**NCHRP 17-93: Updating Safety Performance Functions for Data-Driven Safety Analysis**

**Working White Paper: Guidelines on the Need for Regional Calibration Factors or Calibration Factors for a Specific Year**

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Introduction

Practitioners are often faced with the decision on when to calibrate or update different components of the prediction model. There are two issues to consider here:

* Calibrate if the prediction model was developed in jurisdiction X, but being used in jurisdiction Y.
* Recalibrate the prediction model if there is a change in safety over time.

For both these issues, Task 3 outlined possible approaches that practitioners can use to determine if regional calibrations are needed (instead of using the statewide calibration factor), and if separate calibration factors need to be developed in a particular year (instead of using the calibration factors from the base year). The approaches discussed for both these issues were based on Lord et al., (2015). Lord et al., (2015) recommended the use of base SPFs (without the adjustment factors) for this purpose. The report for Task 3 suggested the exploration of simpler methods, e.g., the use of crash rates, as a possible way for practitioners. To compare the approaches recommended in Lord et al., (2015) versus using crash rates, data compiled as part of two recent projects (NCHRP Project 17-72: Update of Crash Modification Factors for the Highway Safety Manual; NCDOT Project 2020-27: Updated and Regional Calibration Factors for Highway Safety Manual Prediction Models 2016-2019) for rural two-lane roads, rural multi-lane divided roads, and urban two-lane undivided arterials from North Carolina, were utilized. The data collection for this effort was completed in Spring 2021 and have been included in the final report of these two projects. Rural two-lane roads and rural multi-lane divided roads were chosen because these two facility types had sufficient data by region and by year, whereas urban two-lane undivided arterials had sufficient data by year to do these comparisons.

The rest of this document is structured as follows. The next two sections provide a summary of the approaches discussed in Lord et al., (2015) for addressing the two issues mentioned above. This is followed by a brief overview of the prediction models from the 1st edition of the HSM for rural two-lane roads and rural multi-lane divided roads. An overview of the data that were collected is discussed next. This is followed by a summary of the results based on the approaches described in Lord et al., (2015) versus the use of crash rates. The last section provides the recommended guidance based on this comparison.

Background

Calibration if There is a Change in Location

The 1st edition of the HSM recommends calibration because the general level of safety “may vary substantially from one jurisdiction to another for a variety of reasons including climate, driver population, animal populations, crash reporting thresholds, and crash reporting system procedures” (Page A-1 Vol 2; HSM, 2010). Initially, some states started producing one calibration factor for the whole state, but more recently, many states have started estimating calibration factors for different regions within a state. For example, a recent study for the North Carolina Department of Transportation (NCDOT) estimated separate calibration factors for 3 regions in North Carolina (Smith et al., 2017).

Lord et al., (2015) developed an approach that can be used by practitioners for determining if regional calibration factors are needed. For segments, following is an outline for the procedure (Lord et al., 2015):

Step 1. Find the total number of crashes and total segment length in the state (Ns and Ls) and the region (Nr and Lr) under consideration.[[1]](#footnote-1)

Step 2. Find the average ADT in the state () and in the region ().

Step 3. Using the base SPF (i.e., SPF without the CMFs) from the HSM, and used that to predict the number of crashes in the state and the region:

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Where, b0 and b1 are coefficients from the base SPF (for this illustration, it is assumed that the base SPF is of the functional form given above, and appropriate changes will have to be made if a different functional form is used).

Step 4. Find the proxy calibration factors for the state and region as follows:

Step 5. Find as follows:

Lord et al., (2015) recommend that if > 10%, then separate region-specific calibration factors may be warranted.

A similar procedure was recommended for intersections with the following differences:

* Average major and minor road ADT would be needed instead of ADT at a segment level
* The number of intersections is needed instead of the total segment length
* Intersection crashes will need to be compiled instead of segment level crashes
* In Step 3, the base for SPFs for intersections should be used instead of the base SPF for segments

Some state agencies may not have an intersection inventory. In those situations, Lord et al., (2015) recommend that a sample intersection inventory representative of the region and/or state be compiled for used in the calculations. In theory, this process could be undertaken for different facility types, crash types, and severity levels.

Update if There is a Change in Safety over Time

There is guidance in the 1st edition of the HSM that calibration of the prediction models could be done at least every 2 to 3 years. However, this recommendation is simply based on the judgment of the developers of the 1st edition of the HSM, and not based on measures of statistical reliability.

Lord et al., (2015), examined the question of “when to update” by developing a procedure that practitioners could apply to guide them in answering the question for themselves. To use the Lord et al., (2015), the analyst would need to acquire three sources of information that describe conditions during the time period that will be used to determine the updated calibration factor. For segment based CPMs, these sources of information are (1) the total number of crashes, (2) the mean value of ADT or AADT, and (3) the total segment length. For intersection based CPMs, the sources of information are (1) the total number of crashes, (2) the average traffic flow on the major and minor roads, and (3) the number of intersections.

When applying the procedure, the analyst would use the acquired information to periodically compute a “proxy” calibration factor, which is an estimated calibration factor value based on the observed total crashes divided by a predicted total number of crashes for a common time period. The predicted number of crashes is estimated only using the base SPF from the HSM. This proxy factor is then compared with a proxy calibration factor that is calculated for a reference year. If the difference between the two values is more than 10% then the CPM’s calibration factor should be updated. Following is an overview of the procedure for segment based CPMs from Lord et al., (2015):

Step 1. Find the total number of crashes and total segment length (N and L) during a particular year.[[2]](#footnote-2)

Step 2. Find the average ADT () during that year.

Step 3. Using the base SPF (i.e., SPF without the CMFs) from the HSM, and used that to predict the number of crashes during that year:

=

Where, b0 and b1 are coefficients from the base SPF (for this illustration, it is assumed that the base SPF is of the functional form given above, and appropriate changes will have to be made if a different functional form is used).

Step 4. Find the proxy calibration factors for that year:

Step 5. Find as follows:

Lord et al., (2015) recommend that if > 10%, then a calibration factor will need to be estimated for that year.

Overview of Prediction Models in 1st Edition of the HSM

Following sections provide an overview of the prediction models from the 1st edition of the HSM for rural two-lane roads, rural multi-lane divided roads, and urban two-lane undivided arterials.

Rural Two-Lane Roads

For rural two-lane, two-way undivided roads, the predictive model from the 1st edition of the HSM is as follows:

Where, is the predicted average crash frequency for an individual roadway segment for a specific year, is the predicted average crash frequency for base conditions for an individual roadway segment, is the calibration factor for roadway segments of a specific type developed for a particular jurisdiction or geographical area, and to are crash modification factors (also called adjustment factors).

The base condition SPF for predicted average crash frequency for rural two-lane, two-way roadway segments is as follows:

Where, is the average annual daily traffic volume, and is the length of the roadway segment in miles. In other words, the relationship between between AADT is linear. This is important and has implications for the use of the approaches recommended by Lord et al., (2015) versus crash rates.

The overdispersion parameter () is estimated as a function of the length of the roadway segment:

The base conditions for the SPF are as follows (note that a CMF is available for each of these 12 base conditions, and they can be modified based on actual conditions):

* Lane width of 12 feet
* Shoulder width of 6 feet
* Paved shoulder
* Roadside hazard rating of 3
* Driveway density of 5 driveways per mile
* No horizontal curvature
* No centerline rumble strips
* No passing lanes
* No two-way left turn lanes
* No lighting
* No automated speed enforcement
* Grade of 0%

Rural Four-Lane Divided Roads

For rural four-lane, divided roads, the predictive model from the 1st edition of the HSM is as follows:

Where, is the predicted average crash frequency for an individual roadway segment for a specific year, is the predicted average crash frequency for base conditions for an individual roadway segment, is the calibration factor for roadway segments of a specific type developed for a particular jurisdiction or geographical area, and to are crash modification factors (also called adjustment factors).

The base condition SPF for predicted average crash frequency for rural two-lane, two-way roadway segments is as follows:

Where, is the average annual daily traffic volume, is the length of the roadway segment in miles, and and are regression coefficients.

The overdispersion parameter () is estimated as a function of the length of the roadway segment:

Where, is the regression coefficient used to determine the overdispersion parameter.

For total crashes, the regression coefficients are as follows:

Unlike the prediction model for rural two-lane roads, the relationship between and AADT is not linear. However, with *b* (the power for AADT) = 1.049, the relationship is close to being linear (if *b* = 1.0, then the relationship is linear as in the case of rural two-lane roads). Again, this has implications for the use of the approaches recommended by Lord et al., (2015) versus crash rates.

The base conditions for the SPF are as follows (note that a CMF is available for each of these 5 base conditions, and they can be modified based on actual conditions):

* Lane width of 12 feet
* Right shoulder width of 8 feet
* Median width of 30feet
* No lighting
* No automated speed enforcement

Urban Two-Lane Undivided Arterials

For urban two-lane undivided arterials, the predictive model from the 1st edition of the HSM is as follows:

Where, is the predicted average crash frequency for an individual roadway segment for a specific year, is the predicted average crash frequency for an individual roadway segment (excluding vehicle-pedestrian and vehicle-bicycle collisions), is the predicted average crash frequency of vehicle-pedestrian collisions for an individual roadway segment, is the predicted average crash frequency of vehicle-bicycle collisions for an individual roadway segment, is the predicted average crash frequency for base conditions for an individual roadway segment excluding vehicle-pedestrian and vehicle-bicycle collisions), is the calibration factor for roadway segments of a specific type developed for a particular jurisdiction or geographical area, and to are crash modification factors (also called adjustment factors).

The base condition SPF for predicted average crash frequency for urban two-lane undivided arterials is as follows:

Where, is the predicted average crash frequency of multiple-vehicle non-driveway crashes for base conditions, is the predicted average crash frequency of single vehicle crashes for base conditions, and is the predicted average crash frequency of multiple-vehicle driveway related crashes.

The SPF for multiple-vehicle non-driveway crashes is applied as follows:

Where, is the average annual daily traffic volume, is the length of the roadway segment in miles, and and are regression coefficients.

For total crashes, the regression coefficients are as follows:

The SPF for single-vehicle crashes is applied as follows:

Where, is the average annual daily traffic volume, is the length of the roadway segment in miles, and and are regression coefficients.

For total crashes, the regression coefficients are as follows:

The total number of multiple-vehicle driveway related crashes are determined as follows:

Where, is the number of driveway-related collisions per driveway per year for driveway type ,is number of driveways within roadway segment of driveway type including all driveways on both sides of the road, and is the regression coefficient for traffic volume adjustment ( for urban two-lane undivided arterials).

Seven specific driveway types are considered for the modelling. values for each of these driveways is as follows:

* Major commercial driveways -
* Minor commercial driveways -
* Major industrial/institutional driveways -
* Minor industrial/institutional driveways -
* Major residential driveways -
* Minor residential driveways -
* Other driveways -

The base conditions for the SPF are as follows (note that a CMF is available for each of these 4 base conditions, and they can be modified based on actual conditions):

* Absence of on-street parking
* Absence of roadside fixed objects
* No lighting
* No automated speed enforcement

The number of vehicle-pedestrian collisions per year for a roadway segment are estimated as:

Where, is the pedestrian crash adjustment factor (0.036 for posted speed of 30mph or lower, or 0.005 for posted speed greater than 30mph).

The number of vehicle-bicycle collisions per year for a roadway segment are estimated as:

Where, is the bicycle crash adjustment factor (0.018 for posted speed of 30mph or lower, or 0.004 for posted speed greater than 30mph).

Unlike the prediction models for rural two-lane roads and rural multi-lane divided roads, in the prediction model for urban two-lane arterials, *b* (power for AADT) is quite different from 1.0 for multi-vehicle non-driveway collisions (*b* = 1.68), and single vehicle collisions (*b* = 0.56). From that perspective, the relationship between crash frequency and AADT is not linear for these two crash types. Again, this has implications for the use of the approaches recommended by Lord et al., (2015) versus crash rates.

Summary of Data

As mentioned earlier, recent data (2016 – 2019) for rural two-lane roads and rural four-lane divided roads from North Carolina was compiled as part of two recent projects (NCHRP Project 17-72: Update of Crash Modification Factors for the Highway Safety Manual; NCDOT Project 2020-27: Updated and Regional Calibration Factors for Highway Safety Manual Prediction Models 2016-2019). Data were collected for the three regions in North Carolina, i.e., Coast, Mountains, and Piedmont, and were summed to get the state totals. Table 1 shows the sum of mileage (by roadway type by region). Tables 2 and 3 shows the AADT ranges and the total observed crashes (by roadway type by region by year). Note that in the Tables, rural two-lane roads are denoted by Rural 2U, rural four-lane divided roads are denoted by Rural 4D, and urban two-lane undivided arterials are denoted by Urban 2U.

Table . Sum of Mileage (by Roadway Type and Region)

|  |  |  |
| --- | --- | --- |
| **Roadway Type** | **Region** | **Sum of Mileage** |
| Rural 2U | All NC | 732.74 |
| Rural 2U | Coast | 193.78 |
| Rural 2U | Mountain | 277.88 |
| Rural 2U | Piedmont | 261.08 |
| Rural 4D | All NC | 197.27 |
| Rural 4D | Coast | 60.21 |
| Rural 4D | Mountain | 77.28 |
| Rural 4D | Piedmont | 59.78 |
| Urban 2U | All NC | 42.01 |

Table . Summary of Yearly Volume Data (by Roadway Type and Region)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roadway Type** | **Region** | **AADT** | **2016** | **2017** | **2018** | **2019** |
| Rural 2U | All NC | Minimum | 60 | 70 | 65 | 50 |
| Rural 2U | All NC | Maximum | 35000 | 42925 | 50850 | 58775 |
| Rural 2U | All NC | Average | 1965 | 2021 | 2052 | 2083 |
| Rural 2U | Coast | Minimum | 70 | 80 | 70 | 50 |
| Rural 2U | Coast | Maximum | 8700 | 9450 | 10200 | 10950 |
| Rural 2U | Coast | Average | 1613 | 1644 | 1741 | 1839 |
| Rural 2U | Mountain | Minimum | 60 | 70 | 80 | 70 |
| Rural 2U | Mountain | Maximum | 14000 | 14000 | 13500 | 13500 |
| Rural 2U | Mountain | Average | 2257 | 2347 | 2369 | 2391 |
| Rural 2U | Piedmont | Minimum | 75 | 70 | 65 | 60 |
| Rural 2U | Piedmont | Maximum | 35000 | 42925 | 50850 | 58775 |
| Rural 2U | Piedmont | Average | 1686 | 1702 | 1711 | 1720 |
| Rural 4D | All NC | Minimum | 2800 | 2500 | 2700 | 2700 |
| Rural 4D | All NC | Maximum | 34000 | 32000 | 34000 | 38000 |
| Rural 4D | All NC | Average | 13842 | 14100 | 14579 | 15059 |
| Rural 4D | Coast | Minimum | 3000 | 2700 | 2700 | 2700 |
| Rural 4D | Coast | Maximum | 34000 | 32000 | 31500 | 35000 |
| Rural 4D | Coast | Average | 14308 | 14229 | 14718 | 15207 |
| Rural 4D | Mountain | Minimum | 2800 | 2500 | 2800 | 3100 |
| Rural 4D | Mountain | Maximum | 29000 | 28250 | 27500 | 26750 |
| Rural 4D | Mountain | Average | 11708 | 11914 | 11888 | 11863 |
| Rural 4D | Piedmont | Minimum | 4000 | 4700 | 4400 | 3600 |
| Rural 4D | Piedmont | Maximum | 28000 | 30000 | 34000 | 38000 |
| Rural 4D | Piedmont | Average | 16550 | 17172 | 18378 | 19584 |
| Urban 2U | All NC | Minimum | 280 | 265 | 250 | 235 |
| Urban 2U | All NC | Maximum | 29000 | 30250 | 31500 | 32750 |
| Urban 2U | All NC | Average | 8060 | 8242 | 8547 | 8852 |

Table . Total Yearly Observed Crashes (by Roadway Type and Region)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roadway Type** | **Region** | **Crash Type** | **2016** | **2017** | **2018** | **2019** |
| Rural 2U | All NC | Total | 715 | 735 | 717 | 756 |
| Rural 2U | Coast | Total | 186 | 185 | 206 | 195 |
| Rural 2U | Mountain | Total | 266 | 304 | 289 | 314 |
| Rural 2U | Piedmont | Total | 263 | 246 | 222 | 247 |
| Rural 4D | All NC | Total | 646 | 745 | 762 | 758 |
| Rural 4D | Coast | Total | 237 | 264 | 227 | 217 |
| Rural 4D | Mountain | Total | 199 | 250 | 282 | 257 |
| Rural 4D | Piedmont | Total | 210 | 231 | 253 | 284 |
| Urban 2U | All NC | Total | 170 | 170 | 181 | 160 |

Results

This section summarizes the results based on the approach described in Lord et al., (2015), and the use of crash rates. The approach by Lord et al., (2015) used the base condition SPFs from the 1st edition of the HSM (without accounting for the CMFs, i.e., adjustment factors). For the purpose of this analysis, crashes were predicted using both the base condition CMFs (without accounting for adjustment factors), and base condition CMFs (accounting for adjustment factors). Tables 4 – 7 shows the observed total crashes, HSM predicted total crashes (with and without the adjustment factors), and the calibration factors (by region by year). Consistent with the terminology used in Lord et al., (2015), the term proxy calibration factor is used for the calibration factors calculated with just the base model (i.e., without the adjustment factors[[3]](#footnote-3)).

Table . Calibration Factors for All Regions Combined (Rural 2U = 732.74 miles, Rural 4D = 197.27 miles, and Urban 2U = 42.01 miles)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roadway Type** | **Year** | ***Observed Crashes*** | ***HSM Predicted Crashes (w/o Adjustment Factors)*** | ***HSM Predicted Crashes (w/ Adjustment Factors)*** | **Proxy Calibration Factors (w/o Adjustment Factors)** | **Calibration Factors (w/Adjustment Factors)** |
| Rural 2U | 2016 | 715 | 301.22 | 555.48 | ***2.37*** | ***1.29*** |
| Rural 2U | 2017 | 735 | 307.28 | 564.31 | ***2.39*** | ***1.30*** |
| Rural 2U | 2018 | 717 | 313.24 | 572.13 | ***2.29*** | ***1.25*** |
| Rural 2U | 2019 | 756 | 319.27 | 580.00 | ***2.37*** | ***1.30*** |
| Rural 2U | 2016-2019 | 2923 | 1241.00 | 2271.92 | ***2.36*** | ***1.29*** |
| Rural 4D | 2016 | 646 | 515.57 | 516.92 | ***1.25*** | ***1.25*** |
| Rural 4D | 2017 | 745 | 513.89 | 515.52 | ***1.45*** | ***1.45*** |
| Rural 4D | 2018 | 762 | 524.85 | 526.62 | ***1.45*** | ***1.45*** |
| Rural 4D | 2019 | 758 | 536.13 | 538.04 | ***1.41*** | ***1.41*** |
| Rural 4D | 2016-2019 | 2911 | 2089.85 | 2096.51 | ***1.39*** | ***1.39*** |
| Urban 2U | 2016 | 170 | 83.16 | 104.98 | ***2.04*** | ***1.62*** |
| Urban 2U | 2017 | 170 | 85.30 | 107.92 | ***1.99*** | ***1.58*** |
| Urban 2U | 2018 | 181 | 88.92 | 112.40 | ***2.04*** | ***1.61*** |
| Urban 2U | 2019 | 160 | 92.72 | 117.12 | ***1.73*** | ***1.37*** |
| Urban 2U | 2016 - 2019 | 681 | 349.73 | 441.94 | ***1.95*** | ***1.54*** |

Table . Calibration Factors for Coast Region (Rural 2U = 193.78 miles & Rural 4D = 60.21 miles)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roadway Type** | **Year** | ***Observed Crashes*** | ***HSM Predicted Crashes (w/o Adjustment Factors)*** | ***HSM Predicted Crashes (w/ Adjustment Factors)*** | **Proxy Calibration Factors (w/o Adjustment Factors)** | **Calibration Factors (w/Adjustment Factors)** |
| Rural 2U | 2016 | 186 | 69.14 | 118.27 | ***2.69*** | ***1.57*** |
| Rural 2U | 2017 | 185 | 70.15 | 120.06 | ***2.64*** | ***1.54*** |
| Rural 2U | 2018 | 206 | 74.07 | 126.77 | ***2.78*** | ***1.63*** |
| Rural 2U | 2019 | 195 | 78.04 | 133.54 | ***2.50*** | ***1.46*** |
| Rural 2U | 2016-2019 | 772 | 291.40 | 498.64 | ***2.65*** | ***1.55*** |
| Rural 4D | 2016 | 237 | 155.31 | 154.82 | ***1.53*** | ***1.53*** |
| Rural 4D | 2017 | 264 | 149.15 | 148.62 | ***1.77*** | ***1.78*** |
| Rural 4D | 2018 | 227 | 154.43 | 153.97 | ***1.47*** | ***1.47*** |
| Rural 4D | 2019 | 217 | 159.78 | 159.38 | ***1.36*** | ***1.36*** |
| Rural 4D | 2016-2019 | 945 | 618.56 | 616.68 | ***1.53*** | ***1.53*** |

Table . Calibration Factors for Mountain Region (Rural 2U = 277.88 miles & Rural 4D = 77.28 miles)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roadway Type** | **Year** | ***Observed Crashes*** | ***HSM Predicted Crashes (w/o Adjustment Factors)*** | ***HSM Predicted Crashes (w/ Adjustment Factors)*** | **Proxy Calibration Factors (w/o Adjustment Factors)** | **Calibration Factors (w/Adjustment Factors)** |
| Rural 2U | 2016 | 266 | 125.43 | 237.67 | ***2.12*** | ***1.12*** |
| Rural 2U | 2017 | 304 | 129.17 | 243.76 | ***2.35*** | ***1.25*** |
| Rural 2U | 2018 | 289 | 129.19 | 243.11 | ***2.24*** | ***1.19*** |
| Rural 2U | 2019 | 314 | 129.21 | 242.47 | ***2.43*** | ***1.30*** |
| Rural 2U | 2016-2019 | 1173 | 513.00 | 967.01 | ***2.29*** | ***1.21*** |
| Rural 4D | 2016 | 199 | 179.26 | 183.23 | ***1.11*** | ***1.09*** |
| Rural 4D | 2017 | 250 | 183.61 | 187.95 | ***1.36*** | ***1.33*** |
| Rural 4D | 2018 | 282 | 181.67 | 186.13 | ***1.55*** | ***1.52*** |
| Rural 4D | 2019 | 257 | 179.79 | 184.37 | ***1.43*** | ***1.39*** |
| Rural 4D | 2016-2019 | 988 | 724.22 | 741.56 | ***1.36*** | ***1.33*** |

Table . Calibration Factors for Piedmont Region (Rural 2U = 261.08 miles & Rural 4D = 59.78 miles)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roadway Type** | **Year** | ***Observed Crashes*** | ***HSM Predicted Crashes (w/o Adjustment Factors)*** | ***HSM Predicted Crashes (w/ Adjustment Factors)*** | **Proxy Calibration Factors (w/o Adjustment Factors)** | **Calibration Factors (w/Adjustment Factors)** |
| Rural 2U | 2016 | 263 | 106.65 | 199.55 | ***2.47*** | ***1.32*** |
| Rural 2U | 2017 | 246 | 107.96 | 200.49 | ***2.28*** | ***1.23*** |
| Rural 2U | 2018 | 222 | 109.98 | 202.24 | ***2.02*** | ***1.10*** |
| Rural 2U | 2019 | 247 | 112.01 | 203.99 | ***2.21*** | ***1.21*** |
| Rural 2U | 2016-2019 | 978 | 436.60 | 806.28 | ***2.24*** | ***1.21*** |
| Rural 4D | 2016 | 210 | 181.00 | 178.86 | ***1.16*** | ***1.17*** |
| Rural 4D | 2017 | 231 | 181.13 | 178.95 | ***1.28*** | ***1.29*** |
| Rural 4D | 2018 | 253 | 188.75 | 186.53 | ***1.34*** | ***1.36*** |
| Rural 4D | 2019 | 284 | 196.55 | 194.29 | ***1.44*** | ***1.46*** |
| Rural 4D | 2016-2019 | 978 | 747.07 | 738.27 | ***1.31*** | ***1.32*** |

Table 8 shows the crash rates (per million vehicle miles travelled) by roadway type and region using the data from the calibration sample.

Table . Crashes Rates (per MVMT) by Roadway Type and Region

|  |  |  |
| --- | --- | --- |
| **Roadway Type** | **Year** | ***Crash Rates (per MVMT)*** |
| ***All Regions combined*** | ***Coast Region*** | ***Mountain Region*** | ***Piedmont Region*** |
| Rural 2U | 2016 | 634.19 | 718.79 | 566.58 | 658.86 |
| Rural 2U | 2017 | 639.08 | 704.57 | 628.80 | 608.81 |
| Rural 2U | 2018 | 611.55 | 743.05 | 597.67 | 539.29 |
| Rural 2U | 2019 | 632.65 | 667.57 | 649.26 | 589.15 |
| Rural 2U | 2016-2019 | 629.29 | 707.82 | 610.90 | 598.48 |
| Rural 4D | 2016 | 241.75 | 293.86 | 213.32 | 225.13 |
| Rural 4D | 2017 | 279.75 | 340.17 | 262.03 | 247.61 |
| Rural 4D | 2018 | 280.55 | 283.16 | 298.48 | 260.93 |
| Rural 4D | 2019 | 273.74 | 262.31 | 274.73 | 282.21 |
| Rural 4D | 2016-2019 | 269.03 | 294.25 | 262.26 | 254.58 |
| Urban 2U | 2016 | 536.76 | - | - | - |
| Urban 2U | 2017 | 525.69 | - | - | - |
| Urban 2U | 2018 | 540.31 | - | - | - |
| Urban 2U | 2019 | 461.58 | - | - | - |
| Urban 2U | 2016-2019 | 515.23 | - | - | - |

Note. For Urban 2U, sufficient data were not available by region to calculate crash rates or calibration factors.

Change in Location

Relative differences between the calibration factors for the state (all regions combined) and the individual regions were calculated separately for each year and for the combined four years (2016 – 2019). Similar to the suggestion in Lord et al., (2015), the following equation can be used to find the relative difference between the calibration factors for the state (all regions combined) and the mountain region for 2017.

The relative difference between the crash rates (per MVMT) was also derived using the similar method using crash rates (per MVMT) instead of proxy calibration factors. As an example, the following equation can be used to find the relative difference between the crash rates (per MVMT) for the state (all regions combined) and the mountain region for 2017.

Tables 9 and 10 summarize the relative differences between the proxy calibration factors and the crash rates by roadway type. With these Tables, the intent is to determine how well the percentages associated with the proxy calibration factors and the crash rates track with the calibration factors that were calculated using the adjustment factors from the 1st edition of the HSM.

For Rural 2U (Table 9), as expected, the proxy calibration factors, and crash rates (per MVMT) have the same percentage values. This is because for Rural 2U, the relationship between crash frequency and AADT is linear. For the coastal region, the percentages associated with the proxy calibration factors and the crash rates are quite different from the calibration factors with the adjustment factors. For 4D, the percentages associated with the proxy calibration factors and crash rates are closer to the percentages associated with the calibration factors with the adjustment factors. As mentioned earlier, the power for AADT in the Rural 4D SPF is 1.049 (not very different from 1.0). So, both the proxy calibration factors, and crash rates are not very different in terms of their percentages compared to the calibration factors with adjustment factors.

Table . Relative Differences between the Proxy Calibration Factors and Crash rates (per MVMT) for Rural 2U

|  |  |  |  |
| --- | --- | --- | --- |
| **Roadway Type** | **Year** | **Region** | **Relative Difference to State (all regions combined)** |
| ***Proxy Calibration Factors (w/o Adjustment Factors)*** | ***Calibration Factors (w/Adjustment Factors)*** | ***Crash Rates (per MVMT)*** |
| Rural 2U | 2016  | Coast | 13.3% | 22.2% | 13.3% |
| Mountain | 10.7% | 13.0% | 10.7% |
| Piedmont | 3.9% | 2.4% | 3.9% |
| Rural 2U | 2017  | Coast | 10.2% | 18.3% | 10.2% |
| Mountain | 1.6% | 4.2% | 1.6% |
| Piedmont | 4.7% | 5.8% | 4.7% |
| Rural 2U   | 2018  | Coast | 21.5% | 29.7% | 21.5% |
| Mountain | 2.3% | 5.1% | 2.3% |
| Piedmont | 11.8% | 12.4% | 11.8% |
| Rural 2U | 2019 | Coast | 5.5% | 12.0% | 5.5% |
| Mountain | 2.6% | 0.6% | 2.6% |
| Piedmont | 6.9% | 7.1% | 6.9% |
| Rural 2U | 2016-2019  | Coast | 12.5% | 20.3% | 12.5% |
| Mountain | 2.9% | 5.7% | 2.9% |
| Piedmont | 4.9% | 5.7% | 4.9% |

Table . Relative Differences between the Proxy Calibration Factors and Crash rates (per MVMT) for Rural 4D

|  |  |  |  |
| --- | --- | --- | --- |
| **Roadway Type** | **Year** | **Region** | **Relative Difference to State (all regions combined)** |
| ***Proxy Calibration Factors (w/o Adjustment Factors)*** | ***Calibration Factors (w/Adjustment Factors)*** | ***Crash Rates (per MVMT)*** |
| Rural 4D | 2016  | Coast | 21.8% | 22.5% | 21.8% |
| Mountain | 11.4% | 13.1% | 11.8% |
| Piedmont | 7.4% | 6.1% | 6.9% |
| Rural 4D | 2017  | Coast | 22.1% | 22.9% | 21.6% |
| Mountain | 6.1% | 8.0% | 6.3% |
| Piedmont | 12.0% | 10.7% | 11.5% |
| Rural 4D | 2018 | Coast | 1.2% | 1.9% | 0.9% |
| Mountain | 6.9% | 4.7% | 6.4% |
| Piedmont | 7.7% | 6.3% | 7.0% |
| Rural 4D | 2019  | Coast | 3.9% | 3.4% | 4.2% |
| Mountain | 1.1% | 1.1% | 0.4% |
| Piedmont | 2.2% | 3.8% | 3.1% |
| Rural 4D  | 2016-2019 | Coast | 9.7% | 10.4% | 9.4% |
| Mountain | 2.2% | 3.8% | 3.1% |
| Piedmont | 6.0% | 4.6% | 5.4% |

Change in Safety Over Time

Relative year to year differences between the proxy calibration factors were calculated for the state (all regions combined). As an example, the following equation can be used to find the relative difference between the proxy calibration factors for the state (all regions combined) when comparing 2017 to 2016.

The relative difference between the crash rates (per MVMT) was also derived using the similar method using crash rates (per MVMT) instead of proxy calibration factors. As an example, the following equation can be used to find the relative difference between the crash rates (per MVMT) for the state (all regions combined) when comparing 2017 to 2016.

Table 11 summarizes the relative differences between the proxy calibration factors and the crash rates by roadway type for changes over years. As in the case of Tables 9 and 10, for Rural 2U and Rural 4D, the percentages associated with proxy calibration factors, crash rates, and calibration factors with adjustment factors are very similar. However, for Urban 2U, the percentages associated with the proxy calibration factors is much closer to the percentages associated with the calibration factors with the adjustment factors. As mentioned earlier, this may because the power for AADT in the Urban 2U CPMs was quite different from 1.0.

Table . Relative Differences between the Proxy Calibration Factors and Crash rates (per MVMT) for Changes Over Time

|  |  |  |
| --- | --- | --- |
| **Roadway Type** | **Change in Year** | **Relative Difference Over Time** |
| ***Proxy Calibration Factors (w/o Adjustment Factors)*** | ***Calibration Factors (w/Adjustment Factors)*** | ***Crash Rates (per MVMT)*** |
| Rural 2U | 2016 to 2017 | 0.8% | 1.2% | 0.8% |
| 2017 to 2018 | 4.3% | 3.8% | 4.3% |
| 2018 to 2019 | 3.5% | 4.0% | 3.5% |
| Rural 4D  | 2016 to 2017 | 15.7% | 15.6% | 15.7% |
| 2017 to 2018 | 0.1% | 0.1% | 0.3% |
| 2018 to 2019 | 2.6% | 2.6% | 2.4% |
| Urban 2U | 2016 to 2017 | 2.6% | 2.8% | 2.1% |
| 2017 to 2018 | 4.2% | 4.2% | 2.8% |
| 2018 to 2019 | 4.3% | 4.2% | 14.6% |

Discussion and Recommended Guidance

The results from Tables 9 through 11 indicate that for Rural 2U and Rural 4D, there is very little difference between using proxy calibration factors and crash rates to determine whether regional calibration factors are needed, or if calibration is needed for a specific year. However, for Urban 2U, the proxy calibration factors are expected to provide more reliable results regarding calibration is needed for a particular year. Data were not available to calibrate Urban 2U models by region. As mentioned earlier, the primary reason for this difference between Rural facilities investigated in this effort, versus Urban 2U, is the relationship between crash frequency and AADT in the CPM.

Based on these results, the following guidance is recommended for practitioners:

* If the relationship between AADT and crash frequency is close to a linear relationship, then crash rates may be sufficient to determine if regional calibration factors are needed, or to determine if calibration is needed for a specific year. If the SPF is a power model as in the case of Rural 2U, Rural 4D, and Urban 2U, then the power of the AADT term provides insight into whether the relationship is close to a linear relationship. If the power of the AADT term is between 0.9 and 1.1, then the relationship could be considered close to a linear relationship.
* If the power of the AADT term is less than 0.9 or greater than 1.1, or the SPF is a based on a more complex model form such as a *Hoerl* function (Hauer, 2015), then the approaches described in Lord et al., (2015) are expected to provide more reliable guidance regarding the need for regional calibration factors, or the need for calibration factors by year.

References

Hauer, E. (2015), *The Art of Regression Modeling in Road Safety*, Springer.

HSM (2010). “Highway Safety Manual.” American Association of State Highway and Transportation Officials. Washington, D.C.

Lord, D., Geedipally, S., Shirazi, M (2015)*. Improved Guidelines for Estimating the Highway Safety Manual Calibration Factors*. Advancing Transportation Leadership and Safety (ATLAS) Center, Ann Arbor, MI, December 2015.

Smith, S., D. Carter, R. Srinivasan (2017), *Updated and Regional Calibration Factors for Highway Safety Manual Crash Prediction Models*, Report FHWA/NC/2016-09, North Carolina Department of Transportation, February 2017.

1. Instead of the total number of crashes, depending on the application, a specific crash or severity could be included. For segment level crashes, only non-intersection crashes will need to be included. [↑](#footnote-ref-1)
2. Instead of the total number of crashes, depending on the application, a specific crash or severity could be included. For segment level crashes, non-intersection crashes will need to be included. [↑](#footnote-ref-2)
3. Adjustment factors were called Part C CMFs in the 1st edition of the HSM. [↑](#footnote-ref-3)