
Updated Statewide and Regional Calibration Factors for Highway Safety Manual Crash Prediction Models (2020-2023)



NCDOT Project 2025-06
FHWA/NC/2025-06
March 2026



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**RESEARCH &
DEVELOPMENT**

Updated Statewide and Regional Calibration Factors for Highway Safety Manual Crash Prediction Models (2020-2023)

FINAL REPORT

Submitted to:
North Carolina Department of Transportation
Office of Research
(Research Project No. RP2025-06)

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March 2026

ii

Technical Report Documentation Page

1. Report No. <i>FHWA/NC/2025-06</i>	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle <i>Updated Statewide and Regional Calibration Factors for Highway Safety Manual Crash Prediction Models (2020-2023)</i>		5. Report Date March 2026	6. Performing Organization Code
		8. Performing Organization Report No.	
7. Author(s) Vikash V. Gayah, Mohammad Javad Hassan Zada, Xiaohan Gu, Scott Himes, Samantha Arnold		10. Work Unit No. (TRAIS)	
9. Performing Organization Name and Address <i>The Pennsylvania State University (Larson Transportation Institute) Vanasse Hangen Brustlin, Inc</i>		11. Contract or Grant No.	
		13. Type of Report and Period Covered Final Report <i>August 1, 2025 – March 31, 2026</i>	
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Development Unit 104 Fayetteville Street Raleigh, North Carolina 27601		14. Sponsoring Agency Code <i>RP2025-06</i>	
		Supplementary Notes:	
16. Abstract Traffic safety remains the foremost objective of transportation professionals, yet roadway fatalities continue to present a major public safety challenge. The Highway Safety Manual (HSM) provides a critical framework for quantitatively evaluating highway safety performance, with Safety Performance Functions (SPFs) serving as one of its central analytical tools. SPFs relate predicted crash frequency to roadway, traffic, and geometric characteristics, allowing practitioners to estimate the safety performance of specific facility types and assess the effects of design and operational alternatives. Because the design-level SPFs in the HSM were developed using data from a limited number of states, direct application in North Carolina may produce biased results due to differences in traffic conditions, roadway characteristics, crash reporting practices, and other state-specific factors. This project developed updated North Carolina-specific calibration factors and accompanying crash proportion tables for HSM SPFs using 2020 through 2023 data. The study addressed a comprehensive set of roadway segment and intersection facility types, including rural two-lane roads, rural multilane highways, urban and suburban arterials, freeways and ramps, ramp terminals, and roundabouts, as well as newer SPF forms introduced through national research efforts. Following HSM calibration procedures, the research team identified and verified study sites from previous North Carolina calibration efforts, supplemented these locations to satisfy recommended sample size requirements, and assembled the geometric, operational, and crash data needed for calibration. The resulting analyses produced both statewide calibration factors and regional calibration factors for the Mountain, Piedmont, and Coastal regions, where applicable.			
17. Key Words <i>Highway safety manual Calibration factors Crash prediction models</i>		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 41	22. Price

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized

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ACKNOWLEDGEMENTS

This research was sponsored by the North Carolina Department of Transportation. The research team would like to thank the NCDOT technical panel that oversaw this work, including Daniel Carter, Carrie Simpson, Daniell Bagley, Brad Robinson and Kendra Klemann.

EXECUTIVE SUMMARY

Traffic safety remains a critical priority for transportation professionals. The Highway Safety Manual (HSM) provides quantitative tools for informed safety decisions through Safety Performance Function (SPF) models that relate predicted crash frequency to roadway characteristics—however, these SPFs were developed using data from states other than North Carolina that do not adequately reflect crash experience in the state. Thus, the models require jurisdiction-specific calibration to account for variations in traffic patterns, crash reporting systems, and climate conditions.

Several previous NCDOT research projects developed North Carolina-specific calibration factors with the HSM Part C design-level prediction models. This research effort updates these previous calibration factors using current crash data from 2020-2023, as well as developing calibration factors for new facility types so North Carolina's safety analyses reflect current conditions for data-driven decision-making in highway safety improvements. Calibration factors are provided for total crash frequency for the following facility types:

- Roadway segments (rural two-lane highways, rural multilane highways, urban arterials, and urban and rural freeways)
- Intersections (rural and urban, including roundabouts)
- Interchange components (speed change lane segments, ramp segments, and ramp terminals)

Quick reference tables summarizing these calibration factors are provided in Appendix B for easy access during safety analyses.

TABLE OF CONTENTS

Chapter 1.	Introduction.....	1
Chapter 2.	Literature Review.....	3
2.1	1 st edition of the HSM.....	3
2.2	Supplement to the 1 st edition of the HSM.....	4
2.3	NCHRP Project 17-58.....	4
2.4	NCHRP Project 17-70.....	5
2.5	SPF calibration efforts using North Carolina data	5
2.5.1	NCDOT 2009-06.....	5
2.5.2	NCDOT 2009-07.....	5
2.5.3	NCDOT 2010-09.....	5
2.5.4	NCDOT 2016-09.....	5
2.5.5	NCDOT 2020-27.....	6
Chapter 3.	Methodology	7
3.1	Overview of HSM predictive methodology.....	7
3.1.1	Safety Performance Functions	7
3.1.2	Adjustment Factors (AFs).....	7
3.1.3	Calibration Factors.....	7
3.2	Overview of calibration procedure	8
3.2.1	Step 1: Identify facility types for which the applicable Part C predictive model is to be calibrated.....	9
3.2.2	Step 2: Select sites for calibration of the predictive model for each facility type.....	10
3.2.3	Step 3: Obtain data for each facility type applicable to a specific calibration period.....	14
3.2.4	Step 4: Apply the applicable Part C predictive model to predict crash frequency for each site during the calibration period as a whole.....	20
3.2.5	Step 5: Compute calibration factors for use in Part C predictive model.....	20
Chapter 4.	Calibration results	21
4.1	Segment models.....	21
4.1.1	Rural segments.....	21
4.1.2	Urban segments.....	23
4.1.3	Freeway segments.....	25
4.2	Intersection models	27
4.2.1	Rural intersections.....	27
4.2.2	Urban intersections	30
4.2.3	Rural roundabouts.....	34
4.2.4	Urban roundabouts.....	35
4.3	Interchange component models	35
4.3.1	Ramp segments	35

4.3.2	Speed change lanes	36
4.3.3	Ramp terminals	38
Chapter 5.	Implementation plan and technology transfer	40
Chapter 6.	Conclusions and recommendations.....	41
Appendix A.	SPFs and Associated AFs	44
Appendix B.	Quick reference tables.....	66
B.1.	Rural segments	66
B.2.	Urban segments.....	66
B.3.	Freeway segments	67
B.4.	Rural intersections	67
B.5.	Urban intersections	68
B.6.	Roundabouts	68
B.7.	Ramp segments	68
B.8.	Speed change lane segments	69
B.9.	Ramp terminals	69
Appendix B.	Crash type and severity distribution tables	70

LIST OF TABLES

Table 1. Summary of Roadway Segments Included in the Study	12
Table 2. Summary of Intersections Included in the Study	13
Table 3. Summary of Interchange Components Included in the Study	14
Table 4. Data Elements and Sources for Roadway Elements	16
Table 13. Data Elements and Sources for Intersection Elements	17
Table 14. Data Elements and Sources for Interchange Elements	18
Table 15. Statewide Rural 2-Lane Undivided Segments (R2U) Calibration Factors	21
Table 16. Regional Rural 2-Lane Undivided Segments (R2U) Calibration Factors.....	22
Table 17. Statewide Rural 4-Lane Divided Segments (R4D) Calibration Factors	22
Table 18. Regional Rural 4-Lane Divided Segments (R4D) Calibration Factors.....	23
Table 19. Statewide Rural 4-Lane Undivided Segments (R4U) Calibration Factors	23
Table 20. Statewide Urban 2-Lane Undivided Segments (U2U) Calibration Factors	24
Table 21. Statewide Urban 2-Lane with TWLTL Segments (U3T) Calibration Factors.....	24
Table 22. Statewide Urban 4-Lane Divided Segments (U4D) Calibration Factors	24
Table 23. Statewide Urban 4-Lane Undivided Segments (U4U) Calibration Factor.....	24
Table 24. Statewide Urban 4-Lane with TWLTL Segments (U5T) Calibration Factor	25
Table 25. Statewide Urban 6-Lane Divided Segments (U6D) Calibration Factor.....	25
Table 26. Statewide Urban 7-Lane Divided Segments (U7D) Calibration Factor.....	25
Table 27. Statewide Urban 8-Lane Divided Segments (U8D) Calibration Factor.....	25
Table 28. Statewide Rural Freeways with 4 Through Lanes (Rur4Ln) Calibration Factor	26
Table 29. Statewide Urban Freeways with 4 Through Lanes (Urb4Ln) Calibration Factor	26
Table 30. Statewide Urban Freeways with 6 Through Lanes (Urb6Ln) Calibration Factor	26
Table 31. Statewide Urban Freeways with 8 Through Lanes (Urb8Ln) Calibration Factor	27
Table 32. Statewide Rural 2-Lane, Minor Road Stop-Controlled 3-Leg Intersections (Rur2L-3ST) Calibration Factor	27
Table 33. Statewide Rural 2-Lane, Signalized 4-Leg Intersections (Rur2L-4SG) Calibration Factor	28
Table 34. Regional Rural 2-Lane, Signalized 4-Leg Intersections (Rur2L-4SG) Calibration Factor.....	28
Table 35. Statewide Rural 2-Lane, Minor Road Stop-Controlled 4-Leg Intersections (Rur2L-4ST) Calibration Factor	28
Table 36. Regional Rural 2-Lane, Minor Road Stop-Controlled 4-Leg Intersections (Rur2L-4ST) Calibration Factor	29

Table 37. Statewide Rural Multilane, Minor Road Stop-Controlled 3-Leg Intersections (RurML-3ST) Calibration Factor	29
Table 38. Statewide Rural Multilane, Signalized 4-Leg Intersections (RurML-4SG) Calibration Factor..	29
Table 39. Statewide Rural Multilane, Minor Road Stop-Controlled 4-Leg Intersections (RurML-4ST) Calibration Factor	30
Table 40. Statewide Urban Arterial, Signalized 3-Leg Intersections (UrbArt-3SG) Calibration Factor....	31
Table 41. Statewide Urban Arterial, Stop-Controlled 3-Leg Intersections (UrbArt-3ST) Calibration Factor	31
Table 42. Statewide Urban Arterial, Signalized 4-Leg Intersections (UrbArt-4SG) Calibration Factor....	31
Table 43. Regional Urban Arterial, Signalized 4-Leg Intersections (UrbArt-4SG) Calibration Factor	32
Table 44. Statewide Urban Arterial, Stop-Controlled 4-Leg Intersections (UrbArt-4ST) Calibration Factor	32
Table 45. Statewide Urban Arterial, Two-way at Two-way Signalized 4-Leg Intersections with 6-8 Lanes (U68-4SG-2x2) Calibration Factor	32
Table 46. Regional Urban Arterial, One-way at Two-way Signalized 4-Leg Intersections with 6-8 Lanes (U68-4SG-2x2) Calibration Factor	33
Table 47. Statewide Urban Arterial, One-way at One-way or Two-way Signalized 4-Leg Intersections with 6-8 Lanes (U68-4SG-1x1 or2) Calibration Factor	33
Table 48. Statewide Urban Arterial, Two-way at Two-way Stop-Controlled 4-Leg Intersections with 6-8 Lanes (U68-4ST-2x2) Calibration Factor	33
Table 49. Statewide Urban Arterial, One-way at One-way or Two-way Stop-Controlled 4-Leg Intersections with 6-8 Lanes (U68-4ST-1x1 or2) Calibration Factor	34
Table 50. Statewide Urban Arterial, Two-way at Two-way Signalized 3-Leg Intersections with 6-8 Lanes (U68-3SG-2x2) Calibration Factor	34
Table 51. Statewide Urban Arterial, One-way at One-way or Two-way Signalized 3-Leg Intersections with 6-8 Lanes (U68-3SG-1x1 or2) Calibration Factor	34
Table 52. Statewide Rural Roundabouts Calibration Factor.....	35
Table 53. Statewide Urban Roundabouts Calibration Factor.....	35
Table 54. Statewide Entrance Ramp Segment Calibration Factor	36
Table 55. Statewide Exit Ramp Segment Calibration Factor	36
Table 56. Statewide Speed Change Lanes – Ramp Entrance Segments Calibration Factor	37
Table 57. Statewide Speed Change Lanes – Ramp Exit Segments Calibration Factor.....	38
Table 58. Statewide Ramp Terminals Calibration Factor	39
Table 51. Roadway Segments SPFs and Associated AFs.....	44

Table 10. Intersections SPFs and Associated AFs	53
Table 11. Interchange Component SPFs and Associated AFs	58
Table 59. Rural Segments Quick Reference Table	66
Table 60. Urban Segments Quick Reference Table	66
Table 61. Freeway Segments Quick Reference Table	67
Table 62. Rural Intersections Quick Reference Table	67
Table 63. Urban Intersections Quick Reference Table	68
Table 64. Roundabouts Quick Reference Table	68
Table 65. Ramp Segments Quick Reference Table	68
Table 66. Speed Change Lanes Quick Reference Table	69
Table 67. Ramp Terminals Quick Reference Table.....	69

Chapter 1. Introduction

Traffic safety is a primary objective for transportation professionals. However, according to the traffic crash data released by the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) in 2023, 42,514 lives were lost in traffic crashes in 2022, which represents a 7.2% increase in fatal crashes and a 4.2% increase in the fatality rate per 100 million vehicle miles traveled, respectively, over the past three years (NHTSA, 2023). The *Highway Safety Manual* (HSM), published by American Association of State Highway and Transportation Officials (AASHTO) in 2010 and supplement in 2014, provide a set of quantitative tools that help transportation practitioners make more informed decisions regarding highway safety performance (AASHTO, 2010, 2014). One of the most critical tools are Safety Performance Functions (SPF) relating predicted safety performance of individual facilities (measured in terms of predicted annual crash frequency) with their specific features, such as traffic volume or geometric characteristics.

The design-level SPFs included in Part C of the HSM were developed using data from a limited number of states. The resulting SPFs were calibrated to 2002 to 2006 Washington State segments and California intersections (Bahar & Hauer, 2014). Since a variety of features, including traffic flow characteristics, crash reporting system, and climate vary significantly across different states, using the HSM SPFs or other national-level SPFs directly for any state will likely lead to biased predictions. For this reason, jurisdictions need to calibrate these SPFs before they can be applied for meaningful predictive analysis. This calibration is typically done using a calibration factor as recommended by the HSM.

The purpose of this study was to develop updated calibration factors and accompanying default crash severity and collision type distribution tables for the SPFs in the HSM using crash and other data from 2020 to 2023 (inclusive). Five previous NCDOT projects (2009-06, 2009-07, 2010-09, 2016-09, and 2020-27) produced calibration factors that are specific to North Carolina using the HSM SPFS (Saleem et al., 2021). The calibration factors developed from the most recent NCDOT project 2020-27 include those for:

- Rural two-lane roads
- Rural multilane roads
- Urban and suburban arterials
- Urban and rural freeways
- Intersections on rural two-lane highways
- Intersections on rural multilane highways
- Intersections on urban and suburban arterials

The study also developed calibration factors for newer SPFs that were available via other national-level projects, which are expected to be incorporated into the next edition of the *Highway Safety Manual* (HSM2).

The segment facility types for which calibration factors were generated include the following:

- Rural two-lane roads
- Rural multilane roads
- Urban and suburban arterials
- Urban and rural freeways

The intersection types for which calibration factors were generated include the following:

- Intersections on rural two-lane highways
- Intersections on rural multilane highways
- Intersections on urban and suburban arterials and one-way streets
- Roundabouts

The interchange components for which calibration factors were generated include the following:

- Ramp segments
- Speed change lane segments
- Ramp terminals

The remainder of this document is organized as follows. The next section describes the HSM predictive methodology and its application in calculating the calibration factors for this study. The following section presents the results and findings of the calibration factors developed through this research effort. The study produced calibration factors for fifteen types of roadway segments (including four freeway types), eighteen types of intersections, and twelve interchange components. The final section provides an overview of recommendations for future efforts.

Chapter 2. Literature Review

2.1 1st edition of the HSM

The 1st edition of the AASHTO HSM was published in 2010 for highway safety professionals to develop SPFs to calculate roadway safety and calibrate the calculations to be locally applicable. Part A introduces the purpose and scope of the HSM and presents foundational concepts, including human factors principles, that support the analytical methods used throughout the manual. Part B outlines a systematic process for managing safety on existing roadway networks, covering site identification, problem diagnosis, countermeasure selection, economic evaluation, project ranking, and post-implementation assessment.

Part C provides quantitative tools for safety analysis, including SPFs and predictive algorithms that allow practitioners to evaluate current safety conditions, predict future crash performance, and assess the expected safety impacts of proposed design changes. For roadway segments, SPFs are presented for:

- Rural two-lane roads (Chapter 10)
- Rural four-lane divided and undivided roads (Chapter 11)
- Two-lane, three-lane, four-lane divided, four-lane undivided, and five-lane roads in urban and suburban arterials (Chapter 12)

For intersections, SPFs are presented for:

- Three- and four-leg stop-controlled and four-leg signalized intersections on rural two-lane roads (Chapter 10)
- Three- and four-leg stop-controlled and four-leg signalized intersections on rural multilane roads (Chapter 11)
- Three- and four-leg stop-controlled and signalized intersections on urban and suburban arterials (Chapter 12)

The rural segment and intersection SPFs were developed using data from California, Washington, Michigan, Minnesota, and Texas, while the urban and suburban arterial SPFs drew on data from Charlotte, Michigan, Minnesota, and Toronto. North Carolina data were not used in the development of any of these models. All Part C SPFs were estimated using negative binomial regression models, the standard methodology for crash prediction modeling. The HSM specifies that agencies must either calibrate these SPFs to their jurisdiction following the procedure in Part C; or develop their own jurisdiction-specific SPFs using negative binomial regression models.

Part D presents crash modification factors (CMFs) that quantify the expected safety effects of engineering treatments applied to roadway segments, intersections, interchanges, and other facilities. Measures of precision such as standard errors are also provided for each CMF.

2.2 Supplement to the 1st edition of the HSM

NCHRP 17-45 (Bonneson et al., 2012) developed SPFs for freeways and interchanges for inclusion in the HSM. These SPFs were estimated using data from California, Washington, and Maine, and were incorporated into the 2014 supplement to the 1st edition of the HSM (AASHTO, 2014) as Chapter 18. The SPFs cover the following facility types:

- Freeway segments (multiple- and single-vehicle FI and PDO predictive models):
 - Rural 4-, 6-, and 8-lane
 - Urban 4-, 6-, 8-, and 10-lane
- Freeway speed-change lanes (total FI and PDO predictive models):
- Ramp entrance and exit segments for 4-, 6-, 8-, and 10-lane divided freeways
- Ramp and collector-distributor (C-D) roadway segments (rural and urban multiple- and single-vehicle FI and PDO predictive models):
- One-lane and two-lane entrance ramps
- One-lane and two-lane exit ramps
- One-lane and two-lane C-D roads
- Crossroad ramp terminals.

2.3 NCHRP Project 17-58

NCHRP Project 17-58 (Lord et al., 2016) developed SPFs for rural and suburban arterial facility types beyond those included in the 1st edition of the HSM. These models are expected to be incorporated into the 2nd edition of the HSM. For roadway segments, SPFs were developed for:

- Urban 6-lane divided segments
- Urban 7-lane divided segments
- Urban 8-lane divided segments

For intersections, SPFs were developed for various configurations of signalized and stop-controlled 3- and 4-leg intersections on facilities with 6 to 8 lanes, including:

- Two-way at two-way signalized 4-leg intersections
- One-way at one-way or two-way signalized 4-leg intersections
- Two-way at two-way stop-controlled 4-leg intersections
- One-way at one-way or two-way stop-controlled 4-leg intersections
- Two-way at two-way signalized 3-leg intersections
- One-way at one-way or two-way signalized 3-leg intersections

This study used the SPFs from the NCHRP 17-58 appendices to develop North Carolina-specific calibration factors for these facility types.

2.4 NCHRP Project 17-70

NCHRP Project 17-70 (Rodegerdts et al., 2019) developed crash prediction models and methods for roundabouts. The report includes intersection-level SPFs for:

- Rural roundabouts
- Urban roundabouts

These models are also expected to be incorporated into the 2nd edition of the HSM. This study used the intersection-level roundabout SPFs from Chapter 5 of the NCHRP 17-70 report to develop calibration factors for rural and urban roundabouts in North Carolina.

2.5 SPF calibration efforts using North Carolina data

There have been five previous efforts that undertook SPF calibration using North Carolina data.

2.5.1 NCDOT 2009-06

NCDOT 2009-06 (Hummer et al., 2010a) assessed the operational and safety performance of superstreet (restricted crossing U-turn) intersections on North Carolina arterials. The study found that unsignalized superstreets significantly reduced total, angle, and left-turn collisions as well as fatal and injury crashes. As part of this effort, the authors also produced HSM calibration factors for rural multilane stop-controlled intersections using 2004-2009 data.

2.5.2 NCDOT 2009-07

NCDOT 2009-07 (Hummer et al., 2010b) developed standardized field and GIS-based methods for investigating horizontal curve safety on two-lane highways. The study also produced a calibration factor of 1.33 for the HSM rural two-lane undivided roadway segment crash prediction model.

2.5.3 NCDOT 2010-09

NCDOT 2010-09 (Srinivasan and Carter, 2011) estimated North Carolina-specific SPFs for nine crash types across sixteen roadway types for use in network screening, and calibrated the HSM Part C prediction models for six segment and eight intersection facility types using 2007–2009 data.

2.5.4 NCDOT 2016-09

NCDOT 2016-09 (Smith et al., 2017) updated and expanded the previous calibration efforts using 2010-2015 data, producing calibration factors for all Part C segment and intersection models of interest to NCDOT as well as freeway models slated for the next HSM edition. The project also introduced regional calibration factors for the Mountain, Piedmont, and Coastal regions, developed calibration functions for rural two-lane roads, and produced state-specific crash type proportions.

2.5.5 NCDOT 2020-27

NCDOT 2020-27 "Updated and Regional Calibration Factors for Highway Safety Manual Crash Prediction Models (2016-2019)" (Saleem et al., 2021) developed North Carolina-specific calibration factors using 2016–2019 data for the following facility types:

- Roadway Segments:
 - Rural 2-lane undivided segments (regional calibration factors also developed)
 - Rural 4-lane divided segments (regional calibration factors also developed)
 - Urban 2-lane undivided segments
 - Urban 2-lane with TWLTL segments
 - Urban 4-lane divided segments
 - Urban 4-lane undivided segments
 - Urban 4-lane with TWLTL segments
 - Rural freeways (4 through lanes)
 - Urban freeways (4, 6, and 8 through lanes)
- Intersections:
 - Rural 2-lane, minor road stop-controlled 3- and 4-leg intersections (regional calibration factors also developed)
 - Rural 2-lane, signalized 4-leg intersections (regional calibration factors also developed)
 - Rural 4-lane, minor road stop-controlled 3- and 4-leg intersections
 - Rural 4-lane, signalized 4-leg intersections
 - Urban arterial, stop-controlled and signalized 3- and 4-leg intersections

The current study builds upon this most recent effort, updating all calibration factors using 2020–2023 data and expanding the scope to include additional facility types from NCHRP Projects 17-58 and 17-70 as well as interchange components from HSM Chapter 18.

Chapter 3. Methodology

The HSM recommends that agencies calibrate the predictive models to local conditions, as the base models were developed using data from multiple states across the country and were calibrated to Washington State and California data depending on facility type. To improve safety predictions, address North Carolina-specific roadway and traffic characteristics, and support data-driven safety investment decisions, the research team developed state-specific and regional calibration factors for application to North Carolina facilities.

3.1 Overview of HSM predictive methodology

The HSM Part C predictive method provides a quantitative 18-step procedure to estimate the predicted average crash frequency for specific roadway segments and intersections. This methodology enables transportation agencies to estimate safety performance, evaluate the potential safety effects of geometric design decisions, and conduct alternatives analysis based on empirical data. The predictive methodology consists of three primary components: safety performance functions, adjustment factors (AFs), and calibration factors (as demonstrated in Equation 1).

3.1.1 Safety Performance Functions

SPFs are regression models that estimate the predicted average crash frequency for a roadway facility based on traffic volume and, for segments, roadway length. The HSM provides base SPFs for various facility types that represent typical baseline conditions observed in the data used to develop the models.

3.1.2 Adjustment Factors (AFs)

AFs (also described as CMFs in the original HSM) are multiplicative factors used to adjust the base SPF predictions to account for site-specific geometric and operational characteristics that differ from the base conditions. Typical design elements addressed by AFs include lane width, shoulder width, horizontal curves, roadside features, intersection geometry, and traffic control devices. AFs greater than 1.0 indicate an expected increase in crashes, while AFs less than 1.0 indicate an expected decrease.

3.1.3 Calibration Factors

Calibration factors adjust the SPF predictions to reflect local conditions and crash reporting practices within a specific jurisdiction. Since the HSM models were developed using data from multiple states, calibration is essential to account for regional differences in climate, driver behavior, roadway design standards, and crash data collection procedures. The HSM recommends that agencies develop jurisdiction-specific calibration factors to improve prediction accuracy.

Thus, the predicted crash frequency for each site is calculated with these components using Equation 1:

$$N_{predicted} = N_{spf\ x} \times (AF_{1x} \times AF_{2x} \times \dots \times AF_{yx}) \times C_x \quad (1)$$

7

where:

$N_{predicted}$ = predicted average crash frequency for a specific year on facility type x ;

$N_{spf\ x}$ = predicted average crash frequency determined for base conditions of the SPF developed for facility type x ;

AF_{yx} = crash modification factors specific to facility type x and specific geometric design and traffic control features y ; and

C_x = calibration factor to adjust SPF for local conditions for facility type x .

Each predictive model is facility-specific (e.g., urban four-lane divided segments) and calculates predicted crash frequency for a specific year. A key advantage of the HSM predictive methodology is that it estimates long-term predicted average crash frequency rather than relying solely on short-term observed crash data. This approach reduces the potential for regression-to-the-mean bias, which can occur when sites are selected for safety treatment based on temporarily elevated crash frequencies that may not reflect true underlying safety performance. The predictive method is flexible and can estimate crash frequency for historical years using observed traffic volumes or for future years using forecasted traffic volumes, supporting both retrospective analysis and prospective planning.

3.2 Overview of calibration procedure

To adapt the Part C predictive models to local jurisdictional conditions, the HSM recommends developing calibration factors using the five-step procedure outlined below:

Step 1: Identify facility types for which the applicable Part C predictive model is to be calibrated.

Step 2: Select sites for calibration of the predictive model for each facility type.

Step 3: Obtain data for each facility type applicable to a specific calibration period.

Step 4: Apply the applicable Part C predictive model to predict total crash frequency for each site during the calibration period as a whole.

Step 5: Compute calibration factors for use in Part C predictive models.

3.2.1 Step 1: Identify facility types for which the applicable Part C predictive model is to be calibrated.

Following discussion with the NCDOT technical panel, the following facility types were identified for development of calibration factors as a part of this project. Each of these is presented with the source of the underlying crash prediction model used for the calibration procedure.¹

- Roadway Segments
 - Rural 2-lane Undivided Segments (R2U) – HSM Chapter 10
 - Rural 4-lane Divided Segments (R4D) – HSM Chapter 11
 - Rural 4-lane Undivided Segments (R4U) – HSM Chapter 11
 - Urban 2-Lane Undivided Segments (U2U) – HSM Chapter 12
 - Urban 2-Lane with TWLTL Segments (U3T) – HSM Chapter 12
 - Urban 4-Lane Divided Segments (U4D) – HSM Chapter 12
 - Urban 4-Lane Undivided Segments (U4U) – HSM Chapter 12
 - Urban 4-Lane with TWLTL Segments (U5T) – HSM Chapter 12
 - Urban 6-Lane Divided Segments (U6D) – NCHRP Project 17-58 Appendix A
 - Urban 7-Lane Divided Segments (U7D) – NCHRP Project 17-58 Appendix A
 - Urban 8-Lane Divided Segments (U8D) – NCHRP Project 17-58 Appendix A
 - Rural Freeways with 4 Through Lanes (Rur4Ln) – HSM Chapter 18
 - Urban Freeways with 4 Through Lanes (Urb4Ln) – HSM Chapter 18
 - Urban Freeways with 6 Through Lanes (Urb6Ln) – HSM Chapter 18
 - Urban Freeways with 8 Through Lanes (Urb8Ln) – HSM Chapter 18
- Intersections
 - Rural 2-Lane, Minor Road Stop-Controlled 3-Leg Intersections (Rur2L-3ST) – HSM Chapter 10
 - Rural 2-Lane, Signalized 4-Leg Intersections (Rur2L-4SG) – HSM Chapter 10
 - Rural 2-Lane, Minor Road Stop-Controlled 4-Leg Intersections (Rur2L-4ST) – HSM Chapter 10
 - Rural Multilane, Minor Road Stop-Controlled 3-Leg Intersections (RurML-3ST) – HSM Chapter 11
 - Rural Multilane, Signalized 4-Leg Intersections (RurML-4SG) – HSM Chapter 11
 - Rural Multilane, Minor Road Stop-Controlled 4-Leg Intersections (RurML-4ST) – HSM Chapter 11
 - Urban Arterial, Signalized 3-Leg Intersections (UrbArt-3SG) – HSM Chapter 12

¹ The SPFs used in this study were taken from the appendices of the cited NCHRP reports, which contain the proposed HSM draft text at the time of this calibration effort. These SPF parameters may differ from those ultimately published in the HSM 2nd edition. NCDOT should ensure that the SPF parameters used in their application are consistent with those from the specific NCHRP report appendices referenced here.

- Urban Arterial, Stop-Controlled 3-Leg Intersections (UrbArt-3ST) – HSM Chapter 12
- Urban Arterial, Signalized 4-Leg Intersections (UrbArt-4SG) – HSM Chapter 12
- Urban Arterial, Stop-Controlled 4-Leg Intersections (UrbArt-4ST) – HSM Chapter 12
- Urban Arterial, Two-way at Two-way Signalized 4-Leg Intersections with 6-8 lanes (U68-4SG-2x2) – NCHRP Project 17-58 Chapter 6
- Urban Arterial, One-way at One-way or Two-way Signalized 4-Leg Intersections with 6-8 lanes (U68-4SG-1x1or2) – NCHRP Project 17-58 Appendix A
- Urban Arterial, Two-way at Two-way Stop-Controlled 4-Leg Intersections with 6-8 lanes (U68-4ST-2x2) – NCHRP Project 17-58 Appendix A
- Urban Arterial, One-way at One-way or Two-way Stop-Controlled 4-Leg Intersections with 6-8 lanes (U68-4ST-1x1or2) – NCHRP Project 17-58 Appendix A
- Urban Arterial, Two-way at Two-way Signalized 3-Leg Intersections with 6-8 lanes (U68-3SG-2x2) – NCHRP Project 17-58 Appendix A
- Urban Arterial, One-way at One-way or Two-way Signalized 3-Leg Intersections with 6-8 lanes (U68-3SG-1x1or2) – NCHRP Project 17-58 Appendix A
- Rural Roundabouts – NCHRP Project 17-70 Chapter 5 (Intersection-Level Models)
- Urban Roundabouts – NCHRP Project 17-70 Chapter 5 (Intersection-Level Models)
- Interchange components
 - One-lane Entrance Ramp Segment (Ramp 1EN) – HSM Chapter 19
 - One-lane Exit Ramp Segment (Ramp 1EX) – HSM Chapter 19
 - Two-lane Entrance Ramp Segment (Ramp 2EN) – HSM Chapter 19
 - Two-lane Exit Ramp Segment (Ramp 2EX) – HSM Chapter 19
 - Speed Change Lane Ramp Entrance 4 Lanes (4EN) – HSM Chapter 18
 - Speed Change Lane Ramp Exit 4 Lanes (4EX) – HSM Chapter 18
 - Speed Change Lane Ramp Entrance 6 Lanes (6EN) – HSM Chapter 18
 - Speed Change Lane Ramp Exit 6 Lanes (6EX) – HSM Chapter 18
 - Speed Change Lane Ramp Entrance 8 Lanes (8EN) – HSM Chapter 18
 - Speed Change Lane Ramp Exit 8 Lanes (8EX) – HSM Chapter 18
 - Speed Change Lane Ramp Entrance 10 Lanes (10EN) – HSM Chapter 18
 - Speed Change Lane Ramp Exit 10 Lanes (10EX) – HSM Chapter 18
 - Three-leg Terminals at Two-quadrant Partial Cloverleaf A (A2) – HSM Chapter 19
 - Four-leg Terminals at Four-quadrant Partial Cloverleaf A (A4) – HSM Chapter 19
 - Three-leg Terminals at Two-quadrant Partial Cloverleaf B (B2) – HSM Chapter 19
 - Four-leg Terminals with Diagonal Ramps (D4) – HSM Chapter 19

3.2.2 Step 2: Select sites for calibration of the predictive model for each facility type

The calibration process requires detailed site-level data and therefore must be based on a sample of roadway segments or intersections for which such data can be collected. Sample selection is critical and should be as random as possible to avoid bias. The HSM advises against selecting sites in a way that

overrepresents either high- or low-crash locations. Sample size is also important: the HSM recommends a minimum of 30 to 50 sites for each facility type, with the full sample representing at least 100 crashes per year to improve calibration.

For this effort, the research team began with the sites used in the most recent calibration study (Saleem et al., 2021). Each site was reviewed to confirm that it still matched the applicable facility type, and sites that had changed during the study period were removed. Sites for the facility types for which new calibration factors were developed in this project were then identified using features from the NCDOT roadway inventory database. New sites were selected by randomly choosing routes to derive a sample that was representative of the overall network. All segments along those routes were included, taking advantage of nearby locations to improve the efficiency of data collection while still providing diversity across sites for each facility type. To supplement the intersection samples from previous studies, additional intersections were also identified and coded during data collection for the segment facility types.

Table 1 through Table 3 summarize the sample sizes of segments, intersections, and interchange components included in this report. Note that facility types that were included in the previous project – and thus were identified using the same set of sites used in the previous project – are identified by an asterisk (*) in these tables.

Table 1. Summary of Roadway Segments Included in the Study

Facility Type	No. of Segments	Total Mileage
Rural Segments	3,518	857.83
R2U*	2,869	655.69
R2U - Coast*	615	176.10
R2U - Piedmont*	905	234.64
R2U - Mountain*	1,349	244.95
R4D*	601	182.04
R4D - Coast*	154	56.65
R4D - Piedmont*	171	55.25
R4D - Mountain*	276	70.14
R4U*	48	20.11
Urban Segments	363	69.16
U2U*	173	33.94
U3T*	55	9.77
U4D*	14	2.86
U4U*	22	3.57
U5T*	67	12.73
U6D	7	2.27
U7D	16	2.50
U8D	9	1.51
Freeway	85	80.93
Rur4Ln*	20	29.93
Urb4Ln*	24	19.72
Urb6Ln*	24	18.82
Urb8Ln*	17	12.46

Table 2. Summary of Intersections Included in the Study

Facility Type	No. of Intersections
Rural Intersections	610
Rur2L-3ST*	208
Rur2L-3ST – Coast*	47
Rur2L-3ST - Piedmont*	110
Rur2L-3ST - Mountain*	51
Rur2L-4SG*	105
Rur2L-4SG - Piedmont*	59
Rur2L-4ST*	234
Rur2L-4ST - Coast*	103
Rur2L-4ST - Piedmont*	99
Rur2L-4ST - Mountain*	32
RurML-3ST*	14
RurML-4SG*	28
RurML-4ST*	21
Urban Intersections	195
UrbArt-3SG*	7
UrbArt-3ST*	53
UrbArt-4SG*	117
UrbArt-4SG - Coast*	48
UrbArt-4SG - Piedmont*	39
UrbArt-4ST*	18
U68-4SG-2×2	33
U68-3SG-2×2	20
U68-4ST-2×2	8
U68-4SG-1×1or2	55
U68-3SG-1×1or2	2
U68-4ST-1×1or2	3
Rural Roundabouts	33
Urban Roundabouts	64

Table 3. Summary of Interchange Components Included in the Study

Facility Type	Number of Sites
Ramp Segments	85
Ramp 1EN	42
Ramp 2EN	4
Ramp 1EX	36
Ramp 2EX	3
Speed Change Lanes	69
4EN	29
6EN	4
8EN	4
10EN	1
4EX	24
6EX	4
8EX	1
10EX	2
Ramp Terminals	38
Ramp Terminals D4	33
Ramp Terminals A2	1
Ramp Terminals B2	3
Ramp Terminals A4	1

3.2.3 Step 3: Obtain data for each facility type applicable to a specific calibration period

The HSM SPFs require data for each site on various geometric and cross-sectional characteristics, traffic volumes, and crashes. The researchers used various sources including NCDOT databases and GIS files, and Google Earth imagery (including Streetview) to collect the needed data elements. NCDOT provided the crash data from 2020 to 2023. ArcGIS Pro was used to integrate crash data with segment data and to perform segmentation for each facility type. Where site-specific local data were not available, HSM default values were used for certain AFs, including nighttime crash proportions and pedestrian crash proportions; specific instances. Table 51 through Table 53 in Appendix A summarize applicable HSM SPFs and AFs for calibrated facilities in this project. AFs that are not applied in the calibration process are shown as strikethrough text and notes are provided as to why these were not included in the calibration procedure.

Table 4 through Table 6 provide the data elements collected for segments, intersections, and interchanges and the data source for each element. Rural and urban roadway segments, freeways, rural intersections, and urban arterial intersections were collected in the previous calibration project. Data elements for these facility types were examined for accuracy and corrected as necessary. As a part of this process, the research team identified several issues with segmentation for some facility types. For example, rural two-lane roadway segments were not segmented into tangents and curves as suggested in the HSM in previous calibration efforts. This was redone under the current project to better align the segmentation with respect

to HSM definitions and provide curve radius information that was missing. Further, clearly erroneous values in some attributes (e.g., extremely small curve radii or unreasonable lane widths) were manually adjusted by the research team. However, only the obviously incorrect values were manually reviewed and corrected by the research team due to resource constraints.

Table 4. Data Elements and Sources for Roadway Elements

Data Element	Source	Facility Type
Segment length	NCDOT GIS	All
Traffic volume	NCDOT GIS	All
Presence of lighting	Aerial/Streetview imagery	All
Use of automated speed enforcement	n/a – not used in North Carolina	All
Lane width	NCDOT GIS, Aerial/Streetview imagery	Rural 2U, 4D, and freeways
Shoulder type	NCDOT GIS, Aerial/Streetview imagery	Rural 2U and 4D
Shoulder width	NCDOT database	Rural 2U, 4D, and freeways
Presence of TWLTL	Aerial/Streetview imagery	Rural 2U, urban arterials
Lengths of horizontal curves and tangents	Aerial/Streetview imagery, NCDOT GIS	Rural 2U, freeways
Radii of horizontal curves	Aerial/Streetview imagery, NCDOT GIS	Rural 2U, freeways
Number of through traffic lanes	NCDOT GIS, Aerial/Streetview imagery	Urban arterials and freeways
Presence of spiral transition for horizontal curves	n/a – used "Not Present" as default	Rural 2U
Superelevation variance for horizontal curves	n/a – used default value in HSM	Rural 2U
Percent grade	n/a – used default value in HSM*	Rural 2U
Driveway density	Aerial/Streetview imagery	Rural 2U
Presence of passing lane	Aerial/Streetview imagery	Rural 2U
Presence of short 4-lane section	Aerial/Streetview imagery	Rural 2U
Presence of centerline rumble strips	Aerial/Streetview imagery	Rural 2U
Roadside hazard rating	n/a – used default value in HSM	Rural 2U
Presence of median	NCDOT GIS (verified visually)	Urban arterials
Number of driveways by land use type	Aerial/Streetview imagery	Urban arterials
Low speed vs intermediate or high speed	Aerial/Streetview imagery	Urban arterials
Presence of on-street parking	Aerial/Streetview imagery	Urban arterials
Type of on-street parking	Aerial/Streetview imagery	Urban arterials
Roadside fixed object density	Aerial/Streetview imagery	Urban arterials
Area type	NCDOT GIS	Freeways
Median width	NCDOT GIS (verified visually)	Freeways
Length of rumble strips on inside and outside shoulders	Aerial/Streetview imagery	Freeways
Length of (and offset to) median barrier	Aerial/Streetview imagery	Freeways
Length of (and offset to) outside barrier	Aerial/Streetview imagery	Freeways
Clear zone width	Aerial/Streetview imagery	Freeways

Table 5. Data Elements and Sources for Intersection Elements

Data Element	Source	Facility Type
Number of intersection legs	Aerial/Streetview imagery	All
Type of traffic control	Aerial/Streetview imagery	All
Major and minor road AADT	NCDOT GIS	All
Number of approaches with left-turn lanes	Aerial/Streetview imagery	All
Number of approaches with right-turn lanes	Aerial/Streetview imagery	All
Presence of lighting	Aerial/Streetview imagery	All
Intersection skew angle	NCDOT GIS, Aerial/Streetview imagery (measured)	Rural 2U and multilane
Inscribed circle diameter	Aerial/Streetview imagery	Roundabouts
Number of bypass lanes	Aerial/Streetview imagery	Roundabouts
Number of access points	Aerial/Streetview imagery	Roundabouts
Presence of left-turn phasing	Aerial/Streetview imagery	Urban arterials
Type of left-turn phasing	Aerial/Streetview imagery	Urban arterials
Use of right-turn-on-red signal operation	Aerial/Streetview imagery	Urban arterials
Use of red-light cameras	Aerial/Streetview imagery	Urban arterials
Pedestrian volume	n/a – used default values in HSM for Medium-High Pedestrian activity	Urban arterials
Max number of lanes crossed by pedestrians on any approach	Aerial/Streetview imagery	Aerial/Streetview imagery

Table 6. Data Elements and Sources for Interchange Elements

Data Element	Source	Facility Type
Segment length	NCDOT GIS	All
Traffic volume	NCDOT GIS	All
Presence of lighting	Aerial/Streetview imagery	All
Horizontal curve presence	Aerial/Streetview imagery	Ramp segments, Speed change lanes
Lane width	NCDOT GIS, Aerial/Streetview imagery	Ramp segments, Speed change lanes
Left shoulder width	Aerial/Streetview imagery, NCDOT GIS	Ramp segments
Right shoulder width	Aerial/Streetview imagery, NCDOT GIS	Ramp segments
Left side barrier (length and offset)	Aerial/Streetview imagery	Ramp segments
Right side barrier (length and offset)	Aerial/Streetview imagery	Ramp segments
Lane add or drop	Aerial/Streetview imagery	Ramp segments
Ramp speed-change lane presence	Aerial/Streetview imagery	Ramp segments
Inside shoulder width	NCDOT database, Aerial/Streetview imagery	Speed change lanes
Median width	NCDOT GIS (verified visually)	Speed change lanes
Median barrier (length and offset)	Aerial/Streetview imagery	Speed change lanes
Ramp entrance presence	Aerial/Streetview imagery	Speed change lanes — entrance (4EN, 6EN, 8EN)
Ramp exit presence	Aerial/Streetview imagery	Speed change lanes — exit (4EX, 6EX)
Exit ramp capacity	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4) — FI SPF only
Crossroad left-turn lane presence	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4)
Crossroad right-turn lane presence	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4)
Access point frequency	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4)
Segment length (crossroad)	NCDOT GIS	Ramp terminals (A2, B2, D4)
Median width (crossroad)	NCDOT GIS (verified visually)	Ramp terminals (A2, B2, D4)
Protected left-turn operation	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4) — SG only
Channelized right turn on crossroad	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4) — SG only
Channelized right turn on exit ramp	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4) — SG only
Non-ramp public street leg presence	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4) — SG only
Skew angle	Aerial/Streetview imagery	Ramp terminals (A2, B2, D4) — ST only

Note: ST indicates stop-controlled while SG indicates signalized.

To accurately track mileposts and collect the required data, it was necessary for the research team to track along the route in both the GIS environment and Google imagery. To accomplish this, the research team delineated each segment in the GIS line layer (using the indicated begin and end mileposts), then exported that layer to a file that could be read into Google Earth. Since the segments either originated from previous research efforts or were selected from the NCDOT GIS databases according to entire routes, the research team could track along the route, collecting data on each segment sequentially.

The first task for the research team for segments used in previous efforts was to verify that no major changes occurred to the segment between when the previous research was conducted and 2023. If changes were noted (e.g., major construction or change in classification or other attributes), the site was dropped. For new segments, the research team's first task on each segment was to confirm that it was indeed the correct facility type and confirm that the beginning and ending mileposts were correct. Once each segment was confirmed and accurately defined, the research team collected the necessary geometric and cross-section characteristics using a combination of aerial and Streetview imagery.

The researchers collected intersection and interchange data in a similar manner to the segment data. The research team collected geometric data, traffic control, configuration, and other characteristics through viewing the aerial and Streetview imagery. The research team collected all identifying route names and numbers for both the major and minor roads for use in obtaining crash data. Additionally, the research team recorded the latitude and longitude of the intersection to allow for quick locating of the intersection if needed in the future. Individual sites were assigned to NCDOT regions based on the county in which the site was located. These were used to develop region-specific calibration factors for sites with sufficient sample sizes within individual regions.

Crash data from 2020 to 2023 were obtained from NCDOT for the segments, intersections, and interchanges. The research team used ArcGIS Pro to merge crash data provided by NCDOT to road segments. Intersection crashes were identified via querying the NCDOT Traffic Engineering Accident Analysis System (TEAAS). All relevant intersection name combinations were identified and sent to the NCDOT technical panel, which performed the request and returned the list of crashes within 150 ft of each intersection location. Pedestrian and bike crashes were identified using the collision type column with labels that are "PEDESTRIAN" and "PEDALCYCLIST". The research team manually reviewed crash reports for interchanges to assign crashes to individual interchange components.

AADT data were obtained from NCDOT published Traffic Volume Maps for facility types included in this research. For sites missing AADT values, they were interpolated using the average of the preceding and subsequent years' AADT values when both were available.

For the freeway segment models, it was necessary to define a "ramp influence area" (similar to intersection influence area) to avoid including segments in the analysis that were near ramps. To address this issue, the researchers redefined the freeway segments to exclude 0.5 miles on either side of a ramp (measuring from the taper point). The lack of availability of some other data elements also led the

researchers to assume base case scenarios for some AFs; for example, AF for high volume (hourly AADT was not available) and AF for clear zone (clear zone width was not available for all segments).

3.2.4 Step 4: Apply the applicable Part C predictive model to predict crash frequency for each site during the calibration period as a whole

The researchers applied the predictive models for each facility type following the HSM predictive method and also developed Microsoft Excel spreadsheet tools to run the predictive models for the entire group of sample sites. These spreadsheet tools were delivered with this report to be used as a reference when developing new calibration factors in future years.

3.2.5 Step 5: Compute calibration factors for use in Part C predictive model

The researchers calculated the calibration factor for each facility type as indicated in the HSM, by the following method:

$$\text{Calibration Factor} = \frac{\text{Observed Crashes}_{\text{all sites}}}{\text{Predicted Crashes}_{\text{all sites}}} \quad (2)$$

Chapter 4. Calibration Results

The following sections show the calibration factors for segments, intersection, and interchange models, with tables showing observed and predicted crash values. Calibration factors are reported only for facility types where the sample met the HSM and NCHRP reports minimum reliability threshold of 100 or more observed crashes per year. Facility types or years with fewer than the HSM recommended number of crashes are excluded due to unreliability. The crash type and severity distribution tables for each facility type are documented in Appendix C. Facility types with fewer than the HSM recommended sample sizes are shown in grey text.

4.1 Segment models

4.1.1 Rural segments

Compared to HSM base SPF predictions, calibration of R2U segments show total crashes underpredicted statewide (1.365), with annual calibration factors declining sharply from 2.081 in 2020 to 0.862 in 2023. Regional underprediction is highest in Coast (1.574), followed by Piedmont (1.488) and Mountain (1.221).

R4D segments show total crashes underpredicted statewide (1.461), with annual factors remaining relatively stable, ranging from 1.449 in 2020 to 1.417 in 2023, indicating consistent underprediction throughout the study period. Regional underprediction is highest in the Coast region (1.573), followed by Piedmont (1.516) and Mountain (1.319) regions. Unlike R2U, annual factors in the Piedmont region show a slight increasing trend, rising from 1.446 in 2020 to 1.639 in 2023, while Coast and Mountain regions show modest declines over the same period.

R4U segments show slight total crash overprediction statewide (0.996), with annual factors showing variability across the study period, ranging from 0.836 in 2021 to 1.241 in 2020. The statewide sample size is notably small (306 observed crashes over four years), which limits the reliability of these factors. Note that no regional breakdown is available for R4U due to insufficient sample sizes by region.

Table 7. Statewide Rural 2-Lane Undivided Segments (R2U) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
R2U	2020	1,851	889.379	2.081
R2U	2021	1,447	964.072	1.501
R2U	2022	1,091	986.346	1.106
R2U	2023	881	1,021.523	0.862
R2U	2020-2023	5,270	3,861.320	1.365

Table 8. Regional Rural 2-Lane Undivided Segments (R2U) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
R2U - Coast	2020	391	164.324	2.379
R2U - Coast	2021	313	178.234	1.756
R2U - Coast	2022	238	185.321	1.284
R2U - Coast	2023	191	191.980	0.995
R2U - Coast	2020-2023	1,133	719.860	1.574
R2U - Piedmont	2020	588	259.760	2.264
R2U - Piedmont	2021	462	280.036	1.650
R2U - Piedmont	2022	343	286.173	1.199
R2U - Piedmont	2023	282	299.876	0.940
R2U - Piedmont	2020-2023	1,675	1,125.844	1.488
R2U - Mountain	2020	872	465.296	1.874
R2U - Mountain	2021	672	505.802	1.329
R2U - Mountain	2022	510	514.853	0.991
R2U - Mountain	2023	408	529.666	0.770
R2U - Mountain	2020-2023	2,462	2,015.617	1.221

Table 9. Statewide Rural 4-Lane Divided Segments (R4D) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
R4D	2020	589	406.548	1.449
R4D	2021	650	431.864	1.505
R4D	2022	682	461.217	1.479
R4D	2023	693	489.155	1.417
R4D	2020-2023	2,614	1788.784	1.461

Table 10. Regional Rural 4-Lane Divided Segments (R4D) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
R4D - Coast	2020	212	123.354	1.719
R4D - Coast	2021	232	130.219	1.782
R4D - Coast	2022	210	139.861	1.501
R4D - Coast	2023	198	148.360	1.335
R4D - Coast	2020-2023	852	541.794	1.573
R4D - Piedmont	2020	197	136.223	1.446
R4D - Piedmont	2021	206	142.543	1.445
R4D - Piedmont	2022	231	152.720	1.513
R4D - Piedmont	2023	270	164.771	1.639
R4D - Piedmont	2020-2023	904	596.258	1.516
R4D - Mountain	2020	180	146.971	1.225
R4D - Mountain	2021	212	159.101	1.332
R4D - Mountain	2022	241	168.636	1.429
R4D - Mountain	2023	225	176.024	1.278
R4D - Mountain	2020-2023	858	650.732	1.319

Table 11. Statewide Rural 4-Lane Undivided Segments (R4U) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
R4U	2020	80	64.465	1.241
R4U	2021	66	78.982	0.836
R4U	2022	69	80.936	0.853
R4U	2023	91	82.971	1.097
R4U	2020-2023	306	307.355	0.996

4.1.2 Urban segments

Compared to HSM base SPF predictions, calibration of U2U segments show total crashes substantially underpredicted statewide (2.194), with annual factors declining from 2.310 in 2020 to 1.889 in 2023. U3T segments show total crashes underpredicted statewide (1.531), with annual factors declining sharply from 2.053 in 2020 to a low of 1.193 in 2022 before increasing slightly to 1.345 in 2023. U4D segments show total crashes substantially underpredicted statewide (3.023), with annual factors fluctuating, ranging from 2.616 in 2023 to 3.592 in 2020. U4U segments show total crashes substantially underpredicted statewide (3.690), with annual factors declining steadily from 4.113 in 2020 to 3.411 in 2023. U5T segments show total crashes underpredicted statewide (1.396), with annual factors ranging from 1.258 in 2023 to 1.500 in 2021, showing no clear directional trend.

Compared to NCHRP Project 17-58 base SPF predictions on urban multilane segments, U6D segments show total crashes underprediction statewide (1.091), with annual factors showing notable variability, ranging from 0.849 in 2022 to 1.109 in 2023. U7D segments show total crashes underpredicted statewide

(1.361), with annual factors showing high variability, rising from 1.091 in 2020 to 1.673 in 2022 before declining to 1.064 in 2023. U8D segments show total crashes underpredicted statewide (1.933), with annual factors declining from 2.316 in 2020 to 1.657 in 2022 before rising to 1.877 in 2023.

Table 12. Statewide Urban 2-Lane Undivided Segments (U2U) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U2U	2020	119	51.522	2.310
U2U	2021	132	56.288	2.345
U2U	2022	136	59.750	2.276
U2U	2023	120	63.534	1.889
U2U	2020-2023	507	231.095	2.194

Table 13. Statewide Urban 2-Lane with TWLTL Segments (U3T) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U3T	2020	70	34.090	2.053
U3T	2021	58	36.406	1.593
U3T	2022	45	37.708	1.193
U3T	2023	53	39.405	1.345
U3T	2020-2023	226	147.609	1.531

Table 14. Statewide Urban 4-Lane Divided Segments (U4D) Calibration Factors

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U4D	2020	49	13.642	3.592
U4D	2021	38	14.192	2.678
U4D	2022	47	14.497	3.242
U4D	2023	39	14.906	2.616
U4D	2020-2023	173	57.237	3.023

Table 15. Statewide Urban 4-Lane Undivided Segments (U4U) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U4U	2020	91	22.124	4.113
U4U	2021	88	22.948	3.835
U4U	2022	83	24.021	3.455
U4U	2023	86	25.215	3.411
U4U	2020-2023	348	94.308	3.690

Table 16. Statewide Urban 4-Lane with TWLTL Segments (U5T) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U5T	2020	147	107.185	1.371
U5T	2021	165	110.016	1.500
U5T	2022	166	113.518	1.462
U5T	2023	148	117.684	1.258
U5T	2020-2023	626	448.403	1.396

Table 17. Statewide Urban 6-Lane Divided Segments (U6D) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U6D	2020	32	28.885	1.108
U6D	2021	43	32.842	1.309
U6D	2022	29	34.147	0.849
U6D	2023	39	35.152	1.109
U6D	2020-2023	143	131.026	1.091

Table 18. Statewide Urban 7-Lane Divided Segments (U7D) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U7D	2020	38	34.84	1.091
U7D	2021	61	38.57	1.581
U7D	2022	63	37.66	1.673
U7D	2023	39	36.64	1.064
U7D	2020-2023	201	147.71	1.361

Table 19. Statewide Urban 8-Lane Divided Segments (U8D) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U8D	2020	180	77.722	2.316
U8D	2021	169	86.724	1.949
U8D	2022	154	92.937	1.657
U8D	2023	177	94.318	1.877
U8D	2020-2023	680	351.701	1.933

4.1.3 Freeway segments

Compared to HSM base SPF predictions, calibration of Rur4Ln segments show total crashes underpredicted statewide (1.381), with annual factors declining sharply from 2.084 in 2020 to 0.940 in 2023. No regional breakdown is available due to insufficient sample sizes, with most crashes concentrated in a single region.

Table 20. Statewide Rural Freeways with 4 Through Lanes (Rur4Ln) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Rur4Ln	2020	190	91.160	2.084
Rur4Ln	2021	153	103.990	1.471
Rur4Ln	2022	126	108.327	1.163
Rur4Ln	2023	106	112.788	0.940
Rur4Ln	2020-2023	575	416.265	1.381

Urb4Ln segments show total crashes underpredicted statewide (1.474), with annual factors declining steadily from 2.015 in 2020 to 1.075 in 2023. Urb6Ln segments show total crashes underpredicted statewide (1.372), with annual factors declining consistently from 1.815 in 2020 to 1.069 in 2023. Urb8Ln segments show total crashes underpredicted statewide (1.286), with annual factors declining from 1.593 in 2020 to 1.099 in 2023. No regional breakdown is available as crashes are concentrated in the Piedmont region.

Table 21. Statewide Urban Freeways with 4 Through Lanes (Urb4Ln) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Urb4Ln	2020	274	135.957	2.015
Urb4Ln	2021	241	153.857	1.566
Urb4Ln	2022	207	156.759	1.320
Urb4Ln	2023	172	159.979	1.075
Urb4Ln	2020-2023	894	606.552	1.474

Table 22. Statewide Urban Freeways with 6 Through Lanes (Urb6Ln) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Urb6Ln	2020	489	269.495	1.815
Urb6Ln	2021	429	294.036	1.459
Urb6Ln	2022	365	302.489	1.207
Urb6Ln	2023	334	312.356	1.069
Urb6Ln	2020-2023	1,617	1,178.376	1.372

Table 23. Statewide Urban Freeways with 8 Through Lanes (Urb8Ln) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Urb8Ln	2020	421	264.271	1.593
Urb8Ln	2021	388	297.623	1.304
Urb8Ln	2022	356	299.911	1.187
Urb8Ln	2023	333	303.138	1.099
Urb8Ln	2020-2023	1,498	1,164.944	1.286

4.2 Intersection models

4.2.1 Rural intersections

Compared to HSM base SPF predictions, calibration of Rur2L-3ST intersections show total crashes overpredicted statewide (0.672) throughout the years. Rur2L-4SG intersections show total crashes overpredicted statewide (0.831), with annual factors remaining relatively stable. Regionally, Coast region shows underprediction (1.161) with annual factors declining from 1.226 in 2020 to 1.086 in 2023, while both Mountain (0.539) and Piedmont (0.792) regions show overprediction. Mountain shows the strongest overprediction of any region, with annual factors consistently below 0.600 except in 2023 (0.561). Rur2L-4ST intersections show total crashes overpredicted statewide (0.733) throughout the years; all three regions show overprediction: Coast (0.790), Piedmont (0.740), and Mountain (0.559), with Mountain showing the strongest overprediction.

RurML-3ST intersections show total crashes overpredicted statewide (0.824), with annual factors fluctuating widely from 0.492 in 2022 to 1.114 in 2023. The very small sample size (40 observed crashes over four years) makes these factors unreliable. RurML-4SG intersections show total crashes substantially overpredicted statewide (0.499). RurML-4STs show total crashes underpredicted statewide (1.321), with annual factors rising from 1.228 in 2020 to 1.708 in 2022 before declining sharply to 1.006 in 2023.

Table 24. Statewide Rural 2-Lane, Minor Road Stop-Controlled 3-Leg Intersections (Rur2L-3ST) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Rur2L-3ST	2020	159	232.276	0.685
Rur2L-3ST	2021	195	264.578	0.737
Rur2L-3ST	2022	158	270.563	0.584
Rur2L-3ST	2023	203	296.208	0.685
Rur2L-3ST	2020-2023	715	1,063.625	0.672

Table 25. Statewide Rural 2-Lane, Signalized 4-Leg Intersections (Rur2L-4SG) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Rur2L-4SG	2020	364	449.581	0.810
Rur2L-4SG	2021	419	483.990	0.866
Rur2L-4SG	2022	403	494.455	0.815
Rur2L-4SG	2023	433	520.586	0.832
Rur2L-4SG	2020-2023	1,619	1,948.612	0.831

Table 26. Regional Rural 2-Lane, Signalized 4-Leg Intersections (Rur2L-4SG) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Rur2L-4SG - Coast	2020	120	97.912	1.226
Rur2L-4SG - Coast	2021	131	106.475	1.230
Rur2L-4SG - Coast	2022	119	107.014	1.112
Rur2L-4SG - Coast	2023	123	113.237	1.086
Rur2L-4SG - Coast	2020-2023	493	424.639	1.161
Rur2L-4SG - Mountain	2020-2023	172	318.821	0.539
Rur2L-4SG - Piedmont	2020	202	278.850	0.724
Rur2L-4SG - Piedmont	2021	249	297.795	0.836
Rur2L-4SG - Piedmont	2022	241	306.733	0.786
Rur2L-4SG - Piedmont	2023	262	321.774	0.814
Rur2L-4SG - Piedmont	2020-2023	954	1205.153	0.792

Table 27. Statewide Rural 2-Lane, Minor Road Stop-Controlled 4-Leg Intersections (Rur2L-4ST) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Rur2L-4ST	2020	264	321.698	0.821
Rur2L-4ST	2021	296	376.206	0.787
Rur2L-4ST	2022	233	394.053	0.591
Rur2L-4ST	2023	328	438.256	0.748
Rur2L-4ST	2020-2023	1,121	1,530.212	0.733

Table 28. Regional Rural 2-Lane, Minor Road Stop-Controlled 4-Leg Intersections (Rur2L-4ST)
Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Rur2L-4ST - Coast	2020	116	113.809	0.993
Rur2L-4ST - Coast	2021	123	136.644	0.886
Rur2L-4ST - Coast	2022	85	143.151	0.580
Rur2L-4ST - Coast	2023	122	161.969	0.753
Rur2L-4ST - Coast	2020-2023	446	555.573	0.790
Rur2L-4ST - Mountain	2020-2023	142	253.910	0.559
Rur2L-4ST - Piedmont	2020	118	153.744	0.768
Rur2L-4ST - Piedmont	2021	132	176.243	0.749
Rur2L-4ST - Piedmont	2022	118	186.184	0.634
Rur2L-4ST - Piedmont	2023	165	204.558	0.807
Rur2L-4ST - Piedmont	2020-2023	533	720.729	0.740

Table 29. Statewide Rural Multilane, Minor Road Stop-Controlled 3-Leg Intersections (RurML-3ST)
Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
RurML-3ST	2020	9	10.463	0.860
RurML-3ST	2021	10	12.395	0.807
RurML-3ST	2022	6	12.200	0.492
RurML-3ST	2023	15	13.462	1.114
RurML-3ST	2020-2023	40	48.519	0.824

Table 30. Statewide Rural Multilane, Signalized 4-Leg Intersections (RurML-4SG) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
RurML-4SG	2020	164	373.388	0.439
RurML-4SG	2021	196	416.291	0.471
RurML-4SG	2022	245	417.905	0.586
RurML-4SG	2023	224	453.199	0.494
RurML-4SG	2020-2023	829	1,660.783	0.499

Table 31. Statewide Rural Multilane, Minor Road Stop-Controlled 4-Leg Intersections (RurML-4ST)
Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
RurML-4ST	2020	27	21.983	1.228
RurML-4ST	2021	38	27.772	1.368
RurML-4ST	2022	50	29.266	1.708
RurML-4ST	2023	34	33.784	1.006
RurML-4ST	2020-2023	149	112.805	1.321

4.2.2 Urban intersections

Compared to HSM base SPF predictions, calibration of UrbArt-3SG intersections show total crashes underpredicted statewide (2.053), with annual factors showing high variability, ranging from 1.539 in 2022 to 2.348 in 2023. UrbArt-3ST intersections show total crashes underpredicted statewide (1.895), with annual factors remaining relatively stable, ranging from 1.791 in 2020 to 1.974 in 2023. UrbArt-4SG intersections show total crashes substantially underpredicted statewide (3.435), with annual factors remaining relatively stable. All three regions show substantial underprediction: Piedmont is the highest (3.906), followed by Coast (3.281) and Mountain (2.998) regions. Piedmont annual factors increased from 3.698 in 2020 to a peak of 4.146 in 2022 before declining to 3.863 in 2023, while Coast and Mountain regions show modest declines over the study period. UrbArt-4ST intersections show total crashes underpredicted statewide (1.486), with annual factors rising from 1.112 in 2020 to 1.699 in 2022 before declining slightly to 1.534 in 2023.

Compared to NCHRP Project 17-58 base SPF predictions, U68-4SG-2x2 intersections show total crashes substantially underpredicted statewide (2.327), with annual factors stable. All three regions show underprediction: Piedmont (2.646), Mountain (2.760), and Coast (1.935). U68-4SG-1x1or2 intersections show total crashes substantially underpredicted statewide (3.580), with annual factors remaining relatively stable and consistently high. U68-4ST-2x2 intersections show total crashes substantially overpredicted statewide (0.187), with annual factors consistently very low. U68-4ST-1x1or2 intersections show total crashes underpredicted statewide (1.885), with annual factors showing extreme variability. U68-3SG-2x2 intersections show total crashes substantially underpredicted statewide (3.073), with annual factors remaining stable. U68-3SG-1x1or2 intersections show slight overprediction statewide (0.978).

Table 32. Statewide Urban Arterial, Signalized 3-Leg Intersections (UrbArt-3SG) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
UrbArt-3SG	2020	31	15.315	2.024
UrbArt-3SG	2021	38	16.638	2.284
UrbArt-3SG	2022	26	16.898	1.539
UrbArt-3SG	2023	42	17.888	2.348
UrbArt-3SG	2020-2023	137	66.738	2.053

Table 33. Statewide Urban Arterial, Stop-Controlled 3-Leg Intersections (UrbArt-3ST) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
UrbArt-3ST	2020	57	31.817	1.791
UrbArt-3ST	2021	69	35.014	1.971
UrbArt-3ST	2022	66	36.051	1.831
UrbArt-3ST	2023	76	38.506	1.974
UrbArt-3ST	2020-2023	268	141.388	1.895

Table 34. Statewide Urban Arterial, Signalized 4-Leg Intersections (UrbArt-4SG) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
UrbArt-4SG	2020	1,286	377.689	3.405
UrbArt-4SG	2021	1,450	414.366	3.499
UrbArt-4SG	2022	1,466	419.354	3.496
UrbArt-4SG	2023	1,493	446.579	3.343
UrbArt-4SG	2020-2023	5,695	1,657.987	3.435

Table 35. Regional Urban Arterial, Signalized 4-Leg Intersections (UrbArt-4SG) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
UrbArt-4SG - Coast	2020	500	140.176	3.567
UrbArt-4SG - Coast	2021	553	159.891	3.459
UrbArt-4SG - Coast	2022	514	163.140	3.151
UrbArt-4SG - Coast	2023	538	178.328	3.017
UrbArt-4SG - Coast	2020-2023	2,105	641.535	3.281
UrbArt-4SG - Mountain	2020	274	99.070	2.766
UrbArt-4SG - Mountain	2021	312	104.643	2.982
UrbArt-4SG - Mountain	2022	328	105.715	3.103
UrbArt-4SG - Mountain	2023	343	109.804	3.124
UrbArt-4SG - Mountain	2020-2023	1,257	419.232	2.998
UrbArt-4SG - Piedmont	2020	512	138.443	3.698
UrbArt-4SG - Piedmont	2021	585	149.832	3.904
UrbArt-4SG - Piedmont	2022	624	150.499	4.146
UrbArt-4SG - Piedmont	2023	612	158.446	3.863
UrbArt-4SG - Piedmont	2020-2023	2,333	597.220	3.906

Table 36. Statewide Urban Arterial, Stop-Controlled 4-Leg Intersections (UrbArt-4ST) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
UrbArt-4ST	2020	32	28.768	1.112
UrbArt-4ST	2021	48	30.585	1.569
UrbArt-4ST	2022	53	31.196	1.699
UrbArt-4ST	2023	50	32.590	1.534
UrbArt-4ST	2020-2023	183	123.139	1.486

Table 37. Statewide Urban Arterial, Two-way at Two-way Signalized 4-Leg Intersections with 6-8 Lanes (U68-4SG-2x2) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U68-4SG-2x2	2020	686	290.000	2.366
U68-4SG-2x2	2021	734	301.923	2.431
U68-4SG-2x2	2022	656	292.219	2.245
U68-4SG-2x2	2023	671	296.580	2.262
U68-4SG-2x2	2020-2023	2,747	1,180.722	2.327

Table 38. Regional Urban Arterial, One-way at Two-way Signalized 4-Leg Intersections with 6-8 Lanes (U68-4SG-2x2) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U68-4SG-2x2 - Coast	2020	266	132.915	2.001
U68-4SG-2x2 - Coast	2021	275	142.393	1.931
U68-4SG-2x2 - Coast	2022	234	129.825	1.802
U68-4SG-2x2 - Coast	2023	264	131.770	2.003
U68-4SG-2x2 - Coast	2020-2023	1,039	536.903	1.935
U68-4SG-2x2 - Mountain	2020-2023	105	38.048	2.760
U68-4SG-2x2 - Piedmont	2020	395	148.076	2.668
U68-4SG-2x2 - Piedmont	2021	429	149.393	2.872
U68-4SG-2x2 - Piedmont	2022	392	152.943	2.563
U68-4SG-2x2 - Piedmont	2023	387	155.359	2.491
U68-4SG-2x2 - Piedmont	2020-2023	1,603	605.771	2.646

Table 39. Statewide Urban Arterial, One-way at One-way or Two-way Signalized 4-Leg Intersections with 6-8 Lanes (U68-4SG-1x1or2) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U68-4SG-1x1or2	2020	362	104.094	3.478
U68-4SG-1x1or2	2021	400	107.494	3.721
U68-4SG-1x1or2	2022	377	109.698	3.437
U68-4SG-1x1or2	2023	401	108.911	3.682
U68-4SG-1x1or2	2020-2023	1,540	430.197	3.580

Table 40. Statewide Urban Arterial, Two-way at Two-way Stop-Controlled 4-Leg Intersections with 6-8 Lanes (U68-4ST-2x2) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U68-4ST-2x2	2020	23	149.103	0.154
U68-4ST-2x2	2021	39	175.137	0.223
U68-4ST-2x2	2022	28	184.877	0.151
U68-4ST-2x2	2023	40	187.410	0.213
U68-4ST-2x2	2020-2023	130	696.526	0.187

Table 41. Statewide Urban Arterial, One-way at One-way or Two-way Stop-Controlled 4-Leg Intersections with 6-8 Lanes (U68-4ST-1x1or2) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U68-4ST-1x1or2	2020	9	4.526	1.988
U68-4ST-1x1or2	2021	8	5.224	1.531
U68-4ST-1x1or2	2022	4	5.033	0.795
U68-4ST-1x1or2	2023	15	4.316	3.476
U68-4ST-1x1or2	2020-2023	36	19.099	1.885

Table 42. Statewide Urban Arterial, Two-way at Two-way Signalized 3-Leg Intersections with 6-8 Lanes (U68-3SG-2x2) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U68-3SG-2x2	2020	200	65.171	3.069
U68-3SG-2x2	2021	214	70.561	3.033
U68-3SG-2x2	2022	217	68.512	3.167
U68-3SG-2x2	2023	210	69.395	3.026
U68-3SG-2x2	2020-2023	841	273.638	3.073

Table 43. Statewide Urban Arterial, One-way at One-way or Two-way Signalized 3-Leg Intersections with 6-8 Lanes (U68-3SG-1x1or2) Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
U68-3SG-1x1or2	2020	3	0.862	3.480
U68-3SG-1x1or2	2021	1	0.893	1.120
U68-3SG-1x1or2	2020-2023	4	4.089	0.978

4.2.3 Rural roundabouts

Compared to NCHRP Project 17-70 base SPF predictions, calibration of rural roundabouts show total crashes underpredicted statewide (1.969), with annual factors showing variability, ranging from 1.642 in 2020 to 2.309 in 2023.

Table 44. Statewide Rural Roundabouts Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Rural Roundabouts	2020	62	37.752	1.642
Rural Roundabouts	2021	82	38.566	2.126
Rural Roundabouts	2022	69	38.778	1.779
Rural Roundabouts	2023	93	40.279	2.309
Rural Roundabouts	2020-2023	306	155.375	1.969

4.2.4 Urban roundabouts

Compared to NCHRP Project 17-70 base SPF predictions, calibration of urban roundabouts show total crashes underpredicted statewide (2.300), with annual factors rising from 1.791 in 2020 to 2.600 in 2022 before declining slightly to 2.392 in 2023.

Table 45. Statewide Urban Roundabouts Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
Urban Roundabouts	2020	141	78.738	1.791
Urban Roundabouts	2021	198	82.620	2.397
Urban Roundabouts	2022	212	81.530	2.600
Urban Roundabouts	2023	202	84.446	2.392
Urban Roundabouts	2020-2023	753	327.334	2.300

4.3 Interchange component models

For interchange component models, due to limited sample sizes of certain individual facility types, the grouped calibration factors are reported for more reliable calibration results.

4.3.1 Ramp segments

Compared to HSM base SPF predictions, all ramp entrance segments show total crashes overpredicted statewide (0.624), with annual factors ranging from 0.479 in 2020 to 0.854 in 2023. Calibration of Ramp 1EN segments show total crashes overpredicted statewide (0.647), with annual factors ranging from 0.476 in 2021 to 0.886 in 2023. All ramp exit segments show total crashes underpredicted statewide (1.721), with annual factors ranging from 1.473 in 2023 to 2.163 in 2020. Ramp 1EX segments show total crashes underpredicted statewide (1.776), with annual factors showing variability. Ramp 2EN segments show overprediction statewide (0.842). Ramp 2EX segments show total crashes underpredicted statewide (1.477), with annual factors rising from 1.015 in 2020 to 1.879 in 2023.

Table 46. Statewide Entrance Ramp Segment Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
All Ramp Entrance	2020	5	10.433	0.479
All Ramp Entrance	2021	6	11.101	0.540
All Ramp Entrance	2022	7	11.665	0.600
All Ramp Entrance	2023	10	11.704	0.854
All Ramp Entrance	2020-2023	28	44.903	0.624
Ramp 1EN	2020	5	7.756	0.645
Ramp 1EN	2021	4	8.408	0.476
Ramp 1EN	2022	5	8.821	0.567
Ramp 1EN	2023	8	9.032	0.886
Ramp 1EN	2020-2023	22	34.017	0.647
Ramp 2EN	2021	2	1.752	1.141
Ramp 2EN	2022	2	1.848	1.082
Ramp 2EN	2023	2	1.810	1.105
Ramp 2EN	2020-2023	6	7.123	0.842

Table 47. Statewide Exit Ramp Segment Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
All Ramp Exit	2020	20	9.247	2.163
All Ramp Exit	2021	15	9.720	1.543
All Ramp Exit	2022	18	10.364	1.737
All Ramp Exit	2023	15	10.185	1.473
All Ramp Exit	2020-2023	68	39.516	1.721
Ramp 1EX	2020	20	8.090	2.472
Ramp 1EX	2021	13	8.569	1.517
Ramp 1EX	2022	16	9.164	1.746
Ramp 1EX	2023	13	9.078	1.432
Ramp 1EX	2020-2023	62	34.901	1.776
Ramp 2EX	2020	2	1.970	1.015
Ramp 2EX	2021	3	1.960	1.531
Ramp 2EX	2022	3	2.068	1.451
Ramp 2EX	2023	4	2.128	1.879
Ramp 2EX	2020-2023	12	8.126	1.477

4.3.2 Speed change lanes

Compared to HSM base SPF predictions, SCL ramp entrance segments show total crashes generally overpredicted statewide (0.901). SCL ramp exit segments show total crashes overpredicted statewide (0.611), with annual factors ranging from 0.509 in 2020 to 0.613 in 2023. Calibration of 4EN speed change lanes (SCL) show total crashes underpredicted statewide (1.185), with annual factors showing high variability. 4EX speed change lanes show overprediction statewide (0.967), with annual factors

fluctuating around 1.0, ranging from 0.718 in 2020 to 1.092 in 2023. 6EN speed change lanes show total crashes underpredicted statewide (2.114), with annual factors showing high variability, ranging from 0.951 in 2023 to 4.396 in 2020. 6EX speed change lanes show total crashes overpredicted statewide (0.614), with annual factors showing high variability, ranging from 0.225 in 2023 to 0.927 in 2022. 8EN speed change lanes show total crashes underpredicted statewide (1.204), with annual factors showing high variability, ranging from 0.728 in 2021 to 1.894 in 2023.

Table 48. Statewide Speed Change Lanes – Ramp Entrance Segments Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
SCL Ramp Entrance	2020	23	21.887	1.051
SCL Ramp Entrance	2021	18	29.741	0.605
SCL Ramp Entrance	2022	31	30.209	1.026
SCL Ramp Entrance	2023	30	31.354	0.957
SCL Ramp Entrance	2020-2023	102	113.191	0.901
4EN	2020	8	10.236	0.782
4EN	2021	11	11.424	0.963
4EN	2022	20	11.368	1.759
4EN	2023	14	11.700	1.197
4EN	2020-2023	53	44.729	1.185
6EN	2020	7	1.592	4.396
6EN	2021	2	1.834	1.090
6EN	2022	5	2.038	2.453
6EN	2023	2	2.103	0.951
6EN	2020-2023	16	7.568	2.114
8EN	2020	8	6.099	1.312
8EN	2021	5	6.871	0.728
8EN	2022	6	7.048	0.851
8EN	2023	14	7.394	1.894
8EN	2020-2023	33	27.411	1.204

Table 49. Statewide Speed Change Lanes – Ramp Exit Segments Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
SCL Ramp Exit	2020	13	25.545	0.509
SCL Ramp Exit	2021	18	27.990	0.643
SCL Ramp Exit	2022	19	28.445	0.668
SCL Ramp Exit	2023	18	29.341	0.613
SCL Ramp Exit	2020-2023	68	111.321	0.611
4EX	2020	10	13.921	0.718
4EX	2021	16	15.288	1.047
4EX	2022	15	15.211	0.986
4EX	2023	17	15.562	1.092
4EX	2020-2023	58	59.983	0.967
6EX	2020	3	3.566	0.841
6EX	2021	2	3.962	0.505
6EX	2022	4	4.315	0.927
6EX	2023	1	4.441	0.225
6EX	2020-2023	10	16.286	0.614

4.3.3 Ramp terminals

Compared to HSM base SPF predictions, all ramp terminal segments show total crashes generally underpredicted statewide (1.907). Calibration of A2 terminals show total crashes underpredicted statewide (2.644), with annual factors showing variability, ranging from 1.813 in 2022 to 3.692 in 2023. B2 terminals show total crashes underpredicted statewide (2.203), with annual factors rising from 1.551 in 2021 to 2.988 in 2023. D4 terminals show total crashes underpredicted statewide (1.864), with annual factors declining steadily from 1.952 in 2020 to 1.753 in 2023.

Table 50. Statewide Ramp Terminals Calibration Factor

Facility Type	Year	Observed Crashes	Predicted Crashes	Calibration Factor
All Ramp Terminals	2020	175	91.185	1.919
All Ramp Terminals	2021	198	102.575	1.930
All Ramp Terminals	2022	200	106.300	1.881
All Ramp Terminals	2023	210	110.631	1.898
All Ramp Terminals	2020-2023	783	410.692	1.907
A2	2020	4	1.631	2.452
A2	2021	4	1.625	2.462
A2	2022	3	1.655	1.813
A2	2023	7	1.896	3.692
A2	2020-2023	18	6.807	2.644
B2	2020	13	6.400	2.031
B2	2021	10	6.446	1.551
B2	2022	15	6.788	2.210
B2	2023	20	6.693	2.988
B2	2020-2023	58	26.327	2.203
D4	2020	158	80.925	1.952
D4	2021	184	95.469	1.927
D4	2022	182	98.591	1.846
D4	2023	183	104.378	1.753
D4	2020-2023	707	379.363	1.864

Chapter 5. Implementation Plan and Technology Transfer

The results of this project include updated SPF Calibration Factors and Crash Proportions tables for all facility types included in HSM, NCHRP Project 17-70, and NCHRP Project 17-58 with 2020-2023 North Carolina crash data, which allow the national level SPFs to be applied to North Carolina. NCDOT can apply the results of this research effort to support existing or more advanced practices in the Traffic Safety Unit, including:

- **Network screening.** NCDOT can utilize calibrated base SPFs or full predictive methods to implement HSM network screening procedures to identify locations with a potential for safety improvement (SWiPs). Calibrated SPFs support estimation of expected crash frequency and excess expected crash frequency, which serves as a reliable metric for identifying SWiPs.
- **Design-level project alternatives analysis.** NCDOT currently uses calibrated SPFs to support project alternatives analysis for Highway Safety Improvement Program (HSIP) projects and design projects. The results of this effort can be used by the Traffic Safety Unit, designers, and consultants to improve the reliability of alternatives analysis. This research updated existing calibration factors and default crash type and severity distribution tables and developed calibration factors and default distribution tables for new site types for which NCDOT did not currently have access. NCDOT provides locally updated versions of national HSM spreadsheets and NC Crash Proportion Tables on its Safety Planning Resources page which can be updated to include the findings of this calibration effort. The locally updated HSM spreadsheets support estimation of predicted crash frequency and expected crash frequency for project alternatives using calibrated HSM SPFs. This in turn allows NCDOT to reliably conduct economic evaluations from estimated change in crash frequency and severity with locally derived crash costs.
- **Safety Evaluations.** The Safety Evaluation Group examines the effectiveness of safety improvements (i.e., countermeasures) once they are completed to measure the reduction in crash frequency and severity. These evaluations are intended to inform NCDOT and its partners on program and countermeasure effectiveness, which in turn informs future countermeasure installation strategies. The results of this research can directly be used to support implementing calibrated SPFs during this process to reliably estimate expected crash frequency in the study years had no countermeasure been installed.

For all applications, the Traffic Safety Unit, and its partners, can more reliably estimate changes in crash frequency and severity using HSM predictive methods calibrated to more facility types and using more recent supporting crash data. This in turn will allow NCDOT to maximize the return on investments and prioritize investments more effectively.

NCDOT can provide internal training and training to its partners on any tools that have been developed to implement new calibration factors or have been updated to incorporate revised calibration factors and crash type and severity default distributions. This includes existing tools supporting design-level project alternatives analysis or any tools supporting network screening and safety effectiveness evaluations.

Chapter 6. Conclusions and Recommendations

This study developed updated calibration factors and developed calibration factors for new facility types using HSM, NCHRP Project 17-70, and NCHRP Project 17-58 with 2020-2023 North Carolina crash data. The analysis shows that HSM SPFs generally underpredict crash frequencies for most North Carolina facility types when compared to the base SPF predictions, which is consistent with previous calibration efforts. Urban facilities, particularly intersections, show the most severe underprediction, while multi-vehicle crashes are consistently more underpredicted than single-vehicle crashes. Vehicle-pedestrian crashes are systematically underpredicted across urban segments. The calibration factors are generally consistent over the study time period, though annual variations do exist.

Significant regional variations exist among Coast, Mountain, and Piedmont areas, with each region displaying distinct crash patterns. These jurisdiction-specific calibration factors for design-level SPFs enable NCDOT to apply HSM Part C predictive methods to support data-driven decision-making in highway safety planning, design, and operations, supporting more effective resource allocation to improve road safety across North Carolina's transportation network. The crash type and severity distribution tables for each facility type (Appendix C) should inform updates to HSM tables, ensuring alignment with current crash patterns in North Carolina. Quick reference tables presenting the calibration factors by facility type and region are available in Appendix B for convenient application in design-level safety analyses.

The updated statewide and regional calibration factors developed in this study support reliable estimates of predicted crash frequency for project design-level safety analysis. Region-specific calibration factors (Coast, Mountain, Piedmont) are helpful when analyzing facilities within specific geographic areas, and targeted safety strategies can address the unique crash patterns observed in each region. Additionally, addressing vehicle-pedestrian crashes in urban segments through enhanced countermeasures, and resources can be allocated to improve traffic safety for non-motorized road users.

To maintain reliability and relevance, NCDOT should continue with the regular calibration update every 3-5 years to reflect evolving conditions. Further, the sample size for some facility types – particularly the interchange components – was very low. While sample sizes achieved 100 crashes overall, urban arterial segments also generally had small sample sizes that may not be representative of statewide facilities in North Carolina. For this reason, consider focusing future calibration efforts on expanding the sample size for these facility types to estimate more reliable calibration factors.

REFERENCES

- American Association of State Highway and Transportation Officials, 2010. *Highway Safety Manual*, 1st Edition. AASHTO, Washington, D.C.
- American Association of State Highway and Transportation Officials. (2014). *Highway Safety Manual* (1st ed., 2014 supplement)
- Bahar, G., & Hauer, E. (2014). *User's guide to develop Highway Safety Manual safety performance function calibration factors* (NCHRP HR 20-7[332]). AASHTO Committee on Safety.
- Bonneson, J., Geedipally, S.R., Pratt, M., and Lord, D., 2012. *Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges*. NCHRP Project 17-45 Final Report. National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C.
- Hummer, J., Haley, R., Ott, S., Foyle, R., and Cunningham, C., 2010a. *Superstreet Benefits and Capacities*. Report No. FHWA/NC/2009-06. North Carolina State University; North Carolina Department of Transportation. https://rosap.nrl.bts.gov/view/dot/20271/dot_20271_DS1.pdf
- Hummer, J., Rasdorf, W., Findley, D., Zegeer, C., and Sundstrom, C., 2010b. *Procedure for Curve Warning Signing, Delineation, and Advisory Speeds for Horizontal Curves*. Report No. FHWA/NC/2009-07. North Carolina State University; North Carolina Department of Transportation. <https://connect.ncdot.gov/projects/research/RNAProjDocs/2009-07FinalReport.pdf>
- Lord, D., Geedipally, S.R., Persaud, B., Washington, S., van Schalkwyk, I., Ivan, J., Lyon, C., and Jonsson, T., 2016. *Methodology to Predict the Safety Performance of Rural and Suburban Arterials*. NCHRP Project 17-58 Final Report. Transportation Research Board, Washington, D.C. https://dlord.engr.tamu.edu/wp-content/uploads/sites/234/2021/07/Final_Report_NCHRP_17-58_with_Appendices_June_2016.pdf
- National Highway Traffic Safety Administration, 2023. *Early Estimate of Motor Vehicle Traffic Fatalities in 2022*. Report No. DOT HS 813 428. U.S. Department of Transportation, Washington, D.C. <https://www.nsc.org/getmedia/5efb579f-6c0b-47e3-ab87-951e7c0d1dbc/adid-nhtsa-overview-of-mv-crashes-2022.pdf>
- Rodegerdts, L., Bassett, C., Myers, E., Kittelson, W., Kyte, M., Dixon, M., List, G., Flannery, A., Potts, I., Harwood, D., Torbic, D., and Gilmore, D., 2019. *Development of Roundabout Crash Prediction Models and Methods*. NCHRP Project 17-70. Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, Washington, D.C. <https://nap.nationalacademies.org/catalog/25360/development-of-roundabout-crash-prediction-models-and-methods>
- Saleem, T., Srinivasan, R., & Vann, M. (2021). *Updated and regional calibration factors for Highway Safety Manual crash prediction models (2016-2019)* (Report No. FHWA/NC/2020-27). Highway Safety Research Center, University of North Carolina at Chapel Hill; North Carolina Department of Transportation.

Smith, S., Carter, D., and Srinivasan, R., 2017. *Updated and Regional Calibration Factors for Highway Safety Manual Crash Prediction Models*. Report No. FHWA/NC/2016-09. University of North Carolina at Chapel Hill; North Carolina Department of Transportation.

<https://connect.ncdot.gov/projects/research/RNAProjDocs/2016-09%20Final%20Report.pdf>

Srinivasan, R. and Carter, D., 2011. *Development of Safety Performance Functions for North Carolina*. Report No. FHWA/NC/2010-09. Highway Safety Research Center, University of North Carolina at Chapel Hill; North Carolina Department of Transportation.

<https://connect.ncdot.gov/projects/research/RNAProjDocs/2010-09FinalReport.pdf>

Appendix A. SPFs and Associated AFs

Table 51 through Table 53 summarize applicable HSM SPFs and AFs for calibrated facilities in this project. AFs that are not applied in the calibration process are shown as strikethrough text and notes are provided as to why these were not included in the calibration procedure.

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
R2U	Total crashes SPF	<ul style="list-style-type: none"> • Lane width • Shoulder width and type • Horizontal curves (length, radius, spiral transitions) • Horizontal curves (superelevation) • Grades • Driveway density • Centerline rumble strips • Passing lanes • Two-way left-turn lanes • Roadside hazard rating • Lighting • Automated speed enforcement 	<ul style="list-style-type: none"> • Spiral transitions not collected in the previous dataset • Superelevation could not reasonably be measured as it requires field evaluation and superelevation variance is generally known to have minor influence on overall predicted crash frequency. • Passing lane not measured in the previous dataset • Roadside hazard rating not measured in the previous dataset • Automated speed enforcement not applicable in North Carolina • Lighting presence not captured in the previous dataset
R4D	Total crashes SPF / FI SPF	<ul style="list-style-type: none"> • Lane width • Right shoulder width • Median width • Lighting • Automated speed enforcement 	<ul style="list-style-type: none"> • Automated speed enforcement not applicable in North Carolina • Lighting presence not captured in the previous dataset
R4U	Total crashes SPF / FI SPF	<ul style="list-style-type: none"> • Lane width • Shoulder width and type • Sideslopes • Lighting • Automated speed enforcement 	<ul style="list-style-type: none"> • Sideslopes not measured in the previous dataset • Automated speed enforcement not applicable in North Carolina

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
U2U	SV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> • On street parking • Roadside fixed objects • Median width • Lighting • Automated speed enforcement 	<ul style="list-style-type: none"> • For undivided urban road segments, the AF for median width equals 1 in the HSM • Automated speed enforcement not applicable in North Carolina
	MV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> • On street parking • Roadside fixed objects • Median width • Lighting • Automated speed enforcement 	<ul style="list-style-type: none"> • Automated speed enforcement not applicable in North Carolina • For undivided urban road segments, the AF for median width equals 1 in the HSM
	Pedestrian crashes	—	<ul style="list-style-type: none"> • No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> • No applicable SPF/AFs, estimated as proportion of total crashes
U3T	SV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> • On street parking • Roadside fixed objects • Lighting • Automated speed enforcement 	<ul style="list-style-type: none"> • Automated speed enforcement not applicable in North Carolina
	MV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> • On street parking • Roadside fixed objects • Lighting • Automated speed enforcement 	<ul style="list-style-type: none"> • Automated speed enforcement not applicable in North Carolina
	Pedestrian crashes	—	<ul style="list-style-type: none"> • No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> • No applicable SPF/AFs, estimated as proportion of total crashes

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
U4D	SV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> On street parking Roadside fixed objects Median width Lighting Automated speed enforcement 	<ul style="list-style-type: none"> Automated speed enforcement not applicable in North Carolina
	MV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> On street parking Roadside fixed objects Median width Lighting Automated speed enforcement 	<ul style="list-style-type: none"> Automated speed enforcement not applicable in North Carolina
	Pedestrian crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
U4U	SV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> On street parking Roadside fixed objects Median width Lighting Automated speed enforcement 	<ul style="list-style-type: none"> Automated speed enforcement not applicable in North Carolina For undivided urban road segments, the AF for median width equals 1 in the HSM
	MV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> On street parking Roadside fixed objects Median width Lighting Automated speed enforcement 	<ul style="list-style-type: none"> Automated speed enforcement not applicable in North Carolina For undivided urban road segments, the AF for median width equals 1 in the HSM
	Pedestrian crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
U5T	SV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> On street parking Roadside fixed objects Lighting Automated speed enforcement 	<ul style="list-style-type: none"> Automated speed enforcement not applicable in North Carolina
	MV total / FI / PDO crashes SPF	<ul style="list-style-type: none"> On street parking Roadside fixed objects Lighting Automated speed enforcement 	<ul style="list-style-type: none"> Automated speed enforcement not applicable in North Carolina
	Pedestrian crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
U6D	SV FI / PDO crashes SPF	<ul style="list-style-type: none"> Lane width Outside shoulder width Median width Median barrier Railroad crossing Roadside fixed object 	
	MV FI / PDO crashes SPF	<ul style="list-style-type: none"> Lane width Outside shoulder width Median width Median barrier Railroad crossing Driveway 	
	Pedestrian crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
U7D	SV FI / PDO crashes SPF	<ul style="list-style-type: none"> • Lane width • Outside shoulder width • Median width • Median barrier • Railroad crossing • Roadside fixed object 	<ul style="list-style-type: none"> • For U7D road segments, the AF for median width equals 1 in the NCHRP report • For U7D road segments, the AF for median barrier equals 1 in the NCHRP report
	MV FI / PDO crashes SPF	<ul style="list-style-type: none"> • Lane width • Outside shoulder width • Median width • Median barrier • Railroad crossing • Driveway 	<ul style="list-style-type: none"> • For U7D road segments, the AF for median width equals 1 in the NCHRP report • For U7D road segments, the AF for median barrier equals 1 in the NCHRP report
	Pedestrian crashes	—	<ul style="list-style-type: none"> • No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> • No applicable SPF/AFs, estimated as proportion of total crashes
U8D	SV FI / PDO crashes SPF	<ul style="list-style-type: none"> • Lane width • Outside shoulder width • Median width • Median barrier • Railroad crossing • Roadside fixed object 	
	MV FI / PDO crashes SPF	<ul style="list-style-type: none"> • Lane width • Outside shoulder width • Median width • Median barrier • Railroad crossing • Driveway 	
	Pedestrian crashes	—	<ul style="list-style-type: none"> • No applicable SPF/AFs, estimated as proportion of total crashes

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
Rur4Ln	SV FI SPF	<ul style="list-style-type: none"> Horizontal curve Lane width Inside shoulder width Median width Median barrier High volume Outside shoulder width Shoulder rumble strips Outside clearance Outside barrier 	<ul style="list-style-type: none"> No volume concentration during peak hours data collected No outside clearance data collected No outside barrier data collected
	SV PDO SPF	<ul style="list-style-type: none"> Horizontal curve Inside shoulder width Median width Median barrier High volume Outside shoulder width Outside barrier 	<ul style="list-style-type: none"> No volume concentration during peak hours data collected No outside barrier data collected
	MV FI SPF	<ul style="list-style-type: none"> Horizontal curve Lane width Inside shoulder width Median width Median barrier High volume Lane change 	<ul style="list-style-type: none"> No volume concentration during peak hours data collected No lane change data collected

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
	MV PDO SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Lane change 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No lane change data collected
Urb4Ln	SV FI SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Outside shoulder width • Shoulder rumble strips • Outside clearance • Outside barrier 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No outside clearance data collected • No outside barrier data collected
	SV PDO SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Outside shoulder width • Outside barrier 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No outside barrier data collected
	MV FI SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Lane change 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No lane change data collected

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
	MV PDO SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Lane change 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No lane change data collected
Urb6Ln	SV FI SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Outside shoulder width • Shoulder rumble strips • Outside clearance • Outside barrier 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No outside clearance data collected • No outside barrier data collected
	SV PDO SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Outside shoulder width • Outside barrier 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No outside barrier data collected
	MV FI SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Lane change 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No lane change data collected

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
	MV PDO SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Lane change 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No lane change data collected
Urb8Ln	SV FI SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Outside shoulder width • Shoulder rumble strips • Outside clearance • Outside barrier 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No outside clearance data collected • No outside barrier data collected
	SV PDO SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Outside shoulder width • Outside barrier 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No outside barrier data collected
	MV FI SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Lane change 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No lane change data collected

Table 51. Roadway Segments SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
	MV PDO SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Lane change 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected • No lane change data collected

Table 52. Intersections SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
Rur2L-3ST	Total crashes SPF	<ul style="list-style-type: none"> • Intersection skew angle • Intersection left-turn lanes • Lighting 	
Rur2L-4SG	Total crashes SPF	<ul style="list-style-type: none"> • Intersection left-turn lanes • Intersection right-turn lanes • Lighting 	
Rur2L-4ST	Total crashes SPF	<ul style="list-style-type: none"> • Intersection skew angle • Intersection left-turn lanes • Lighting 	
RurML-3ST	Total crashes SPF	<ul style="list-style-type: none"> • Intersection skew angle • Intersection left-turn lanes • Intersection right-turn lanes • Lighting 	
	FI crashes SPF	<ul style="list-style-type: none"> • Intersection skew angle • Intersection left-turn lanes • Intersection right-turn lanes • Lighting 	

Table 52. Intersections SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
RurML-4SG	Total crashes SPF	<ul style="list-style-type: none"> • Intersection right-turn lanes • Lighting 	
	FI crashes SPF	<ul style="list-style-type: none"> • Intersection right-turn lanes • Lighting 	
RurML-4ST	Total crashes SPF	<ul style="list-style-type: none"> • Intersection skew angle • Intersection left-turn lanes • Intersection right-turn lanes • Lighting 	
	FI crashes SPF	<ul style="list-style-type: none"> • Intersection skew angle • Intersection left-turn lanes • Intersection right-turn lanes • Lighting 	
UrbArt-3SG	SV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> • Intersection left-turn lanes • Intersection left-turn signal phasing • Intersection right-turn lanes • Right-turn-on-red • Lighting • Red light cameras 	<ul style="list-style-type: none"> • Red light cameras not applicable in North Carolina
	MV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> • Intersection left-turn lanes • Intersection left-turn signal phasing • Intersection right-turn lanes • Right-turn-on-red • Lighting • Red light cameras 	<ul style="list-style-type: none"> • Red light cameras not applicable in North Carolina
	Pedestrian crashes SPF	<ul style="list-style-type: none"> • Bus stops • Schools • Alcohol sales establishments 	<ul style="list-style-type: none"> •

Table 52. Intersections SPF and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
UrbArt-3ST	SV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> Intersection left-turn lanes Intersection right-turn lanes Lighting 	<ul style="list-style-type: none">
	MV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> Intersection left-turn lanes Intersection right-turn lanes Lighting 	<ul style="list-style-type: none">
	Pedestrian crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
UrbArt-4SG	SV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> Intersection left-turn lanes Intersection left-turn signal phasing Intersection right-turn lanes Right-turn-on-red Lighting Red-light cameras 	<ul style="list-style-type: none"> Red light cameras not applicable in North Carolina
	MV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> Intersection left-turn lanes Intersection left-turn signal phasing Intersection right-turn lanes Right-turn-on-red Lighting Red-light cameras 	<ul style="list-style-type: none"> Red light cameras not applicable in North Carolina
	Pedestrian crashes SPF	<ul style="list-style-type: none"> Bus stops Schools Alcohol sales establishments 	<ul style="list-style-type: none">
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes

Table 52. Intersections SPF and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
UrbArt-4ST	SV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> • Intersection left-turn lanes • Intersection right-turn lanes • Lighting 	•
	MV total / FI / PDO crashes SPFs	<ul style="list-style-type: none"> • Intersection left-turn lanes • Intersection right-turn lanes • Lighting 	•
	Pedestrian crashes	—	• No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	• No applicable SPF/AFs, estimated as proportion of total crashes
U68-4SG-2x2	FI / PDO crashes SPFs	<ul style="list-style-type: none"> • Lighting • Intersection left-turn signal phasing • Right-turn-on-red • U-turn prohibition • Right-turn channelization • Number of lanes 	•
	Pedestrian crashes SPF	<ul style="list-style-type: none"> • Bus stops • Schools • Alcohol sales establishments 	<ul style="list-style-type: none"> • No bus stops data collected • No school data collected • No alcohol sales establishments data collected
	Bicycle crashes	—	• No applicable SPF/AFs, estimated as proportion of total crashes
U68-4SG-1x1or2	FI / PDO crashes SPFs	<ul style="list-style-type: none"> • Lighting • Number of lanes 	
	Pedestrian crashes SPF	<ul style="list-style-type: none"> • Bus stops • Schools • Alcohol sales establishments 	<ul style="list-style-type: none"> • No bus stops data collected • No school data collected • No alcohol sales establishments data collected
	Bicycle crashes	—	• No applicable SPF/AFs, estimated as proportion of total crashes
U68-4ST-2x2	FI / PDO crashes SPFs	<ul style="list-style-type: none"> • Lighting 	•

Table 52. Intersections SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
	Pedestrian crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
U68-4ST-1x1or2	FI / PDO crashes SPFs	<ul style="list-style-type: none"> Lighting 	<ul style="list-style-type: none">
	Pedestrian crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
U68-3SG-2x2	FI / PDO crashes SPFs	<ul style="list-style-type: none"> Lighting Intersection left-turn signal phasing Right-turn-on-red U-turn prohibition Right-turn channelization Number of lanes 	
	Pedestrian crashes SPF	<ul style="list-style-type: none"> Bus stops Schools Alcohol sales establishments 	<ul style="list-style-type: none"> No bus stops data collected No school data collected No alcohol sales establishments data collected
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes
U68-3SG-1x1or2	FI / PDO crashes SPFs	<ul style="list-style-type: none"> Lighting Number of lanes 	
	Pedestrian crashes SPF	<ul style="list-style-type: none"> Bus stops Schools Alcohol sales establishments 	<ul style="list-style-type: none"> No bus stops data collected No school data collected No alcohol sales establishments data collected
	Bicycle crashes	—	<ul style="list-style-type: none"> No applicable SPF/AFs, estimated as proportion of total crashes

Table 52. Intersections SPFs and Associated AFs

Facility Type	SPF Model(s)	AFs	Notes
Rural Roundabouts	FI SPF (one circulating lane)	<ul style="list-style-type: none"> • Outbound-only leg presence • Inscribed circle diameter • Right-turn bypass lane presence • Driveways or unsignalized public street approaches 	
	PDO SPF (one circulating lane)	<ul style="list-style-type: none"> • Driveways or unsignalized public street approaches 	
Urban Roundabouts	FI SPF (one circulating lane)	<ul style="list-style-type: none"> • Outbound-only leg presence • Inscribed circle diameter • Right-turn bypass lane presence • Driveways or unsignalized public street approaches 	
	PDO SPF (one circulating lane)	<ul style="list-style-type: none"> • Driveways or unsignalized public street approaches 	

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
Ramp IEN	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Left shoulder width • Right shoulder width • Left side barrier • Right side barrier • Lane add or drop • Ramp speed-change lane 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Left shoulder width • Right shoulder width • Left side barrier 	

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
		<ul style="list-style-type: none"> • Right side barrier 	
Ramp 1EX	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Left shoulder width • Right shoulder width • Left side barrier • Right side barrier • Lane add or drop • Ramp speed-change lane 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Left shoulder width • Right shoulder width • Left side barrier • Right side barrier 	
Ramp 2EN	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Left shoulder width • Right shoulder width • Left side barrier • Right side barrier • Lane add or drop • Ramp speed-change lane 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Left shoulder width • Right shoulder width • Left side barrier • Right side barrier 	
	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Left shoulder width 	

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
		<ul style="list-style-type: none"> • Right shoulder width • Left side barrier • Right side barrier • Lane add or drop • Ramp speed-change lane 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Left shoulder width • Right shoulder width • Left side barrier • Right side barrier 	
4EN	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Ramp entrance 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Ramp entrance 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
4EX	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Ramp exit 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Ramp exit 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
6EN	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Ramp entrance 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Ramp entrance 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
6EX	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Ramp exit 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
		<ul style="list-style-type: none"> • High volume • Ramp exit 	
8EN	FI crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Lane width • Inside shoulder width • Median width • Median barrier • High volume • Ramp entrance 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Ramp entrance 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
	PDO crashes SPF	<ul style="list-style-type: none"> • Horizontal curve • Inside shoulder width • Median width • Median barrier • High volume • Ramp entrance 	<ul style="list-style-type: none"> • No volume concentration during peak hours data collected
A2	FI crashes SPF	<ul style="list-style-type: none"> • Exit ramp capacity • Crossroad left-turn lane • Crossroad right-turn lane • Access point frequency • Segment length • Median width • Protected left-turn operation (SG only) • Channelized right turn on crossroad (SG only) 	

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
		<ul style="list-style-type: none"> • Channelized right turn on exit ramp (SG only) • Non-ramp public street leg (SG only) • Skew angle (ST only) 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Crossroad left-turn lane • Crossroad right-turn lane • Access point frequency (SG only) • Segment length (SG only) • Median width (SG only) • Protected left-turn operation (SG only) • Channelized right turn on crossroad (SG only) • Channelized right turn on exit ramp (SG only) • Non-ramp public street leg (SG only) 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Crossroad left-turn lane • Crossroad right-turn lane • Access point frequency (SG only) • Segment length (SG only) • Median width (SG only) • Protected left-turn operation (SG only) • Channelized right turn on crossroad (SG only) • Channelized right turn on exit ramp (SG only) 	

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
		<ul style="list-style-type: none"> • Non-ramp public street leg (SG only) 	
B2	FI crashes SPF	<ul style="list-style-type: none"> • Exit ramp capacity • Crossroad left-turn lane • Crossroad right-turn lane • Access point frequency • Segment length • Median width • Protected left-turn operation (SG only) • Channelized right turn on crossroad (SG only) • Channelized right turn on exit ramp (SG only) • Non-ramp public street leg (SG only) • Skew angle (ST only) 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Crossroad left-turn lane • Crossroad right-turn lane • Access point frequency (SG only) • Segment length (SG only) • Median width (SG only) • Protected left-turn operation (SG only) • Channelized right turn on crossroad (SG only) • Channelized right turn on exit ramp (SG only) • Non-ramp public street leg (SG only) 	

Table 53. Interchange Component SPFs and Associated AFs

Facility Type	SPF Model	AFs	Notes
D4	FI crashes SPF	<ul style="list-style-type: none"> • Exit ramp capacity • Crossroad left-turn lane • Crossroad right-turn lane • Access point frequency • Segment length • Median width • Protected left-turn operation (SG only) • Channelized right turn on crossroad (SG only) • Channelized right turn on exit ramp (SG only) • Non-ramp public street leg (SG only) • Skew angle (ST only) 	
	PDO crashes SPF	<ul style="list-style-type: none"> • Crossroad left-turn lane • Crossroad right-turn lane • Access point frequency (SG only) • Segment length (SG only) • Median width (SG only) • Protected left-turn operation (SG only) • Channelized right turn on crossroad (SG only) • Channelized right turn on exit ramp (SG only) • Non-ramp public street leg (SG only) 	

Note: ST indicates stop-controlled while SG indicates signalized.

Appendix B. Quick Reference Tables

The following quick-reference tables summarize the calibration factors for segment, intersection, and interchange component models. Factors derived using the HSM target of at least 100 observed crashes per year are shown in *bold italics*. An asterisk (*) indicates calibration factors based on fewer than 20 observed crashes per year.

B.1. Rural segments

Table 54. Rural Segments Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
R2U	All	<i>2.081</i>	<i>1.501</i>	<i>1.106</i>	<i>0.862</i>	<i>1.365</i>
R2U	Coast	<i>2.379</i>	<i>1.756</i>	<i>1.284</i>	<i>0.995</i>	<i>1.574</i>
R2U	Piedmont	<i>2.264</i>	<i>1.650</i>	<i>1.199</i>	<i>0.940</i>	<i>1.488</i>
R2U	Mountain	<i>1.874</i>	<i>1.329</i>	<i>0.991</i>	<i>0.770</i>	<i>1.221</i>
R4D	All	<i>1.449</i>	<i>1.505</i>	<i>1.479</i>	<i>1.417</i>	<i>1.461</i>
R4D	Coast	<i>1.719</i>	<i>1.782</i>	<i>1.501</i>	<i>1.335</i>	<i>1.573</i>
R4D	Piedmont	<i>1.446</i>	<i>1.445</i>	<i>1.513</i>	<i>1.639</i>	<i>1.516</i>
R4D	Mountain	<i>1.225</i>	<i>1.332</i>	<i>1.429</i>	<i>1.278</i>	<i>1.319</i>
R4U	All	1.043	0.843	0.614	1.052	<i>0.887</i>

B.2. Urban segments

Table 55. Urban Segments Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
U2U	All	<i>2.310</i>	<i>2.345</i>	<i>2.276</i>	<i>1.889</i>	<i>2.194</i>
U3T	All	2.053	1.593	1.193	1.345	<i>1.531</i>
U4D	All	3.592	2.678	3.242	2.616	<i>3.023</i>
U4U	All	4.113	3.835	3.455	3.411	<i>3.690</i>
U5T	All	<i>1.371</i>	<i>1.500</i>	<i>1.462</i>	<i>1.258</i>	<i>1.396</i>
U6D	All	1.108	1.309	0.849	1.109	<i>1.091</i>
U7D	All	1.091	1.581	1.673	1.064	<i>1.361</i>
U8D	All	<i>2.316</i>	<i>1.949</i>	<i>1.657</i>	<i>1.877</i>	<i>1.933</i>

B.3. Freeway segments

Table 56. Freeway Segments Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
Rur4Ln	All	<i>2.084</i>	<i>1.471</i>	<i>1.163</i>	<i>0.940</i>	<i>1.381</i>
Urb4Ln	All	<i>2.015</i>	<i>1.566</i>	<i>1.320</i>	<i>1.075</i>	<i>1.474</i>
Urb6Ln	All	<i>1.815</i>	<i>1.459</i>	<i>1.207</i>	<i>1.069</i>	<i>1.372</i>
Urb8Ln	All	<i>1.593</i>	<i>1.304</i>	<i>1.187</i>	<i>1.099</i>	<i>1.286</i>

B.4. Rural intersections

Table 57. Rural Intersections Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
Rur2L-3ST	All	<i>0.685</i>	<i>0.737</i>	<i>0.584</i>	<i>0.685</i>	<i>0.672</i>
Rur2L-4SG	All	<i>0.810</i>	<i>0.866</i>	<i>0.815</i>	<i>0.832</i>	<i>0.831</i>
Rur2L-4SG	Coast	<i>1.226</i>	<i>1.230</i>	<i>1.112</i>	<i>1.086</i>	<i>1.161</i>
Rur2L-4SG	Mountain	0.577	0.489	0.533	0.561	<i>0.539</i>
Rur2L-4SG	Piedmont	<i>0.724</i>	<i>0.836</i>	<i>0.786</i>	<i>0.814</i>	<i>0.792</i>
Rur2L-4ST	All	<i>0.821</i>	<i>0.787</i>	<i>0.591</i>	<i>0.748</i>	<i>0.733</i>
Rur2L-4ST	Coast	<i>0.993</i>	<i>0.886</i>	0.580	<i>0.753</i>	<i>0.790</i>
Rur2L-4ST	Mountain	0.554	0.648	0.464	0.572	<i>0.559</i>
Rur2L-4ST	Piedmont	<i>0.768</i>	<i>0.749</i>	<i>0.634</i>	<i>0.807</i>	<i>0.740</i>
RurML-3ST	All	0.860*	0.807*	0.492*	1.114*	0.824
RurML-4SG	All	<i>0.439</i>	<i>0.471</i>	<i>0.586</i>	<i>0.494</i>	<i>0.499</i>
RurML-4ST	All	1.228	1.368	1.708	1.006	<i>1.321</i>

B.5. Urban intersections

Table 58. Urban Intersections Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
UrbArt-3SG	All	2.024	2.284	1.539	2.348	2.053
UrbArt-3ST	All	1.791	1.971	1.831	1.974	1.895
UrbArt-4SG	All	3.405	3.499	3.496	3.343	3.435
UrbArt-4SG	Coast	3.567	3.459	3.151	3.017	3.281
UrbArt-4SG	Mountain	2.766	2.982	3.103	3.124	2.998
UrbArt-4SG	Piedmont	3.698	3.904	4.146	3.863	3.906
UrbArt-4ST	All	1.112	1.569	1.699	1.534	1.486
U68-4SG-2x2	All	2.366	2.431	2.245	2.262	2.327
U68-4SG-2x2	Coast	2.001	1.931	1.802	2.003	1.935
U68-4SG-2x2	Mountain	2.775	2.960	3.174	2.116	2.760
U68-4SG-2x2	Piedmont	2.668	2.872	2.563	2.491	2.646
U68-4SG-1x1or2	All	3.478	3.721	3.437	3.682	3.580
U68-4ST-2x2	All	0.154	0.223	0.151	0.213	0.187
U68-4ST-1x1or2	All	1.988*	1.531*	0.795*	3.476*	1.885
U68-3SG-2x2	All	3.069	3.033	3.167	3.026	3.073
U68-3SG-1x1or2	All	3.480*	1.120*	0.000*	0.000*	0.978*

B.6. Roundabouts

Table 59. Roundabouts Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
Rural Roundabouts	All	1.642	2.126	1.779	2.309	1.969
Urban Roundabouts	All	1.791	2.397	2.600	2.392	2.300

B.7. Ramp segments

Table 60. Ramp Segments Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
All Ramp Entrance	All	0.479*	0.540*	0.600*	0.854*	0.624
All Ramp Exit	All	2.163	1.543*	1.737*	1.473*	1.721
Ramp 1EN	All	0.645*	0.476*	0.567*	0.886*	0.647
Ramp 1EX	All	2.472	1.517*	1.746*	1.432*	1.776
Ramp 2EN	All	0.000*	1.141*	1.082*	1.105*	0.842*
Ramp 2EX	All	1.015*	1.531*	1.451*	1.879*	1.477*

B.8. Speed change lane segments

Table 61. Speed Change Lanes Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
SCL Ramp Entrance	All	1.051	0.605*	1.026	0.957	0.901
SCL Ramp Exit	All	0.509*	0.643*	0.668*	0.613*	0.611
4EN	All	0.782*	0.963*	1.759	1.197*	1.185
4EX	All	0.718*	1.047*	0.986*	1.092*	0.967
6EN	All	4.396*	1.090*	2.453*	0.951*	2.114*
6EX	All	0.841*	0.505*	0.927*	0.225*	0.614*
8EN	All	1.312*	0.728*	0.851*	1.894*	1.204

B.9. Ramp terminals

Table 62. Ramp Terminals Quick Reference Table

Facility Type	Region	2020	2021	2022	2023	2020-2023
All Ramp Terminal	All	1.919	1.930	1.881	1.898	1.907
A2	All	2.452*	2.462*	1.813*	3.692*	2.644*
B2	All	2.031*	1.551*	2.210*	2.988	2.203
D4	All	1.952	1.927	1.846	1.753	1.864

Appendix B. Crash Type and Severity Distribution Tables

2020-2023 North Carolina crash data from the sites selected for this effort were used to prepare the crash type and crash severity distribution tables for roadway segments, intersections, and interchange components included in this study. Results presented in these tables can support disaggregate analysis efforts for targeted safety improvements. These results are intended to replace default distributions presented in the HSM with localized data. The table numbering convention is consistent with HSM and NCHRP reports consulted for this study for easy reference. It should be noted that some pedestrian and bicycle fatal and incapacitating injury crash type distributions may display as 0% in the tables; however, this is likely attributable to rounding or small sample sizes rather than an absence of these crash types in the datasets.

Table 10-3. Distribution for Crash Severity Level on Rural Two-Lane, Two-Way Roadway Segments

Crash Severity Level	Proportion of Total Roadway Segment Crashes
Fatal	0.80
Incapacitating Injury	11.29
Non-incapacitating Injury	11.65
Possible injury	12.60
Total fatal plus injury	36.34
Property damage only	63.66
Unknown	0.00
Total	100.00

Table 10-4. Distribution by Collision Type for Specific Crash Severity Levels on Rural Two-Lane, Two-Way Roadway Segments

Collision Type	Proportion of Total Roadway Segment Crashes by Crash Severity Level		
	FI	PDO	Total (All Severity Levels Combined)
SINGLE-VEHICLE CRASHES			
Collision with animal	1.41	10.48	7.18
Collision with bicycle	0.00	0.00	0.00
Collision with pedestrian	0.00	0.00	0.00
Overtaken	0.94	0.18	0.46
Ran off road	41.20	34.90	37.19
Other single-vehicle crash	18.85	13.74	15.60
Total single-vehicle crashes	62.40	59.30	60.43
MULTIPLE-VEHICLE CRASHES			
Angle collision	3.09	6.68	5.38
Head-on collision	5.85	5.07	5.35
Rear-end collision	14.91	18.09	16.93
Sideswipe collision	5.39	4.58	4.87
Other multiple-vehicle collision	8.36	6.28	7.04
Total multiple-vehicle crashes	37.60	40.70	39.57
Total Crashes	100.00	100.00	100.00

Table 10-12. Nighttime Crash Proportions for Rural Unlighted Roadway Segments

Roadway Type	Proportion of Total Nighttime Crashes by Severity Level		Proportion of Crashes that Occur at Night
	FI	PDO	
Rural Two-Lane, Two-Way	0.32	0.68	0.47

Table 10-5. Distribution for Crash Severity Level at Rural Two-Lane, Two-Way Intersections

Crash Severity Level	Proportion of Total Intersection Crashes		
	Three-Leg Stop-Controlled Intersections	Four-Leg Stop-Controlled Intersections	Four-Leg Signalized Intersections
Fatal	0.42	1.34	0.31
Incapacitating Injury	1.96	4.28	0.68
Non-incapacitating Injury	9.65	16.15	9.51
Possible injury	16.92	19.71	17.79
Total fatal plus injury	28.95	41.48	28.29
Property damage only	68.67	57.09	70.78
Unknown	2.38	1.43	0.93
Total	100	100	100

Table 10-6. Distribution by Collision Type and Manner of Collision at Rural Two-Lane, Two-Way Intersections

Collision Type	Three-Leg Stop-Controlled			Four-Leg Stop-Controlled			Four-Leg Signalized		
	FI	PDO	Total	FI	PDO	Total	FI	PDO	Total
SINGLE-VEHICLE CRASHES									
Collision with animal	0.97	6.72	4.9	0.86	5	3.21	0	0.87	0.62
Collision with bicycle	0.97	0	0.28	0.22	0	0.09	0	0	0
Collision with pedestrian	0.97	0	0.28	0.43	0	0.18	0.22	0	0.06
Overturned	1.93	1.02	1.54	0.86	0.16	0.45	1.09	0.09	0.43
Ran off road	21.74	20.37	21.96	5.59	11.41	10.08	3.49	4.8	4.82
Other single-vehicle crash	2.42	3.46	3.36	0.22	0.62	0.62	2.18	0.52	0.99
Total single-vehicle crashes	29	31.57	32.32	8.18	17.19	14.63	6.98	6.28	6.92
MULTIPLE-VEHICLE CRASHES									
Angle collision	6.28	4.68	5.03	62.8	38.12	47.81	28.6	11.61	16.43
Head-on collision	2.42	0.2	0.84	1.29	0.47	0.8	1.75	0.44	0.8
Rear-end collision	20.29	29.74	26.29	10.97	23.75	22.4	26.42	42.32	37.55
Sideswipe collision	3.38	2.44	2.66	0.86	2.66	1.87	2.18	9.51	7.35
Other multiple-vehicle collision	30.48	21.43	21.26	10.65	0.78	0.71	26.31	14.57	19.54
Total multiple-vehicle crashes	62.85	58.49	56.08	86.57	65.78	73.59	85.26	78.45	81.67
Unknown Collision Type	8.15	9.94	11.6	5.25	17.03	11.78	7.76	15.27	11.41
Total Crashes	100	100	100	100	100	100	100	100	100

Table 10-15. Nighttime Crash Proportions for Rural Two-Way, Two-Lane Unlighted Intersections

Intersection Type	Proportion of Crashes that Occur at Night
Three-Leg Stop-Controlled	0.251
Four-Leg Stop-Controlled	0.228
Four-Leg Signalized	0.153

Table 11-4. Distribution of Crashes by Collision Type and Crash Severity Level for Rural 4-Lane Undivided Roadway Segments

Collision Type	Proportion of Crashes by Collision Type and Crash Severity Level			
	Total	Fatal and Injury (KABC)	Fatal and Injury (KAB only)	PDO
Head-on	0.091	0.067	0.085	0.103
Sideswipe	0.125	0.149	0.156	0.124
Rear-end	0.096	0.152	0.144	0.070
Angle	0.140	0.111	0.105	0.169
Single	0.455	0.448	0.413	0.465
Other	0.093	0.073	0.097	0.069
Total	1.000	1.000	1.000	1.000
Single (without Animal)	0.455	0.448	0.413	0.465

Table 11-15. Nighttime Crash Proportions for Rural 4-Lane Undivided Unlighted Roadway Segments

Roadway Type	Proportion of Total Nighttime Crashes by Severity Level		Proportion of Crashes that Occur at Night
	Fatal and Injury	PDO	
Rural 4-Lane Undivided	0.299	0.701	0.453

Table 11-16. Distribution of Crashes by Collision Type and Crash Severity Level for Rural 4-Lane Divided Roadway Segments

Collision Type	Proportion of Crashes by Collision Type and Crash Severity Level			
	Total	Fatal and Injury (KABC)	Fatal and Injury (KAB only)	PDO
Head-on	0.009	0.011	0.013	0.001
Sideswipe	0.121	0.084	0.022	0.120
Rear-end	0.169	0.223	0.118	0.137
Angle	0.084	0.110	0.109	0.066
Single	0.550	0.440	0.676	0.623
Other	0.067	0.132	0.062	0.053
Total	1.000	1.000	1.000	1.000
Single (without Animal)	0.353	0.402	0.656	0.323

Table 11-19. Nighttime Crash Proportions for Rural 4-Lane Divided Unlighted Roadway Segments

Roadway Type	Proportion of Total Nighttime Crashes by Severity Level		Proportion of Crashes that Occur at Night
	Fatal and Injury	PDO	
Rural 4-Lane Divided	0.266	0.734	0.423

Table 11-9. Distribution of Rural 4-Lane Intersection Crashes by Collision Type and Crash Severity

Collision Type	Three-Leg Intersections with Minor-Road Stop Control			
	Total	Fatal and Injury (KABC)	Fatal and Injury (KAB only)	PDO
Head-on	0.000	0.000	0.000	0.000
Sideswipe	0.125	0.065	0.054	0.144
Rear-end	0.437	0.452	0.497	0.375
Angle	0.092	0.201	0.258	0.073
Single	0.223	0.174	0.114	0.249
Other	0.123	0.108	0.077	0.159
Total	1.000	1.000	1.000	1.000

Table 11-9. Distribution of Rural 4-Lane Intersection Crashes by Collision Type and Crash Severity

Collision Type	Three-Leg Intersections with Minor-Road Stop Control			
	Total	Fatal and Injury (KABC)	Fatal and Injury (KAB only)	PDO
Head-on	0.000	0.000	0.000	0.000
Sideswipe	0.125	0.065	0.054	0.144
Rear-end	0.437	0.452	0.497	0.375
Angle	0.092	0.201	0.258	0.073
Single	0.223	0.174	0.114	0.249
Other	0.123	0.108	0.077	0.159
Total	1.000	1.000	1.000	1.000
Collision Type	Four-Leg Intersections with Minor-Road Stop Control			
	Total	Fatal and Injury (KABC)	Fatal and Injury (KAB only)	PDO
Head-on	0.006	0.027	0.021	0.001
Sideswipe	0.052	0.020	0.036	0.124
Rear-end	0.030	0.025	0.028	0.053
Angle	0.489	0.731	0.693	0.266
Single	0.182	0.034	0.065	0.238
Other	0.241	0.163	0.157	0.318
Total	1.000	1.000	1.000	1.000
Collision Type	Four-Leg Signalized Intersections			
Collision Type	Total	Fatal and Injury (KABC)	Fatal and Injury (KAB only)	PDO
Head-on	0.016	0.032	0.041	0.008
Sideswipe	0.117	0.034	0.037	0.171
Rear-end	0.402	0.328	0.304	0.419
Angle	0.193	0.391	0.406	0.166
Single	0.089	0.060	0.083	0.035
Other	0.183	0.155	0.129	0.201
Total	1.000	1.000	1.000	1.000

Table 11-24. Nighttime Crash Proportions for Rural 4-Lane Unlighted Intersections

Intersection Type	Proportion of Crashes that Occur at Night
3-leg stop controlled with minor road stop control	0.225
4-leg stop controlled with minor road stop control	0.196

Table 12-4. Distribution of Multiple-Vehicle Non-driveway Collisions for Urban Roadway Segments by Manner of Collision Type

Collision Type	Proportion of Crashes by Severity Level for Specific Road Types									
	2U		3T		4U		4D		5T	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	0.630	0.648	0.539	0.495	0.425	0.443	0.408	0.449	0.352	0.374
Head-on collision	0.030	0.014	0.046	0.008	0.026	0.002	0.024	0.009	0.033	0.008
Angle collision	0.095	0.097	0.168	0.176	0.231	0.135	0.282	0.182	0.274	0.178
Sideswipe, same direction	0.017	0.065	0.040	0.094	0.048	0.243	0.072	0.216	0.065	0.221
Sideswipe, opposite direction	0.060	0.050	0.001	0.036	0.012	0.013	0.029	0.011	0.023	0.023
Other multiple-vehicle collisions	0.168	0.126	0.206	0.191	0.258	0.164	0.185	0.133	0.253	0.196
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 12-6. Distribution of Single-Vehicle Crashes for Urban Roadway Segments by Collision Type

Collision Type	Proportion of Crashes by Severity Level for Specific Road Types									
	2U		3T		4U		4D		5T	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Collision with animal	0.061	0.293	0.032	0.298	0.000	0.133	0.006	0.388	0.026	0.316
Collision with fixed object	0.020	0.099	0.036	0.064	0.009	0.054	0.003	0.108	0.026	0.046
Collision with other object	0.119	0.231	0.148	0.242	0.061	0.263	0.087	0.157	0.182	0.244
Other single-vehicle collision	0.800	0.377	0.784	0.396	0.930	0.550	0.904	0.347	0.766	0.394
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B-1. Total Crash Proportions for Collision Types Presented in Table 12-4

Collision Type	Proportion of Crashes by Severity Level for Specific Road Types				
	2U	3T	4U	4D	5T
Rear-end collision	0.633	0.519	0.437	0.426	0.355
Head-on collision	0.025	0.024	0.018	0.019	0.022
Angle collision	0.095	0.172	0.183	0.235	0.226
Sideswipe, same direction	0.037	0.074	0.147	0.149	0.139
Sideswipe, opposite direction	0.058	0.022	0.018	0.024	0.031
Other multiple-vehicle collisions	0.152	0.189	0.197	0.147	0.227
Total	1.000	1.000	1.000	1.000	1.000

Table B-2. Total Crash Proportions for Collision Types Presented in Table 12-6

Collision Type	Proportion of Crashes by Severity Level for Specific Road Types				
	2U	3T	4U	4D	5T
Collision with Animal	0.176	0.18	0.071	0.201	0.179
Collision with fixed object	0.06	0.059	0.027	0.061	0.038
Collision with other object	0.181	0.197	0.178	0.132	0.218
Other single-vehicle collision	0.583	0.564	0.724	0.606	0.565
Total	1.000	1.000	1.000	1.000	1.000

Table 12-21. Proportion of Urban Fixed-Object Crashes

Road Type	Proportion of Fixed-Object Collisions
2-lane undivided	0.065
2-lane with TWLTL	0.052
4-lane undivided	0.025
4-lane divided	0.014
4-lane with TWLTL	0.032

Table 12-23. Nighttime Crash Proportions for Urban Unlighted Roadway Segments

Roadway Type	Proportion of Total Nighttime Crashes by Severity Level		Proportion of Crashes that Occur at Night
	Fatal and Injury	PDO	
2-lane undivided	0.299	0.724	0.135
2-lane with TWLTL	0.307	0.704	0.008
4-lane undivided	0.386	0.625	0.083
4-lane divided	0.464	0.561	0.030
4-lane with TWLTL	0.403	0.612	0.046

Table 12-11. Distribution of Multiple-Vehicle Collisions for Urban Intersections by Collision Type

Collision Type	Proportion of Crashes by Severity Level for Specific Road Types							
	3-leg stop control with minor road stop control		3-leg signalized		4-leg stop controlled with minor road stop control		4-leg signalized	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	0.434	0.394	0.439	0.471	0.162	0.262	0.417	0.467
Head-on collision	0.043	0.013	0.020	0.006	0.032	0.009	0.044	0.018
Angle collision	0.240	0.215	0.278	0.161	0.601	0.389	0.300	0.185
Sideswipe	0.077	0.208	0.019	0.196	0.031	0.157	0.072	0.191
Other multiple-vehicle collisions	0.206	0.170	0.244	0.166	0.174	0.183	0.167	0.139
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B-3. Total Crash Proportions for Collision Types Presented in Table 12-11

Collision Type	Proportion of Total Crashes by Severity Level for Specific Road Types			
	3-leg stop control with minor road stop control	3-leg signalized	4-leg stop controlled with minor road stop control	4-leg signalized
Rear-end collision	0.424	0.446	0.202	0.440
Head-on collision	0.031	0.012	0.032	0.037
Angle collision	0.231	0.204	0.498	0.243
Sideswipe	0.141	0.100	0.086	0.136
Other multiple-vehicle collisions	0.173	0.238	0.182	0.144
Total	1.000	1.000	1.000	1.000

Table 12-13. Distribution of Single-Vehicle Crashes for Urban Intersections by Collision Type

Collision Type	Proportion of Crashes by Severity Level for Specific Road Types							
	3-leg stop control with minor road stop control		3-leg signalized		4-leg stop controlled with minor road stop control		4-leg signalized	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Collision with parked vehicle	0.003	0.031	0.202	0.003	0.004	0.093	0.015	0.025
Collision with animal	0.041	0.187	0.004	0.289	0.003	0.184	0.018	0.099
Collision with fixed object	0.110	0.156	0.000	0.144	0.224	0.183	0.107	0.252
Collision with other object	0.003	0.062	0.002	0.000	0.004	0.000	0.076	0.048
Other single-vehicle collision	0.829	0.517	0.782	0.554	0.671	0.526	0.776	0.445
Non Collision	0.014	0.047	0.010	0.010	0.094	0.014	0.008	0.131
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B-4. Total Crash Proportions for Collision Types Presented in Table 12-13

Collision Type	Proportion of Total Crashes by Severity Level for Specific Road Types			
	3-leg stop control with minor road stop control	3-leg signalized	4-leg stop controlled with minor road stop control	4-leg signalized
Collision with parked vehicle	0.024	0.103	0.049	0.028
Collision with animal	0.110	0.161	0.095	0.069
Collision with fixed object	0.146	0.079	0.210	0.197
Collision with other object	0.036	0.012	0.018	0.058
Other single-vehicle collision	0.662	0.633	0.613	0.619
Non Collision	0.022	0.012	0.015	0.029
Total	1.000	1.000	1.000	1.000

Table 12-27. Nighttime Crash Proportions for Urban Unlighted Intersections

Intersection Type	Proportion of Crashes that Occur at Night
3-leg stop controlled with minor road stop control	0.104
4-leg stop controlled with minor road stop control	0.071
3- and 4-leg signalized	0.029

Table 18-6. Distribution of Multiple-Vehicle Crashes by Crash Type for Freeway Segments

Area Type	Crash Type Category	Proportion of Crashes by Severity	
		FI	PDO
Rural	Head-on	0.027	0.014
	Right-angle	0.014	0.002
	Rear-end	0.767	0.504
	Sideswipe	0.183	0.476
	Other multiple-vehicle crashes	0.009	0.004
	Total	1.000	1.000
Urban	Head-on	0.020	0.008
	Right-angle	0.033	0.032
	Rear-end	0.694	0.578
	Sideswipe	0.232	0.377
	Other multiple-vehicle crashes	0.021	0.005
	Total	1.000	1.000

Table B-5. Total Crash Proportions for Collision Types Presented in Table 18-6

Area Type	Crash Type Category	Proportion of Total Crashes
		Total (FI + PDO)
Rural	Head-on	0.022
	Right-angle	0.018
	Rear-end	0.640
	Sideswipe	0.303
	Other multiple-vehicle crashes	0.017
	Total	1.000
Urban	Head-on	0.025
	Right-angle	0.003
	Rear-end	0.634
	Sideswipe	0.256
	Other multiple-vehicle crashes	0.082
	Total	1.000

Table 18-8. Distribution of Single-Vehicle Crashes by Crash Type for Freeway Segments

Area Type	Crash Type Category	Proportion of Crashes by Severity	
		FI	PDO
Rural	Crash with animal	0.092	0.253
	Crash with fixed object	0.671	0.547
	Crash with other object	0.056	0.154
	Crash with parked vehicle	0.013	0.016
	Other single-vehicle crashes	0.168	0.030
	Total	1.000	1.000
Urban	Crash with animal	0.022	0.128
	Crash with fixed object	0.623	0.500
	Crash with other object	0.044	0.230
	Crash with parked vehicle	0.019	0.002
	Other single-vehicle crashes	0.292	0.140
	Total	1.000	1.000

Table B-6. Total Crash Proportions for Collision Types Presented in Table 18-8

Area Type	Crash Type Category	Proportion of Total Crashes
Rural	Crash with animal	0.165
	Crash with fixed object	0.604
	Crash with other object	0.096
	Crash with parked vehicle	0.004
	Other single-vehicle crashes	0.131
	Total	1.000
Urban	Crash with animal	0.070
	Crash with fixed object	0.559
	Crash with other object	0.135
	Crash with parked vehicle	0.014
	Other single-vehicle crashes	0.222
	Total	1.000

Table 51-1. Distribution of Multiple-Vehicle Collisions for Roadway Segments by Manner of Collision Type

Collision Type	6U		6D		7T		8D	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	--	--	0.521	0.440	0.390	0.411	0.652	0.576
Head-on collision	--	--	0.087	0.143	0.049	0.019	0.000	0.002
Angle collision	--	--	0.174	0.066	0.390	0.093	0.093	0.085
Sideswipe, same direction	--	--	0.098	0.153	0.077	0.210	0.106	0.144
Sideswipe, opposite direction	--	--	0.120	0.187	0.094	0.258	0.124	0.169
Other multiple-vehicle collisions	--	--	0.000	0.011	0.000	0.009	0.025	0.024
Total	--	--	1.000	1.000	1.000	1.000	1.000	1.000

Table B-7. Total Crash Proportions for Collision Types Presented in Table 51-1

Collision Type	6U	6D	7T	8D
	--	0.456	0.425	0.596
Rear-end collision	--	0.132	0.115	0.002
Head-on collision	--	0.088	0.163	0.087
Angle collision	--	0.142	0.130	0.133
Sideswipe, same direction	--	0.173	0.159	0.156
Sideswipe, opposite direction	--	0.009	0.008	0.026
Other multiple-vehicle collisions	--	1.000	1.000	1.000
Total				

Table 52-1. Distribution of Single-Vehicle Crashes for Roadway Segments by Collision Type for Arterials with Six or More Lanes

Collision Type	6U		6D		7T		8D	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Collision with fixed object - left	--	--	0.023	0.008	0.034	0.006	0.028	0.007
Collision with fixed object - right	--	--	0.487	0.534	0.423	0.456	0.412	0.398
Collision with other object	--	--	0.278	0.203	0.285	0.227	0.314	0.215
Other single-vehicle collision	--	--	0.212	0.255	0.258	0.311	0.246	0.380
Total	--	--	1.000	1.000	1.000	1.000	1.000	1.000

Table B-8. Total Crash Proportions for Collision Types Presented in Table 52-1

Collision Type	6U	6D	7T	8D
Collision with fixed object - left	--	0.011	0.016	0.025
Collision with fixed object - right	--	0.526	0.501	0.41
Collision with other object	--	0.216	0.228	0.299
Other single-vehicle collision	--	0.247	0.255	0.266
Total	--	1.000	1.000	1.000

Table 61-1 Distribution of Total Vehicle Collisions for Intersections with Six or More Lanes by Collision Type

Manner of Collision	3ST		3SG		4ST		4SG	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	--	--	0.456	0.423	0.398	0.445	0.401	0.378
Head-on collision	--	--	0.009	0.021	0.015	0.011	0.023	0.019
Angle collision	--	--	0.058	0.043	0.044	0.053	0.057	0.049
Sideswipe	--	--	0.167	0.134	0.178	0.156	0.142	0.167
Other multiple-vehicle	--	--	0.112	0.134	0.098	0.112	0.121	0.089
Single-vehicle crashes	--	--	0.198	0.245	0.267	0.223	0.256	0.298
Total	--	--	1.000	1.000	1.000	1.000	1.000	1.000

Table B-9: Total Crash Proportions for Collision Types Presented in Table 61-1

Manner of Collision	3ST	3SG	4ST	4SG
Rear-end collision	--	0.431	0.404	0.384
Head-on collision	--	0.018	0.016	0.02
Angle collision	--	0.047	0.044	0.051
Sideswipe	--	0.142	0.167	0.161
Other multiple-vehicle	--	0.129	0.107	0.096
Single-vehicle crashes	--	0.233	0.262	0.288
Total	--	1.000	1.000	1.000

Table 64-1. Nighttime Crash Proportions for Unlighted Intersections

Intersection Type	Proportion of Crashes That Occur at Night
3ST	--
4ST	0.086
3SG and 4SG	0.043

Table 79. Distribution of Total Vehicle Collisions for 1x2 or 1x1 Intersections by Collision Type

Manner of Collision	3SG		4ST		4SG	
	FI²	PDO	FI	PDO	FI	PDO
Rear-end collision	--	0.378	0.423	0.456	0.387	0.412
Head-on collision	--	0.019	0.021	0.009	0.012	0.018
Angle collision	--	0.167	0.134	0.167	0.189	0.156
Sideswipe	--	0.049	0.043	0.058	0.036	0.055
Other multiple-vehicle	--	0.089	0.134	0.112	0.098	0.125
Single-vehicle crashes	--	0.298	0.245	0.198	0.278	0.234
Total	--	1.000	1.000	1.000	1.000	1.000

² No FI crashes were observed at the 3SG 1x1or2 intersections that were included in this study from 2020 through 2023.

Table B-10. Total Crash Proportions for Collision Types Presented in Table 79

Manner of Collision	3SG	4ST	4SG
Rear-end collision	0.378	0.392	0.391
Head-on collision	0.019	0.02	0.013
Angle collision	0.167	0.157	0.184
Sideswipe	0.049	0.047	0.039
Other multiple-vehicle	0.089	0.103	0.102
Single-vehicle crashes	0.298	0.281	0.271
Total	1.000	1.000	1.000

Table 82. Nighttime Crash Proportions for Unlighted Intersections

Intersection Type	Proportion of Crashes That Occur at Night
3ST	--
4ST	0.082
3SG and 4SG	0.057

Table 19-6. Default Distribution of Multiple-Vehicle Crashes by Crash Type for Ramp

Area Type	Crash Type Category	Proportion of Crashes by Severity	
		FI	PDO
Rural or urban	Head-on	0.023	0.015
	Right-angle	0.256	0.267
	Rear-end	0.487	0.423
	Sideswipe	0.134	0.178
	Other multiple-vehicle crashes	0.100	0.117
	Total	1.000	1.000

Table B-11. Total Crash Proportions for Collision Types Presented in Table 19-6

Area Type	Crash Type Category	Proportion of Total Crashes
Rural or urban	Head-on	0.017
	Right-angle	0.264
	Rear-end	0.442
	Sideswipe	0.165
	Other multiple-vehicle crashes	0.112
	Total	1.000

Table 19-9. Default Distribution of Single-Vehicle Crashes by Crash Type for Ramp Segments

Area Type	Crash Type Category	Proportion of Crashes by Severity	
		FI	PDO
Rural	Crash with animal	0.023	0.015
	Crash with fixed object	0.487	0.423
	Crash with other object	0.100	0.117
	Crash with parked vehicle	0.134	0.178
	Other single-vehicle crashes	0.256	0.267
	Total	1.000	1.000
Urban	Crash with animal	0.018	0.021
	Crash with fixed object	0.512	0.398
	Crash with other object	0.080	0.147
	Crash with parked vehicle	0.156	0.189
	Other single-vehicle crashes	0.234	0.245
	Total	1.000	1.000

Table B-12. Total Crash Proportions for Collision Types Presented in Table 19-9

Area Type	Crash Type Category	Proportion of Total Crashes
Rural	Crash with animal	0.017
	Crash with fixed object	0.442
	Crash with other object	0.112
	Crash with parked vehicle	0.165
	Other single-vehicle crashes	0.264
	Total	1.000
Urban	Crash with animal	0.020
	Crash with fixed object	0.432
	Crash with other object	0.127
	Crash with parked vehicle	0.179
	Other single-vehicle crashes	0.242
	Total	1.000

Table 18-10. Default Distribution of Ramp-Entrance-Related Crashes by Crash Type

Area Type	Crash Type	Crash Type Category	Proportion of Crashes by Severity	
			FI	PDO
Rural	Multiple vehicle	Head-on	0.012	0.009
		Right-angle	0.076	0.098
		Rear-end	0.041	0.032
		Sideswipe	0.098	0.145
		Other multiple-vehicle crash	0.187	0.223
	Single vehicle	Crash with animal	0.064	0.078
		Crash with fixed object	0.298	0.287
		Crash with other object	0.085	0.067
		Crash with parked vehicle	0.052	0.041
		Other single-vehicle crashes	0.087	0.020
		Total	1.000	1.000
Urban	Multiple vehicle	Head-on	0.015	0.011
		Right-angle	0.198	0.201
		Rear-end	0.324	0.312
		Sideswipe	0.112	0.123
		Other multiple-vehicle crash	0.087	0.076
	Single vehicle	Crash with animal	0.056	0.084
		Crash with fixed object	0.043	0.038
		Crash with other object	0.089	0.072
		Crash with parked vehicle	0.048	0.045
		Other single-vehicle crashes	0.028	0.038
		Total	1.000	1.000

Table B-13. Total Crash Proportions for Collision Types Presented in Table 18-10

Area Type	Crash Type	Crash Type Category	Proportion of Total Crashes
Rural	Multiple vehicle	Head-on	0.010
		Right-angle	0.093
		Rear-end	0.034
		Sideswipe	0.134
		Other multiple-vehicle crash	0.214
	Single vehicle	Crash with animal	0.075
		Crash with fixed object	0.290
		Crash with other object	0.071
		Crash with parked vehicle	0.044
		Other single-vehicle crashes	0.035
		Total	1.000
Urban	Multiple vehicle	Head-on	0.012
		Right-angle	0.200
		Rear-end	0.315
		Sideswipe	0.120
		Other multiple-vehicle crash	0.079
	Single vehicle	Crash with animal	0.077
		Crash with fixed object	0.039
		Crash with other object	0.076
		Crash with parked vehicle	0.046
		Other single-vehicle crashes	0.036
		Total	1.000

Table 18-12. Default Distribution of Ramp-Exit-Related Crashes by Crash Type

Area Type	Crash Type	Crash Type Category	Proportion of Crashes by Severity	
			FI	PDO
Rural	Multiple vehicle	Head-on	0.019	0.013
		Right-angle	0.092	0.087
		Rear-end	0.035	0.041
		Sideswipe	0.087	0.156
		Other multiple-vehicle crash	0.214	0.189
	Single vehicle	Crash with animal	0.048	0.092
		Crash with fixed object	0.345	0.278
		Crash with other object	0.076	0.062
		Crash with parked vehicle	0.044	0.038
		Other single-vehicle crashes	0.04	0.044
		Total	1.000	1.000
Urban	Multiple vehicle	Head-on	0.078	0.081
		Right-angle	0.014	0.008
		Rear-end	0.367	0.298
		Sideswipe	0.123	0.167
		Other multiple-vehicle crash	0.189	0.234
	Single vehicle	Crash with animal	0.081	0.055
		Crash with fixed object	0.029	0.036
		Crash with other object	0.052	0.067
		Crash with parked vehicle	0.039	0.031
		Other single-vehicle crashes	0.028	0.023
		Total	1.000	1.000

Table B-14. Total Crash Proportions for Collision Types Presented in Table 18-12

Area Type	Crash Type	Crash Type Category	Proportion of Total Crashes
Rural	Multiple vehicle	Head-on	0.014
		Right-angle	0.088
		Rear-end	0.040
		Sideswipe	0.139
		Other multiple-vehicle crash	0.195
	Single vehicle	Crash with animal	0.081
		Crash with fixed object	0.294
		Crash with other object	0.065
		Crash with parked vehicle	0.039
		Other single-vehicle crashes	0.045
		Total	1.000
Urban	Multiple vehicle	Head-on	0.080
		Right-angle	0.009
		Rear-end	0.315
		Sideswipe	0.156
		Other multiple-vehicle crash	0.223
	Single vehicle	Crash with animal	0.061
		Crash with fixed object	0.034
		Crash with other object	0.063
		Crash with parked vehicle	0.033
		Other single-vehicle crashes	0.026
		Total	1.000

Table 19-16. Default Distribution of Signal-Controlled Ramp Terminal Crashes by Crash Type

Area Type	Crash Type	Crash Type Category	Proportion of Crashes by Severity	
			FI	PDO
Rural	Multiple vehicle	Head-on	0.014	0.009
		Right-angle	0.036	0.032
		Rear-end	0.201	0.223
		Sideswipe	0.123	0.145
		Other multiple-vehicle crash	0.081	0.098
	Single vehicle	Crash with animal	0.067	0.078
		Crash with fixed object	0.312	0.287
		Crash with other object	0.089	0.067
		Crash with parked vehicle	0.043	0.041
		Other single-vehicle crashes	0.034	0.020
		Total	1.000	1.000
Urban	Multiple vehicle	Head-on	0.041	0.043
		Right-angle	0.011	0.015
		Rear-end	0.298	0.312
		Sideswipe	0.156	0.112
		Other multiple-vehicle crash	0.092	0.087
	Single vehicle	Crash with animal	0.078	0.056
		Crash with fixed object	0.189	0.198
		Crash with other object	0.076	0.089
		Crash with parked vehicle	0.038	0.048
		Other single-vehicle crashes	0.021	0.040
		Total	1.000	1.000

Table B-15: Total Crash Proportions for Collision Types Presented in Table 19-16

Area Type	Crash Type	Crash Type Category	Proportion of Total Crashes
Rural	Multiple vehicle	Head-on	0.011
		Right-angle	0.033
		Rear-end	0.216
		Sideswipe	0.138
		Other multiple-vehicle crash	0.093
	Single vehicle	Crash with animal	0.075
		Crash with fixed object	0.295
		Crash with other object	0.074
		Crash with parked vehicle	0.042
		Other single-vehicle crashes	0.023
		Total	1.000
Urban	Multiple vehicle	Head-on	0.042
		Right-angle	0.014
		Rear-end	0.308
		Sideswipe	0.125
		Other multiple-vehicle crash	0.089
	Single vehicle	Crash with animal	0.063
		Crash with fixed object	0.195
		Crash with other object	0.085
		Crash with parked vehicle	0.045
		Other single-vehicle crashes	0.034
		Total	1.000

Table 19-21. Default Distribution of One-Way Stop-Controlled Ramp Terminal Crashes by Crash Type

Area Type	Crash Type	Crash Type Category	Proportion of Crashes by Severity	
			FI	PDO
Rural	Multiple vehicle	Head-on	0.035	0.036
		Right-angle	0.019	0.013
		Rear-end	0.214	0.189
		Sideswipe	0.087	0.167
		Other multiple-vehicle crash	0.092	0.081
	Single vehicle	Crash with animal	0.048	0.092
		Crash with fixed object	0.345	0.278
		Crash with other object	0.076	0.072
		Crash with parked vehicle	0.044	0.045
		Other single-vehicle crashes	0.040	0.027
		Total	1.000	1.000
Urban	Multiple vehicle	Head-on	0.029	0.038
		Right-angle	0.014	0.008
		Rear-end	0.367	0.298
		Sideswipe	0.123	0.156
		Other multiple-vehicle crash	0.078	0.076
	Single vehicle	Crash with animal	0.052	0.084
		Crash with fixed object	0.189	0.234
		Crash with other object	0.081	0.055
		Crash with parked vehicle	0.039	0.031
		Other single-vehicle crashes	0.028	0.020
		Total	1.000	1.000

Table B-16: Total Crash Proportions for Collision Types Presented in Table 19-21

Area Type	Crash Type	Crash Type Category	Proportion of Total Crashes
Rural	Multiple vehicle	Head-on	0.036
		Right-angle	0.015
		Rear-end	0.197
		Sideswipe	0.143
		Other multiple-vehicle crash	0.084
	Single vehicle	Crash with animal	0.079
		Crash with fixed object	0.298
		Crash with other object	0.073
		Crash with parked vehicle	0.044
		Other single-vehicle crashes	0.031
		Total	1.000
Urban	Multiple vehicle	Head-on	0.035
		Right-angle	0.010
		Rear-end	0.319
		Sideswipe	0.146
		Other multiple-vehicle crash	0.077
	Single vehicle	Crash with animal	0.074
		Crash with fixed object	0.221
		Crash with other object	0.063
		Crash with parked vehicle	0.033
		Other single-vehicle crashes	0.022
		Total	1.000

Table 19-45. Default Distribution of All-Way Stop-Controlled Ramp Terminal Crashes by Crash Type

Area Type	Crash Type	Crash Type Category	Proportion of Crashes by Severity	
			FI	PDO
Rural	Multiple vehicle	Head-on	0.032	0.041
		Right-angle	0.021	0.012
		Rear-end	0.234	0.176
		Sideswipe	0.098	0.134
		Other multiple-vehicle crash	0.076	0.089
	Single vehicle	Crash with animal	0.064	0.073
		Crash with fixed object	0.301	0.324
		Crash with other object	0.052	0.084
		Crash with parked vehicle	0.041	0.035
		Other single-vehicle crashes	0.081	0.032
		Total	1.000	1.000
Urban	Multiple vehicle	Head-on	0.038	0.029
		Right-angle	0.012	0.009
		Rear-end	0.356	0.267
		Sideswipe	0.134	0.178
		Other multiple-vehicle crash	0.089	0.092
	Single vehicle	Crash with animal	0.073	0.064
		Crash with fixed object	0.176	0.245
		Crash with other object	0.064	0.067
		Crash with parked vehicle	0.035	0.033
		Other single-vehicle crashes	0.023	0.016
		Total	1.000	1.000

Table B-17: Total Crash Proportions for Collision Types Presented in Table 19-45

Area Type	Crash Type	Crash Type Category	Proportion of Total Crashes
Rural	Multiple vehicle	Head-on	0.039
		Right-angle	0.014
		Rear-end	0.191
		Sideswipe	0.125
		Other multiple-vehicle crash	0.086
	Single vehicle	Crash with animal	0.071
		Crash with fixed object	0.318
		Crash with other object	0.076
		Crash with parked vehicle	0.037
		Other single-vehicle crashes	0.043
		Total	1.000
Urban	Multiple vehicle	Head-on	0.031
		Right-angle	0.010
		Rear-end	0.29
		Sideswipe	0.167
		Other multiple-vehicle crash	0.091
	Single vehicle	Crash with animal	0.066
		Crash with fixed object	0.227
		Crash with other object	0.066
		Crash with parked vehicle	0.034
		Other single-vehicle crashes	0.018
		Total	1.000

Table 5-70. Recommended Distribution of FI Collisions for Roundabouts by Manner of Collision Type

Crash Type	Crash Type Category	Proportion of FI Crashes	
		1 Circulating Lane	
		3 Legs	4 Legs
Multiple-Vehicle	Head On	0.031	0.028
	Right Angle	0.018	0.014
	Rear End	0.423	0.389
	Sideswipe, Same Dir.	0.098	0.134
	Other	0.067	0.076
Single-Vehicle	Animal	0.054	0.062
	Fixed Object	0.187	0.212
	Other Object	0.072	0.054
	Parked Vehicle	0.029	0.022
	Other	0.021	0.009
	Total	1.000	1.000

Table 5-71. Recommended Distribution of PDO Collisions for Roundabouts by Manner of Collision Type

Crash Type	Crash Type Category	1 Circulating Lane			
		3 Legs		4 Legs	
		Rural	Urban	Rural	Urban
Multiple-Vehicle	Head On	0.041	0.036	0.038	0.011
	Right Angle	0.012	0.009	0.014	0.198
	Rear End	0.287	0.312	0.278	0.298
	Sideswipe, Same Dir.	0.145	0.123	0.156	0.043
	Other	0.098	0.081	0.092	0.087
Single-Vehicle	Animal	0.078	0.067	0.084	0.076
	Fixed Object	0.189	0.201	0.187	0.134
	Other Object	0.089	0.089	0.072	0.089
	Parked Vehicle	0.035	0.041	0.039	0.035
	Other	0.026	0.041	0.040	0.029
	Total	1.000	1.000	1.000	1.000

Table B-18: Total Crash Proportions for Collision Types Presented in Tables 5-70 and 5-71

Crash Type	Crash Type Category	1 Circulating Lane	
		3 Legs	4 Legs
Multiple-Vehicle	Head On	0.037	0.021
	Right Angle	0.011	0.118
	Rear End	0.323	0.307
	Sideswipe, Same Dir.	0.125	0.089
	Other	0.083	0.087
Single-Vehicle	Animal	0.068	0.076
	Fixed Object	0.196	0.161
	Other Object	0.086	0.079
	Parked Vehicle	0.037	0.034
	Other	0.034	0.028
	Total	1.000	1.000