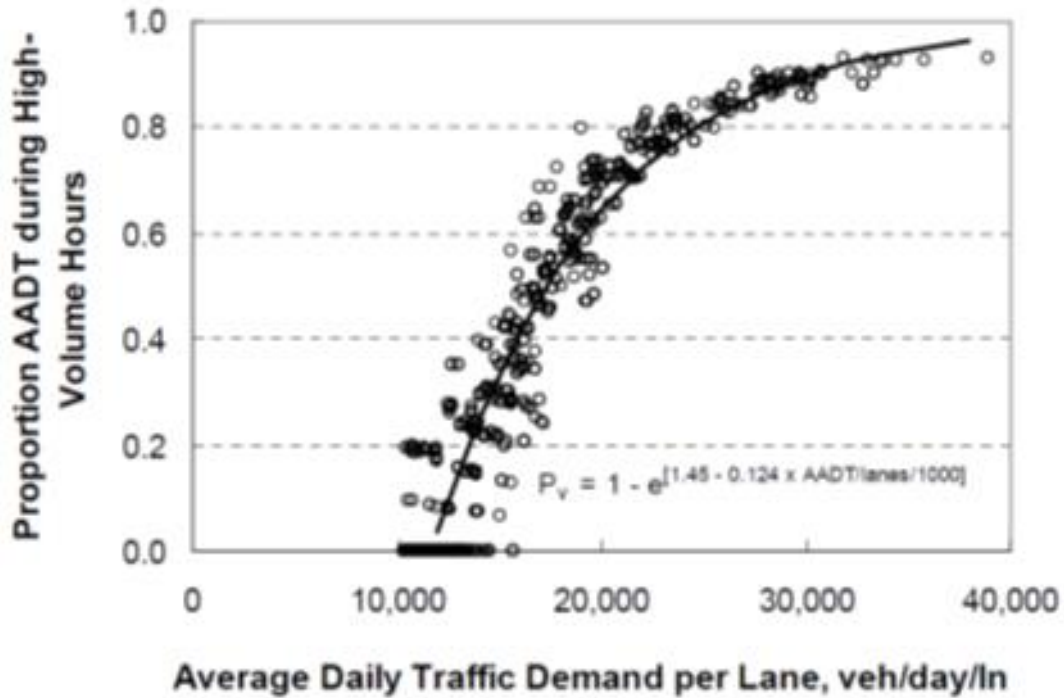
**Figure 7.10 Proportion of high volume estimate (Bonneson et al., 2012)**

*7.2.3 Desired Data*

7.2.3.1 Proportion of Inside/Outside Rumble Strips

The proportion of the length of freeway segment that contains rumble strips should be estimated. Rumble strips should be measured separately for each shoulder type and travel of direction. The proportion input value must be between 0 and 1.

7.2.3.2 Outside Clear Zone Width

The clear zone distance in feet is measured periodically along the length of the freeway segment from the roadside edge in both directions (including shoulder) to vertical obstructions such as non-traversable slopes, fences, or utility poles. Barriers are not considered for the analysis of clear zone width since barriers are covered independently in other CMFs. Also, isolated trees are not considered part of the clear zone. Figure 7.11 shows an example of clear zone width measurements of different roadside components. An average is recommended for different components located at different distances.
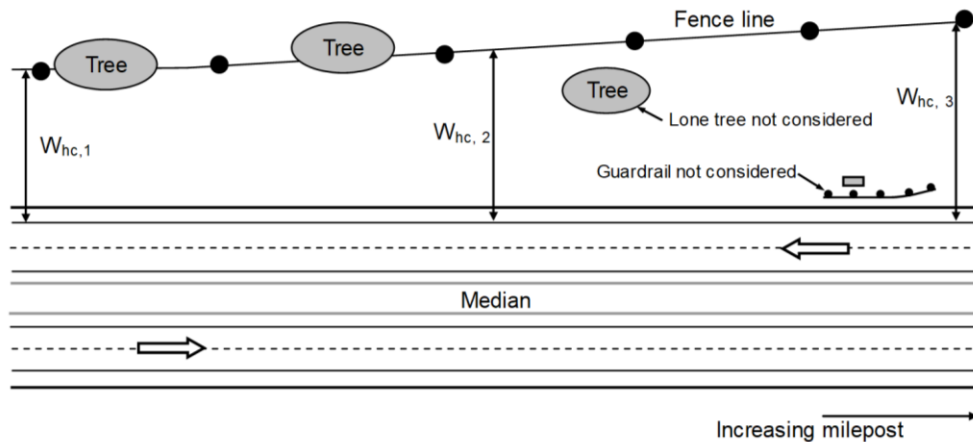
**Figure 7.11 Clear zone width measurements (AASHTO 2010)**

7.2.3.3 Curve Radius

The radius of a curve, in part or in whole, should be measured in feet along the inside edge of the curved travelway. If the roadway is curved in both directions, the equivalent radius of curve should be computed with the following equation:

$$R^* = \left[\left(\frac{0.5}{R_i{}^2}\right) + \left(\frac{0.5}{R_j{}^2}\right)\right]^{-0.5}$$ 

(7.1)

where $R^*$ is the equivalent radius of curvature (ft), $R_i$ is the radius of curvature on roadside $i$; and $R_j$ is the radius of curvature on roadside $j$.

7.2.3.4 Length of Curve in Segment

The length of the curve within the boundaries of the segment should be recorded. This length should not exceed the length of the segment. Figure 7.12 illustrates different variations of freeway segment curves and shows how the curve length should be measured for each case. The three variations are: 1) only one roadside of the segment is curved, 2) both roadsides are curved concentrically, and (3) both roadsides are not curved concentrically.
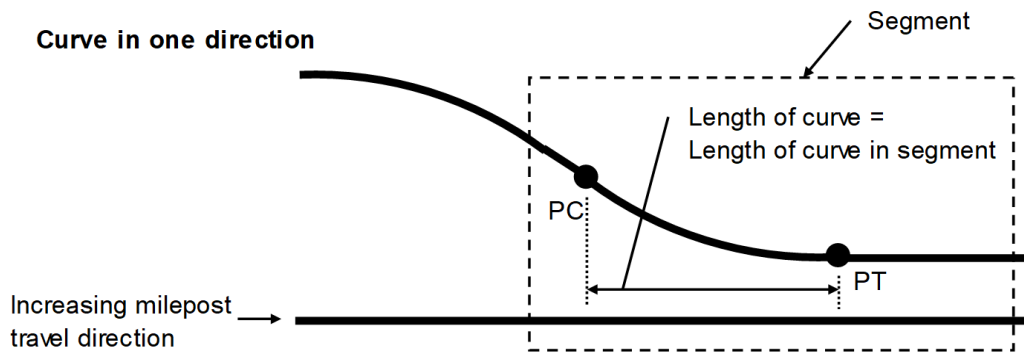
**(a) Curve in one direction of travel**
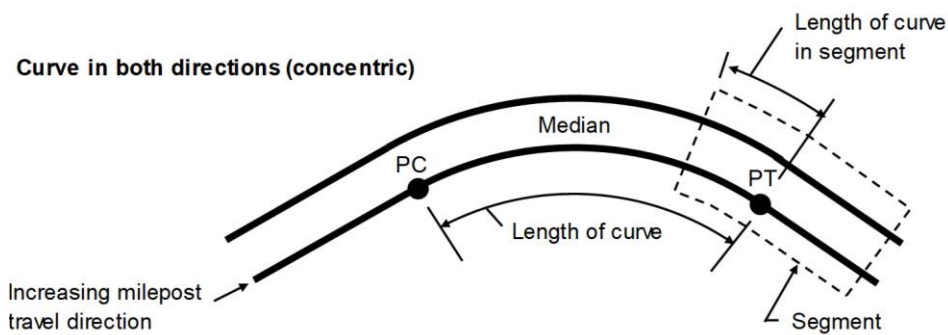


**(b) Concentric curve in both direction of travel**
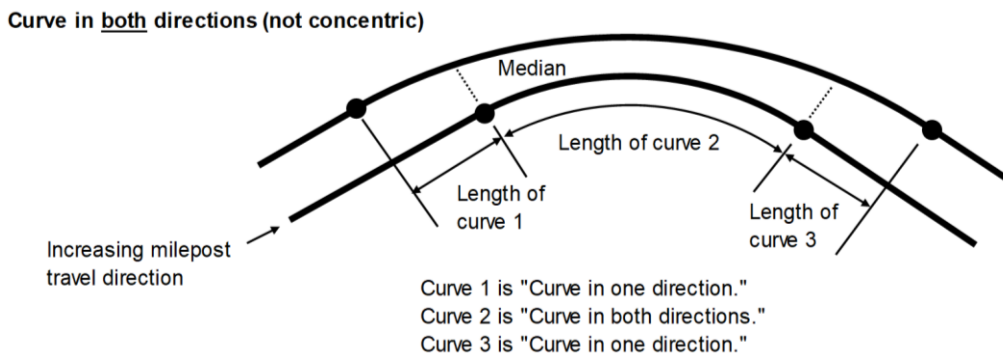


**(c) Not concentric curve in both directions of travel**

**Figure 7.12 Freeway segment curve length (AASHTO 2010)**

### 7.3 HSM Prediction Methodology

As described in Chapter 18 of the supplement to the HSM, the SPFs for freeway segments predict the number of total crashes on the segment per year for the base conditions that are shown in Table 7.1. The SPFs for freeway segments include four models: PDO single-vehicle crashes, PDO multi-vehicle crashes, fatal/injury single-vehicle crashes, and fatal/injury multi-

vehicle crashes. The SPFs are based on the AADT and length of the segment. A general form of the SPF equation used to predict average crash frequency for a segment of freeway is shown as Equation 7.2.

$$N_{p,w,x,y,z} = N_{spf,w,x,y,z} \times \left( CMF_{1,w,x,y,z} \times CMF_{2,w,x,y,z} \times \ldots \times CMF_{m,w,x,y,z} \right) \times C_{w,x,y,z} \qquad \textbf{(7.2)}$$

where $N_{p,\,w,\,x,\,y,\,z}$ is the predicted average crash frequency for a specific year for site type $w$, cross section or control type $x$, crash type $y$, and severity $z$ (crashes/yr); $N_{spf,\,w,\,x,\,y,\,z}$ is the predicted average crash frequency determined for base conditions of the SPF developed for site type $w$, cross section or control type $x$, crash type $y$, and severity $z$ (crashes/year); $CMF_{m,\,w,\,x,\,y,\,z}$ is the crash modification factors specific to site type $w$, cross section or control type $x$, crash type $y$, and severity $z$ for specific geometric design and traffic control features $m$; and $C_{w,\,x\,y,\,z}$ is the calibration factor to adjust SPF for local conditions for site type $w$, cross section or control type $x$, crash type $y$, and severity $z$.

**Table 7.1 Base conditions for multiple/single vehicle crashes for freeway segment SPFs**

| Description | MV Base Condition | SV Base Condition |
|---|---|---|
| Horizontal Curve | Not Present | Not Present |
| Lane Width | 12 ft | 12 ft |
| Inside Paved Shoulder Width | 6 ft | 6 ft |
| Median Width | 60 ft | 60 ft |
| Median Barrier | Not Present | Not Present |
| Hours with Volume > 1000veh/h/lane | None | None |
| Upstream Ramp Entrances | > 0.5 mi from segment | n/a |
| Downstream Ramp Exits | > 0.5 mi from segment | n/a |
| Type B Weaving Section | Not Present | n/a |
| Outside Shoulder Width | n/a | 10 ft |
| Shoulder Rumble Strip | n/a | Not Present |
| Outside Clearance | n/a | 30 ft Clear Zone |
| Outside Barrier | n/a | Not Present |

In order to determine the total average crash frequency of a freeway segment, a sum of the average crash frequencies given by each of the four SPF models must be computed. This summation is shown in Equation 7.3.

$$N_{p,\,fs,n,at,as} = N_{p,\,fs,n,mv,fi} + N_{p,\,fs,n,sv,fi} + N_{p,\,fs,n,mv,pdo} + N_{p,\,fs,n,sv,pdo} \qquad \textbf{(7.3)}$$

where $N_{p,\,fs,\,n,\,y,\,z}$ is the predicted average crash frequency of a freeway segment with $n$ lanes, crash type $y$ ($y = sv$: single vehicle, $mv$: multiple vehicle, $at$: all types), and severity $z$ ($z = fi$: fatal and injury, $pdo$: property damage only, $as$: all severities) (crashes/year); and $N_{spf,\,fs,\,n,\,y,\,z}$ is the predicted average crash frequency of a freeway segment with base conditions, $n$ lanes, crash type

$y$ ($y = sv$: single vehicle, $mv$: multiple vehicle, $at$: all types), and severity $z$ ($z = fi$: fatal and injury, $pdo$: property damage only) (crashes/year).

The general form of each SPF model is given by Equation 7.4. The output of this equation is the average crash frequency given a set of base conditions. This output is then used in the summation within Equation 7.3.

$$N_{spf, fs, n, mv, z} = L^* \times \exp(a + b \times \ln[c \times AADT_{fs}])$$
(7.4)

where $N_{spf, fs, n, mv, z}$ is the predicted average multiple-vehicle crash frequency of a freeway segment with base conditions, $n$ lanes, and severity $z$ ($z = fi$: fatal and injury, $pdo$: property damage only) (crashes/yr); $L^*$ is the effective length of freeway segment (mi); $AADT_{fs}$ is the AADT volume of freeway segment (veh/day); and $a, b, c$ is the regression coefficients.

**7.4 Sampling Considerations**

The sampling process consisted of using the sites from the previous calibration as the calibration starting point (Sun et al. 2013). The previous samples were generated for freeway segments from the lists of all segments for each district and each facility type using Missouri TMS database queries (Sun et al. 2013). Some of these initiated or ended at interchanges. After several research projects involving freeway interchange crash data, several issues were identified regarding the location and assignment of interchange crashes (Claros et al. 2015, Sun et al. 2016). In order to avoid crash landing problems and inadvertently including crashes that are not related to freeway segments, the revised samples for this project do not include any segments near interchange facilities. The boundary of interchanges was determined based on the taper point of speed change lanes and a distance of 1,600 ft upstream or downstream from the gore point of add/drop lanes. The 1600 ft threshold is 100 ft (an extra buffer) beyond the commonly used 1500 ft influence area (Lu et al. 2013, TRB 2010).

The new samples were based on the previous calibration locations but the segments were moved upstream or downstream away from interchanges. The segments were separated into urban and rural samples with a minimum length of 0.5 miles and with no interchange facilities. During the sampling process, an attempt was made to obtain a minimum of five samples from each district. However, it was not possible to meet this goal for the urban six-lane freeway segments because most of the samples were located in the Saint Louis and Kansas City districts. Freeway segments with significant variation in cross section, such as a change in median width or median type were avoided. Specific considerations for each freeway type are described in the next section.

7.4.1 Sampling for Rural Four-Lane Freeway Segments

There were sufficient numbers of rural four-lane freeway samples to obtain at least one sample per district. The sample set for calibration included 45 sites. The general sampling approach involved attempting to obtain 35 at-large samples from the state of Missouri but more sites were

added above the minimum number. This was because rural freeway segments have fewer crashes than urban segments.

A list of samples for rural four-lane freeway segments is shown in Table 7.2. The samples were distributed among the seven MoDOT districts as follows:

- 9 samples from the Central District,
- 7 samples from the Kansas City District,
- 3 samples from the Northeast District,
- 9 samples from the Northwest District,
- 7 samples from the Southeast District,
- 1 sample from the Saint Louis District,
- 9 samples from the Southwest District.

The samples were representative of geographic diversity from around the state of Missouri. The sample set consisted mostly of interstate freeways, although US highways such as US 40, US 71, and US 60 were also represented in the sample set. Most of the major interstate freeways, including IS 44, IS 35, IS 55, IS 29, and IS 70 were represented in the sample set. The sample set included freeway segments from 26 counties in Missouri. All sites from the previous calibration were explored; some sites were dropped because they included interchange areas. Some new sites were added.

**Table 7.2 List of sites for rural four-lane freeway segments**

| Site ID | District | Description | Primary Direction | Primary Begin Log | Primary End Log | Length (mi) | County |
|---|---|---|---|---|---|---|---|
| 1 | CD | IS 44 | E | 211.188 | 212.873 | 1.685 | Crawford |
| 2 | CD | IS 44 | E | 204.59 | 207.126 | 2.536 | Crawford |
| 3 | CD | IS 44 | E | 146.065 | 148.855 | 2.79 | Pulaski |
| 4 | CD | US 40 | E | 138.93 | 140.88 | 1.952 | Boone |
| 5 | CD | US 40 | E | 94.344 | 98.147 | 3.803 | Cooper |
| 6 | CD | IS 70 | E | 106.82 | 109.745 | 2.93 | Cooper |
| 7 | CD | IS 70 | E | 118.05 | 120.68 | 2.625 | Boone |
| 8 | SW | IS 44 | E | 67.33 | 68.25 | 0.92 | Greene |
| 9 | SW | IS 44 | E | 47.45 | 48.83 | 1.376 | Lawrence |
| 10 | SW | IS 44 | E | 34.04 | 36.51 | 2.471 | Lawrence |
| 11 | SW | IS 44 | E | 19.022 | 20.218 | 1.196 | Jasper |
| 12 | SW | US 71 | S | 278.98 | 279.57 | 0.586 | Newton |
| 13 | SW | US 71 | S | 286.881 | 288.69 | 1.809 | Newton |
| 14 | SW | US 71 | S | 303.868 | 304.872 | 1.004 | McDonald |
| 15 | KC | US 40 | E | 47.042 | 48.888 | 1.846 | Lafayette |
| 16 | KC | US 40 | E | 60.971 | 62.755 | 1.784 | Lafayette |
| 17 | KC | US 40 | E | 72.979 | 74.87 | 1.891 | Saline |
| 18 | KC | US 71 | S | 83.685 | 84.514 | 0.829 | Platte |
| 19 | KC | US 71 | S | 160.785 | 162.415 | 1.63 | Cass |
| 20 | KC | US 71 | S | 89.532 | 91.654 | 2.122 | Platte |
| 21 | KC | US 40 | E | 79.968 | 82.938 | 2.97 | Saline |
| 22 | NE | IS 70 | E | 181.709 | 183.356 | 1.647 | Montgomery |
| 23 | NE | IS 70 | E | 175.506 | 177.665 | 2.159 | Montgomery |
| 24 | NE | IS 70 | E | 170.83 | 174.371 | 3.541 | Montgomery |
| 25 | SW | US 71 | S | 293.461 | 294.974 | 1.513 | Newton |
| 26 | SW | US 71 | S | 264.06 | 264.718 | 0.658 | Jasper |
| 27 | NW | IS 35 | S | 8.296 | 11.262 | 2.966 | Harrison |
| 28 | NW | IS 35 | S | 22.391 | 24.19 | 1.799 | Harrison |
| 29 | NW | US 71 | S | 78.062 | 82.50 | 4.435 | Buchanan |
| 30 | NW | US 71 | S | 57.157 | 57.898 | 0.741 | Andrew |
| 31 | NW | IS 229 | S | 0.851 | 1.599 | 0.748 | Andrew |
| 32 | NW | IS 29 | S | 56.937 | 58.385 | 1.448 | Andrew |
| 33 | NW | IS 29 | S | 25.313 | 26.865 | 1.552 | Holt |
| 34 | NW | IS 35 | S | 14.897 | 16.18 | 1.283 | Harrison |
| 35 | NW | IS 35 | S | 34.303 | 35.573 | 1.27 | Daviess |

**Table 7.2 Continued**

| Site ID | District | Description | Primary Direction | Primary Begin Log | Primary End Log | Length (mi) | County |
|---------|----------|-------------|-------------------|-------------------|-----------------|-------------|--------|
| 36 | SE | IS 55 | S | 129.384 | 132.199 | 2.815 | Scott |
| 37 | SE | IS 55 | S | 177.398 | 179.583 | 2.185 | Pemiscot |
| 38 | SE | IS 55 | S | 202.256 | 204.123 | 1.867 | Pemiscot |
| 39 | SE | US 60 | E | 322.889 | 326.586 | 3.697 | Mississippi |
| 40 | SE | IS 55 | S | 152.133 | 156.676 | 4.543 | New Madrid |
| 41 | SE | IS 55 | S | 86.241 | 89.645 | 3.404 | Perry |
| 42 | SE | US 60 | E | 317.408 | 320.91 | 3.502 | Mississippi |
| 43 | SL | IS 55 | S | 39.522 | 40.096 | 0.574 | Jefferson |
| 44 | CD | IS 70 | E | 138.267 | 141.406 | 3.139 | Callaway |
| 45 | CD | IS 70 | E | 144.602 | 146.303 | 1.701 | Callaway |

7.4.2 Sampling for Urban Four-Lane Freeway Segments

There were sufficient samples to obtain five samples per district for urban four-lane segments. The sample set for calibration included 41 sites. The general sampling approach involved attempting to obtain 35 at-large samples from the state of Missouri.

A list of samples for urban four-lane freeway segments is shown in Table 7.3. The samples were distributed among the seven MoDOT districts as follows:

- 6 samples from the Central District,
- 9 samples from the Kansas City District,
- 3 samples from the Northeast District,
- 6 samples from the Northwest District,
- 4 samples from the Southeast District,
- 8 samples from the Saint Louis District,
- 5 samples from the Southwest District.

The samples were representative of geographic diversity from around the state of Missouri. The sample set consisted mostly of interstate freeways, although US highways such as US 36, US 50, US 65, US 71, US 160, and US 169 were also represented in the sample set. Most of the major interstate freeways, including IS 44 or IS 70 were represented in the sample set. The sample set included freeway segments from 20 counties in Missouri, as well as segments from large counties such as St. Charles and small counties such as Christian.

**Table 7.3 List of sites for urban four-lane freeway segments**

| No. | City | County | District | Description | Primary Dir. | Primary Begin Log | Primary End Log | Length (mi) |
|---|---|---|---|---|---|---|---|---|
| 1 | Laclede | Lebanon | CD | IS 44 | E | 127.71 | 128.82 | 1.10 |
| 2 | Laclede | Lebanon | CD | IS 44 | E | 129.38 | 129.88 | 0.50 |
| 3 | Jefferson City | Cole | CD | US 50 | E | 134.93 | 135.64 | 0.71 |
| 4 | Jefferson City | Cole | CD | US 50 | E | 136.27 | 136.99 | 0.72 |
| 5 | Sullivan | Crawford | CD | IS 44 | E | 223.10 | 224.17 | 1.07 |
| 6 | Boonville | Cooper | CD | IS 70 | E | 102.10 | 103.18 | 1.08 |
| 7 | Harrisonville | Cass | KC | US 71 | S | 154.00 | 154.51 | 0.51 |
| 8 | Peculiar | Cass | KC | US 71 | S | 145.18 | 145.87 | 0.69 |
| 9 | Kansas City | Clay | KC | US 169 | N | 7.66 | 8.64 | 0.99 |
| 10 | Kansas City | Clay | KC | US 169 | N | 9.37 | 10.59 | 1.22 |
| 11 | Kansas City | Platte | KC | MO 152 | E | 1.89 | 3.40 | 1.51 |
| 12 | Belton | Cass | KC | US 71 | N | 176.59 | 177.71 | 1.12 |
| 13 | Lee's Summit | Jackson | KC | MO 291 | N | 23.69 | 24.46 | 0.76 |
| 14 | Lee's Summit | Jackson | KC | MO 291 | N | 25.60 | 26.54 | 0.94 |
| 15 | Kansas City | Clay | KC | IS 435 | S | 22.49 | 24.85 | 2.36 |
| 16 | Hannibal | Marion | NE | US 36 | E | 189.71 | 190.30 | 0.59 |
| 17 | Warrenton | Warren | NE | IS 70 | E | 193.83 | 194.83 | 1.00 |
| 18 | Hannibal | Marion | NE | US 36 | E | 188.28 | 189.00 | 0.72 |
| 19 | Saint Joseph | Buchanan | NW | IS 29 | N | 52.94 | 54.85 | 1.91 |
| 20 | Saint Joseph | Buchanan | NW | IS 29 | N | 51.04 | 52.22 | 1.18 |
| 21 | Saint Joseph | Buchanan | NW | IS 229 | S | 13.36 | 14.05 | 0.68 |
| 22 | Saint Joseph | Buchanan | NW | IS 29 | N | 49.25 | 50.27 | 1.02 |
| 23 | Saint Joseph | Buchanan | NW | US 36 | E | 4.22 | 4.75 | 0.53 |
| 24 | Saint Joseph | Buchanan | NW | IS 229 | N | 7.99 | 9.14 | 1.15 |
| 25 | Cape Girardeau | Scott | SE | IS 55 | N | 90.22 | 91.35 | 1.13 |
| 26 | Jackson | Cape Girardeau | SE | IS 55 | N | 100.32 | 101.80 | 1.48 |
| 27 | Sikeston | Scott | SE | IS 55 | N | 69.77 | 73.32 | 3.54 |
| 28 | Cape Girardeau | Cape Girardeau | SE | IS 55 | N | 96.85 | 99.49 | 2.63 |
| 29 | Sullivan | Franklin | SL | IS 44 | E | 224.84 | 225.53 | 0.69 |
| 30 | Wentzville | St. Charles | SL | IS 70 | E | 205.34 | 207.83 | 2.48 |
| 31 | Lake Saint Louis | St. Charles | SL | IS 64 | E | 1.87 | 2.89 | 1.03 |
| 32 | Lake Saint Louis | St. Charles | SL | IS 64 | E | 4.81 | 5.89 | 1.08 |
| 33 | O'Fallon | St. Charles | SL | IS 64 | E | 7.05 | 9.26 | 2.22 |
| 34 | Saint Clair | Franklin | SL | IS 44 | E | 240.75 | 241.86 | 1.11 |
| 35 | Villa Ridge | Franklin | SL | IS 44 | W | 42.54 | 44.00 | 1.46 |
| 36 | Festus | Jefferson | SL | IS 55 | N | 177.03 | 178.36 | 1.33 |
| 37 | Joplin | Newton | SW | IS 44 | E | 7.03 | 8.31 | 1.28 |
| 38 | Joplin | Newton | SW | IS 44 | E | 9.79 | 11.25 | 1.46 |
| 39 | Springfield | Greene | SW | US 160 | E | 96.12 | 97.87 | 1.75 |
| 40 | Carthage | Jasper | SW | US 71 | N | 56.16 | 57.09 | 0.94 |
| 41 | Ozark | Christian | SW | US 65 | N | 38.82 | 41.16 | 2.34 |

7.4.3 Sampling for Urban Six-Lane Freeway Segments

There were only sufficient numbers of sites to obtain samples from three different districts: Kansas City, St. Louis, and Southwest. Urban six-lane freeways are not commonly used across Missouri except in densely populated regions. For this reason, it was not possible to find suitable sites from every single district. The sample set for calibration included 54 sites. It was desired to utilize samples with a minimum of 0.3 miles in length in order to eliminate excessively short segments. Urban interchange spacing tends to be shorter than rural spacing.

A list of samples for urban six-lane freeway segments is shown in Table 7.4. The samples were distributed among three MoDOT districts as follows:

- 25 samples from the Kansas City District,
- 25 samples from the Saint Louis District,
- 4 samples from the Southwest District.

The samples attempted to represent geographic diversity from around the state of Missouri from among the districts that had six-lane segments. The sample set consisted mostly of interstate freeways, although US and state highways such as US 71, US 65, and MO 370 were also represented in the sample set.  Most of the major interstate freeways, including IS 70, IS 49, IS 29, IS 35, IS 435, IS 270, IS 44, IS 64, IS 270, and IS 55 were represented in the sample set. The sample set included freeway segments from eight counties in Missouri, mostly from densely populated regions in which six-lane freeways are more frequently encountered.

**Table 7.4 List of sites for urban six-lane freeway segments**

| No. | City | County | District | Description | Primary Direction | Begin Log | End Log | Length (mi) |
|---|---|---|---|---|---|---|---|---|
| 1 | Independence | Jackson | KC | IS 70 | E | 11.57 | 12.37 | 0.80 |
| 2 | Independence | Jackson | KC | IS 70 | E | 12.93 | 13.75 | 0.82 |
| 3 | Independence | Jackson | KC | IS 70 | E | 14.37 | 14.96 | 0.59 |
| 4 | Blue Springs | Jackson | KC | IS 70 | E | 18.87 | 19.71 | 0.84 |
| 5 | Grandview | Jackson | KC | IS 49 | N | 174.56 | 175.22 | 0.66 |
| 6 | Grandview | Jackson | KC | IS 49 | N | 173.86 | 174.47 | 0.61 |
| 7 | Barnhart | Jefferson | SL | IS 55 | N | 182.47 | 183.13 | 0.66 |
| 8 | Kansas City | Jackson | KC | US 71 | N | 198.12 | 198.62 | 0.50 |
| 9 | Kansas City | Jackson | KC | IS 70 | W | 244.97 | 245.45 | 0.48 |
| 10 | Kansas City | Platte | KC | IS 29 | N | 8.78 | 9.28 | 0.50 |
| 11 | Kansas City | Platte | KC | IS 29 | N | 9.28 | 9.83 | 0.55 |
| 12 | Platte City | Platte | KC | IS 29 | N | 20.11 | 20.65 | 0.54 |
| 13 | Platte City | Platte | KC | IS 29 | N | 20.65 | 21.49 | 0.84 |
| 14 | Kansas City | Clay | KC | IS 35 | N | 7.21 | 8.04 | 0.83 |
| 15 | Kansas City | Jackson | KC | IS 435 | N | 6.37 | 7.00 | 0.63 |
| 16 | Kansas City | Jackson | KC | IS 435 | N | 7.00 | 7.86 | 0.86 |
| 17 | Kansas City | Jackson | KC | IS 470 | E | 2.41 | 3.00 | 0.59 |
| 18 | Kansas City | Jackson | KC | IS 470 | E | 3.00 | 3.66 | 0.66 |
| 19 | Lee's Summit | Jackson | KC | IS 470 | E | 5.77 | 6.43 | 0.66 |
| 20 | Eureka | St. Louis | SL | IS 44 | E | 266.89 | 267.40 | 0.51 |
| 21 | Bridgeton | St. Louis | SL | IS 70 | E | 233.43 | 233.93 | 0.50 |
| 22 | Barnhart | Jefferson | SL | IS 55 | N | 183.20 | 183.85 | 0.65 |
| 23 | St. Louis | St. Louis | SL | IS 70 | E | 237.00 | 237.50 | 0.50 |
| 24 | St. Charles | St. Charles | SL | MO 370 | E | 3.07 | 4.39 | 1.32 |
| 25 | St. Charles | St. Charles | SL | MO 370 | E | 5.54 | 7.42 | 1.88 |
| 26 | Richmond Heights | St. Louis | SL | IS 64 | E | 33.13 | 33.67 | 0.54 |
| 27 | Chesterfield | St. Louis | SL | IS 64 | E | 22.31 | 22.96 | 0.65 |
| 28 | Chesterfield | St. Louis | SL | IS 64 | E | 21.27 | 21.81 | 0.54 |
| 29 | Chesterfield | St. Louis | SL | IS 64 | E | 17.88 | 18.52 | 0.64 |
| 30 | Chesterfield | St. Louis | SL | IS 64 | E | 14.94 | 16.31 | 1.37 |
| 31 | Lake St. Louis | St. Charles | SL | IS 70 | E | 212.27 | 213.65 | 1.38 |
| 32 | O'Fallon | St. Charles | SL | IS 70 | E | 214.39 | 215.64 | 1.25 |
| 33 | O'Fallon | St. Charles | SL | IS 70 | E | 223.44 | 223.92 | 0.48 |
| 34 | St. Peters | St. Charles | SL | IS 70 | E | 224.14 | 224.82 | 0.68 |

**Table 7.4 Continued**

| No. | City | County | District | Description | Primary Direction | Begin Log | End Log | Length (mi) |
|---|---|---|---|---|---|---|---|---|
| 35 | St. Charles | St. Charles | SL | IS 70 | E | 225.55 | 226.64 | 1.09 |
| 36 | Bridgeton | St. Louis | SL | IS 70 | E | 232.33 | 232.95 | 0.62 |
| 37 | St. Louis | St. Louis | SL | IS 70 | E | 239.91 | 240.76 | 0.85 |
| 38 | St. Louis | St. Louis City | SL | IS 70 | E | 246.56 | 246.94 | 0.38 |
| 39 | Springfield | Greene | SW | US 65 | S | 260.08 | 260.46 | 0.38 |
| 40 | Springfield | Greene | SW | US 65 | S | 263.62 | 263.98 | 0.36 |
| 41 | Springfield | Greene | SW | US 65 | S | 259.61 | 259.92 | 0.31 |
| 42 | Springfield | Greene | SW | US 65 | S | 265.77 | 266.54 | 0.77 |
| 43 | Grandview | Jackson | KC | IS 49 | N | 172.57 | 173.02 | 0.45 |
| 44 | Independence | Jackson | KC | IS 70 | E | 15.19 | 15.73 | 0.54 |
| 45 | Independence | Jackson | KC | IS 70 | E | 15.73 | 16.30 | 0.57 |
| 46 | St. Louis | St. Louis City | SL | IS 64 | E | 37.11 | 37.58 | 0.47 |
| 47 | Independence | Jackson | KC | IS 70 | E | 16.30 | 16.83 | 0.53 |
| 48 | Blue Springs | Jackson | KC | IS 70 | E | 17.06 | 17.66 | 0.60 |
| 49 | Blue Springs | Jackson | KC | IS 70 | E | 17.66 | 18.22 | 0.56 |
| 50 | Eureka | St. Louis | SL | IS 44 | E | 262.48 | 263.27 | 0.79 |
| 51 | Eureka | St. Louis | SL | IS 44 | E | 263.27 | 263.96 | 0.69 |
| 52 | Florissant | St. Louis | SL | IS 270 | E | 28.74 | 29.40 | 0.66 |
| 53 | Florissant | St. Louis | SL | IS 270 | E | 30.22 | 30.63 | 0.41 |
| 54 | Barnhart | Jefferson | SL | IS 55 | N | 184.06 | 184.60 | 0.54 |

## 7.5 Data Collection

A list of the data types collected for freeway segments, and their sources, is presented in Table 7.5. The TMS map application was used to obtain data regarding segment length, log miles, and crashes. ARAN and Google Earth were used to derive roadway and geometric data that were not available in TMS. This included data such as outside shoulder width, inside shoulder width, effective median width, barrier offset, proportion of segment length with median and outside barrier, outside barrier length, proportion of segment with type B weave section, proportion of segment with outside and inside rumble strips, and distance to the nearest upstream entrance ramp or downstream exit ramp. The locations of the beginning and end of ramp tapers and ramp gore areas were estimated from the continuous log mile provided in TMS map application. The ramp log mile locations were used to determine the location of speed change lanes, to calculate the effective segment length, and to calculate the distance to the nearest upstream entrance ramp and nearest downstream ramp. The effective median width was estimated graphically from aerial photographs (Google 2016). The horizontal curve radius and horizontal curve length were

estimated using the procedures described in chapter 3. It should be noted that for freeway segments, the curve length included only the portion of the curve that was within the segment limits. In addition, the curve side of the road (both roadbeds, left roadbed only, or right roadbed only) was also a required input. The HSM values for the base conditions were used for the clear zone width and proportion of high volume, since these data were not readily available from any sources.

**Table 7.5 List of data sources for freeway segments**

| Data Description | Source |
|---|---|
| AADT | TMS |
| Length (mi) | TMS |
| Effective Length (mi) | TMS/ARAN |
| Average Lane Width (ft) | TMS |
| Effective Median Width (ft) | Aerials |
| Average Inside Shoulder Width (ft) | ARAN |
| Average Outside Shoulder Width (ft) | ARAN |
| Proportion of Segment Length with Median Barrier | ARAN |
| Average Median Barrier Offset | ARAN |
| Outside Barrier Length (ft) | ARAN |
| Proportion of Segment Length with Outside Barrier | ARAN |
| Average Outside Barrier Offset (ft) | ARAN |
| Outside Clear Zone Width (ft) | HSM Default |
| Proportion of Segment with Inside Rumble Strips | ARAN |
| Proportion of Segment with Outside Rumble Strips | ARAN |
| Proportion of High Volume | HSM Default |
| Proportion of Weave | ARAN |
| Length of Weave | ARAN |
| Distance to Exit or Entrance Ramp | ARAN |
| Ramp AADT | TMS, Other Sources |
| Horizontal Curve Radius (ft) | Aerials |
| Horizontal Curve Length within Site (ft) | ARAN |
| Number of PDO SV Crashes | TMS |
| Number of PDO MV Crashes | TMS |
| Number of FI SV Crashes | TMS |
| Number of FI MV Crashes | TMS |

Several important considerations needed to be taken into account for the collection of freeway crash data. The first consideration relates to the classification of crashes that occurred within the limits of a speed-change lane. HSM mainline freeway models are divided into segments and speed-change lanes. A speed-change lane is either an entrance or an exit area with limits extending from the beginning or end of the taper to the gore point. It is worth noting that these facilities are separate from weaving sections because speed change lanes contain their own taper points while weaving sections typically do not. It is important to consider how crashes that occur

on freeway segments adjacent to ramps are to be treated. On the one hand, such crashes are physically located on a segment and not on a ramp; on the other, crashes occurring on mainline lanes adjacent to ramps could be the result of ramp traffic and associated with merging or diverging conflicts. In both Missouri and Illinois, crashes located on all lanes associated with ramps were excluded from the segment calibration, consistent with NCHRP 17-45. For example, a crash that occurred between the gore and the taper point would be excluded from segment calibration. Even though this approach identifies all speed-change-related crashes, it may also identify some freeway crashes that were not caused by speed-change lanes. To avoid the inclusion of crashes and the inconsistency in the location and assignment of crashes at interchange facilities, the freeway segments considered in this calibration did not include speed change lanes. Thus, segments were homogenous facilities that were limited by the taper of speed change lanes, if present.

In addition, it was necessary to separate the number of crashes by severity and the number of vehicles involved in the crash. As discussed in Section 7.3 on HSM methodology, HSM models single and multi-vehicle crashes separately. The TMS Accident Browser provides information regarding crash severity in its output. However, it does not provide information regarding the number of vehicles that were involved in a crash. Therefore, all crash reports that matched the accident browser crash queries, occurring between 2012-2014, were requested from MoDOT to retrieve the required information for the number of vehicles involved in crashes. In other words, for every crash occurring within a freeway segment, the number of vehicles involved was queried using the crash image number. Thus, this was a two stage crash data querying process where the crashes were identified first, and then the number of vehicles involved was then identified. Alternately, the crash data could have also been collected via an ODBC query that joined multiple tables (databases) so that all the relevant crash criteria, such as location, date, severity, and number of vehicles, could be queried simultaneously. This alternate approach was not used this time as there were technical problems with the ODBC connection.

7.5.1 Summary Statistics for Rural Four-Lane Freeway Segments

Descriptive statistics for rural four-lane freeway segments are shown in Table 7.6. The average AADT was 21,850 vpd, with a standard deviation of 8,021 vpd. Thus, the sample set contained a wide range of AADT values. The average effective length of the segments was 2.09 miles, with a standard deviation of 1 mile. The segments were relatively uniform with respect to lane width, inside shoulder width, and outside shoulder width. The average effective median width was 51 feet, with a standard deviation of 10 feet. Most of the segments contained a median barrier, as indicated by the average value of 0.65 for the proportion of segment with median barrier. Outside barriers were less common, as indicated by the average value of 0.1 for the proportion of segment with outside barrier.

**Table 7.6 Sample descriptive statistics for rural four-lane freeway segments**

| Description | Ave. | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| AADT(2013) | 21,850 | 4,336 | 39,777 | 8,021 |
| Length (mi) | 2.09 | 0.57 | 4.54 | 1.00 |
| Effective Length (mi) | 2.09 | 0.57 | 4.54 | 1.00 |
| Average Lane Width (ft) | 11.8 | 11.5 | 12 | 0.24 |
| Effective Median Width (ft) | 51 | 30 | 60 | 10 |
| Average Inside Shoulder Width (ft) | 4.1 | 3 | 6 | 0.8 |
| Average Outside Shoulder Width (ft) | 9.5 | 8 | 10.5 | 0.63 |
| Proportion of Segment Length with Median Barrier | 0.65 | 0.0 | 1.0 | 0.5 |
| Average Median Barrier Offset | 16.87 | 0.0 | 31.5 | 8.92 |
| Outside Barrier Length (ft) | 2,253 | 0 | 12,033 | 2,826 |
| Proportion of Segment Length with Outside Barrier | 0.10 | 0.00 | 0.46 | 0.10 |
| Average Outside Barrier Offset (ft) | 7.6 | 0.0 | 12 | 4 |
| Outside Clear Zone Width (ft) | 30 | 30 | 30 | 0 |
| Proportion of Segment with Inside Rumble Strips | 1.0 | 1.0 | 1.0 | 0.0 |
| Proportion of Segment with Outside Rumble Strips | 1.0 | 1.0 | 1.0 | 0.0 |
| Proportion of High Volume | 0 | 0 | 0 | 0 |
| Proportion of Weave Increasing Direction | 0 | 0 | 0 | 0 |
| Length of Weave Increasing Direction | 0 | 0 | 0 | 0 |
| Proportion of Weave Decreasing Direction | 0 | 0 | 0 | 0 |
| Length of Weave Decreasing Direction | 0 | 0 | 0 | 0 |
| Distance to Entrance Ramp Increasing Direction(ft) | 2,430 | 776 | 15,856 | 2,766 |
| AADT Entrance Ramp Increasing Direction (2013) | 891 | 76 | 5,082 | 1,049 |
| Distance to Exit Ramp Increasing Direction (ft) | 8,723 | 1,225 | 42,451 | 7,861 |
| AADT Exit Ramp Increasing Direction (2013) | 894 | 102 | 5,265 | 11,89 |
| Distance to Entrance Ramp Decreasing Direction (ft) | 8,715 | 1,109 | 42,541 | 7,940 |
| AADT Entrance Ramp Decreasing Direction (2013) | 877 | 89 | 4,885 | 1,119 |
| Distance to Exit Ramp Decreasing Direction (ft) | 2,471 | 803 | 15,814 | 2,733 |
| AADT Exit Ramp Decreasing Direction (2013) | 838 | 94 | 3,279 | 780 |
| Horizontal Curve Radius (ft) | 6,427 | 5,896 | 7,225 | 704 |
| Horizontal Curve Length within Site (ft) | 2,021 | 1,425 | 2,999 | 853 |
| Number of PDO SV Crashes | 14 | 0 | 47 | 11.8 |
| Number of PDO MV Crashes | 6.7 | 0 | 24 | 6.1 |
| Number of FI SV Crashes | 2.4 | 0 | 10 | 2.2 |
| Number of FI MV Crashes | 1.6 | 0 | 6 | 1.6 |

All of the segments contained both inside and outside rumble strips. None of the segments contained a type B weaving section. The average distance to the nearest upstream entrance ramp or downstream exit ramp varied from around 2,000 feet to 8,000 feet. The average ramp AADT was approximately 860 vpd. The segments had an average value of 6,427 feet for the horizontal curve radius. The average horizontal curve length within site was 2,021 feet.

## 7.5.2 Summary Statistics for Urban Four-Lane Freeway Segments

Descriptive statistics for urban four-lane freeway segments are shown in Table 7.7. The average AADT was 32,329 vpd, with a standard deviation of 14,898 vpd. Thus, the sample set contained a wide range of AADT values. The average effective length of the segments was 1.27 miles, with a standard deviation of 0.66 miles. The segments were relatively uniform with respect to lane width, inside shoulder width, and outside shoulder width. The average effective median width was 51 feet, with a standard deviation of 11.22 feet. Most of the segments contained median barriers, as indicated by the average value of 0.77 for the proportion of segment with median barrier. Outside barriers were less common, as indicated by the average value of 0.16 for the proportion of segment with outside barrier.

**Table 7.7 Sample descriptive statistics for urban four-lane freeway segments**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| AADT (2012-2014) | 32,329 | 5,030 | 38,383 | 14,898 |
| Effective Length (mi) | 1.27 | 0.50 | 3.54 | 0.66 |
| Average Lane Width (ft) | 12.00 | 12.00 | 12.50 | 0.19 |
| Effective Median Width (ft) | 51.00 | 40.00 | 90.00 | 11.22 |
| Average Inside Shoulder Width (ft) | 4.89 | 3.00 | 12.00 | 1.63 |
| Average Outside Shoulder Width (ft) | 9.66 | 8.00 | 12.00 | 0.80 |
| Proportion of Segment Length with Median Barrier | 0.77 | 0.00 | 1.00 | 0.41 |
| Average Median Barrier Offset (ft) | 18.67 | 0.00 | 29.75 | 8.76 |
| Proportion of Segment Length with Outside Barrier | 0.16 | 0.00 | 0.53 | 0.16 |
| Average Outside Barrier Offset (ft) | 7.33 | 0.00 | 13.00 | 4.35 |
| Outside Clear Zone Width (ft) | 30.00 | 30.00 | 30.00 | 0.00 |
| Proportion of Segment with Inside Rumble Strips | 1.00 | 1.00 | 1.00 | 0.00 |
| Proportion of Segment with Outside Rumble Strips | 1.00 | 1.00 | 1.00 | 0.00 |
| Proportion of High Volume (2012-2014) | 0.04 | 0.00 | 0.49 | 0.12 |
| Proportion of Weave Increasing Direction | 0.00 | 0.00 | 0.00 | 0.00 |
| Length of Weave Increasing Direction (ft) | 0.00 | 0.00 | 0.00 | 0.00 |
| Proportion of Weave Decreasing Direction | 0.00 | 0.00 | 0.00 | 0.00 |
| Length of Weave Decreasing Direction (ft) | 0.00 | 0.00 | 0.00 | 0.00 |
| Distance to Entrance Ramp Increasing Direction (ft) | 2,371 | 401 | 23,237 | 4,510 |
| AADT Entrance Ramp Increasing Direction (2012-2014) | 2,632 | 146 | 6,912 | 1,697 |
| Distance to Exit Ramp Increasing Direction (ft) | 2,905 | 259 | 39,109 | 6,847 |
| AADT Exit Ramp Increasing Direction (2012-2014) | 2,625 | 276 | 6,495 | 1,800 |
| Distance to Entrance Ramp Decreasing Direction (ft) | 4,353 | 533 | 58,307 | 11,042 |
| AADT Entrance Ramp Decreasing Direction (2012-2014) | 2,561 | 262 | 6,268 | 1,688 |
| Distance to Exit Ramp Decreasing Direction (ft) | 2,247 | 290 | 22,994 | 4,498 |
| AADT Exit Ramp Decreasing Direction (2012-2014) | 2,693 | 135 | 7,735 | 1,836 |
| Horizontal Curve Radius (ft) | 5,592 | 1,928 | 17,024 | 3,802 |
| Horizontal Curve Length within Site (ft) | 2,316 | 829 | 7,810 | 1,743 |
| Number of FI MV Crashes | 2.44 | 0.00 | 12 | 2.86 |
| Number of FI SV Crashes | 2.32 | 0.00 | 7 | 1.63 |
| Number of PDO MV Crashes | 8.85 | 0.00 | 43 | 10.31 |
| Number of PDO SV Crashes | 10.59 | 0.00 | 37 | 8.01 |

All of the segments contained both inside and outside rumble strips. None of the segments contained a type B weaving section. The average distance to the nearest upstream entrance ramp or downstream exit ramp varied from around 2,000 feet to 3,000 feet. As expected, the distance to the nearest ramp is shorter for the urban segments as compared to the rural segments. The average ramp AADT was approximately 2,600 vpd. The segments had an average value of 5,592 feet for the horizontal curve radius.

7.5.3 Summary Statistics for Urban Six-Lane Freeway Segments

Descriptive statistics for urban six-lane freeway segments are shown in Table 7.8. The average bidirectional AADT was 88,875 vpd, with a standard deviation of 28,380 vpd. The average effective length of the segments was 0.69 miles, with a standard deviation of 0.30 miles. The segments were relatively uniform with respect to lane width, inside shoulder width, and outside shoulder width with the exception of one site containing a comparatively large inside shoulder. The average effective median width was 21.90 feet with a standard deviation of 9.45 feet. This large standard deviation is possibly due to the site containing a large inside shoulder and, in turn, a relatively large effective median when compared to the rest of the sites. All 54 sites contained a median barrier of some sort, as indicated by the descriptive statistics for the proportion of segment with median barrier with an average, minimum, and maximum of 1.00. The presence of outside barriers was less common, as indicated by the average value of 0.30 for the proportion of segment with outside barrier, and was not consistent as evidenced by the 0.27 standard deviation value.

**Table 7.8 Sample descriptive statistics for urban six-lane freeway segments**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| Bidirectional AADT (2012-2014) | 88,875 | 41,693 | 177,020 | 28,380 |
| Effective Length (mi) | 0.69 | 0.31 | 1.88 | 0.30 |
| Average Lane Width (ft) | 11.81 | 10.00 | 12.80 | 0.63 |
| Effective Median Width (ft) | 21.90 | 10.00 | 46.50 | 9.45 |
| Average Inside Shoulder Width (ft) | 8.52 | 4.00 | 17.50 | 2.87 |
| Average Outside Shoulder Width (ft) | 10.55 | 5.00 | 14.30 | 1.67 |
| Proportion of Segment Length with Median Barrier | 1.00 | 1.00 | 1.00 | 0.00 |
| Average Median Barrier Offset (ft) | 10.10 | 3.29 | 23.00 | 4.44 |
| Proportion of Segment Length with Outside Barrier | 0.30 | 0.00 | 1.00 | 0.27 |
| Average Outside Barrier Offset (ft) | 12.16 | 8.15 | 49.80 | 7.15 |
| Outside Clear Zone Width (ft) | 54.81 | 10.00 | 190.00 | 34.56 |
| Proportion of Segment with Inside Rumble Strips | 0.74 | 0.00 | 1.00 | 0.39 |
| Proportion of Segment with Outside Rumble Strips | 0.73 | 0.00 | 1.00 | 0.40 |
| Proportion of High Volume (2012-2014) | 0.31 | 0.00 | 0.89 | 0.27 |
| Proportion of Weave Increasing Direction | 0.07 | 0.00 | 0.94 | 0.18 |
| Length of Weave Increasing Direction (ft) | 203.65 | 0.00 | 2,821.00 | 543.65 |
| Proportion of Weave Decreasing Direction | 0.06 | 0.00 | 0.84 | 0.19 |
| Length of Weave Decreasing Direction (ft) | 179.85 | 0.00 | 2,529.00 | 538.92 |
| Distance to Entrance Ramp Increasing Direction (ft) | 2,779 | 576 | 14,974 | 2,814 |
| AADT Entrance Ramp Increasing Direction (2012-2014) | 4,648 | 353 | 15,131 | 3,438 |
| Distance to Exit Ramp Increasing Direction (ft) | 2,741 | 195 | 9,911 | 2,328 |
| AADT Exit Ramp Increasing Direction (2012-2014) | 5,231 | 559 | 13,939 | 3,010 |
| Distance to Entrance Ramp Decreasing Direction (ft) | 3,044 | 69 | 13,337 | 2,747 |
| AADT Entrance Ramp Decreasing Direction (2012-2014) | 4,802 | 472 | 14,242 | 2,995 |
| Distance to Exit Ramp Decreasing Direction (ft) | 2,946 | 327 | 15,074 | 2,938 |
| AADT Exit Ramp Decreasing Direction (2012-2014) | 5,337 | 222 | 14,026 | 3,346 |
| Horizontal Curve Radius (ft) | 6,257 | 1,713 | 37,262 | 9,363 |
| Horizontal Curve Length within Site (ft) | 1,375 | 488 | 2,561 | 708 |
| Number of Observed FI MV Crashes | 7.61 | 0.00 | 41.00 | 7.68 |
| Number of Observed FI SV Crashes | 3.50 | 0.00 | 10.00 | 1.99 |
| Number of Observed PDO MV Crashes | 23.72 | 0.00 | 94.00 | 20.63 |
| Number of Observed PDO SV Crashes | 8.20 | 0.00 | 21.00 | 5.42 |

## 7.6 Results and Discussion

The original HSM models were developed using data from California, Maine, and Washington (Bonneson et al. 2012). Some descriptive statistics for the data used to develop the HSM model for freeway segments are shown in Table 7.9. In summary, the HSM freeway data consisted of

1,880 segments covering 510 miles in three different states. The crash data included crashes between 2005 and 2007 for Washington and California, and between 2004 and 2006 for Maine.

**Table 7.9 Descriptive statistics for HSM freeway data**

| State | Number of Segments | Total Length (mi) | Minimum AADT (vpd) | Maximum AADT (vpd) |
|---|---|---|---|---|
| California | 533 | 209 | 17,000 | 308,000 |
| Maine | 203 | 101 | 11,300 | 83,700 |
| Washington | 1,144 | 200 | 9,600 | 197,000 |

7.6.1 Results for Rural Four-Lane Freeway Segments

7.6.1.1 Calibration Factors

The calibration factors for rural four-lane freeway segments are shown in Table 7.10. The IHSDM output is shown in Figures 7.13-7.16. These results indicate that the number of property-damage-only crashes for single/multiple-vehicle crashes observed in Missouri was greater than the number of crashes predicted by the HSM freeway methodology, while the number of fatal/injury crashes for single/multiple-vehicle crashes were less than the number of crashes predicted by the HSM methodology. Some possible reasons for the calibration values deviating from 1.0 include differences in driver behavior, difference in PDO crash reporting, and the sampling of segments with or without speed change lanes. The PDO reporting threshold for California, Washington, and Maine are all higher than the $500 used in Missouri.

**Table 7.10 Calibration results for rural four-lane freeway segments**

| No. | Dist[1]. | Segment | Begin Log | Length | FI[2] | | | | PDO[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MV | | SV | | MV | | SV | |
| | | | | | Obs[4] | Prd[5] | Obs | Prd | Obs | Prd | Obs | Prd |
| 1 | CD | IS 44 | 211.188 | 1.685 | 0 | 2.26 | 2 | 5.53 | 6 | 4.14 | 26 | 12.05 |
| 2 | CD | IS 44 | 204.59 | 2.536 | 0 | 2.9 | 2 | 6.78 | 11 | 5.01 | 32 | 16.06 |
| 3 | CD | IS 44 | 146.065 | 2.79 | 6 | 3.11 | 4 | 6.79 | 6 | 5.26 | 27 | 17.19 |
| 4 | CD | US 40 | 138.93 | 1.952 | 1 | 3.43 | 3 | 6.8 | 19 | 6.62 | 22 | 15.9 |
| 5 | CD | US 40 | 94.344 | 3.803 | 1 | 4.03 | 10 | 10.28 | 15 | 6.7 | 33 | 22.68 |
| 6 | CD | IS 70 | 106.82 | 2.93 | 1 | 4.26 | 9 | 9.28 | 10 | 7.98 | 19 | 21.28 |
| 7 | CD | IS 70 | 118.05 | 2.625 | 2 | 3.98 | 6 | 8.13 | 16 | 7.62 | 32 | 19.29 |
| 8 | SW | IS 44 | 67.33 | 0.92 | 1 | 1.89 | 1 | 2.97 | 5 | 3.94 | 6 | 8.04 |
| 9 | SW | IS 44 | 47.45 | 1.376 | 2 | 1.61 | 5 | 3.99 | 8 | 2.89 | 5 | 8.57 |
| 10 | SW | IS 44 | 34.04 | 2.471 | 0 | 2.56 | 3 | 6.81 | 8 | 4.43 | 13 | 14.3 |
| 11 | SW | IS 44 | 19.022 | 1.196 | 2 | 1.41 | 0 | 3.35 | 7 | 2.54 | 4 | 7.43 |
| 12 | SW | US 71 | 278.98 | 0.586 | 0 | 0.29 | 1 | 1.1 | 2 | 0.39 | 2 | 2.16 |
| 13 | SW | US 71 | 286.881 | 1.809 | 0 | 0.8 | 1 | 3.48 | 0 | 1.03 | 5 | 6.55 |
| 14 | SW | US 71 | 303.868 | 1.004 | 0 | 0.19 | 1 | 1.25 | 1 | 0.19 | 0 | 2.11 |
| 15 | KC | US 40 | 47.042 | 1.846 | 1 | 2.29 | 2 | 5.71 | 8 | 4.13 | 15 | 12.16 |
| 16 | KC | US 40 | 60.971 | 1.784 | 2 | 1.67 | 0 | 4.15 | 3 | 2.76 | 15 | 9.94 |
| 17 | KC | US 40 | 72.979 | 1.891 | 3 | 1.6 | 3 | 4.19 | 6 | 2.53 | 19 | 9.65 |
| 18 | KC | US 71 | 83.685 | 0.829 | 3 | 0.98 | 1 | 2.08 | 5 | 1.69 | 7 | 5.2 |
| 19 | KC | US 71 | 160.785 | 1.63 | 0 | 0.88 | 2 | 3.25 | 2 | 1.25 | 2 | 6.4 |
| 20 | KC | US 71 | 89.532 | 2.122 | 2 | 2.57 | 2 | 5.5 | 12 | 4.53 | 18 | 13.46 |
| 21 | KC | US 40 | 79.968 | 2.97 | 3 | 3.08 | 3 | 7.56 | 17 | 5.24 | 32 | 17.48 |
| 22 | NE | IS 70 | 181.709 | 1.647 | 3 | 2.28 | 3 | 4.89 | 15 | 4.23 | 15 | 11.5 |
| 23 | NE | IS 70 | 175.506 | 2.159 | 4 | 3.29 | 3 | 6.35 | 6 | 6.15 | 24 | 15.72 |
| 24 | NE | IS 70 | 170.83 | 3.541 | 2 | 3.28 | 3 | 8.32 | 16 | 5.42 | 27 | 19.48 |
| 25 | SW | US 71 | 293.461 | 1.513 | 0 | 0.63 | 1 | 2.67 | 0 | 0.81 | 0 | 5.06 |
| 26 | SW | US 71 | 264.06 | 0.658 | 1 | 0.3 | 0 | 1.12 | 3 | 0.39 | 1 | 2.3 |
| 27 | NW | IS 35 | 8.296 | 2.966 | 0 | 0.93 | 2 | 4.36 | 2 | 1.14 | 6 | 8.45 |
| 28 | NW | IS 35 | 22.391 | 1.799 | 0 | 0.65 | 1 | 2.71 | 0 | 0.82 | 4 | 5.54 |
| 29 | NW | US 71 | 78.062 | 4.435 | 5 | 5 | 6 | 11.3 | 24 | 8.8 | 47 | 27.41 |
| 30 | NW | US 71 | 57.157 | 0.741 | 2 | 0.42 | 1 | 1.46 | 2 | 0.6 | 4 | 3.02 |
| 31 | NW | IS 229 | 0.851 | 0.748 | 0 | 0.05 | 0 | 0.63 | 0 | 0.04 | 0 | 0.9 |
| 32 | NW | IS 29 | 56.937 | 1.448 | 2 | 0.68 | 2 | 2.74 | 2 | 0.91 | 11 | 5.4 |
| 33 | NW | IS 29 | 25.313 | 1.552 | 0 | 0.51 | 2 | 2.32 | 0 | 0.62 | 2 | 4.58 |
| 34 | NW | IS 35 | 14.897 | 1.283 | 0 | 0.48 | 2 | 2.07 | 1 | 0.62 | 1 | 4.09 |
| 35 | NW | IS 35 | 34.303 | 1.27 | 0 | 0.46 | 0 | 2.02 | 0 | 0.58 | 1 | 3.96 |

**Table 7.10 Continued**

| No. | Dist[1]. | Segment | Begin Log | Length | FI[2] | | | | PDO[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MV | | SV | | MV | | SV | |
| | | | | | Obs[4] | Prd[5] | Obs | Prd | Obs | Prd | Obs | Prd |
| 36 | SE | IS 55 | 129.384 | 2.815 | 4 | 1.84 | 5 | 5.88 | 4 | 2.71 | 21 | 12.74 |
| 37 | SE | IS 55 | 177.398 | 2.185 | 1 | 1.46 | 1 | 4.68 | 9 | 2.18 | 10 | 9.99 |
| 38 | SE | IS 55 | 202.256 | 1.867 | 0 | 0.96 | 0 | 3.47 | 1 | 1.29 | 6 | 7.23 |
| 39 | SE | US 60 | 322.889 | 3.697 | 5 | 1.59 | 1 | 6.68 | 4 | 2.12 | 13 | 12.72 |
| 40 | SE | IS 55 | 152.133 | 4.543 | 3 | 2.87 | 3 | 9.43 | 10 | 4.16 | 23 | 20.29 |
| 41 | SE | IS 55 | 86.241 | 3.404 | 1 | 1.93 | 3 | 6.38 | 6 | 2.66 | 21 | 13.98 |
| 42 | SE | US 60 | 317.408 | 3.502 | 2 | 1.65 | 3 | 6.62 | 5 | 2.26 | 5 | 12.76 |
| 43 | SL | IS 55 | 39.522 | 0.574 | 0 | 0.42 | 1 | 1.26 | 1 | 0.64 | 4 | 2.69 |
| 44 | CD | IS 70 | 138.267 | 3.139 | 4 | 3.05 | 3 | 7.75 | 17 | 5.11 | 32 | 17.76 |
| 45 | CD | IS 70 | 144.602 | 1.701 | 1 | 2.94 | 3 | 5.38 | 7 | 5.82 | 19 | 13.53 |
| **Sum** | | | | | 70 | 83.46 | 110 | 219.47 | 302 | 141 | 631 | 489 |
| **Calibration Factors** | | | | | **0.839** | | **0.501** | | **2.143** | | **1.290** | |

Notes: [1]District, [2]Fatal and Injury, [3]Property Damage Only, [4]Observed crashes, and [5]Predicted crashes.
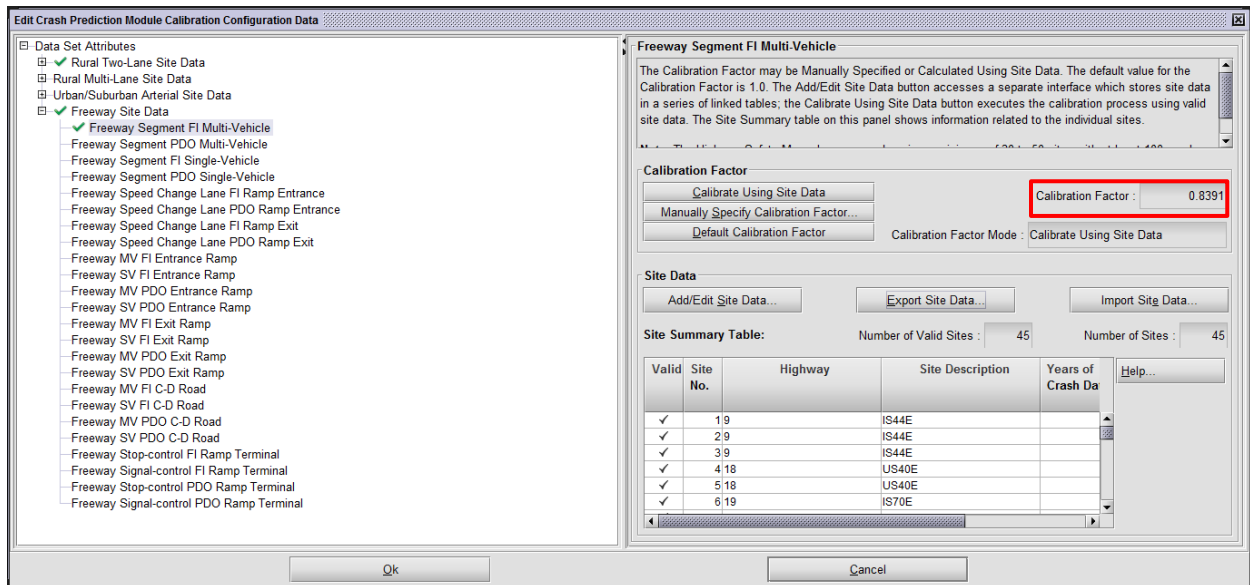


**Figure 7.13 Calibration output for rural four-lane freeways (FI multi-vehicle)**
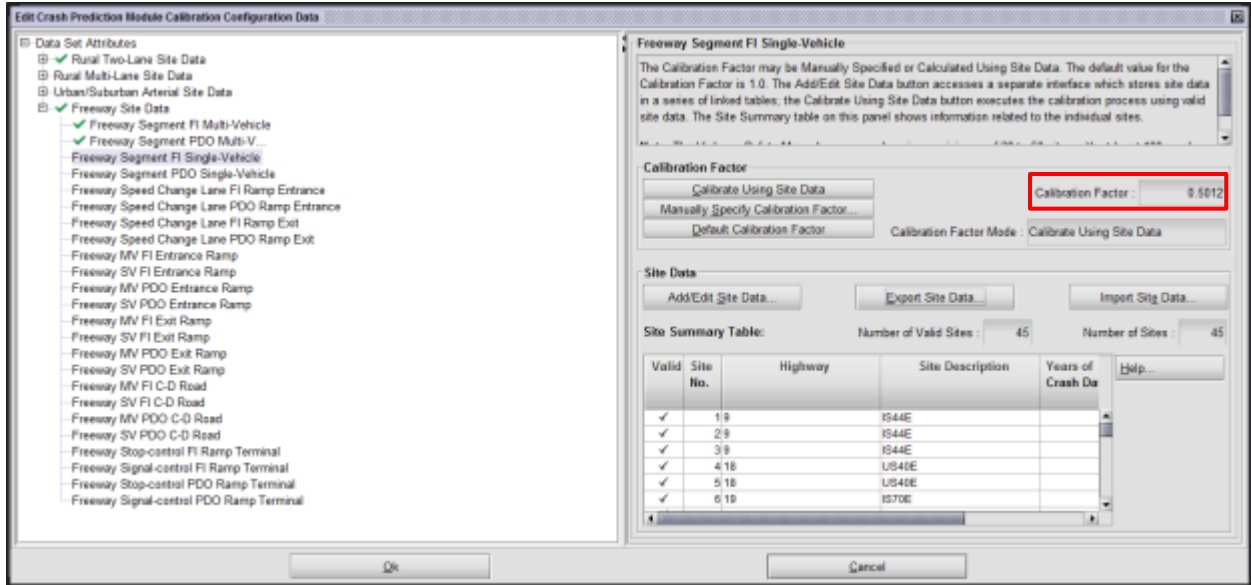
**Figure 7.14 Calibration output for rural four-lane freeways (FI single-vehicle)**
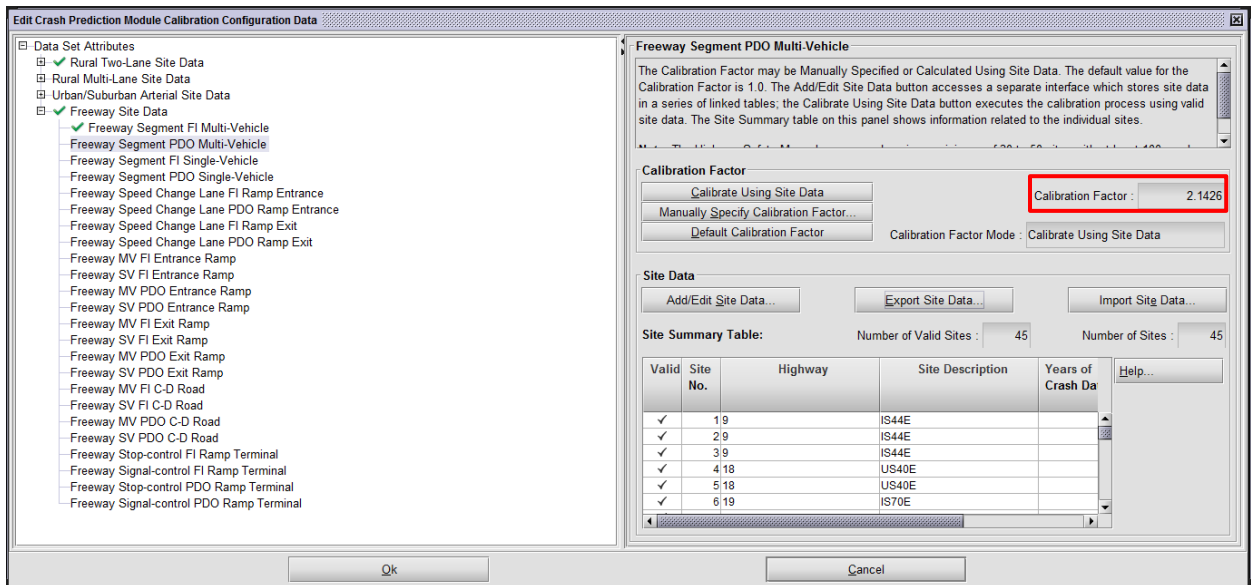


**Figure 7.15 Calibration output for rural four-lane freeways (PDO multi-vehicle)**
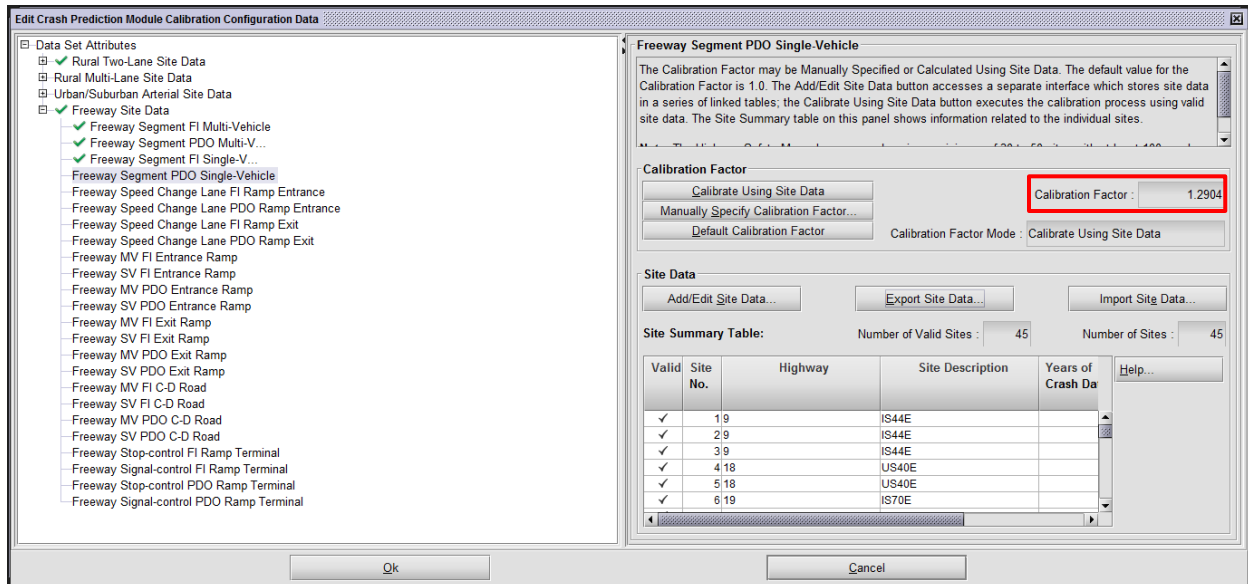
**Figure 7.16 Calibration output for rural four-lane freeways (PDO single-vehicle)**

7.6.1.2 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 7.11 shows the obtained SDFs for rural four-lane freeway segments.

**Table 7.11 Severity distribution factors for rural four-lane freeway segments**

| Severity | MV | | SV | |
|---|---|---|---|---|
| | Crashes | SDF | Crashes | SDF |
| Fatal | 5 | 0.014 | 1 | 0.001 |
| Disabling Injury | 11 | 0.030 | 19 | 0.026 |
| Minor Injury | 54 | 0.146 | 90 | 0.121 |
| Property Damage Only | 300 | 0.811 | 633 | 0.852 |

7.6.1.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of predicted crashes according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since HSM and Missouri crash type categories differed. Therefore, different categories were aggregated to provide similar classifications than those recommended by the HSM. The crash types were also divided by multiple and single vehicle crashes. Table 7.12 provides the CDFs for rural four-lane freeway segments.

**Table 7.12 Crash type distribution factors for rural four-lane freeway segments**

| Multiple-Vehicle | | |
|---|---|---|
| **Collision Type** | **Crashes** | **CDF** |
| Head-on | 0 | 0 |
| Angle | 1 | 0.003 |
| Rear-End | 151 | 0.408 |
| Sideswipe | 123 | 0.332 |
| Other | 95 | 0.257 |
| Single-Vehicle | | |
| **Collision Type** | **Crashes** | **CDF** |
| Crash with Parked Vehicle | 0 | 0 |
| Crash with Fixed Objective | 14 | 0.019 |
| Crash with Animal | 89 | 0.120 |
| Out of Control | 536 | 0.721 |
| Others | 104 | 0.140 |

7.6.2 Results for Urban Four-Lane Freeway Segments

7.6.2.1 Calibration Factors

The calibration factors for urban four-lane freeway segments are shown in Table 7.13. The IHSDM output is shown in Figures 7.17-7.20. These results indicate that the number of property-damage-only crashes observed in Missouri, both single and multiple vehicle, were greater than the number of crashes predicted by the HSM freeway methodology, while the number of fatal/injury crashes, both single and multiple vehicle, were less than the number of crashes predicted by the HSM methodology. Some possible reasons for the calibration values deviating from 1.0 include differences in driver behavior, difference in PDO crash reporting, and the sampling of segments with or without speed change lanes. Again, the higher PDO reporting thresholds used for the HSM model states is one explanation for the PDO calibration factors being greater than 1.0.

**Table 7.13 Calibration results for urban four-lane freeway segments**

| No. | Dist.[1] | Segment | Begin Log | Length (mi) | FI[2] | | | | PDO[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MV | | SV | | MV | | SV | |
| | | | | | Obs[4] | Prd[5] | Obs | Prd | Obs | Prd | Obs | Prd |
| 1 | CD | IS 44 E | 127.71 | 1.10 | 1 | 2 | 1 | 3 | 1 | 4 | 5 | 7 |
| 2 | CD | IS 44 E | 129.38 | 0.50 | 0 | 1 | 2 | 1 | 1 | 1 | 3 | 3 |
| 3 | CD | US 50 E | 134.93 | 0.71 | 2 | 1 | 1 | 2 | 1 | 1 | 4 | 4 |
| 4 | CD | US 50 E | 136.27 | 0.72 | 1 | 2 | 3 | 2 | 5 | 4 | 2 | 7 |
| 5 | CD | IS 44 E | 223.10 | 1.07 | 1 | 2 | 2 | 3 | 5 | 3 | 8 | 7 |
| 6 | CD | IS 44 E | 102.10 | 1.08 | 1 | 2 | 1 | 3 | 3 | 3 | 18 | 7 |
| 7 | KC | IS 70 E | 154.00 | 0.51 | 0 | 1 | 2 | 1 | 5 | 2 | 10 | 4 |
| 8 | KC | US 71 S | 145.18 | 0.69 | 1 | 2 | 3 | 2 | 7 | 3 | 8 | 5 |
| 9 | KC | US 71 S | 7.66 | 0.99 | 4 | 5 | 2 | 4 | 6 | 11 | 6 | 10 |
| 10 | KC | US 169 N | 9.37 | 1.22 | 1 | 4 | 3 | 4 | 3 | 6 | 10 | 10 |
| 11 | KC | US 169 N | 1.89 | 1.51 | 0 | 0 | 0 | 2 | 1 | 0 | 8 | 3 |
| 12 | KC | MO 152 E | 176.59 | 1.12 | 3 | 3 | 3 | 4 | 4 | 5 | 11 | 8 |
| 13 | KC | US 71 N | 23.69 | 0.76 | 9 | 6 | 1 | 4 | 31 | 13 | 11 | 8 |
| 14 | KC | MO 291 N | 25.60 | 0.94 | 8 | 8 | 5 | 5 | 41 | 17 | 14 | 10 |
| 15 | KC | MO 291 N | 22.49 | 2.36 | 0 | 3 | 0 | 7 | 3 | 4 | 10 | 13 |
| 16 | NE | IS 435 S | 189.71 | 0.59 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 2 |
| 17 | NE | US 36 E | 193.83 | 1.00 | 2 | 3 | 2 | 4 | 7 | 6 | 29 | 9 |
| 18 | NE | IS 70 E | 188.28 | 0.72 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 2 |
| 19 | NW | US 36 E | 52.94 | 1.91 | 0 | 4 | 5 | 6 | 16 | 7 | 24 | 14 |
| 20 | NW | IS 70 E | 51.04 | 1.18 | 2 | 3 | 2 | 4 | 9 | 5 | 13 | 9 |
| 21 | NW | IS 64 E | 13.36 | 0.68 | 1 | 1 | 3 | 1 | 3 | 1 | 8 | 3 |
| 22 | NW | IS 64 E | 49.25 | 1.02 | 1 | 3 | 0 | 3 | 9 | 5 | 10 | 8 |
| 23 | NW | IS 64 E | 4.22 | 0.53 | 0 | 1 | 0 | 1 | 0 | 1 | 2 | 3 |
| 24 | NW | IS 29 N | 7.99 | 1.15 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 2 |
| 25 | SE | IS 29 N | 90.22 | 1.13 | 5 | 2 | 3 | 3 | 7 | 4 | 5 | 8 |
| 26 | SE | IS 229 S | 100.32 | 1.48 | 4 | 3 | 2 | 4 | 4 | 4 | 12 | 9 |
| 27 | SE | IS 29 N | 69.77 | 3.54 | 3 | 3 | 2 | 7 | 4 | 4 | 23 | 14 |
| 28 | SE | US 36 E | 96.85 | 2.63 | 3 | 6 | 4 | 7 | 17 | 9 | 15 | 17 |
| 29 | SL | IS 229 N | 224.84 | 0.69 | 3 | 1 | 1 | 2 | 4 | 2 | 7 | 4 |
| 30 | SL | IS 55 N | 205.34 | 2.48 | 2 | 13 | 5 | 11 | 22 | 24 | 37 | 25 |
| 31 | SL | IS 55 N | 1.87 | 1.03 | 6 | 4 | 2 | 4 | 20 | 8 | 5 | 10 |
| 32 | SL | IS 55 N | 4.81 | 1.08 | 5 | 5 | 1 | 3 | 12 | 9 | 11 | 9 |
| 33 | SL | IS 55 N | 7.05 | 2.22 | 12 | 14 | 4 | 9 | 43 | 28 | 24 | 20 |
| 34 | SL | IS 44 E | 240.75 | 1.11 | 0 | 3 | 1 | 3 | 4 | 4 | 9 | 8 |
| 35 | SL | IS 44 W | 42.54 | 1.46 | 3 | 5 | 3 | 5 | 13 | 8 | 22 | 13 |
| 36 | SL | IS 55 N | 177.03 | 1.33 | 6 | 6 | 4 | 5 | 20 | 11 | 9 | 13 |
| 37 | SW | IS 44 E | 7.03 | 1.28 | 0 | 3 | 5 | 4 | 3 | 4 | 11 | 9 |
| 38 | SW | IS 44 E | 9.79 | 1.46 | 0 | 2 | 3 | 4 | 8 | 4 | 6 | 8 |
| 39 | SW | US 160 E | 96.12 | 1.75 | 7 | 5 | 7 | 6 | 4 | 8 | 8 | 15 |
| 40 | SW | US 71 N | 56.16 | 0.94 | 0 | 1 | 1 | 2 | 2 | 1 | 3 | 4 |
| 41 | SW | US 65 N | 38.82 | 2.34 | 3 | 7 | 3 | 8 | 14 | 13 | 11 | 19 |
| **Sum** | | | | | **100** | **141** | **95** | **158** | **363** | **248** | **434** | **362** |
| **Calibration Factors** | | | | | **0.708** | | **0.603** | | **1.461** | | **1.200** | |

Notes: [1]District, [2]Fatal and Injury, [3]Property Damage Only, [4]Observed crashes, and [5]Predicted crashes.
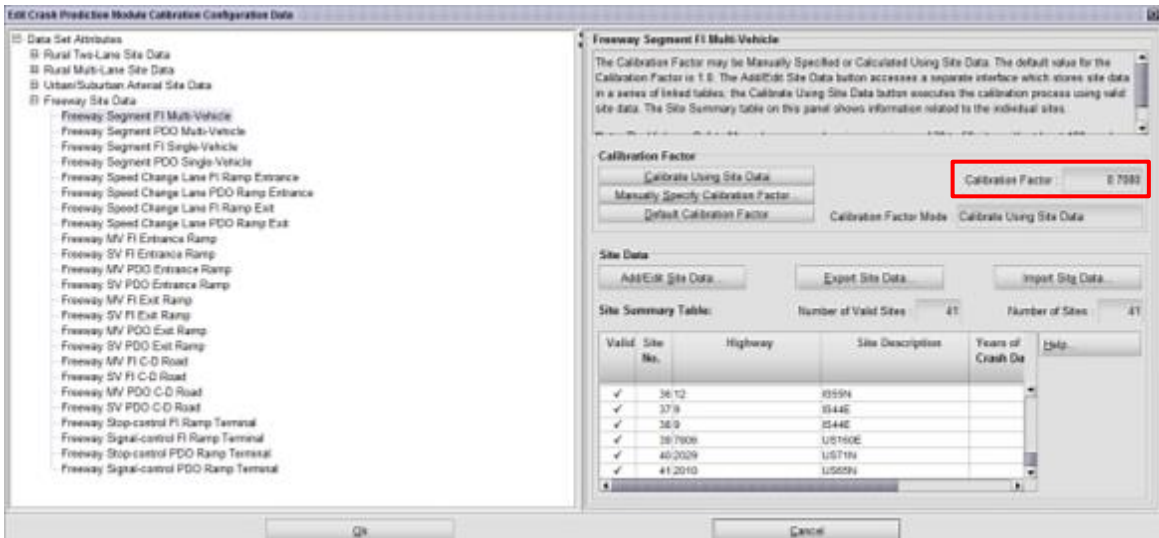
**Figure 7.17 Calibration output for urban four-lane freeways (FI multi-vehicle)**
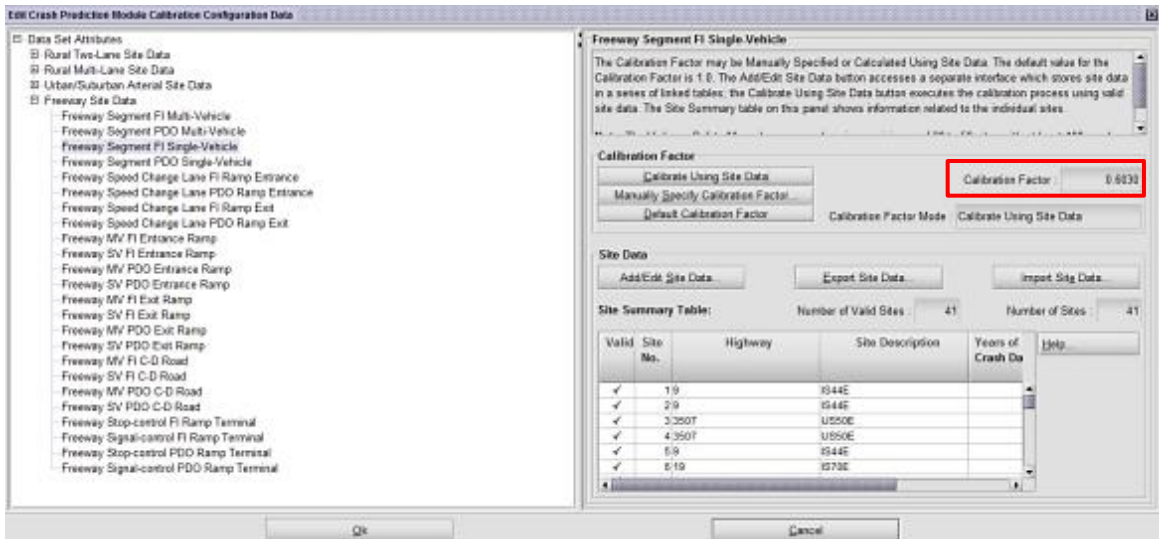


**Figure 7.18 Calibration output for urban four-lane freeways (FI single-vehicle)**
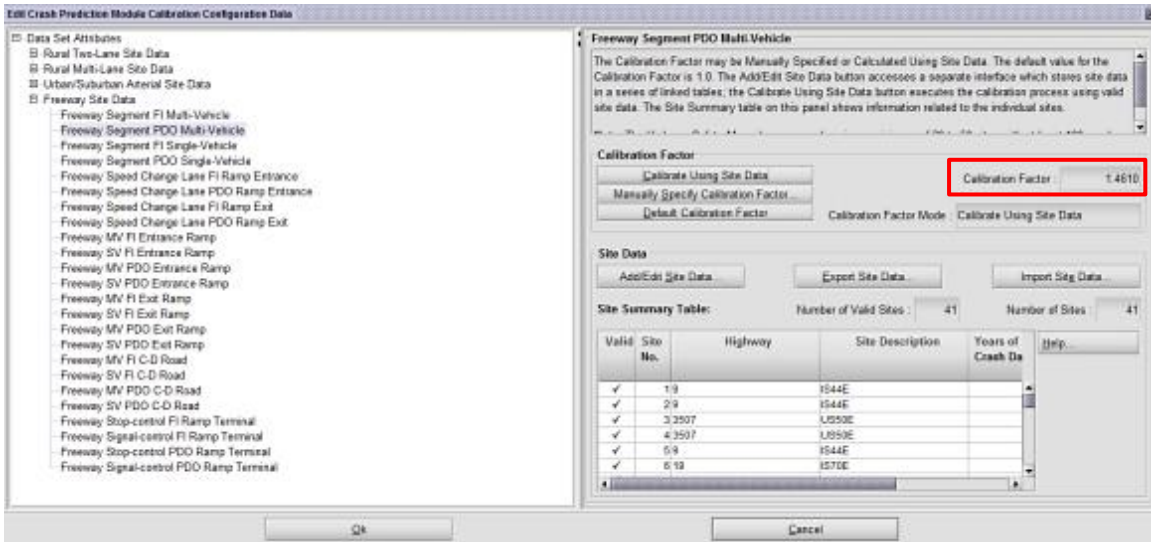
**Figure 7.19 Calibration output for urban four-lane freeways (PDO multi-vehicle)**
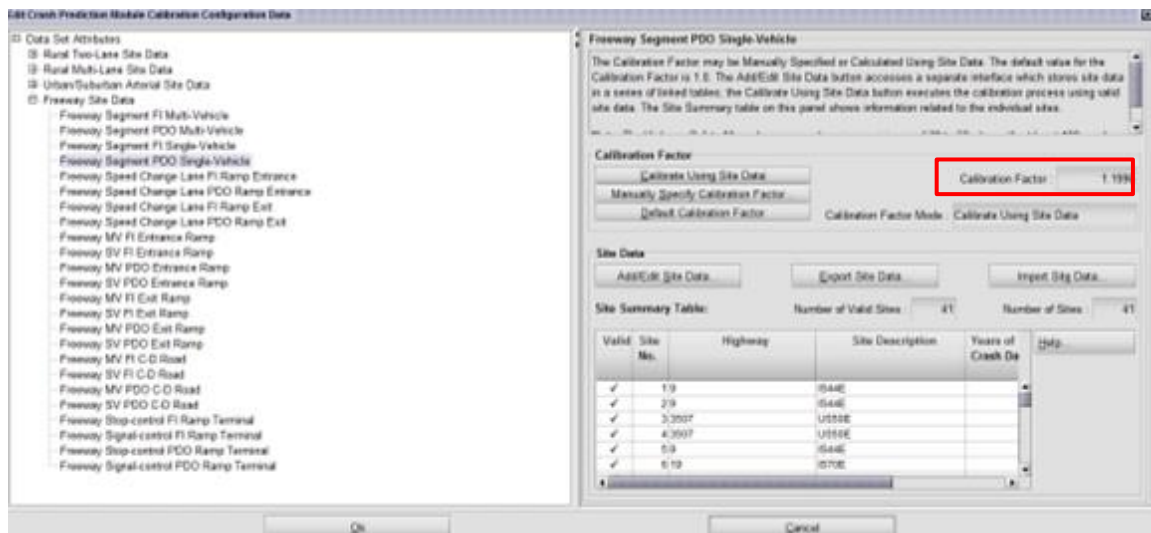


**Figure 7.20 Calibration output for urban four-lane freeways (PDO single-vehicle)**

7.6.2.2 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 7.14 shows the obtained SDFs for urban four-lane freeway segments.

112

**Table 7.14 Severity Distribution Factors for urban four-lane freeway segments**

| Severity | MV | | SV | |
|---|---|---|---|---|
| | Crashes | SDF | Crashes | SDF |
| Fatal | 4 | 0.009 | 6 | 0.011 |
| Disabling Injury | 14 | 0.030 | 17 | 0.032 |
| Minor Injury | 82 | 0.177 | 72 | 0.136 |
| Property Damage Only | 363 | 0.784 | 434 | 0.820 |

7.6.2.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of crashes from the prediction according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since HSM and Missouri crash type categories differed. Therefore, different categories were aggregated to provide similar classifications as those recommended by the HSM. The crash types were also divided by multiple and single vehicle crashes. Table 7.15 provides the CDFs for urban four-lane freeway segments.

**Table 7.15 Crash type distribution factors for urban four-lane freeway segments**

| Multiple-Vehicle | | |
|---|---|---|
| Collision Type | Crashes | CDF |
| Angle | 2 | 0.004 |
| Head-on | 7 | 0.016 |
| Sideswipe | 105 | 0.233 |
| Rear-end | 252 | 0.560 |
| Other | 84 | 0.187 |
| Single-Vehicle | | |
| Collision Type | Crashes | CDF |
| Crash with Parked Vehicle | 13 | 0.024 |
| Crash with Fixed Object | 16 | 0.030 |
| Crash with Animal | 83 | 0.154 |
| Out of Control | 370 | 0.688 |
| Other | 56 | 0.104 |

7.6.3 Results for Urban Six-Lane Freeway Segments

7.6.3.1 Calibration Factors

The calibration factors for urban six-lane freeway segments are shown in Table 7.16. The IHSDM output is shown in Figures 7.21-7.24. These results indicate that the number of property-damage-only multiple vehicle crashes observed in Missouri was greater than the number of crashes predicted by the HSM freeway methodology, while the number of property-damage-only

single vehicle crashes, fatal/injury single-vehicle crashes, and fatal/injury multiple vehicle crashes were less than the number of crashes predicted by the HSM methodology. There could be many reasons for these differences, as was discussed previously in the section detailing the results for four-lane freeways. However, it is important to note that the sites for this HSM calibration did not contain any speed-change lane facilities and contained longer freeway segments on average compared to the previous calibration efforts. Additionally, the introduction of the high volume proportion parameter was new to this calibration as well and contributed to the difference in results for this facility type.

**Table 7.16 Calibration results for urban six-lane freeway segments**

| No. | Dist.[1] | Segment | Begin Log | Length (mi) | FI[2] | | | | PDO[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MV | | SV | | MV | | SV | |
| | | | | | Obs4 | Prd5 | Obs | Prd | Obs | Prd | Obs | Prd |
| 1 | KC | IS 70 E | 11.57 | 0.80 | 10 | 14 | 6 | 4 | 30 | 32 | 7 | 12 |
| 2 | KC | IS 70 E | 12.93 | 0.82 | 18 | 16 | 5 | 5 | 29 | 36 | 2 | 13 |
| 3 | KC | IS 70 E | 14.37 | 0.59 | 7 | 8 | 5 | 3 | 15 | 18 | 1 | 9 |
| 4 | KC | IS 70 E | 18.87 | 0.84 | 3 | 4 | 7 | 3 | 17 | 8 | 11 | 10 |
| 5 | KC | IS 49 N | 174.56 | 0.66 | 8 | 6 | 5 | 4 | 31 | 12 | 12 | 10 |
| 6 | KC | IS 49 N | 173.86 | 0.61 | 3 | 6 | 5 | 3 | 14 | 10 | 8 | 9 |
| 7 | SL | IS 55 N | 182.47 | 0.66 | 4 | 3 | 4 | 3 | 10 | 6 | 3 | 7 |
| 8 | KC | US 71 N | 198.12 | 0.50 | 12 | 5 | 2 | 3 | 34 | 10 | 10 | 8 |
| 9 | KC | IS 70 W | 244.97 | 0.48 | 12 | 9 | 2 | 4 | 29 | 14 | 1 | 10 |
| 10 | KC | IS 29 N | 8.78 | 0.50 | 2 | 12 | 1 | 3 | 15 | 22 | 7 | 7 |
| 11 | KC | IS 29 N | 9.28 | 0.55 | 3 | 9 | 4 | 3 | 11 | 20 | 7 | 8 |
| 12 | KC | IS 29 N | 20.11 | 0.54 | 0 | 2 | 0 | 2 | 4 | 3 | 3 | 4 |
| 13 | KC | IS 29 N | 20.65 | 0.84 | 0 | 2 | 1 | 2 | 4 | 3 | 6 | 5 |
| 14 | KC | IS 35 N | 7.21 | 0.83 | 8 | 6 | 5 | 5 | 32 | 12 | 10 | 10 |
| 15 | KC | IS 435 N | 6.37 | 0.63 | 7 | 4 | 3 | 3 | 4 | 9 | 12 | 8 |
| 16 | KC | IS 435 N | 7.00 | 0.86 | 4 | 7 | 5 | 7 | 5 | 14 | 12 | 15 |
| 17 | KC | IS 470 E | 2.41 | 0.59 | 0 | 6 | 2 | 2 | 2 | 12 | 3 | 8 |
| 18 | KC | IS 470 E | 3.00 | 0.66 | 1 | 7 | 1 | 3 | 11 | 14 | 2 | 9 |
| 19 | KC | IS 470 E | 5.77 | 0.66 | 5 | 6 | 4 | 3 | 27 | 11 | 12 | 9 |
| 20 | SL | IS 44 E | 266.89 | 0.51 | 5 | 4 | 1 | 2 | 13 | 7 | 1 | 8 |
| 21 | SL | IS 70 E | 233.43 | 0.50 | 4 | 10 | 2 | 4 | 11 | 25 | 4 | 9 |
| 22 | SL | IS 55 N | 183.20 | 0.65 | 1 | 3 | 2 | 3 | 10 | 6 | 8 | 7 |
| 23 | SL | IS 70 E | 237.00 | 0.50 | 13 | 11 | 3 | 3 | 17 | 26 | 7 | 7 |
| 24 | SL | MO 370 | 3.07 | 1.32 | 3 | 6 | 1 | 4 | 8 | 9 | 7 | 13 |
| 25 | SL | MO 370 | 5.54 | 1.88 | 1 | 9 | 5 | 6 | 13 | 16 | 8 | 21 |
| 26 | SL | IS 64 E | 33.13 | 0.54 | 11 | 32 | 6 | 6 | 43 | 79 | 7 | 11 |
| 27 | SL | IS 64 E | 22.31 | 0.65 | 41 | 16 | 3 | 4 | 88 | 38 | 5 | 11 |
| 28 | SL | IS 64 E | 21.27 | 0.54 | 34 | 12 | 4 | 3 | 94 | 29 | 5 | 9 |
| 29 | SL | IS 64 E | 17.88 | 0.64 | 7 | 7 | 2 | 3 | 19 | 15 | 2 | 8 |
| 30 | SL | IS 64 E | 14.94 | 1.37 | 9 | 14 | 2 | 6 | 29 | 31 | 4 | 17 |
| 31 | SL | IS 70 E | 212.27 | 1.38 | 2 | 16 | 2 | 6 | 19 | 33 | 10 | 20 |
| 32 | SL | IS 70 E | 214.39 | 1.25 | 5 | 18 | 5 | 8 | 24 | 37 | 17 | 18 |
| 33 | SL | IS 70 E | 223.44 | 0.48 | 4 | 18 | 2 | 7 | 33 | 40 | 13 | 17 |
| 34 | SL | IS 70 E | 224.14 | 0.68 | 6 | 10 | 2 | 4 | 26 | 22 | 4 | 10 |

**Table 7.16 Continued**

| No. | Dist.[1] | Segment | Begin Log | Length (mi) | FI[2] | | | | PDO[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MV | | SV | | MV | | SV | |
| | | | | | Obs[4] | Prd[5] | Obs | Prd | Obs | Prd | Obs | Prd |
| 35 | SL | IS 70 E | 225.55 | 1.09 | 14 | 20 | 2 | 7 | 63 | 48 | 11 | 17 |
| 36 | SL | IS 70 E | 232.33 | 0.62 | 23 | 16 | 7 | 4 | 82 | 40 | 21 | 10 |
| 37 | SL | IS 70 E | 239.91 | 0.85 | 14 | 19 | 6 | 6 | 29 | 47 | 15 | 13 |
| 38 | SL | IS 70 E | 246.56 | 0.38 | 13 | 12 | 10 | 3 | 24 | 21 | 21 | 7 |
| 39 | SW | US 65 S | 260.08 | 0.38 | 1 | 2 | 0 | 2 | 0 | 3 | 0 | 4 |
| 40 | SW | US 65 S | 263.62 | 0.36 | 6 | 2 | 4 | 2 | 24 | 4 | 12 | 4 |
| 41 | SW | US 65 S | 259.61 | 0.31 | 7 | 1 | 3 | 1 | 17 | 2 | 8 | 3 |
| 42 | SW | US 65 S | 265.77 | 0.77 | 4 | 4 | 2 | 4 | 2 | 8 | 4 | 9 |
| 43 | KC | IS 49 N | 172.57 | 0.45 | 8 | 4 | 3 | 3 | 51 | 7 | 19 | 6 |
| 44 | KC | IS 70 E | 15.19 | 0.54 | 7 | 12 | 6 | 2 | 22 | 22 | 5 | 8 |
| 45 | KC | IS 70 E | 15.73 | 0.57 | 4 | 10 | 3 | 3 | 11 | 20 | 3 | 7 |
| 46 | SL | IS 64 E | 37.11 | 0.47 | 14 | 7 | 3 | 4 | 56 | 15 | 6 | 8 |
| 47 | KC | IS 70 E | 16.30 | 0.53 | 13 | 6 | 3 | 2 | 24 | 14 | 8 | 7 |
| 48 | KC | IS 70 E | 17.06 | 0.60 | 6 | 7 | 4 | 3 | 16 | 16 | 18 | 8 |
| 49 | KC | IS 70 E | 17.66 | 0.56 | 6 | 7 | 6 | 3 | 19 | 15 | 19 | 7 |
| 50 | SL | IS 44 E | 262.48 | 0.79 | 2 | 4 | 2 | 3 | 8 | 7 | 6 | 9 |
| 51 | SL | IS 44 E | 263.27 | 0.69 | 3 | 3 | 5 | 4 | 6 | 6 | 16 | 9 |
| 52 | SL | IS 270 E | 28.74 | 0.66 | 3 | 19 | 3 | 5 | 18 | 47 | 6 | 11 |
| 53 | SL | IS 270 E | 30.22 | 0.41 | 7 | 11 | 5 | 3 | 30 | 23 | 4 | 7 |
| 54 | SL | IS 55 N | 184.06 | 0.54 | 3 | 3 | 3 | 2 | 8 | 5 | 10 | 6 |
| **Sum** | | | | | **411** | **486** | **189** | **196** | **1,281** | **1,050** | **443** | **519** |
| **Calibration Factors** | | | | | **0.846** | | **0.964** | | **1.22** | | **0.854** | |

Notes: [1]District, [2]Fatal and Injury, [3]Property Damage Only, [4]Observed crashes, and [5]Predicted crashes.
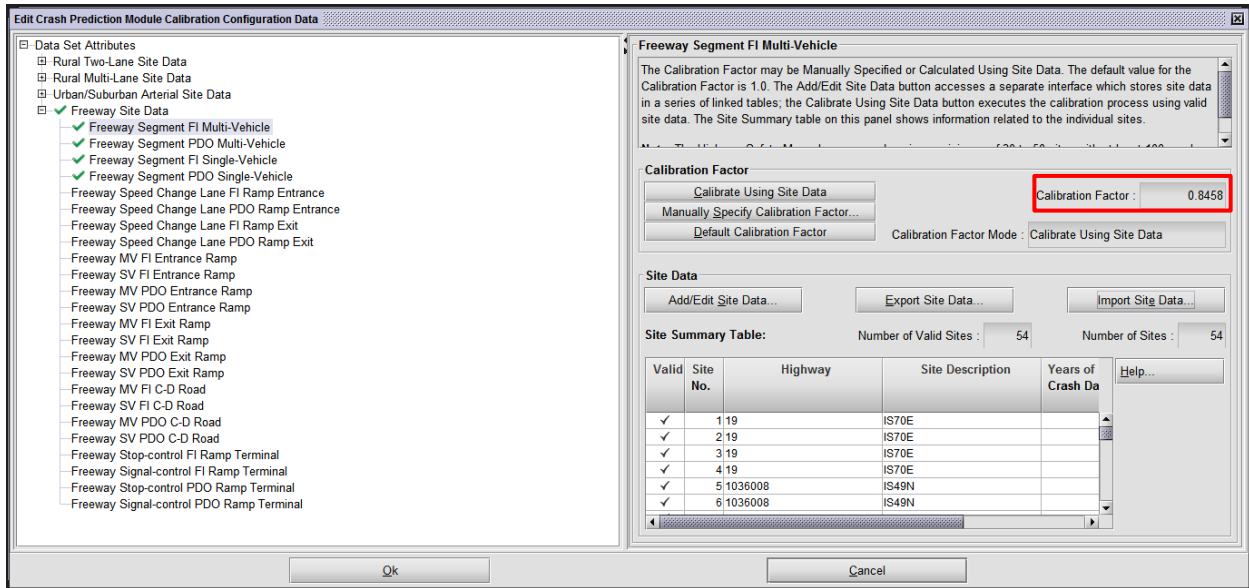
**Figure 7.21 Calibration output for urban six-lane freeways (FI multi-vehicle)**
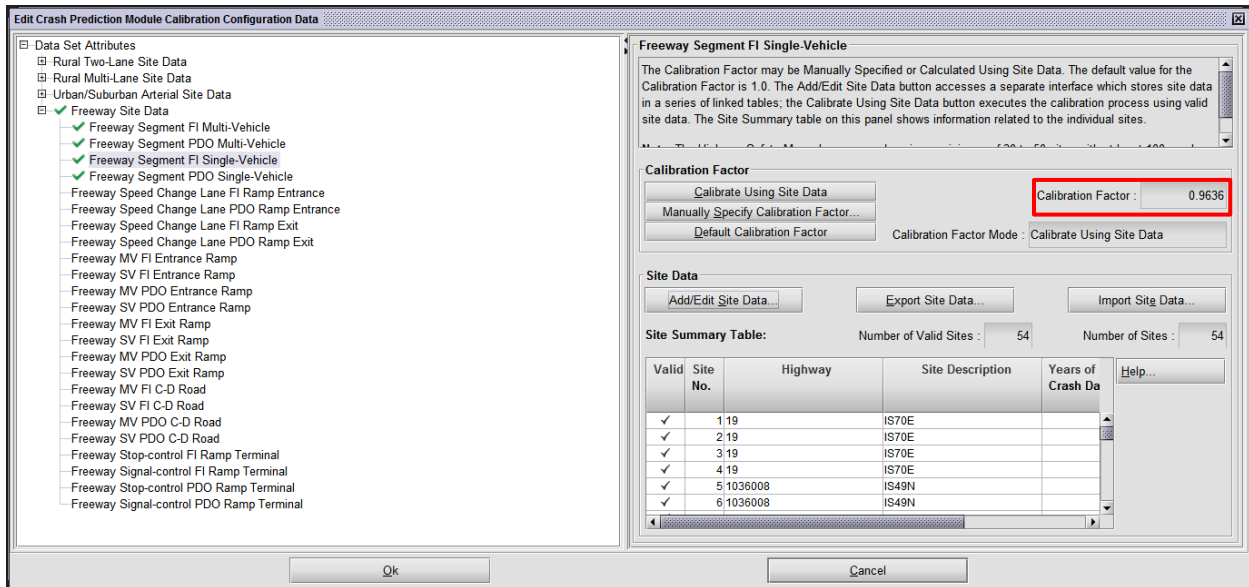


**Figure 7.22 Calibration output for urban six-lane freeways (FI single-vehicle)**

117
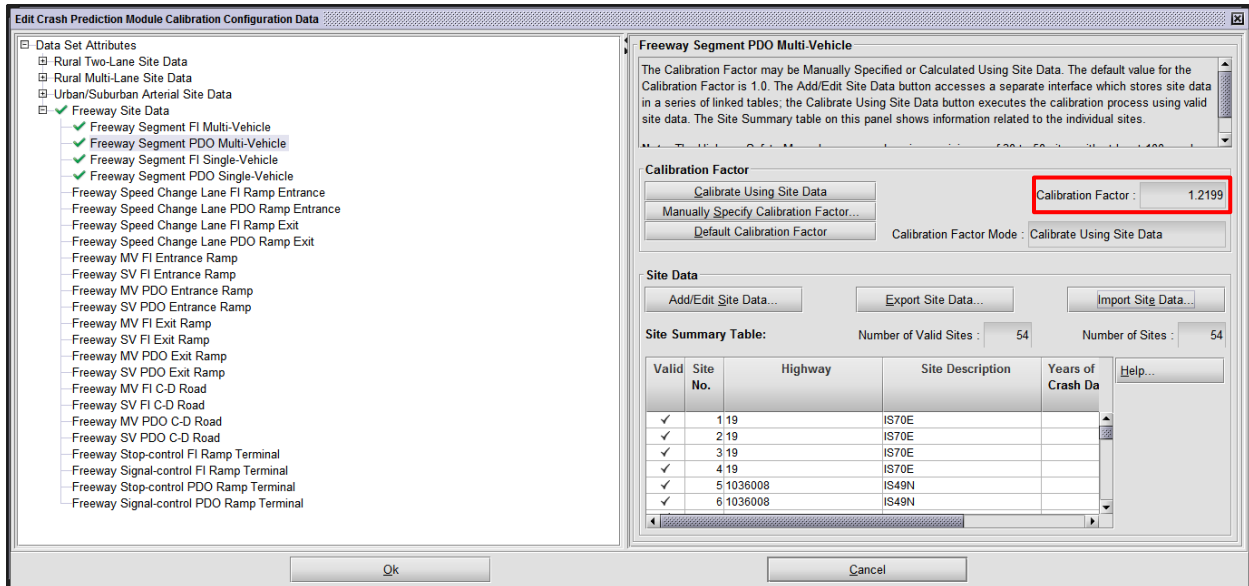
**Figure 7.23 Calibration output for urban six-lane freeways (PDO multi-vehicle)**
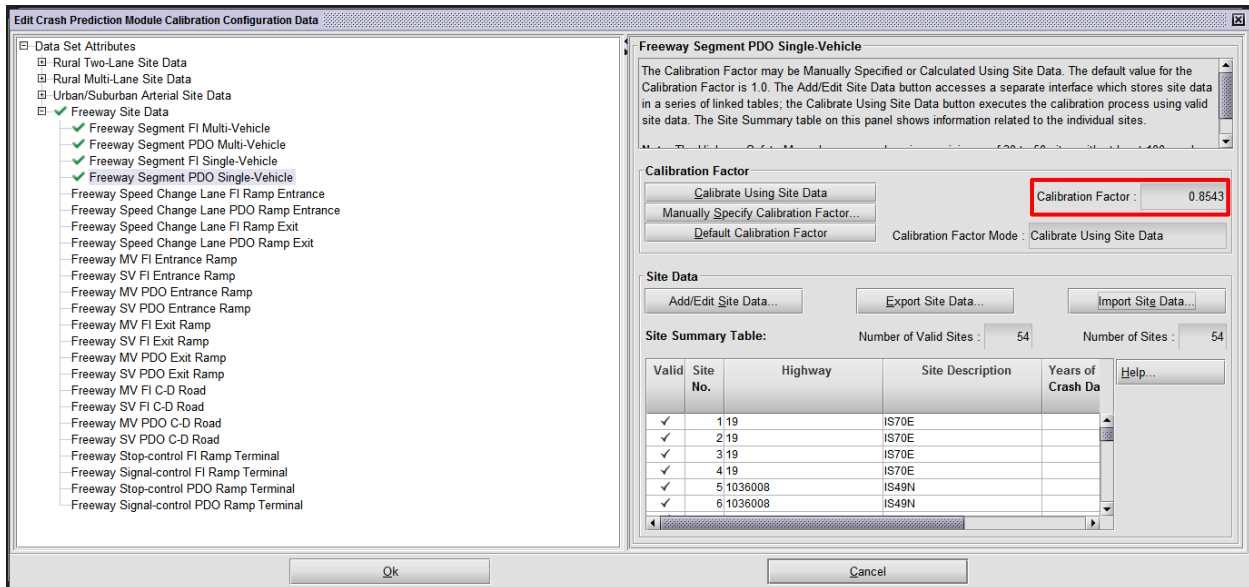


**Figure 7.24 Calibration output for urban six-lane freeways (PDO single-vehicle)**

7.6.3.2 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only for both multi-vehicle and single vehicle crashes. Table 7.17 shows the obtained SDFs for urban six-lane freeway segments.

**Table 7.17 Severity distribution factor for urban six-leg freeway segments**

| Severity | MV | | SV | |
|---|---|---|---|---|
| | Crashes | SDF | Crashes | SDF |
| Fatal | 4 | 0.002 | 9 | 0.014 |
| Disabling Injury | 31 | 0.018 | 23 | 0.036 |
| Minor Injury | 376 | 0.222 | 157 | 0.248 |
| Property Damage Only | 1281 | 0.757 | 443 | 0.701 |

7.6.3.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of crashes from the prediction according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required since there are multiple crash type categories included in the crash reports. For example, crashes that were classified as "Left-turn Right Angle" or "Right-turn Right Angle" collisions were included as "Right Angle" crashes in the CDF distribution. Therefore, different categories were aggregated to provide similar classifications that are recommended by the HSM. The crash types were also divided by multiple and single vehicle crashes. It should be noted that the crash query results returned crashes with parked cars as multi-vehicle crashes while the HSM classifies them as single-vehicle crashes. For this reason, parked vehicle crashes were reclassified as single-vehicle crashes to calculate the CDF. Table 7.18 provides the CDFs for urban six-leg freeway segments.

**Table 7.18 Crash type distribution factors for urban six-leg freeway segments**

| Multiple-Vehicle | | |
|---|---|---|
| Collision Type | Crashes | CDF |
| Angle | 9 | 0.005 |
| Head-on | 22 | 0.013 |
| Sideswipe | 437 | 0.261 |
| Rear-end | 1,024 | 0.612 |
| Other | 181 | 0.108 |
| **Single-Vehicle** | | |
| Collision Type | Crashes | CDF |
| Crash with Parked Vehicle | 19 | 0.029 |
| Crash with Fixed Object | 39 | 0.060 |
| Crash with Animal | 33 | 0.051 |
| Out of Control | 466 | 0.716 |
| Other | 94 | 0.144 |

# CHAPTER 8. URBAN SIGNALIZED INTERSECTIONS

## 8.1 Introduction

Urban signalized intersections have facility specific geometric, operational, and surrounding area conditions. Chapter 12 of the HSM describes the methodology for crash prediction for signalized intersections, including both three-leg and four-leg signalized intersections. This chapter contains a detailed description of the data requirements, the HSM prediction methodology, and the calibration results.

## 8.2 Calibration Data Requirements

The input data in the IHSDM is divided into required and desired data. The required data consist of site, crash, and traffic data. The desired data is optional and includes variables such as pedestrian facilities, bus stops, alcohol sales establishments, and educational facilities.

### 8.2.1 Required Site Data

### 8.2.1.1 Number of Approaches with Left-turn Lanes

Left-turn lanes at a signalized intersection are defined as exclusive lanes for left-turn operations and are in addition to through lanes. An exclusive left-turn lane includes an entering taper with sufficient storage length to accommodate queued vehicles. Figure 8.1(a) shows a conventional left-turn configuration at a four-leg signalized intersection. There are variations of offsets between opposing left-turns. Negative offsets and positive offsets may be located in approaches with sufficient median separation to accommodate left-turns. Figure 8.1(b) shows a negative offset and Figure 8.1(d) shows a positive offset. Some intersections have through lanes converted to left-turn lanes with no offset as illustrated in Figure 8.1(b). For the purposes of the IHSDM data input for urban signalized intersections, the number of approaches with left-turn lanes is counted. The input value for four-leg signalized intersections should be between 0 and 4, and for three-leg signalized intersection should be between 0 and 2.

**(a) Diagram of major road left-turns**
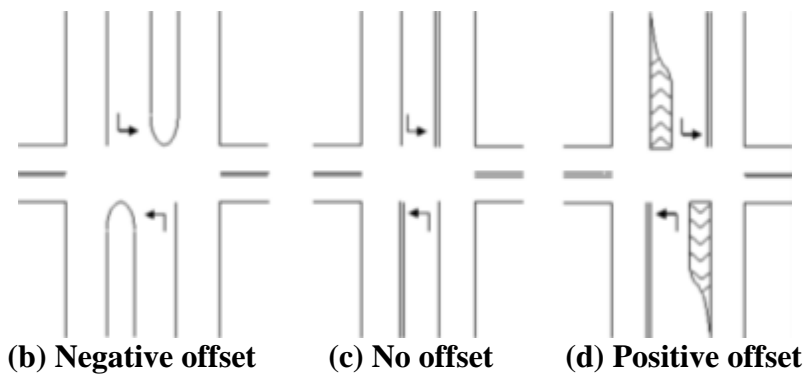


**(b) Negative offset**    **(c) No offset**    **(d) Positive offset**

**Figure 8.1 Diagrams for left-turn movements (ODOT, 2012; Chandler et al., 2013)**

8.2.1.2 Number of Approaches with Right-turn Lanes

Right-turn lanes at a signalized intersection are defined as exclusive lanes for right-turn operations at intersections. A right-turn lane with higher speeds may exist with an entering taper, sufficient lane queue storage, and channelization, as illustrated in Figure 8.2(a). For lower speed designs, shown in Figure 8.2(b), a through lane may be designated as a right-turn lane with a smaller turn radii and without channelization. In the IHSDM data input for urban signalized intersections, the number of approaches with right-turn lanes is counted. The input value should be between 0 and 4 for four-leg signalized intersections, and 0 to 2 for three-leg signalized intersections.
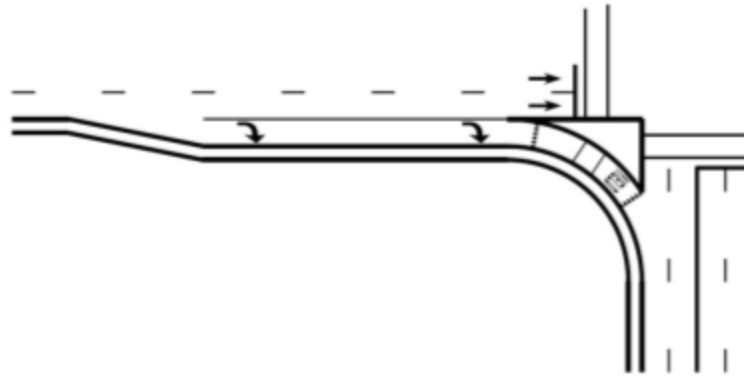
**(a) Right-turn higher speed design**
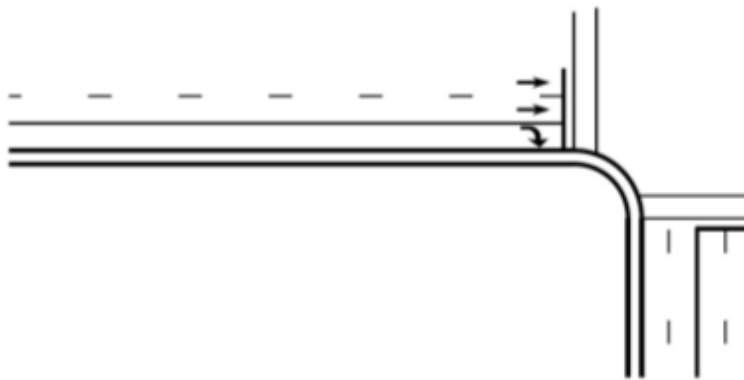


**(b) Right-turn lower speed design**

**Figure 8.2. Common right-turn configurations (ODOT 2012)**

8.2.1.3 Presence of Lighting

Illumination close to the intersection is considered lighting. The IHSDM data input only requires specifying whether or not there is lighting at the intersection (i.e. yes or no). Figure 8.3 shows common lighting configurations.

**(a) Common intersection lighting layout    (b) Street view of intersection with lighting**

**Figure 8.3. Intersection lighting (Gibbons et al. 2008, Google 2016)**

8.2.1.4 Number of Approaches with Permissive Left-turns

Permissive left-turn phasing refers to two opposing approaches operating simultaneously with left-turns allowed but having to yield to opposing traffic and pedestrians. Figure 8.4 shows common signal head configurations for permissive left-turns.
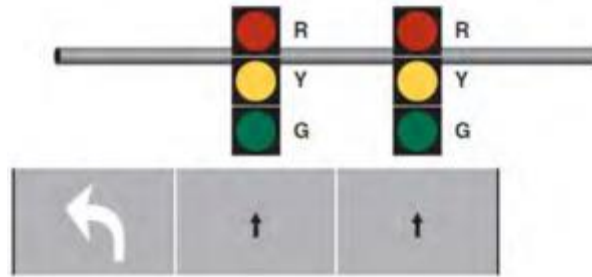
**(a) Signals heads over the through lanes**
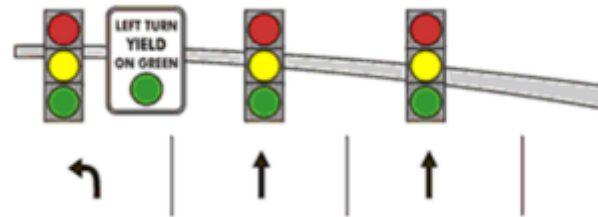


**(b) Signals heads over though lanes and left-turn lane**
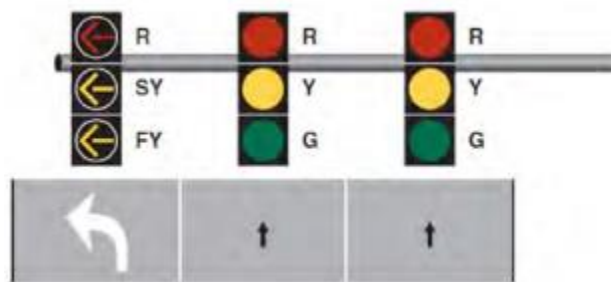


**(c) Signal head over left-turn lane with flashing yellow**

**Figure 8.4 Common permissive left-turn signals  (Chandler et al. 2013, MUTCD 2009)**

In the IHSDM data input for urban signalized intersections, the number of approaches with permissive left-turn phasing is counted. The input value should be between 0 and 4 for four-leg signalized intersections and between 0 and 2 for three-leg signalized intersections.

8.2.1.5 Number of Approaches with Permissive/Protective Left-turns

A combination of a protected only left-turn phasing with permissive left-turn phasing is referred to as protected/permissive. According to the MUTCD (2009), the two signal head configurations are (1) left-turn lane and adjacent through lane sharing same signal head and (2) separate signal head(s) exclusively for left-turn(s).

The first configuration is illustrated in Figure 8.5(a). A five signal head configuration is commonly used for dual signalization for the left and adjacent through lane. This signal configuration is also known as "dog house". The second signal configuration provides a signal

head for exclusive signalization of the left-turn protected/permissive phase as illustrated in Figure 8.5(b).



**(a) Dog house with accompanying sign**     **(b) Four vertical signal head over left-turn lane**
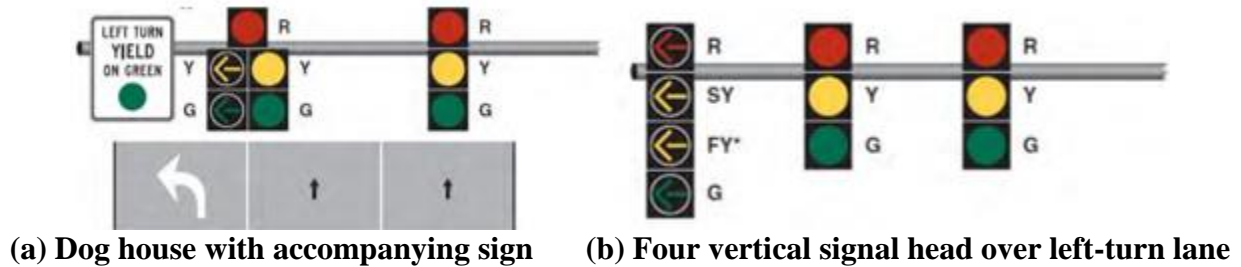
**Figure 8.5 Permissive/protected left-turn signals (Chandler et al. 2013)**

In the IHSDM data input for urban signalized intersections, the number of approaches with protected/permissive left-turn phasing is counted. The input value for four-leg signalized intersections should be between 0 and 4 and for three-leg signalized intersection should be between 0 and 2.

8.2.1.6 Number of Approaches with Protected Left-turn

Protected left-turn phasing provides a separate phase for left-turning movements with left-turn arrow signalization. There is not any pedestrian or vehicular traffic allowed that conflicts with the protected left-turn movements (Chandler et al. 2013). Figure 8.6 shows commonly used protected only left-turn signal configurations.



**a) Signal head with left-turn arrows**     **b) Signal with arrows and sign**
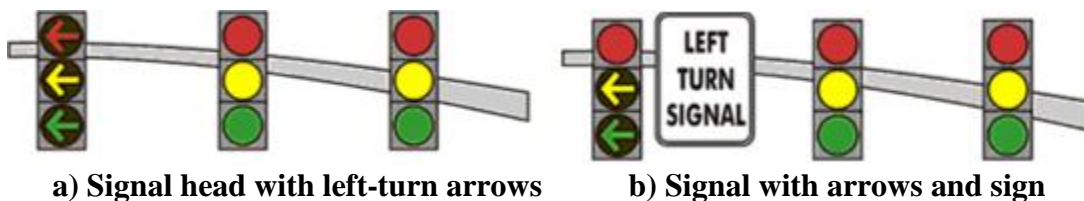
**Figure 8.6 Protected only left-turn signals (MUTCD 2009)**

In the IHSDM data input for urban signalized intersections, the number of approaches with protected only left-turn phasing is counted. The input value for four-leg signalized intersections should be between 0 and 4 and for three-leg signalized intersection should be between 0 and 2.

8.2.1.7 Number of Approaches on Which Right-Turn on Red is Prohibited

Some signalized intersections may have inadequate sight distance to vehicles approaching from the left. Geometry, pedestrian exclusive phase, and skew angle less than 75 degrees may also contribute to inadequate visibility and operation of right turns (Harkey et al. 2014). Therefore, right-turn movement on red may be prohibited. Figure 8.7(a) shows an example of an

intersection with skew angle and Figure 8.7(b) shows the different signs recommended by the MUTCD (2009).



**(a) Right-turn on red prohibited**          **(b) No turn on red signs**
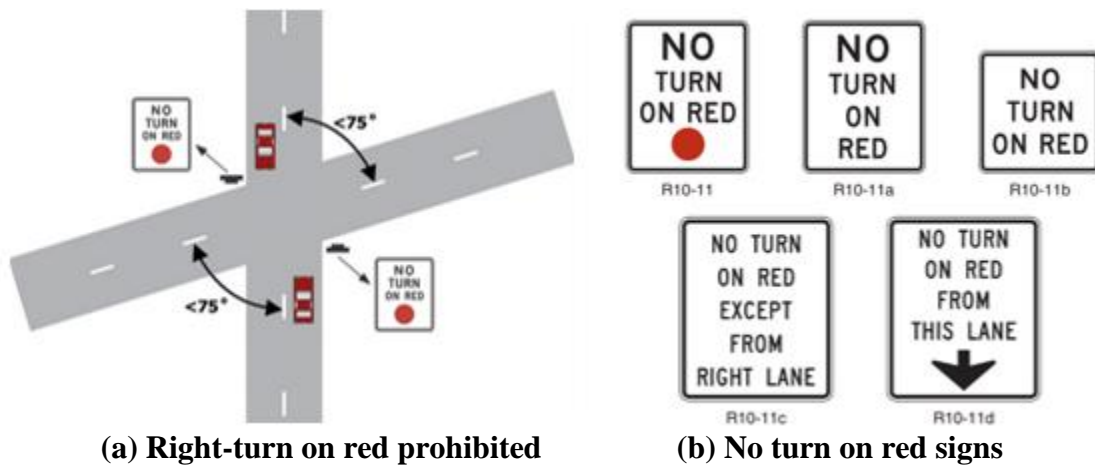
**Figure 8.7 Right-turn on red prohibited (Harkey et al. 2014, MUTCD 2009)**

8.2.1.8 Presence of Red Light Cameras

Red light cameras are automated enforcement at signalized intersections that capture and record information through images to enforce red light running violations. The IHSDM data input only requires specifying whether or not there is a red light camera at the intersection (i.e. yes or no). Figure 8.8 shows an example of a red light camera.



**Figure 8.8 Red light camera (Google, 2016)**

8.2.2 Required Crash and Traffic Data

8.2.2.1 Years of Crash Data

The years associated with the calibration should be specified. The IHSDM considers up to three years for the input data.

8.2.2.2 Observed Number of Crashes

The observed number of crashes at an intersection are the crashes attributed to the geometry and operation of signalized intersections. The HSM provides guidance for crash assignment based on intersection physical and functional areas (AASHTO, 2010). The Green Book (AASHTO, 2011) defines an intersection as "the general area where two or more roadways join or cross, including the roadway and roadside facilities for traffic movements within the area." An at-grade intersection is defined "by both its physical and functional areas". The functional area "extends both upstream and downstream from the physical intersection area and includes any auxiliary lanes and their associated channelization". The functional area on each approach to an intersection consists of (1) decision distance, (2) maneuver distance, and (3) queue storage distance. Figure 8.9 illustrates both physical and functional areas with the intersection area colored in gray. MoDOT assigns crashes to an intersection if it is located within 132 feet of the intersection.



**(a) Physical area**          **(b) Functional area**
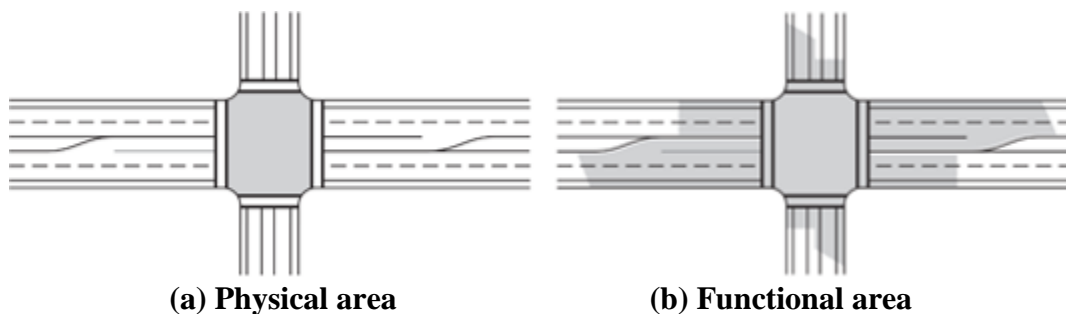
**Figure 8.9 Intersection physical and functional areas (AASHTO 2010)**

In the IHSDM data input for urban signalized intersections, the total number of observed crashes for the years specified in the calibration should be used (i.e. 3 years).

8.2.2.3 Major Road AADT

The major road at an intersection may be determined by considering the road classification hierarchy and AADT. Usually, the major road experiences the higher AADT as compared to the minor road. However, when the AADT of both approaching roads are similar, the highest road classification hierarchy should be designated as the major road. The major road AADT for every year specified in the calibration is inputted into the IHSDM.

8.2.2.4 Minor Road AADT

The minor road is designated as the road that holds less traffic and has a lesser hierarchy compared to the other road. The minor road AADT for every year specified in the calibration is inputted in the IHSDM.

8.2.3 Desired Site Data

8.2.3.1 Pedestrian Volumes Crossing All Intersection Legs

Pedestrian volumes are used to estimate vehicle pedestrian collisions. Based on an observation of the surroundings and pedestrian facilities at intersections, the level of pedestrian activity can be estimated. The estimate is in terms of pedestrian crossings per day. In Table 8.1, the different level of pedestrian activity for input in the IHSDM data are provided for three and four leg intersections.

**Table 8.1 Estimates of pedestrian volumes (AASHTO, 2010)**

| General Level of Pedestrian Activity | Estimate of PedVol (pedestrians/day) for Use in Equation 12-29 | |
|---|---|---|
| | 3SG Intersections | 4SG Intersections |
| High | 1,700 | 3,200 |
| Medium-high | 750 | 1,500 |
| Medium | 400 | 700 |
| Medium-low | 120 | 240 |
| Low | 20 | 50 |

8.2.3.2 Maximum Number of Lanes Crossed by Pedestrians

According to the HSM (AASHTO 2010):
> The maximum number of traffic lanes that a pedestrian must cross in any crossing maneuver at the intersection should be counted. Both through and turning lanes that are crossed by a pedestrian along the crossing path are considered. If the crossing path is broken by an island that provides a suitable refuge for the pedestrian so that the crossing may be accomplished in two (or more) stages, then the number of lanes crossed in each stage is considered separately. To be considered as a suitable refuge, an island must be raised or depressed; a flush or painted island is not treated as a refuge.

It should be noted that, only the longest crossing path is considered (one crossing path) and not the sum of all approaching legs or paths (AASHTO 2010). Figure 8.10 illustrates the procedure to count the maximum number of lanes crossed. In this example, the maximum number of lanes crossed is six. The right turn lanes were not counted since there were islands that provided appropriate refuge for pedestrians to cross at different stages.

**Figure 8.10 Example of maximum number of lanes crossed (Google 2016)**

8.2.3.3 Number of Bus Stops within 1,000 ft of Intersection

According to the HSM (AASHTO 2010):

> Multiple bus stops at the same intersection (i.e., bus stops in different intersection quadrants or located some distance apart along the same intersection leg) are counted separately. Bus stops located at adjacent intersections would also be counted as long as any portion of the bus stop is located within 1,000 ft of the intersection being evaluated.

HSM recommends for local transit bus stops records to be used to determine the number of stops within the 1000 ft threshold at an intersection. If no records are available, aerial photographs could be used. It should be noted that the bus stops could be relocated or replaced over time. Figure 8.11 shows an example of three bus stops within 1,000 ft from the center of the intersection.

**Figure 8.11 Intersection bus stops (Google 2016)**

8.2.3.4 Number of Schools within 1,000 ft of Intersection

According to the HSM (AASHTO 2010): "A school may be counted if any portion of the school grounds is within 1,000 ft of the intersection." Figure 8.12 shows an example of school next to the intersection.



**Figure 8.12 Educational facility close to intersection (Google 2016)**

130

The use of local school registration data is desirable. However, aerial photographs could be used if no other data is available. It should be noted that the educational facilities might not have been present during the period of analysis of the calibration.

8.2.3.5 Number of Alcohol Sales Establishments within 1,000 ft of Intersection

According to the HSM (AASHTO 2010):

> Any alcohol sales establishment wholly or partly within 1,000 ft of the intersection may be counted. The CMF includes any alcohol sales establishment, which may include liquor stores, bars, restaurants, convenience stores, or grocery stores. Alcohol sales establishments are counted if they are on any intersection leg or even on another street, as long as they are within 1,000 ft of the intersection being evaluated.

The use of local business registration data is desirable. However, aerial photographs could be used if no other data is available. It should be noted that the alcohol sales establishments might not have been present during the period of analysis of the calibration. Figure 8.13 shows an example of alcohol sales establishments identified near an intersection. The establishments were verified individually since not all businesses sell alcohol (e.g., fast food restaurants).
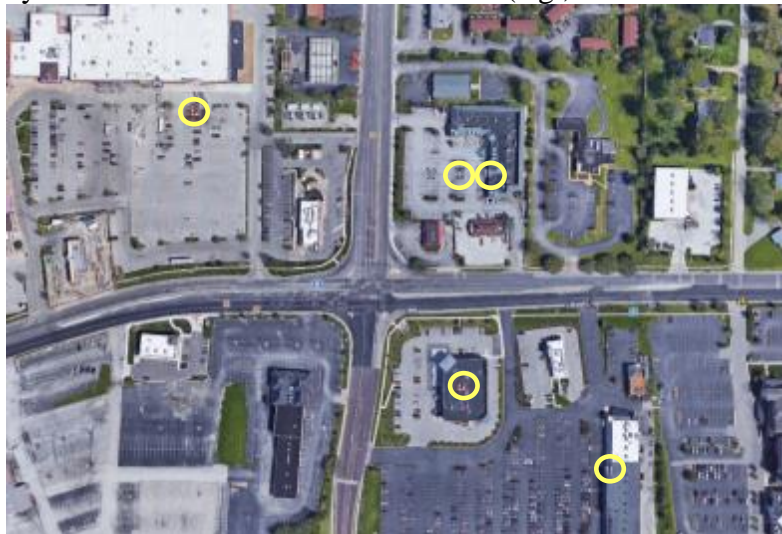


**Figure 8.13 Alcohol sale establishments close to an intersection (Google 2016)**

**8.3 HSM Prediction Methodology**

As described in chapter 12 of the HSM (AASHTO 2010), the SPFs for urban signalized intersections predict the number of total crashes at the intersection per year for base conditions. The SPF is based on the major AADT and minor AADT of the intersection. The SPFs include four functions in order to predict all possible crash frequencies. These functions include $N_{bimv}$, $N_{bisv}$, $N_{pedi}$, and $N_{bikei}$. The $N_{bimv}$ term is the predicted average number of multiple vehicle crashes for base conditions, $N_{bisv}$ is the predicted average number of single vehicle crashes for base conditions, $N_{pedi}$ is the predicted average number of pedestrian involved crashes for base conditions, and $N_{bikei}$ is the predicted average number of bicyclist-involved crashes for base conditions.

In order to predict the number of crashes that may occur within an urban or suburban arterial intersection, the following equations are applied.

$$N_{\text{predicted } int} = C_i \text{ x } (N_{bi} + N_{pedi} + N_{bikei}) \tag{8.1}$$

$$N_{bi} = N_{spf\ int} \text{ x } (CMF_{1i} \text{ x } CMF_{2i} \text{ x } ... \text{ x } CMF_{6i}) \tag{8.2}$$

where $N_{\text{predicted } int}$ is the total predicted average crash frequency within an intersection for a selected year, $N_{spf\ int}$ is the predicted number of total intersection crashes per year for base conditions (excluding vehicle-pedestrian and vehicle-bicycle collisions), and $N_{bi}$ is the predicted average crash frequency within an intersection (excluding vehicle-pedestrian and vehicle-bicycle collisions).

The general form of the SPF is given by:

$$N_{spf\ int} = N_{bimv} + N_{bisv} \tag{8.3}$$

$$N_{bimv} = exp[a + b \text{ x } ln(AADT_{maj}) + c \text{ x } ln(AADT_{min})] \tag{8.4}$$

$$N_{bisv} = exp[a + b \text{ x } ln(AADT_{maj}) + c \text{ x } ln(AADT_{min})] \tag{8.5}$$

where $N_{bimv}$ is the number of multiple vehicles crashes, $N_{bisv}$ is the number of single vehicles crashes, $AADT_{maj}$ is the annual average daily traffic (vehicles/day) for major road (both directions of travel combined), $AADT_{min}$ is the annual average daily traffic (vehicles/day) for minor road (both directions of travel combined), and $a, b, c$ are regression coefficients.

The number of vehicle-pedestrian crashes predicted for an intersection over a given year was determined with an SPF and a set of CMFs. The number of vehicle–bicycle crashes is predicted in a similar fashion. The following shows the model used for vehicle-pedestrian crashes within signalized intersections.

$$N_{pedi} = N_{pedbase} \text{ x } CMF_{1p} \text{ x } CMF_{2p} \text{ x } CMF_{3p} \tag{8.6}$$

where, $N_{pedbase}$ is the predicted number of vehicle-pedestrian collisions per year for base conditions at signalized intersections and $CMF_{1p}…CMF_{3p}$ are the crash modification factors for vehicle-pedestrian collisions at signalized intersections.

Values for $N_{pedbase}$ depend on total AADT, minor AADT, major AADT, pedestrian volume, and maximum number of lanes crossed by pedestrian.

The predicted number of vehicle-bicycle crashes at signalized intersections over a given year was determined by the following:

$$N_{bikei} = N_{bi} \text{ x } f_{bikei} \tag{8.6}$$

where f$_{bikei}$ is the bicycle crash adjustment factor.

Crash modification factors (CMF) introduce facility traits into the prediction. Thus, the HSM prediction models have specific base condition for each CMF. Table 8.2 shows the base conditions used as crash modification factors for signalized intersections.

**Table 8.2 Base conditions used for intersection crash predictions**

| Crash Modification Factor | Base Condition |
| --- | --- |
| Intersection Left-Turn Lanes | Not Present |
| Intersection Left-Turn Signal Phasing | Permissive left-turn phasing |
| Intersection Right-Turn Lanes | Not Present |
| Right-Turn-on-Red | Permitting |
| Lighting | Not Present |
| Red-Light Cameras | Not Present |
| Bus stops within 1,000 ft of the intersection | Not Present |
| School within 1,000 ft of the intersection | Not Present |
| Alcohol sale establishments within 1,000 ft of the intersection | Not Present |

## 8.4 Sampling

Most samples from the previous calibration were used. The samples that were dropped from the previous sample set were sites that experienced significant changes in geometry, operations, and/or classification. In addition, some intersections were dropped because the sites did not meet the urban signalized intersection classification criteria (e.g., ramp terminals). Since some facilities had to be dropped, additional samples were selected to complete the HSM minimum requirements for calibration. The sampling process was through random selection from the intersection list generated in the previous calibration project (Sun et al. 2013).

The list of samples for urban three-leg signalized intersections is shown in Table 8.3. There was only one sample each for the Northeast and Northwest districts. The sample set included five samples from the Southeast District, seven samples from the Southwest District, and ten samples from the St. Louis District. Each of the remaining districts had five samples. The intersections included public road intersections as well as commercial driveway entrances that were signalized. Intersections from the major metropolitan areas of St. Louis, Kansas City, and Springfield were included in the sample set. In addition, smaller communities such as Boonville and Mexico were also represented in the sample set.

**Table 8.3 List of sites for urban three-leg signalized intersections**

| No. | District | Description | Int. No. | City | County |
|---|---|---|---|---|---|
| 1 | CD | RT B/MO 87 (Main St.) and MO 87 (Bingham Rd.) | 188779 | Boonville | Cooper |
| 2 | CD | US 63 (N Bishop Ave.) and RT E (University Ave.) | 409359 | Rolla | Phelps |
| 3 | CD | LP 44 and MO 17 | 431017 | Waynesville | Pulaski |
| 4 | CD | BU 50 (Missouri Blvd.) and Seay Place - Walmart (724 W Stadium Blvd) | 651041 | Jefferson City | Cole |
| 5 | CD | BU 50 and Stoneridge Blvd (Kohls entrance) | 302396 | Jefferson City | Cole |
| 6 | KC | MO 291 (NE Cookingham Dr.) and N Stark Ave. | 121469 | Kansas City | Clay |
| 7 | KC | US 40 and East 47th St. S | 168735 | Kansas City | Jackson |
| 8 | KC | MO 291 (NE Cookingham Dr.) and N Flintlock Road | 123483 | Liberty | Clay |
| 9 | KC | US 40 and Entrance to Blue Ridge Crossing | 929297 | Kansas City | Jackson |
| 10* | KC | US 69 and Indiana Ave. | 137412 | Kansas City | Clay |
| 11 | NE | MO 15 and Boulevard St. | 143089 | Mexico | Audrain |
| 12 | NW | RT YY (Mitchell Ave.) and Woodbine Dr. | 68340 | St. Joseph | Buchanan |
| 13 | SE | US 61 and Old Orchard Rd. | 489147 | Jackson | Cape Girardeau |
| 14 | SE | RT K and Siemers Dr. | 496486 | Cape Girardeau | Cape Girardeau |
| 15 | SE | US 61 and Smith Ave. | 574289 | Sikeston | Scott |
| 16 | SE | Business 60 and Walmart Entrance | 588152 | Dexter | Stoddard |
| 17* | SE | BU 60 (N Westwood Blvd.) and Valley Plaza Entrance | 651105 | Poplar Bluff | Butler |
| 18 | SL | MO 100 and Woodgate Dr. | 288254 | St. Louis | St. Louis |
| 19 | SL | MO 231 (Telegraph Rd.) and Black Forest Dr. | 324301 | St. Louis | St. Louis |
| 20 | SL | RT B (Natural Bridge Rd.) and Fee Fee Rd. | 928641 | St. Louis | St. Louis |
| 21 | SL | MO 180 and Stop n Save (St. John Crossing) | 251803 | St. John | St. Louis |
| 22 | SL | MO 267 (Lemay Ferry Rd.) and Victory Dr. | 313246 | St. Louis | St. Louis |
| 23 | SL | MO 47(W. Gravois Ave.) and MO 30 (Commercial Ave.) | 347423 | St. Clair | Franklin |
| 24 | SL | RT D and Page Industrial Blvd. | 257667 | St. Louis | St. Louis |
| 25* | SL | MO 100 and Holloway Rd. | 291512 | Ballwin | St. Louis |
| 26* | SL | N Hanley Rd. and University PI DR. | 249780 | St. Louis | St. Louis |
| 27* | SL | Marine Ave. and Dorsett Rd. | 253124 | Maryland Heights | St. Louis |
| 28 | SL | Big Bend Rd. and New Ballwin Rd. | 299708 | Ballwin | St. Louis |
| 29 | SW | LP 49B/BU 60/BU 71 (N Rangeline Rd.) and Turkey Creek Road (North Park Ln) | 543380 | Joplin | Jasper |
| 30 | SW | RT D (Sunshine St.) and Lone Pine Ave. | 523828 | Springfield | Greene |
| 31 | SW | MO 744 (E Kearney St.) and N Cresthaven Ave. | 932947 | Springfield | Greene |
| 32 | SW | MO 744 (E Kearney St.) and N Neergard Ave. | 512492 | Springfield | Greene |
| 33 | SW | US 60 and Lowe's Ln | 963973 | Monett | Barry |
| 34 | SW | MO 66 (7th St.) and Walmart (2623 W. 7th St.) | 963880 | Joplin | Jasper |
| 35 | SW | MO 571 (S Grand Ave.) and Walmart Entrance | 963860 | Carthage | Jasper |

* Indicates a new site replacing a site used in the previous calibration.

A list of samples for urban four-leg signalized intersections is shown in Table 8.4. The sample set included five samples from each district. Intersections from the major metropolitan areas of St. Louis, Kansas City, Springfield, and St. Joseph were included in the sample set. In addition, smaller communities such as Cape Girardeau and Moberly were also represented in the sample set.

**Table 8.4 List of sites for urban four-leg signalized intersections**

| No. | District | Description | Int. No. | City | County |
|---|---|---|---|---|---|
| 1 | CD | MO 32 and MO 19 (Main St.) | 458532 | Salem | Dent |
| 2 | CD | MO 64 (N Jefferson Ave.) and MO 5 (W 7th St.) | 452499 | Lebanon | Laclede |
| 3 | CD | MO 32 and RT J/HH | 458516 | Salem | Dent |
| 4 | CD | BU 50 (Missouri Blvd.) and St. Mary's Blvd./W Stadium Blvd. | 302287 | Jefferson City | Cole |
| 5 | CD | US 63 (N. Bishop Ave.) and 10th St. | 409975 | Rolla | Phelps |
| 6 | KC | US 50 (E Broadway Blvd.) and Engineer Ave. | 262974 | Sedalia | Pettis |
| 7 | KC | MO 152 and Shoal Creek Pkwy. | 924806 | Kansas City | Clay |
| 8 | KC | MO 7 and Clark Rd./Keystone Dr. | 178087 | Blue Springs | Jackson |
| 9 | KC | US 40 and Sterling Ave. | 165662 | Kansas City | Jackson |
| 10 | KC | MO 7 and US 40 | 175906 | Blue Springs | Jackson |
| 11 | NE | US 63 (N Missouri St.) and Vine St. | 73685 | Macon | Macon |
| 12 | NE | BU 63 (S Morley St.) and RT EE (E Rollins St.) | 106134 | Moberly | Randolph |
| 13 | NE | US 24 and BU 63 (N Morley St.) | 102590 | Moberly | Randolph |
| 14 | NE | MO 47 and Old US 40 (E Veterans Memorial Pkwy.) | 219337 | Warrenton | Warren |
| 15 | NE | MO 47 and Main St. (Sydnorville Rd.) | 179534 | Troy | Lincoln |
| 16 | NW | US 169 (N Belt Hwy.) and MO 6/LP 29 (Frederick Ave.) | 64653 | St. Joseph | Buchanan |
| 17 | NW | US 169 (N Belt Hwy.) and Faraon St. | 66131 | St. Joseph | Buchanan |
| 18 | NW | US 169 (S Belt Hwy.) and RT YY (Mitchell Ave.) | 68315 | St. Joseph | Buchanan |
| 19 | NW | MO 6 (E 9th St.) and Harris Ave. | 41614 | Trenton | Grundy |
| 20* | NW | MO 752 and King Hill Ave. | 75399 | Saint Joseph | Buchanan |
| 21 | SE | BU 60 (W Pine St.) and N 5th St. | 597292 | Poplar Bluff | Butler |
| 22 | SE | US 61 (N Kingshighway St.) and MO 51 (N Perryville Blvd.) | 439049 | Perryville | Perry |
| 23 | SE | US 61 (S Kingshighway St.) and RT K (William St.) | 496355 | Cape Girardeau | Cape Girardeau |
| 24 | SE | MO 53 and MO 142/RT WW | 599957 | Poplar Bluff | Butler |
| 25 | SE | MO 47 and Berry Rd. | 412009 | Bonne Terre | St. Francois |
| 26 | SL | MO 115 (Natural Bridge Ave.) and Goodfellow Blvd. | 258418 | St. Louis | St. Louis City |
| 27 | SL | MO 185 and Springfield Ave. | 368007 | Sullivan | Franklin |
| 28 | SL | MO 47 (N Main St.) and Commercial Ave. | 345142 | St. Clair | Franklin |
| 29 | SL | MO 30 (Gravois Ave.) and Holly Hills Blvd. | 295564 | St. Louis | St. Louis City |
| 30 | SL | MO 115 (Natural Bridge Ave.) and Marcus Ave. | 262408 | St. Louis | St. Louis City |
| 31 | SW | MO 744 and Summit Ave. | 512290 | Springfield | Greene |
| 32 | SW | US 60 and RT P/S Main Ave. | 540602 | Republic | Greene |
| 33 | SW | MO 18 (Ohio St.) and BU 13 (S 2nd St.) | 345687 | Clinton | Henry |
| 34 | SW | MO 14 (W Mt. Vernon St.) and RT M (N Nicholas Rd.) | 554723 | Nixa | Christian |
| 35* | SW | MO 14 and RT M | 523287 | Nixa | Christian |

* Indicates a new site replacing a site used in the previous calibration.

**8.5 Data Collection**

A list of the data types collected for urban signalized intersections and their sources is shown in Table 8.5. Aerial photographs were used to determine the number of approaches with turn lanes, the maximum number of lanes crossed by pedestrians, and the number of bus stops, schools, and alcohol sales establishments within 1,000 feet. ARAN and aerial and street view photographs were used to determine the presence of lighting at intersections. MoDOT districts provided information regarding left-turn phasing and the number of approaches with prohibited right-turn-on-red movements. A list of signalized intersections with red light running cameras was provided by MoDOT. Pedestrian volumes were estimated with street view and aerial imaging according to the presence of pedestrian facilities and paths.

**Table 8.5 List of data sources for urban signalized intersections**

| Data Description | Source |
|---|---|
| AADT | TMS |
| No. of Approaches with Left-Turn Lanes | Aerials |
| No. of Approaches with Right-Turn Lanes | Aerials |
| No. of Approaches with Permissive LT Phasing | MoDOT |
| No. of Approaches with Protected/Permissive LT Phasing | MoDOT |
| No. of Approaches with Protected LT Phasing | MoDOT |
| Pedestrian Volumes (Crossings/Day) | Estimated pedestrian activity |
| Max. Number of Lanes Crossed by Pedestrians | Aerials |
| Number of Bus Stops within 1,000 ft | Aerials |
| Number of Schools within 1,000 ft | Aerials |
| Number of Alcohol Sales Establishments within 1000 ft | Aerials |
| Presence of Lighting | ARAN and Street View |
| Presence of Red-Light Running Cameras | MoDOT |
| No. of Crashes | TMS |

8.5.1 Summary Statistics

8.5.1.1 Urban Three-Leg Signalized Intersections

Descriptive statistics for urban three-leg signalized intersections are shown in Table 8.6. The average AADT for the major approaches was 17,451 vpd, and the average AADT for the minor approach was 2,946 vpd. The average number of approaches with left turn lanes was 1.8, and the average number of approaches with right turn lanes was 1.3, indicating that the presence of turn lanes was common at these intersections. The most common type of left turn phasing for the intersection approaches was protected phasing followed by protected and permissive phasing. The prohibition of right-turn-on red was not very common at these intersections, as shown by the average value of 0.1 for the number of approaches with prohibited right-turn-on-red (at two intersections). The average pedestrian volume was 119.7 and the maximum number of lanes

crossed was 4.4, indicating that many of these intersections were located on multilane arterials. The average values for the number of bus stops, schools, and alcohol sales establishments were all less than 1.6. The average number of crashes was 15.1. The standard deviation was 13.3, indicating that the number of crashes at these intersections varied considerably. The total number of crashes for these intersections was 529, which was greater than the minimum of 300 crashes recommended by the HSM. A total of 33 of these intersections had lighting, while none of the intersections had red-light running cameras.

**Table 8.6 Descriptive statistics for urban three-leg signalized intersections**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| Major AADT (2014) | 17,451 | 4,007 | 44,280 | 9,206 |
| Minor AADT (2014) | 2,946 | 188 | 7,035 | 1,735 |
| No. of Approaches With Left Turn Lanes | 1.8 | 1 | 2 | 0.4 |
| No. of Approaches with Right Turn Lanes | 1.3 | 0 | 2 | 0.8 |
| No. of Approaches with Permissive Left Turn Phasing | 0.1 | 0 | 1 | 0.3 |
| No. of Approaches with Protected/Permissive Left Turn Phasing | 0.6 | 0 | 1 | 0.5 |
| No. of Approaches with Protected Left Turn Phasing | 1.3 | 1 | 2 | 0.4 |
| No. of Approaches with Prohibited RTOR | 0.1 | 0 | 1 | 0.2 |
| Pedestrian Volumes Crossing All Intersection Legs | 119.7 | 20 | 750 | 140.8 |
| Max. Number of Lanes Crossed by Pedestrians | 4.4 | 3 | 6 | 0.9 |
| No. of Bus Stops within 1000 ft | 1 | 0 | 5 | 1.5 |
| No. of Schools within 1000 ft | 0.2 | 0 | 1 | 0.4 |
| No. of Alcohol Sales Establishments within 1000 ft | 1.6 | 0 | 4 | 1.3 |
| Number of Crashes | 15.1 | 1 | 55 | 13.3 |
| **Description** | **No. of Intersections** | | | |
| Presence of lighting | 33 | | | |
| Presence of red-light running cameras | 0 | | | |

8.5.1.2 Urban Four-Leg Signalized Intersections

Descriptive statistics for urban four-leg signalized intersections are shown in Table 8.7. The average AADT for the major approaches was 16,183 vpd, similar to urban three-leg intersections, and the average AADT for the minor approaches was 7,549 vpd. The average number of approaches with left turn lanes was 3.3 (1.8 times larger than three-leg), and the average number of approaches with right turn lanes was 1.8, indicating that the presence of turn lanes was common at these intersections. The sampled intersections had some variation in left turn phasing, with protected permissive left turn phasing being the most common. There was only one intersection approach at which a right-turn-on-red was prohibited. The average value

for the maximum number of lanes crossed by pedestrians was 4.6, indicating that many of these intersections were located on multilane arterials. The average values for the number of bus stops, schools, and alcohol sales establishments were all less than or equal to 2.0. The average number of crashes was 39.2, indicating that four-leg intersections experienced more crashes than three-leg intersections. The standard deviation for the number of crashes was 29.7, indicating that the number of crashes at these intersections varied considerably. The total number of crashes was 1,372, which was greater than the minimum of 300 crashes recommended by the HSM. All of these intersections had lighting, while only one had red-light-running cameras.

**Table 8.7 Descriptive statistics for urban four-leg signalized intersections**

| Description | Average | Min. | Max. | Std. Dev. |
|---|---|---|---|---|
| Major AADT (2014) | 16,183 | 5,202 | 44,834 | 8,761 |
| Minor AADT (2014) | 7,549 | 1,421 | 25,521 | 6,138 |
| No. of Approaches With Left Turn Lanes | 3.3 | 1 | 4 | 1 |
| No. of Approaches with Right Turn Lanes | 1.8 | 0 | 4 | 1.6 |
| No. of Approaches with Permissive Left Turn Phasing | 0.9 | 0 | 4 | 1.4 |
| No. of Approaches with Protected/Permissive Left Turn Phasing | 1.6 | 0 | 4 | 1.6 |
| No. of Approaches with Protected Left Turn Phasing | 1.5 | 0 | 4 | 1.7 |
| No. of Approaches with Prohibited RTOR | 0 | 0 | 1 | 0.2 |
| Pedestrian Volumes Crossing All Intersection Legs | 294 | 50 | 700 | 219.1 |
| Max. Number of Lanes Crossed by Pedestrians | 4.6 | 3 | 6 | 1.1 |
| No. of Bus Stops within 1,000 ft | 0.9 | 0 | 8 | 1.8 |
| No. of Schools within 1,000 ft | 0.3 | 0 | 5 | 0.9 |
| No. of Alcohol Sales Establishments within 1,000 ft | 2 | 0 | 4 | 1.5 |
| Number of Crashes | 39.2 | 4 | 118 | 29.7 |
| **Description** | **No. of Intersections** | | | |
| Lighting | 35 | | | |
| Presence of red-light running cameras | 1 | | | |

## 8.6 Results and Discussion

The results presented in this section include calibration factors, severity distribution factors, and crash type distribution factors for urban signalized intersections.

### 8.6.1 Calibration Factors

The calibration factor for urban three-legged signalized intersections (U3SG) is 2.95 and for urban four-leg signalized intersections (U4SG) is 5.21. The number of observed and predicted

crashes by facility is presented in Table 8.8. In addition, the IHSDM output is shown in Figure 8.14. These results indicate that the number of crashes observed at three-leg and four-leg signalized intersections in Missouri were greater than the number of crashes predicted by the HSM for these facility types.

**Table 8.8 Calibration results for urban signalized intersections**

| No. | Int. No. | Crashes | | No. | Int. No. | Crashes | |
|---|---|---|---|---|---|---|---|
| | | Observed | Predicted | | | Observed | Predicted |
| 1 | 188779 | 7 | 2 | 1 | 458532 | 21 | 5 |
| 2 | 409359 | 21 | 5 | 2 | 452499 | 73 | 6 |
| 3 | 431017 | 12 | 3 | 3 | 458516 | 17 | 4 |
| 4 | 651041 | 4 | 3 | 4 | 302287 | 43 | 5 |
| 5 | 302396 | 18 | 4 | 5 | 409975 | 31 | 9 |
| 6 | 121469 | 8 | 5 | 6 | 262974 | 22 | 7 |
| 7 | 168735 | 16 | 7 | 7 | 924806 | 76 | 15 |
| 8 | 123483 | 23 | 6 | 8 | 178087 | 29 | 9 |
| 9 | 929297 | 14 | 4 | 9 | 165662 | 58 | 7 |
| 10 | 143089 | 19 | 3 | 10 | 175906 | 88 | 13 |
| 11 | 68340 | 9 | 3 | 11 | 73685 | 10 | 5 |
| 12 | 288254 | 5 | 9 | 12 | 106134 | 26 | 4 |
| 13 | 324301 | 15 | 16 | 13 | 102590 | 54 | 4 |
| 14 | 489147 | 36 | 3 | 14 | 219337 | 26 | 10 |
| 15 | 496486 | 55 | 2 | 15 | 179534 | 12 | 7 |
| 16 | 574289 | 33 | 4 | 16 | 64653 | 56 | 12 |
| 17 | 588152 | 9 | 1 | 17 | 66131 | 67 | 10 |
| 18 | 928641 | 1 | 2 | 18 | 68315 | 55 | 12 |
| 19 | 251803 | 9 | 6 | 19 | 41614 | 4 | 4 |
| 20 | 313246 | 7 | 7 | 20 | 597292 | 19 | 6 |
| 21 | 347423 | 28 | 4 | 21 | 439049 | 19 | 3 |
| 22 | 651105 | 5 | 8 | 22 | 496355 | 99 | 9 |
| 23 | 543380 | 16 | 6 | 23 | 599957 | 32 | 3 |
| 24 | 257667 | 8 | 11 | 24 | 258418 | 98 | 12 |
| 25 | 523828 | 25 | 10 | 25 | 368007 | 6 | 2 |
| 26 | 932947 | 14 | 4 | 26 | 345142 | 21 | 4 |
| 27 | 512492 | 8 | 4 | 27 | 295564 | 11 | 12 |
| 28 | 963973 | 3 | 2 | 28 | 262408 | 41 | 11 |
| 29 | 963880 | 27 | 3 | 29 | 512290 | 23 | 13 |
| 30 | 963860 | 2 | 3 | 30 | 540602 | 45 | 10 |
| 31 | 137412 | 3 | 4 | 31 | 345687 | 17 | 2 |
| 32 | 291512 | 53 | 13 | 32 | 554723 | 15 | 6 |
| 33 | 249780 | 3 | 5 | 33 | 75399 | 34 | 6 |
| 34 | 253124 | 3 | 2 | 34 | 412009 | 6 | 2 |
| 35 | 299708 | 10 | 5 | 35 | 523287 | 118 | 15 |
| **Sum** | | **529** | **179** | **Sum** | | **1,372** | **263** |
| **Calibration Factor** | | **2.95** | | **Calibration Factor** | | **5.21** | |
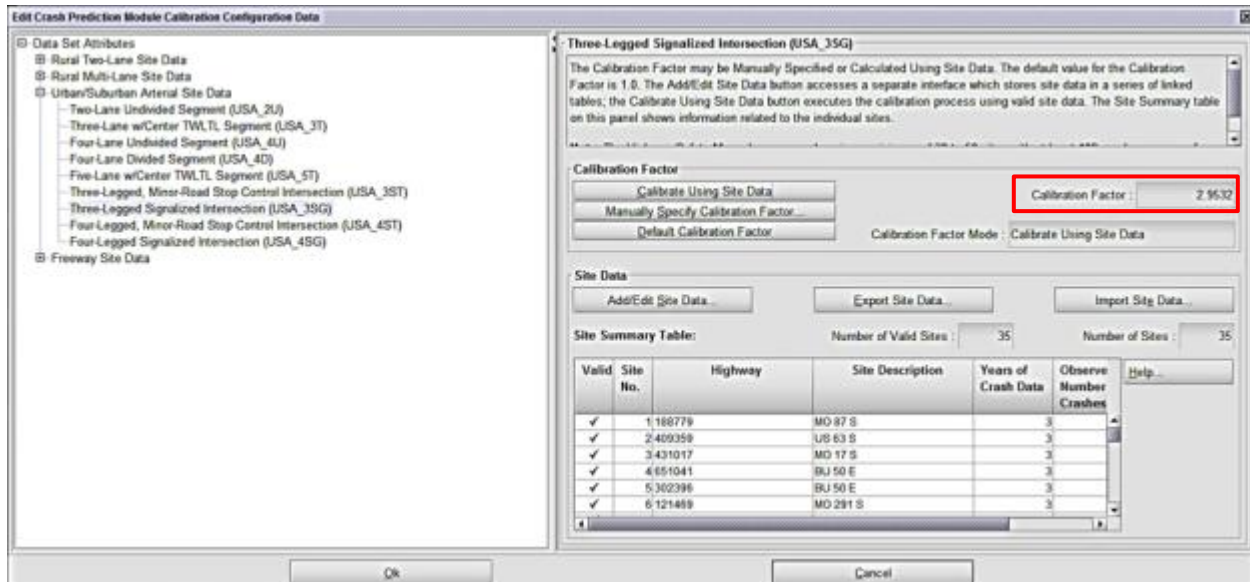
**(a) IHSDM calibration output for urban three-leg signalized intersection**
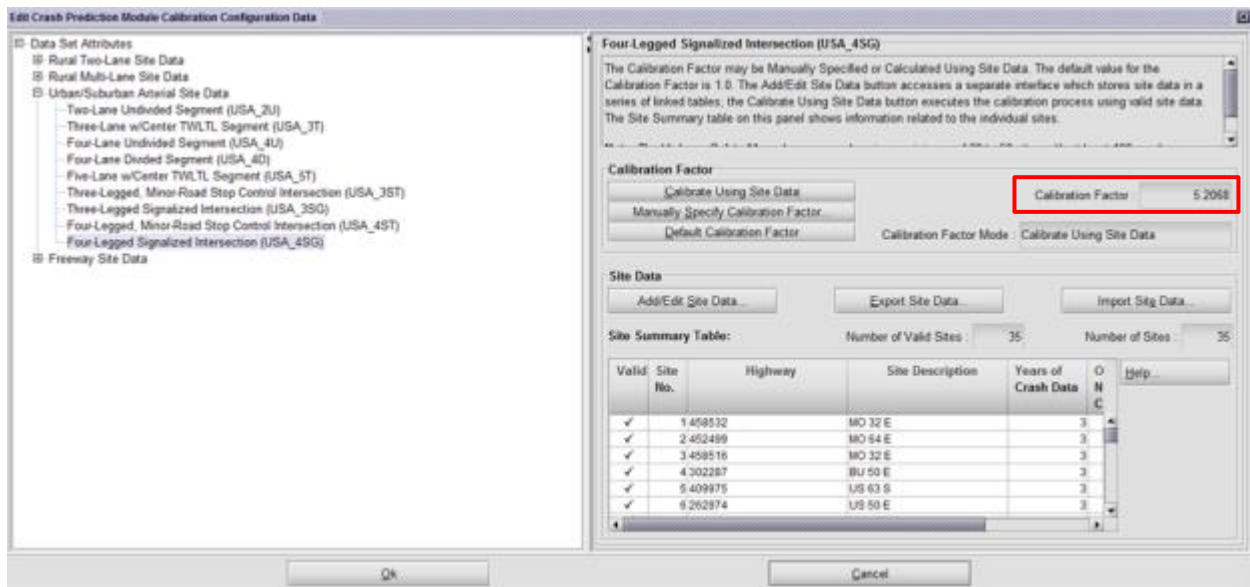


**(b) IHSDM calibration output for urban four-leg signalized intersection**

**Figure 8.14 IHSDM calibration output for urban signalized intersections**

For comparison, calibration results for a few other states are shown in Table 8.9. In comparison to the calibration factors obtained in other states, Missouri has larger calibration factors, which is consistent with the previous calibration (Sun et al. 2013). But other states also experienced large calibration factors. For example, Florida had values of 2.10 and 2.05 for U3SG and U4SG, respectively. North Carolina had values of 2.47 and 2.79 for U3SG and U4SG, respectively. And Ohio had values of 1.92 and 2.01 for U3SG and U4SG, respectively.

141

As explained in the previous report, possible explanations for the larger Missouri calibration values are the differences in the Missouri and HSM definitions of intersection crashes, data differences between Missouri and the sites used to develop the HSM predictive models, and recent changes in driver behavior, such as the increase in mobile device use. An example of a data difference is the differing property damage thresholds used in various states for allowing crash reporting. Some states such as Minnesota, North Carolina, Oregon, Washington, and California, have much higher thresholds than the $500 Missouri threshold. Because of these differences, it is recommended for Missouri to develop its own SPFs for urban four-legged and three-legged signalized intersections. Some possible reasons for the high calibration factor are explored in more detail in the following sections.

**Table 8.9 Calibration results for urban signalized intersections**

| State | Facility | Years of Data | Calibration Factor |
|---|---|---|---|
| Florida (Srinivasan et al. 2011) | U3SG KABC | 2005 | 1.98 |
| | | 2006 | 1.90 |
| | | 2007 | 2.10 |
| | | 2008 | 1.87 |
| | | 2009 | 1.41 |
| | U4SG KABC | 2005 | 2.05 |
| | | 2006 | 1.91 |
| | | 2007 | 1.82 |
| | | 2008 | 1.79 |
| | | 2009 | 1.84 |
| Maryland (Shin et al., 2014) | U3SG | 2008-2010 | 0.40 |
| | U4SG | | 0.48 |
| North Carolina (Srinivasan and Carter, 2011) | U3SG | 2007-2009 | 2.47 |
| | U4SG | | 2.79 |
| Oregon (Dixon et al., 2012) | U3SG | 2004-2006 | 0.75 |
| | U4SG | | 1.10 |
| Ohio (ODOT, 2014) | U3SG | N/A | 1.92 |
| | U4SG | | 2.01 |

8.6.1.1 Differences in Definition of Intersection Crash

One possible contributing factor to the higher calibration factor is the difference between Missouri and the HSM in the definition of an intersection crash. According to the Missouri STARS Manual, an officer is to enter "AT" if an accident occurred in an intersection for the "DISTANCE FROM" field and the "LOCATION" field (MTRC 2002). Note that the Missouri Uniform Accident Records (MUAR) form, unlike some other states, does not have a checkbox for an officer to indicate that the crash was "intersection-related." The new STARS Manual (MSC 2012) was revised on January 1, 2012, thus, it was not applicable to the data collected before that date. The new manual also had similar instructions for marking "AT" for the "LOCATION" field, with a slightly different description of "if the crash occurred within the

confines of the intersection…" According to Myrna Tucker from MoDOT Transportation Management System (TMS), if a crash occurred within 132 feet of an intersection, the crash was assigned an intersection number. Ms. Tucker explained that the distance was determined by MoDOT traffic engineers many years ago. This was also confirmed by Michael Curtit and John Miller, MoDOT Highway Safety and Traffic. However, this 132 foot threshold does not appear to be applied uniformly. When crash reports were reviewed manually for a DDI terminal study, crashes outside this distance were still assigned to intersections (Claros et al. 2015).

The HSM SPFs for signalized intersections were developed in the NCHRP 17-26 project and reported in NCHRP 129 (Harwood et al. 2007). The intersection criteria were the same as those used in the IHSDM, and are as follows:

1. An accident classified by the investigating officer was coded as "at intersection."
2. An accident on an intersection leg within 250 ft of the intersection was assigned to the intersection if the investigating officer or coder classified it as "intersection-related."

The purpose of this set of criteria is to ensure that only accidents that occurred because of intersection characteristics were assigned to the intersection. It is clear that the Missouri criteria for an intersection crash differs from the one used for HSM SPF development. The two main differences are the "intersection-related" checkbox and the difference in distance threshold. Nevertheless, it is unclear how much of the large calibration factor can be attributed to the intersection criteria difference. On the one hand, the omission of "intersection-related" crashes means that Missouri over-classifies some crashes, since not all crashes within 132 feet are intersection-related. For example, driveway-related crashes within 132 feet would be misclassified as intersection crashes. On the other hand, Missouri's threshold is smaller, thus it would under-classify intersection-related crashes that occurred between 132 and 250 feet; for example, a queue-related rear end crash could be misclassified. But, as previous discussed, the 132 foot threshold was not consistently applied.

8.6.1.2 Differences in Data

In addition to differences in the definition of an intersection crash, there were also differences between the data used for SPF development in the HSM and in the calibration of the HSM for Missouri. The data used for SPF development of signalized intersections came from Minnesota and North Carolina (Harwood et al. 2007). The Minnesota urban and suburban intersections were on state routes, and were all located in the Twin Cities metropolitan area. The North Carolina intersections were located in Charlotte, and were recommended by city traffic engineers. The totals of 96 and 108 intersections represent a significant, but not very large, number of intersections. The crash data for Minnesota was from 1998 to 2002, and the crash data for North Carolina was from 1997 to 2003.

The use of Charlotte and the Twin Cities for HSM SPF development points to some possible explanations for the high Missouri calibration factor. First, the HSM models were based on data from highly populated urban areas. The HSM definition of urban areas is much broader, and is based on FHWA guidelines, which defines urban areas as having a population of greater than

5,000. The HSM also gives the user discretion in making the determination of whether an area is urban. The calibration data set for the Missouri study included a broader range of the sizes of urban areas. In addition, the AADT ranges for the samples from Twin Cities and Charlotte may be higher than the AADT ranges in the Missouri study, since the Missouri data set included samples from smaller urban areas. The HSM models did not include some of the characteristics of signalized intersections, such as turn lane lengths, length of all-red interval, size of signal heads, and presence of flashing yellow arrows, factors that could have increased crash values.

Finally, there may not be much variation in some of the traffic signal characteristics of the Twin Cities and Charlotte. For example, the Twin Cities and/or MnDOT may have certain standards for signalized intersections that they incorporate into most of their designs. The Missouri calibration data set included intersections from many different cities that may display more differences with regard to signalization.

It is unclear to what degree differences between the state of Missouri and the states of Minnesota and North Carolina contributed to the large calibration factor. It is unlikely that the Twin Cities and Charlotte were exceptionally safe cities in terms of driver behavior, geometric design, and signal timing, since they were chosen as candidate sites for SPF development.

8.6.1.3 Changes in Driver Behavior over Time

Another possible explanation for the higher calibration factor could be changes in driver behavior. The HSM models for signalized intersections were based on crash data from 1997 to 2003. It is likely that many aspects of driver behavior have changed since that time. For example, distracted driving seems to have become more prevalent, especially with drivers who text and talk on cell phones. Distracted driving could be a significant factor in rear end crashes at intersections. It may be noted that the state of Oregon, which reported lower calibration values, had a primary cell phone law that prohibited all drivers from texting or talking on cell phones (IIHS). In contrast, the Missouri primary cell phone law only prohibited texting for drivers 21-years-old and younger.

8.6.2 Severity Distribution Factors

Using the data from calibration, severity distribution factors (SDF) were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 8.10 shows the obtained SDFs for urban signalized intersections. Although the factors for three and four leg are similar, using the appropriate factor for each facility type is recommended.

**Table 8.10 Severity Distribution Factors**

| Severity | Three-Leg | | Four-Leg | |
|---|---|---|---|---|
| | **Crashes** | **SDF** | **Crashes** | **SDF** |
| Fatal | 1 | 0.002 | 3 | 0.002 |
| Disabling Injury | 10 | 0.019 | 34 | 0.025 |
| Minor Injury | 107 | 0.202 | 300 | 0.219 |
| Property Damage Only | 411 | 0.777 | 1,035 | 0.754 |

8.6.3 Crash Type Distribution Factors

The crash type distribution factors (CDF) are used to determine the proportion of predicted crashes according to the type of crash. The data available from the calibration was used to estimate these factors. Some data processing was required in order to match Missouri crash type categories to the HSM categories. Therefore, different categories were aggregated to provide similar classifications as those recommended by the HSM. The crash types were also divided into multiple and single vehicle crashes. Pedestrian and cyclist crashes were not considered for these factors since there are specific SPFs for those types of crashes. Table 8.11 provides the CDFs for urban signalized intersections.

**Table 8.11 Crash type distribution factors**

| Multiple-Vehicle | | | | |
|---|---|---|---|---|
| **Collision Type** | **Three-Leg** | | **Four-Leg** | |
| | **Crashes** | **CDF** | **Crashes** | **CDF** |
| Rear End | 255 | 0.520 | 732 | 0.574 |
| Angle | 155 | 0.316 | 319 | 0.250 |
| Sideswipe | 48 | 0.098 | 146 | 0.115 |
| Head-on | 22 | 0.045 | 74 | 0.058 |
| Other | 10 | 0.020 | 4 | 0.003 |
| Single-Vehicle | | | | |
| **Collision Type** | **Three-Leg** | | **Four-Leg** | |
| | **Crashes** | **CDF** | **Crashes** | **CDF** |
| Out of Control | 23 | 0.719 | 62 | 0.747 |
| Deer | 4 | 0.125 | 2 | 0.024 |
| Parking or Parked Car | 2 | 0.063 | 6 | 0.072 |
| Fixed Object | 1 | 0.031 | 6 | 0.072 |
| Other | 2 | 0.063 | 7 | 0.084 |

# CHAPTER 9. UNSIGNALIZED INTERSECTIONS

## 9.1 Introduction and Scope

Multiple chapters of the HSM describe the methodology for crash prediction on different types of unsignalized intersections. All of the following unsignalized intersection types were calibrated as part of this project:

- Rural Two-Lane Three-Leg Unsignalized Intersections      (Chapter 10 of HSM)
- Rural Two-Lane Four-Leg Unsignalized Intersections      (Chapter 10 of HSM)
- Rural Multilane Three-Leg Unsignalized Intersections      (Chapter 11 of HSM)
- Rural Multilane Four-Leg Unsignalized Intersections      (Chapter 11 of HSM)
- Urban Three-Leg Unsignalized Intersections      (Chapter 12 of HSM)
- Urban Four-Leg Unsignalized Intersections      (Chapter 12 of HSM)

## 9.2 Calibration Data Requirement

For this calibration project, the results produced from 3-leg and 4-leg stop-controlled intersections are applicable to rural 2-lane roads, rural multilane roads, and urban/suburban arterials. For each of these facilities, a number of CMFs are applicable. This chapter will discuss how the values for these CMFs are determined for the Missouri calibration.

9.2.1 Required Site Data

9.2.1.1 Number of Approaches with Left-turn Lanes

A left-turn lane is the lane used for left turn movements. There is 0 or 1 left-turn lane for a 3-leg stop-controlled intersection. There are 0, 1 or 2 left-turn lanes for a 4-leg stop-controlled intersection. The HSM applies a CMF for left-turn lanes only on the uncontrolled major road approaches to stop-controlled intersections. Figure 9.1 shows different left-turn lane configurations at intersections.
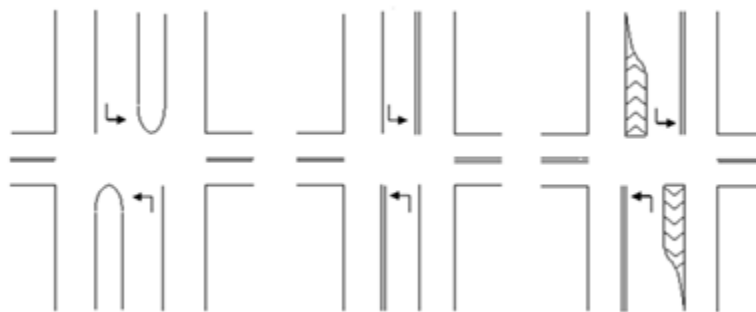


**Figure 9.1. Left-turn lane configurations (Chandler et al., 2013)**

Figure 9.2 shows examples of aerial and street view images of a 3-leg stop-controlled intersection. The north/south road in Figure 9.2(a) is the major road, and the east/west road in Figure 9.2(a) is a minor road. The reason for the major/minor road determination is that, as shown in Figure 9.2(b) and 9.2(c), the major road does not have a stop sign while the minor road does. Only the left-turn lane(s) on the major road needs to be counted. As the example in Figures 9.2(a) and (b) shows, the intersection has only one left-lane for HSM purposes.

**(a) Aerial view**
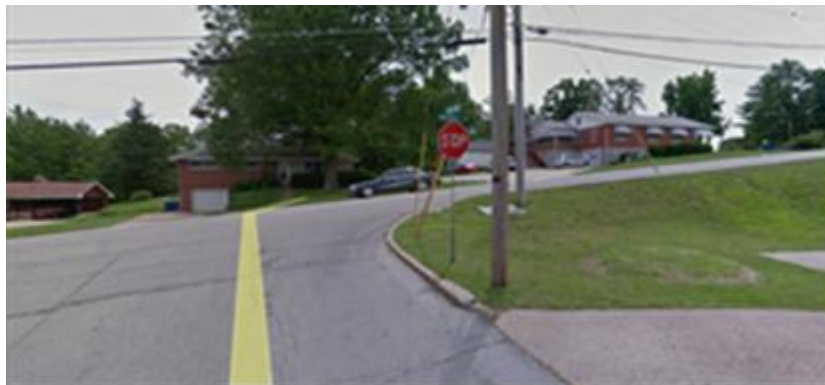


**(b) A major approach**



**(c) The minor approach**

**Figure 9.2 Example of 3-leg stop-controlled intersection (Google 2016)**

Figure 9.3 shows an example of aerial and street view images of a 4-leg stop-controlled intersection. The north/south road in Figure 9.3(a) is a major road, and the east/west road in Figure 9.3(a) is a minor road. The reason for the major/minor road designation is that the major road does not have a stop sign while the minor road does, as shown in Figure 9.3(b) and (c). Again, only the left-turn on the major road needs to be counted. As Figure 9.3(a) shows, the intersection has two left-turn lanes for HSM purposes, one in each north/south direction.

**(a) Aerial view**


**(b) A major approach**


**(c) A minor approach**

**Figure 9.3 Example of a 4-leg stop-controlled intersection (Google 2016)**

9.2.1.2 Number of Approaches with Right-Turn Lanes

A right-turn lane is an exclusive lane for right-turns. There can be 0 or 1 right-turn lane for a 3-leg stop-controlled intersection. There can be up to 4 right-turn lanes for a 4-leg stop-controlled intersection, but the HSM applies a CMF for right-turn lanes only on the uncontrolled major road approaches to stop-controlled intersections.

Figure 9.4 shows an example of aerial and street view image of a 3-leg stop-controlled intersection. The north/south road in Figure 9.4(a) is the major road, and the east/west road in the Figure 9.4(a) is a minor road. The reason for the major/minor determination is that, as shown in Figure 9.4(b), the major road does not have stop sign, but the minor road does, as shown in Figure 9.4(c). Only the right–turn lane on the major road needs to be counted. As Figure 9.4(a) and (b) show, the intersection has only one right-turn lane for HSM purposes.

**(a) Aerial view**



**(b) A major approach**



**(c) The minor approach**

**Figure 9.4 Example of a 3-leg stop-controlled intersection (Google 2016)**

9.2.1.3 Presence of Light

Illumination close to the intersection is considered lighting. Street view and ARAN are used to verify the presence of lighting (i.e. 'yes' or 'no'). Figure 9.5 shows an example of a light pole close to an intersection.



**Figure 9.5 Aerial and street view images of presence of light (Google 2016)**

9.2.1.4 Intersection Skew Angle

Skew angle for an intersection is defined as the absolute value of the deviation from an intersection angle of 90 degrees. The absolute value is used in the definition of skew angle because positive and negative skew angle are considered to have similar effects. Reducing the skew angle of three or four-leg stop-controlled intersections on rural multilane highways reduces total intersection crashes. Figure 9.6 illustrates skew angle.
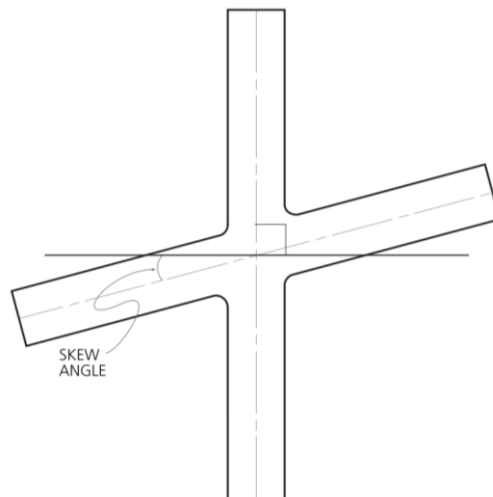


**Figure 9.6 Skew angle (AASHTO 2010)**

In the following example, aerial images of a 3-leg and a 4-leg stop-controlled intersection were reviewed. This was accomplished by using the "compass tool" image overlay, an option available for Google Earth. The major road was reoriented in the north/south direction to align with the compass tool. Then the deviation of the minor road can be measured from the east/west direction in degrees. Figure 9.7 shows the skew angle for the sample minor road on a 3-leg intersection is approximately 30 degrees. Figure 9.8 shows the skew angle for the sample minor road on a 4-leg intersection is approximately 30 degrees.



**Figure 9.7 Skew angle measurement for a 3-leg stop-controlled intersection (Google 2016)**



**Figure 9.8 Skew angle measurement for a 4-leg stop-controlled intersection (Google 2016)**

9.2.2 Required Traffic Data

9.2.2.1 AADT

Both the major road entering AADTs and minor road entering AADTs are needed. The following default HSM rules should be followed:

- If AADT data is available for only a single year, the same value is assumed to apply to all years of the before period.
- If two or more years of the AADT data are available, the AADT for intervening years are computed by interpolation.
- The AADT for the years before the first years for which data is available is assumed to be equal to the AADT for the first year.
- The AADT for the years after the last year for which data is available is assumed to be equal to the last year.

In the following example, the AADT of a 3-leg stop-controlled intersection was collected. In Figure 9.9(a), the east/west road is the minor road and the north/south road is the major road. The queries were conducted using ODBC in which the intersection identification number (SS_INTRSC_NUMBER) and years (SS_INTRSC_YEAR) of data were used, as shown in Figure 9.9(b). The resulting AADT table is shown in Figure 9.9(c). The direction in column three of Figure 9.9(c) means the entering direction. There are three directions: east, north and south. There is no west approach to the 3-leg stop-controlled intersection. In this case, the major road AADT should be the sum of northbound and southbound AADTs. The minor road AADT is the eastbound AADT. Figure 9.9(c) shows the major road AADT as 10,139 (sum of both approaches) in 2012 and the minor road AADT as 426 in 2012.

**(a) Aerial view (Google 2016)**



**(b) TMS query for AADT**

| SS_INTRSC_ | LEG_DESIGN | LEG_TRAVELWAY_NAME | LEG_DIRECTI | LEG_CONTIN | LEG_AADT |
|---|---|---|---|---|---|
| 2012 | CST | SWIFTS HWY | E | 0.213 | 426 |
| 2013 | CST | SWIFTS HWY | E | 0.213 | 471 |
| 2014 | CST | SWIFTS HWY | E | 0.213 | 497 |
| 2012 | CST | SOUTHWEST BLVD | N | 1.194 | 5273 |
| 2013 | CST | SOUTHWEST BLVD | N | 1.194 | 5820 |
| 2014 | CST | SOUTHWEST BLVD | N | 1.194 | 6146 |
| 2012 | CST | SOUTHWEST BLVD | S | 0.84 | 4866 |
| 2013 | CST | SOUTHWEST BLVD | S | 0.84 | 5388 |
| 2014 | CST | SOUTHWEST BLVD | S | 0.84 | 5698 |
| 2013 | CST | SWIFTS HWY | W | 0 | 471 |
| 2014 | CST | SWIFTS HWY | W | 0 | 497 |

**(c) AADT query results**

**Figure 9.9 Aerial and street view, and AADT of a 3-leg stop-controlled intersection**

In the following example, the AADT of a 4-leg stop-controlled intersection was collected. In Figure 9.10(a), the east/west road is the minor road and the north/south road is the major road. The resulting AADT table is shown in Figure 9.10(b). The direction in column three of Figure 9.10(b) means the entering direction. There are four directions: east, west, north and south. In this case, the major road AADT is the sum of northbound and southbound AADTs. The minor

road AADT is the sum of the eastbound and westbound AADTs. As shown in Figure 9.10(b), the major road AADT is 10,291 in 2012, and the minor road AADT is 864 in 2012.



**(a) Aerial view (Google 2016)**

| SS_INTRSC_` | LEG_DESIGN | LEG_TRAVELWAY_NAME | LEG_DIRECTI | LEG_CONTIN | LEG_AADT |
|---|---|---|---|---|---|
| 2012 | CST | 38TH ST | E | 0.256 | 432 |
| 2013 | CST | 38TH ST | E | 0.256 | 399 |
| 2014 | CST | 38TH ST | E | 0.256 | 412 |
| 2012 | CST | MAIN ST | N | 1.122 | 5283 |
| 2013 | CST | MAIN ST | N | 1.122 | 4992 |
| 2014 | CST | MAIN ST | N | 1.122 | 5008 |
| 2012 | CST | MAIN ST | S | 3.327 | 5008 |
| 2013 | CST | MAIN ST | S | 3.327 | 4499 |
| 2014 | CST | MAIN ST | S | 3.327 | 4805 |
| 2012 | CST | 38TH ST | W | 0.308 | 432 |
| 2013 | CST | 38TH ST | W | 0.308 | 399 |
| 2014 | CST | 38TH ST | W | 0.308 | 412 |

**(b) AADT query results**

**Figure 9.10 Aerial and street view, and AADTs of a 4-leg stop-controlled intersection**

## 9.3 HSM Methodology

As described in the HSM, the SPFs for unsignalized intersections predict the number of total crashes per year for the base conditions. The SPF is based on different considerations for each intersection type. Therefore, the methodology is described separately for each intersection type.

9.3.1 Rural Two-Lane Three- and Four-Leg Unsignalized Intersections

Chapter 10 of the HSM presents the SPFs for rural two-lane three- and four-leg unsignalized intersections. Major and minor stop control road traffic volumes (AADT) are used for the prediction of average crash frequency for intersection related crashes within the limits of a particular intersection. The SPFs consider rural two-way road intersections with two through lanes only, in both the major and minor road legs, without including the turning lanes.

The SPFs for both intersection types are given by:

$$N_{spf\ 3ST} = \exp\left[-9.86 + 0.79 \times \ln(AADT_{maj}) + 0.49 \times \ln(AADT_{min})\right] \qquad \textbf{(9.1)}$$

$$N_{spf\ 4ST} = \exp\left[-8.56 + 0.60 \times \ln(AADT_{maj}) + 0.61 \times \ln(AADT_{min})\right] \qquad \textbf{(9.2)}$$

where $N_{spf\ 3ST}$ is the predicted intersection related crash frequency for base conditions for rural three-leg stop-controlled intersections, $N_{spf\ 4ST}$ is the predicted intersection related crash frequency for base conditions for rural four-leg stop-controlled intersections, $AADT_{maj}$ is the AADT (vehicles per day) on the major road, and $AADT_{min}$ is the AADT (vehicles per day) on the minor road.

Table 9.1 presents the parameters applicable for both three-leg and four-leg intersection equations. The AADT ranges shown in Figure 9.1 for major and minor approaches are common for rural areas. The base conditions assumed for both three-leg and four-leg intersections SPFs are presented in Table 9.2. The base conditions represent a perpendicular intersection with stop control in all directions.

**Table 9.1 SPFs rural unsignalized three/four-leg stop-controlled intersection parameters**

| Intersection Type | Rural Unsignalized | |
| --- | --- | --- |
| | Three-Leg Stop-Controlled | Four-Leg Stop-Controlled |
| Overdispersion Parameter (k) | 0.54 | 0.24 |
| AADT$_{maj}$ | 0 to 19,500 vehicles per day | 0 to 14,700 vehicles per day |
| AADT$_{min}$ | 0 to 4,300 vehicles per day | 0 to 3,500 vehicles per day |

**Table 9.2 SPFs rural unsignalized three/four-leg stop-controlled intersection base conditions**

| Base Conditions | Description |
| --- | --- |
| Intersection Skew Angle | 0° |
| Intersection Left-Turn Lanes | None of the approaches without stop control |
| Intersection Right-Turn Lanes | None of the approaches without stop control |
| Lighting | None |

9.3.2 Rural Multilane Three- and Four-Leg Unsignalized Intersections

Chapter 11 of the HSM presents the SPFs for rural multilane three- and four-leg unsignalized intersections. Major and minor stop control road traffic volumes (AADT) are used for the prediction of average crash frequency for intersection related crashes within the limits of a particular intersection. The SPFs are applicable to rural multilane highway facilities with four

through lanes and stop control on minor road approaches. The SPFs for both three- and four-leg intersection types are given by:

$$N_{spf\ 3ST} = \exp\left[-12.526 + 1.204 \times \ln\left(AADT_{maj}\right) + 0.236 \times \ln(AADT_{min})\right] \quad (9.3)$$

$$N_{spf\ 4ST} = \exp\left[-10.008 + 0.848 \times \ln\left(AADT_{maj}\right) + 0.448 \times \ln(AADT_{min})\right] \quad (9.4)$$

where, $N_{spf\ 3ST}$ is the predicted intersection related crash frequency for base conditions for multilane three-leg stop-controlled intersections, $N_{spf\ 4ST}$ is the predicted intersection related crash frequency for base conditions for multilane four-leg stop-controlled intersections, $AADT_{maj}$ is the AADT (vehicles per day) on the major road, and $AADT_{min}$ is the AADT (vehicles per day) on the minor road.

Table 9.3 shows the parameters applicable to the three- and four-leg stop control intersection equations. Table 9.4 shows the base conditions for both SPF equations.

**Table 9.3 Rural multilane three/four-leg stop control intersection SPF parameters**

| Intersection Type | Rural Unsignalized Multilane | |
|---|---|---|
| | Three-Leg Stop-Controlled | Four-Leg Stop-Controlled |
| Overdispersion Parameter (k) | 0.460 | 0.494 |
| AADT$_{maj}$ | 0 to 78,300 vehicles per day | 0 to 78,300 vehicles per day |
| AADT$_{min}$ | 0 to 23,000 vehicles per day | 0 to 7,400 vehicles per day |

**Table 9.4 Multilane three/four-leg stop control intersection SPF base conditions**

| Base Conditions | Description |
|---|---|
| Intersection Skew Angle | 0° |
| Intersection Left-Turn Lanes | 0, except on stop-control approaches |
| Intersection Right-Turn Lanes | 0, except on stop-control approaches |
| Lighting | None |

*9.3.3 Urban Three- and Four-Leg Unsignalized Intersections*

Chapter 11 of the HSM presents the SPFs for urban three- and four-leg unsignalized intersections. Major and minor road traffic volumes (AADT) are used for the prediction of average crash frequency for intersection related crashes within the limits of a particular intersection. The SPFs are applicable for intersections on urban and suburban arterials with stop control on minor road approaches. The SPF is divided in two components, accounting for multiple-vehicle collisions and single-vehicle collisions for the base conditions. The total crash frequency is the sum of the multi-vehicle and single-vehicle collisions, as follows:

$$N_{spf\ int} = N_{bimv} + N_{bisv} \quad \textbf{(9.5)}$$

where $N_{spf\ int}$ is the predicted total average crash frequency of intersection related crashes for base conditions (excluding vehicle-pedestrian and vehicle-bicycle collisions), $N_{bimv}$ is the predicted average number of multiple-vehicle collisions for base conditions, and $N_{bisc}$ is the predicted average number of single-vehicle collisions for base conditions.

Multiple-Vehicle Collisions:

$$N_{bimv\ 3ST} = \exp\left[-13.36 + 1.11 \times \ln(AADT_{maj}) + 0.41 \times \ln(AADT_{min})\right] \qquad (9.6)$$

$$N_{bimv\ 4ST} = \exp\left[-8.90 + 0.82 \times \ln(AADT_{maj}) + 0.25 \times \ln(AADT_{min})\right] \qquad (9.7)$$

where $N_{bimv\ int}$ is the predicted average number of multiple-vehicle collisions for base conditions, $AADT_{maj}$ is the AADT (vehicles per day) on the major road, and $AADT_{min}$ is the AADT (vehicles per day) on the minor road.

Single-Vehicle Crashes:

$$N_{bisv\ 3ST} = \exp\left[-6.81 + 0.16 \times \ln(AADT_{maj}) + 0.51 \times \ln(AADT_{min})\right] \qquad (9.8)$$

$$N_{bisv\ 4ST} = \exp\left[-5.33 + 0.33 \times \ln(AADT_{maj}) + 0.12 \times \ln(AADT_{min})\right] \qquad (9.9)$$

where, $N_{bisv\ int}$ is the predicted average number of single-vehicle collisions for base conditions, $AADT_{maj}$ is the AADT (vehicles per day) on the major road, and $AADT_{min}$ is the AADT (vehicles per day) on the minor road.

Table 9.5 shows the overdispersion parameters that are applicable for the three- and four-leg intersection equations. Table 9.6 shows the AADT ranges that are applicable to the SPFs.

**Table 9.5 SPFs Urban unsignalized multiple-vehicle collision overdispersion parameters**

| Overdispersion Parameter (k) | Urban Unsignalized | |
| --- | --- | --- |
| | Three-Leg Stop-Controlled | Four-Leg Stop-Controlled |
| Multiple-Vehicle Collisions | 0.80 | 0.40 |
| Single- Vehicle Collisions | 1.14 | 0.65 |

**Table 9.6 SPFs applicable AADT ranges**

| Intersection Type | Urban Unsignalized | |
| --- | --- | --- |
| | Three-Leg Stop-Controlled | Four-Leg Stop-Controlled |
| AADT$_{maj}$ | 0 to 45,700 vehicles per day | 0 to 46,800 vehicles per day |
| AADT$_{min}$ | 0 to 9,300 vehicles per day | 0 to 5,900 vehicles per day |

## 9.4 Sampling

Because this project is a recalibration, there was an attempt to use the same sample of sites from the previous calibration efforts. However, it was necessary to verify that a site has not undergone geometric or other changes that would disqualify the site. Each site was examined for multiple attributes that must be present in order to be classified as a certain type of intersection. These attributes include the number of undivided lanes on the major roadway segment, the presence of three or four approach legs, and the existence of stop control on the minor road only. Of particular note were the addition of lanes, work zone areas that disrupt traffic, changes in control type, and changes in rural/urban classification.

Different challenges were encountered during the sampling of unsignalized intersections. Initially, visual identification was used to verify the existence of stop control on the minor road. But it was difficult to perform stop control verification for certain rural areas, since neither ARAN records nor street view images existed; these samples, therefore, were not included. In general, sampling for unsignalized intersections in rural areas was more difficult than in urban areas, due to the difficulty in obtaining information related to leg names, locations, and specific intersections.

Another challenge encountered during intersection sampling was difficulty in finding samples for rural multilane three/four-leg unsignalized intersections. Many considerations were used to attempt to obtain samples following the basic criteria of randomness and consistency with intersection type characteristics. The first consideration was to examine major facilities only. Unfortunately, no samples were found. Therefore, instead of sampling intersections directly, the sampling was based on the rural multilane highway segments as discussed in Chapter 5. Although it remained difficult to find rural multilane unsignalized three-leg intersections, since some districts did not have a large set of intersections along a facility within the district's region, the lack of samples was compensated for by using available samples from other districts. Because of the sampling process, a total of 416 unsignalized intersections were sampled.

The lists of intersections are found in Tables 9.7-9.12. The tables contain the intersection number that was used for the identification and collection of data. The locations (county and district) of intersections were also included. The lists display 10 intersections that were collected for each district. As mentioned previously, when a district lacked sufficient samples for rural multilane intersections, the deficit was compensated for with samples from other districts.

Table 9.7 is the list of rural two-lane three-leg unsignalized intersections. Table 9.8 is the list of rural two-lane four-leg unsignalized intersections. Table 9.9 is the list of rural multilane three-leg unsignalized intersections. Seventy-one rural multilane three-leg intersections were initially selected. However, one intersection was misclassified since it had a fourth leg, and so it was dropped. Table 9.10 is the list of rural multilane four-leg unsignalized intersections. Sixty-seven rural multilane four-leg intersections were initially identified. However, one intersection was a J-turn and was dropped. The rural multilane lists, for three- and four-leg intersections, contain almost all such intersections in Missouri due to the scarcity of such intersections in Missouri. Table 9.11 is the list of urban three-leg unsignalized intersections. Table 9.12 is the list of urban

four-leg unsignalized intersections. Several sites were changed from the previous calibration due to various reasons, including geometric changes and erroneous intersection numbers.

**Table 9.7 List of sites for rural two-lane three-leg unsignalized intersections**

| Site No | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 1 | CD | Grand Av, Hwy H, Moniteau, MO 65025 | 277931 | Moniteau |
| 2 | CD | County Road 4029, Hwy 94, Summit, Callaway, MO 65043 | 301833 | Callaway |
| 3 | CD | Bottom Diggins Rd, Hwy E, Union, Washington, MO 63630 | 398249 | Washington |
| 4 | CD | County Road 240A, Hwy 32, Spring Creek West, Missouri 65560 | 462095 | Dent |
| 5 | CD | Blank Rd, Hwy Hh, Vanpool Rd, Moniteau, MO 65074 | 313734 | Moniteau |
| 6 | CD | County Road 432, Hwy 240, Howard, MO 65274 | 165855 | Howard |
| 7 | CD | Cannon Mines Rd, Hwy 21, Union, Washington, MO 63630 | 395691 | Washington |
| 8 | CD | Jim Henry Road, Hwy 17, Jim Henry, Miller, MO 65032 | 358162 | Miller |
| 9 | CD | James Rd, Hwy Ff,  Richland, Laclede, MO 65556 | 437012 | Laclede |
| 10 | CD | 5th St, Hwy 50, Rosebud, Gasconade, MO 63091 | 341235 | Gasconade |
| 11 | KC | Top Water Street, Hwy Z, Bates City, Lafayette, MO 64011 | 1024754 | Lafayette |
| 12 | KC | Slusher School Rd, Hwy 13, Lexington, Lafayette, MO 64067 | 148501 | Lafayette |
| 13 | KC | Bell Rd, Hwy 13, Davis, Lafayette, MO 64037 | 183496 | Lafayette |
| 14 | KC | Goose Creek Rd, Hwy Pp, Concordia, Lafayette, MO 64020 | 194504 | Lafayette |
| 15 | KC | Boyer Rd, Hwy 210, Fishing River, Clay, MO 64024 | 128338 | Clay |
| 16 | KC | Main Street Road, Hwy 127, Sedalia, Pettis, MO 65301 | 257933 | Pettis |
| 17 | KC | State Hwy Z, Bainbridge Rd, Bates City, Lafayette, MO 64011 | 182234 | Lafayette |
| 18 | KC | State Hwy Kk, W 196th St, Polk, Ray, MO 64062 | 101512 | Ray |
| 19 | KC | State Hwy Hh, Shippy Rd, Sni-A-Bar, Lafayette, MO | 199141 | Lafayette |
| 20 | KC | 12th St, S Main St, Holden, Johnson, MO 64040 | 259956 | Johnson |
| 21 | NE | Hwy V, CRD 15, Clark, MO 63453 | 117 | Clark |
| 22 | NE | County Road 557, Hwy P, Vandalia, Audrain, MO 63382 | 119371 | Audrain |
| 23 | NE | State Hwy Dd, County road 84, Revere, Clark, MO 63465 | 5567 | Clark |
| 24 | NE | County Road 283, Hwy U, Warren, Marion, Missouri 63461 | 73147 | Marion |
| 25 | NE | County Road 439, Hwy Ww, Shelbina, Shelby, Missouri 63468 | 81668 | Shelby |
| 26 | NE | County Road 931, Hwy M Union, Monroe, Missouri 65263 | 111199 | Monroe |
| 27 | NE | Dragonfly Pl, Hwy 149, Walnut Creek, Macon, MO 63539 | 56428 | Macon |
| 28 | NE | County Road 229, Hwy C, Warren, Marion, MO 63456 | 66821 | Marion |
| 29 | NE | Lackland St, Hwy Ww, New Florence, Montgomery, MO 63363 | 200260 | Montgomery |
| 30 | NE | Pike 57, Pike 58, RA, Pike, MO 63441 | 98338 | Pike |
| 31 | NW | S 185 Street, Missouri DD, Marion, Daviess, MO 64647 | 49142 | Daviess |
| 32 | NW | W 185 Street, Missouri DD, Marion, Daviess, MO 64647 | 49076 | Daviess |
| 33 | NW | Hwy 129, Hwy J, New Boston, Linn, MO 63557 | 51127 | Linn |
| 34 | NW | Hwy H, McCurry Grove Rd, MO 64438 | 30409 | Gentry |
| 35 | NW | West North Street, Hwy Y, Plattsburg, Clinton, MO 64477 | 89124 | Clinton |
| 36 | NW | State Hwy A, Hwy 190, Chillicothe, Livingston, MO 64601 | 59129 | Livingston |
| 37 | NW | Garden Dr, Hwy Hh, Union, Sullivan, MO 63545 | 30013 | Sullivan |
| 38 | NW | 11th St, E McPherson St, Hwy 246, Nodaway, MO 64461 | 2101 | Nodaway |
| 39 | NW | 370 St, Hwy H, Cooper, Gentry, MO 64438 | 31927 | Gentry |

**Table 9.7 Continued**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 40 | NW | 332 Street, Hwy 190, Jackson, Daviess, MO 64648 | 56702 | Daviess |
| 41 | SE | Midvale Rd, Hwy 17, Carroll, Texas, MO 65571 | 516183 | Texas |
| 42 | SE | Bowden Drive, Hwy Y, Doniphan, Ripley, MO 63935 | 616858 | Ripley |
| 43 | SE | County Road 76-221, Hwy 76, Ava, Douglas, MO 65608 | 569355 | Douglas |
| 44 | SE | Emma St, Mc Kinley Ave, Hwy DD, Fisk, Butler, MO 63940 | 592827 | Butler |
| 45 | SE | 7 Falls Dr, State Rd C, Ste. Genevieve, MO 63670 | 925236 | Genevieve |
| 46 | SE | State Hwy U, Hwy 76, Miller, Douglas, MO | 563643 | Douglas |
| 47 | SE | Hwy 160, 3rd St, Ozark, MO 65655 | 659340 | Ozark |
| 48 | SE | County Road 223, Hwy M, Stoddard, MO 63825 | 564661 | Stoddard |
| 49 | SE | County Road 95-142, Hwy 95, Douglas County, MO 65711 | 564170 | Douglas |
| 50 | SE | Garfield St, US 60 Bus,  Willow Springs, Howell, MO 65793 | 563127 | Howell |
| 51 | SL | Hyfield School Rd, Hwy P, De Soto, Jefferson, MO 63020 | 373777 | Jefferson |
| 52 | SL | Lynch Rd, St. Josephs Rd, Hwy F, Jefferson, MO 63051 | 334130 | Jefferson |
| 53 | SL | Grafton Ferry Rd, Hwy 94, St. Charles, MO 63301 | 197233 | St. Charles |
| 54 | SL | Hwy V, Hwy 94, St. Charles, MO 63301 | 199154 | St. Charles |
| 55 | SL | Rolling Stone Ln, John MacKeever Rd, Jefferson, MO 63069 | 333345 | Jefferson |
| 56 | SL | Big Pine Pl, State Road H, Big River, Jefferson, MO 63020 | 377213 | Jefferson |
| 57 | SL | Plass Rd, Buckeye Rd, Festus, Jefferson, MO 63028 | 360531 | Jefferson |
| 58 | SL | Hwy V, Marais Becket Rd, St. Charles, MO 63301 | 199192 | St. Charles |
| 59 | SL | Klondike Rd, Hwy B, Hillsboro, Jefferson, MO 63050 | 354737 | Jefferson |
| 61 | SW | 19th St, Cassville, Hwy 37, Main St, Barry, MO 65625 | 1010106 | Barry |
| 62 | SW | Fr 1195, Hwy 248, Mineral, Barry, MO | 602021 | Barry |
| 63 | SW | State Hwy Dd, 951Rd, Cedar, MO 64744 | 423141 | Cedar |
| 64 | SW | County Road 2130, Missouri T, Lawrence, MO 65610 | 547167 | Lawrence |
| 65 | SW | Poppy Ln, Hwy 14, Lincoln, Christian, MO 65610 | 555567 | Christian |
| 66 | SW | East 405th Road, Hwy Aa, Northeast Marion, Polk, MO | 455897 | Polk |
| 67 | SW | Osage Rd, Hwy DD, Niangua, Webster, MO 65713 | 498873 | Webster |
| 68 | SW | Glen Oaks Dr, Hwy 86, Blue Eye, Stone, MO 65611 | 636407 | Stone |
| 69 | SW | South Ward Street, Hwy 39, Stockton, Cedar, MO 65785 | 452012 | Cedar |
| 70 | SW | Wilson Rd, Hwy Zz, Lincoln, Christian, MO 65631 | 548004 | Christian |

**Table 9.8 List of sites for rural two-lane four-leg unsignalized intersections**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 1 | CD | Rasa Dr, N Pine Rd, Hwy 135, Stover, Morgan, MO 65078 | 309234 | Morgan |
| 2 | CD | Pigeon Dr (County Rd Bb-225), Route BB, Laclede, MO 65536 | 439001 | Laclede |
| 3 | CD | Normandy Dr, Hwy 32, Lebanon, Laclede, MO 65536 | 459214 | Laclede |
| 4 | CD | Elkstown Road, Hwy 5, Lebanon, Cooper, MO | 249169 | Cooper |
| 5 | CD | Hwy 32, State Hwy P, County Rd 418, Dent County, MO 65560 | 457991 | Dent |
| 6 | CD | County Line Rd, Hwy Aa, Saline, Miller, MO | 337073 | Miller |
| 7 | CD | Scott Ave, Hwy K, Blackwater, Cooper, MO 65322 | 185659 | Cooper |
| 8 | CD | County Road 404, 406, Hwy A, Moniteau, Howard, MO 65248 | 150348 | Howard |
| 9 | CD | Strassner Rd, Hwy F, Hwy W, Gasconade, MO 65041 | 941340 | Gasconade |
| 10 | CD | Humphrey Creek Road, Hwy A, Osage, Miller, MO | 376560 | Miller |
| 11 | KC | Hwy 58, Third St, Holden, Johnson, MO 64040 | 257488 | Johnson |
| 12 | KC | SW 701st Rd, SW County Road VV, Johnson, MO | 247971 | Johnson |
| 13 | KC | Marshall School Rd, Hwy 24, Lexington, Lafayette, MO 64067 | 144057 | Lafayette |
| 14 | KC | Market St, Hwy 371, Dearborn, Platte, MO 64439 | 94741 | Platte |
| 15 | KC | Egypt Rd, Hwy 210, Orrick, Ray, MO 64077 | 131307 | Ray |
| 16 | KC | Stillhouse RD, Mize Rd, Co Hwy 4s, Jackson, MO 64075 | 179272 | Jackson |
| 17 | KC | Florence Rd, Hwy 135, Hwy 50, Smithton, Pettis, MO 65350 | 266798 | Pettis |
| 18 | KC | Hwy 224, 10th St, Lexington, Lafayette, MO 64067 | 139264 | Lafayette |
| 19 | KC | East 237th Street, SE Bend Ln, Hwy 291, Cass, MO 64701 | 265534 | Cass |
| 20 | KC | State Hwy Zz, Hwy 52, Hwy E, Washington, Pettis, MO | 314183 | Pettis |
| 21 | NE | County Road 155, 154, State Hwy Aa, Knox, MO 63537 | 31011 | Knox |
| 22 | NE | Hwy B, CRD 960 958, Scotland, MO | 498 | Scotland |
| 23 | NE | Cherry St, Clow St, Hwy C, Ewing, Lewis, MO 63440 | 1029271 | Lewis |
| 24 | NE | County Road 457, Hwy J, Prairie, Audrain, MO | 122384 | Audrain |
| 25 | NE | W Missouri Ave, Maple St, Vandalia, Audrain, MO 63382 | 1037510 | Audrain |
| 26 | NE | North 1st Street, W Cedar Ave, Clarence, Shelby, MO 63437 | 72647 | Shelby |
| 27 | NE | 5th St, Hwy 61, Lewis, MO | 43610 | Lewis |
| 28 | NE | East Maple Street, State Hwy E, Curryville, Pike, MO 63339 | 114079 | Pike |
| 29 | NE | Tennessee Street, N 3rd St, Hwy 79, Louisiana, Pike, MO | 1026494 | Pike |
| 30 | NE | Henderson Street, Hwy 61, Route B, Canton, Lewis, MO 63435 | 35796 | Lewis |
| 31 | NW | Main St, 8th St, Eagleville, Harrison, MO 64442 | 8607 | Harrison |
| 32 | NW | Mike Rd, Hwy 5, Missouri D, Salt Creek, Chariton, MO 64676 | 87502 | Chariton |
| 33 | NW | Washington St, N 22nd St, Hwy 5, Putnam, MO 63565 | 8111 | Putnam |
| 34 | NW | 6th Street, Hwy 246, Sheridan, Worth, MO 64486 | 4139 | Worth |
| 35 | NW | West Truman Street, Kansas Ave, Route JJ, Linn, MO 64658 | 76413 | Linn |
| 36 | NW | Jade Pl, Karma Ave, State Hwy D, Madison, Mercer, MO 64679 | 22531 | Mercer |
| 37 | NW | North Van Buren Street, Hwy 136, Albany, Gentry, MO 64402 | 26276 | Gentry |
| 38 | NW | Vawter Rd, Vawter Rd, Rte DD, Taylor, Sullivan County, MO | 41297 | Sullivan |

**Table 9.8 Continued**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 39 | NW | Talc Ln, State Hwy Y, Franklin, Grundy, MO 64679 | 27746 | Grundy |
| 40 | NW | State Hwy M, Hwy C, Worth, MO 64499 | 14176 | Worth |
| 41 | SE | State Hwy F, Luyster St (School), Koshkonong, MO 65692 | 626406 | Oregon |
| 42 | SE | Pcr 452, Hwy A, Chirch St, Brazeau, Perry, MO | 453325 | Perry |
| 43 | SE | County Road 738, 702, Hwy Y, Bollinger, MO 63787 | 513096 | Bollinger |
| 44 | SE | County Road 3250, Route W, Sisson, Howell, MO | 587463 | Howell |
| 45 | SE | County Road 613, 612, Hwy V, Girardeau, MO 63701 | 478407 | Cape Girardeau |
| 46 | SE | S 10th St, Hwy 19, Oregon County, MO | 637405 | Oregon |
| 47 | SE | County Road 40, Missouri O, Iron, MO 63623 | 447271 | Iron |
| 48 | SE | County Road 324, Hwy 61, New Madrid, MO 63873 | 640131 | New Madrid |
| 49 | SE | State Hwy W, Rose St, Oran, Scott, MO 63771 | 536334 | Scott |
| 50 | SE | County Road 650, Hwy 51, Broseley, Butler, MO 63932 | 608573 | Butler |
| 51 | SL | Wilderness Ln, Old Colony Rd, Hwy Dd, MO 63341 | 268319 | St. Charles |
| 52 | SL | Tin House Rd, Hwy Y, Hillsboro, Jefferson, MO 63050 | 373859 | Jefferson |
| 53 | SL | Hendricks Rd, Hwy 30, Prairie, Franklin, MO | 352615 | Franklin |
| 54 | SL | Valles Mines School Rd, Valles Mines PO Rd, MO 63020 | 393922 | Jefferson |
| 55 | SL | Lake Virginia Dr, Zion Rd, Hwy P, Festus, MO | 368471 | Jefferson |
| 56 | SL | 4 Mile Rd, Hwy A, St. Johns, Franklin, MO 63090 | 316496 | Franklin |
| 57 | SL | Yeates Rd, Boeuf Creek Rd, Hwy 100, Franklin, MO 63068 | 296187 | Franklin |
| 58 | SL | Segelhorst Rd, Hwy 50, Lyon, Franklin, MO 63056 | 336257 | Franklin |
| 59 | SL | Hwy H, Hwy J, Hwy 94, St. Charles, MO 63301 | 195523 | St. Charles |
| 60 | SL | Iron Hill Rd, Hwy Tt, Saint Clair, Franklin, MO 63077 | 344139 | Franklin |
| 61 | SW | Main Street, Hwy 160, Greenfield, Dade, MO 65661 | 485991 | Dade |
| 62 | SW | NE 9003 Rd, Hwy D, Bates, MO | 352932 | Bates |
| 63 | SW | East 460th Road, Hwy Vv, Hwy 123, MO 65649 | 466699 | Polk |
| 64 | SW | Lady Rd, Hwy C, Washington, Vernon, MO 64772 | 422047 | Vernon |
| 65 | SW | Gum Rd, Hwy 43, Five Mile, Newton, MO | 569360 | Newton |
| 66 | SW | NE 100th Ln, Hwy C, Milford, Barton, MO 64759 | 466633 | Barton |
| 67 | SW | Lamar St, Sarcoxie St, Hwy 37, Avilla, Jasper, MO 64859 | 519300 | Jasper |
| 68 | SW | SW 150th Ln, Hwy 126, South West, Barton, MO 64832 | 487311 | Barton |
| 69 | SW | Linden Ave, Hwy 14, Hwy 125,Christian, MO 65753 | 562392 | Christian |
| 70 | SW | 1st St, Hwy P, St. Clair, MO 64724 | 375649 | St. Clair |

**Table 9.9 List of sites for rural multilane three-leg unsignalized intersections**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 1 | NW | Iris Trail, Hwy 71, White Cloud, Nodaway, MO | 34899 | Nodaway |
| 2 | NW | County Road 54, Hwy 71, Rosendale, Andrew, MO 64483 | 40661 | Andrew |
| 3 | NE | Rte J, Hwy 63, Macon, MO | 53678 | Macon |
| 4 | NW | County Road 364, Hwy 59 (71), Savannah, Andrew, MO 64485 | 54991 | Andrew |
| 5 | NW | Ava Dr, Hwy 36, Wheeling, Livingston, MO 64688 | 67148 | Livingston |
| 6 | NW | State Hwy Ab, Hwy 31, Hwy 36, Easton, Buchanan, MO 64443 | 70321 | Buchanan |
| 7 | NE | Kensington Pl, Hwy 63, Macon, MO 63552 | 77998 | Macon |
| 8 | NE | State Hwy Hh, Hwy 61, Clay, Ralls, MO | 80248 | Ralls |
| 9 | NE | State Hwy J, Hwy 24, Ralls, MO | 80408 | Ralls |
| 10 | NE | Hwy Ww, Hwy 61, Cuivre, Pike, MO | 122588 | Pike |
| 11 | NE | Hwy F, Hwy 61, Eolia, Lincoln, MO 63344 | 136430 | Lincoln |
| 12 | NE | Timber Ridge Dr and Hwy 61 | 169476 | Lincoln |
| 13 | CD | County Rd 158, Hwy 54, Jackson, Callaway, MO 65231 | 181777 | Callaway |
| 14 | SL | Cinder Rd, Hwy 67, West Alton, St. Charles, MO 63386 | 207828 | St. Charles |
| 15 | KC | NW 375th Rd, Hwy 50, Johnson, MO | 222211 | Johnson |
| 16 | KC | Elm Hills Blvd, Hwy 65, Sedalia, Pettis, MO 65301 | 273240 | Pettis |
| 17 | KC | Missouri TT, Hwy 7, Harrisonville, Cass, Missouri 64701 | 292231 | Cass |
| 18 | SL | Elizabeth Anne Ln, Hwy 100, Franklin, MO | 317163 | Franklin |
| 19 | CD | State Hwy D, Hwy 54, Lohman, Cole, MO | 328837 | Cole |
| 20 | SW | NW Hwy DD, Hwy 7, Honey Creek, Henry, MO | 334896 | Henry |
| 21 | SW | Frisch Avenue, Hwy 65, Lincoln, Benton, MO 65338 | 340675 | Benton |
| 22 | SW | Jenny Ln, Hwy 65, Lincoln, Benton, MO 65338 | 341135 | Benton |
| 23 | SW | Airport Rd, Hwy 65, Lincoln, Benton, MO 65338 | 341182 | Benton |
| 24 | SW | Northwest 311 Road, Hwy 7, Fields Creek, Henry, MO 64735 | 342130 | Henry |
| 25 | SW | Locust St, Hwy 65, Lincoln, Benton, MO 65338 | 342235 | Benton |
| 26 | SW | State Hwy Ac, Hwy 65, Benton, MO | 346252 | Benton |
| 27 | SW | Cedargate Dr, Hwy 65, Benton, MO | 357162 | Benton |
| 28 | SE | Valles Mines Rd, Hwy 67, Valles Mines, MO 63087 | 395973 | Jefferson |
| 29 | CD | 5th St, Hwy 54, Camdenton, Camden, MO 65020 | 400983 | Camden |
| 30 | CD | 4th Street, Hwy 54, Camdenton, Camden, MO 65020 | 401000 | Camden |
| 31 | CD | 3rd St, Hwy 54, Camdenton, Camden, MO 65020 | 401063 | Camden |
| 32 | CD | Grant Ave, Hwy 54, Camdenton, Camden, MO 65020 | 401324 | Camden |
| 33 | CD | Iowa St (Lake Ave), Hwy 54, Camdenton, Camden, MO 65020 | 402187 | Camden |
| 34 | SW | Hwy UU, Hwy 13, St. Clair, MO | 426433 | St. Clair |
| 35 | SE | County Road 220, Hwy 67, Mine La Motte, Madison, MO 63645 | 461488 | Madison |
| 36 | SE | State Hwy H and Hwy 67 | 462363 | Madison |
| 37 | SW | Rocks Dale Rd, Hwy 65, Dallas, MO | 470050 | Dallas |
| 38 | SE | County Road 417, Hwy 67, Central, Madison, MO 63645 | 478605 | Madison |
| 39 | SE | County Road 303, Hwy 67, Madison, MO | 486267 | Madison |
| 40 | SE | Hwy EE, Hwy 67, Cedar Creek, Wayne, MO | 499137 | Wayne |

**Table 9.9 Continued**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 41 | SW | State Hwy O, Diggins, Webster, MO 65746 | 526207 | Webster |
| 42 | SW | Northwest 351 Road, Hwy 7, Fields Creek, Henry, MO 64735 | 651611 | Henry |
| 43 | KC | OR 50 (Old Highway 50), Hwy 50, Pettis, Missouri 65301 | 652956 | Pettis |
| 44 | NW | 400th Street, Hwy 71, White Cloud, Nodaway, MO | 654173 | Nodaway |
| 45 | NW | County Road 140, Hwy 71, Bolckow, Andrew, MO 64427 | 654183 | Andrew |
| 46 | NW | County Road 139, Hwy 71, Rosendale, Andrew, MO 64483 | 654186 | Andrew |
| 47 | NE | State Hwy Dd, Hwy 24 (Hwy 36), Marion, MO | 919584 | Marion |
| 48 | NW | 112 SE, Hwy 36, Easton, Buchanan, Missouri 64443 | 954216 | Buchanan |
| 49 | NE | County Road 494, Hwy 61, Canton, Lewis, MO 63448 | 954295 | Lewis |
| 50 | NE | County Road 263, Hwy 24, South River, Marion, MO | 982897 | Marion |
| 51 | CD | County Road 348, Hwy 54, New Bloomfield, Callaway, MO 65063 | 984961 | Callaway |
| 52 | SL | S Buck Creek Rd and  Hwy 67 | 996785 | Jefferson |
| 53 | SE | County Road 547, Hwy 67, Black River, Wayne, MO 63967 | 1014034 | Wayne |
| 54 | SW | Crossroads Dr, Hwy 65, South Benton, Dallas, MO 65622 | 1022960 | Dallas |
| 55 | SE | County Road 454, 450, Hwy 67, Twelvemile, Madison, MO 63964 | 1023614 | Madison |
| 56 | SE | County Road 452, Hwy 67, Twelvemile, Madison, MO 63964 | 1024242 | Madison |
| 57 | SW | Lamine St, Hwy 65, Benton, MO 65338 | 1039950 | Benton |
| 58 | SE | County Road 302, Hwy 67, Cedar Creek, Wayne, MO 63636 | 1042119 | Wayne |
| 59 | SW | Meyer Rd, Hwy 65, North Lindsey, Benton, MO | 1054123 | Benton |
| 60 | CD | State Hwy K, Hwy 50, Walker, Moniteau, MO 65018 | 1021606/ 1021605 | Moniteau |
| 61 | NE | Thompson St, Hwy 24, Hwy 61, Palmyra, Marion, MO 63461 | 1024454/10 24455 | Marion |
| 62 | KC | Hwy H, Hwy 65, Saline, MO | 170127/930 296 | Saline |
| 63 | SL | Wise Rd, Hwy 67, West Alton, St. Charles, MO 63386 | 203232/203 079 | St. Charles |
| 64 | CD | Missouri A, Hwy 54, Camden, MO | 396153/396 155 | Camden |
| 65 | SE | Tower Rd, Hwy 67, Big River, St. Francois, MO 63628 | 398410/976 253 | St. Francois |
| 66 | SE | Pike Run Rd, Hwy 67, Big River, St. Francois, MO | 399038/976 296 | St. Francois |
| 67 | SW | NW 1401 Rd, Hwy 7, Bogard, Henry, MO 64788 | 651600/327 958 | Henry |
| 68 | NW | Hwy 33, Hwy 36, Dekalb, MO | 68202/6816 2 | Dekalb |
| 69 | NE | State Hwy H, Hwy 24, South River, Marion, MO | 78472/9829 00 | Marion |
| 70 | SW | Branson Creek Boulevard, Hwy 65, Hollister, Taney, MO 65672 | 978785/978 785 | Taney |

**Table 9.10 List of sites for rural multilane four-leg unsignalized intersections**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 1 | NE | County Road 312, 338, Marion, MO 63471 | 55861 | Marion |
| 2 | NE | County Road 1330 (A102)(1420), Hwy 63,Randolph,MO 65270 | 97866 | Randolph |
| 3 | KC | County Road 339 (318), Hwy UU, Saline, MO 65340 | 176331 | Saline |
| 4 | CD | County Road 14, Hwy 54, Callaway, MO 65262 | 187945 | Callaway |
| 5 | KC | Buckeye Rd, Hwy 50, Pettis, MO 65337 | 246176 | Pettis |
| 6 | CD | County Road 394, Hwy 63, Callaway, MO 65039 | 279662 | Callaway |
| 7 | KC | E 315th St, Hwy 7, Cass, MO 64747 | 312342 | Cass |
| 8 | KC | O'Bannon Rd, Hwy 7, Cass, MO 64747 | 313066 | Cass |
| 9 | SL | Jones Ln, Hwy 100, Franklin, MO 63090 | 313754 | Franklin |
| 10 | SW | Northwest 900 Road, Hwy 7, Henry, MO 64739 | 323701 | Henry |
| 11 | SW | Northwest 800 Road, Hwy 7, Henry, MO 64788 | 326085 | Henry |
| 12 | SW | State Hwy HH, N W 500 Bc, Benton, MO 65338 | 337086 | Benton |
| 13 | SW | Zion Church Rd, Hwy 65,Benton, MO 65338 | 343348 | Benton |
| 14 | SW | State Hwy H , N W 351 Bc, Benton, MO 65338 | 344457 | Benton |
| 15 | SW | SW 400 Rd, Hwy 52, Henry, MO 64735 | 355004 | Henry |
| 16 | SW | Southwest 450th Road, Hwy 52, Henry, MO 64735 | 355980 | Henry |
| 17 | SW | SE 900 Rd, Hwy 13, Henry, MO 64740 | 367926 | Henry |
| 18 | SW | NE 1270 Rd (SE 1100 Rd), Hwy 13, Henry, MO 64740 | 372958 | Henry |
| 19 | SE | Canterberry Rd, Hwy 67, St. Francois, MO 63640 | 451074 | St. Francois |
| 20 | SW | Woodstock Rd, Hwy 65, Dallas, MO 65644 | 480168 | Dallas |
| 21 | SE | County Road 303, 211, Wayne, MO 63956 | 503562 | Wayne |
| 22 | SE | County Road 213, Hwy 67, Wayne, MO 63964 | 512804 | Wayne |
| 23 | SW | NE 800 Rd, 7th St, St. Clair, MO 64763 | 653589 | St. Clair |
| 24 | NW | 395th St, Hwy 71, Nodaway, MO 64423 | 654171 | Nodaway |
| 25 | NW | County Road 137 ,41, Andrew, MO 64483 | 654174 | Andrew |
| 26 | NW | County Road 80, 36, Andrew, MO 64427 | 654182 | Andrew |
| 27 | CD | Forest Rd, Hwy 50, Moniteau, MO 65018 | 655027 | Moniteau |
| 28 | SW | SE 1150, Hwy 13, St. Clair. MO 64738 | 941779 | St. Clair |
| 29 | SW | East 310th Road, Hwy 13, Polk, MO 65674 | 941785 | Polk |
| 30 | CD | County Line Rd , Hwy 50, Moniteau, MO 65023 | 975965 | Moniteau |
| 31 | CD | Shooters Club Rd, Hwy 50, Moniteau. MO 65018 | 976005 | Moniteau |
| 32 | NE | State Hwy U, Hwy 24, Marion, MO 63456 | 982890 | Marion |
| 33 | SE | State Hwy O, Monday Ln, Butler MO 63967 | 1014049 | Butler |
| 34 | SE | County Road 501, 401, Butler MO 63967 | 1014051 | Butler |
| 35 | SW | Foose Rd, Hwy 65, Jackson, Dallas, MO 65622 | 1019957 | Dallas |
| 36 | SE | County road 216, 305, Wayne, MO 63964 | 1042125 | Wayne |
| 37 | SE | Hwy 49, Hwy 172, Wayne, MO 63967 | 1014045 | Wayne |
| 38 | CD | Jacket Factory Road, Hwy 50, Moniteau, MO 65018 | 1021590 | Moniteau |
| 39 | SE | State Highway C, Hwy 67, Madison, MO 63645 | 1024002 | Madison |
| 40 | SE | County Road 209, 303, Oregon, MO 63645 | 1042121 | Oregon |
| 41 | SE | County Road 211, 303, Wayne, MO 63956 | 1042123 | Wayne |

**Table 9.10 Continued**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 42 | NE | Creech Ln,  Hwy 61, Lincoln, MO 63379 | 158982/158986 | Lincoln |
| 43 | CD | Missouri T,  Hwy 54, Callaway, MO 65231 | 177959/177956 | Callaway |
| 44 | KC | State Hwy CC,  Hwy 65, Pettis, MO 65351 | 199292/210624 | Pettis |
| 45 | KC | NW 821st Rd,  Hwy 50, Johnson, MO 64019 | 226286/226104 | Johnson |
| 46 | CD | County Road 338,  Hwy 54, Callaway, MO 65063 | 244134/984721 | Callaway |
| 47 | KC | State Hwy T,  Hwy 50, Pettis, MO 65301 | 249999/250088 | Pettis |
| 48 | KC | Missouri T,  Hwy 7, Cass, MO 64747 | 296848/296743 | Cass |
| 49 | NW | 370th St,  Hwy 71, Nodaway, MO 64423 | 30947/654167 | Nodaway |
| 50 | SL | St Johns Rd,  Hwy 100, Franklin MO 63090 | 312682/1024463 | Franklin |
| 51 | SL | Hwy 100, Hwy V, Franklin. MO 63055 | 318872/1024465 | Franklin |
| 52 | CD | Abbott Rd,  Hwy 54, Miller, MO 65032 | 344653/344604 | Miller |
| 53 | SW | SE 700 Rd,  Hwy 52, Henry ,MO 64740 | 362072/653616 | Henry |
| 54 | CD | State Hwy V,  Hwy 54, Miller, MO 65026 | 367877/367923 | Miller |
| 55 | SL | Timbercreek Dr,  Baisch Dr, Jefferson, MO 63020 | 388534/997231 | Jefferson |
| 56 | NE | County Road 567,  Hwy 61, Lewis, MO 63448 | 48315/48292 | Lewis |
| 57 | NE | State Hwy V,  Hwy 61, Lewis, MO 63471 | 49594/49602 | Lewis |
| 58 | NE | County Road 349,  308, Marion, MO 63471 | 51604/51603 | Marion |
| 59 | NW | Hwy 36,  Hwy 5, Linn, MO 64651 | 66977/67046 | Linn |
| 60 | NW | State Highway C,  Hwy Z, Buchanan, MO 64443 | 69991/70053 | Buchanan |
| 61 | NE | County Road 441,  409, Marion, MO 63401 | 70986/70950 | Marion |
| 62 | NE | County Rd 1745 (B56),  1640 (A40), Randolph, MO 65239 | 935184/92565 | Randolph |
| 63 | SW | SE 750 Rd,  Hwy 13, St. Clair, MO 64738 | 970861/417848 | St. Clair |
| 64 | CD | Murphy Ford Rd,  Hwy 50, Cole, MO 65023 | 975964/975956 | Cole |
| 65 | CD | 9 Hills Rd,  Hwy 50, Cole, MO 65109 | 975966/975958/975962 | Cole |
| 66 | CD | Route U,  Hwy 50, Cole, MO 65023 | 975983/975990 | Cole |

**Table 9.11 List of sites for urban three-leg unsignalized intersections**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 1 | CD | Swifts Highway, Southwest Blvd, Jefferson City, Cole, MO 65109 | 305939 | Cole |
| 2 | CD | Court St, Hwy 5, New Franklin, Howard, MO 65274 | 175046 | Howard |
| 3 | CD | Young St, E 10th St, Dent Ford Rd, Salem, Dent, MO 65560 | 456083 | Dent |
| 4 | CD | Hwy W, US54W TO RTW, Callaway, MO | 297854 | Callaway |
| 5 | CD | Holloway Street, Rolla, 11th St, Phelps County, MO 65401 | 409794 | Phelps |
| 6 | CD | Maywood Dr, W Edgewood Dr, Jefferson City, Cole, MO 65109 | 305756 | Cole |
| 7 | CD | Grace Ln, Sombart Rd, Boonville, Cooper, MO 65233 | 959247 | Cooper |
| 8 | CD | North Park Avenue, W 4th St, Salem, Dent, MO 65560 | 456871 | Dent |
| 9 | CD | Fuqua Drive, Hwy 5, US 40, Boonville, Cooper, MO 65233 | 196263 | Cooper |
| 10 | CD | County Road 3060, Rd 44, Old St James Rd, Hy Point Ind. Dr, Rolla, Phelps, Missouri 65401 | 405755 | Phelps |
| 11 | KC | Victor St, Prospect Ave, Kansas City, Jackson, MO 64128 | 159600 | Jackson |
| 12 | KC | Hillcrest Road, E 107th Rd, Kansas City, Jackson, MO | 195531 | Jackson |
| 13 | KC | Swope Ln, N Fairview Dr, Independence, Jackson, MO 64056 | 148666 | Jackson |
| 14 | KC | Rhodus Rd, NE 1040th St, Excelsior Springs, Clay, MO 64024 | 115223 | Clay |
| 15 | KC | Northwest Robinhood Lane, NW 108th St, Kansas City, Platte, MO | 121303 | Platte |
| 16 | KC | Oak Terrace, 64113, Kansas City, Jackson, MO 64113 | 176297 | Jackson |
| 17 | KC | Lauren St, Birmingham Rd, Liberty, Clay, MO 64068 | 939962 | Clay |
| 18 | KC | Killion Dr, E 24th St, Sedalia, Pettis, MO 65301 | 267677 | Pettis |
| 19 | KC | Ella St, Hwy 58, Belton, Cass, MO 64012 | 223036 | Cass |
| 20 | KC | Cole Rd, E Ketucky Rd, Jackson, Missouri 64050 | 147308 | Jackson |
| 21 | NE | Sparks Avenue, Buchanan St, Moberly, Randolph, MO 65270 | 1031957 | Randolph |
| 22 | NE | Daugherty St, Rollings St, Macon, MO 63552 | 73300 | Macon |
| 23 | NE | W Normal St, S Osteopathy, Kirksville, Adair, MO 63501 | 32041 | Adair |
| 24 | NE | East Anderson Street, Agricultural St, Hwy J, Mexico, Audrain, MO 65265 | 141064 | Audrain |
| 25 | NE | Hwy Ee, E Burkhart St, Moberly, Randolph, MO 65270 | 106291 | Randolph |
| 26 | NE | E Goggin St, S Rutherford, Macon, MO 63552 | 73953 | Macon |
| 27 | NE | Perkins Blvd, W Perry St, Troy, Lincoln, MO 63379 | 181671 | Lincoln |
| 28 | NE | N Abat St, W Liberty St, Hwy Ff, Mexico, Audrain, Missouri 65265 | 141791 | Audrain |
| 29 | NE | W Bourke Street, Sunset Hills Dr, Macon, MO 63552 | 73408 | Macon |
| 30 | NE | S Spoede Ln, E Veterans Memorial Pkwy, OR 70, Truesdale, Warren, MO | 219459 | Warren |
| 31 | NW | Parker Rd, Washington St, St. Joseph, Buchanan, MO 64504 | 77417 | Buchanan |
| 32 | NW | South Market Street, Lincoln Ter, Maryville, Nodaway, MO 64468 | 19167 | Nodaway |
| 33 | NW | South East Street, E 2nd St, Cameron, Clinton, MO 64429 | 72581 | Clinton |
| 34 | NW | Helena St, St Joseph Ave, Hwy 59, Buchanan, MO 64505 | 62916 | Buchanan |
| 35 | NW | Wilton Dr, Elizabeth St, St. Joseph, Buchanan, MO 64504 | 76153 | Buchanan |
| 36 | NW | W 8th St, Cherry St, Cameron, DeKalb, Missouri 64429 | 71210 | Dekalb |
| 37 | NW | Prindle St, S 4th St, St. Joseph, Buchanan, MO 64504 | 74533 | Buchanan |
| 38 | NW | West Meadow Lane, Messanie St, St. Joseph, Buchanan, MO 64501 | 67330 | Buchanan |

**Table 9.11 Continued**

| Site No. | District | Description | Intersection No. | County |
|---|---|---|---|---|
| 39 | NW | Mary St, S 22md St, St. Joseph, Buchanan, MO | 67534 | Buchanan |
| 40 | NW | County Line Rd, 28th Terrace, St. Joseph, Andrew County, MO | 59571 | Andrew |
| 41 | SE | South Pacific Street, Merriwether St, Cape Girardeau, MO 63703 | 496314 | Cape Girardeau |
| 42 | SE | Hwy K, Loraine St, Bonne Terre, St. Francois, MO 63628 | 412211 | St. Francois |
| 43 | SE | East Elk Street, N Nelson Ave, Dexter, Stoddard, MO 63841 | 589794 | Stoddard |
| 44 | SE | East Elk Street, Gibson Ave, State Route CC, Dexter, Stoddard, MO 63841 | 602197 | Howell |
| 45 | SE | Glenn Drive, County Line Rd, Sikeston, Scott, MO 63801 | 577242 | Scott |
| 46 | SE | Hovis Farm Rd, W Main St. Hwy Z,  Park Hills, MO 63601 | 421875 | St. Francois |
| 47 | SE | Highland Avenue, W 3rd St, Caruthersville, Pemiscot, MO 63830 | 645579 | Pemiscot |
| 48 | SE | Burgoyne Drive, Hwy 63, West Plains, Howell, MO 65775 | 601287 | Howell |
| 49 | SE | Clay Street, Hwy K, Perry, St. Francois, MO 63628 | 412269 | St. Francois |
| 50 | SE | Vine St, N Front St, Hwy 32, Park Hills, St. Francois, MO 63601 | 424183 | St. Francois |
| 51 | SL | Patricia Ridge Drive, Old Halls Ferry Rd, Black Jack, St. Louis, MO 63033 | 226548 | St. Louis |
| 52 | SL | Kossuth Ave, Gano Ave, St. Louis, MO | 264601 | St. Louis city |
| 53 | SL | Cabanne Ave, Union Blvd, St. Louis, MO | 267897 | St. Louis city |
| 54 | SL | Midland Blvd, Bryant Ave, St. Louis, MO | 1019326 | St. Louis |
| 55 | SL | Sapphire Ave, College Ave, St. Louis, MO 63136 | 250551 | St. Louis |
| 56 | SL | Ringer Rd, Kinswood Ln, OR 255, St. Louis, MO | 316451 | St. Louis |
| 57 | SL | South Duchesne Drive, Walter PI, St. Charles, MO 63301 | 225902 | St. Charles |
| 58 | SL | Wall Street, E Maple Ave, Wentzville, St. Charles, MO 63385 | 219068 | St. Charles |
| 59 | SL | Glaser Rd, N Service Rd E, OR 44, Sullivan, Franklin, MO 63080 | 361456 | Franklin |
| 60 | SL | Sadonia Ave, Moran Dr, St. Louis, MO 63135 | 233589 | St. Louis |
| 61 | SW | Glenwood Ave, W Farm Rd 178, E Hines St, Republic, Greene, MO 65738 | 937218 | Greene |
| 62 | SW | State Hwy Mm, Nevada St, Oronogo, Jasper, MO | 519949 | Jasper |
| 63 | SW | South Grant Street, Hwy 96, E Grant Ave, Carthage, Jasper, MO 64836 | 522684 | Jasper |
| 64 | SW | South Peyton Street, E Ohio St, Hwy 18, Clinton, Henry, MO 64735 | 345735 | Henry |
| 65 | SW | E Portland St, S Fairway St, Springfield, Greene, MO | 522711 | Greene |
| 66 | SW | Mill St, N Main St, Willard, Greene, MO 65781 | 539712 | Greene |
| 67 | SW | West Cherokee Street, S Weaver Ave, Springfield, Greene, MO 65807 | 524371 | Greene |
| 68 | SW | South Cavalier Avenue, E Cherry St, Springfield, Greene, MO 65802 | 518931 | Greene |
| 69 | SW | Michigan Avenue, E 7th St, Hwy 66,  Joplin, Jasper, MO | 545140 | Jasper |
| 70 | SW | Adams St, W Hadley St, Aurora, Lawrence, MO 65605 | 569431 | Lawrence |

**Table 9.12 List of sites for urban four-leg unsignalized intersections**

| Site No. | District | Description | Intersec. No. | County |
|---|---|---|---|---|
| 1 | CD | Marshall St, E High St, Jefferson City, Cole, MO 65101 | 304938 | Cole |
| 2 | CD | Vintage Ln, Vintage Ct, Rte C, Jefferson City, MO 65109 | 312195 | Cole |
| 3 | CD | North Aurora Street, W 1st St, Eldon, Miller, MO 65026 | 349377 | Miller |
| 4 | CD | Vine St, Hwy 5, Hwy 40, Main St, Boonville, Cooper, MO 65233 | 187208 | Cooper |
| 5 | CD | Clark Ave, Atchison St, Moreau Dr, Jefferson City, MO 65101 | 308178 | Cole |
| 6 | CD | Fulkerson St, High St, Jefferson City, Cole, MO 65109 | 301453 | Cole |
| 7 | CD | Hough St, McKinley St, Jefferson City, Cole, MO 65101 | 306250 | Cole |
| 8 | CD | North Dilworth, Missouri J, County Rd 322, Salem, Dent, MO 65560 | 456497 | Dent |
| 9 | CD | Atkinson Rd, William Woods Ave, Fulton, Callaway, MO 65251 | 209569 | Callaway |
| 10 | CD | North Grand Avenue, W 9th St, Eldon, Miller, MO 65026 | 350342 | Miller |
| 11 | KC | Northwest Old Pike Road, NW 53rd St, Gladstone, Clay, MO 64118 | 136897 | Clay |
| 12 | KC | Charlotte St, E 43rd St, Kansas City, MO 64131 | 165415 | Jackson |
| 13 | KC | Main St, 38th St, Kansas City, Jackson, MO | 163188 | Jackson |
| 14 | KC | North Huntsman Boulevard, N Campbell Blvd, Hwy 58, Raymore, Cass, MO 64083 | 224016 | Cass |
| 15 | KC | North 81st Terrace, NE Antioch Rd, Kansas City, Clay, MO 64119 | 1014604 | Clay |
| 16 | KC | North Holmes Street, NE 45th St, Kansas City, Clay, MO | 139797 | Clay |
| 17 | KC | Crysler St, E 42nd St, Kansas City, Jackson, MO 64133 | 166696 | Jackson |
| 18 | KC | W Black Diamond St, College St, Richmond, Ray, MO 64085 | 122705 | Ray |
| 19 | KC | Ararat Dr, S Park Dr, Sni A Bar Rd, Kansas City, Jackson, MO | 168731 | Jackson |
| 20 | KC | Northeast 39th Street, N Prather Rd, Hwy 1, Kansas City, Clay, MO | 141967 | Clay |
| 21 | NE | Center St, N 7th St, Hannibal, Marion, MO 63401 | 76414 | Marion |
| 22 | NE | State Hwy Mm, W Main St, Warrenton, MO 63383 | 222282 | Warren |
| 23 | NE | South Sturgeon Street, E Rollings St, Moberly, Randolph, MO 65270 | 106143 | Randolph |
| 24 | NE | W Brewington Ave, Hwy 63, Kirksville, Adair, MO 63501 | 28087 | Adair |
| 25 | NE | S Cuivre St, W Main St, Bowling Green, Pike, MO 63334 | 1026956 | Pike |
| 26 | NE | Wightman St, S 4th St, Moberly, Randolph, MO 65270 | 106235 | Randolph |
| 27 | NE | Magnolia Ave, Bird St, Hannibal, Marion, MO 63401 | 76551 | Marion |
| 28 | NE | W Pearson St, N Washington St, Mexico, Audrain, MO 65265 | 1038144 | Audrain |
| 29 | NE | County Road 418, Hwy Mm, Hannibal, Marion, MO 63401 | 77182 | Marion |
| 30 | NE | Holman Rd, Fisk Ave, Moberly, Randolph, MO 65270 | 106542 | Randolph |
| 31 | NW | Jules St, N 7th St, St. Joseph, Buchanan, MO | 66244 | Buchanan |
| 32 | NW | South Harris Street, N Harris St, 2nd St, State Hwy A, Cameron, Clinton, MO 64429 | 72360 | Clinton |
| 33 | NW | West 24th Street, Princeton Rd, Route AA, Trenton, Grundy, MO 64683 | 40344 | Grundy |
| 34 | NW | Jules St, Main St, St. Joseph, Buchanan, MO | 66236 | Buchanan |
| 35 | NW | Lulu St, 22nd St, Trenton, Grundy, MO 64683 | 40463 | Grundy |
| 36 | NW | N Mulberry Street, W 11th St, Maryville, Nodaway, MO 64468 | 17320 | Nodaway |

**Table 9.12 Continued**

| Site No. | District | Description | Intersec. No. | County |
|---|---|---|---|---|
| 37 | NW | E Franklin Street, N 4th St, St. Joseph, Buchanan, MO 64501 | 65213 | Buchanan |
| 38 | NW | Cook Rd, Riverside Rd, St. Joseph, Buchanan, MO | 60813 | Buchanan |
| 39 | NW | Market St, W Main St, Rushville, Buchanan, MO 64484 | 63827 | Buchanan |
| 40 | NW | N Dewey Street, Hwy 46, Maryville, Nodaway, MO 64468 | 18163 | Nodaway |
| 41 | SE | Mary Street, Hwy 61, Jackson, Cape Girardeau, MO 63755 | 484881 | Cape Girardeau |
| 42 | SE | Hwy 25, Broadwater Rd, CRD 524, Como, New Madrid, MO 63863 | 625178 | New Madrid |
| 43 | SE | Walker Avenue, 9th St, Caruthersville, Pemiscot, MO 63830 | 645764 | Pemiscot |
| 44 | SE | South Henderson Avenue, Independence St, Cape Girardeau, MO 63703 | 496062 | Cape Girardeau |
| 45 | SE | Alice St, Neat St, Poplar Bluff, Butler, MO 63901 | 596476 | Butler |
| 46 | SE | Sikes Ave, Hwy 61, Sikeston, Scott, MO 63801 | 573513 | Scott |
| 47 | SE | Locust Avenue, Hwy 84, Caruthersville, Pemiscot, MO 63830 | 645659 | Pemiscot |
| 48 | SE | Carleton Ave, 4th St, Caruthersville, Pemiscot, MO 63830 | 645616 | Pemiscot |
| 49 | SE | Daisy Ave, Adams St, Jackson, Cape Girardeau, MO 63755 | 645616 | Cape Girardeau |
| 50 | SE | Carzon Rd, Hwy K, Perry, St. Francois, MO 63628 | 412139 | St. Francois |
| 51 | SL | Ohio Avenue, Arsenal Ave, St. Louis, MO | 286596 | St. Louis city |
| 52 | SL | Russell Blvd, 13th St, St. Louis, MO | 283857 | St. Louis city |
| 53 | SL | Chariot Dr, Gladiator Dr, Fenton, St. Louis, MO 63026 | 309450 | St. Louis |
| 54 | SL | Leonard Ave, Washington Blvd, St. Louis, MO | 273816 | St. Louis city |
| 55 | SL | Creekside Ln, Chambray Ct, St. Louis, MO 63141 | 266616 | St. Louis |
| 56 | SL | North Mosley Road, Terra Mar Ln, Hunters Pond Rd, St. Louis, MO 63141 | 268375 | St. Louis |
| 57 | SL | Monique Ct, Boca Raton Dr, Willott Rd, St. Peters, St. Charles, MO 63376 | 232797 | St. Charles |
| 58 | SL | Parnell St, Warren St, St. Louis, MO | 269334 | St. Louis city |
| 59 | SL | Hampton Avenue, Hartford St, St. Louis, MO | 285072 | St. Louis city |
| 60 | SL | Baxter Rd, Summer Ridge Dr, Manchester, St. Louis, MO | 277546 | St. Louis |
| 61 | SW | Kickapoo Ave, E Grant St, Springfield, Greene, MO | 520141 | Greene |
| 62 | SW | W Atlantic St, N Main St, Springfield, Greene, MO | 513439 | Greene |
| 63 | SW | East 33rd Street, Finley Ave, Joplin, Newton, MO 64804 | 551867 | Newton |
| 64 | SW | South Lillian Avenue, W Madison St, Bolivar, Polk, MO 65613 | 463380 | Polk |
| 65 | SW | Morgan Avenue, W Cofield St, Aurora, Lawrence, MO 65605 | 566266 | Lawrence |
| 66 | SW | South Fountain Street, W Main St, Carterville, Jasper, MO 64835 | 529689 | Jasper |
| 67 | SW | Daniels St, S Carnation Rd, Aurora, Lawrence, MO 65605 | 569938 | Lawrence |
| 68 | SW | Highland Ave, Hwy 66, Joplin, Jasper, MO 64801 | 545220 | Jasper |
| 69 | SW | North Pine Street, E Hubble Dr, Hwy CC, Marshfield, Webster, MO 65706 | 497046 | Webster |
| 70 | SW | East Hickory Street, RU 71, N Osage Blvd, Nevada, Vernon, MO 64772 | 428046 | Vernon |

**9.5 Data Collection**

The data required for urban unsignalized intersections consisted of AADTs for major and minor approaches, number of approaches with left/right turn lanes, skew angle, and the presence of lighting. A list of the data types collected and their sources is shown in Table 9.13. Aerial photographs were used to determine the presence of either left or right turning lanes, the number of legs, and the skew angle. ARAN video, along with aerial and street view photographs, were used to determine the presence of lighting at the intersections. The AADTs from 2012 to 2014, and total crashes were collected from the TMS system.

**Table 9.13 List of data sources for unsignalized intersections**

| Data Description | Source |
|---|---|
| AADT | TMS |
| No. of Approaches with Left-Turn Lanes | Aerials |
| No. of Approaches with Right-Turn Lanes | Aerials |
| Presence of Lighting | ARAN and Street View |
| No. of Crashes | TMS |

Several challenges were encountered during the collection of data for urban unsignalized intersections. One such issue was the total number of crashes for the three-year time period, which was considerably fewer than the HSM recommendation of at least 100 crashes for a facility type. Even with oversampling (i.e., 70 sites), the total number of crashes observed for unsignalized facility types was still below the HSM recommendation. Another difficulty occurred when the crash query was initiated. The program that was utilized had to be handled in a particular way or else the crash query might produce incorrect results. For example, after searching for the desired intersection number, careful consideration was required when selecting the intersecting travelways. The minor leg direction, especially, was sometimes problematic. If a direction other than the minor approach leg were selected, the query would show that no crashes were observed on that site. However, if the approach direction was chosen as the selected travelway, the query would produce crashes if there were actual crashes observed at the intersection within the specified timeframe.

9.5.1 Summary Statistics for Unsignalized Intersections

Descriptive statistics for all unsignalized intersections are shown in Table 9.14. The average AADT was much higher for rural multilane (i.e., 12,070 and 9,609) compared to rural two-lane intersections (i.e., 1,366 and 1,712). The average AADT for urban intersections was 4,319 and 4,511, respectively, for three- and four-leg intersections.

The highest average skew angle observed was 14.4 degrees for rural two-lane three-leg intersections. Approaches with left turn lanes was most common for rural multilane intersections, with an average of 0.8 (three-leg) and 1.6 (four-leg). The row entitled, "Number of Crashes in 3

Years," is the total number of crashes for all the sites in a particular facility type. As can be seen in Table 9.14, the three types of intersections that experienced the recommended 100 crashes were urban four-leg intersections (172 crashes), rural multilane three-leg intersections (169 crashes), and rural multilane four-leg intersections (144 crashes).

**Table 9.14 Sample descriptive statistics unsignalized intersections**

| Description | Ave. | Min. | Max. | Std. Dev. | Ave. | Min. | Max. | Std. Dev. | Ave. | Min. | Max. | Std. Dev. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intersection Type | R2L 3ST[1] | | | | R2L 4ST[2] | | | | U 3ST[3] | | | |
| Major AADT (2014) | 1365.5 | 34.0 | 7264.0 | 1671.8 | 1711.7 | 42.0 | 8464.0 | 2185.3 | 4318.5 | 26.0 | 19752.0 | 4447.7 |
| Minor AADT (2014) | 73.3 | 1.0 | 768.0 | 111.4 | 238.7 | 4.0 | 3170.0 | 455.1 | 301.6 | 12.0 | 3887.0 | 548.6 |
| No. of App. W/ Left-Turn Lanes | 0.0 | 0.0 | 1.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 1.0 | 0.4 |
| No. of App.W/ Right-Turn Lanes | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Skew Angle | 14.4 | 0.0 | 70.0 | 21.1 | 8.9 | 0.0 | 70.0 | 14.6 | N/A | N/A | N/A | N/A |
| Crashes/Site/3 Years | 0.3 | 0.0 | 3.0 | 0.7 | 0.6 | 0.0 | 6.0 | 1.3 | 0.8 | 0.0 | 6.0 | 1.4 |
| Number of Crashes in 3 Years | 22 | | | | 44 | | | | 57 | | | |
| No. of Intersections W/ Lighting | 7 | | | | 26 | | | | 53 | | | |
| Description | Ave. | Min. | Max. | Std. Dev. | Ave. | Min. | Max. | Std. Dev. | Ave. | Min. | Max. | Std. Dev. |
| Intersection Type | U 4ST[4] | | | | RML 3ST[5] | | | | RML 4ST[6] | | | |
| Major AADT (2014) | 4510.7 | 30.0 | 23975.0 | 4881.8 | 12069.7 | 2754.0 | 35500.0 | 7837.3 | 9608.5 | 3352.0 | 21740.0 | 4008.2 |
| Minor AADT (2014) | 616.2 | 14.0 | 4984.0 | 821.3 | 372.1 | 5.0 | 1329.0 | 325.2 | 474.9 | 134.0 | 1834.0 | 314.6 |
| No. of App. W/ Left-Turn Lanes | 0.2 | 0.0 | 2.0 | 0.6 | 0.8 | 0.0 | 2.0 | 0.5 | 1.6 | 0.0 | 2.0 | 0.8 |
| No. of App.W/ Right-Turn Lanes | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 1.0 | 0.4 | 0.2 | 0.0 | 2.0 | 0.5 |
| Skew Angle | N/A | N/A | N/A | N/A | 5.2 | 0.0 | 40.0 | 9.8 | 4.7 | 0.0 | 30.0 | 8.5 |
| Crashes/Site/3 Years | 2.5 | 0.0 | 27.0 | 4.0 | 2.4 | 0.0 | 46.0 | 5.9 | 2.2 | 0.0 | 23.0 | 3.3 |
| Number of Crashes in 3 Years | 172 | | | | 169 | | | | 144 | | | |
| No. of Intersections W/ Lighting | 66 | | | | 11 | | | | 5 | | | |

Notes: [1]R2L 3ST      Rural Two-Lane Three-Leg Unsignalized Intersections
      [2]R2L 4ST      Rural Two-Lane Four-Leg Unsignalized Intersections
      [3]U 3ST      Urban Three-Leg Unsignalized Intersections
      [4]U 4ST      Urban Four-Leg Unsignalized Intersections
      [5]RML 3ST      Rural Multilane Three-Leg Unsignalized Intersections
      [6]RML 4ST      Rural Multilane Four-Leg Unsignalized Intersections

## 9.6 Results and Discussion

### 9.6.1 Rural Two-Lane Three- and Four-Leg Stop-Sign Intersections

The base HSM SPF models developed for rural two-lane unsignalized stop control intersections considered crashes within 250 ft (76 m) of a particular intersection, using negative binomial regression analysis. The data used for the regression analysis were obtained from 382 three-leg stop-controlled intersections in Minnesota, which included five years of crash data (1985-1989), and 324 four-leg stop-controlled intersections, also from Minnesota, which included five years of crash data (1985-1989) for each intersection (Harwood et al. 2000).

The calibration factor for rural two-lane unsignalized intersections in Missouri yielded the calibration factor values of 0.69 for three-leg intersections, and 0.41 for four-leg intersections. Figure 9.11 shows the IHSDM output for the three-leg intersection calibration, and Figure 9.12 shows the output for the four-leg intersection calibration. Table 9.15 shows the calibration results for the individual sites. These results indicate that the number of crashes observed at rural two-lane three-leg and four-leg unsignalized intersections in Missouri were less than the number of crashes predicted by the HSM for the same intersection types.



**Figure 9.11 Calibration output for rural two-lane three-leg unsignalized intersections**

**Figure 9.12 Calibration output for rural two-lane four-leg unsignalized intersections**

**Table 9.15 Rural two-lane three- and four-leg unsignalized intersection results**

| | Three-Leg | | | | Four-Leg | | |
|---|---|---|---|---|---|---|---|
| **No.** | **Int. No.** | **Crashes** | | **No.** | **Int. No.** | **Crashes** | |
| | | **Observed** | **Predicted** | | | **Observed** | **Predicted** |
| 1 | 277931 | 0 | 0.2222 | 1 | 309234 | 0 | 0.3465 |
| 2 | 301833 | 0 | 0.5181 | 2 | 439001 | 1 | 1.185 |
| 3 | 398249 | 0 | 0.1771 | 3 | 459214 | 6 | 1.5552 |
| 4 | 462058 | 0 | 0.3604 | 4 | 249169 | 1 | 0.8395 |
| 5 | 313734 | 0 | 0.0188 | 5 | 457991 | 3 | 3.9527 |
| 6 | 165855 | 0 | 0.7175 | 6 | 337073 | 0 | 0.2433 |
| 7 | 395691 | 3 | 1.7822 | 7 | 185659 | 0 | 0.208 |
| 8 | 358162 | 1 | 0.3312 | 8 | 150348 | 0 | 0.1743 |
| 9 | 437012 | 0 | 0.0244 | 9 | 941340 | 0 | 0.5666 |
| 10 | 341235 | 1 | 2.476 | 10 | 376560 | 1 | 0.1095 |
| 11 | 1024754 | 0 | 0.3335 | 11 | 257488 | 0 | 1.2743 |
| 12 | 148501 | 1 | 1.5098 | 12 | 247971 | 0 | 0.3627 |
| 13 | 183496 | 0 | 1.8426 | 13 | 144057 | 3 | 3.1319 |
| 14 | 194504 | 0 | 0.0501 | 14 | 94741 | 0 | 0.3375 |
| 15 | 128338 | 1 | 2.1804 | 15 | 131307 | 1 | 1.4396 |
| 16 | 257933 | 0 | 0.2433 | 16 | 179272 | 0 | 1.4468 |
| 17 | 182234 | 0 | 0.3335 | 17 | 266798 | 3 | 14.943 |
| 18 | 101512 | 0 | 0.0855 | 18 | 139264 | 3 | 0.9872 |
| 19 | 199141 | 0 | 0.0829 | 19 | 265534 | 0 | 6.6787 |
| 20 | 259956 | 0 | 0.0511 | 20 | 314183 | 0 | 1.7611 |
| 21 | 117 | 0 | 0.0129 | 21 | 31011 | 0 | 0.0724 |
| 22 | 119371 | 0 | 0.1997 | 22 | 498 | 0 | 0.02 |
| 23 | 5567 | 0 | 0.021 | 23 | 1029271 | 0 | 0.3368 |
| 24 | 73147 | 0 | 0.0263 | 24 | 122384 | 0 | 0.4329 |
| 25 | 81668 | 0 | 0.0194 | 25 | 1037510 | 0 | 1.0193 |
| 26 | 111199 | 0 | 0.0216 | 26 | 72647 | 0 | 0.0958 |
| 27 | 56428 | 0 | 0.0409 | 27 | 43610 | 0 | 0.8797 |
| 28 | 66821 | 0 | 0.059 | 28 | 114079 | 0 | 0.1016 |
| 29 | 200260 | 0 | 0.1389 | 29 | 1026494 | 0 | 0.0182 |
| 30 | 98338 | 0 | 0.0034 | 30 | 35796 | 0 | 0.1379 |
| 31 | 49142 | 0 | 0.0306 | 31 | 8607 | 0 | 0.0155 |
| 32 | 49076 | 0 | 0.0306 | 32 | 87502 | 1 | 0.669 |
| 33 | 51127 | 0 | 0.0849 | 33 | 8111 | 0 | 0.8551 |
| 34 | 30409 | 0 | 0.0396 | 34 | 4139 | 0 | 0.1008 |
| 35 | 89124 | 0 | 0.1261 | 35 | 76413 | 0 | 0.0804 |
| 36 | 59129 | 0 | 0.6982 | 36 | 22531 | 0 | 0.0397 |

**Table 9.15 Continued**

| Three-Leg | | | | Four-Leg | | | |
|---|---|---|---|---|---|---|---|
| **No.** | **Int. No.** | **Crashes** | | **No.** | **Int. No.** | **Crashes** | |
| | | **Observed** | **Predicted** | | | **Observed** | **Predicted** |
| 37 | 30013 | 0 | 0.0088 | 37 | 26276 | 0 | 0.6971 |
| 38 | 2101 | 0 | 0.0559 | 38 | 41297 | 0 | 0.0131 |
| 39 | 31927 | 0 | 0.0106 | 39 | 27746 | 0 | 0.065 |
| 40 | 56702 | 0 | 0.2425 | 40 | 14176 | 1 | 0.3458 |
| 41 | 516183 | 0 | 0.9281 | 41 | 626406 | 0 | 0.0655 |
| 42 | 616858 | 1 | 0.1933 | 42 | 453325 | 0 | 0.4245 |
| 43 | 569355 | 0 | 0.05 | 43 | 513096 | 0 | 0.0305 |
| 44 | 592827 | 0 | 0.0442 | 44 | 587463 | 0 | 0.3528 |
| 45 | 925236 | 0 | 0.0723 | 45 | 478407 | 0 | 0.2061 |
| 46 | 563643 | 0 | 0.2156 | 46 | 637405 | 1 | 0.9892 |
| 47 | 659340 | 3 | 0.6481 | 47 | 447271 | 0 | 0.1295 |
| 48 | 564661 | 0 | 0.1805 | 48 | 640131 | 0 | 1.2359 |
| 49 | 564170 | 0 | 0.2114 | 49 | 536334 | 0 | 0.4963 |
| 50 | 563127 | 0 | 0.4225 | 50 | 608573 | 3 | 0.2778 |
| 51 | 373777 | 0 | 0.314 | 51 | 268319 | 0 | 0.5353 |
| 52 | 334130 | 0 | 0.175 | 52 | 373859 | 0 | 1.6047 |
| 53 | 197233 | 1 | 0.5288 | 53 | 352615 | 0 | 2.566 |
| 54 | 199154 | 1 | 1.9143 | 54 | 393922 | 0 | 1.8128 |
| 55 | 333345 | 0 | 0.1915 | 55 | 368471 | 0 | 2.7782 |
| 56 | 377213 | 2 | 0.4809 | 56 | 316496 | 5 | 8.2053 |
| 57 | 360531 | 0 | 0.2189 | 57 | 296187 | 1 | 7.6337 |
| 58 | 199192 | 0 | 0.4244 | 58 | 336257 | 1 | 4.755 |
| 59 | 354737 | 2 | 1.975 | 59 | 195523 | 2 | 4.2138 |
| 60 | 338859 | 0 | 0.0515 | 60 | 344139 | 0 | 1.0168 |
| 61 | 1010106 | 1 | 0.8574 | 61 | 485991 | 0 | 1.6488 |
| 62 | 602021 | 0 | 0.3099 | 62 | 352932 | 0 | 0.2977 |
| 63 | 423141 | 0 | 0.0106 | 63 | 466699 | 1 | 0.4945 |
| 64 | 547167 | 1 | 0.0611 | 64 | 422047 | 0 | 0.4381 |
| 65 | 555567 | 2 | 0.8011 | 65 | 569360 | 5 | 9.8368 |
| 66 | 455897 | 0 | 0.0377 | 66 | 466633 | 0 | 0.0954 |
| 67 | 498873 | 0 | 0.9577 | 67 | 519300 | 0 | 2.1379 |
| 68 | 636407 | 1 | 2.7442 | 68 | 487311 | 0 | 0.5318 |
| 69 | 452012 | 0 | 1.1088 | 69 | 562392 | 0 | 5.3213 |
| 70 | 548004 | 0 | 0.3293 | 70 | 375649 | 1 | 0.4247 |
| Sum | | 22 | 31.6696 | Sum | | 44 | 108.0962 |
| Calibration Factor | | 0.694672493 | | Calibration Factor | | 0.407044836 | |

### 9.6.2 Rural Multilane Three- and Four-Leg Stop-Sign Intersections

The base HSM SPF models developed for rural multilane unsignalized intersections with stop control in the minor road include accidents within 250 ft (76 m) of a particular intersection. The selected model for the regression analysis was the negative binomial, since it took into account the overdispersion commonly found in crash data. The data used for the regression analysis were obtained from 403 three-leg stop-controlled intersections and 403 four-leg stop-controlled intersections in California. Depending upon the particular site, between three years to 10 years of data was used (Lord et al. 2008).

The calibration factor for rural multilane unsignalized intersections in Missouri produced the calibration factor values of 0.95 for three-leg intersections and 0.65 for four-leg intersections. Figures 9.13 and 9.14 show the IHSDM output for the calibration of three-leg and four-leg intersections, respectively. Table 9.16 shows the calibration results for individual sites. These results indicate that the number of crashes observed at rural multilane three-leg unsignalized intersections in Missouri was similar to the value predicted by the HSM for this site type. For four-leg intersections, the number of crashes observed was much less than the number of crashes predicted by the HSM for this site type.
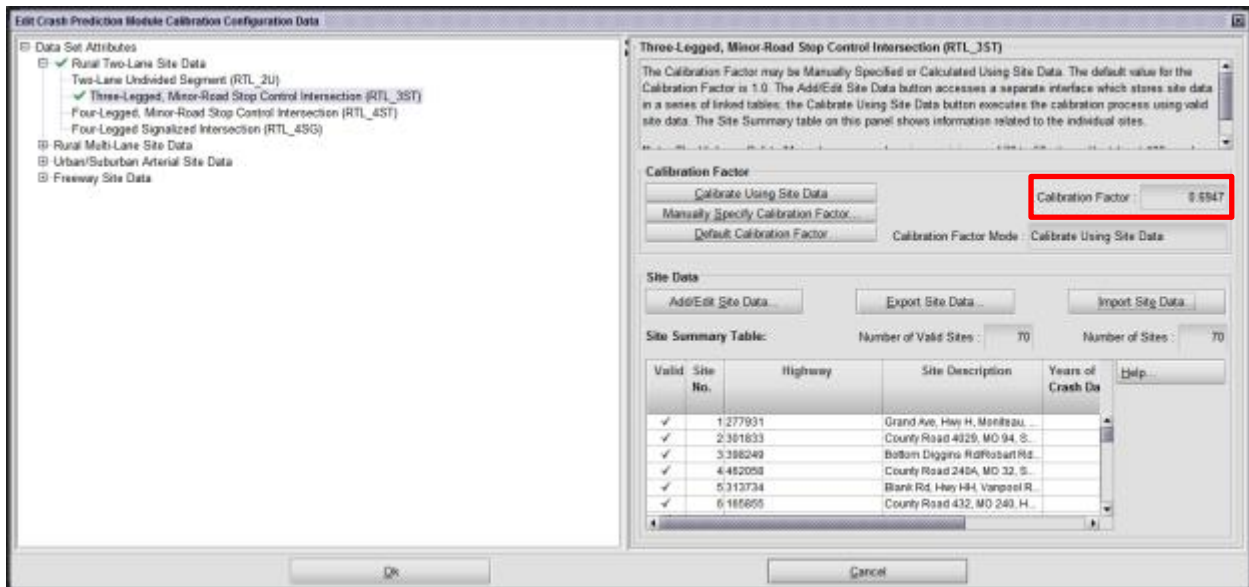


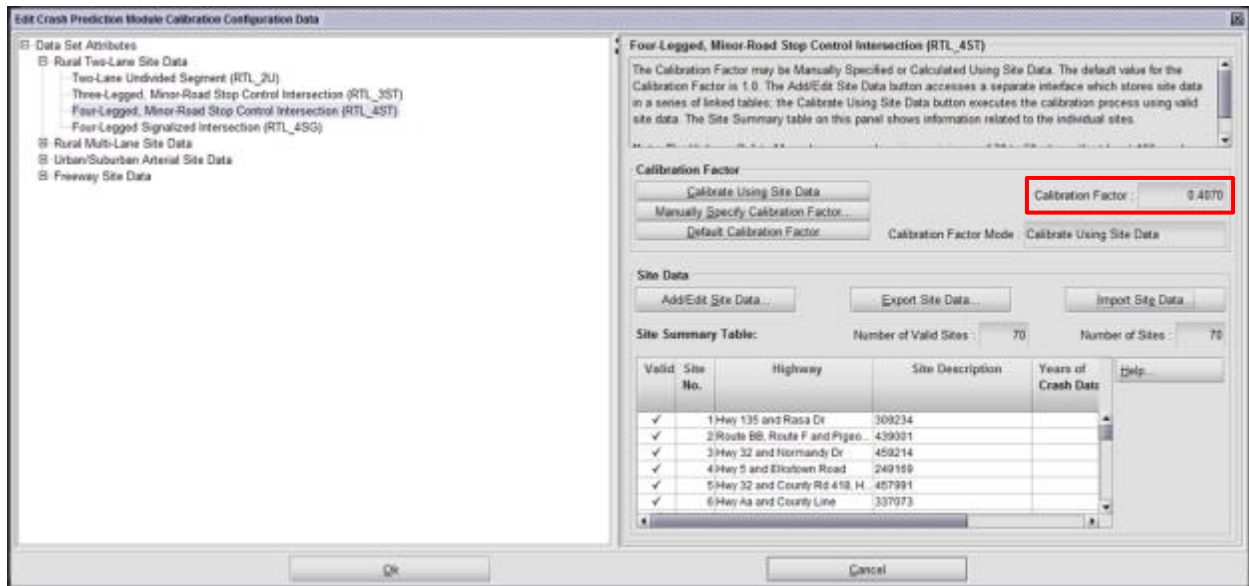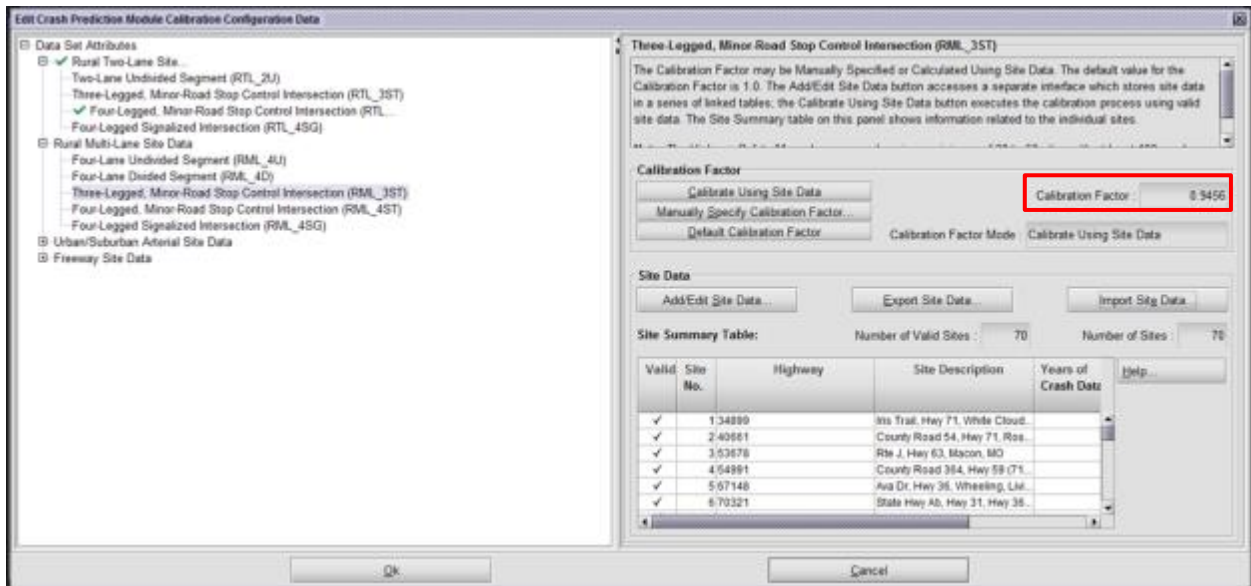**Figure 9.13 Calibration output for rural multilane three-leg unsignalized intersections**
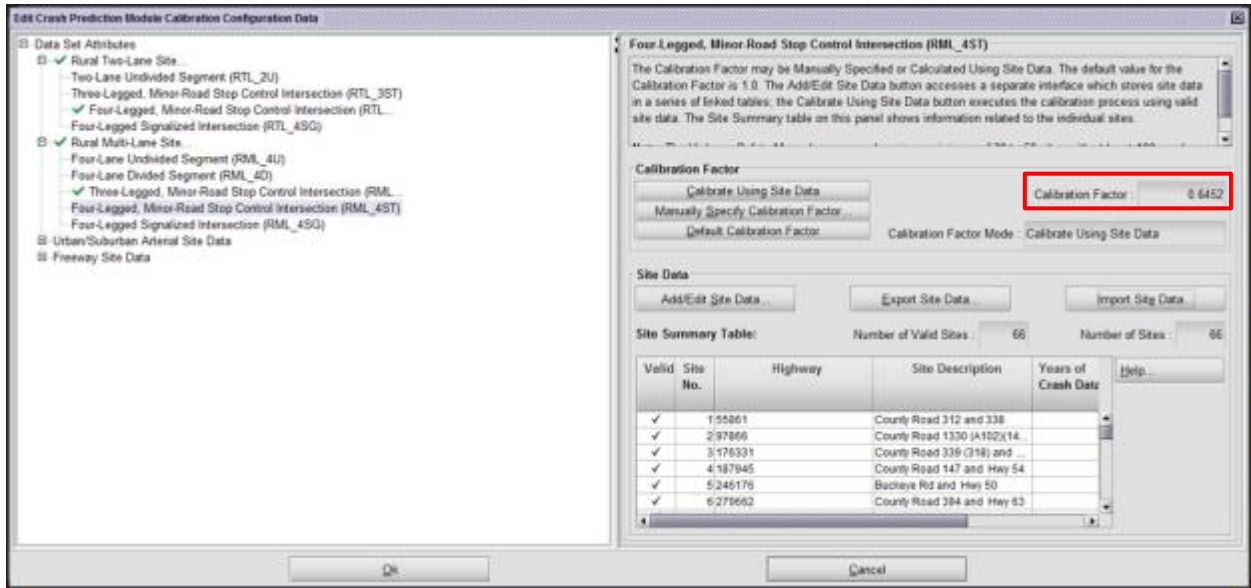
**Figure 9.14 Calibration output for rural multilane four-leg unsignalized intersection**

**Table 9.16 Rural multilane three- and four-leg unsignalized intersection results**

| Three-Leg | | | | Four-Leg | | | |
|---|---|---|---|---|---|---|---|
| No. | Int. No. | Crashes | | No. | Int. No. | Crashes | |
| | | Obs. | Pred. | | | Obs. | Pred. |
| 1 | 34899 | 0 | 0.943 | 1 | 55861 | 0 | 2.9941 |
| 2 | 40661 | 0 | 0.9747 | 2 | 97866 | 2 | 2.7163 |
| 3 | 53678 | 1 | 0.6598 | 3 | 176331 | 3 | 1.9851 |
| 4 | 54991 | 4 | 2.5371 | 4 | 187945 | 5 | 2.4138 |
| 5 | 67148 | 0 | 1.5404 | 5 | 246176 | 0 | 5.78 |
| 6 | 70321 | 2 | 1.1834 | 6 | 279662 | 4 | 6.4279 |
| 7 | 77998 | 0 | 2.5614 | 7 | 312342 | 0 | 2.9345 |
| 8 | 80248 | 4 | 3.392 | 8 | 313066 | 0 | 7.1691 |
| 9 | 80408 | 6 | 1.786 | 9 | 313754 | 1 | 3.5438 |
| 10 | 122588 | 4 | 2.1338 | 10 | 323701 | 0 | 7.2391 |
| 11 | 136430 | 2 | 1.522 | 11 | 326085 | 0 | 6.9691 |
| 12 | 169476 | 1 | 6.2813 | 12 | 337086 | 0 | 1.4552 |
| 13 | 181777 | 0 | 2.2964 | 13 | 343348 | 1 | 3.3975 |
| 14 | 207828 | 4 | 8.7491 | 14 | 344457 | 3 | 3.8688 |
| 15 | 222211 | 3 | 3.9346 | 15 | 355004 | 0 | 3.8992 |
| 16 | 273240 | 7 | 3.3363 | 16 | 355980 | 0 | 3.3545 |
| 17 | 292231 | 1 | 2.0437 | 17 | 367926 | 1 | 2.9783 |
| 18 | 317163 | 2 | 2.2482 | 18 | 372958 | 1 | 2.6104 |
| 19 | 328837 | 0 | 2.3535 | 19 | 451074 | 0 | 2.9314 |
| 20 | 334896 | 0 | 0.9784 | 20 | 480168 | 0 | 3.3467 |
| 21 | 340675 | 0 | 0.9726 | 21 | 503562 | 0 | 0.6748 |
| 22 | 341135 | 2 | 0.9736 | 22 | 512804 | 1 | 0.8567 |
| 23 | 341182 | 1 | 0.9736 | 23 | 653589 | 1 | 3.4569 |
| 24 | 342130 | 1 | 1.7668 | 24 | 654171 | 2 | 2.4283 |
| 25 | 342235 | 0 | 0.9736 | 25 | 654174 | 0 | 1.331 |
| 26 | 346252 | 1 | 0.8091 | 26 | 654182 | 0 | 3.3727 |
| 27 | 357162 | 0 | 1.3635 | 27 | 655027 | 0 | 2.5269 |
| 28 | 395973 | 0 | 4.3504 | 28 | 941779 | 1 | 2.0516 |
| 29 | 400983 | 2 | 9.5136 | 29 | 941785 | 2 | 2.0516 |
| 30 | 401000 | 2 | 7.3757 | 30 | 975965 | 1 | 1.5502 |
| 31 | 401063 | 3 | 9.8006 | 31 | 976005 | 1 | 1.4854 |
| 32 | 401324 | 8 | 7.3757 | 32 | 982890 | 2 | 1.3503 |
| 33 | 402187 | 3 | 5.2651 | 33 | 1014049 | 1 | 1.0399 |
| 34 | 426433 | 0 | 0.877 | 34 | 1014051 | 0 | 1.4842 |
| 35 | 461488 | 2 | 0.9962 | 35 | 1019957 | 0 | 2.1307 |
| 36 | 462363 | 0 | 1.2616 | 36 | 1042125 | 0 | 0.6736 |

**Table 9.16 Continued**

| Three-Leg | | | | Four-Leg | | | |
|---|---|---|---|---|---|---|---|
| No. | Int. No. | Crashes | | No. | Int. No. | Crashes | |
| | | Obs. | Pred. | | | Obs. | Pred. |
| 37 | 470050 | 0 | 1.4295 | 37 | 1014045/568338 | 2 | 1.4346 |
| 38 | 478605 | 0 | 0.3023 | 38 | 1021590/1021587 | 5 | 3.077 |
| 39 | 486267 | 0 | 0.4498 | 39 | 1024002/474565 | 4 | 2.0971 |
| 40 | 499137 | 0 | 0.3641 | 40 | 1042121/501937 | 0 | 0.6748 |
| 41 | 526207 | 3 | 3.0201 | 41 | 1042123/503562 | 0 | 0.7601 |
| 42 | 651611 | 0 | 2.7827 | 42 | 158982/158986 | 5 | 4.8275 |
| 43 | 652956 | 1 | 2.665 | 43 | 177959/177956 | 4 | 2.8051 |
| 44 | 654173 | 0 | 1.6304 | 44 | 199292/210624 | 2 | 2.8311 |
| 45 | 654183 | 0 | 1.2009 | 45 | 226286/226104 | 2 | 10.4716 |
| 46 | 654186 | 0 | 1.2009 | 46 | 244134/984721 | 5 | 5.8356 |
| 47 | 919584 | 0 | 1.038 | 47 | 249999/250088 | 3 | 6.8382 |
| 48 | 954216 | 1 | 3.3195 | 48 | 296848/296743 | 4 | 2.5172 |
| 49 | 954295 | 0 | 1.1896 | 49 | 30947/654167 | 2 | 1.5481 |
| 50 | 982897 | 1 | 1.0174 | 50 | 312682/1024463 | 5 | 4.5021 |
| 51 | 984961 | 2 | 3.7041 | 51 | 318872/1024465 | 23 | 9.1166 |
| 52 | 996785 | 11 | 12.3544 | 52 | 344653/344604 | 3 | 3.4836 |
| 53 | 1014034 | 0 | 0.4366 | 53 | 362072/653616 | 2 | 2.6373 |
| 54 | 1022960 | 0 | 0.8065 | 54 | 367877/367923 | 6 | 5.9549 |
| 55 | 1023614 | 0 | 0.3731 | 55 | 388534/997231 | 5 | 8.8413 |
| 56 | 1024242 | 0 | 0.3731 | 56 | 48315/48292 | 1 | 1.9537 |
| 57 | 1039950 | 0 | 0.9736 | 57 | 49594/49602 | 0 | 3.9099 |
| 58 | 1042119 | 1 | 0.3783 | 58 | 51604/51603 | 0 | 5.7083 |
| 59 | 1054123 | 0 | 0.8075 | 59 | 66977/67046 | 5 | 2.5587 |
| 60 | 1021606/1021605 | 0 | 0.8297 | 60 | 69991/70053 | 4 | 2.5922 |
| 61 | 1024454/1024455 | 7 | 1.5377 | 61 | 70986/70950 | 1 | 9.6786 |
| 62 | 170127/930296 | 1 | 2.5213 | 62 | 935184/92565 | 1 | 2.0952 |
| 63 | 203232/203079 | 46 | 6.6039 | 63 | 970861/417848 | 2 | 2.6399 |
| 64 | 396153/396155 | 12 | 6.3786 | 64 | 975964/975956 | 1 | 1.5646 |
| 65 | 398410/976253 | 1 | 2.9512 | 65 | 975966/975958/975962 | 5 | 2.2889 |
| 66 | 399038/976296 | 2 | 2.9512 | 66 | 975983/975990 | 9 | 1.4688 |
| 67 | 651600/327958 | 1 | 1.8086 | Sum | | 144 | 223.1922 |
| 68 | 68202/68162 | 6 | 1.2219 | Calibration Factor | | 0.645183837 | |
| 69 | 78472/982900 | 3 | 1.7397 | | | | |
| 70 | 978785/978785 | 4 | 2.2662 | | | | |
| Sum | | 169 | 178.7312 | | | | |

184

| | |
|---|---|
| Calibration Factor | 0.945553994 |

9.6.3 Urban Arterial Three- and Four-Leg Stop Control Intersections

The base HSM SPF models developed for urban unsignalized intersections with stop control in the minor road included accidents within 250 ft (76 m) of a particular intersection but only those that the officer determined was intersection-related. Different SPFs were developed using regression analysis with the negative binomial distribution. The different SPFs included multiple-vehicle, single vehicle, vehicle-pedestrians, and vehicle-bicycle collisions. The data used for the regression analysis was obtained from 83 (36 Minnesota, and 47 North Carolina) three-leg stop-controlled intersections, and 96 (48 Minnesota, and 48 North Carolina) four-leg stop-controlled intersections. The accident data obtained for the study consisted of four years (1988-2002) of Minnesota intersection data and four years (1997-2003) of North Carolina intersection data (Harwood et al. 2007).

As shown in Figure 9.15 and 9.16, the calibration factor for urban arterial unsignalized intersections in Missouri produced the calibration factor values of 1.28 for three-leg intersections, and 1.27 for four-leg intersections. Table 9.17 shows the calibration results for individual sites. These results indicate that the number of crashes observed at urban arterial three-leg and four-leg unsignalized intersections in Missouri were more than the number of crashes predicted by the HSM for these site types.
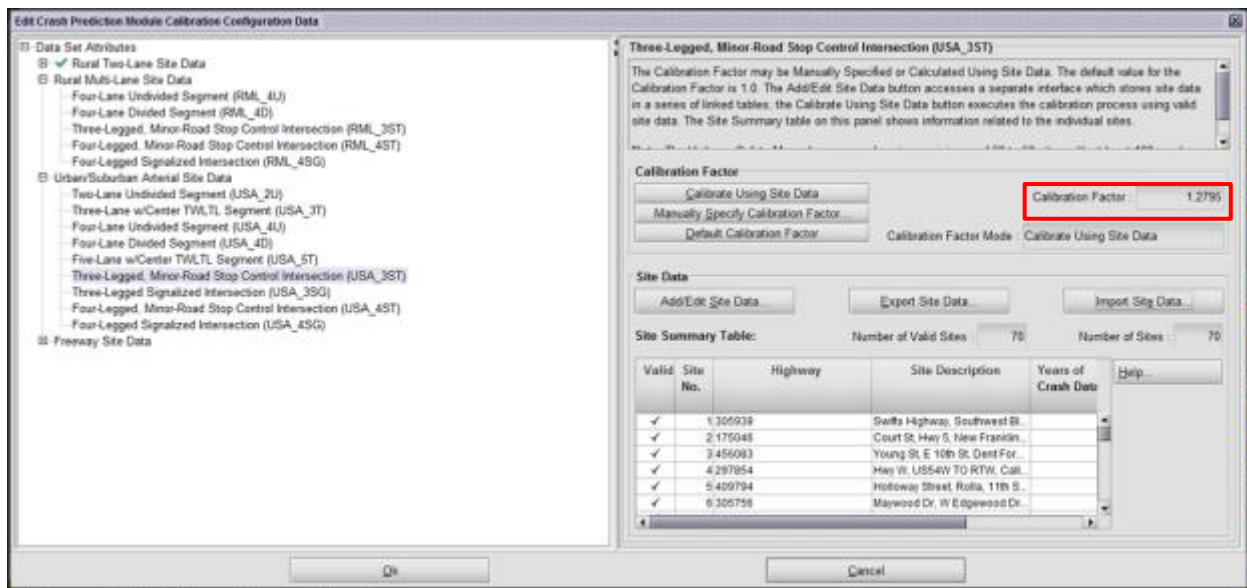


**Figure 9.15 Calibration output for urban three-leg unsignalized intersections**
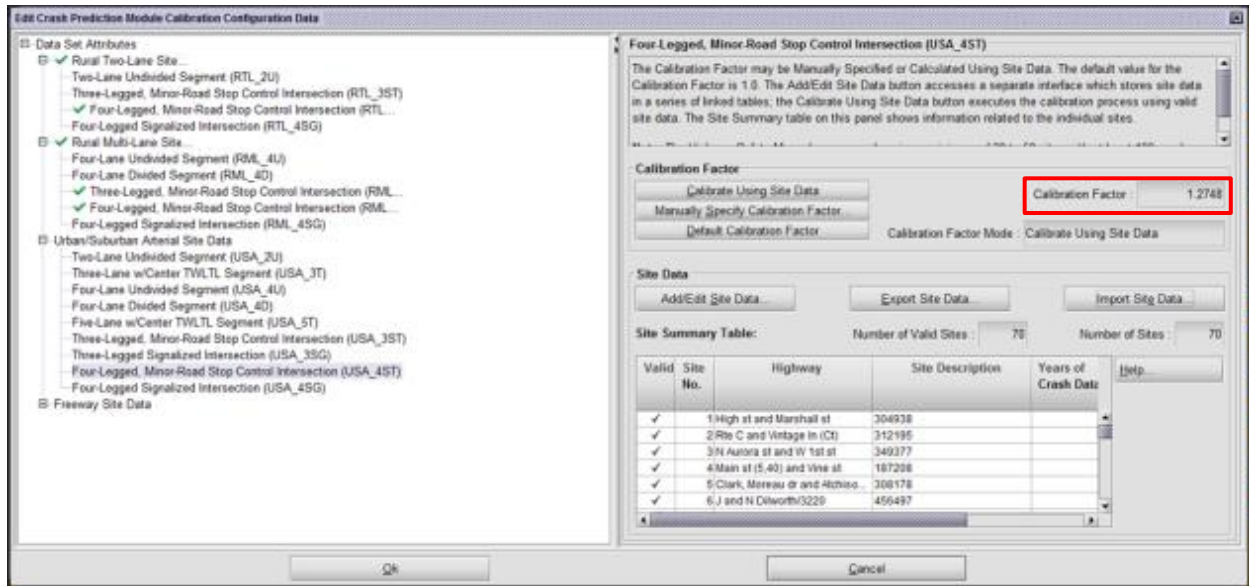
**Figure 9.16 Calibration output for urban four-leg unsignalized intersections**

**Table 9.17 Urban three- and four-leg unsignalized intersection results**

| | Three-Leg | | | | Four-Leg | | |
|---|---|---|---|---|---|---|---|
| No. | Int. No. | Crashes | | No. | Int. No. | Crashes | |
| | | Observed | Predicted | | | Observed | Predicted |
| 1 | 305939 | 1 | 1.3569 | 1 | 304938 | 2 | 1.5651 |
| 2 | 175046 | 0 | 0.2124 | 2 | 312195 | 0 | 2.1724 |
| 3 | 456083 | 0 | 0.0482 | 3 | 349377 | 2 | 0.5576 |
| 4 | 297854 | 0 | 0.3626 | 4 | 187208 | 3 | 4.8639 |
| 5 | 409794 | 1 | 0.384 | 5 | 308178 | 4 | 2.8623 |
| 6 | 305756 | 0 | 0.3061 | 6 | 456497 | 1 | 1.1398 |
| 7 | 959247 | 0 | 0.2429 | 7 | 209569 | 2 | 1.4923 |
| 8 | 456871 | 0 | 0.044 | 8 | 350342 | 1 | 0.7692 |
| 9 | 196263 | 0 | 1.0225 | 9 | 645895 | 3 | 3.2437 |
| 10 | 405755 | 1 | 0.5968 | 10 | 310182 | 0 | 0.5858 |
| 11 | 159600 | 1 | 0.8677 | 11 | 136897 | 0 | 2.7267 |
| 12 | 195531 | 0 | 0.4291 | 12 | 165415 | 0 | 0.3736 |
| 13 | 148666 | 0 | 0.3232 | 13 | 163188 | 27 | 4.5707 |
| 14 | 115223 | 0 | 0.0381 | 14 | 224016 | 4 | 4.6689 |
| 15 | 121303 | 0 | 0.1421 | 15 | 139797 | 0 | 0.752 |
| 16 | 176297 | 1 | 1.5222 | 16 | 166696 | 2 | 1.7632 |
| 17 | 939962 | 0 | 0.0924 | 17 | 122705 | 2 | 0.4366 |
| 18 | 267677 | 0 | 0.2399 | 18 | 168731 | 0 | 0.8411 |
| 19 | 223036 | 5 | 1.8955 | 19 | 141967 | 0 | 2.7657 |
| 20 | 147308 | 0 | 0.5364 | 20 | 156640 | 3 | 1.7429 |
| 21 | 1031957 | 0 | 0.2498 | 21 | 76414 | 2 | 0.8567 |
| 22 | 73300 | 1 | 0.0923 | 22 | 222282 | 3 | 3.8284 |
| 23 | 32041 | 0 | 1.2296 | 23 | 106143 | 0 | 2.5855 |
| 24 | 141064 | 0 | 0.3728 | 24 | 28087 | 1 | 3.6513 |
| 25 | 106291 | 1 | 0.6967 | 25 | 1026956 | 0 | 0.6593 |
| 26 | 73953 | 0 | 0.0537 | 26 | 106235 | 2 | 0.2206 |
| 27 | 181671 | 0 | 0.0676 | 27 | 76551 | 0 | 0.4096 |
| 28 | 141791 | 1 | 0.4342 | 28 | 1038144 | 0 | 0.4286 |
| 29 | 73408 | 1 | 0.2057 | 29 | 77182 | 5 | 2.1846 |
| 30 | 219459 | 5 | 0.8922 | 30 | 106542 | 3 | 1.1339 |
| 31 | 77417 | 0 | 0.0394 | 31 | 66244 | 0 | 1.3415 |
| 32 | 19167 | 0 | 0.7981 | 32 | 72360 | 2 | 0.8241 |
| 33 | 72581 | 0 | 0.0496 | 33 | 40344 | 2 | 0.9969 |
| 34 | 62916 | 3 | 2.0155 | 34 | 66236 | 0 | 0.4215 |
| 35 | 76153 | 0 | 0.0763 | 35 | 40463 | 0 | 0.2464 |
| 36 | 71210 | 0 | 0.0785 | 36 | 17320 | 3 | 0.9704 |
| 37 | 74533 | 0 | 0.0568 | 37 | 65213 | 0 | 0.4952 |
| 38 | 67330 | 0 | 0.9022 | 38 | 60813 | 0 | 1.6315 |

**Table 9.17 Continued**

| | Three-Leg | | | | Four-Leg | | |
|---|---|---|---|---|---|---|---|
| | | **Crashes** | | | | **Crashes** | |
| **No.** | **Int. No.** | **Observed** | **Predicted** | **No.** | **Int. No.** | **Observed** | **Predicted** |
| 39 | 67534 | 6 | 1.4762 | 39 | 63827 | 0 | 0.1514 |
| 40 | 59571 | 0 | 0.358 | 40 | 18163 | 1 | 1.1513 |
| 41 | 496314 | 1 | 0.1121 | 41 | 484881 | 15 | 4.7638 |
| 42 | 412211 | 3 | 0.7851 | 42 | 625178 | 3 | 2.3698 |
| 43 | 589794 | 0 | 0.0538 | 43 | 645764 | 0 | 0.1176 |
| 44 | 602197 | 0 | 0.3511 | 44 | 496062 | 4 | 1.7974 |
| 45 | 577242 | 0 | 0.0813 | 45 | 596476 | 2 | 0.2477 |
| 46 | 421875 | 2 | 0.5137 | 46 | 573513 | 6 | 2.0934 |
| 47 | 645579 | 2 | 0.4949 | 47 | 645659 | 2 | 3.5169 |
| 48 | 601287 | 4 | 1.1713 | 48 | 645616 | 1 | 1.0037 |
| 49 | 412269 | 0 | 0.8632 | 49 | 485469 | 1 | 0.8663 |
| 50 | 424183 | 0 | 0.5577 | 50 | 412139 | 6 | 2.5887 |
| 51 | 226548 | 0 | 1.176 | 51 | 286596 | 1 | 2.8729 |
| 52 | 264601 | 1 | 0.0482 | 52 | 283857 | 10 | 1.8503 |
| 53 | 267897 | 0 | 2.8798 | 53 | 309450 | 0 | 2.2299 |
| 54 | 1019326 | 4 | 0.9285 | 54 | 273816 | 2 | 2.743 |
| 55 | 250551 | 0 | 0.1267 | 55 | 266616 | 0 | 0.782 |
| 56 | 316451 | 0 | 1.4699 | 56 | 268375 | 1 | 1.2452 |
| 57 | 225902 | 1 | 1.8974 | 57 | 232797 | 3 | 3.1885 |
| 58 | 219068 | 0 | 0.2175 | 58 | 269334 | 0 | 5.0751 |
| 59 | 361456 | 0 | 0.138 | 59 | 285072 | 5 | 8.5303 |
| 60 | 233589 | 0 | 0.2312 | 60 | 277546 | 4 | 3.5811 |
| 61 | 937218 | 1 | 0.2641 | 61 | 520141 | 4 | 2.3897 |
| 62 | 519949 | 0 | 0.0551 | 62 | 513439 | 2 | 1.4219 |
| 63 | 522684 | 0 | 2.6202 | 63 | 551867 | 0 | 0.4196 |
| 64 | 345735 | 2 | 1.0154 | 64 | 463380 | 0 | 0.9044 |
| 65 | 522711 | 1 | 0.3224 | 65 | 566266 | 1 | 0.5355 |
| 66 | 539712 | 1 | 0.469 | 66 | 529689 | 3 | 1.3601 |
| 67 | 524371 | 1 | 0.7469 | 67 | 569938 | 0 | 1.2819 |
| 68 | 518931 | 2 | 1.0252 | 68 | 545220 | 3 | 4.748 |
| 69 | 545140 | 3 | 2.9328 | 69 | 497046 | 3 | 2.6 |
| 70 | 569431 | 0 | 0.193 | 70 | 428046 | 10 | 3.7197 |
| Sum | | 57 | 44.5497 | Sum | | 172 | 134.9266 |
| Calibration Factor | | 1.279469895 | | Calibration Factor | | 1.27476717 | |

9.6.4 Severity Distribution Factors

Utilizing the data used for calibration, severity distribution factors were computed according to the classification used in Missouri. Crash severity factors were obtained for Fatal, Disabling Injury, Minor Injury, and Property Damage Only crashes. Table 9.18 shows the severity distribution factors for stop-controlled intersections. Fatal and Disabling Injury crashes had higher proportions for rural multilane facilities.

**Table 9.18 Severity Distribution Factors**

| Percentage of Total Crashes by Collision Type | | | | | | |
|---|---|---|---|---|---|---|
| **Crash Severity Level** | **U 3ST[1]** | **U 4ST[2]** | **R2L 3ST[3]** | **R2L 4ST[4]** | **RML 3ST[5]** | **RML 4ST[6]** |
| Fatal | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 1.4 |
| Disabling Injury | 3.5 | 2.9 | 4.5 | 2.3 | 6.5 | 7.6 |
| Minor Injury | 22.8 | 23.3 | 22.7 | 20.5 | 24.9 | 26.4 |
| Property Damage Only | 73.7 | 73.8 | 72.7 | 77.3 | 68.0 | 64.6 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Notes:   [1]U 3ST = Urban Three-Leg Unsignalized Intersections
[2]U 4ST = Urban Four-Leg Unsignalized Intersections
[3]R2L 3ST = Rural Two-Lane Three-Leg Unsignalized Intersections
[4]R2L 4ST = Rural Two-Lane Four-Leg Unsignalized Intersections
[5]RML 3ST = Rural Multilane Three-Leg Unsignalized Intersections
[6]RML 4ST = Rural Multilane Four-Leg Unsignalized Intersections

9.6.5 Crash Type Distribution Factors

The crash type distribution factors represent the proportion of predicted crashes by crash type. The data available from the calibration was used to estimate these factors. Some data processing was required since Missouri crash type categories differed from the HSM. Therefore, different categories were aggregated to provide similar classifications to those recommended by the HSM. The crash types were also divided by multiple and single vehicle crashes. Tables 9.19-9.21 show crash type distribution for stop-controlled intersections.

**Table 9.19 Rural two-lane 3-and 4-leg stop-controlled intersection crash types**

| Percentage of Total Crashes by Collision Type | | | | | | |
|---|---|---|---|---|---|---|
| | Three-Leg | | | Four-Leg | | |
| **Collision Type** | **Fatal and Injury** | **Property Damage Only** | **Total** | **Fatal and Injury** | **Property Damage Only** | **Total** |
| **Single-vehicle** | | | | | | |
| Collision with animal | 0 | 6.3 | 4.5 | 0 | 5.9 | 4.5 |
| Collision pedestrian and bicycle | 16.7 | 0 | 4.5 | 0 | 0 | 0 |
| Out of control | 16.7 | 50 | 40.9 | 30 | 17.6 | 20.5 |
| Other single-vehicle crashes | 0 | 0 | 0 | 0 | 5.9 | 4.5 |
| Total single-vehicle crashes | 33.3 | 56.3 | 50 | 30 | 29.4 | 29.5 |
| **Multiple-Vehicle** | | | | | | |
| Sideswipe | 0 | 0 | 0 | 20 | 5.9 | 9.1 |
| Angle collision | 50 | 18.8 | 27.3 | 20 | 23.5 | 22.7 |
| Rear end and head on collision | 16.7 | 12.5 | 13.6 | 30 | 32.4 | 31.8 |
| Other multiple-vehicle collision | 0 | 12.5 | 9.1 | 0 | 8.8 | 6.8 |
| Total multiple-vehicle collision | 66.7 | 43.8 | 50 | 70 | 70.6 | 70.5 |
| Total crashes | 100 | 100 | 100 | 100 | 100 | 100 |

**Table 9.20 Rural multilane 3-leg and 4-leg stop-controlled intersection crash types**

| Percentage of Total Crashes by Collision Type | | | | | | |
|---|---|---|---|---|---|---|
| | Three-Leg | | | Four-Leg | | |
| **Collision Type** | **Fatal and Injury** | **Property Damage Only** | **Total** | **Fatal and Injury** | **Property Damage Only** | **Total** |
| **Single-vehicle** | | | | | | |
| Collision with animal | 1.9 | 5.2 | 4.1 | 2 | 3.2 | 2.8 |
| Collision pedestrian and bicycle | 1.9 | 0 | 0.6 | 0 | 0 | 0 |
| Out of control | 11.1 | 20 | 17.2 | 25.5 | 29 | 27.8 |
| Other single-vehicle crashes | 3.7 | 4.3 | 4.1 | 7.8 | 19.4 | 15.3 |
| Total single-vehicle crashes | 18.5 | 29.6 | 26 | 35.3 | 51.6 | 45.8 |
| **Multiple-Vehicle** | | | | | | |
| Sideswipe | 13 | 4.3 | 7.1 | 2 | 1.1 | 1.4 |
| Angle collision | 42.6 | 24.3 | 30.2 | 52.9 | 26.9 | 36.1 |
| Rear end and head on collision | 18.5 | 31.3 | 27.2 | 9.8 | 10.8 | 10.4 |
| Other multiple-vehicle collision | 7.4 | 10.4 | 9.5 | 0 | 9.7 | 6.3 |
| Total multiple-vehicle collision | 81.5 | 70.4 | 74 | 64.7 | 48.4 | 54.2 |
| Total crashes | 100 | 100 | 100 | 100 | 100 | 100 |

**Table 9.21 Crash type distribution for urban 3-leg and 4-leg stop-controlled intersections**

| Percentage of Total Crashes by Collision Type | | | | | | |
|---|---|---|---|---|---|---|
| | Three-Leg | | | Four-Leg | | |
| Collision Type | Fatal and Injury | Property Damage Only | Total | Fatal and Injury | Property Damage Only | Total |
| **Single-vehicle** | | | | | | |
| Collision with animal | 0 | 0 | 0 | 0 | 0 | 0 |
| Collision pedestrian and bicycle | 6.7 | 0 | 1.8 | 11.1 | 0.8 | 3.5 |
| Out of control | 13.3 | 11.9 | 12.3 | 15.6 | 5.5 | 8.1 |
| Other single-vehicle crashes | 13.3 | 9.5 | 10.5 | 4.4 | 6.3 | 5.8 |
| Total single-vehicle crashes | 33.3 | 21.4 | 24.6 | 31.1 | 12.6 | 17.4 |
| **Multiple-Vehicle** | | | | | | |
| Sideswipe | 6.7 | 16.7 | 14 | 2.2 | 7.9 | 6.4 |
| Angle collision | 13.3 | 14.3 | 14 | 44.4 | 31.5 | 34.9 |
| Rear end and head on collision | 46.7 | 33.3 | 36.8 | 22.2 | 28.3 | 26.7 |
| Other multiple-vehicle collision | 0 | 14.3 | 10.5 | 0 | 19.7 | 14.5 |
| Total multiple-vehicle collision | 66.7 | 78.6 | 75.4 | 68.9 | 87.4 | 82.6 |
| Total crashes | 100 | 100 | 100 | 100 | 100 | 100 |

**9.7 Comparison to Previous Calibration**

9.7.1 Rural Two-Lane Three and Four-Leg Stop-Sign Intersections

The calibration results for rural two-lane three-leg intersection facilities closely resembled prior calibration results using data from 2009 to 2011. The previous calibration efforts found a calibration factor of 0.77, which was only slightly higher than the recent results of 0.69. This similarity is likely due to the fact that the input variables showed little variation as well. The average AADTs for major roads decreased slightly from 1421 to 1365.5 while the minor roads remained nearly unchanged (from 72 to 73.3).

The calibration results for rural two-lane four-leg intersection facilities also closely resembled prior calibration results using data from 2009 to 2011. The previous calibration efforts found a calibration factor of 0.49, which was only slightly higher than the recent result of 0.41. This similarity is likely due the fact that the input variables showed very little variation as well. The average AADTs for major roads decreased slightly from 1746.5 to 1711.7 while the minor roads remained nearly unchanged (from 243.9 to 238.7). Note that the source of AADT could affect its accuracy, depending on whether the AADT was a measured value or an estimated value from growth factors.

9.7.2 Rural Multilane Three- and Four-Leg Stop-Sign Intersections

The calibration results for rural multilane three-leg intersections were fairly close to prior calibration results using data from 2009 to 2011. The previous calibration found a calibration factor of 1.12, which was slightly higher than the recent result of 0.95. This similarity is likely reflected in the fact that the input variables showed little variation as well. The average AADT for the major road was 11,972 for 2009 to 2011 and it was 12,070 for 2012-2014. The minor road AADT was 350 for 2009 to 2011 and it was 372 for 2012-2014.

The calibration results for rural multilane four-leg intersection facilities also closely resembled prior calibration results using data from 2009 to 2011. The previous calibration efforts found a calibration factor of 0.71 which was only slightly higher than the recent result of 0.65. This similarity is likely reflected in the fact that the input variables showed little variation as well. The average AADT for the major road was 9,561 for 2009 to 2011 while it was 9,609 for 2012 to 2014. The minor road AADT was 470 for 2009 to 2011 while it was 475 for 2012 to 2014.

9.7.3 Urban Arterial Three and Four-Leg Stop-Sign Intersections

The calibration results for urban arterial three-leg intersection facilities were fairly close to prior calibration results using data from 2009 to 2011. The previous calibration efforts found a calibration factor of 1.06, which was slightly lower than the recent result of 1.28. The AADT values were similar for the major road, 4,312 to 4,319, and for the minor road, 304 to 302. Thus, the slight increase was due to other factors.

The calibration results for urban arterial four-leg intersection facilities closely resembled prior calibration results using site from 2009 to 2011. The previous calibration efforts found a calibration factor of 1.30, which was slightly higher than the recent results of 1.27. This similarity is likely reflected in the fact that the input variables showed little variation as well. The average AADT for the major road increased from 4,488.8 to 4,511, while the minor road increased from 608 to 616.

9.7.4 Summary

Table 9.22 shows that the new calibration factors for stop-controlled intersections are similar to previous calibration factors. The total observed crashes are almost the same between the two period of 2009-2011 and 2012-2014.

**Table 9.22 Summary of HSM intersection calibration results for Missouri**

| Facility Type | Previous (2009-2011) | | | New (2012-2014) | | |
|---|---|---|---|---|---|---|
| | All Sites | Total Observed Crashes | Calibration Factor | All Sites | Total Observed Crashes | Calibration Factor |
| U 3ST[1] | 70 | 52 | 1.06 | 70 | 57 | 1.28 |
| U 4ST[2] | 70 | 179 | 1.30 | 70 | 172 | 1.27 |
| R2L 3ST[3] | 70 | 25 | 0.77 | 70 | 22 | 0.69 |
| R2L 4ST[4] | 70 | 49 | 0.49 | 70 | 44 | 0.41 |
| RML 3ST[5] | 71 | 191 | 1.12 | 70 | 169 | 0.95 |
| RML 4ST[6] | 67 | 159 | 0.71 | 66 | 144 | 0.65 |

Notes:  [1]U 3ST = Urban Three-Leg Unsignalized Intersections
[2]U 4ST = Urban Four-Leg Unsignalized Intersections
[3]R2L 3ST = Rural Two-Lane Three-Leg Unsignalized Intersections
[4]R2L 4ST = Rural Two-Lane Four-Leg Unsignalized Intersections
[5]RML 3ST = Rural Multilane Three-Leg Unsignalized Intersections
[6]RML 4ST = Rural Multilane Four-Leg Unsignalized Intersections

# CHAPTER 10. DISTRIBUTION OF CRASH SEVERITY

## 10.1 Introduction and Scope

Crash severity data is important in addition to crash frequency since the impact of crashes differs greatly depending on severity. The impact of crashes, in turn, affects how agencies prioritize and implement their safety plans. In Chapters 4 through 9, the calibration results of sixteen facility types were presented. The Missouri calibration factors allow the use of HSM SPFs for modeling and analyzing crash frequency on Missouri roadways. In order to obtain the number of crashes by severity in Missouri, severity distribution factors (SDFs) are needed. This chapter presents the results from an analysis of crashes throughout the state of Missouri. Included in the results is a comparison of the distribution of crash severity between the samples used for calibration and comprehensive statewide data. When the results of this chapter is coupled with the results from Chapter 4 through 9, the number of crashes on Missouri facilities can then be estimated for the specific severities of Fatal, Disabling Injury, Minor injury, and Property Damage Only.

## 10.2 Rural Two-Lane Undivided Segment Crash Severity

Table 10.1 shows the query criteria used for identifying all crashes in Missouri that occurred on rural two-lane undivided roadways. Table 10.2 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on two-lane undivided segments in Missouri was 30,940, and the total number of crashes from the calibration sample was 283. The comparison between the sample and the population SDFs showed that they were very similar.

**Table 10.1 Rural two-lane undivided segment criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE_ NAME | FUNC_CLASS_NAME | INTERSECTION_ NO |
|---|---|---|---|
| "RURAL" | "TWO-LANE/SUPER TWO-LANE " | "LOCAL/MAJOR COLLECTOR/MINOR ARTERIAL/MINOR COLLECTOR/PRINCIPAL ARTERIAL" | "0" |

**Table 10.2 Rural two-lane undivided segment severity distribution**

| Severity | R two-lane U | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 9 | 0.032 | 624 | 0.020 |
| Disabling Injury | 23 | 0.081 | 2,609 | 0.084 |
| Minor Injury | 68 | 0.240 | 8,225 | 0.266 |
| Property Damage Only | 183 | 0.647 | 19,482 | 0.630 |
| Total Crashes | 283 | 1.000 | 30,940 | 1.000 |

## 10.3 Rural Multilane Divided Segment Crash Severity

Table 10.3 shows the query criteria used for identifying all crashes in Missouri that occurred on rural multilane divided roadways. Table 10.4 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on multilane divided segments in Missouri was 808, and the total number of crashes from the calibration sample was 517. The comparison between the sample and the population SDFs showed that they were also very similar.

**Table 10.3 Rural multilane divided segment criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE_ NAME | FUNC_CLASS_NAME | INTERSECTION_ NO |
| --- | --- | --- | --- |
| "RURAL" | "EXPRESSWAY" | "MAJOR COLLECTOR/MINOR ARTERIAL/PRINCIPAL ARTERIAL" | "0" |

**Table 10.4 Rural multilane divided segment severity distribution**

| Severity | R ML D | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 6 | 0.012 | 11 | 0.014 |
| Disabling Injury | 20 | 0.039 | 35 | 0.043 |
| Minor Injury | 118 | 0.228 | 198 | 0.245 |
| Property Damage Only | 373 | 0.721 | 565 | 0.699 |
| Total Crashes | 517 | 1.000 | 808 | 1.000 |

## 10.4 Urban Two-Lane Undivided Segment Crash Severity

Table 10.5 shows the query criteria used for identifying all crashes in Missouri that occurred on urban two-lane undivided roadways. Table 10.6 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on two-lane undivided segments in Missouri was 13,554, and the total number of crashes from the calibration sample was 366. The comparison between the sample and the population SDFs showed that they were similar except for disabling injury.

**Table 10.5 Urban two-lane undivided segment criteria**

| URBAN_RURAL_CLASS | ROADWAY_TYPE_NAME | FUNC_CLASS_NAME | INTERSECTION_NO |
|---|---|---|---|
| "URBAN/URBANIZED" | "TWO-LANE/SUPER TWO-LANE " | "LOCAL/MAJOR COLLECTOR/MINOR ARTERIAL/MINOR COLLECTOR/PRINCIPAL ARTERIAL" | "0" |

**Table 10.6 Urban two-lane undivided severity distribution**

| Severity | U two-lane U | | All | |
|---|---|---|---|---|
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 4 | 0.011 | 106 | 0.008 |
| Disabling Injury | 5 | 0.014 | 528 | 0.039 |
| Minor Injury | 87 | 0.238 | 3,188 | 0.235 |
| Property Damage Only | 270 | 0.738 | 9,733 | 0.718 |
| Total Crashes | 366 | 1.000 | 13,554 | 1.000 |

## 10.5 Urban Four-Lane Divided Segment Crash Severity

Table 10.7 shows the query criteria used for identifying all crashes in Missouri that occurred on urban four-lane divided roadways. Table 10.8 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on four-lane divided segments in Missouri was 17,483, and the total number of crashes from the calibration sample was 403. The comparison between the sample and the population SDFs showed that there were minor differences throughout the various severities.

196

**Table 10.7 Urban four-lane divided segment criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE_ NAME | FUNC_CLASS_NAME | INTERSECTION_ NO |
|---|---|---|---|
| "URBAN/URBANIZED" | "EXPRESSWAY" | "LOCAL/MAJOR COLLECTOR/MINOR ARTERIAL/MINOR COLLECTOR/PRINCIPAL ARTERIAL" | "0" |

**Table 10.8 Urban four-lane divided severity distribution**

| Severity | U 4 L D | | All | |
|---|---|---|---|---|
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 7 | 0.017 | 48 | 0.003 |
| Disabling Injury | 15 | 0.037 | 421 | 0.024 |
| Minor Injury | 101 | 0.251 | 3,994 | 0.228 |
| Property Damage Only | 280 | 0.695 | 13,020 | 0.745 |
| Total Crashes | 403 | 1.000 | 17,483 | 1.000 |

## 10.6 Urban Five-Lane Undivided Segment Crash Severity

Table 10.9 shows the query criteria used for identifying all crashes in Missouri that occurred on urban five-lane undivided roadways. Table 10.10 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on five-lane undivided segments in Missouri was 9,172, and the total number of crashes from the calibration sample was 721. The comparison between the sample and the population SDFs showed that they were similar.

**Table 10.9 Urban five-lane undivided segment criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE_ NAME | FUNC_CLASS_NAME | INTERSECTION_ NO |
|---|---|---|---|
| "URBAN/URBANIZED" | "5 LANE SECTION" | "LOCAL/MAJOR COLLECTOR/MINOR ARTERIAL/ PRINCIPAL ARTERIAL" | "0" |

**Table 10.10 Urban five-lane undivided severity distribution**

| Severity | U 5L | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 2 | 0.003 | 30 | 0.003 |
| Disabling Injury | 11 | 0.015 | 193 | 0.021 |
| Minor Injury | 197 | 0.273 | 2,292 | 0.250 |
| Property Damage Only | 511 | 0.709 | 6,657 | 0.726 |
| Total Crashes | 721 | 1.000 | 9,172 | 1.000 |

## 10.7 Rural Four-Lane Freeway Segment Crash Severity

Table 10.11 shows the query criteria used for identifying all crashes in Missouri that occurred on rural four-lane freeway segments. Table 10.12 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on rural four-lane freeway segments in Missouri was 11,758, and the total number of crashes from the calibration sample was 1,113. The comparison between the sample and the population SDFs showed that they were slightly different.

**Table 10.11 Rural four-lane freeway segment criteria**

| URBAN_RURAL_CLASS | ROADWAY_TYPE_NAME | FUNC_CLASS_NAME | INTERSECTION_ NO |
| --- | --- | --- | --- |
| "RURAL" | "FREEWAY" | "INTERSTATE/FREEWAY" | "0" |

**Table 10.12 Rural four-lane freeway severity distribution**

| Severity | R FW | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 6 | 0.005 | 108 | 0.009 |
| Disabling Injury | 30 | 0.027 | 413 | 0.035 |
| Minor Injury | 144 | 0.129 | 1,738 | 0.148 |
| Property Damage Only | 933 | 0.838 | 9,499 | 0.808 |
| Total Crashes | 1,113 | 1.000 | 11,758 | 1.000 |

## 10.8 Urban Four-Lane and Six-Lane Freeway Segment Crash Severity

Table 10.13 shows the query criteria used for identifying all crashes in Missouri that occurred on urban four- and six-lane freeway segments. Table 10.14 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on urban four- and six-lane freeway segments in Missouri was 40,635, and the total number of crashes from the calibration sample was 3,316. The comparison between the sample and the population SDFs showed that they were similar.

**Table 10.13 Urban four-lane and six-lane freeway segment criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE_ NAME | FUNC_CLASS_NAME | INTERSECTION_ NO |
|---|---|---|---|
| "URBAN/URBANIZED" | "FREEWAY" | "INTERSTATE/FREEWAY" | "0" |

**Table 10.14 Urban four-lane and six-lane freeway severity distribution**

| Severity | U FW | | All | |
|---|---|---|---|---|
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 23 | 0.007 | 170 | 0.004 |
| Disabling Injury | 85 | 0.026 | 886 | 0.022 |
| Minor Injury | 687 | 0.207 | 8,757 | 0.216 |
| Property Damage Only | 2,521 | 0.760 | 30,822 | 0.759 |
| Total Crashes | 3,316 | 1.000 | 40,635 | 1.000 |

## 10.9 Urban Three-Leg Signalized Intersection Crash Severity

Table 10.15 shows the query criteria used for identifying all crashes in Missouri that occurred on urban three-leg signalized intersections. Table 10.16 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on urban three-leg signalized intersections in Missouri was 1,631, and the total number of crashes from the calibration sample was 529. The comparison between the sample and the population SDFs showed that fatal and disabling injury were similar, but minor injury and PDO were slightly different.

**Table 10.15 Urban three-leg signalized intersection criteria**

| URBAN_RURAL _ CLASS | ROADWAY_TYPE_ NAME | NO_OF_APPRCH _LEGS | INTERSECTION _ NO | SIGNALIZED _FLAG |
|---|---|---|---|---|
| "URBAN/URBA NIZED" | Exclude "Ramp" | 3 | Excluded "0" | Y |

**Table 10.16 Urban three-leg signalized intersection severity distribution**

| Severity | U 3SG | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 1 | 0.002 | 4 | 0.002 |
| Disabling Injury | 10 | 0.019 | 33 | 0.020 |
| Minor Injury | 107 | 0.202 | 430 | 0.264 |
| Property Damage Only | 411 | 0.777 | 1,164 | 0.714 |
| Total Crashes | 529 | 1.000 | 1,631 | 1.000 |

## 10.10 Urban Four-Leg Signalized Intersection Crash Severity

Table 10.17 shows the query criteria used for identifying all crashes in Missouri that occurred on urban four-leg signalized intersections. Table 10.18 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on urban four-leg signalized intersections in Missouri was 11,314, and the total number of crashes from the calibration sample was 1,372. The comparison between the sample and the population SDFs showed that they were similar.

**Table 10.17 Urban four-leg signalized intersection criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE_ NAME | NO_OF_APPRCH_ LEGS | INTERSECTION_ NO | SIGNALIZED_ FLAG |
| --- | --- | --- | --- | --- |
| "URBAN/URBANIZED" | Excluded "Ramp" | 4 | Excluded "0" | Y |

**Table 10.18 Urban four-leg signalized intersection severity distribution**

| Severity | U 4SG | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 3 | 0.002 | 26 | 0.002 |
| Disabling Injury | 34 | 0.025 | 233 | 0.021 |
| Minor Injury | 300 | 0.219 | 2577 | 0.228 |
| Property Damage Only | 1035 | 0.754 | 8478 | 0.749 |
| Total Crashes | 1372 | 1.000 | 11314 | 1.000 |

## 10.11 Rural Two-lane Three-Leg Unsignalized Intersection Crash Severity

Table 10.19 shows the query criteria used for identifying all crashes in Missouri that occurred on rural two-lane three-leg unsignalized intersections. Table 10.20 shows the severity distribution

factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on rural two-lane three-leg unsignalized intersections in Missouri was 431, and the total number of crashes from the calibration sample was 22. The comparison between the sample and the population SDFs showed that they were somewhat different. The difference is unsurprising since there were few crashes on rural two-lane three-leg unsignalized intersections.

**Table 10.19 Rural two-lane three-leg unsignalized intersection criteria**

| URBAN_RURAL _ CLASS | ROADWAY_TYPE_ NAME | NO_OF_APPRCH _LEGS | INTERSECTION _ NO | SIGNALIZED _FLAG |
|---|---|---|---|---|
| "RURAL" | "TWO-LANE/SUPER TWO-LANE " | 3 | Excluded "0" | N |

**Table 10.20 Rural two-lane three-leg unsignalized intersection severity distribution**

| Severity | R 3ST | | All | |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
|---|---|---|---|---|
| Fatal | 0 | 0.000 | 2 | 0.005 |
| Disabling Injury | 1 | 0.045 | 17 | 0.039 |
| Minor Injury | 5 | 0.227 | 85 | 0.197 |
| Property Damage Only | 16 | 0.727 | 327 | 0.759 |
| Total Crashes | 22 | 1.000 | 431 | 1.000 |

## 10.12 Rural Two-lane Four-Leg Unsignalized Intersection Crash Severity

Table 10.21 shows the query criteria used for identifying all crashes in Missouri that occurred on rural two-lane four-leg unsignalized intersections. Table 10.22 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on rural two-lane four-leg unsignalized intersections in Missouri was 8,652, and the total number of crashes from the calibration sample was 44. The comparison between the sample and the population SDFs showed that they were somewhat different. The difference is unsurprising since the calibration sample only contained 44 crashes.

**Table 10.21 Rural two-lane four-leg unsignalized intersection criteria**

| URBAN_RURAL _ CLASS | ROADWAY_TYPE_ NAME | NO_OF_APPRCH _LEGS | INTERSECTION _ NO | SIGNALIZED _FLAG |
|---|---|---|---|---|
| "RURAL" | "TWO-LANE/SUPER TWO-LANE " | 4 | Excluded "0" | N |

**Table 10.22 Rural two-lane four-leg unsignalized intersection severity distribution**

| Severity | R 4ST | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 0 | 0.000 | 122 | 0.014 |
| Disabling Injury | 1 | 0.023 | 546 | 0.063 |
| Minor Injury | 9 | 0.205 | 2,269 | 0.262 |
| Property Damage Only | 34 | 0.773 | 5,715 | 0.661 |
| Total Crashes | 44 | 1.000 | 8,652 | 1.000 |

## 10.13 Rural Multilane Three-Leg Unsignalized Intersection Crash Severity

Table 10.23 shows the query criteria used for identifying all crashes in Missouri that occurred on rural multilane three-leg unsignalized intersections. Table 10.24 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on rural multilane three-leg unsignalized intersections in Missouri was 612, and the total number of crashes from the calibration sample was 169. The comparison between the sample and the population SDFs showed that they were somewhat different.

**Table 10.23 Rural multilane three-leg unsignalized intersection criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE_ NAME | NO_OF_APPRCH_ LEGS | INTERSECTION_ NO | SIGNALIZED_ FLAG |
| --- | --- | --- | --- | --- |
| "RURAL" | "3 LANE/5 LANE /EXPRESSWAY/ MULTILANE LANE/SHARED FOUR LANE " | 3 | Excluded "0" | "N" |

**Table 10.24 Rural multilane three-leg unsignalized intersection severity distribution**

| Severity | R ML 3ST | | All | |
| --- | --- | --- | --- | --- |
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 1 | 0.006 | 8 | 0.013 |
| Disabling Injury | 11 | 0.065 | 43 | 0.070 |
| Minor Injury | 42 | 0.249 | 177 | 0.289 |
| PDO | 115 | 0.680 | 384 | 0.627 |
| Total | 169 | 1.000 | 612 | 1.000 |

## 10.14 Rural Multilane Four-Leg Unsignalized Intersection Crash Severity

Table 10.25 shows the query criteria used for identifying all crashes in Missouri that occurred on rural multilane four-leg unsignalized intersections. Table 10.26 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on rural multilane four-leg unsignalized intersections in Missouri was 562, and the total number of crashes from the calibration sample was 144. The comparison between the sample and the population SDFs showed that they were somewhat different.

**Table 10.25 Rural multilane four-leg unsignalized intersection criteria**

| URBAN_RURAL _ CLASS | ROADWAY_TYPE_ NAME | NO_OF_APPRCH _LEGS | INTERSECTION _ NO | SIGNALIZED _FLAG |
|---|---|---|---|---|
| "RURAL" | "3 LANE/5 LANE /EXPRESSWAY/ MULTILANE LANE/SHARED FOUR LANE " | 4 | Excluded "0" | N |

**Table 10.26 Rural multilane four-leg unsignalized intersection severity distribution**

| Severity | R ML 4ST | | All | |
|---|---|---|---|---|
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 2 | 0.014 | 4 | 0.007 |
| Disabling Injury | 11 | 0.076 | 37 | 0.066 |
| Minor Injury | 38 | 0.264 | 142 | 0.253 |
| Property Damage Only | 93 | 0.646 | 379 | 0.674 |
| Total Crashes | 144 | 1.000 | 562 | 1.000 |

## 10.15 Urban Three-Leg Unsignalized Intersection Crash Severity

Table 10.27 shows the query criteria used for identifying all crashes in Missouri that occurred on urban three-leg unsignalized intersections. Table 10.28 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on urban three-leg unsignalized intersections in Missouri was 1,575, and the total number of crashes from the calibration sample was 57. The comparison between the sample and the population SDFs showed that they were somewhat different.

**Table 10.27 Urban three-leg unsignalized intersection criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE _ NAME | NO_OF_APP RCH_LEGS | FUNC_CLASS_ NAME | SIGNALIZED _FLAG |
|---|---|---|---|---|
| "URBAN/URBANIZE D" | Exclude "FREEWAY /RAMP " | 3 | "PRINCIPAL ARTERIAL/MIN OR ARTERIAL" | "N" |

**Table 10.28 Urban three-leg unsignalized intersection severity distribution**

| Severity | U 3ST | | All | |
|---|---|---|---|---|
| | Samples | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 0 | 0.000 | 5 | 0.003 |
| Disabling Injury | 2 | 0.035 | 44 | 0.028 |
| Minor Injury | 13 | 0.228 | 394 | 0.250 |
| Property Damage Only | 42 | 0.737 | 1,132 | 0.719 |
| Total Crashes | 57 | 1.000 | 1,575 | 1.000 |

## 10.16 Urban Four-Leg Unsignalized Intersection Crash Severity

Table 10.29 shows the query criteria used for identifying all crashes in Missouri that occurred on urban four-leg unsignalized intersections. Table 10.30 shows the severity distribution factor for both the calibration sample and the entire Missouri population of data. The total number of crashes on urban four-leg unsignalized intersections in Missouri was 13,290, and the total number of crashes from the calibration sample was 172. The comparison between the sample and the population SDFs showed that they were similar.

**Table 10.29 Urban four-leg unsignalized intersection criteria**

| URBAN_RURAL_ CLASS | ROADWAY_TYPE _ NAME | NO_OF_APPRCH _ LEGS | FUNC_CLASS_NAM E | SIGNALIZED _ FLAG |
|---|---|---|---|---|
| "URBAN/URBANIZED " | Excluded "FREEWAY/RAMP " | 4 | "PRINCIPAL ARTERIAL/MINOR ARTERIAL" | "N" |

**Table 10.30 Urban four-leg unsignalized intersection severity distribution**

| Severity | U 4ST | | All | |
|---|---|---|---|---|
| | Sample | | Population Data | |
| | Crashes | SDF | Crashes | SDF |
| Fatal | 0 | 0 | 48 | 0.004 |
| Disabling Injury | 5 | 0.029 | 341 | 0.026 |
| Minor Injury | 40 | 0.233 | 3388 | 0.255 |
| Property Damage Only | 127 | 0.738 | 9513 | 0.716 |
| Total Crashes | 172 | 1.000 | 13290 | 1.000 |

# CHAPTER 11. CONCLUSION

This calibration project addressed all the most common Missouri transportation facilities with the exception of freeway interchanges. Freeway interchanges were already calibrated recently as part of an earlier project. The calibration of less common facilities would not be beneficial as the small sample sizes would not provide adequate data for calibration. By applying the calibration values produced in this project, the safety analyst has the confidence that the results are applicable to the state of Missouri.

The HSM has revolutionized how safety data is analyzed. Whereas, previously, the use of the observed number of crashes was the oft-used measure; now, the expected crash frequency becomes the guiding measure for making data-driven safety decisions. This new approach is able to address the regression-to-the-mean problem. This approach also considers both the observed number of crashes and the predicted number of crashes based on the wealth of national research. By calibrating the HSM, the safety analyst takes advantage of the national safety experience while simultaneously accounting for local Missouri characteristics.

There are several items of note resulting from the comparison of the previous calibration factors to the current calibration factors. For most facilities, there were some slight changes in the calibration factor values. These are expected; otherwise continued calibration would not be needed. However, it is beneficial to consider a few specific facility types. For urban four-lane freeway segments, the multi-vehicle PDO factor has decreased from 3.59 to 1.46. The primary reason for the decrease in value is due to the avoidance of the vicinity of interchanges. The sites from the previous calibration were reused, but they were moved away from the interchange vicinity. Queuing and turbulence near speed change lanes could result in crashes occurring on the mainline. Such crashes should not be classified as segment crashes because they are primarily a function of interchange operation. For urban signalized intersections, the three-leg and four-leg calibration values continue to be high (i.e., 2.95 and 5.21). These high calibration values do not mean that Missouri intersections are unsafe when compared to the rest of the US. The various possible reasons for these values were discussed in detail in section 8.5.1. A good alternate approach to calibration is to develop Missouri-specific SPFs for these two facility types, thus eliminating the need to use these high calibration values.

The HSM recommends that recalibration be performed continuously every two to three years. The recalibration makes sure that changes in driver behavior, vehicular technology, land-use, climate, and crash reporting is taken into account when modeling with the HSM. For example, the Missouri Uniform Crash Report was updated in 2012. With the experience gained from each calibration, future calibrations become more efficient and more accurate. One example of a lesson learned from the previous calibration is that the vicinity of interchange facilities should be avoided in the sampling for freeway segments in order to avoid including interchange related crashes. HSM calibration helps to promote the use of the HSM as it keeps the HSM models current and applicable to local conditions. Thus, the recalibration of the HSM on an ongoing basis is recommended.

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