



0-7083 Develop Highway Safety Manual (HSM) Safety Performance Functions (SPFs) and Calibration Factors for Texas

ACS20 Mid-Year Meeting
June 28, 2023



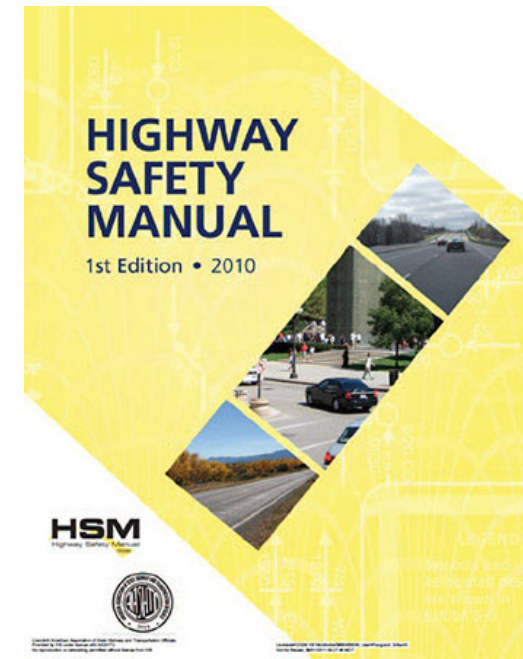
Problem

- Texas does not currently have local SPFs or calibration factors for the HSM SPFs.
- Existing Texas SPFs are too old.
- HSM does not include frontage road SPFs
- Ramps considered in HSM are different from ramps in Texas
- Texas does not have an intersection database

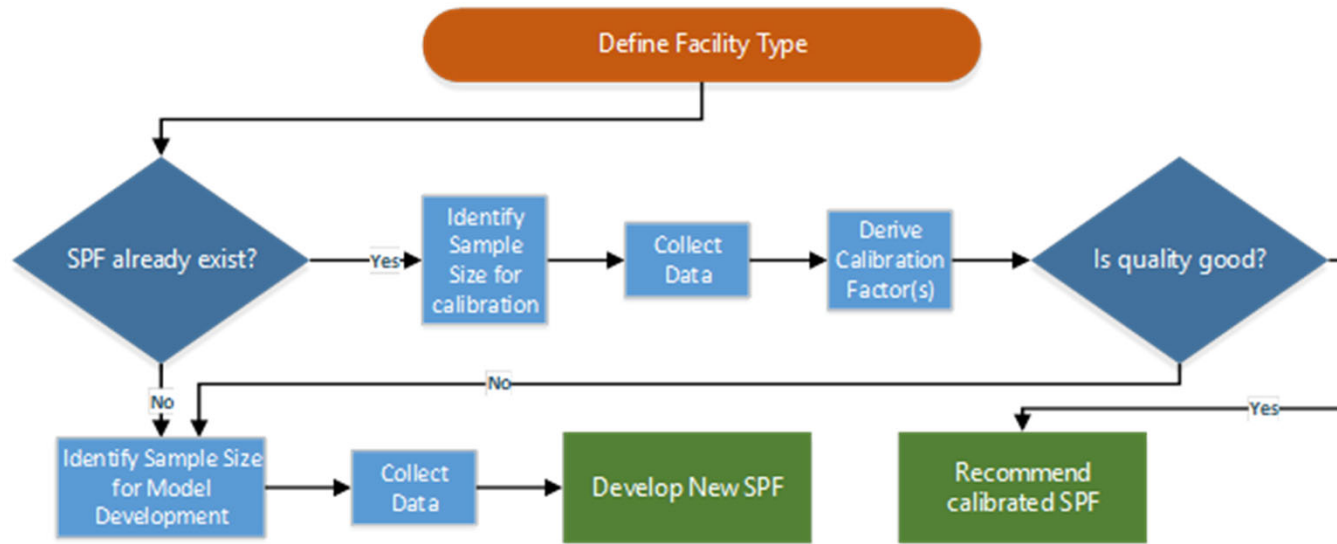


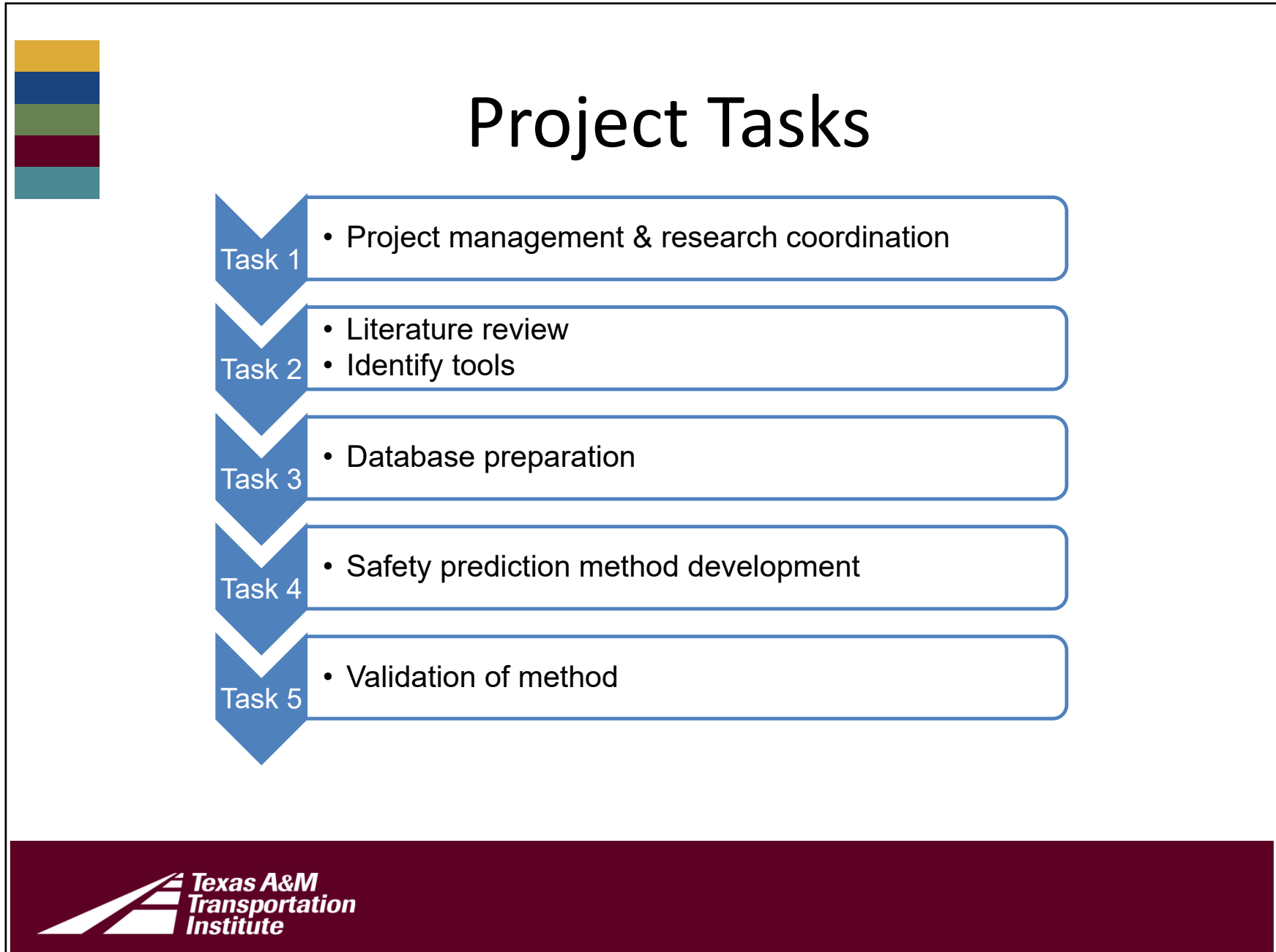
Project Objectives

- Calibrate the Part C prediction models of the HSM for conditions in the State of Texas and develop calibration factors
- Develop up to five new SPFs for facility types with poor quality calibration factors and for facilities that do not have SPFs in the HSM



SPF Development Process







Segment database

- TxDOT's Roadway Inventory (RHiNo) database
- TxDOT's Crash Records Information System (CRIS) for the years 2015 to 2019.



Freeway database

- Rural
 - 4-lanes
 - 6-lanes

} Stratified random sampling
- Urban
 - 4-lanes
 - 6-lanes
 - 8-lanes
 - 10-lanes
 - 11+ -lanes
 - Managed lanes

} TxDOT Project 0-7067



Sample Size Determination

- For a level of relative precision, dispersion parameter, and level of confidence, the required sample size is:

Standard Normal threshold
For a required confidence level

$$n = \frac{Z^2}{\gamma^2} \left(\kappa + \frac{1}{\bar{y}} \right)$$

Dispersion parameter

Relative precision required
In the estimation of c

Average number of
Crashes per site



Intersection database

- Intersection database generated using HERE network data
- Used six steps to prepare the data



Frontage Road database

- Used RHiNo database
- Types of frontage roads:
 - Rural 2-way (R2W)
 - Rural 1-way (R1W)
 - Urban 2-way (U2W)
 - Urban 1-way (U1W)



Frontage Road database

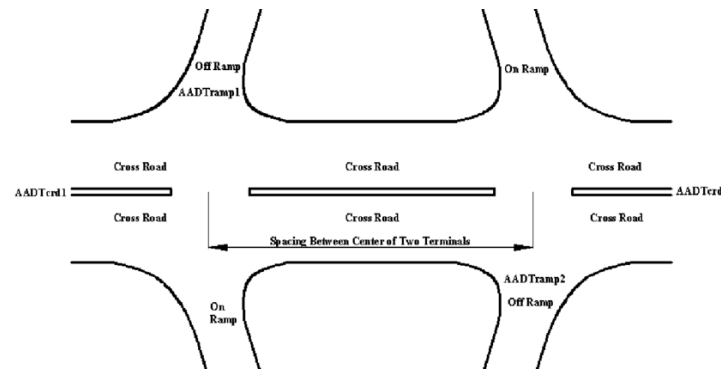
- Sample size

Facility Type	Population Size	Final Sample Size by Region				
		Total	East	North	South	West
R1W	1,549	276	48	141	78	9
R2W	5,030	413	25	149	94	145
U1W	15,519	128	30	45	37	16
U2W	1,717	100	10	36	15	39

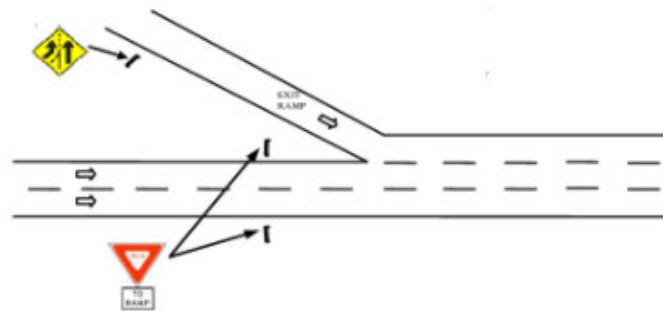


Ramp segments

- Typical ramps in the HSM



- Typical ramps in Texas





Ramp segments

- Database provided by the TxDOT
 - Extracted from STARS II
- Provided as an excel file
- Team geolocated and developed an ArcMap model
- Joined with “Statewide area types” shapefile



Ramp segments

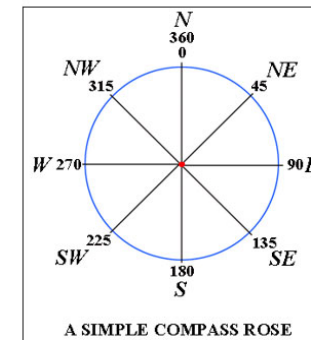
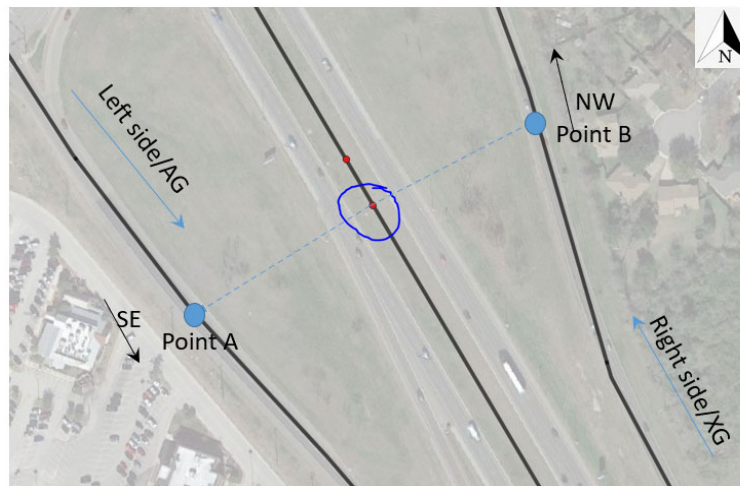
- Sample size

Area Type	Population Size	Final Sample Size
Rural	1,408	499
Urban	6,417	143



Crash Assignment

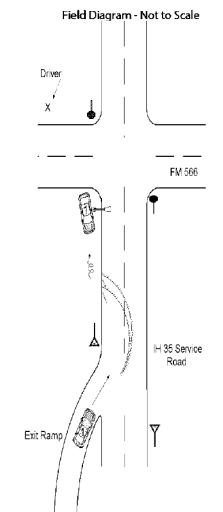
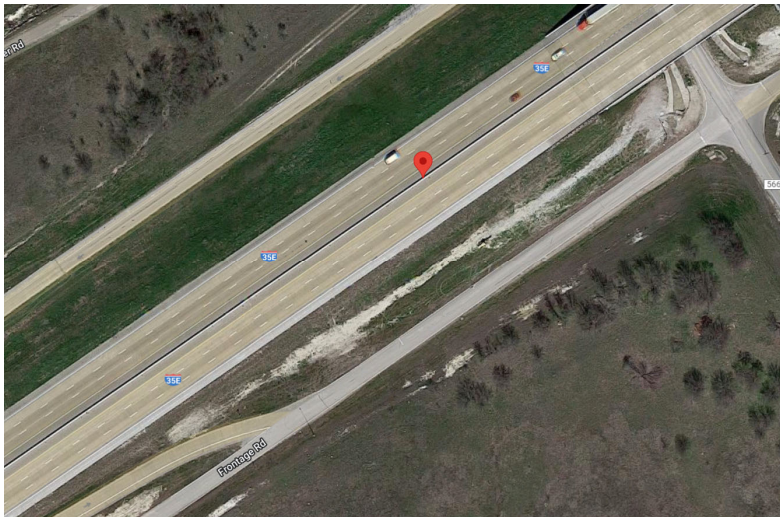
- No easy way to assign frontage road and ramp crashes
- All crashes assigned to centerline
- Used vehicle direction to assign





Crash Assignment

– Example crash





Frontage Road database

- Crash assignment
 - Manually checked every crash to assign to two-way frontage roads
 - Manually checked crashes on one-way frontage roads that have questionable direction



Ramp segments

- Crash assignment
 - Manually checked crashes on ramps that have questionable direction



Frontage Road database

- Collected the following variables:
 - Edge markings
 - Lane width
 - Shoulder width
 - Driveway density
 - Ramp presence
 - Rumble strips
 - Lighting
 - Speed limit
 - Horizontal curves



Ramp segments

- Collected the following variables:
 - Ramp type (Entrance or exit)
 - Entrance/Exit Side (Left or right)
 - Ramp length
 - Ramp Configuration (Curved or straight)
 - Area type
 - Number of lanes
 - Lane width
 - Left shoulder width
 - Right shoulder width
 - Lighting
 - Speed limit
 - Left side barrier presence
 - Right side barrier presence
 - Lane add or drop



Safety Prediction Method Development

Segments

- Rural
 - Two-lane } HSM Chapter 10
 - Multi-lane divided } HSM Chapter 11
 - Multi-lane undivided }
- Urban
 - Two-lane (2U)
 - Two-lane with TWLTL (3T)
 - Four-lane divided (4U)
 - Four-lane undivided (4D)
 - Four-lane with TWLTL (5T) } HSM Chapter 12



Safety Prediction Method Development

Segments

- Freeways
 - Main lanes } HSM Chapter 18
 - Ramps } New SPFs
 - Frontage roads } New SPFs



Safety Prediction Method Development

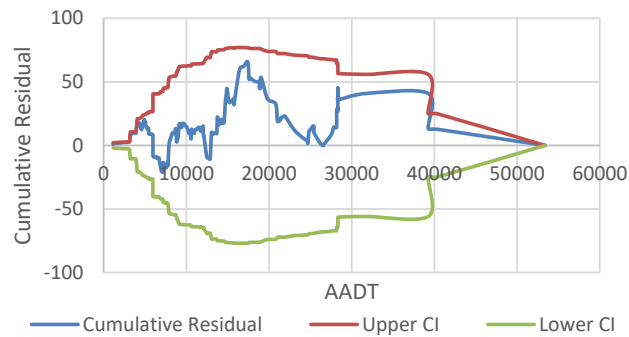
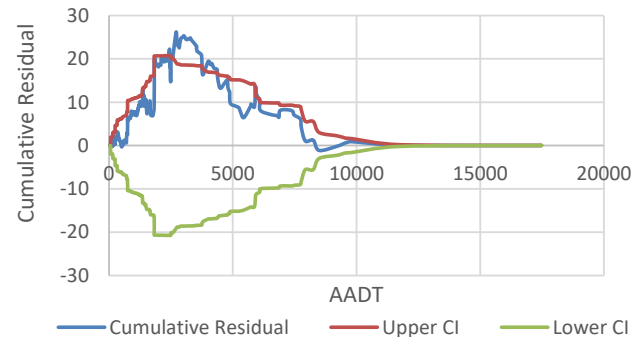
Intersections

- Signalized
 - Three-legged
 - Four-legged
 - Stop-controlled
 - Three-legged
 - Four-legged
- HSM Ch. 10, 11, 12

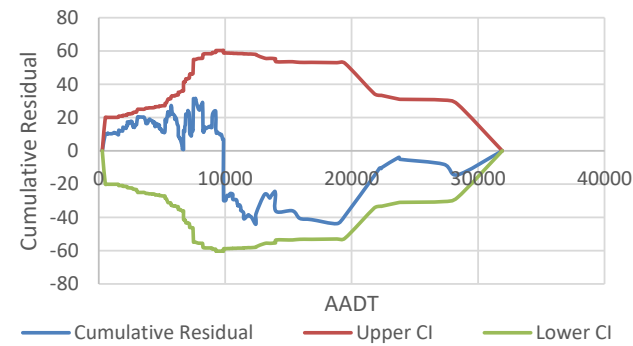


Example CURE Plots

R2U



R4D



R4U



Segments

Seg. Type	Coll. Type	C	SE of C	MAD	MSPE	Modified R ²	Dispersion Parameter	CV	Exceeding 95% CI
R2U	All	0.82	0.09	0.77	1.97	0.62	0.43	0.11	14%
R4D	All	0.91	0.10	3.41	34.09	0.61	0.62	0.11	19%
R4U	All	0.69	0.09	1.90	17.16	0.61	0.66	0.13	24%
U2U	MV	0.94	0.21	1.44	11.04	0.37	1.25	0.23	37%
	SV	1.10	0.27	1.01	5.78	0.5	0.65	0.25	1%
U3T	MV	0.61	0.11	1.33	7.01	0.42	0.86	0.18	4.8%
	SV	1.48	0.25	0.7	1.7	0.63	0.44	0.17	0.6%
U4D	MV	1.67	0.35	3.79	70.49	0.27	1.91	0.21	50.4%
	SV	1.97	0.20	1.44	6.11	0.38	0.57	0.1	0.0%
U4U	MV	1.34	0.27	4.32	98.25	0.54	1.14	0.2	26.9%
	SV	1.5	0.18	1.17	3.81	0.53	0.52	0.12	17.9%
U5T	MV	0.50	0.08	5.34	91.75	-0.12	1.29	0.16	53%
	SV	0.74	0.09	1.53	5.62	0.19	0.65	0.12	49%



Freeway Mainlanes

SPFs

No. of Lanes	Crash Type	Crash Count		Local Calibration Factor C
		Observed	Predicted	
4	MV FI	27	40.56	0.67
	MV PDO	60	78.20	0.77
	SV FI	53	93.87	0.56
	SV PDO	137	200.81	0.68
6	MV FI	125	198.49	0.63
	MV PDO	296	492.47	0.60
	SV FI	118	166.98	0.71
	SV PDO	346	426.40	0.81

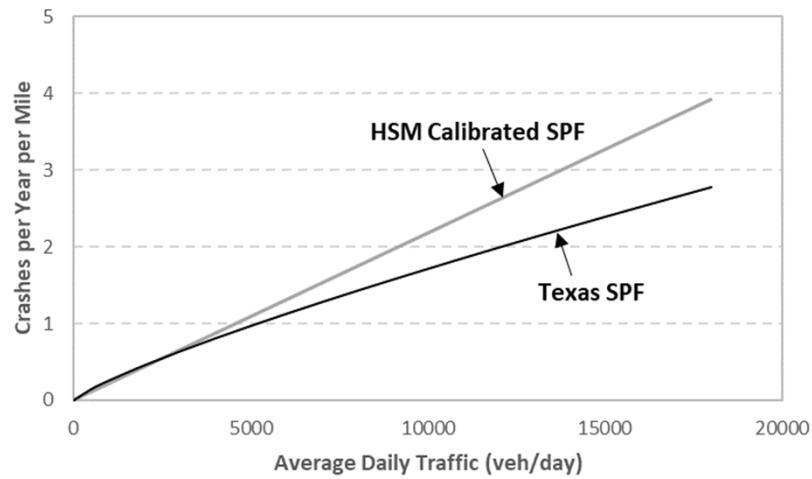


Freeway Mainlanes

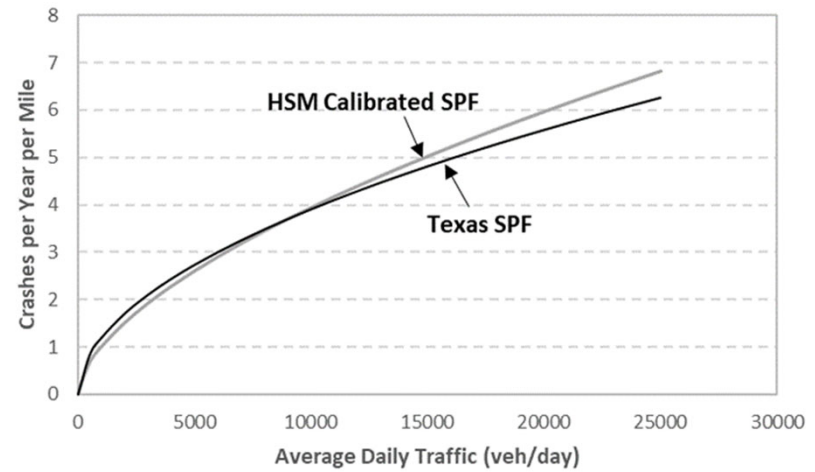
SDFs

Variable	Variable Value by Number of Lanes		
	4	6	All
N_{o_KABC}	80	243	323
N_{o_KAB}	46	145	191
N_{p_KABC}	134.43	365.47	499.90
N_{p_KAB}	68.06	160.08	228.14
$P_{o,KAB}$	0.58	0.60	0.59
$P_{p,KAB}$	0.51	0.44	0.46
C_{SDF}	1.32	1.90	1.72

Functional Form - Examples



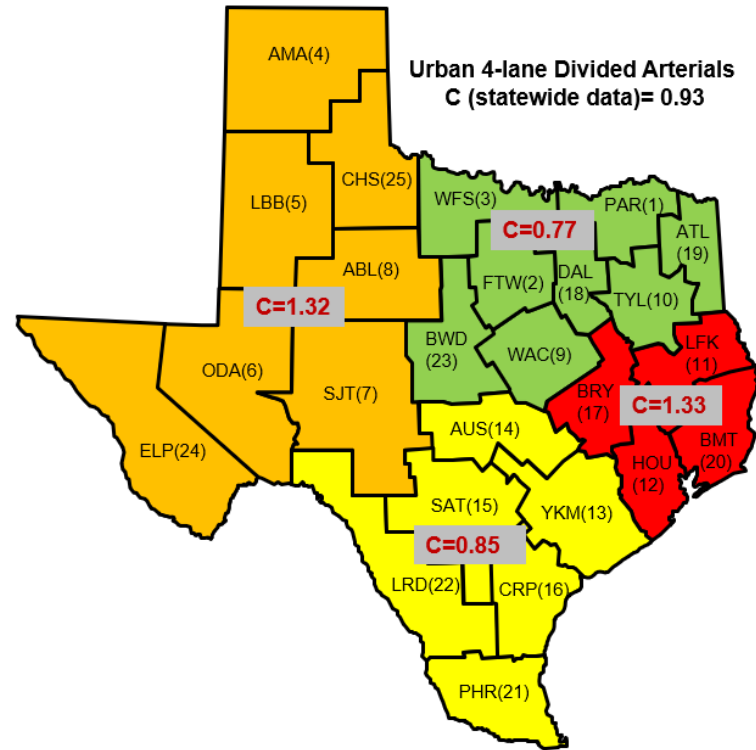
R2U Segments



R2U - 4SG



Region-Specific Factors





Region-Specific Factors

Region	District Numbers	Facility Type							
		R2U	R4D	R4U	U2U	U3T	U4D	U4U	U5T
North	1,2,3,9,10,18,19,23	1.10	0.91	0.89	0.91	1.02	0.82	0.80	0.68
South	13,14,15,16,21,22	0.60	1.11	1.03	1.05	0.83	0.91	0.86	0.80
East	11,12,17,20	1.20	1.01	1.23	0.82	1.46	1.42	0.85	1.63
West	4,5,6,7,8,24,25	0.94	0.90	0.71	1.19	1.00	1.41	1.59	1.00

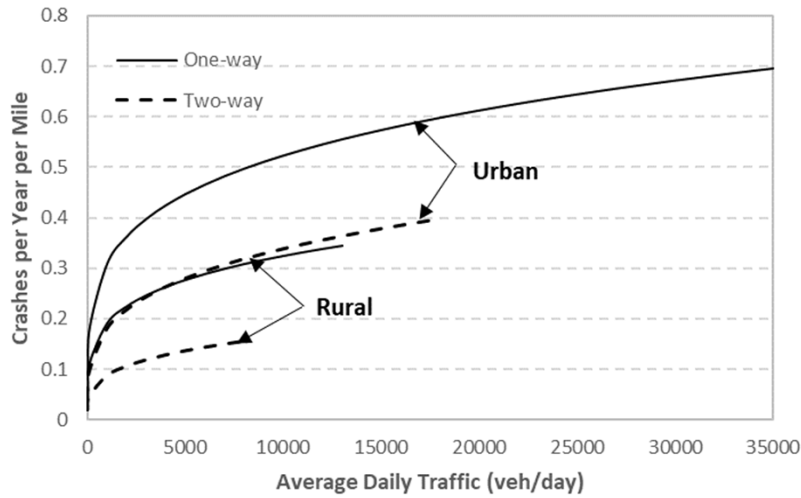


Safety Prediction Method Development

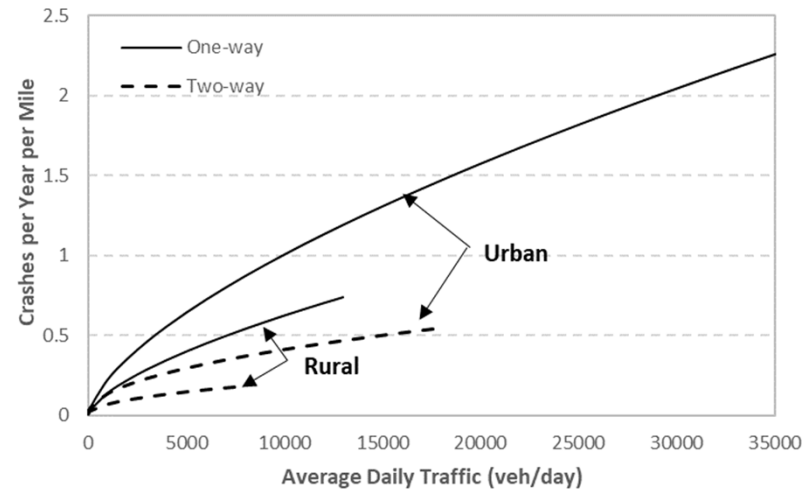
- Types of frontage roads:
 - Rural 2-way (R2W)
 - Rural 1-way (R1W)
 - Urban 2-way (U2W)
 - Urban 1-way (U1W)



SPFs – Frontage Roads



Single-vehicle Crashes



Multi-vehicle Crashes



SPFs – Frontage Roads

Severity	One-way		Two-way	
	Rural	Urban	Rural	Urban
K	0.9%	0.4%	4.4%	0.6%
A	4.6%	1.3%	6.1%	0.6%
B	8.7%	10.4%	11.4%	10.3%
C	13.3%	18.2%	16.7%	12.8%
O	72.4%	69.6%	61.4%	76.3%

14.2%

21.9%



SPFs – Frontage Roads

CMFs developed for frontage roads:

- Access point density
- Ramp presence
- Posted speed limit
- Horizontal curve density

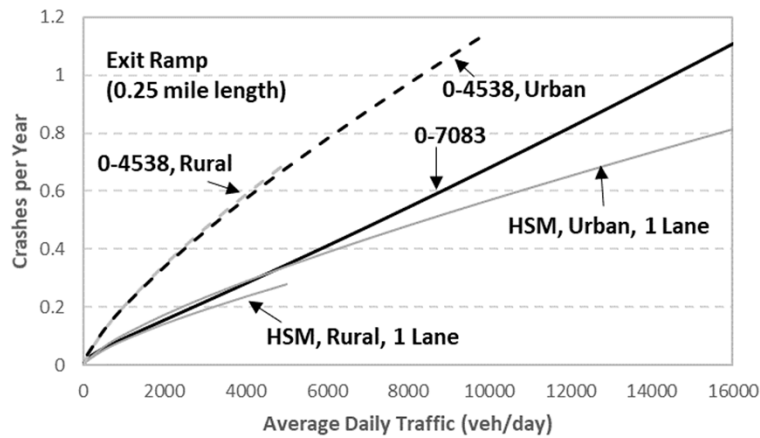


SPFs - Ramps

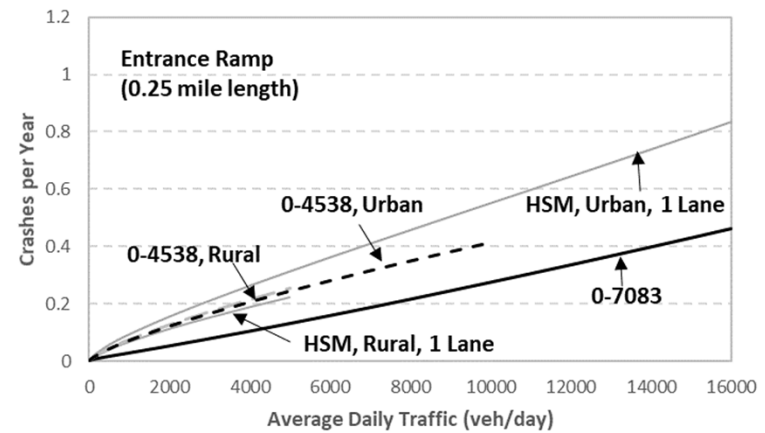
- Types of Ramps:
 - Entrance
 - Exit



SPFs – Ramps



Exit Ramp



Entrance Ramp



SPFs – Ramps

Severity	Ramp Type	
	Exit	Entrance
K	0.4%	2.9%
A	3.3%	2.9%
B	10.7%	20.0%
C	15.6%	18.6%
O	70.1%	55.7%

14.4%

25.8%



SPF - Ramps

CMFs developed for ramp segments:

- Horizontal curve presence
- Left shoulder width
- Right shoulder width
- Barrier presence



Implementation

Spreadsheet tool

Highway Safety Manual Calculations for Texas

Developed by: Michael P. Pratt and Srinivas R. Geedipally
Version 2

FOREWORD

This software can be used to estimate crash frequency on freeways, ramps, and frontage roads as a function of geometric, access, and traffic control data. It is intended for use by engineers and technicians responsible for roadway design and safety analysis.

This software is intended for use with the reports identified below. The analyst is encouraged to read the documents to obtain an understanding of how best to use the software and interpret its output.

Full documentation of Highway Safety Manual models and data needs:

Highway Safety Manual, First Edition, Supplement, Chapters 18 & 19.
American Association of State Highway and Transportation Officials, Washington, DC, 2014.

Documentation of the procedures to calibrate HSM models to Texas conditions for urban freeways and development of models for urban freeway managed-lane facilities:

Pratt, Michael P., Srinivas R. Geedipally, Minh Le, Lingtao Wu, Raul Avelar, Subasish Das, and Dominique Lord.
Enhancing Freeway Safety Prediction Models. Technical Report 0-7067-R1.
Texas A&M Transportation Institute, College Station, Texas, 2022.

Documentation of the procedures to calibrate HSM models to Texas conditions for rural freeways, ramps, and frontage roads:

Geedipally, Srinivas, R., Karen K. Dixon, Raul Avelar, Subasish Das, Michael P. Pratt, Ioannis Tsapakis, Lingtao Wu, and Dominique Lord. *Development of Highway Safety Manual Safety Performance Functions and Calibration Factors for Texas*. Technical Report 0-7083-R1. Texas A&M Transportation Institute, College Station, Texas, 2022.

Empirical Bayes analysis principles:

Bonneson, J. and K. Zimmerman. Procedure for Using Accident Modification Factors in the Highway Design Process. Report 0-4703-P5. Texas Transportation Institute, College Station, Texas 2007.

The equations used in this software are documented in these reports. Analysts should refer to the report whenever they have questions about the modeling approach, assumptions, or limitations.

INSTRUCTIONS

This software consists of analysis worksheets for three types of roadway facilities. Key cells on these worksheets are color-coded to indicate the type of data entered or displayed. The following list identifies the meaning of each cell color.

Blue cells represent "input data." Each time the worksheet is used, the values in these cells should be changed to represent the roadway segment being evaluated. Input data must be provided by the analyst.

