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Calibrating the *Highway Safety Manual* Predictive Methods for Texas Highways: Technical Report

Technical Report 5-7083-01-R1

Cooperative Research Program

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16. Abstract

The *Highway Safety Manual* (HSM) contains safety performance functions (SPFs) that are used in project-level decision-making to estimate the average crash frequency by severity level for existing conditions, alternatives to existing conditions, or proposed new roadways. Because most existing HSM SPFs were developed for states other than Texas, SPF calibration is needed to apply for Texas highways. Calibration is conducted to account for differences in crash reporting procedures, thresholds, driver characteristics, animal population, and weather conditions, among others. The Texas Department of Transportation (TxDOT) sponsored Research Projects 0-7083 and 0-7067 that derived local calibration factors for the SPFs documented in the HSM Chapters 10, 11, 12, and 18. Researchers also developed new safety prediction models for frontage roads and ramp segments. These projects developed analysis spreadsheet tools to help implement the new models and facilitate analysis of all rural and urban roadway segments and intersections.

The researchers developed training workshop and webinar materials to assist TxDOT practitioners and consulting firms in their application of these new resources. The researchers presented these workshops and the webinar to safety stakeholders about the safety prediction methods and usage of spreadsheet tools for estimating the average crash frequency at a particular site and in evaluating different cross-sectional alternatives. This training will help safety professionals in evaluating complex trade-offs between safety, operations, community impacts, and costs that are often necessary when planning and designing highway projects.

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CALIBRATING THE *HIGHWAY SAFETY MANUAL* PREDICTIVE METHODS FOR TEXAS HIGHWAYS: TECHNICAL REPORT

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DISCLAIMER

This research was sponsored by the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data published herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. It is not intended for construction, bidding, or permitting purposes. The engineer in charge of the project was Srinivas R. Geedipally, P.E. #109898.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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- Jade Adediwura, Project Manager, Research and Technology Implementation Office, TxDOT.
- Khalid Jamil, Section Director, Traffic Simulation and Safety Analysis, Design Division, TxDOT.
- Mark Middleton, Transportation Engineer, Traffic Simulation and Safety Analysis, Design Division, TxDOT.
- Stephen Ratke, Senior Safety & Geometric Design Engineer, FHWA Texas Division.

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INTRODUCTION

The *Highway Safety Manual* (HSM) contains safety performance functions (SPFs) that are used in project-level decision-making to estimate the average crash frequency by severity level for existing conditions, alternatives to existing conditions, or proposed new roadways. Because most existing HSM SPFs were developed for states other than Texas, SPF calibration is needed to apply for Texas highways. Calibration is conducted to account for differences in crash reporting procedures, thresholds, driver characteristics, animal population, and weather conditions, among others.

Recently, the Texas Department of Transportation (TxDOT) sponsored two research projects to develop safety prediction methods for all Texas highways. These projects include the following:

- Research Project 0-7083 (*1*): Develop Highway Safety Manual (HSM) Safety Performance Functions (SPFs) and Calibration Factors for Texas.
- Research Project 0-7067 (*2*): Enhancing Freeway Safety Prediction Models.

The safety prediction methods are used to predict safety performance and help with the complex trade-offs between safety, operations, community impacts, and costs that are often necessary when planning and designing highway projects. These projects developed analysis spreadsheet tools to help implement the new methods and facilitate analysis of all rural and urban roadway segments and intersections.

Researchers conducted a pilot testing of the safety prediction methodology by selecting a sample of roadways and using the spreadsheets to obtain crash estimates. This exercise assisted in validating the quality of the spreadsheets, guidance related to the spreadsheets, and the predictive methodology. It also yielded insights into the challenges in collecting required data, issues with data inputs, problems with the interpretation of results, potential shortcomings of predictive methods, and areas for improvement.

Researchers developed slides, visual aids, and handout materials and presented training workshops and a webinar for TxDOT practitioners to demonstrate the use of the spreadsheet tools. These hands-on trainings contained multiple examples for estimating the average crash frequency at a particular site and for evaluating different cross-sectional alternatives.

This report consists of three main parts following this Introduction section. The first part describes the workshop and webinar that were developed and conducted. The second part describes the spreadsheet updates. The third part summarizes the project activities and provides suggestions for future activities.

WORKSHOP AND WEBINAR DESCRIPTION

This section provides a description of the workshop and webinar content and a review of the presentations at three workshop venues in Texas, the 97th Annual Transportation Short Course, and an online webinar. The first subsection provides an overview of the workshop course, which is followed by a review of the learning objectives. Then, the course format and venues are outlined, and the participant evaluations are summarized. The final subsection documents the short course and webinar presentation details.

WORKSHOP OVERVIEW

The workshop objectives were to (a) inform participants about safety prediction methods and their use in project-level decision-making to estimate the average crash frequency by severity level for existing conditions, alternatives to existing conditions, or proposed new roadways; (b) inform participants about guidelines and software tools to help implement the new models and facilitate analysis of all rural and urban roadway segments and intersections; and (c) demonstrate the use of these tools. The workshops were developed for TxDOT practitioners and consulting firms.

The following two activities were undertaken in relation to the workshop:

- Develop training materials (i.e., visual aids, handouts, hands-on training sessions, and spreadsheet tools) that impart the information needed to conduct safety analysis.
- Conduct one 4-hour training course at each of the three venues.

WORKSHOP LEARNING OBJECTIVES

The course content was tailored to facilitate participant learning. The visual aids were primarily in the form of a PowerPoint® presentation. These presentations included numerous photographs, illustrations, and example situations for discussion. The visual aids were supplemented with printed materials that included a Participant’s Guide that contained a print copy of the visual aids.

The following key points were emphasized throughout the workshop:

- Safety impact should be considered when planning projects.
- Evidence-based safety prediction methods that provide state and local agencies with the means to quantify safety impacts should be used.
- Methods documented in the *Highway Safety Manual* have been calibrated to Texas conditions.

Each of these key points was repeated throughout the workshop to emphasize its importance and ensure information retention by participants.

WORKSHOP FORMAT

The workshop presentations consisted of approximately four hours of instruction, which included a presentation about safety prediction methods, demonstration of the spreadsheet tools, and hands-on training of the tools. The visual aids used in the course consisted primarily of 100 PowerPoint® slides.

The course agenda is provided in Table 1. It consisted of four lessons. These lessons comprehensively described the importance of considering the safety impacts while planning projects, data-driven scientific methods for quantifying safety, and availability of easy-to-use spreadsheet tools to estimate crashes. The agenda also included two hands-on training sessions after lunch.

Table 1. Workshop Agenda.

Start Time	Lesson	Objectives
10:00	Introduction and Scope	
10:15	Lesson 1: Safety Models	Present an overview of the *Highway Safety Manual* contents. Explain the safety analysis components, including Safety Performance Functions, Crash Modification Factors, and Calibration. Present the calibration results and new models developed for managed lane freeways, frontage roads, and ramps.
11:25	Lesson 2: Spreadsheet Tools	Provide an overview of the spreadsheet tools, including data needs, guidance, and modeling output details.
12:00	Lunch Break	
1:00	Lesson 3: Hands-On Training Part 1	Conduct hands-on training by providing examples of non-freeway segments and intersections in rural and urban areas.
2:15	Lesson 4: Hands-On Training Part 2	Conduct hands-on training by selecting and analyzing a rural freeway, frontage road and an exit ramp.
3:00	Adjourn	

The first hands-on training session involved providing sample problems with input data to the participants and asking them to download the appropriate spreadsheet. Once they entered the data, they were asked to provide answers to multiple questions. If they had difficulty entering the data, the instructors assisted them. The answers to the questions were discussed in detail and also showed the safety performance of various alternative designs. These four facilities were covered in Lesson 3:

- Rural stop-controlled intersection.
- Rural multi-lane divided highway segment.
- Urban undivided arterial segment.
- Urban divided arterial segment.

For the second hands-on training, in Austin, the participants were asked to select a freeway section they prefer. Due to the complexity, they requested the instructors select one for them. As a result, the instructors selected a section on I-45 near Madisonville for the Dallas and Houston workshops. They were first given guidance about the segmentation process and then asked the number of segments they would divide the proposed section into. Second, they were asked to collect the data variables from the TxDOT data sources and Google earth aerial photography and street views and input them into the spreadsheets. Once completed, these were the questions asked:

- How many segments will you divide this mainline section into?
- What is the traffic volume on the main lanes?
- What is the traffic volume of the frontage road?
- Which ramps are included in milepost measurements?
- Which ramp feeds traffic into or out of the segment?
- What are the distances to relevant ramps?
- How are barriers counted?
- Which design elements have the greatest effect (positive or negative) on multi-vehicle (MV) crash frequency?
- What is the crash frequency on the freeway?

WORKSHOP VENUES

Three workshop presentations were conducted. Table 2 summarizes the locations, dates, and attendance numbers for each course presentation. All course presentations were held at TxDOT facilities. Practitioners from the TxDOT districts, as well as from several consultant firms that are safety stakeholders, were able to attend.

Table 2. Course Venues and Attendance.

City	Venue	Date	Participant Count
Austin	TxDOT Austin District, Stassney Campus	9/28/2023	24
Dallas	TxDOT Dallas District	10/27/2023	30
Houston	TxDOT Houston District	1/22/2024	12
Total	All venues	All dates	66

WORKSHOP EVALUATION

Participants were given evaluation forms near the end of each workshop presentation and asked to comment on the course content and format. The evaluation form contained four questions on the course content and four questions on the participant's general observations about the strengths and weaknesses of the course format.

The four questions that inquired about course content were the following:

1. Did the course meet your expectations?
2. Was the material presented at the correct level of difficulty?
3. Was the topic of the course covered adequately (nothing left out, no one topic overemphasized)?
4. Was the software easy to use?

Participants were instructed to respond to each question using a scale of 1 to 5, as shown in Table 3.

Table 3. Scoring Criteria.

Score	Opinion
1	No/Strongly Disagree
2	Somewhat Disagree
3	Maybe/Neutral
4	Somewhat Agree
5	Yes/Strongly Agree

Each question was posed such that a *yes* response indicated a high degree of satisfaction. Table 4 summarizes the responses to the first four questions.

Table 4. Participant Evaluations of Workshop Content.

Course Venue	Number of Responses	Average Participant Response by Question				Average
		1	2	3	4	
Austin	24	4.5	4.2	4.3	4.5	4.4
Dallas	30	4.7	4.3	4.1	4.2	4.3
Houston	12	4.6	4.3	4.3	4.5	4.4
Average	66	4.6	4.3	4.2	4.4	4.4

The second set of four questions inquired about each participant's general observations of course strengths and weaknesses. Unlike the first four questions, the questions in the second set were open-ended. The specific questions posed to the participants included:

5. What did you like most about the course?
6. What did you like least about the course?
7. What can we do to improve this course?
8. Do you have any other comments?

Of the 66 course participants, 56 provided responses either completely or partially to Questions 5–8. Some even provided detailed responses to Questions 1–4. When asked what portion of the training course the participant liked best, the most common responses were the hands-on training lessons with the spreadsheet tool, the presentation organization and interactive nature, obtaining safety prediction knowledge, and the questions and answers. Regarding the presentation, participants liked the instruction style, inclusion of examples, interactivity, and opportunity for question-and-answer sessions and discussions of issues that the practitioners encounter in their work.

A few participants thought that the course time was short and noted that more time would have been helpful. Many participants expressed concerned about the technology difficulties at the venue. Some participants felt that the room in Dallas was too small, and a few participants had to sit outside the room.

Several comments provided by early workshop participants led to key improvements to the workshop format and guidance material in the spreadsheet tool. For example, the first workshop in Austin asked the participants to select a freeway, but the participants suggested that the instructors select one. This recommendation was implemented in the second and third workshops. Several workshop participants also suggested adding more guidance and changing the color coding, and those were subsequently implemented.

SHORT COURSE AND WEBINAR PRESENTATION

The project team made a brief presentation at the 97th Annual Transportation Short Course held in College Station, Texas. The presentation included details about the safety prediction methods, spreadsheet tools, and announcement of workshops and webinar. After the workshop series was completed, the research team conducted a webinar online on January 24, 2024, to reach a wide range of audiences. More than 100 people attended the webinar. The agenda focused on the highlights from the workshops but omitted the hands-on training sessions.

MODEL AND SOFTWARE UPDATES

MODEL UPDATES

As a result of pilot testing, the research team updated a few models and adjusted some calibration and region-specific factors. No changes were made to rural highway SPFs. Table 5 provides the updated urban arterial SPF equations.

Table 5. Updated Urban Arterial SPF Equations.

Model*	Equation	Overdispersion Parameter
MV non-driveway, U2U segments	$N_{spf,rs,mv} = L\, e^{\mathbf{-12.281}} AADT^{\mathbf{1.335}}$	0.81
MV non-driveway, U4U segments	$N_{spf,rs,mv} = L\, e^{\mathbf{-14.795}} AADT^{\mathbf{1.668}}$	0.867
MV non-driveway, U4D segments	$N_{spf,rs,mv} = L\, e^{\mathbf{-11.524}} AADT^{\mathbf{1.249}}$	0.967
MV non-driveway, U5T segments	$N_{spf,rs,mv} = L\, e^{\mathbf{-8.189}} AADT^{\mathbf{0.971}}$	1.148
MV, 3ST intersections	$N_{spf,3ST,mv} = e^{-14.492} {AADT_{maj}}^{1.26} {AADT_{min}}^{0.38}$	0.81
SV, 3ST intersections	$N_{spf,3ST,sv} = e^{-9.087} {AADT_{maj}}^{0.21} {AADT_{min}}^{0.72}$	1.34
MV, 4ST intersections	$N_{spf,4ST,mv} = e^{-14.235} {AADT_{maj}}^{1.053} {AADT_{min}}^{0.705}$	0.59
SV, 4ST intersections	$N_{spf,4ST,sv} = e^{-8.095} {AADT_{maj}}^{0.53} {AADT_{min}}^{0.12}$	0.19
MV, 3SG intersections	$N_{spf,3SG,mv} = e^{-15.945} {AADT_{maj}}^{1.48} {AADT_{min}}^{0.27}$	1.39
SV, 3SG intersections	$N_{spf,3SG,sv} = e^{-8.458} {AADT_{maj}}^{0.42} {AADT_{min}}^{0.27}$	0.11
MV, 4SG intersections	$N_{spf,4SG,mv} = e^{-11.5392} {AADT_{maj}}^{1.106} {AADT_{min}}^{0.278}$	1.44
SV, 4SG intersections	$N_{spf,4SG,sv} = e^{-10.525} {AADT_{maj}}^{0.68} {AADT_{min}}^{0.27}$	0.01

*MV = multi-vehicle; SV = single-vehicle; U2U = urban two-lane; U4U = urban four-lane undivided; U4D = urban four-lane divided; U5T = urban four-lane with a two-way left turn lane; 3ST = three-leg stop-controlled; 4ST = four-leg stop-controlled; 3SG = three-leg signalized; 4SG = four-leg signalized, rs = roadway segment,
L = segment length, AADT = annual average daily traffic (vehicles per day), $AADT_{maj}$ = major-road AADT, $AADT_{min}$ = minor-road AADT.

The calibration factors in Table 58 and Table 78 of the Research Project 0-7083 (*1*) report were updated to values shown in Table 6 and Table 7, respectively.

Table 6. Goodness-of-Fit Measures for Rural Freeway Recalibrated Models—Stage 2.

No. of Lanes	Crash Type	C	SE of C	MAD	MSPE	Modified R^2	Dispersion Parameter	CV	Exceeding 95% CI
4	MV FI	0.67	0.13	0.59	0.62	1.26	0.01	0.19	12%
	MV PDO	0.77	0.22	1.12	3.10	0.70	0.66	0.29	0%
	SV FI	0.56	0.17	1.22	2.94	0.11	1.06	0.31	17%
	SV PDO	0.68	0.12	2.11	8.59	0.61	0.38	0.18	0%
6	MV FI	0.63	0.07	1.52	4.27	0.90	0.06	0.11	0%
	MV PDO	0.60	0.09	3.88	26.48	0.60	0.36	0.15	45%
	SV FI	0.71	0.09	1.59	4.88	0.69	0.21	0.14	0%
	SV PDO	0.81	0.11	4.54	34.07	0.53	0.32	0.13	0%
4-6	MV FI	0.64	0.06	2.37	1.04	0.93	0.05	0.09	0%
	MV PDO	0.62	0.08	15.39	2.52	0.69	0.41	0.13	24%
	SV FI	0.66	0.08	3.96	1.43	0.61	0.32	0.12	0%
	SV PDO	0.77	0.08	20.87	3.26	0.64	0.35	0.11	0%

Table 7. Calibration Factors for MV Driveway-Related Collisions.

Segment Type	Number of Segments	Crash Count		Local Calibration Factor *C*
		Observed	Predicted	
U2U	125	104	80.31	1.30
U3T	117	91	91.46	0.99
U4D	118	71	34.14	2.08
U4U	152	566	591.51	0.96
U5T	136	668	727.04	0.92

The crash adjustment factors in Table 80 and Table 81 of the Research Project 0-7083 (*1*) report were updated to values shown in Table 8 and Table 9, respectively. When no pedestrian or bicycle crashes were experienced on some road types, the research team recommended using the adjustment factors from the HSM.

Table 8. Pedestrian Crash Adjustment Factor for Urban Arterials (f_{pedr}).

Road Type	Posted Speed 30 mph or Lower			Posted Speed Greater Than 30 mph		
	Total Pedestrian Crashes	Total MV and SV Crashes*	f_{pedr}	Total Pedestrian Crashes	Total MV and SV Crashes*	f_{pedr}
U2U	5	465	0.011	0	35	0.005
U3T	6	302	0.020	2	49	0.041
U4D	17	1485	0.011	0	32	0.009
U4U	24	1291	0.019	1	187	0.019
U5T	24	1242	0.019	0	31	0.023

*Excludes pedestrian and bicycle crashes.

Table 9. Bicycle Crash Adjustment Factor for Urban Arterials (f_{biker}).

Road Type	Posted Speed 30 mph or Lower			Posted Speed Greater Than 30 mph		
	Total Bicycle Crashes	Total MV and SV Crashes*	f_{biker}	Total Bicycle Crashes	Total MV and SV Crashes*	f_{biker}
U2U	1	465	0.002	0	35	0.004
U3T	0	302	0.027	0	49	0.007
U4D	3	1485	0.002	0	32	0.002
U4U	5	1291	0.004	2	187	0.011
U5T	4	1242	0.003	2	31	0.065

*Excludes pedestrian and bicycle crashes.

The region-specific adjustment factors in Table 88 and Table 89 of the Research Project 0-7083 (*1*) report were updated to values shown in Table 10 and Table 11, respectively.

Table 10. Updated Calibration Adjustment Factors for Non-Freeway Facilities.

Region	District Numbers	Facility Type							
		R2U	R4D	R4U	U2U	U3T	U4D	U4U	U5T
North	1, 2, 3, 9, 10, 18, 19, 23	1.15	0.96	0.91	1.07	1.11	0.91	1.14	0.76
South	13, 14, 15, 16, 21, 22	0.73	1.13	0.90	1.02	0.82	1.01	0.77	0.82
East	11, 12, 17, 20	1.01	0.98	1.21	0.88	1.37	1.35	1.06	1.55
West	4, 5, 6, 7, 8, 24, 25	1.00	0.77	0.79	1.09	1.00	0.80	1.23	1.00

Table 11. Updated Calibration Adjustment Factors for Freeway Facilities.

Region	District Numbers	Collision Type/Severity			
		SV FI	SV PDO	MV FI	MV PDO
North	1, 2, 3, 9, 10, 18, 19, 23	0.89	1.07	0.93	1.00
South	13, 14, 15, 16, 21, 22	0.97	0.76	0.87	0.81
East	11, 12, 17, 20	1.25	1.15	1.45	1.63
West	4, 5, 6, 7, 8, 24, 25	0.71	0.93	0.76	0.93

SOFTWARE UPDATES

In Research Projects 0-7067 and 0-7083, the research teams built or updated spreadsheet tools to assist practitioners in applying HSM safety prediction methodologies to Texas roadway facilities. These spreadsheet tools included the following:

- HSM_FWY: freeway segments, ramps, and frontage road segments.
- HSM_R2U: rural two-lane undivided highway segments and intersections.
- HSM_RMU_RMD: rural multilane undivided or divided highway segments and intersections.
- HSM_URB_SUB: urban and suburban arterial segments and intersections.

As part of pilot testing, the research team tested these spreadsheet tools by applying them to a set of Texas facilities using team members who were not involved in previous tool development efforts. These tests helped to identify issues to address regarding calculation accuracy and user-friendliness. As a result, the research team made updates to all four spreadsheet tools and submitted the updated tools to TxDOT on July 31, 2023. They made additional revisions after each workshop based on the feedback obtained during the hands-on training lessons. The research team maintains publicly-available copies of the tools on a Center for Transportation Safety web page (https://cts.tti.tamu.edu/project/list-of-safety-tools/).

The research team made the following changes to address calculation accuracy:

- HSM_FWY:
    - Fixed calculation errors on the freeways and frontage roads worksheets.
    - Computed new SPF coefficients and overdispersion parameters for combined 4–6-lane rural freeway segments.
    - Entered the SPF coefficients and overdispersion parameters for combined 4–10-lane urban freeway segments that were documented in Research Report 0-7067-R1.
- HSM_R2U: computed an updated set of region adjustment factors for segments.
- HSM_RMU_RMD: computed an updated set of region adjustment factors for segments.
- HSM_URB_SUB:
    - Computed an updated set of region adjustment factors for segments.
    - Computed new SPF coefficients and overdispersion parameters for MV non-driveway and MV driveway-related crashes on 2U, 4U, 4D, and 5T segments.
    - Computed new pedestrian crash adjustment factors for 2U, 4U, 4D, and 5T segments with posted speed limits greater than 30 mph.
    - Computed a new bicycle crash adjustment factor for 3T segments with posted speed limits less than or equal to 30 mph.
    - Computed new bicycle crash adjustment factors for 2U, 3T, 4U, and 4D segments with posted speed limits greater than 30 mph.

The research team made the following changes to address user-friendliness and clarity:

- All spreadsheet tools:
    - Changed the “region” input to “TxDOT district” and added calculations to find the appropriate region adjustment factor from the chosen TxDOT district.
    - Added a link to the TxDOT Statewide Planning Map (https://www.txdot.gov/apps/statewide_mapping/StatewidePlanningMap.html) next to the annual average daily traffic (AADT) input data cells.
    - Configured the AADT range warnings to allow the user to enter values outside the range of the relevant model but provide a warning about the AADT range limits.
    - Locked the calculation cells and protected the worksheets (without a password).
- HSM_FWY:
    - Changed the “expected crash frequency” labels to indicate “expected” if empirical Bayes analysis is used or “predicted” if empirical Bayes analysis is not used.
    - Added data validation to most data entry cells.

    - Added conditional formatting to the Freeways worksheet to gray out the ramp number of lanes input cells if the area type is rural.
    - Added conditional formatting to the Freeways and Ramps worksheets to gray out the barrier offset input cells if no barrier is present.
    - Added a diagram to the Frontage Roads worksheet to define the access data input variables (minor intersections, driveways, entrance gores, and exit gores).
    - Unlocked yellow calibration factor cells on the ramps and frontage roads worksheets that were previously locked.
- HSM_R2U:
    - Changed the color-coding scheme to match the freeway spreadsheet tool.
    - Added cell notes (identified by red triangles and contained in text balloons) to explain various input data variables.
    - Added guidance to the Instructions worksheet to instruct the user to enter base conditions for input variables for which data are not available.
    - Reformulated the input for driveways on the Segment worksheets so the user enters number of driveways instead of driveway density.
    - Added a link to report FHWA-RD-99-207 on the Segment worksheets so users can obtain a description of the roadside hazard rating variable.
    - Removed a redundant input cell for intersection skew angle from the Intersection worksheets.
    - Reconfigured the Site Total worksheets to allow tabulation without empirical Bayes.
    - Revised the color coding on the Site Total and Project Total worksheets to match the number of segments and intersections for the facility of interest (based on the use of the cells in the green column).
- HSM_RMU_RMD:
    - Changed the color-coding scheme to match the freeway spreadsheet tool.
    - Added cell notes (identified by red triangles and contained in text balloons) to explain various input data variables.
    - Added guidance to the Instructions worksheet to instruct the user to enter base conditions for input variables for which data are not available.
    - Added conditional formatting to the data entry cells for turn lanes to match the specified intersection type (e.g., a three-leg intersection can only have 0 or 1 non-controlled approaches with a turn lane).
    - Reconfigured the Site Total worksheets to allow tabulation without empirical Bayes.
    - Revised the color coding on the Site Total and Project Total worksheets to match the number of segments and intersections for the facility of interest (based on the use of the cells in the green column).
- HSM_URB_SUB:
    - Changed the color-coding scheme to match the freeway spreadsheet tool.
    - Added cell notes (identified by red triangles and contained in text balloons) to explain various input data variables.
    - Added guidance to the Instructions worksheet to instruct the user to enter base conditions for input variables for which data are not available.

- Applied conditional formatting to gray out unneeded input data cells on the Segment and Intersection worksheets (e.g., median width if the selected roadway type is an undivided configuration, or the inputs for signalized or unsignalized intersections depending on the specified intersection type).
- Added conditional formatting to the data entry cells for turn lanes to match the specified intersection type (e.g., a three-leg intersection can only have 0 or 1 non-controlled approaches with a turn lane).
- Reconfigured the Site Total worksheets to allow tabulation without empirical Bayes.
- Revised the color coding on the Site Total and Project Total worksheets to match the number of segments and intersections for the facility of interest (based on the use of the cells in the green column).

SUMMARY AND RECOMMENDATIONS

The researchers presented three workshops at TxDOT district or division facilities around the state, reaching a total of 66 participants representing various districts and several consultant firms. The workshop participants gave positive feedback about the material, especially the hands-on training sessions and the data review session in each workshop.

The researchers supplemented the workshops with one webinar presentation online to provide training to more than 100 participants. The webinar provided an abbreviated version of the material presented at the workshops but not the hands-on training sessions.

With the completion of Research Projects 0-7067 and 0-7083 and Implementation Project 5-7083, TxDOT practitioners now have HSM-based safety prediction models that are calibrated to Texas conditions, new models for frontage roads and ramps, and a set of spreadsheet tools to assist with application of the models. Research at the federal level is now in progress to publish the second edition of the HSM, which will contain updated models for some facility types that were included in the first edition, as well as new models for various types of facilities that were not included in the first edition (e.g., urban one-way streets, roundabouts, five-leg intersections, and all-way stop-controlled intersections, among others). Once the second edition of the HSM is published, a new round of research efforts will be needed to calibrate the new or updated HSM models to Texas conditions and to update spreadsheet tools with the newly-calibrated models. Training workshops and webinar(s) will also be needed to train the practitioners regarding the new and updated material included in the second edition of the HSM.

REFERENCES

1. Geedipally, S.R., Dixon, K., Wu, L., Pratt, M.P., Avelar, R., Das, S., Tsapakis, I., Lord, D., and Saini, G. (2022). Calibrating the *Highway Safety Manual* Predictive Methods for Texas Highways (FHWA/TX-22/0-7083-R1). Texas A&M Transportation Institute.
2. Pratt, M. P., Geedipally, S.R., Le, M., Wu, L., Avelar, R., Das, S., and Lord, D., (2022). Enhancing Freeway Safety Prediction Models (FHWA/TX-22/0-7067-R1). Texas A&M Transportation Institute.