COMMITTEE ON SAFETY PERFORMANCE AND ANALYSIS (ACS 20) AGENDA – 2022 MID-YEAR MEETING (August 2, 4, 16, and 18)

Additional material to be posted: http://www.trbacs20.org

Tuesday, August 2, 2022
11:00 am – 3:30 pm EDT

11:00 am Call to Order and Introductions Karen Dixon

11:30 am – 1:00 pm

Update on Second Edition of AASHTO Highway Safety Manual and Related NCHRP Research:

- NCHRP 17-71A, Proposed AASHTO Highway Safety Manual (HSM) Second Edition, Stephen Read and Darren Torbic (60 minutes)
- NCHRP 17-84, Pedestrian and Bicycle Safety Performance Functions for the Highway Safety Manual, Darren Torbic (30 minutes)

1:00 pm – 1:30 pm **Break**

1:30 pm – 3:30 pm

Practical Applications of the HSM Bonnie Polin, Kelly Hardy, Stephen Read

Thursday, August 4, 2022
11:00 am – 3:30 pm EDT

11:00 am Welcome or Welcome Back! Karen Dixon

11:00 am – 1:00 pm

Presentation of Safety Related NCHRP Research (30 minutes each):

- NCHRP 22-45, Informing the Selection of Countermeasures by Evaluating, Analyzing, and Diagnosing Contributing Factors that Lead to Crashes, John Campbell
- NCHRP 22-46, Human Factors Guidelines for Road Systems, Proposed 4th Edition, John Campbell
- NCHRP 17-93, Updating Safety Performance Functions for Data-Driven Safety Analysis, Raghavan Srinivasan
- NCHRP 07-29, Development of the 8th Edition of AASHTO's A Policy on the Geometric Design of Highways and Streets, Ingrid Potts

1:00 pm – 1:30 pm **Break**

1:30 pm – 3:30 pm

Presentation of Speed and Safety Related NCHRP Research (40 minutes each):

- NCHRP 17-76, Guidance for the Setting of Speed Limits, Kay Fitzpatrick
- NCHRP 17-92, Developing Safety Performance Functions for Rural Two-Lane Highways that Incorporate Speed Measures, Karen Dixon
- NCHRP 03-139, Next Generation of the USLIMITS2 Speed Limit Setting Expert System, Raghavan Srinivasan

Tuesday, August 16, 2022

11:00 am – 3:30 pm EDT

11:00 am Welcome or Welcome Back! Karen Dixon

11:00 am – 1:00 pm

Presentation of Safety Related NCHRP Research:

- NCHRP 17-85, Development and Application of Crash Severity Models for the Highway Safety Manual, John Ivan (60 minutes)
- NCHRP 17-89, Safety Performance of Part-Time Shoulder Use on Freeways, Pete Jenior (30 minutes)
- NCHRP 17-89A, HOV/HOT Freeway Crash Prediction Method for the Highway Safety Manual, Scott Himes (30 minutes)

1:00 pm – 1:30 pm **Break**

1:30 pm – 3:30 pm

Subcommittee Meetings Subcommittee Chairs

Thursday, August 18, 2022

11:00 am – 3:30 pm EDT

11:00 am Welcome or Welcome Back! Karen Dixon

11:00 am – 1:00 pm

Subcommittee Meetings Subcommittee Chairs

Research Needs Statements Doug Harwood

1:00 pm – 1:30 pm **Break**

1:30 pm – 3:30 pm **Business Meeting**

1:30 pm Call to Order Karen Dixon

1:40 pm	Secretary and Communications Report Approval of Previous Meeting Minutes	Derek Troyer
1:45 pm	TRB Staff Report/Section Update NCHRP Update	Bernardo Kleiner David Jared
2:00 pm	Reports – Committee Activities • Subcommittee Updates • Status of Research Needs Statements • Paper Reviews • Paper Award Process	 Subcommittee Chairs Doug Harwood Xiao Qin To Be Determined
2:50 pm	Organizational Updates USDOT Updates – (Tentative) AASHTO Update	 Carol Tan (FHWA) Kelly Hardy
3:10 pm	State of the Committee and a Look Forward • Planning for 2023 Annual Meeting • 2024 Midyear Meeting	Karen Dixon
3:20 pm	Other News • Upcoming Events • Reports from other Committees/Organizations • Open Floor	
3:30 pm	Adjourn	

NCHRP Project 17-71A

Proposed AASHTO Highway Safety Manual, Second Edition

TRB ACS20 Midyear Meeting
August 2022

Texas A&M Transportation Institute

HDR

Exponent

Harwood Road Safety, LLC

Mr. Brelend C. Gowan

Ogle Research, LLC

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Agenda

- AASHTO Update (Committee on Safety)
- Review of project objective and outline of HSM2
- Status of draft chapters
- Single-state calibration
- Freeway rumble strip CMF
- Review and coordination with NCHRP Projects 17-89 (PTSU) and 17-89A (HOV/HOT)
- Plans for current quarter
- Questions

AASHTO Update

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American Association of State Highway and Transportation Officials
AASHTO

Committee on Safety: Safety Analysis and Evaluation Subcommittee & HSM Steering Committee

Stephen W. Read, P.E. Virginia DOT
ACS 20 Mid-year Meeting Aug 02, 2022

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AASHTO

HSM2 17-71A On-going Support

- Panel, HSM Steering, and ACS20 review comments compilation process has been working well
- Working on third group of chapters
- Identified issues have precipitated separate meetings:
  - For completed chapters – ramp terminal severity predictions
  - For ongoing chapters – single state calib.; freeway rumble severity; PTSU consistency

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American Association of State Highway and Transportation Officials
AASHTO

Future HSM2 Efforts

- Future of analysis tools – considerations with ULSC input
  - Web-based tools from ongoing NCHRP projects & industry
  - NCHRP based Excel (with state enhancements/refinements)
  - Vender developed tools
- User Discussion Forum
  - ULSC survey gave direction
  - Practical Applications and ULSC will give next steps

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Future HSM2 Efforts

- Topical Webinars
  - Re-establishing Safety Analysis and Evaluation SC to lead
  - Consider Part C and D research topics
  - Share Safe Systems Approach topics with TZD-SC
  - Work with other AASHTO Comm for overlapping topics

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AASHTO

Thank you.

Questions?

Stephen Read – Virginia DOT stephen.read@vdot.virginia.gov
Bonnie Polin – Massachusetts DOT bonnie.polin@state.ma.us
Kelly Hardy – AASHTO khardy@aashto.org

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Review of Project Objective and HSM2 Outline

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Project Objective

- Complete work initiated as part of NCHRP Project 17-71 to develop and prepare a proposed HSM2 in a format suitable for adoption as an AASHTO publication
  - Proposed HSM2 will synthesize and incorporate relevant ongoing and completed research including completed NCHRP Project 17-71 deliverables, related documents, and user feedback to expand the scope and quality of HSM2 to increase application and improve its usability

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The HSM2 Will…

- **Expand** upon the methodologies in HSM1
- **Incorporate** new models and research completed since HSM1
- **Modify** practices based on user experiences and needs

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HSM
Highway Safety Manual
AASHTO

Outline of HSM2

HSM2 (Ch.)	HSM1 (Ch.)	Chapter Title
		Preface
1	1	Introduction and Overview to the Highway Safety Manual
Part A- Fundamentals		
		Introduction to Part A
2	3	Road Safety Principles **(Previously titled "Fundamentals")**
3	2	Human Factors
4		**Pedestrians and Bicyclists (NEW)**
Part B – Roadway Safety Management Process		
		Introduction to Part B
5		**Areawide Evaluation (NEW) (NCHRP Project 17-81: Macro-Level Safety Planning)**
6	4	Network Screening
7	5	Diagnosis
8	6	Countermeasure Selection
9	7	Economic Appraisal
10	8	Project Prioritization
11	9	Safety Effectiveness Evaluation
12		**Systemic Safety Management (NEW)**
Part C – Predictive Method		
		Introduction to Part C
13		**Developing, Calibrating, & Using Safety Performance Functions and Crash Prediction Models (NEW)**
14	10	Predictive Method for Rural Two-Lane, Two-Way Roads
15	11	Predictive Method for Rural Multilane Highways
16	12	Predictive Method for Urban and Suburban Arterials
17	18	Predictive Method for Freeways
18	19	Predictive Method for Ramps
Part D – Crash Modification Factors		
		Introduction to Part D
19		**Selecting Crash Modification Factors (NEW)**
20		**Applying Crash Modification Factors (NEW)**
		Glossary (Applicable to all Parts)

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Status of Draft Chapters

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Task 6 – Submission and Review Schedule

HSM2 Chapter	Short Title	Individual Chapter Drafts					Full Draft (all chapters)
		Submit for Review and Comments					
		(12/1/21)	(3/16/22)	(7/15/22)	(10/31/22)	(2/28/23)	(5/31/23)
	Preface	X					X
Chapter 1	Intro & Overview		X				X
Part A—Fundamentals							
	Introduction		X				X
Chapter 2	Road Safety Principles			X			X
Chapter 3	Human Factors			X			X
Chapter 4	Peds & Bikes					X	X
Part B—Roadway Safety Management Process							
	Introduction	X					X
Chapter 5	Areawide Evaluation		X				X
Chapter 6	Network Screening			X			X
Chapter 7	Diagnosis				X		X
Chapter 8	Countermeasure Selection				X		X
Chapter 9	Economic Appraisal	X					X
Chapter 10	Project Prioritization	X					X
Chapter 11	Effectiveness Evaluation			X			X
Chapter 12	Systemic Safety Mgt				X		X
Part C—Predictive Method							
	Introduction		X				X
Chapter 13	Calibration and EB				X		X
Chapter 14	Rural Two-Lane				X		X
Chapter 15	Rural Multilane			X			X
Chapter 16	Urb/Sub Arterials					X	X
Chapter 17	Freeways					X	X
Chapter 18	Ramps		X				X
Part D—Crash Modification Factors							
	Introduction	X					X
Chapter 19	Selecting CMFs		X				X
Chapter 20	Applying CMFs			X			X

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Task 6 – Submission and Review Schedule

HSM2 Chapter	Short Title	Individual Chapter Drafts					Full Draft (all chapters)
		Submit for Review and Comments					
		(12/1/21)	(3/16/22)	(7/15/22)	(10/31/22)	(2/28/23)	(5/31/23)
	Preface	X					X
Chapter 1	Intro & Overview		X				X
Part A—Fundamentals							
	Introduction		X				X
Chapter 2	Road Safety Principles			X			X
Chapter 3	Human Factors			X			X
Chapter 4	Peds & Bikes					X	X
Part B—Roadway Safety Management Process							
	Introduction	X					X
Chapter 5	Areawide Evaluation		X				X
Chapter 6	Network Screening			X			X
Chapter 7	Diagnosis				X		X
Chapter 8	Countermeasure Selection				X		X
Chapter 9	Economic Appraisal	X					X
Chapter 10	Project Prioritization	X					X
Chapter 11	Effectiveness Evaluation			X			X
Chapter 12	Systemic Safety Mgt				X		X
Part C—Predictive Method							
	Introduction		X				X
Chapter 13	Calibration and EB				X		X
Chapter 14	Rural Two-Lane				X		X
Chapter 15	Rural Multilane			X			X
Chapter 16	Urb/Sub Arterials					X	X
Chapter 17	Freeways					X	X
Chapter 18	Ramps		X				X
Part D—Crash Modification Factors							
	Introduction	X					X
Chapter 19	Selecting CMFs		X				X
Chapter 20	Applying CMFs			X			X

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		(12/1/21)	(3/16/22)	(7/15/22)	(10/31/22)	(2/28/23)	(5/31/23)
	Preface	X					X
Chapter 1	Intro & Overview		X				X
Part A—Fundamentals							
	Introduction		X				X
Chapter 2	Road Safety Principles			X			X
Chapter 3	Human Factors			X			X
Chapter 4	Peds & Bikes					X	X
Part B—Roadway Safety Management Process							
	Introduction	X					X
Chapter 5	Areawide Evaluation		X				X
Chapter 6	Network Screening			X			X
Chapter 7	Diagnosis				X		X
Chapter 8	Countermeasure Selection				X		X
Chapter 9	Economic Appraisal	X					X
Chapter 10	Project Prioritization	X					X
Chapter 11	Effectiveness Evaluation			X			X
Chapter 12	Systemic Safety Mgt				X		X
Part C—Predictive Method							
	Introduction		X				X
Chapter 13	Calibration and EB				X		X
Chapter 14	Rural Two-Lane				X		X
Chapter 15	Rural Multilane			X			X
Chapter 16	Urb/Sub Arterials					X	X
Chapter 17	Freeways					X	X
Chapter 18	Ramps		X				X
Part D—Crash Modification Factors							
	Introduction	X					X
Chapter 19	Selecting CMFs		X				X
Chapter 20	Applying CMFs			X			X

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		Submit for Review and Comments					
		(12/1/21)	(3/16/22)	(7/15/22)	(10/31/22)	(2/28/23)	(5/31/23)
	Preface	X					X
Chapter 1	Intro & Overview		X				X
Part A—Fundamentals							
	Introduction		X				X
Chapter 2	Road Safety Principles			X			X
Chapter 3	Human Factors			X			X
Chapter 4	Peds & Bikes					X	X
Part B—Roadway Safety Management Process							
	Introduction	X					X
Chapter 5	Areawide Evaluation		X				X
Chapter 6	Network Screening			X			X
Chapter 7	Diagnosis				X		X
Chapter 8	Countermeasure Selection				X		X
Chapter 9	Economic Appraisal	X					X
Chapter 10	Project Prioritization	X					X
Chapter 11	Effectiveness Evaluation			X			X
Chapter 12	Systemic Safety Mgt				X		X
Part C—Predictive Method							
	Introduction		X				X
Chapter 13	Calibration and EB				X		X
Chapter 14	Rural Two-Lane				X		X
Chapter 15	Rural Multilane			X			X
Chapter 16	Urb/Sub Arterials					X	X
Chapter 17	Freeways					X	X
Chapter 18	Ramps		X				X
Part D—Crash Modification Factors							
	Introduction	X					X
Chapter 19	Selecting CMFs		X				X
Chapter 20	Applying CMFs			X			X

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	Preface	X					X
Chapter 1	Intro & Overview		X				X
Part A—Fundamentals							
	Introduction		X				X
Chapter 2	Road Safety Principles			X			X
Chapter 3	Human Factors			X			X
Chapter 4	Peds & Bikes					X	X
Part B—Roadway Safety Management Process							
	Introduction	X					X
Chapter 5	Areawide Evaluation		X				X
Chapter 6	Network Screening			X			X
Chapter 7	Diagnosis				X		X
Chapter 8	Countermeasure Selection				X		X
Chapter 9	Economic Appraisal	X					X
Chapter 10	Project Prioritization	X					X
Chapter 11	Effectiveness Evaluation			X			X
Chapter 12	Systemic Safety Mgt				X		X
Part C—Predictive Method							
	Introduction		X				X
Chapter 13	Calibration and EB				X		X
Chapter 14	Rural Two-Lane				X		X
Chapter 15	Rural Multilane			X			X
Chapter 16	Urb/Sub Arterials					X	X
Chapter 17	Freeways					X	X
Chapter 18	Ramps		X				X
Part D—Crash Modification Factors							
	Introduction	X					X
Chapter 19	Selecting CMFs		X				X
Chapter 20	Applying CMFs			X			X

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Reviews

- Received comments from first two rounds of submissions/draft chapters
- 17-71A Team reviews all of the comments and identifies substantive comments that our research team would like input from the project panel to resolve
  - Met April 18th to review substantive comments from 1st round of submissions
  - Plan to meet September 23rd to review substantive comments from 2nd round of submissions (and outstanding comments from 1st round)

Single-State Calibration

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Single-State Calibration

- Research team met virtually on May 18th with members of the project panel and several subject matter experts to discuss single-state calibration in HSM2 Part C
- Purpose of the meeting was to determine the need for single-state calibration in HSM2 Part C

Panel Members	External Subject Matter Experts	Research Team
• Bonnie Polin	• Jim Bonneson (Kittelson)	• Darren Torbic
• Stephen Read	• Frank Gross (VHB)	• Doug Harwood
• Daniel Carter	• Kim Kolody (Jacobs)	• Karen Dixon
• Cong Chen	• Dominque Lord (TTI)	• Ingrid Potts
• Jerry Roche	• Raghavan Srinivasan (HSRC-UNC)	• Dan Cook
• Kelly Hardy	• Saleem Taha (HSRC-UNC)	• Raul Avelar
• Richard Retting	• Christina McDaniel-Wilson (ODOT)	

Single-State Calibration (cont.)

- General agenda of meeting:
  - Darren Torbic and Bonnie Polin provided a brief background
  - Doug Harwood presented background information on history of single-state calibration for HSM1
  - Raghavan Srinivasan presented work related to single-state calibration completed under NCHRP 17-72
  - Jim Bonneson presented an assessment of level-of-effort required for single-state calibration for HSM2 prepared by 17-71 Research Team
  - Open discussion among meeting participants

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Single-State Calibration (cont.)

- Primary takeaways:
  - Everyone believed single-state calibration was important for HSM2
  - Single-state calibration for HSM2 will require a major effort
    - Need to take advantage of work completed under NCHRP 17-72
    - Need to be creative on how to address remaining SPFs
  - If single-state calibration is not performed for all HSM2 SPFs, HSM2 needs to provide guidance to users

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Single-State Calibration (cont.)

- Since meeting, research team was made aware of work performed by FHWA highlighting counterintuitive results between signalized and unsignalized crossroad ramp terminals in Ch 18 (Ramps)

- Need to develop a plan for single-state calibration
  - Plan unlikely to be developed before all Part C chapters are completed (or near completion)

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Freeway Rumble Strip CMF

Freeway Rumble Strip CMF

- Research team met virtually on May 19th with FHWA to discuss their recent review of the safety effects of shoulder rumble strips on freeways in HSM1
- FHWA used IHSDM to conduct their review
- In summary, FHWA found that the current severity distribution function (SDF) for freeways predicts an increase in fatal (K) and serious injury (A) crashes when shoulder rumble strips are present
  - This is counterintuitive given that shoulder rumble strips are listed as one of FHWA's proven safety countermeasures
- No resolution to this issue was agreed upon at the conclusion of the meeting

Freeway Rumble Strip CMF (cont.)

- Potential next steps were discussed as follows:
  - Exclude shoulder rumble strip adjustment from SDF
  - Conduct sponsored research
- FHWA currently has a request for proposal out to address this issue
  - Goal is to be able to incorporate the results from this research into HSM2

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Review and Coordination with NCHRP 17-89/17-89A Projects

Part-Time Shoulder Use and HOV/HOT Lanes

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Review of NCHRP Project 17-89 – Part-Time Shoulder Use

- Project 17-89 developed Adjustment Factors (AFs) for:
  - part-time shoulder use (PTSU) “lanes” and transition zones
  - turnouts provided for stopped vehicles outside shoulders with PTSU
- Project 17-89 decided not to use the existing HSM1 Chapter 18 predictive method for freeway segments because this existing method addressed two-way segments
- PTSU AFs were developed for use with a new predictive method for directional freeway segments

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Review of NCHRP Project 17-89: Part-Time Shoulder Use

- Project 17-89 recommended keeping the HSM1 method for two-way freeway segments AND including a new chapter with the directional freeway segment method for use where PTSU is considered

- Held conference call with Project 17-89 PI, Pete Jenior, to consider options for integrating results from 17-89 into HSM2

Review of NCHRP Project 17-89 – Part-Time Shoulder Use

- New chapter with the directional freeway segment method for use where PTSU is considered is NOT recommended
    - The Project 17-89 method (with no PTSU present) will give different predictions than the HSM1 method
    - This option would create confusion among HSM users
    - This option would create opportunities for mischief
        - A user could select whichever of the two answers they like best

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Intended Direction – Convert Chapter 18 Two-Way Method to a Directional Method and Add the New PTSU AFs

- Convert HSM1 Chapter 18 method to a directional freeway segment method and incorporate the new 17-89 AFs in that method
- Strengths:
  - Maintains consistency with the existing HSM1 freeway procedure
  - Recognizes that freeway segment operations and PTSU operation are, by their nature, directional
  - Maintains compatibility between the existing HSM1 freeway segment and ramp prediction methods
  - Sensitivity analysis of the Chapter 18 and 17-89 methods will be needed to assess whether the new AFs need to be modified to work with the Chapter 18 method
- Limitations
  - No two-way freeway segment method would be available

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Review of NCHRP Project 17-89A: HOV/HOT Lanes

- Project 17-89A recommended keeping the HSM1 method for two-way freeway segments AND including a new chapter with the directional freeway segment method for use where HOV/HOT lanes are considered
- The Project 17-89A analysis procedure can only be used to assess freeway segments with HOV/HOT lanes
  - Project 17-89A has not developed any method to compare safety performance of a given freeway segment with and without HOV/HOT lanes
  - Project 17-89A recommended comparing their results for freeway segments with HOV/HOT lanes to the HSM1 Chapter 18 results for freeway segments without HOV/HOT lanes
  - The two procedures have SPFs that appear similar, but the AFs in the two procedures are very different

Review of NCHRP Project 17-89A HOV/HOT Lanes

- A conference call with Dr. Scott Himes was held in January 2022
- Dr. Himes agreed with our initial assessment that the results of Project 17-89A cannot be easily integrated with the existing HSM Chapter 18 freeway procedure

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Review of NCHRP Project 17-89A HOV/HOT Lanes

POTENTIAL OPTIONS FOR HSM2

Option A—publish the Project 17-89A results as a separate chapter for freeways with HOV/HOT lanes. WE DO NOT RECOMMEND THIS.

Option B—publish the Project 17-89A results in an appendix in HSM2 with explicit warnings about the potential incompatibilities with HSM2 Chapter 17

Option C—publish the Project 17-89A results on an HSM2-related web site with explicit warnings about the potential incompatibilities with HSM2 Chapter 17

Option D—do not publish the Project 17-89A results in the HSM2 or on an HSM2-relared web site

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Coordination between NCHRP Project 17-71A and Continuation of NCHRP Project 17-89

- Recently learned that additional funds have been added to NCHRP 17-89 (PTSU) primarily to support pilot testing of the PTSU models by state DOTs that operate such facilities
- Our 17-71A team will meet with the 17-89 panel to discuss the objective and scope of this 17-89 continuation project and coordinate both projects as best as possible
- The same panel oversees both 17-89 and 17-89A projects
  - The continuation project will not address HOV/HOT lanes (17-89A)

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Plans for Current Quarter

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Plans for Current Quarter

- Prepare 4th round of draft chapters:
  - Ch 7. Diagnosis
  - Ch 8. Countermeasure Selection
  - Ch 12. Systemic Evaluation
  - Ch 13. Developing, Calibrating, and Using Safety Performance Functions and Crash Prediction Models
  - Ch 14. Predictive Method for Rural Two-Lane, Two-Way Roads

    - Note: Ch 3. Pedestrians and Bicycles
      - Now planned for submission with 5th round of materials (2/28/23)

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Questions???

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814-574-9194

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MRIGlobal
National Solutions Worldwide Impact

Pedestrian and Bicycle Safety Performance Functions for the Highway Safety Manual (NCHRP 17-84)

Research Team

MRIGlobal Larson Institute SafeTREC Abley, NZ

Texas A&M Transportation Institute

Transportation Research Center

Defense Energy Health

8/9/2022

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Research Objective and Scope

- **Objective**
  - Develop pedestrian and bicycle SPFs for transportation practitioners at all levels to better inform planning, design, and operations decisions
- **Scope**
  - Develop pedestrian and bicycle SPFs for:
    - Roadway segments and intersections
    - Rural and urban areas

Primary Work Plans

- **Work Plan A** – Develop Pedestrian and Bicycle SPFs using Available Exposure Data
- **Work Plan B** – Develop and Test an Alternative Approach to Pedestrian and Bicycle Crash Prediction based on Road Assessment Program (RAP) Methodology
- **Work Plan C** – Develop Probability of Pedestrian and Bicycle Crashes Based on Crash Data in the Absence of Pedestrian and Bicycle Volume Data

Work Plan A – Develop Pedestrian and Bicycle SPFs using Available Exposure Data

- Negative binomial regression
  - Segment form

$$N_{spf} = \text{AADT}^{\beta_{AADT}} \times \text{AADT}_{\text{m}}^{\beta_{AADT_m}} \times L \times e^{\boldsymbol{\beta X}}$$

  - Intersection form

$$N_{spf} = \text{AADT}_{\text{ent}}^{\beta_{AADT_{ent}}} \times \text{AADT}_{\text{m,ent}}^{\beta_{AADT_{m,ent}}} \times e^{\boldsymbol{\beta X}}$$

AADT – traffic volume (veh/day)

AADT_{ent} - traffic volume entering intersection (veh/day)

AADT_{m} – non-motorized traffic volume (veh/day)

$\text{AADT}_{\text{m,ent}}$ – non-motorized traffic volume entering intersection (veh/day)

L – segment length

$\boldsymbol{X}$ – other candidate independent variables

Work Plan A – Develop Pedestrian and Bicycle SPFs using Available Exposure Data

- Models for urban roadway segments
  - Two lane roads
  - Four lane roads (divided and undivided)
  - One-way roads (1-ln, 2-ln, and 3-ln)
- Models for urban intersections
  - Three-leg stop controlled
  - Three-leg signalized
  - Four-leg stop controlled
  - Four-leg signalized (2×2 and 2×1)
- Severity levels
  - All injuries
  - Fatal and serious
- Exposure only and expanded models (i.e., include adjustment factors)

Work Plan A – Develop Pedestrian and Bicycle SPFs using Available Exposure Data

- Adjustment factors for <u>segment</u> models:
  - <u>Pedestrian</u> models
    - Presence of sidewalk buffer
    - Lane width
    - Presence of a median
    - Speed limit (greater than 25 mph)
    - Number of lanes (one-way roads)
    - Number of bus stops within 1,000 ft
    - Number of schools within 1,000 ft
    - Number of liquor establishments within 1,000 ft

Work Plan A – Develop Pedestrian and Bicycle SPFs using Available Exposure Data

- Adjustment factors for segment models:
  - Bicycle models
    - Presence of a buffered bike lane
    - Lane width
    - Presence of a median
    - Speed limit (greater than 25 mph)
    - Number of lanes (one-way roads)
    - Number of bus stops within 1,000 ft
    - Number of schools within 1,000 ft
    - Number of liquor establishments within 1,000 ft

Work Plan A – Develop Pedestrian and Bicycle SPFs using Available Exposure Data

- Adjustment factors for <u>intersection</u> models (4SG 2×2):
  - <u>Pedestrian</u> models
    - Right turn on red
    - Type of left-turn signal phasing
    - Number of liquor establishments within 1,000 ft

Work Plan A – Develop Pedestrian and Bicycle SPFs using Available Exposure Data

- Adjustment factors for intersection models (4SG 2×2):
  - Bicycle models
    - Presence of bicycle facilities entering the intersection
    - Type of left-turn signal phasing
    - Number of schools within 1,000 ft

Work Plan B – Develop and Test an Alternative Approach to Pedestrian and Bicycle Crash Prediction based on Road Assessment Program (RAP) Methodology

- Initially procedures included an AF for roundabouts
  - This AF could be used to evaluate proposed roundabouts for future conditions
- The AF for roundabouts has been removed
  - These models cannot be used to evaluate roundabouts

Draft HSM2 Text

- Recommendations:
  - Incorporate exposure-only models from **Work Plan A** into network screening chapter
  - Incorporate **Work Plan B** models into Part C chapters
    - Rural 2-lane roads
    - Rural multilane highways
  - Incorporate **Work Plan A & B** models into Part C Chapter
    - Urban/suburban arterials
  - Incorporate **Work Plan C** results into new pedestrian and bicycle chapter

Schedule

- Submitted draft final report and other project deliverables (including draft text for HSM2) to NCHRP on 3/15/22
- POP extended to 8/31/22 to revise final report and other project deliverables in response to panel comments
  – To date, we have not received panel comments on the draft project deliverables

Questions???

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Traffic Operations and Roadway Safety Division
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Texas A&M Transportation Institute

8/9/2022 Transportation Research Center 13

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AASHTO

Highway Safety Manual
Practical Applications

Bonnie Polin, Massachusetts DOT
Stephen Read, Virginia DOT
Kelly Hardy, AASHTO

Agenda

- Practical Applications Task Force
- Recommendations
- User Forum
- Discussion

Practical Applications Task Force

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- User Liaison Task Force focused on recommendations to improve the practical application of the Highway Safety Manual
- Mix of representatives State DOTS, researchers, consultants, FHWA and developers
- Two meetings were held January 26th and February 7th, 2022
- Task Force members included:

Bonnie Polin	Geni Bahar	Kelly Hardy	Ryan Cunningham
Brian Frazer	Henry Brown	Kim Kolody	Tim Barnett
Daniel Carter	Jacob Farnsworth	Mike Colety	Tim Collin
Danny Anderson	Jerry Roche	Mike Dimaiuta	Virginia O’Connor
Frank Gross	Karla Rodrigues Silva	Pete Jenior	Xiao Qin

- 11 recommendations produced

Recommendations

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1. AASHTO/FHWA/TRB/NCHRP Contract for technical assistance where the contractor can reach out to specific researchers/experts, provide them funding to respond to specific questions
    - Especially as part of the users' forum
    - FHWA DDSA has a contract but helpful to have flexibility to bring in others, NHTSA may have something similar
    - They key is to have expert non-volunteers provide accurate and expeditious responses to questions.
    - Ranked very high as a recommendation that would solve many of the noted concerns.
- Questions for TRB:
    - *How often are researchers asked for help / follow up and guidance on their HSM-related research?*
    - *Is this viewed as a need on your end?*
    - *What other way do you see that researchers can provide the guidance for response to questions in the forum should questions arise?*

2. NCHRP research for HSM work includes a provision for on-call assistance by the contractor.
    - Like HCM help with follow on research needs.
    - Ranked relatively low because contract may have expired after research is made public and is put in use.
    - The above recommendation could include assistance from the researcher so if the above recommendation moved forward, no reason for this one.

HSM User Discussion Forum

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- **Growing interest in creating a forum to…**
  - Increase user interactions and peer exchange
  - Identify, respond to technical questions in centralized platform
  - Share news, research, and information
- **Looking for volunteers for a Pilot Test!**
  - ~15 volunteers from various backgrounds
  - Activities include:
    - Post at least two relevant topics
    - Respond to at least five topics
    - Test out critical features including notifications, profile, flagging, etc.

Want to volunteer? Fill out this form:
https://forms.office.com/g/VJLSqsESeH

Recommendations

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3. NCHRP research for HSM must have an added task of a webinar for a presentation to practitioners of practical use with case studies and edge case discussions before the research is finalized and final report prepared.

    - Ranked high and would provide the practical edge cases that would be needed for recommendation 3.
    - It would also give practitioners a chance to test the practical uses of the research before it is finalized.
    - Discuss with NCHRP after TRB/AASHTO

- Questions for TRB:
    - *How doable/practical to solicit edge cases to include in a webinar?*
    - *How doable/practical to include edge cases?*
    - *Does this help to make the implementation plan part of the research project more practical?*
    - *Would it help the AASHTO Steering Committee to put together a write up of what is helpful to practitioners?*
    - *When drafting research needs statements, including an objective for developing and including practical edge cases?*

4. NCHRP research for HSM work includes a section in the final report about how to deal with a number of edge cases.

    - Ranked medium but there were questions how the edge cases could be determined before the research is finalized.
    - If the above recommendation were implemented, this would simply be part of the research tasks and report.

Recommendations

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5. Begin to understand transferability of calibrations / location specific SPFs so that it is defensible ("accurate enough").

- Synthesis as a first step to get calibrations for all facility types and how used in various jurisdiction.
- Ranked high to determine what entities have done for calibration, Identify those that could not calibrate and why? And what has been done for variable/model sensitivity to calibrate.
- Thank you, Kelly Hardy, Daniel Carter and Karla Rodrigues Silva. Approved as a synthesis.
- Synthesis Topic 54-10 State Customization of Highway Safety Manual Methods.

6. NCHRP research for HSM includes factors in CPM (crash prediction models) for similar types of jurisdictions (similar to the level, rolling, mountainous terrain in some Level of Service calculations).

- Research need and a RNS will need to be prepared.
- Medium because we may need to wait until the synthesis is completed.

- Questions for TRB
  - *Do we need to wait for the synthesis to be completed?*
  - *What is the feasibility of conducting this research and what would be some challenges?*
  - *Would this change the way we think of calibration?*

Recommendations

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7. Provide a practitioner's application guidance document on how to use HSM Part C (and other parts) for edge cases or situations that are not fully covered in the HSM.

- How to handle unique situations.
- For Part b – more in depth how to use it.
- Suggested research project builds on 17-50 Users' Guide.
- Workshops where we developed flowcharts may be good to add in.
- This is different from 17-83 "training" and is more guidance.
- Ranked high and Tim Barnett updated/modified a RNS that was previously submitted, and it came back ranked high so this should move forward.

Recommendations

8. Develop uniform legal language or caveats (with data back-up) on how this is the best methodology

- Recommendation to use even though it may not be perfect but, but it is the best methodology to use as of now.
- Ranked low because it was being held off until better defined

Questions for TRB

- *Is it appropriate?*
- *If a statement like this were contained in the HSM, would that impact the way you develop the research or the responses you provide?*
- *How to best use your research to answer questions that may not fit exactly?*

Recommendations

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9. Work with software developers to ensures the software tools either requires site specific SPFs / calibrations or includes disclaimers/warnings automatically so it is not just garbage in / garbage out with black box results.

- Errors and warnings need to have context (both at time of input and on the output).
- Ability for software by governed by limits depending on jurisdiction.
- This is being held off because this should be a guiding principle in software development.
- It was thought it better to make sure it is clear how to apply tools. There should be clear guidance.
- But this did not result in any specific recommendation just keep in mind.

Recommendations

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10. National / good representation of states database of crash data (fatal / serious injuries) with attributes needed so we can all use the same dataset.

- Would help with research and with more diverse states' models developed for HSM.
- Maybe expand HSIS to cover more states and / or develop a FARS type database of suspected serious injury crashes.
- Ranked high and Jerry Roche working with others at FHWA regarding HSIS, and how to increase the number of states involved.
- Then need to reach out to states (through AASHTO Committee on Safety(?)) to gain interest.

- Questions for TRB
  - *Do many research projects start with HSIS?*
  - *Would having more states' data help with research projects?*

Recommendations

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11. National / NCHRP has a requirement that data must be available so it can add to a database for others to use.
    - Need a uniform way of accepting all data in a repository (Bureau of Transportation Statistics, HSH, etc.)
    - Ranked high recommendation to pursue.
    - What does NCHRP do with the data, do they need to provide a schema so it can all be collected uniformly so it can be used by others?
    - Discuss with NCHRP after TRB/AASHTO

- Questions for TRB
    - *How often do researchers' data come from previous NCHRP projects data?*
    - *Is that typically the starting point and is it easy to access?*

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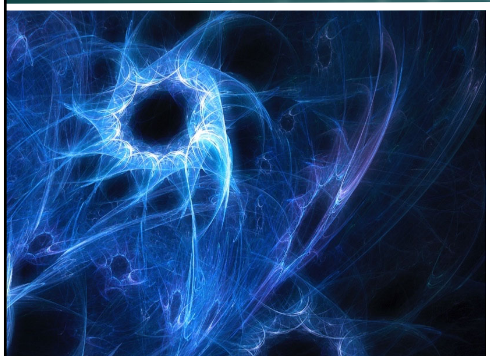
AASHTO

Discussion

Bonnie Polin at bonnie.polin@state.ma.us
Stephen Read at stephen.read@vdot.virginia.gov
Kelly Hardy at highwaysafetymanual@aashto.org



NCHRP Project 22-45: Informing the Selection of Countermeasures by Evaluating, Analyzing, and Diagnosing Contributing Factors that Lead to Crashes

Project Update for ACS20, August 4, 2022

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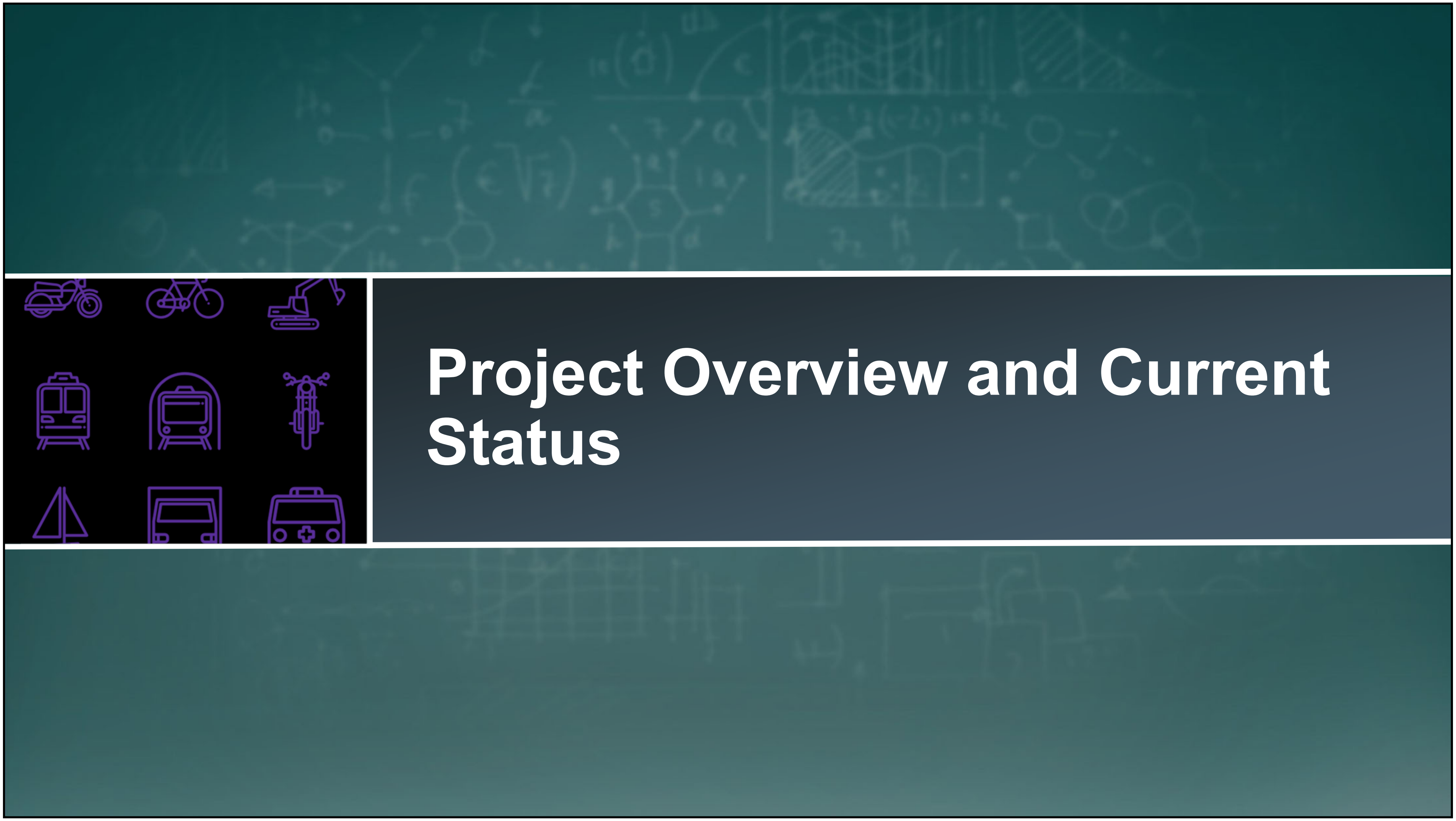
Discussion Topics

- Project Overview and Current Status
- Assess Previous Research
- Conduct Focus Groups with Practitioners
- Define Procedures, Methods, & Tools – Review of the Proposed 'Practitioner's Toolbox'
- 2023 Practitioners' Workshop



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Project Team

Team Member	Organization	Capabilities & Role
John Campbell	Exponent	• PI • Human Factors • Road user behavior • Diagnostic assessment & HF tools
Liberty Hoekstra-Atwood Katie Lucaites	Exponent	• Human Factors • Literature reviews and synthesis • Task/workload analysis tools and methods
Darren Torbic Ingrid Potts	Texas A&M Transportation Institute	• Traffic Engineering • Knowledge of existing tools • Strong ties to the practitioner community • Countermeasure selection tools

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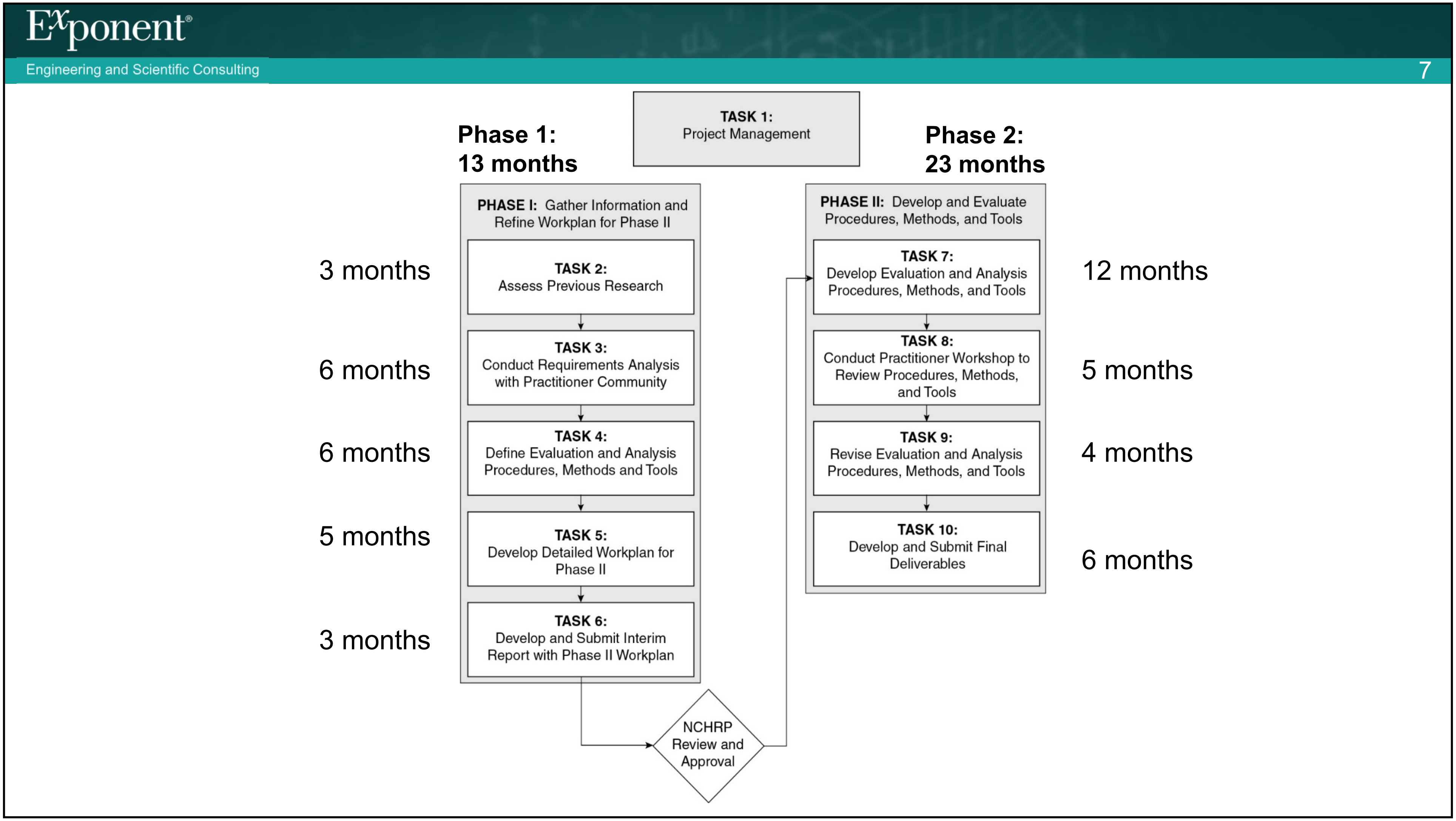
Project Objectives

1. Develop new methods and tools for diagnosing contributing factors leading to crashes & identifying matching countermeasures
2. Address a wide variety of contributing factors leading to crashes

Overview of General Approach

- Identify Procedures, Methods, and Tools that:
  - Reflect practitioner's **needs,**
  - Provide **value** to the diagnostic assessment/countermeasure selection process,
  - Are **viable** to develop,
- Develop Procedures, Methods, and Tools that are:
  - **Empirical** (grounded in relevant scientific studies and data),
  - **Practical** (understandable and usable for day-to-day use by practitioners),
  - **Actionable** (providing multi-modal, context-sensitive insights implementable by State DOTs).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Phase 1:
13 months
TASK 1:
Project Management
Phase 2:
23 months
PHASE I: Gather Information and Refine Workplan for Phase II
3 months
TASK 2:
Assess Previous Research
6 months
TASK 3:
Conduct Requirements Analysis with Practitioner Community
6 months
TASK 4:
Define Evaluation and Analysis Procedures, Methods and Tools
5 months
TASK 5:
Develop Detailed Workplan for Phase II
3 months
TASK 6:
Develop and Submit Interim Report with Phase II Workplan
NCHRP Review and Approval
PHASE II: Develop and Evaluate Procedures, Methods, and Tools
TASK 7:
Develop Evaluation and Analysis Procedures, Methods, and Tools
12 months
TASK 8:
Conduct Practitioner Workshop to Review Procedures, Methods, and Tools
5 months
TASK 9:
Revise Evaluation and Analysis Procedures, Methods, and Tools
4 months
TASK 10:
Develop and Submit Final Deliverables
6 months

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Task 2: Assess Previous Research

- **Key Findings (frameworks for diagnosing crashes):**
  - There are many different ways to characterize crashes, for example:
    - as a sequence of linked events (Heinrich's approach)
    - when a "trajectory of accident opportunities" align (Reason's swiss cheese model),
    - When external disturbances, component failure, or dysfunctional interactions among system components are not adequately handled (Leveson's approach)
  - There are common themes across these explanations and models that are helpful:
    1. crashes are often a result of a complex interactions between an individual (e.g., a driver) and the environment (e.g., a darkly-lit, curved roadway)
    2. there is usually not one singular "hazard" on the roadway that will necessarily lead to a crash, rather there are a specific set of conditions that interfere with the intentions and successful performance of a driver.
    3. most crashes happen when the demands of the driving task exceed the capabilities of the driver

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Task 2: Assess Previous Research

- **Key Findings (human factors aspects of crashes):**
  - While many data sources related to human factors are available, most are academic, full of psychological terminology, and fail to break down the larger field of human factors into understandable chunks
  - These materials not accessible by or understandable to the typical practitioner
  - However, there are some key human factors issues that play a disproportionate role in crashes that can be readily explained to the practitioner
    - Expectations
    - Visibility
    - Workload
    - Perception-Reaction Time

Conduct Practitioner Focus Groups

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Task 3: Conduct Requirements Analysis with Practitioner Community

- **37 Participants in a series of 2-hr focus groups:**
  - State Highway Safety Offices (SHSOs)
  - Federal Highway Administration (FHWA)
  - National Highway Traffic Safety Administration (NHTSA)
  - Federal Motor Carrier Safety Administration (FMCSA)
  - National Sheriffs' Association (NSA)
  - Centers for Disease Control (CDC)
  - Substance Abuse and Mental Health Services Administration (SAMHSA)
  - National Association of State EMS Officials (NASEMSO)

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Task 3: Conduct Requirements Analysis with Practitioner Community (cont.)

- **Discussion Topics:**
  - When responding to a crash, what methods or tools do you currently use to determine the underlying causes and contributing factors leading to a crash? Do the methods/tools differ by the type of crash/mode, location, context, etc.?
  - What do you like about these methods/tools? Do you believe something is missing in your current approach? What are the key gaps?
  - Do these methods/tools address a wide variety of crash-contributing factors or are there key contributing factors (such as human factors and driver behavior) not addressed by these methods/tools?
  - What process or steps do you use to diagnosis a safety concern at a location (e.g., review safety data, assess supporting documentation, assess field conditions)?

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Task 3: Conduct Requirements Analysis with Practitioner Community (cont.)

- **Discussion Topics:**
  - How do you incorporate human factors issues, such as visibility and driver workload?
  - What process or steps do you use to select a countermeasure for implementation at a location (e.g., identify crash-contributing factors, identify countermeasures that may address the contributing factors, possible cost-benefit analysis)? Do you consider contraindications of potential countermeasures? Before implementation, do you consider other types of potential impacts a countermeasure may have (e.g., on traffic operations or the environment)?
  - Do these processes/steps differ depending upon crash type, location, context, etc.?
  - Do you believe something is being overlooked or is missing in your current approach to diagnosis and/or countermeasure selection; where are the key gaps?

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Task 3: Conduct Requirements Analysis with Practitioner Community (cont.)

- **Key Themes that emerged from the Focus Groups:**

1. Basic procedures and tools are available and the practitioner community understands them and knows how to use them
2. Practitioners desired more and better information on human factors, yet emphasized that lengthy procedures will not work
3. The focus of new tools should be on ease-of-use (simple and fast) vs. any specific presentation method

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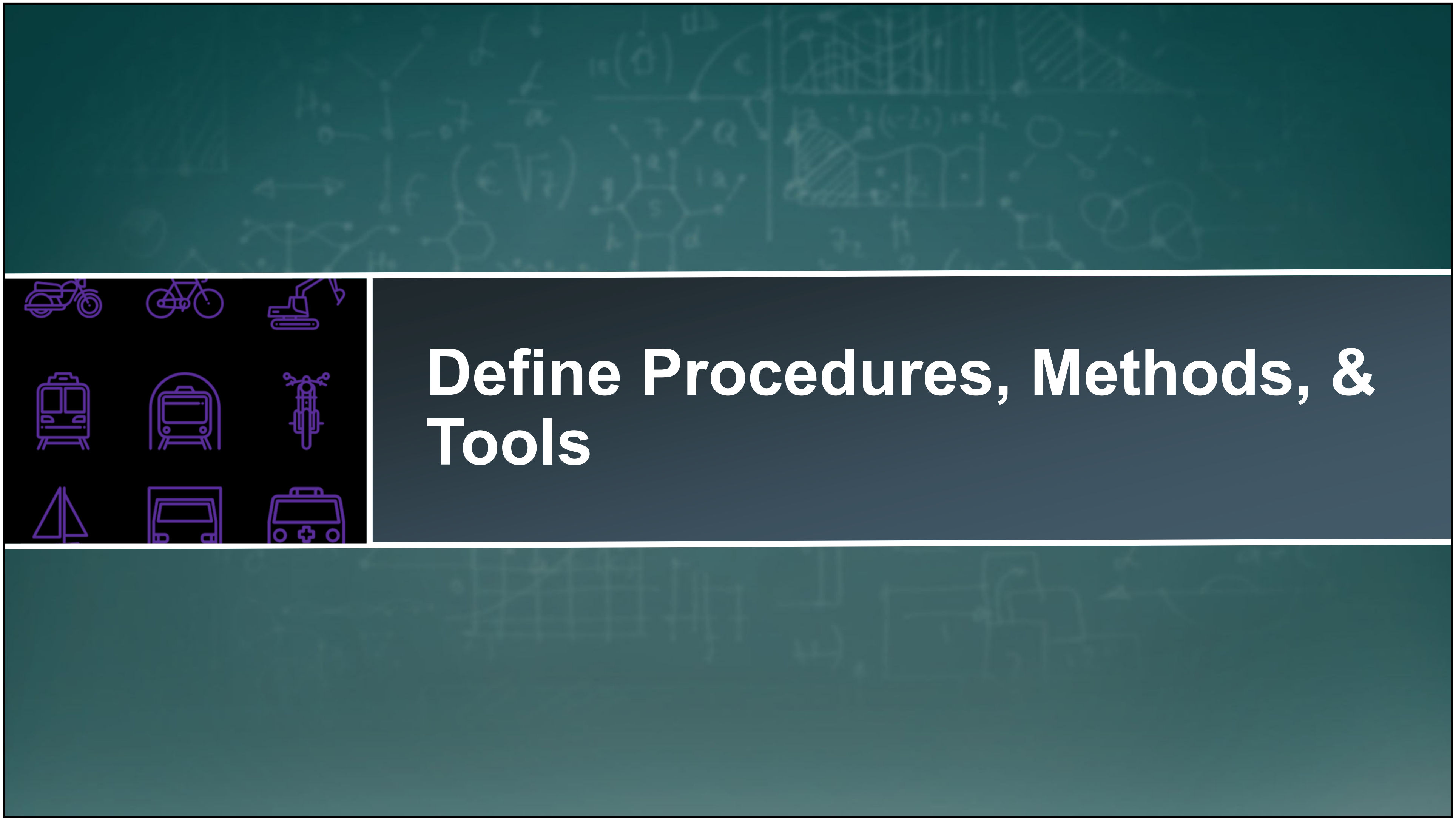
Implications of the Literature Review and the Focus Groups for the Project

1. A key gap in current diagnostic assessment and countermeasure selection procedures are the key human factors-related contributors to crashes, as well as the behavioral implications of countermeasures.
2. Practitioners lack the time and the bandwidth to work their way through long, complicated procedures and tools. Such tools exist and, despite their relevance, rigor, and comprehensiveness (e.g., *Safety Analyst*) they do not seem to be widely used among the practitioner community.
3. Current sources do not always clearly describe the links between the contributing factors to crashes and effective countermeasures.



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Task 4: Define Evaluation and Analysis Procedures, Methods, and Tools

- **Scope:** Develop a clear and complete description of each procedure, method, and tool to be developed and refined in Phase II.
- **Approach:**
  - Integrate Task 2-3 findings
  - Develop a broader framework for the research products
  - Define the new and enhanced methods and tools for comprehensive diagnostic assessment methods and countermeasure selection across modes and in different roadway contexts using crash type, severity, and other data
  - Communicate to the project panel the need, value, and viability of the products
  - Support the development of a realistic and thorough workplan in Task 5.

Task 4: Define Evaluation and Analysis Procedures, Methods, and Tools

- **Overview of Planned Products**
  - An integrated guidebook that contains the methods, tools, and training developed in this project. Key chapters:
    - Introduction
    - How to Use
    - Diagnostic Methods
    - Countermeasure Selection
    - Training Materials
    - References
    - Glossary
    - Index

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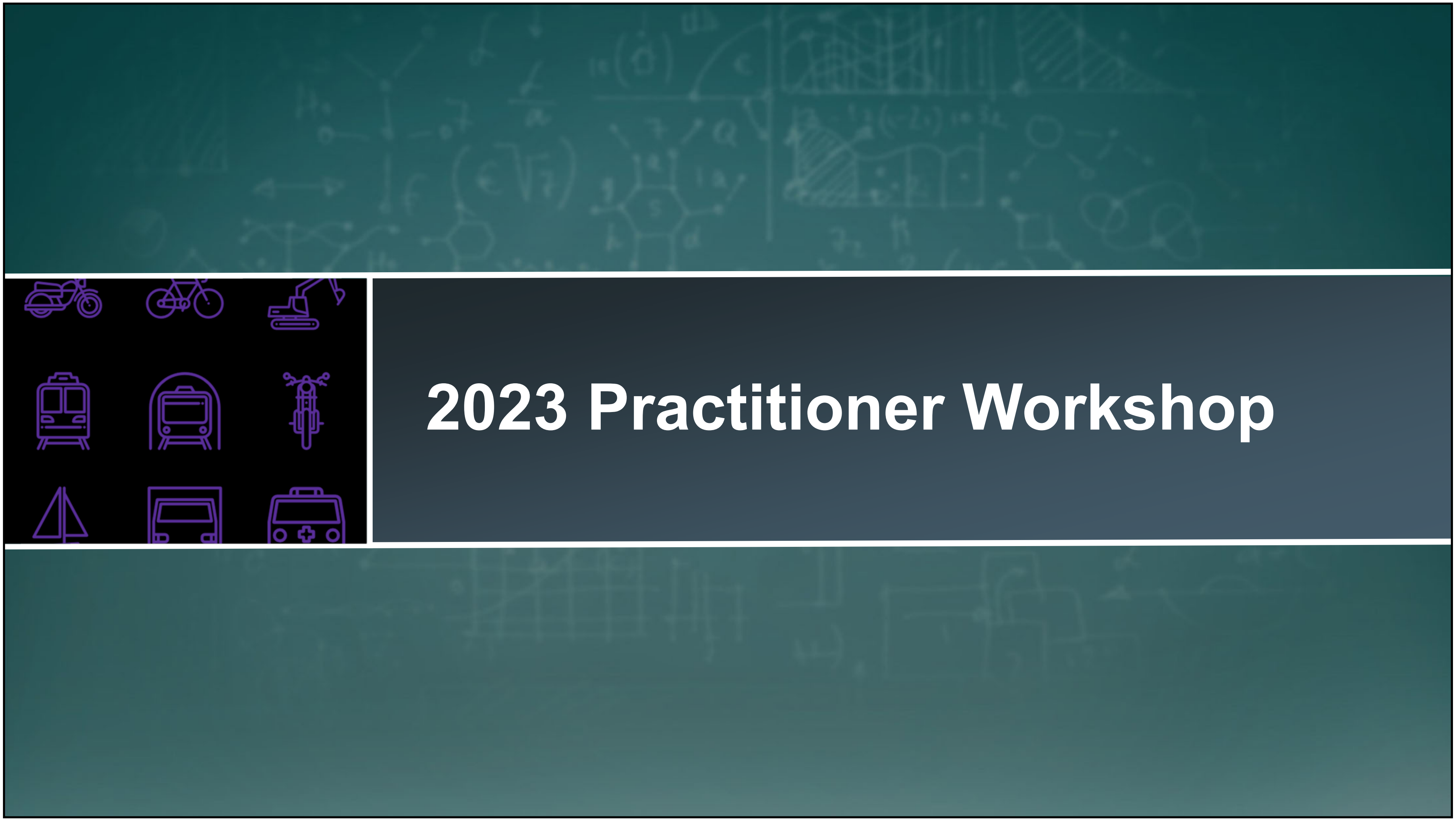
The Practitioner's Toolbox: Improving Diagnostic Assessment of Crashes and Selecting Effective Countermeasures

- **10 key products**
  - Tools
  - Methods
  - Training

Tool, Method, or Training	Roadway	Technological	Behavioral	Human Factors	Socioeconomic	Demographic	Weather	Land Use
1. Human Factors vs. Driver Behavior (Tool)	●	●	●	●		●	○	
2. Overview of Key Human Factors Issues in Crash Diagnostics (Tool)	●	●	●	●				
3. The Role of Expectations in Driver Behavior (Tool)	●		●	●		●		●
4. How Roadway Visibility Impacts Safety (Tool)	●		●	●		●	○	
5. Excessive Driver Workload as a Contributing Factor to Crashes (Tool)	●	●		●		●		
6. Driver Response Time: Implications for Design (Tool)	●	●	●	●		●	○	
7. Incorporating Task Analysis & Workload Analysis into Diagnostic Assessment (Method)	●	●	●	●				
8. Decision Trees to Help Select Countermeasures for Target Crash Types and Facility Types (Tool)	●	●	●	●			○	
9. Decision Trees to Help Select Countermeasures for Target Pedestrian and Bicyclist Crash Types and Facility Types (Tool)	●	●	●	●	○	○		○
10. The Practitioner's Toolbox: Methods for Improving Diagnostic Assessment of Crashes and Countermeasure Selection (On-demand Training)	●	●	●	●	●	●	○	●

● = Key Focus
○ = Addressed



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Practitioner Workshop

- Obtain feedback from practitioners
  - February 2023
  - 1.5 days
  - Overview of Project
  - Walkthroughs of tools, methods and training
  - Breakout sessions to discuss
  - Feedback to the research team

- Post-workshop – revise products to reflect feedback

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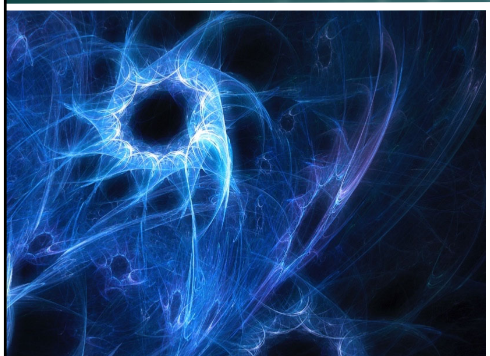

NCHRP Project 22-46: Human Factors Guidelines for Road Systems, 4th Edition

Project Update for ACS20, August 4, 2022

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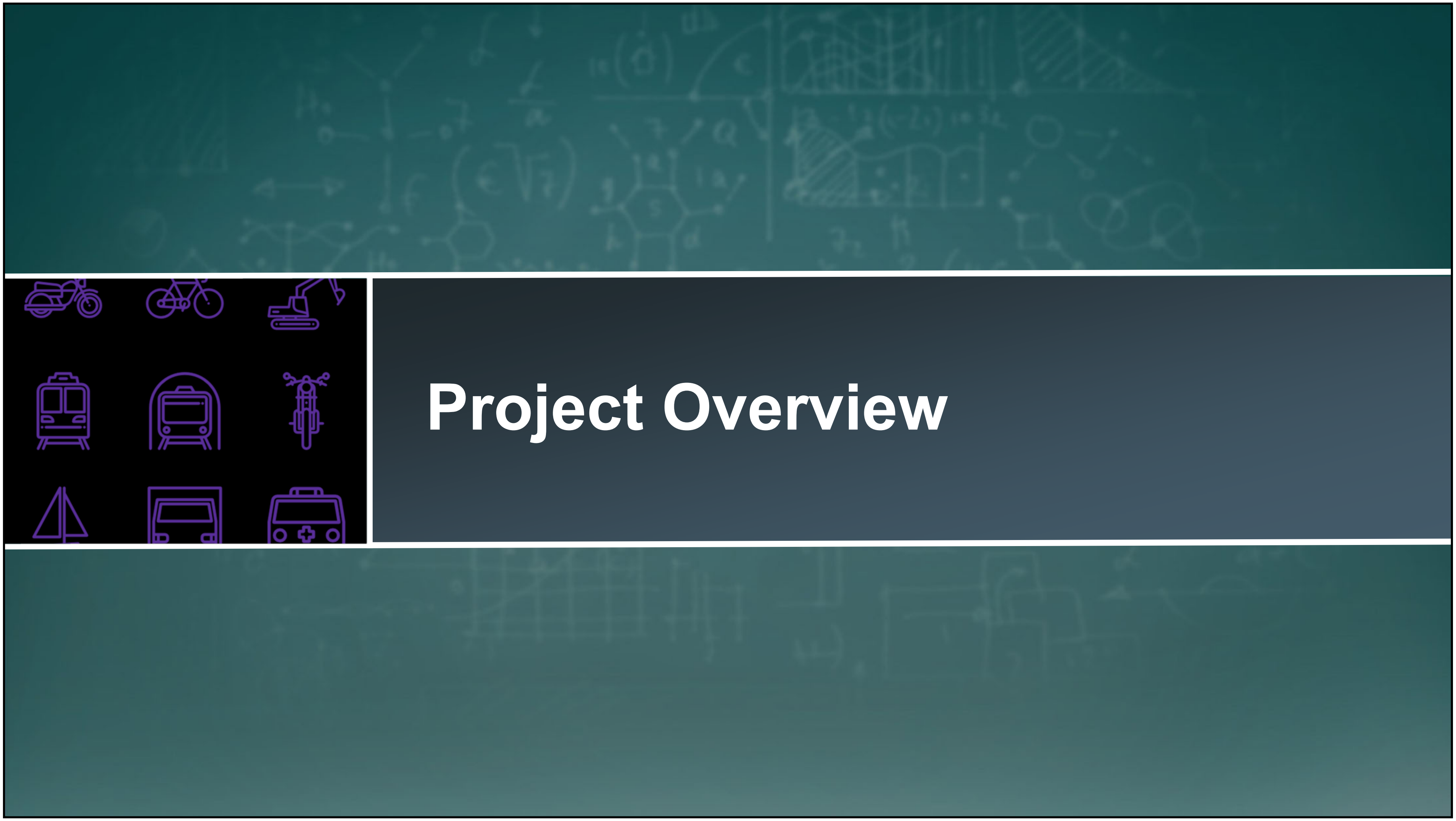
Agenda

- Project Overview and Current Status
- Practitioner Survey
- Develop HFG4 Priorities and Recommendations
- Plans for the HFG4



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Team Member	Organization	Capabilities & Role
John Campbell Liberty Hoekstra-Atwood	Exponent®	• Project management • Human Factors • Road user behavior • Guideline development
Darren Torbic Ingrid Potts Sue Chrysler	Texas A&M Transportation Institute	• Highway engineering and design • Strong ties to the practitioner community • Guideline development
Bryan Katz	toXcel	• Instructor for the HFG course administered through NHI • Extensive MUTCD experience

Project Overview - Objectives for the HFG4

(1) Prepare a *Human Factors Guidelines for Road Systems*, *Fourth Edition (HFG4).*

(2) Provide a supplement to the *AASHTO HSM* with other safety tools and processes.

(3) Document the best available HF and road/user interaction research and practices in road safety analyses and design.

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Project Overview - Research Approach

Activities	Tasks
Identify HFG4 Requirements and Available Data Sources	• Task 1: Assess Existing Human Factors Literature - Underway • Task 2: Develop Draft Practitioner Survey - Completed • Task 3: Conduct Practitioner Survey - Completed
Determine HFG4 Content and Develop Workplan	• Task 4: Develop Recommendations to Update the Content of the HFG - Complete • Task 5: Develop and Submit Interim Report - Complete
Develop and Pilot Draft HFG4 Content	• Task 6: Develop Updated Content for the HFG4 - Underway • Task 7: Conduct Pilot Studies
Finalize HFG4 and Other Deliverables	• Task 8: Prepare and Submit Draft and Final Deliverables

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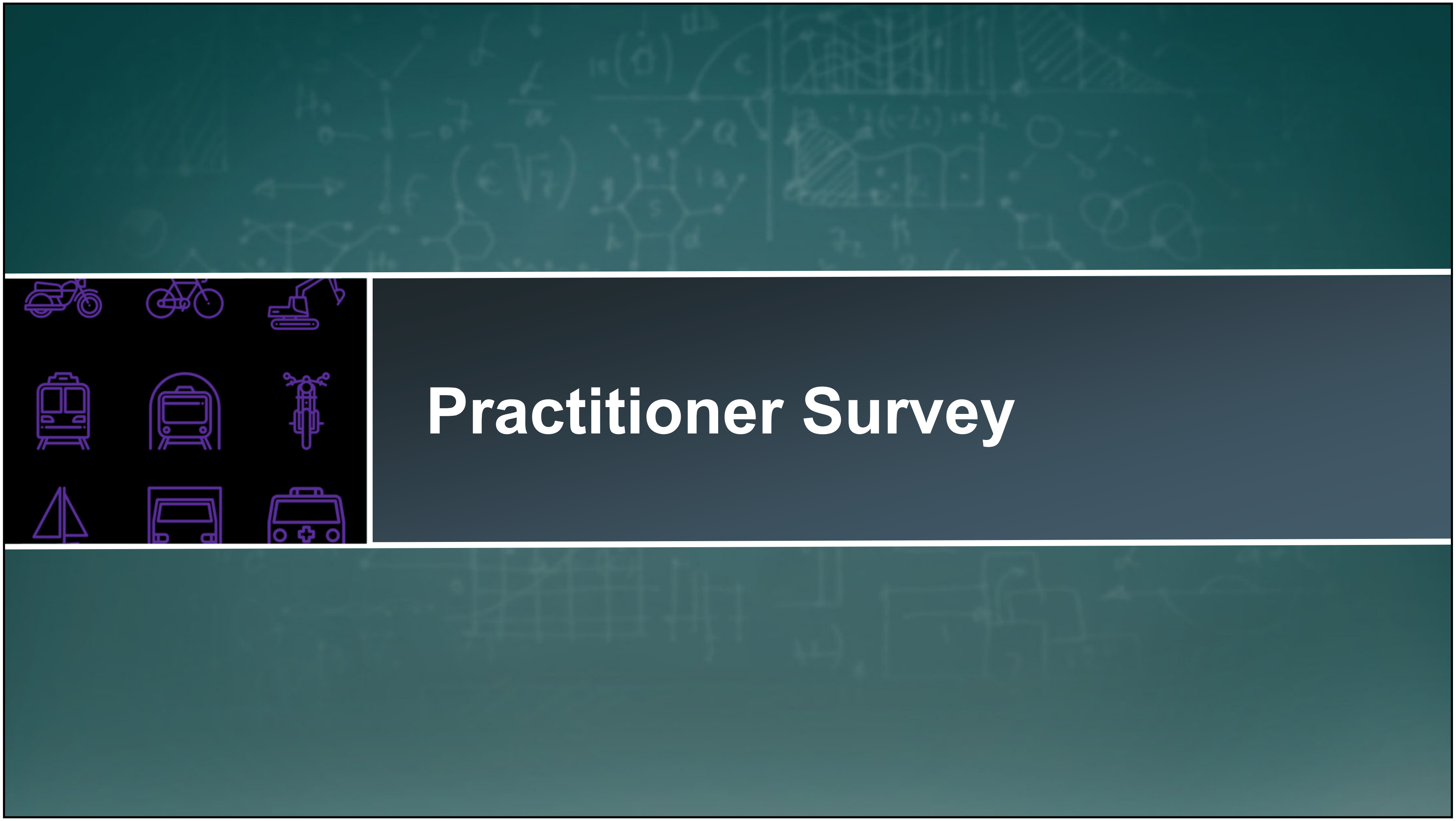
History of the HFG – Research Products

- Development of the Human Factors Guidelines for Road Systems (HFG) has been an ongoing project since 2001.
- 2001-2005 – Initial scoping and content identification
- 600A (2008) Chapters 1, 2, 3, 4, 5, 10, 11, 13, 22, 23, 26
- 600B (2008) Added Ch. 6 & updated Ch. 23, added Tutorials
- 600C (2010) Chapters 16, 17, 18, 19, 20, 22, added Tutorials 4, 5, & 6, plus other updates
- 2nd Edition (2012) – Added Chapters 7, 8, 9, 12, 14, 15, & 2; added a glossary and an index
- 3rd Edition (2020) Added Chapters on pedestrians, bicyclists, roundabouts, 3 new tutorials, updates to Chapters 1, 5, & 10



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Task 2: Develop Practitioner Survey

- **Survey Items (12 or 9 items):**
  - Demographics and job responsibilities (Questions 1-3)
  - One question on the respondent's level of familiarity with the HFG (Question 4)
  - Based on their response to Question 4, respondents received a different set of questions depending on whether they reported being familiar (Questions 5-10) or unfamiliar (Questions 11-13) with the HFG. All respondents received Questions 14 and 15.
  - For those familiar with the HFG: What types of design issues or problems users apply the HFG to, which chapters are the most/least useful, and what new chapters/topics would be most useful (Questions 5-10)
  - For those unfamiliar with the HFG: Why respondents have not used the HFG and what new chapters/topics would be most useful (Questions 11-13)
  - One question to gauge the respondent's understanding of the difference between human factors issues and driver behavior issues (Question 14)
  - One question about recommendations for improving the HFG (Question 15)

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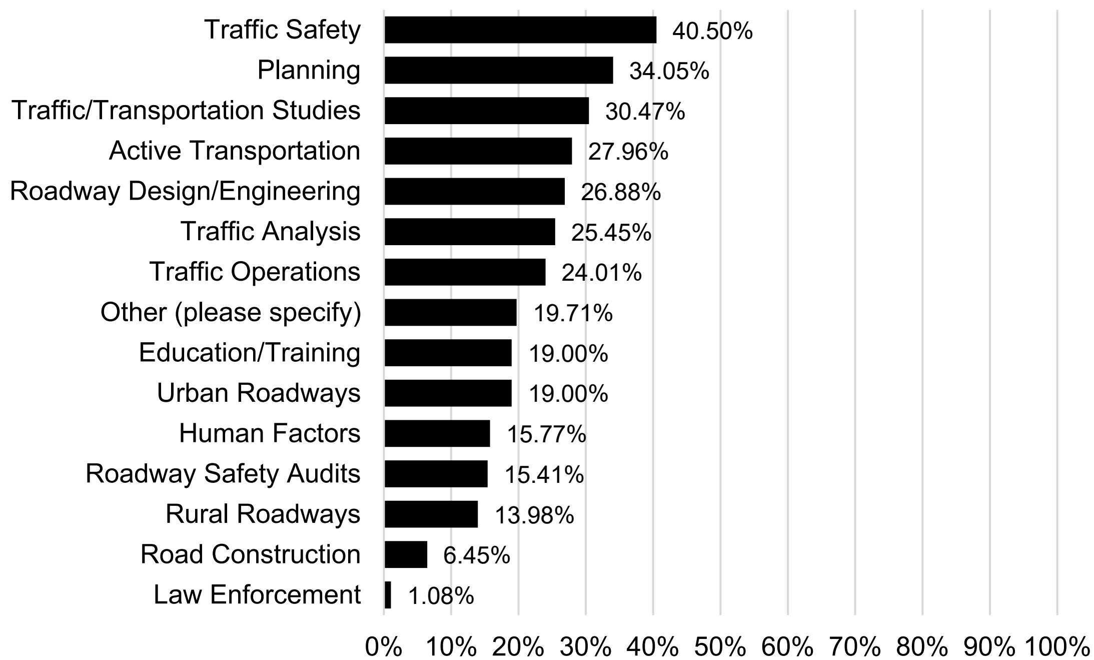
Task 3: Conduct Draft Practitioner Survey

- **Results (general):**

Q1 What are your primary job responsibilities?
(check all that apply)
(279 respondents)



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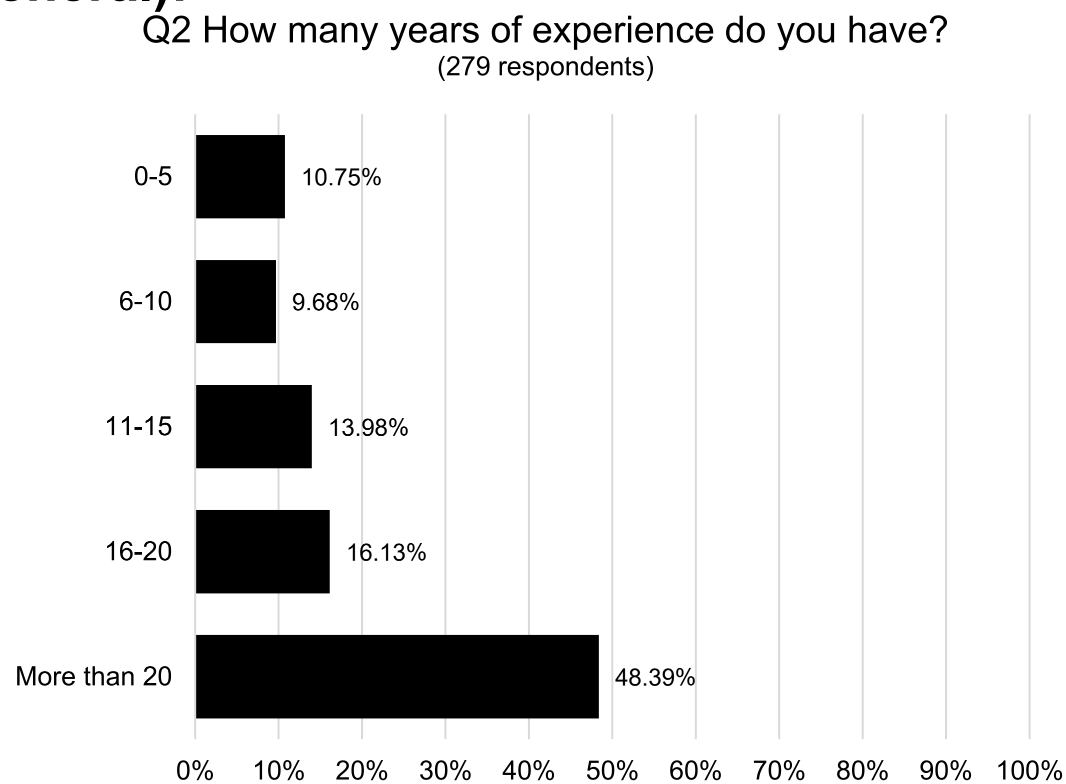
Task 3: Conduct Draft Practitioner Survey

- **Results (general):**



Task 3: Conduct Draft Practitioner Survey

- Q14: How would you describe the differences between human factors issues vs. driver behavior issues as they relate to roadway safety?
- 194 responses
- Only 37 responses (19%) correctly distinguished human factors issues from driver behavior issues

Develop HFG4 Priorities and Recommendations

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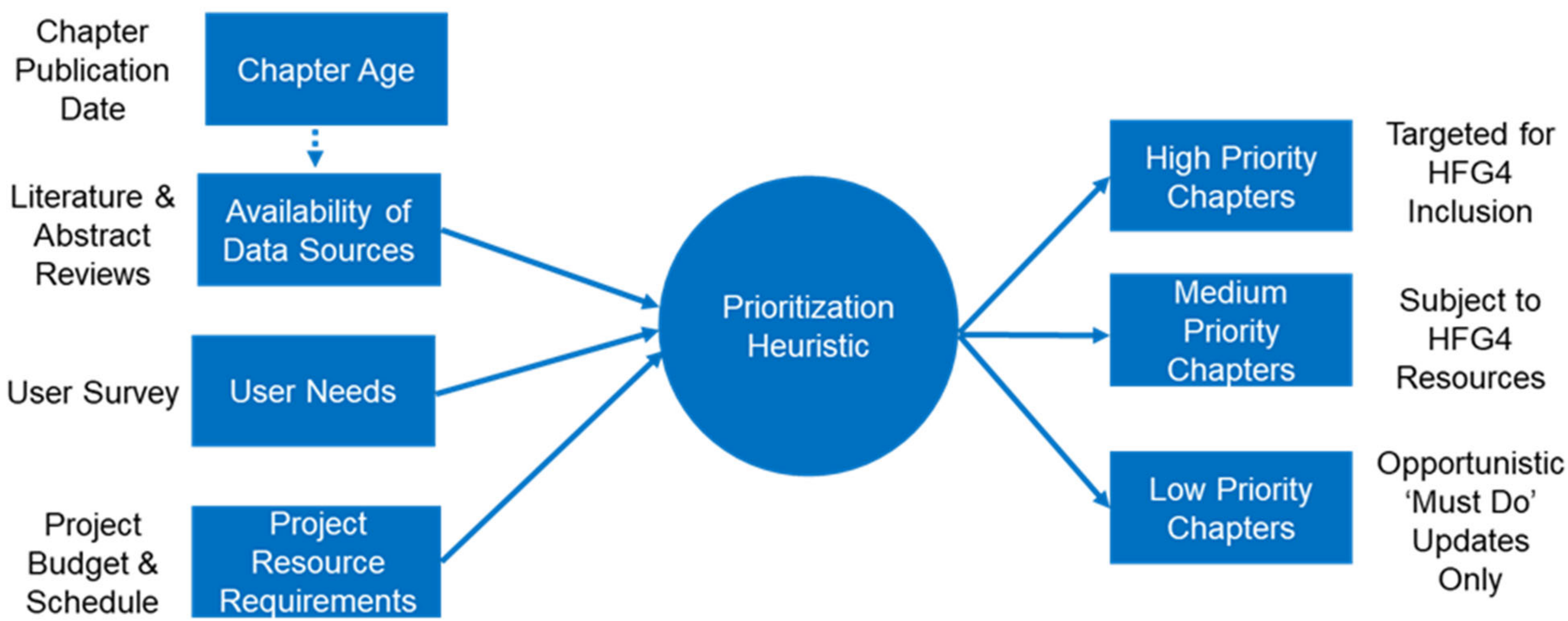
Task 4: Develop Recommendations to Update the HFG Chapter Prioritization Process



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Task 4: Develop Recommendations to Update the HFG

- **Recommended Approach to HFG4 Development:**
  - Develop high-priority chapters, + transit topics in the Urban Environments chapter.
  - Develop medium-priority chapters as time and budget allow, signing and work zones might be next in line to be updated
  - Reorganize the HFG to reflect HFG3 and HFG4 additions/updates
    - Identify 'spots' for the new HFG3 & HFG4 chapters
    - Re-number chapters/guidelines, cross references, ToC, & index to reflect the HFG4

High	Medium	Low
6 - Horizontal Curves	12 - Interchanges	7- Vertical Curves
11 - Signalized Intersections	13 - Work Zones	8 - Tangents
17 - Speed	15 – Urban Environments	9 – Transition Zones
Complete Streets	18 - Signing	14 – Rail Highway Grade Crossings
Older Road Users	21 - Lighting	16 –Rural Environments
	Transit	19 - CMS
		20-Markings
		Motorcycles
		Heavy Vehicles
		Connected/Automated Vehicles

Plans for the HFG4

New Guidelines

- *Curves (Horizontal Alignment) – 1 new guideline*
- *Signalized Intersections – 1 new guideline*
- *Urban Environments/Transit – 3 new guidelines*
- *New Chapter: Complete Streets – 5 guidelines*
- *New Chapter: Older Road Users – 5 guidelines*

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Curves (Horizontal Alignment): Countermeasures to Reduce Vehicle Speeds Entering Horizontal Curves

Overview: This guideline describes countermeasures that support improvements in curve detection and driver performance through the use of pavement surface markings and other types of treatments (e.g., transverse rumble strips).

Example of transverse stripes entering a curve; "Slow" text with arrow.

Key Sources

Babić, D., Fiolić, M., Babić, D., & Gates, T. (2020). Road markings and their impact on driver behaviour and road safety: A systematic review of current findings. *Journal of Advanced Transportation*, *2020*.

Katz, B., & Rakha, H. A. (2008). *Determination of Effective Design of Peripheral Transverse Bars to Reduce Speeds on a Controlled Roadway*. In *Proceedings of the 87th Transportation Research Board annual meeting, Washington, DC*.

Wood, J., & Donnell, E. T. (2020). Empirical Bayes Before-After Evaluation of Horizontal Curve Warning Pavement Markings on Two-Lane Rural Highways in Pennsylvania. *Accident Analysis & Prevention*, *146*.

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Signalized Intersections: Countermeasures to Reduce Left-Turn Crashes During Permissive Phases

Overview: Drivers must assess gaps in the opposing traffic stream to complete a left turn. Rejecting adequate gaps can lead to delays, while accepting inadequate gaps could lead to a collision. Countermeasures are offset left-turn lanes and flashing yellow arrow signals.

Examples: Offset left turn lane at a signalized intersection; Flashing yellow arrow signal

Key Sources

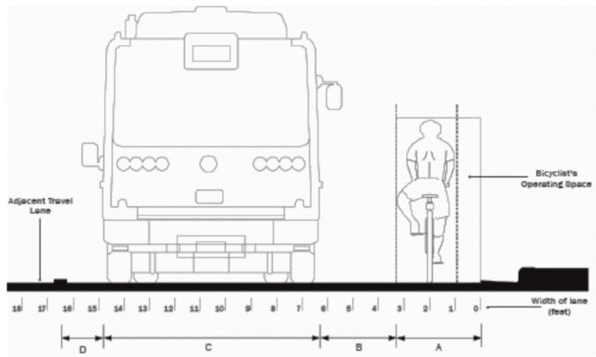
Fitzpatrick, K., Brewer, M. A., Dorothy, P., & Park, E. S. (2014). *Design Guidance for Intersection Auxiliary Lanes*.

Srinivasan, R., Lan, B., Carter, D., Smith, S., & Signor, K. (2020). *Safety Evaluation of Flashing Yellow Arrows at Signalized Intersections [techbrief]* (No. FHWA-HRT-19-035). United States. Federal Highway Administration. Office of Safety Research and Development.

Song, Y., Chitturi, M. V., Bremer, W. F., Bill, A. R., & Noyce, D. A. (2022). Review of United States research and guidelines on left turn lane offset: Unsignalized intersections and signalized intersections with permitted left turns. *Journal of Traffic and Transportation Engineering (English Edition)*.

Urban Environments: Bus Roadway Facilities

Overview: This guideline discusses bus facilities that affect driver, bicyclist, and pedestrian safety. The traffic flow considerations of each facility will be discussed.



Example Figure from Hillsman et al., 2012

Key Sources

Agrawal, A. W., Goldman, T., & Hannaford, N. (2012). *Shared-use bus priority lanes on city streets: Case studies in design and management* (No. CA-MTI-12-2606). Mineta Transportation Institute.

Duduta, N., Adriazola, C., Hidalgo, D., Lindau, L. A., & Jaffe, R. (2012). Understanding road safety impact of high-performance bus rapid transit and busway design features. *Transportation research record*, *2317*(1), 8-14.

Hillsman, E. L., Hendricks, S. J., & Fiebe, J. (2012). *A summary of design, policies and operational characteristics for shared bicycle/bus lanes* (No. NCTR 77937/BDK85 977-32). Florida. Dept. of Transportation.

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Urban Environments: Light Rail and Streetcar Roadway Facilities

Overview: This guideline discusses Light Rail and Streetcar facilities that impact driver, bicyclist, and pedestrian safety. The traffic flow considerations of each facility will be discussed.

Example Figure from Baranowski et al., 2014

Key Sources

American Association of State Highway and Transportation Officials. (2014). *Guide for Geometric Design of Transit Facilities on Highways and Streets*.

Currie, G., Reynolds, J., Naznin, F., & Law, J. (2017). Exploring the Safety Performance of Tram Roundabouts. In *Proceedings of the 96th Transportation Research Board annual meeting, Washington, DC*.

Novales, M., Orro, A., & Bugarín, M. R. (2010). Track geometry for light rail systems. *Transportation research record*, *2146*(1), 18-25.

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Urban Environments: Transit Access and Ridership

Overview: Individuals are more motivated to take transit if it is expeditious, pleasant, and convenient. This guideline discusses transit treatments that are known to encourage or discourage public transportation use.

Example Figure of facilities that encourage transit access (e.g., bicycle electronic card access lockers; San Jose Public Library)

Key Sources

Gould, J., & Zhou, J. (2010). Social Experiment to Encourage Drive-Alone Commuters to Try Transit. *Transportation Research Record: Journal of the Transportation Research Board*, *2144*, pp 93-101.

Weinzimmer, D., Sanders, R., Dittrich, H., & Cooper, J. F. (2015). Evaluation of the Safe Routes to Transit Program in California. *Transportation Research Record: Journal of the Transportation Research Board*, *2534*, pp 92–100.

Zamir, K. R., Nasri, A., Baghaei, B., Mahapatra, S., & Zhang, L. (2014). Effects of Transit-Oriented Development on Trip Generation, Distribution, and Mode Share in Washington, D.C., and Baltimore, Maryland. *Transportation Research Record: Journal of the Transportation Research Board*, *2413*, pp 45–53.

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Complete Streets: Overview and Heuristics

Overview: This guideline discusses the main themes of Complete Streets, evaluation metrics related to human safety and performance, and real-world case studies of complete streets evaluations.

Complete Streets Element	Definition	Source
All Users and Modes	*Users of the transportation system are equally deserving of safe transportation facilities. Complete streets should accommodate people of all ages and abilities.* *Complete streets users include, but are not limited to, motorists, cyclists, pedestrians, transit and school bus riders, delivery and service personnel, freight haulers, and emergency responders.*	*Seskin et al., 2012*

Example Complete Streets Definitions Table

Key Sources

LaPlante, J. N., & McCann, B. (2011). Complete streets in the United States. In *90th Annual Meeting of the Transportation Research Board, Washington, DC, USA*.

Ray, B. L. (2016). NCHRP report: Evolutions in the geometric design of highways and streets: Integrating performance-based analysis. *TR News*, (301).

Seskin, S., & McCann, B. (2012). Complete streets policy analysis 2011. http://www.completestreets.org/webdocs/resources/cs-policyanalysis.pdf

Complete Streets: Key References for Complete Streets Design Information

Overview: A significant amount of research has been done on Complete Streets policy and road diet conversions. This Guideline helps practitioners identify existing, relevant human factors guidance.

Guidance document	Primary human factors considerations	This guidance is compatible with AASHTO standards	This guidance is compatible with MUTCD standards	Rigor rating	Additional project characteristics
Document Title, Year, and Authors	*Sight distance*	*Yes*	*No*	*Based primarily on Expert Judgement*	*Midblock crosswalks, bicycle lanes*

Example Complete Streets Document Reference Table

Key Sources

Designing context-sensitive solutions for urban thoroughfares. (2011). *Texas Transportation Researcher*, *47*(1), 13. https://trid.trb.org/view/1103598

Federal Highway Administration. (2022). *Moving to a complete streets design model: A report to congress on opportunities and challenges*. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-03/Complete Streets Report to Congress.pdf

Kueper, D. (2010). A context sensitive state design manual. *ITE Journal*, *80*(11), pp 30-35. https://trid.trb.org/view/1085159

Complete Streets: Complete Streets Implications for Drivers

Overview: This guideline will discuss how Complete Streets designs can both support and pose a challenge for drivers travelling through them.

Example Figure from Swan, 2020 of a Complete Streets Traffic Calming Design that can impact driver workload

Key Sources

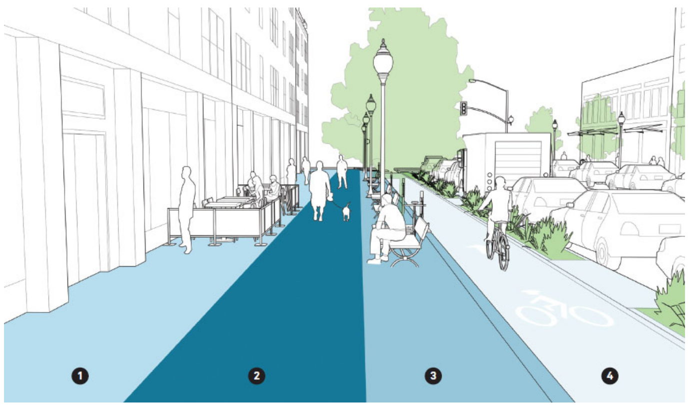
Liu, Z., Ahlström, C., Forsman, Å., & Kircher, K. (2020). Attentional Demand as a Function of Contextual Factors in Different Traffic Scenarios. *Human Factors*, *62*(7), pp 1171-1189. https://doi.org/https://doi.org/10.1177/0018720819869099

Marshall, W. E., Coppola, N., & Golombek, Y. (2018). Urban clear zones, street trees, and road safety. *Research in Transportation Business & Management*, *29*, pp 136-143. https://doi.org/https://doi.org/10.1016/j.rtbm.2018.09.003

Swan, J. (2020). Traffic calming design guidelines. In *Transportation Association of Canada 2020 Conference and Exhibition-The Journey to Safer Roads*.

Complete Streets: Complete Streets Implications for Pedestrians

Overview: This guideline will discuss how Complete Streets designs can both support and pose a challenge for pedestrians travelling through them.



Example Figure from GDCI & NACTO, 2016 depicting pedestrian clear path (2) and a separate zone for cyclists (4)

Key Sources

Davis, S. J., Pugliese, B. J., & Barton, B. K. (2019). The intersection of pedestrian safety and multimodal perception. *Transportation research part F: Traffic psychology and behaviour*, *67*, 205-216.

MacDonald, E., Sanders, R., & Anderson, A. (2010). Performance measures for complete, green streets: a proposal for urban arterials in California. http://www.uctc.net/research/papers/UCTC-FR-2010-12.pdf

Nuworsoo, C., Cooper, E., Cushing, K., & Jud, E. (2012). Integration of bicycling and walking facilities into the infrastructure of urban communities. *Mineta Transportation Institute Report 11-05*.

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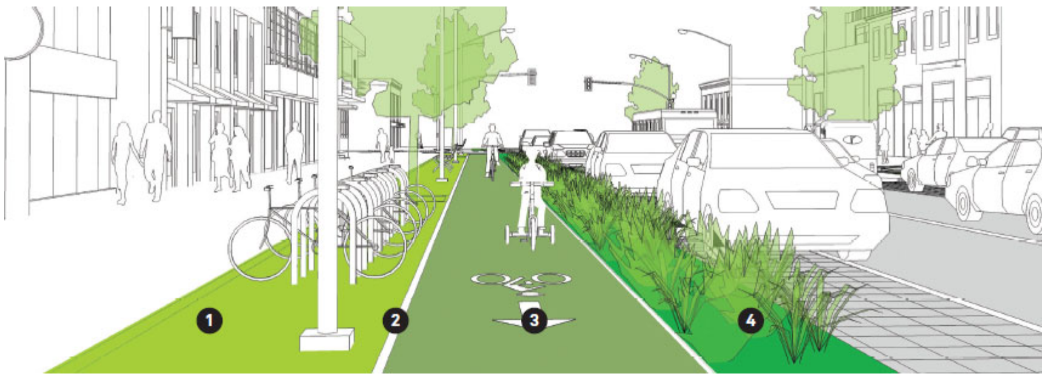
Complete Streets: Complete Streets Implications for Bicyclists

Overview: This guideline will discuss how Complete Streets designs can both support and pose a challenge for bicyclists navigating through them.



Example Figure from GDCI & NACTO, 2016 depicting dedicated cycle facilities

Key Sources

Dai, B., & Dadashova, B. (2021). Review of contextual elements affecting bicyclist safety. *Journal of Transport & Health*, *20*.

Monsere, C. M., McNeil, N., Wang, Y., & Sanders, R. (2019). *Contextual Guidance at Intersections for Protected Bicycle Lanes*. https://ppms.trec.pdx.edu/media/project_files/NITC-RR-987-Contextual_Guidance_at_Intersections_for_Protected_Bicycle_Lanes.pdf

Schultheiss, B., Sanders, R., Judelman, B., Boudart, J., Blackburn, L., Brookshire, K., Nordback, K., Thomas, L., Van Veen, D. & Embry, M. (2018). *Literature Review: Resource Guide for Separating Bicyclists from Traffic*. https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18030.pdf

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Older Road Users: Older Driver Crash Risk, Crash Causation Factors, and Fitness to Drive

Overview: This guideline discusses older driver crash statistics, crash characteristics, how changes in aging drivers' functional capabilities relate to certain crash configurations, how well older drivers self-assess their fitness to drive, and how older drivers may regulate their driving to minimize risk.

Crash Configuration	Age-related Cognitive and Functional Ability Degradation	Sources
Head-on collision	*Vision* *Attention*	*Du et al., 2014*

Examples of Common Older Driver Crash Configuration - Reference Table

Key Sources

Baldwin, C. L., Lewis, B. A., & Greenwood, P. M. (2019). *Designing transportation systems for older adults*. CRC Press.

Choi, H., & Feng, J. (2018). Older drivers' self-awareness of functional declines influences adoption of compensatory driving behaviors. In *Proceedings of the 95th Transportation Research Board annual meeting, Washington, DC*.

Du, Y., & Chan, C. Y. (2014). Older Driver Crash Risk Modeling by AdaBoost. In *Proceedings of the 93rd Transportation Research Board annual meeting, Washington, DC*.

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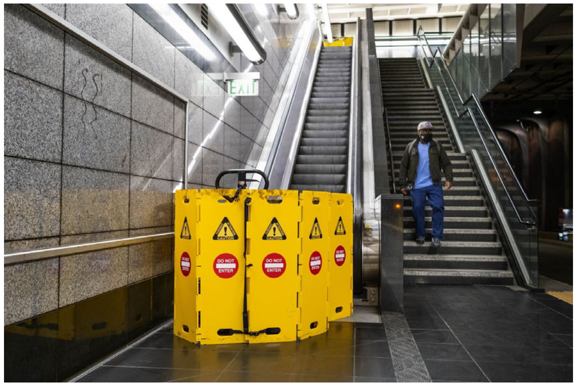
Older Road Users: Older Road Users Travel Patterns and Alternative Transportation

Overview: This guideline discusses how older driver transportation patterns shift how designers can support older road user safety as they travel along road systems or through road system transition zones.



Example Figure of facilities that affect older road users' access (e.g., poorly maintained escalator; Seattle Times, 2021)

Key Sources

Kim, S. (2011). Transportation Alternatives of the Elderly after Driving Cessation. Transportation Research Record, 2265(1), 170–176.

Ma, S., & Hanley, P. F. (2013). Spatial Interaction Between Older Population Clusters And Crashes Involved With Older Drivers. In *Proceedings of the 92nd Transportation Research Board annual meeting, Washington, DC*.

Maisel, J., Damle, U., & Lenker, J. (2010). A Systematic Review of Research on Boarding/Disembarking. In *Proceedings of the 89th Transportation Research Board annual meeting, Washington, DC*.

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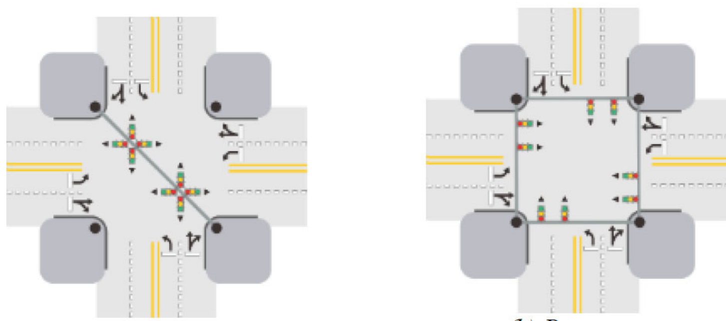
Older Road Users: Older Driver Considerations for Intersections and Left Turns

Overview: Road-based mitigation strategies to support older drivers navigating through intersections and left turn maneuvers.



(a) Diagonal span *(b) Box span*

Example Figure from Andridge et al., 2017

Key Sources
Brewer, M., Murillo, D., & Pate, A. (2014). *Handbook for designing roadways for the aging population* (No. FHWA-SA-14-015). United States. Federal Highway Administration. Office of Safety.
Hassan, H., & Doulabi, S. (2021). *Exploring traffic safety problems and challenges of older roads' users in Louisiana: Causes and countermeasures* (No. 20SALSU13). Transportation Consortium of South-Central States.
Woldeamanuel, M. G., & Hankes, N. (2011). To Stop or Not to Stop? Factors Affecting the Stopping Behavior of Drivers at Stop-Sign Controlled Intersection. In *Proceedings of the 89th Transportation Research Board annual meeting, Washington, DC.*

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Older Road Users: Older Driver Considerations for Curves, Markings, Signs, and Lighting

Overview: Road-based mitigation strategies that support older drivers navigating through curves and using markings, signs, and lighting.

Figure 51. White edge lines, centerline RPMs, and chevrons on a horizontal curve

Example Figure from Brewer et al., 2014

Key Sources

Baldwin, C. L., Lewis, B. A., & Greenwood, P. M. (2019). *Designing transportation systems for older adults*. CRC Press.

Brewer, M., Murillo, D., & Pate, A. (2014). *Handbook for designing roadways for the aging population* (No. FHWA-SA-14-015). United States. Federal Highway Administration. Office of Safety.

Hassan, H., & Doulabi, S. (2021). Exploring traffic safety problems and challenges of older roads' users in Louisiana: Causes and countermeasures. Retrieved from https://digitalcommons.lsu.edu/transet_pubs/105

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Older Road Users: Older Driver Factors Affecting Merging Behavior

Overview: Older drivers may have difficulty performing lane change maneuvers and merging. This guideline describes road treatments support older drivers successfully performing these maneuvers.

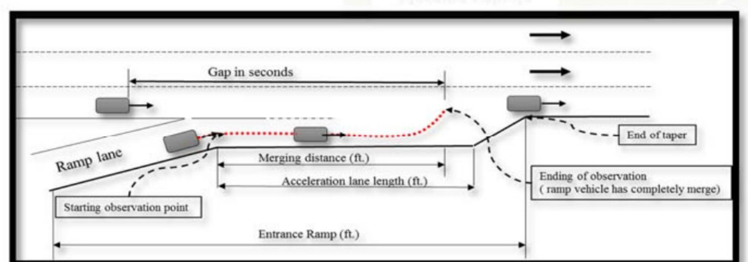

Figure 3.8. Typical merging maneuver data extraction process.

Example Figure from Lwambagaza et al., 2016

Key Sources

Brewer, M., Murillo, D., & Pate, A. (2014). *Handbook for designing roadways for the aging population* (No. FHWA-SA-14-015). United States. Federal Highway Administration. Office of Safety.

Lwambagaza, L., Sando, T., & Ozguven, E. E. (2018). Older Drivers' Behavior at On-Ramp Merging Areas. In *Proceedings of the 97th Transportation Research Board annual meeting, Washington, DC*.

Vardaki, S. (2008). Investigation of actual and perceived behavior of older drivers on freeways. *Transportation Research Record*, *2078*(1), 41-48.

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Task 5: Develop and Submit Interim Report

- **Additional HFG4 Activities:**
  1) Edit HFG3 materials to reflect remaining reviewer comments from 17-80
  2) Reconcile and reconstruct all HFG2 text and graphics files into the HFG4
  3) Revise all HFG4 materials to reflect: (1) updates to key reference documents (e.g., Green Book, MUTCD, ITE Traffic Engineering Handbook, ITE Traffic Control Devices Handbook)
  4) Revise all HFG4 materials to reflect: (2) best practices in terminology (e.g., crash/accidents, ‘risk’ ‘safety’, ‘hazards’)[1] and to avoid inadvertently creating tort liability implications

Task 6: Develop Updated Content for the 4th Edition HFG

- **Scope:** (1) Develop updated content for the HFG4 based on the Task 4 recommendations approved by NCHRP in Task 5, and (2) outline of the pilot studies to be conducted in Task 7.

- **Approach:**
  - Develop guidelines and tutorials using the process and Style Guide developed in earlier projects
  - Conduct integrative reviews and analyses of key data sources
  - Describe recruitment procedures, plans for the pilots, including scope, training, evaluation procedures and schedule

Questions and Discussion

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www.hsrc.unc.edu

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

UNC Highway Safety Research Center (HSRC)
Vanasse Hangen Brustlin (VHB)
Kittelson and Associates (KAI)

1

Background

- HSM recommends the calibration of prediction models using jurisdiction data
  - Substantial resources needed for calibration
  - Models offered in the HSM are continuing to increase (e.g., 2nd edition of the HSM versus the 1st edition of the HSM)
  - Proposed simple calibration approach may not improve reliability

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2

Objectives

- Determine how frequently SPFs and SPF adjustment factors should be updated
- Determine under what conditions these should be updated
- Develop an implementable approach and guidance for maintaining and updating existing future functions and factors

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Research Approach

- Task 1 – Literature review
- Task 2 – Assess state of practice
- Task 3 – Develop approaches for updating existing and future SPFs, SPF adjustment factors, and SDFs
- Task 4 – Identify data sources, compile sample data, and develop guidelines
- Task 5 – Develop work plan for Phase 2 and Interim Report
- Task 6 – Interim Meeting

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Research Approach

- Task 7 – Demonstrate the proposed approach using test cases
- Task 8 – Develop implementation guidance
- Task 9 – Coordinate with NCHRP and AASHTO committees for review and comment
- Task 10 – Develop final deliverables

Task 1: Literature Review

- What is calibration?
- Approaches for calibration
- Issues associated with calibration
- Calibration of SPFs and CMFs
- Jurisdiction-specific SPFs vs calibrated models
- Functional form of SPFs

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Task 2: Assess State of Practice

- Assessed the state of practice regarding crash prediction model (CPM) development, viability, and implementation
- Survey of state agencies and researchers to learn about:
  - Current practices with respect to CPM development and maintenance
  - State of practice with respect to:
    - CPF development and maintenance including costs
    - Challenges for CPM application
    - Frequency of CPM updates and strengths
    - Weaknesses of CPM functional forms

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Task 3: Prioritized List of Topics

Subtask Title	Subtask Number	Topic Number	Topic
When to calibrate or update	3.1	1	Calibrate if there is a change in location
		2	Update if there is a change in safety over time
How to calibrate or update	3.2	1	Combined calibration data for similar site types
		2	Reliability of extrapolating calibration factor across crash type and severity categories
		3	Maintain standardized database
		4	Prioritizing input data elements
		5	Minimum site sample size
		6	Calibrated model fit statistics
		7	Selecting the calibration function
		8	Calibrated model fit statistics (calibration function)

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Task 4: Identify Data Sources, Compile Sample Data, and Develop Guidelines

- The goal is to develop initial guidelines based on literature review and existing data
- Data from NCHRP 17-72 and NCDOT project were used
  - This led to delays
- Developed six working papers with initial guidelines and procedures

Task 5 (Interim Report and Work Plan for Phase 2)

- Two-pronged approach for Task 7 depending on topic area under consideration
  - Topics 5 through 8 (subtask 3.2):
    - Test case to demonstrate the minimum sample size, calibration factor, and fit statistics
    - Test case to demonstrate the selection of a calibration function, estimation of its coefficients, and assessment of fit statistics
    - Comprehensive demonstration of calibration process

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Approach for Task 7, *contd.*

- Subtask 3.1 (topics 1 and 2) and Subtask 3.2 (topics 1, 2, 3, and 4):
  - Guidance based on empirical analysis was developed in Task 4 using North Carolina data
  - Possible refinements will be undertaken based on utilizing larger data sets

Topics 5 through 8 of Subtask 3.2

- Case 1. Calculate minimum sample size, calibration factor, and fit
- Case 2. Calculate Calibration Function and Fit
- Case 3. Comprehensive demonstration of calibration process

Overall structure

- Background
- Annotated test case
  - Overview
  - Data requirements and assumptions
  - Calculations
  - Results and interpretation

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Topics 1 and 2 of subtask 3.1 and topics 1 through 4 of subtask 3.2

- Need for regional calibration factors or calibration factors for a specific year
- Combined calibration for similar site types, or crash types, and severity categories
- Maintaining standardized databases and prioritizing input data elements

Overall Structure

- Background
- Initial guidance
- Proposed refinements to initial guidance

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Task 8: Develop implementation guidance

- CPM Management Manual
- General process for developing resources:
  - Concept
  - Draft
  - Internal review/pilot and revisions
  - External review/pilot and revisions

Task 9: Coordinate with NCHRP and AASHTO Committees for Review and Comment

- Two meetings
  - TRB Committees (ANB20 and ANB25)
  - AASHTO Committee on Safety
  - Researchers and practitioners
- Summarize the discussion, prepare a response, and steps for addressing concerns

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Task 10: Final Deliverables

- A final report
- A guidance document including a CPM management manual
- Prioritized recommendations for future research
- A powerpoint presentation
- Implementation plan

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Project Status

- Significant delays due to staffing issues related to Covid and data collection from NCHRP 17-72
- Submitted interim report in early July
- Hope to have an interim meeting soon

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NCHRP Project 7-29

Development of an 8th Edition of the AASHTO *Green Book* (GB8)

TRB ACS20 Committee Midyear Meeting

August 4, 2022

Texas A&M Transportation Institute

Ingrid Potts, PI (TTI)

Karen Dixon, Co-PI (TTI)

1

NCHRP Project 7-29 Development of GB8

- Texas A&M Transportation Institute
  - Ingrid Potts, Principal Investigator
  - Karen Dixon, Co-Principal Investigator
- VHB
- Toole Design
- Harwood Road Safety, LLC
- Exponent (John Campbell)

Harwood Road Safety, LLC

2

Research Approach

PHASE I

- Task 1—Kickoff Meeting
- Task 2—Review Materials from Past and Ongoing Projects
- Task 3—Develop White Paper
- Task 4—Draft Author's Guide
- Task 5—Develop Annotated Outline for GB8
- Task 6—Develop Work Plan for Phase II
- Task 7—Prepare Interim Report

PHASE II

- **Task 8—Develop First Draft of GB8**
- Task 9—Develop Second Draft of GB8
- Task 10—Prepare Other Final Deliverables

3

3

Key Recent and Upcoming Dates

- Panel meeting held March 30, 2022.
- Team received authorization to proceed with Phase II on May 17, 2022.
- Target date for first chapter submittal (Part I chapters): August 31, 2022.

4

Rethinking the Title

Current Title: *A Policy on Geometric Design of Highways and Streets*

- AASHTO *Green Book* is not a standard, regulation, or requirement.
- Agencies may use all or parts of the *Green Book* as they see fit, or develop their own design guidelines, manuals, or policies.

Key Features of GB8

- GB past editions
  - Not design-process oriented.
  - Focused on presenting geometric design principles, dimensional design criteria, and tabulated values.
  - Treated by some as fixed requirements (this interpretation is not intended by AASHTO).
- GB8
  - Performance-based geometric design process.
  - Sufficiently flexible to meet project goals and objectives within project constraints.
  - Actively discourage interpretation of dimensional criteria and tabulated values as fixed requirements.
  - Encourage use of performance-based approach.

6

Key Features of GB8

- Performance-based design process informed by quantitative performance measures (where available).
  - Provide guidance on known performance measures vs lack of performance relationships.
- Design flexibility with active discouragement of "one-size-fits-all" design.
- Multimodal perspective to address all permissible transportation modes:
  - Pedestrians, bicycles, transit, automobiles, and trucks.

7

7

Key Features of GB8

- Context classification will be a central organizing element.
  - General representation of the needs and expectations of pedestrians, bicyclists, and transit users, and of the community as a whole.
- Different guidance for different project types:
  - New construction
  - Reconstruction
  - Rehabilitation

8

Role of Context Classification

9

Role of Context Classification

- A *context classification system* characterizes roadways by their surrounding environment and how the roadway fits into the community. GB7 includes five contexts—two for rural areas and three for urban areas:
  - Rural context
  - Rural town context
  - Suburban context
  - Urban context
  - Urban core context
- AASHTO has proposed the addition of a sixth context class—industrial, warehouse, or port roads. The project panel is in favor of a sixth context category called "**special contexts**."

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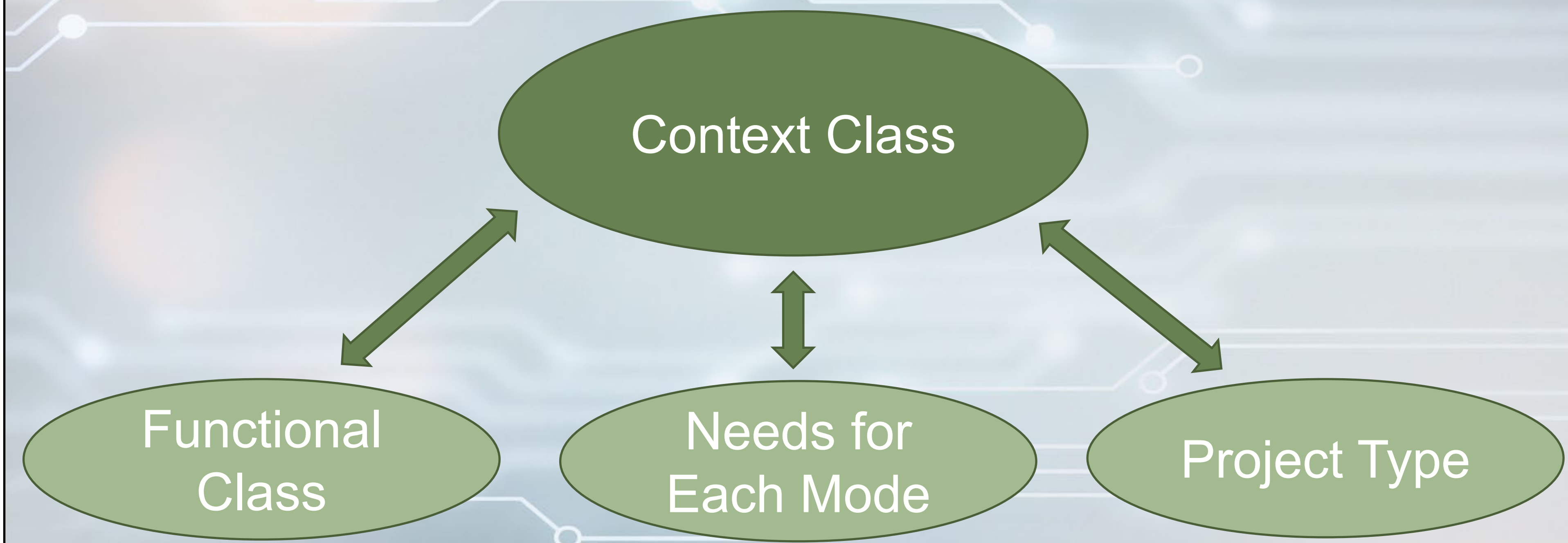
Role of Context Classification as it Relates to Functional Classification, Needs for Each Mode, and Project Type



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11

Performance Issues to be Addressed in GB8

12

Performance Issues to be Addressed in GB8

GB8 will define a full range of performance measures to be considered in making geometric design decisions. Performance measures that may be considered include, but are not limited to:

- Measures of operational and trip efficiency and comfort/ease of use for each transportation mode:
  - Pedestrian
  - Bicycle ("level of traffic stress")
  - Automobile
  - Transit
  - Truck
- Existing and expected future crash frequency and severity
- Construction cost
- Future maintenance cost

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Performance Issues to be Addressed in GB8

- Accessibility for persons with disabilities
- Available right-of-way
- Impacts on existing and potential future development
- Operational flexibility during future incidents and maintenance activities
- Community impacts and quality of life
- Impacts on historical structures
- Equity

Not a complete list

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Performance Issues to be Addressed in GB8

- Impacts on the natural environment:
  - Air quality
  - Noise
  - Wetlands preservation
  - Wildlife/endangered species
  - Water quality/stormwater management
  - Habitat
  - Trees/tree canopy
- Preservation of archeological artifacts

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GB8 Outline

Top-Level Outline for GB8

- Part I – Introduction
  - Part I will provide an introduction to GB8 and describe what is found in GB8 and how GB8 differs from previous editions. It will also introduce concepts and terms that are central to GB8, with an emphasis on new concepts introduced for the first time in this edition.
- Part II – Performance-Based Design Process
  - Part II will present details of a performance-based design process and address how to apply performance-based design to a specific project.
- Part III – Design Controls and Criteria
  - Part III will present the design controls and criteria for geometric design and will reflect material currently found in GB7 Chapters 3, 4, 9, and 10, with substantial expansion to present performance relationships as well as design criteria.
- Part IV – Tailoring Geometric Design to Roadway Context
  - Part IV will discuss how geometric design criteria and performance measures vary between context classes.

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Part I—Introduction

Part I—Introduction	
Chapter 1	Overview
Chapter 2	Framework for Geometric Design
Chapter 3	Performance-Based Design
Chapter 4	Project Needs and Objectives

Part II—Performance-Based Design Process

Part II—Performance-Based Design Process	
Chapter 5	Performance Analysis Tools
Chapter 6	Steps in Performance-Based Design

Part III—Design Controls and Criteria

Part III—Design Controls and Criteria	
Chapter 7	Design Controls
Chapter 8	Roadway Alignment
Chapter 9	Cross-Section Elements
Chapter 10	At-Grade Intersections
Chapter 11	Freeways
Chapter 12	Interchanges
Chapter 13	Other Elements Affecting Geometric Design

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Part IV—Tailoring Geometric Design to Roadway Context

Part IV—Tailoring Geometric Design to Roadway Context	
Chapter 14	Rural and Natural Context
Chapter 15	Rural Towns Context
Chapter 16	Suburban Context
Chapter 17	Urban Context
Chapter 18	Urban Core Context
Chapter 19	Special Contexts*

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Communication and Outreach

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Communication and Outreach Plan

AASHTO Groups

- Substantial communication and outreach with key AASHTO groups:
  - AASHTO Council on Highways and Streets (CHS)
  - AASHTO Council on Active Transportation (CAT)
  - AASHTO Committee on Design (COD)
  - AASHTO Technical Committee on Geometric Design (TCGD)
  - AASHTO Joint Technical Committee on Nonmotorized Transportation (TCNMT)

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Communication and Outreach Plan

- Groups represented on the project panel:
  - FHWA
  - AASHTO Council on Active Transportation (CAT)
  - AASHTO Technical Committee on Geometric Design (TCGD)
  - AASHTO Committee on Safety (COS)
  - National Association of City Transportation Officials (NACTO)

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Communication and Outreach Plan

Other (Non-AASHTO) Professional Groups

- Up to 40 other professional groups (including TRB committees and professional organizations and interest groups):
  - Distribute survey
  - Conduct webinar
- Professional groups include (but are not limited to):
  - National Association of City Transportation Officials (NACTO)
  - Association of Pedestrian & Bicycle Professionals (APBP)
  - National Complete Streets Coalition
  - Congress for the New Urbanism (CNU)
  - League of American Bicyclists

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Contact Info

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NCHRP 17-76
Guidance for the Setting of Speed Limits

Kevin Haas, Oregon Department of Transportation
Kay Fitzpatrick, Texas A&M Transportation Institute
Tim Gates, Michigan State University
Mike Pratt, Texas A&M Transportation Institute

TRB Safety Performance Committee, August 4, 2022

NCHRP 17-76

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REASON FOR NCHRP 17-76

NCHRP 17-76 2

Background

- Original draft problem statement focused on rural conditions
- Panel recognized the need to provide holistic review of the setting of speed limits
- Recent events support that need

NCHRP 17-76 3

Other Publications (After NCHRP 17-76 Started)

- **NACTO 2017** policy: "State rules or laws that set speed limits at the 85th percentile speed should be repealed"
- **NACTO 2020** report: *City Limits, Setting Safe Speed Limits on Urban Streets*
- **National Transportation Safety Board** (*Reducing Speeding-Related Crashes Involving Passenger Vehicles*) provides specific recommendations, such as removing guidance in MUTCD that speed limits should be within 5 mph of the 85th percentile speed
- Several **state initiatives**

NCHRP 17-76

Other Approaches (After NCHRP 17-76 Started)

- Neighborhood slow zones
- Citywide speed limits (25 mph):
  - Boston, Massachusetts
  - New York City, New York
  - Seattle, Washington
  - Austin, Texas
  - Portland, Oregon (residential streets at 20 mph

NCHRP 17-76

NCHRP 17-76 Objectives

- Identify and describe factors that influence operating speed
- Provide guidance (**User Guide** and **Tool**) to make informed decisions related to establishing speed limits on roadways

OVERVIEW OF SPEED LIMITS & NCHRP 17-76

NCHRP 17-76

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How Are States Setting PSL?

Frequency	Factor Used by 31 States
All or Most of States	• **85th percentile speed** • Crash history
Over half of states	• Roadside development or land use • Traffic (pedestrians, bicyclists) condition or volume • Maximum or minimum speed allowed in state • Sight distance
About 1/3 states	• Parking, shoulder, pavement condition, access
<1/3 states, but > 3 states	• Functional class, pedestrians, transitions, urban streets • Alignment (e.g., grade, horizontal and/or vertical curves) • Cross section (e.g., lane width, roadway width) • Traffic control devices

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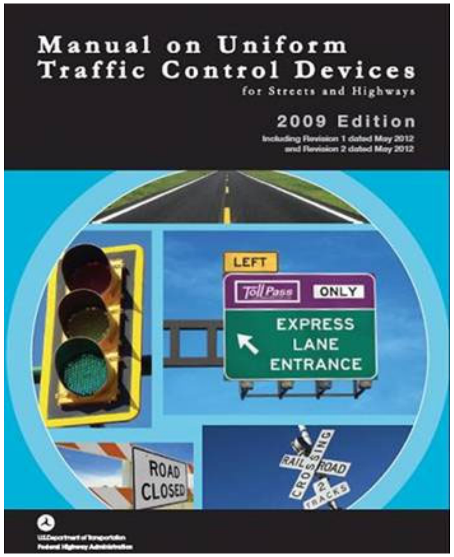
Existing Guidance

- **MUTCD**
  - Traffic study using 85th percentile speed of free-flowing traffic along with consideration of other factors
- Several **other resources** available
  - FHWA website and reports, USLIMITS2, ITE website, state documents, NACTO, etc.



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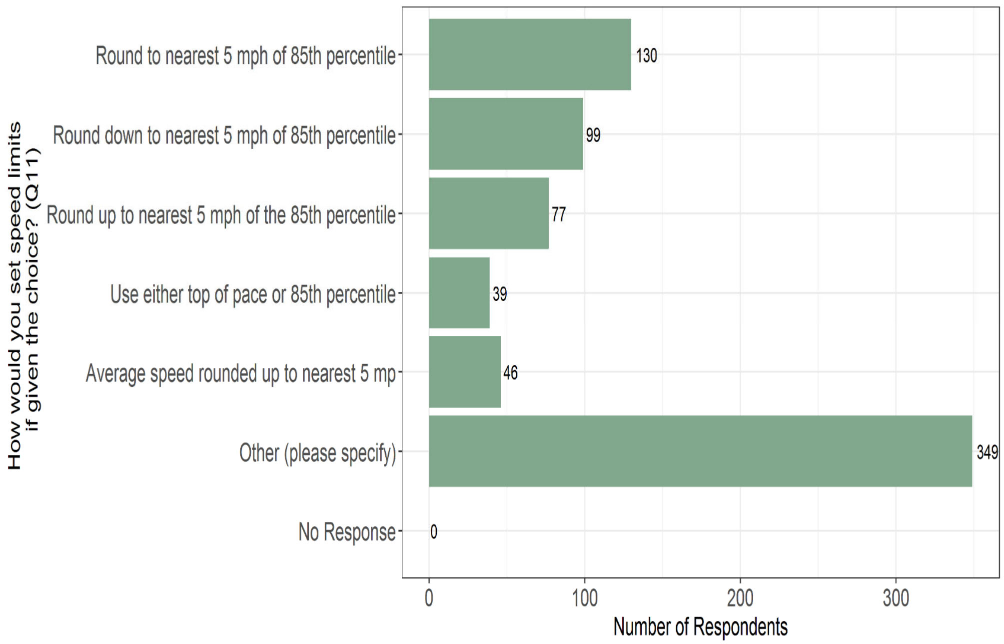
NCUTCD Task Force on Speed Limits

- Task Force addressing recommendations from NTSB
- Key direction / suggested changes to MUTCD:
  - Keep MUTCD general (detailed procedure => guides)
  - Emphasize that other factors have a role in setting speed limits (in addition to 85^{th}) / reorganized list of factors
  - Retain reference to 85^{th} percentile, particularly for freeways, expressways, and rural areas

Q11: How would you set speed limits if given the choice?



NCHRP 17-76 User Guide and Tool
Guiding Principles

- Easy to explain (relatively)
- Consistent results – use of decision rules
- Defendable – demonstrate sources of decision rules
- Avoid "black box" feel
- Flexible so future knowledge can update decision rules

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Developing Guide and Tool
Guiding Principles (Continued)

- Can be used for all roadway types / contexts
- Group similar roadway types / contexts
- Different set of decision rules for each roadway type / context groups

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Developing Decision Rules

- Previous literature
- Key reference documents
- A portion of NCHRP 17-76 Phase II funds set aside for original research
  - Focus on suburban / urban arterials
  - Data from:
    - Michigan (roadway geometric, volume, and crash data)
    - Texas (also able to consider operating speed data)

FINDINGS FROM MICHIGAN AND TEXAS

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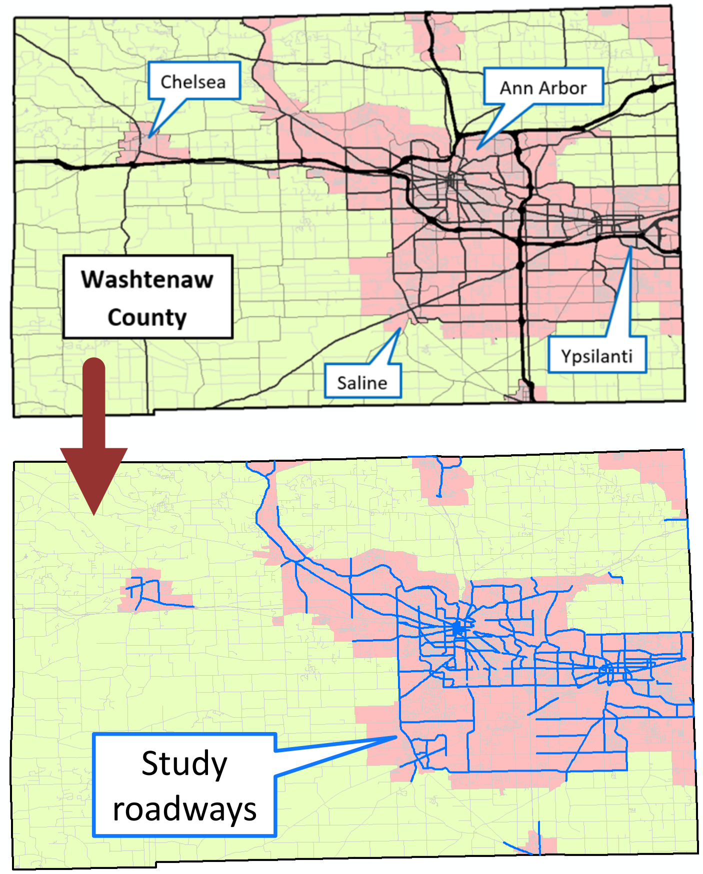
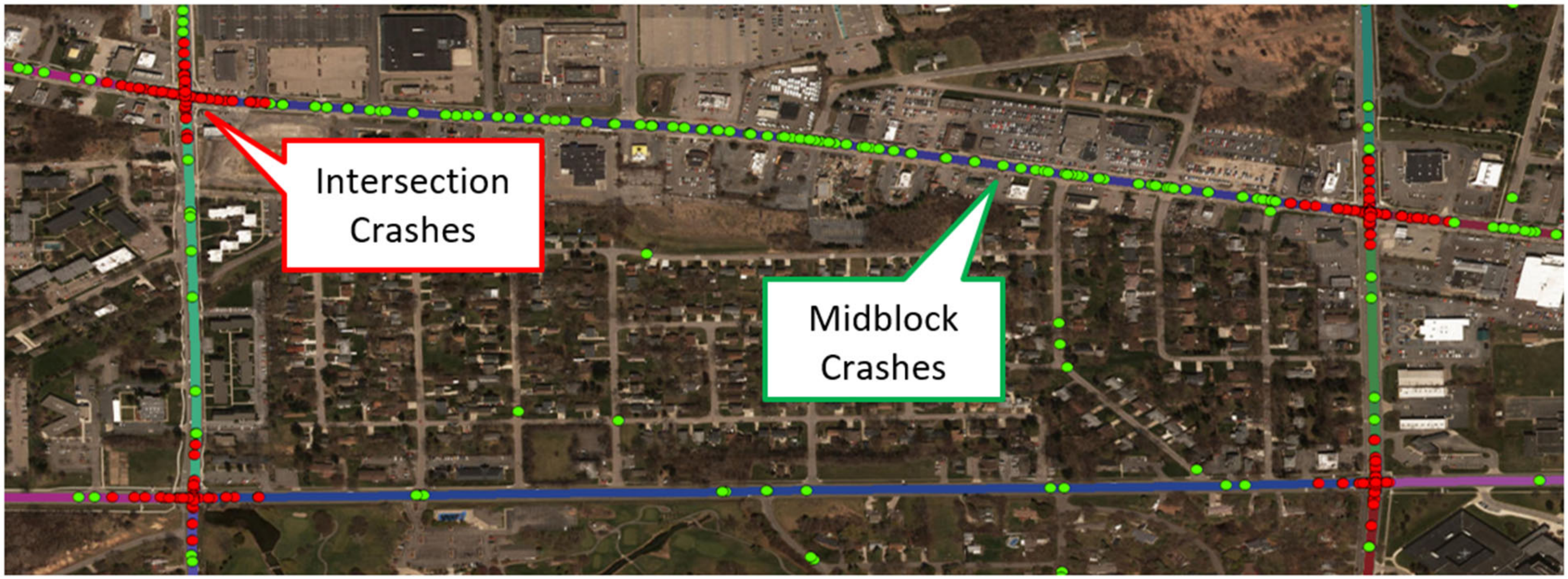
Washtenaw County Roadway Inventory Data

- Approximately **313 miles** out of ~3,000 miles of public roadway selected for safety analysis which **met criteria for inclusion**

Characteristic	Criteria
Posted Speed Limit	25 to 50 miles per hour
National Functional Class	Includes Other Principal Arterial, Minor Arterial, Major Collector, Minor Collector Excludes Interstates, Other Freeways, and Local
Historical Traffic Volume	Must include recent AADT estimate
Urban Boundary	Includes roadways which fall within or extend from urban census boundary



Traffic Crash Data Collection



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Additional Geometric and Roadway Characteristics

- Access Point Density
- Bicycle Lane Present
- Bus Stop Present
- Midblock Crosswalk Present
- Curb and Gutter Present
- Surrounding Land Use
- Horizontal Alignment
- End Point Intersection Type
- Lane Width
- Median Type and Width
- Number of Lanes
- On Street Parking
- Sidewalk Present
- Distance Between Sidewalk and Travel Lane
- Surface Width
- Adjacent School Present

Relationships between Roadway Characteristics and Posted Speed Limit

Variables Associated with Posted Speed Limit ($\alpha < 0.05$)

- Access Point Density
- Functional Classification
- Horizontal Curve Present
- Median Present
- On-Street Parking
- Distance between Travel Lane and Sidewalk

Variables Not Associated with Posted Speed Limit ($\alpha > 0.05$)

- Surrounding Land Use
- Lane Width
- Signalized Intersections
- Surface Width
- Adjacent School Present

NCHRP 17-76

Michigan Data's Impact on Decision Rules

- Data support the inclusion of two variables which were previously included in USLIMITS2, consistent with Texas data:
  - Traffic signal density
  - Access point density (with break points of 40 and 60 per mile)
- Also provides evidence for including **median type**
  - Only used for identifying average crash rates for similar roadways in USLIMITS2
  - Raised medians performed better than no median or TWLTL
  - TWLTs performed better than no median

NCHRP 17-76

Roadway & Traffic Variables

- Bike lane
- Curb vs shoulder
- Development (residential or other)
- Access density (driveways & unsig)
- Signal density
- Intersection #legs (segment ends)
- Length of segment
- Presence of horizontal curves
- Type of median
- On-street parking
- Posted speed limit (PSL)
- Presence of school zone
- Presence of sidewalk
- Daily volume
- Presence of midblock ped crossing
- Distance between vehicle and sidewalk
- Functional class

Crash Data

- Obtained from TxDOT
- Used non-intersection (segment) crashes (NID)
  - Not intersection crash
  - Driveway-related crash
- Considered both KABCO and KABC severity level groups
  - K = fatal, A or B = injury, C = compliant, O = no injury

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Speed Data

- City of Austin traffic count data
  - 2016 and 2017 data
  - Most on 2-lane streets (residential or collectors)
- Sites collected as part of NCHRP 17-76
  - 2018 data
  - Arterials, typically 4 lanes

Posted Speed Limit (mph)	# Segments	Length (mi)
25	169	52
30	318	138
35	68	36
40	51	37
45	43	28
50	12	13
55	2	2
Grand Total	**663**	**305**

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Speed Measures

Speed Measures	Description
Abs(PSL–Avg)	Absolute value of posted speed limit minus average speed (mph)
CoefVar	Coefficient of variation of speed
Pace	Percent of vehicles in 10-mph pace for the site (%)
PerOvPSL	Percent of observations over the speed limit for the site (%)
PSL	Posted speed limit (mph)
PSL–Avg	Posted speed limit minus average speed (mph)
PSL–S85	Posted speed limit minus 85th percentile speed (mph)
S85–Avg	85th percentile speed minus average speed (mph)
SpdAve	Average speed (mph)
StdSpd	Standard deviation (mph)

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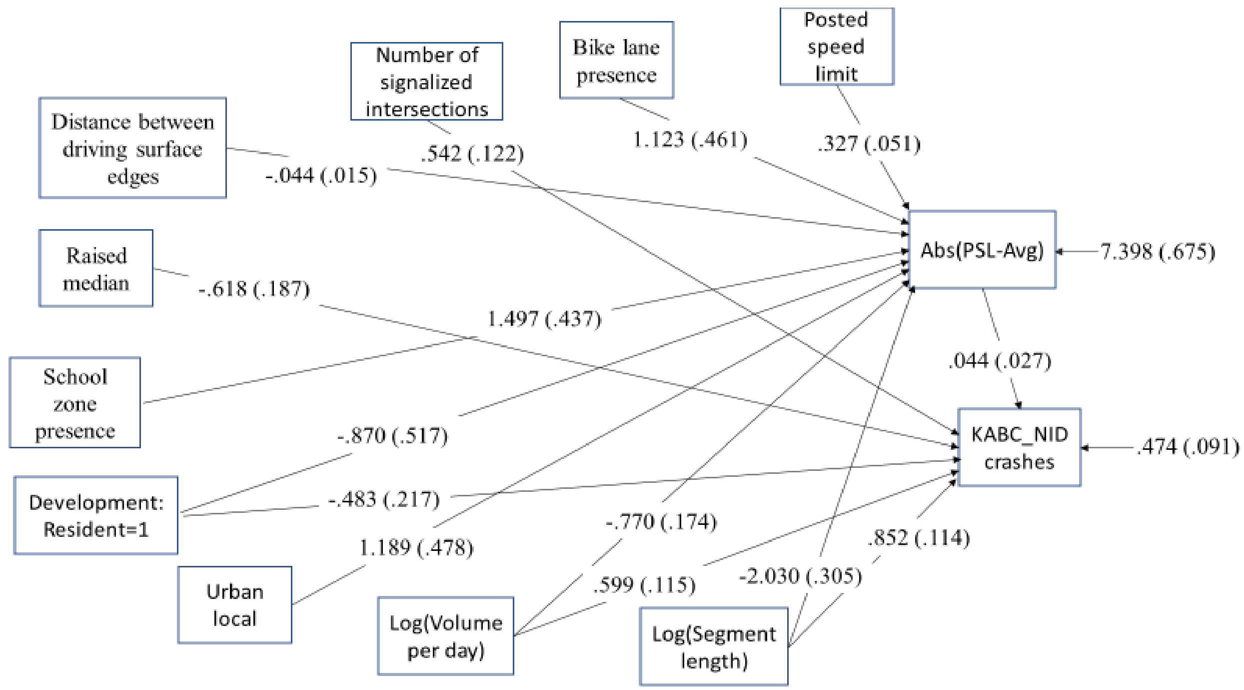
Path Statistical Analysis

- Goal = consider the effect of speed on crashes while accounting for the effects of other roadway characteristics on speed and crashes
  - Perhaps PSL affects crashes through operating speed (i.e., indirectly affects crashes)
  - Perhaps other roadway characteristics also affect crashes through operating speed

Path Analysis – Segments w/PSL 20-45



Box → Variable

Line connecting input variable with outcome variable → Coefficient (standard error)

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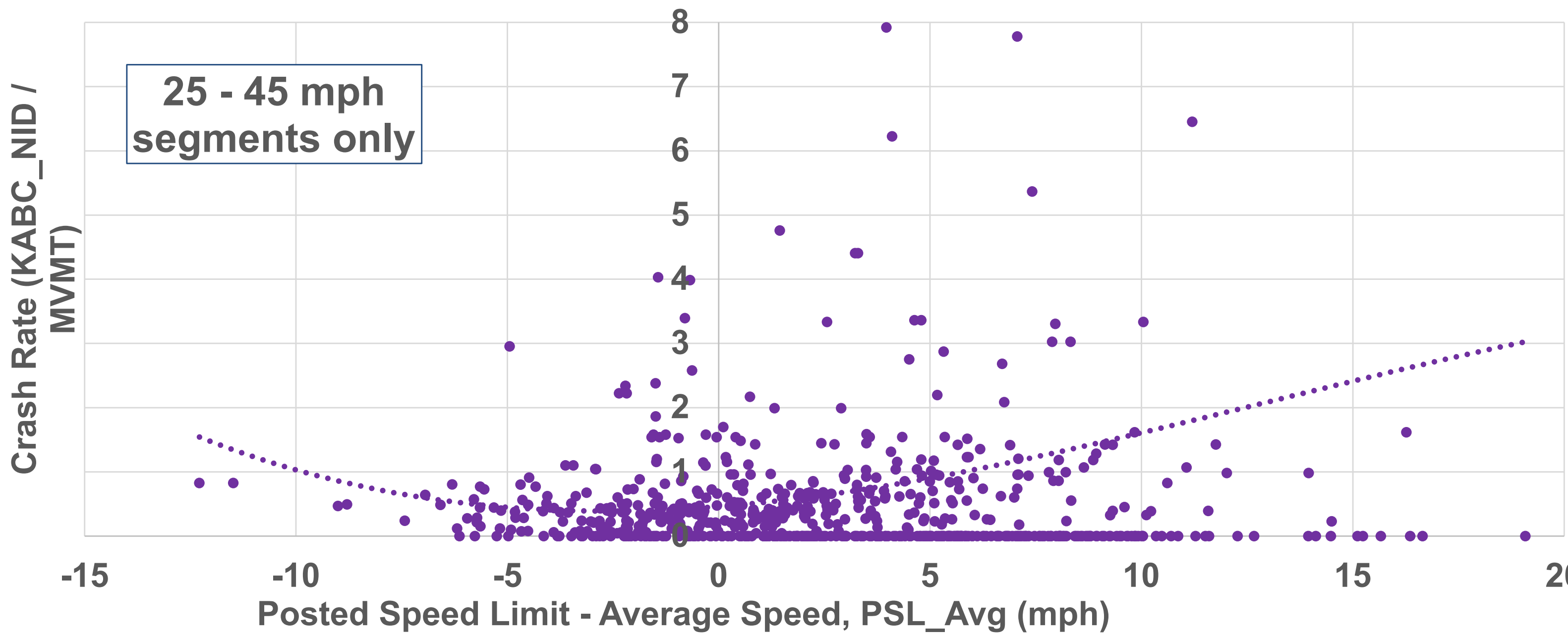
Crash Rate and PSL-Average Speed



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Other Key Findings

- Number of signals / signal density
  - More crashes with higher signal densities
- On-street parking
  - More crashes with on-street parking
- Median type
  - Fewer crashes for raised median as compared to no median or TWLTL

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SLS-PROCEDURE / SLS-TOOL

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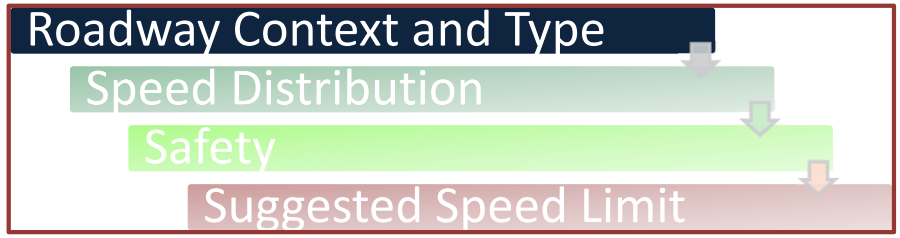
Speed Limit Setting Groups



Type \ Context	Rural	Rural Town	Suburban	Urban	Urban Core
Freeway	Limited Access	Limited Access	Limited Access	Limited Access	Limited Access
Principal Arterial	Undeveloped	Developed	Developed	Developed	Full Access
Minor Arterial	Undeveloped	Developed	Developed	Developed	Full Access
Collector	Undeveloped	Full Access	Developed	Full Access	Full Access
Local	Undeveloped	Full Access	Full Access	Full Access	Full Access

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Considering Safety and Roadway Characteristics

- Decision rules for each speed limit setting group
  - Considers geometric variables, human factors, and safety
- Decision rules identify:
  - Which speed distribution measure to start with (85th or 50th)
  - How to round (rounding closest or rounding down)

NCHRP 17-76

Developing Decision Rules in 17-76

- Findings from research, especially:
  - Freeways: NCHRP Project 17-45, NCHRP Report 783
  - Developed: Austin and Washtenaw data (17-76 data)
  - Undeveloped: Stapleton et al, Das et al, Gates et al
  - Rules used in USLIMITS2
- Guidance documents (*Green Book, Highway Safety Manual*)
- Expert opinions (research team, project panel)

Tool Demonstration

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Example 1: Limited Access - Spreadsheet

NCHRP 17-76 Speed Limit Setting Tool

Site Description Data			Color-Coding Legend
Urban	Roadway context		Aqua = basic input cell
Freeway	Roadway type	Clear all data	Denim = basic input cell with drop-down menu
Yes	Are crash data available?		Orange = optional input cell (not needed for calculations)
User	Analyst		Green = optional input cell (use if data are available, leave blank otherwise)
12/31/2019	Date	Enter default data	Rose = intermediate calculations
	Roadway name		Purple = final analysis results
Example 1	Description		Yellow = field data or agency policy value — *adjust with caution and justification*
65	Current speed limit (mph)	Test macros	
	Notes		Note: The "Test macros" button provides a message to verify proper macro operation.

Analysis Results		Advisory, Calculated, or Warning Messages
Limited-access	Speed limit setting group	
70	**Suggested speed limit (mph)**	This value is determined by speed data & site characteristics.

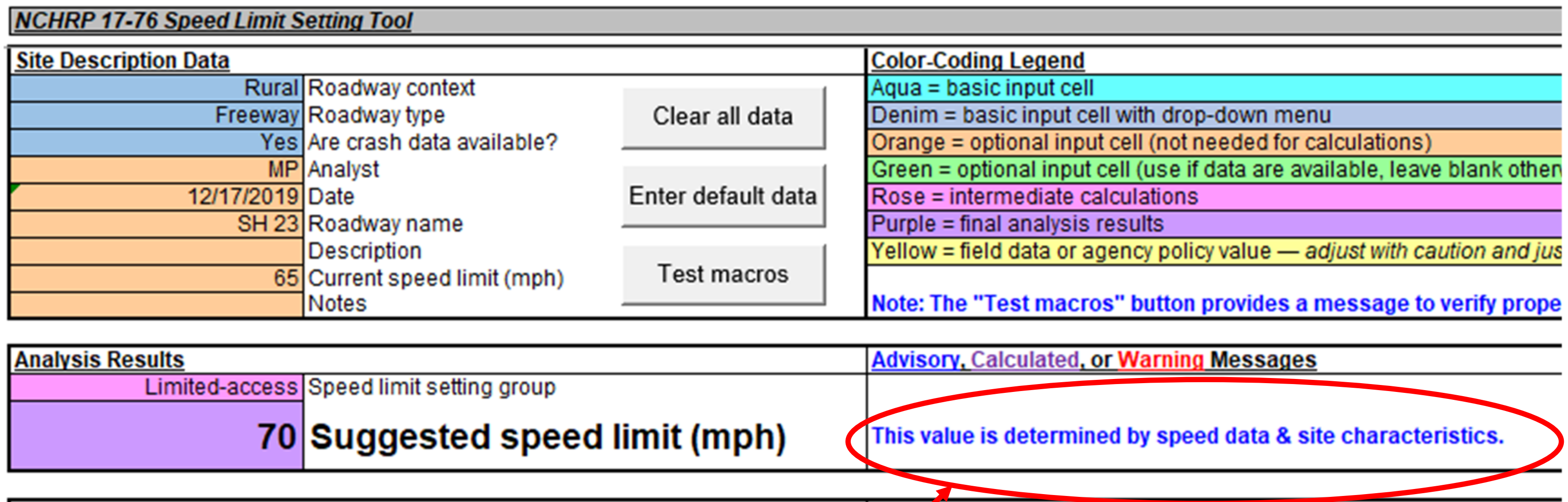
Speed Data		Advisory, Calculated, or Warning Messages
70	Maximum speed limit (mph)	
71	85th-percentile speed (mph)	
67	50th-percentile speed (mph)	

Site Characteristics		Advisory, Calculated, or Warning Messages
6.5	Segment length (mi)	
130,000	AADT (two-way total) (veh/d)	
6	Number of lanes (two-way total)	
200	Directional design-hour truck volume (trk/hr)	
5	Number of interchanges	1.3 miles between interchanges
60	Design speed (mph)	
2	Grade (%)	
10	Outside shoulder width (ft)	
2	Inside shoulder width (ft)	Rounded-Down 85th
No	Adverse alignment present?	

Crash Data		Advisory, Calculated, or Warning Messages
3	Number of years of crash data	
25,000	Average AADT for crash data period (veh/d)	
16	All (KABCO) crashes for crash data period	Observed KABCO crash rate = 8.99 crashes / 100 MVMT
4	Fatal & injury (KABC) crashes for crash data period	Observed KABC crash rate = 2.25 crashes / 100 MVMT
	Average KABCO crash rate (crashes / 100 MVMT)	HSIS average KABCO crash rate = 79.8 crashes / 100 MVMT
	Average KABC crash rate (crashes / 100 MVMT)	HSIS average KABC crash rate = 21.24 crashes / 100 MVMT
103.7	1.3 x average KABCO crash rate (crashes / 100 MVM	
27.6	1.3 x average KABC crash rate (crashes / 100 MVMT)	
91.1	Critical KABCO crash rate (crashes / 100 MVMT)	
27.2	Critical KABC crash rate (crashes / 100 MVMT)	

Welcome | **Analysis** | Support Tables

Example 1: Limited Access - Spreadsheet



The basis for the suggested speed limit decision is noted here

Example 1: Limited Access - Spreadsheet

Variables that influence the calculated suggested speed limit are noted with advisory or calculated messages

2	Grade (%)	
10	Outside shoulder width (ft)	
2	Inside shoulder width (ft)	Rounded-Down 85th
No	Adverse alignment present?	

Crash Data		Advisory, Calculated, or Warning Messages
3	Number of years of crash data	
25,000	Average AADT for crash data period (veh/d)	
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Welcome | Analysis | Support Tables

CONCLUSIONS / RESEARCH NEEDS

NCHRP 17-76

Conclusions

- Selecting posted speed limit influenced by many factors
  - Add **ROADWAY CONTEXT & TYPE** to the list
- Operating speed most common but other techniques gaining in use in other countries and in US cities
- Draft MUTCD language – includes suggested changes
- NCHRP 17-76 SLS-Tool
  - Fact-based decision rules that consider driver speed choice and safety

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Research Needs

- Relationship(s) among operating speed, roadway characteristics, posted speed limit, crashes
  - More is needed
- Specific criteria for ped / bike volume, bike lane type, sidewalk characteristics
- Alternative speed limit approaches for city streets
- Speed management techniques

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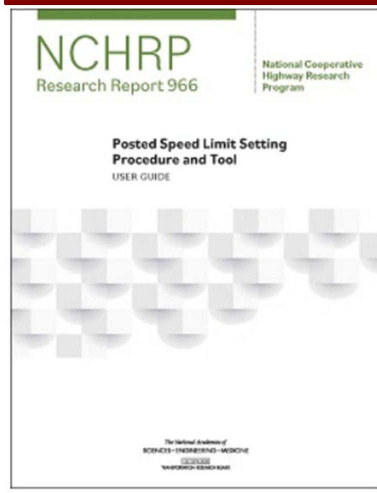
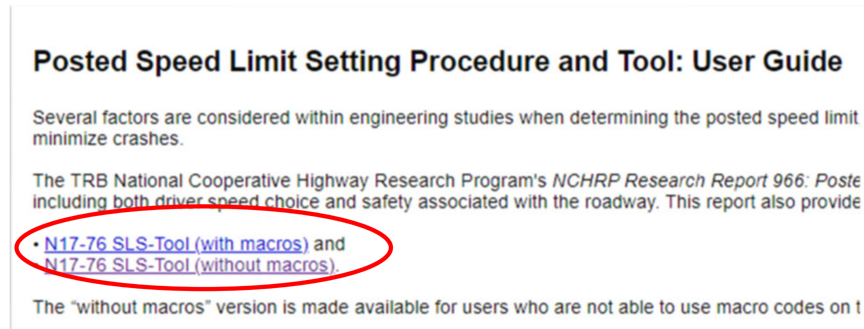
NCHRP 17-76 Deliverables

http://www.trb.org/main/blurbs/182038.aspx

Research Report

User Guide and Tool





NCHRP 17-76
Guidance for the Setting of Speed Limits

Questions?

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Can FARS Speed data be used to consistently find speed related crashes?

First let me clarify that each state has their own method for tracking crash information and none of them are wrong in my opinion. This discussion notes some different outcomes of speeding classification of fatal crashes in two states when they might be expected to be more uniform. Hopefully this presentation highlights the strong effect of wording, various alternative designations and order of options on the classification of crash information.

In the following discussion neither Florida or Illinois crash data classification and processing is superior. Understanding why they are different may help make all crash reporting more uniform.

Note: When putting this presentation together, there was no examination of previous work in this field so apologies if others have already looked into to these issues

Initial reason for comparison of Illinois and Florida speeding related fatal crashes

- In Illinois one of the main traffic safety emphasis areas is the reduction of speeding and aggressive driving.
- FARS notes that about 39% of Illinois traffic fatalities are in crashes identified as speed related. The Florida rate is about 9.5%.
- It seemed logical to reach out to FDOT to identify best practices in managing speed and apply them in Illinois where appropriate to reduce traffic fatalities.
- Illinois typically has a traffic fatality rate of 1.0 fatalities per 100 million vehicle miles traveled. For Florida the rate is near 1.5.
- If Florida has a fatality rate 50% higher than Illinois, is it reasonable to assume that speed is a factor much less frequently in Florida?
- Is all data that we use in calculations “equal”?

FARS guidance for speed related crashes.

FARS

D22 - Speeding Related

FORMAT: 1 numeric

SAS NAME: Vehicle.SPEEDREL

ELEMENT VALUES:

Codes	Attributes
0	No
2	Yes, Racing
3	Yes, Exceeded Speed Limit
4	Yes, Too Fast for Conditions
5	Yes, Specifics Unknown
9	Reported as Unknown

- MMUCC advises against officers speculating on speeding information.

Model Minimum Uniformed Crash Criteria (MMUCC) (Illustration 2)

P13. Speeding-Related

Definition Indication of whether the investigating officer suspects that the driver involved in the crash was speeding based on verbal or physical evidence and not on speculation alone.

Attribute Values:

Select 1

01 No
02 Exceeded Speed Limit
03 Racing
04 Too Fast for Conditions

99 Unknown

Illinois speed identification process in crash reports

Each vehicle has FARS speed issue identified

SPEEDING RELATED (SPDR)
0 No
1 Yes, racing
2 Yes, exceeded speed limit
3 Yes, too fast for conditions
4 Yes, specifics unknown
9 Unknown

Each driver may have “driving too fast for conditions” identified

DRIVER ACTION (DRVA)	
1 None	12 License restriction
2 Failed to yield	13 Stopped school bus
3 Disregarded control devices	14 Emergency vehicle on call
4 Too fast for conditions	15 Evading police vehicle
5 Improper turn	16 Other
6 Wrong way/side	44 Texting
7 Followed too closely	45 Cell phone use other than texting
8 Improper lane change	46 Overcorrected
9 Improper backing	99 Unknown
10 Improper passing	
11 Improper parking	

Each crash may have “Failing to reduce speed to avoid crash” identified as one of two main causes of the crash. In 2018 the two FARS speed categories were removed as causes. Never a Florida option.

Prior to 2018 all speed issues were considered “Causes” of a crash- There might be previous training that is difficult to overcome

1	Exceeding authorized speed limit
2	Failing to yield right-of way
3	Following too closely
4	Improper overtaking/passing
5	Driving on wrong side/wrong way
6	Improper turning/no signal
7	Turning right on red
8	Under the influence of alcohol/drugs(use when arrest is effected)
10	Equipment – vehicle condition
11	Weather
12	Road engineering/surface/marking defects
13	Road construction/maintenance
14	Vision obscured (signs, tree limbs, buildings, etc.)
15	Driving skills/knowledge/experience
17	Physical condition of driver
18	Unable to determine
19	Had been drinking (use when arrest is not made)
20	Improper lane usage
21	Animal
22	Disregarding yield sign
23	Disregarding stop sign
24	Disregarding other traffic signs
25	Disregarding traffic signals
26	Disregarding road markings
27	Exceeding safe speed for conditions
28	Failing to reduce speed to avoid crash
29	Passing stopped school bus
30	Improper backing
32	Evasive action due to animal, object, non-motorist
40	Distraction – from outside vehicle
41	Distraction – from inside vehicle

“Operating vehicle in erratic, reckless, careless, negligent or aggressive manner” is a “Cause” in Illinois (#50) While in Florida it is a driver action (listed #2 and #31)- Does this matter?

CODE	CAUSE TYPE
02	Failing to yield right-of-way
03	Following too closely
04	Improper overtaking/passing
05	Driving on wrong side/wrong way
06	Improper turning/no signal
07	Turning right on red
08	Under the influence of alcohol/drugs (use when arrest is effected)
10	Equipment - vehicle condition
11	Weather
12	Road engineering/surface/marking defects
13	Road construction/maintenance
14	Vision obscured (signs, tree limbs, buildings, etc.)
15	Driving skills/knowledge/experience
17	Physical condition of driver
18	Unable to determine
19	Had been drinking (use when arrest is not made)
20	Improper lane usage
21	Animal
22	Disregarding yield sign
23	Disregarding stop sign
24	Disregarding other traffic signs
25	Disregarding traffic signals
26	Disregarding road markings
28	Failing to reduce speed to avoid crash
29	Passing stopped school bus
30	Improper backing
32	Evasive action due to animal, object, nonmotorist
40	Distraction - from outside vehicle
41	Distraction - from inside vehicle
43	Distraction - other electronic device (navigation device, DVD player, etc.)
44	Texting
45	Cell phone use other than texting
50	Operating vehicle in erratic, reckless, careless, negligent or aggressive manner
60	Motorcycle advancing legally on red light
61	Bicycle advancing legally on red light
62	Obstructed crosswalks
63	Related to bus stop
99	Not applicable

Florida crash reports follow the FARS categories for "too fast for conditions and "Exceeded posted speed" but does not track "Racing"

DRIVER

Drivers Actions at Time of Crash

1st			3rd
186	1 No Contributing Action 2 Operated MV in Careless or Negligent Manner 3 Failed to Yield Right-of- Way 4 Improper Backing 6 Improper Turn 10 Followed too Closely 11 Ran Red Light 12 Drove too Fast for Conditions 13 Ran Stop Sign 15 Improper Passing 17 Exceeded Posted Speed 21 Wrong Side of Wrong Way 25 Failed to Keep in Proper Lane	26 Ran off Roadway 27 Disregarded other Traffic Sign 28 Disregarded Other Road Markings 29 Over-Correcting/Over-Steering 30 Swerved or Avoided : Due to Wind, Slippery Surface, MV, Object, Non-Motorist in Roadway, etc. 31 Operated MV in Erratic, Reckless or Aggressive Manner 77 Other Contributing Action	
2nd			4th

It was related that in Florida officers are "**generally not present at the time of the crash and do not like to make assumptions without solid evidence"** – this would limit identifying speeding crashes. This is rational, but may vary across jurisdictions and states.

The speeding/too fast issue is not tracked for each vehicle, but instead may be identified as one of the driver's actions. Up to four actions can be included. "Operated MV in Carless or Negligent Manner"(#2) is the most common driver action identified in Florida fatal crashes. #31 in the crash form is "Operating the Vehicle in an Erratic, Reckless or Aggressive Manner" but it only used 1/8th as often-are they that different?. It is not known if some speeding crashes are assigned to these categories- it may vary depending on many factors.

Discussions revealed that officers may feel that issuing a citation will identify issues associated with a crash, but it is problematic to accurately track all of the citations.

The identification of driver actions in Florida seems to heavily identify careless driving in fatal crashes and less often note reckless, aggressive or erratic behavior. Carless driving is listed as the first option (after "none") in the crash report.

FLHSMV: 2019 Annual Report: First Driver Actions

Driver Action Fatal Crash	Count	Share of all vehicles
Disregarded Other Road Markings	3	0%
Disregarded Other Traffic Sign	3	0%
Drove too Fast for Conditions	58	2%
Exceeded Posted Speed	134	5%
Failed to Keep in Proper Lane	266	11%
Failed to Yield Right of Way	428	17%
Followed too Closely	8	0%
Improper Backing	9	0%
Improper Passing	51	2%
Improper Turn	40	2%
No Contributing Action	0	0%
Not Specified	0	0%
Operated MV in Careless or Negligent Manner	663	26%
Operated MV in Erratic, Reckless or Aggressive Manner	89	4%
Other Contributing Action	332	13%
Over Correcting/Over Steering	23	1%
Ran off Roadway	152	6%
Ran Red Light	85	3%
Ran Stop Sign	57	2%
Swerved or Avoided :	19	1%
Wrong Side or Wrong Way	101	4%

FARS Vehicle File DR_SF1NAME and Speed Category

FARS Florida DR_SF1NAME	Share of reported
Careless Driving	39%
Failure to Yield Right-of-Way	24%
Yes, Exceeded Speed Limit	11%
Improper Lane Usage	10%
Failure to Obey Actual Traffic Sign,Traffic Control Devices or Traffic Officers;Failure to Obey Safety Zone Traffic Laws	7%
Operating the Vehicle in an Erratic, Reckless or Negligent Manner.	5%
Yes, Too Fast for Conditions	5%
Driving on Wrong Side of Two-Way Trafficway (Intentional or Unintentional)	4%
Overcorrecting	3%
Passing on Right Side	2%
Making Other Improper Turn	2%
Passing with Insufficient Distance or Inadequate Visibility or Failing to Yield to Overtaking Vehicle	1%
Following Improperly	1%

Missing Values each account for less than 1 %. Total 4%

The Florida crash form allows up to four drive actions to be identified but more than one action was rarely identified- Does this affect the likelihood that speeding will be identified?

Florida FARS Crashes	
Speeding or driver information included for fatal crash	Total FARS Crashes
Yes, Exceeded Speed Limit	197
Yes, Too Fast for Conditions	76
No speeding identified, but some driver action listed	1473
No speeding information or driver action	1102

Number of Driver Actions Listed-Florida FARS	Number of Vehicles
0 Driver actions listed	2844
1 Driver actions listed	1676
2 Driver actions listed	140
3 Driver actions listed	15
4 Driver actions listed	0

The effect of additional crash form information on the share of Illinois crashes associated with speeding.

- For Illinois, 27.5% of the fatal crashes have at lease one driver identified as Too Fast for Conditions or Exceeded Posted Speed-the Florida and FARS definition.
- When additional crashes, with a driver action listed as “4 Too fast for conditions”-are added, there is a total of 32.3% of fatal crashes being speed related.
- When additional crashes with cause1 = “Failing to reduce speed to avoid crash” is added there are a total of 38.0% of fatal crashes being speed related (This is basically the value reported by FARS)
- Adding Cause2 =“Failing to reduce speed to avoid crash” results in 46.0% of fatal crashes being speed related.

In Illinois, only 3.9% of the crashes analyzed had the first cause of “Operating Vehicle In Reckless Manner”/ Operating vehicle in erratic, reckless, careless, negligent or aggressive manner. This a very different outcome than in Florida

Prior to 2018 all speeding identified in Illinois crash reports were listed as a “Cause”. Officers who frequently speeding as a cause of a crash now try and describe a new cause and this has led to increases on other causes identified and increase in “None” as a cause. In the current form, a speeding vehicle will be identified although speeding might not be considered a “Cause”

Next steps?

Thank You

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NCHRP 03-139: Next Generation of the USLIMITS2 Speed Limit Expert System

UNC Highway Safety Research Center

Michigan State University

Toxcel

1

Study Objectives

- Determine what changes are needed for the USLIMITS2 (developed in NCHRP 03-67 in 2006) decision algorithm
- Update the algorithm and conduct user testing
- Identify and incorporate enhancements that will increase the user base
- Develop an implementation and training plan

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Tasks

- Phase I (Completed)
  - Task 1: Literature review and nationwide practice
  - Task 2: Conduct review of current USLIMITS2 program
  - Task 3: Prepare interim report and work plan for Phase II
    - Virtual meeting with NCHRP panel

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3

Tasks

- Phase II
  - Task 4: Develop framework, acceptance process, and decision rules for next generation of USLIMITS2 (ongoing)
  - Task 5: Develop updated work plan to incorporate Task 4 results and software implementation options
  - Task 6: Develop the software leading to USLIMITS3
  - Task 7: Prepare draft user manual and conduct beta testing
  - Task 8: Prepare technical report and work plan for Phase III
  - Task 9: Host a virtual demonstration of USLIMITS3 for the NCHRP panel

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Tasks

- Phase III
  - Task 10: Update system and user manual based on beta testing findings
  - Task 11: Conduct a virtual demonstration of user acceptance
  - Task 12: Work with FHWA to implement the program on FHWA's server
  - Task 13: Prepare a maintenance guide for the website administrator
  - Task 14: Develop an implementation, marketing, outreach, and training plan

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Task 1: Literature Review and Nationwide Practice

- **Completed**
- Introduction
- Relationship between Speed, Risk, and Safety
- Effects of Speed Limit Changes on Travel Speeds and Safety
- Methods for Setting Speed Limits
- Decision Support Systems (brief overview)
- Conclusions

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Task 2: Review of Current USLIMITS2 program

- **Completed**
- Two documents
  - USLIMITS2 user feedback since 2016 (Toxcel)
  - Summary of USLIMITS2 and the speed limit setting tool developed in NCHRP 17-76 (Michigan State University)

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Task 3: Interim Report and Work Plan for Phase II

- **Draft documents completed**
- Document describing the proposed use of case studies to determine the decision rules for the expert system
  - Use results of case studies to determine decision rules for the expert system

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Case Studies

- Michigan State University (led by Dr. Tim Gates) has led this activity
- I will let Dr. Gates give an overview

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9

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Speed Limit Setting Expert Panel Survey – Summary of Progress

August 4, 2022

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NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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NCHRP 03-139 Speed Limit Setting Survey Development

- Purpose is to inform development of next generation *USLIMITS2*
- Survey includes two components:
  - **Pre-survey** initially provided via email to collect panelist information, including:
    - Employer type and position type
    - Work experience related to traffic speeds
    - Tools utilized when setting speed limits
    - Level of importance of various factors when making speed limit decisions
  - A series of **speed limit setting case reviews** were then provided to panelists with complete pre-survey survey data
    - Distributed based upon panelist's response to pre-survey

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Expert and Expanded Panelists

- First, NCHRP project panel was surveyed to help guide representation on development of **"expert"** and **"expanded"** panels
- **Expert** panel was directly recruited based on feedback from project panel to help guide the next generation USLIMITS2 development and review cases
- **Expanded** panelists were recruited to review additional cases

Project Panel Survey Results: Please provide the approximate percentage of each agency/entity category to be represented on the EXPERT and EXPANDED panels**:**

	Expert Panel				Expanded Panel			
Agency	Min.	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.
State DOT	20%	50%	31%	10.6%	20%	50%	27%	10.8%
City or Other Municipality	20%	30%	26%	3.5%	20%	25%	23%	2.5%
County Road Agency	5%	25%	17%	7.0%	5%	25%	18%	6.5%
Other Transportation Agency or Entity	5%	15%	11%	3.2%	5%	20%	14%	5.0%
Law Enforcement	3%	15%	10%	3.2%	3%	15%	10%	3.7%
Other	0%	10%	5%	3.5%	2%	10%	8%	3.2%

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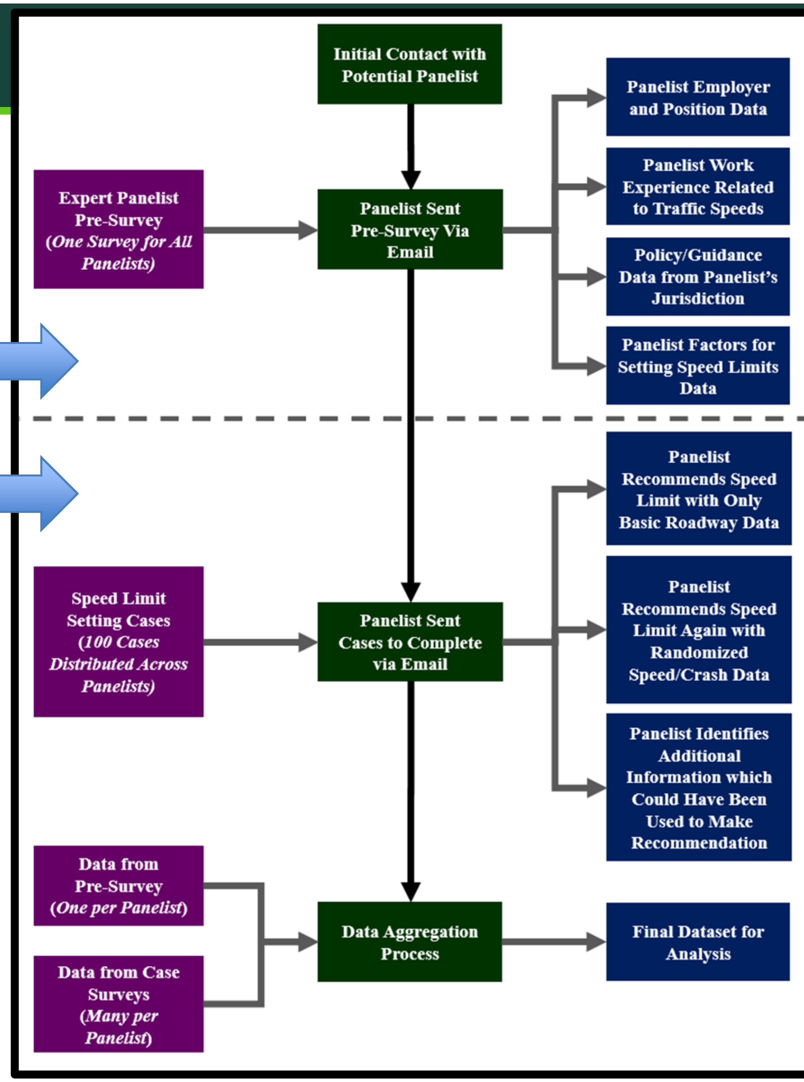
Expert Panel Survey Process

Pre-survey completed by 224

Case reviews completed by 181
(2,071 cases reviewed)



Traffic Speed Experience Block

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Do you have experience in any of the following areas related to traffic speeds? (Select all that apply)

- Setting Speed Limits (including development and/or application of methods, tools, guidelines, or policies for setting speed limits)
- Performing Speed Studies (for purposes other than setting speed limits)
- Speed Management (including traffic calming, traffic control devices, and other strategies or technologies for managing traffic speeds)
- Speed Limit Laws/Statutes (including development or adjudication)
- Speed Enforcement
- Geometric Design (e.g., design speed, advisory speed, sight distance, horizontal/vertical alignment)
- Research
- Other (Please Describe)
- No Related Experience

→

Separate block for panelists with speed limit setting experience

Multiple choice/answer question to obtain traffic speed experience

Speed Limit Setting Experience Block

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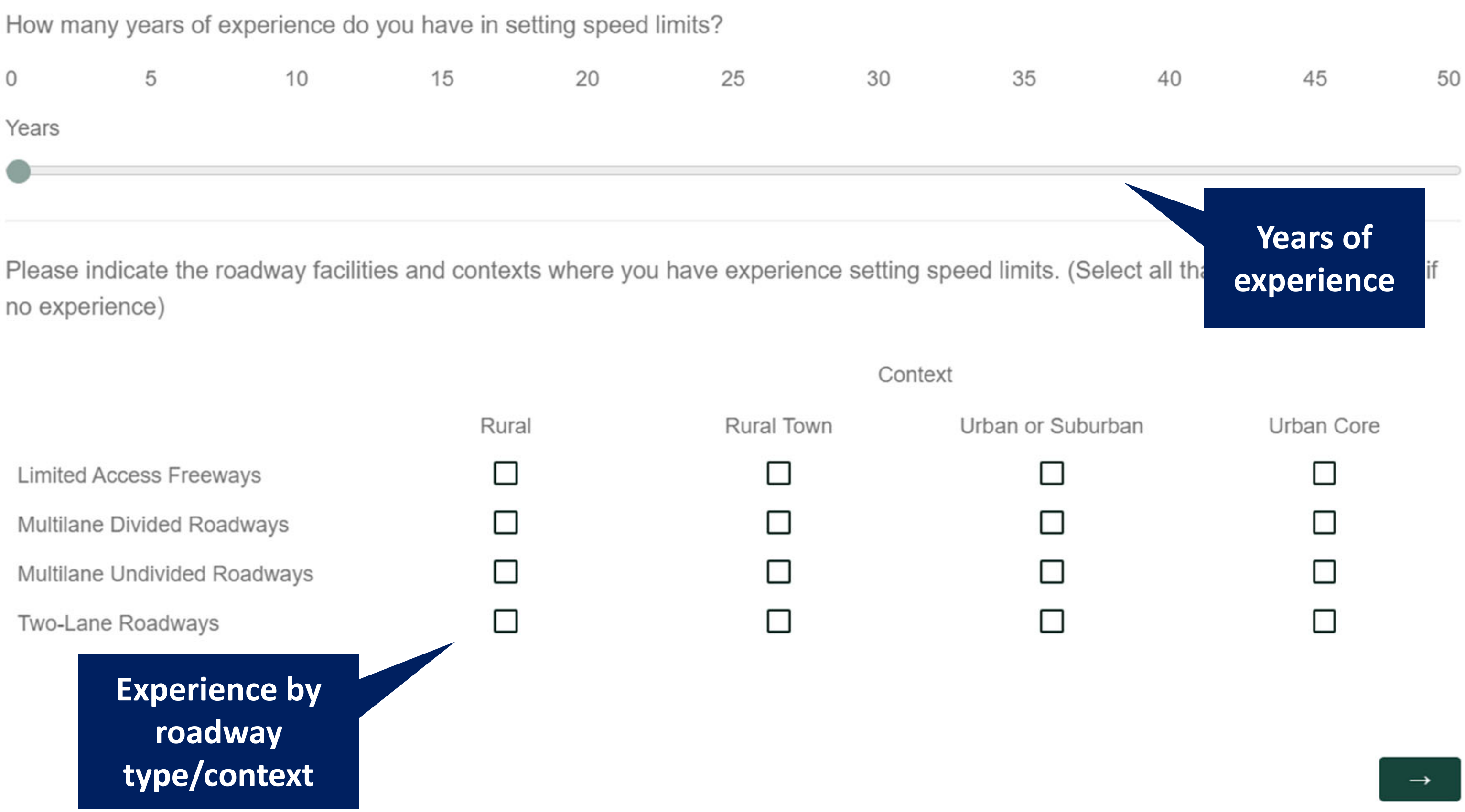

Policy and Tools Block

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Which approaches and/or tools does your agency typically use when setting speed limits? (select all that apply)

- Engineering Approach (e.g., speed limits are typically based on 85th percentile speed, which is then adjusted according to roadway, roadside, and/or road user characteristics)
- Road Risk Approach (e.g., speed limits are typically based on the function or classification of the road, which is then adjusted according to roadway, roadside, and/or road user characteristics)
- Injury Minimization or Safe Systems Approach (e.g., speed limits are typically set according to the crash types that are likely to occur, the impact forces that result, and the human body's tolerance to withstand these forces)
- Citywide or Default Approach (e.g., speed limits are set based on municipal boundaries or type of street)
- USLIMITS2
- NCHRP Report 966/Project 17-76 Tool
- Other Method (please describe)
- Other Tool (please describe)
- Unsure
- None

Agency approaches to speed limit setting

Engineering Factors Block

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Level of importance assessment

How important are each of the following factors with respect to setting speed limits?

	Not Important	Somewhat Important	Very Important	Not Applicable or Unsure
Roadway Type/Functional Class (e.g., freeway, two-lane highway)	○	○	○	○
Area Type/Context (e.g., rural, urban)	○	○	○	○
Traffic Volume	○	○	○	○
Truck Volume (or Percentage)	○	○	○	○
Roadside Development Type (e.g., residential, commercial, industrial)	○	○	○	○
Horizontal/Vertical Curvature	○	○	○	○
Available Sight Distance	○	○	○	○
Grade/Terrain	○	○	○	○
Number of Lanes	○	○	○	○
Lane Width	○	○	○	○
Shoulder Characteristics	○	○	○	○
Median Type (e.g., grassy, barrier, painted, none)	○	○	○	○
Median Width	○	○	○	○
Rumble Strips	○	○	○	○
Roadside Objects/Clear Zone	○	○	○	○
Number of Access Points (e.g., intersections, driveways, ramps)	○	○	○	○
Number of Traffic Signals or Stop Signs	○	○	○	○
Sidewalk or Shared-Use Path	○	○	○	○
On-Road Bicycle Lane	○	○	○	○
Pedestrian Activity Level	○	○	○	○
Bicycle Activity Level	○	○	○	○

	Not Important	Somewhat Important	Very Important	Not Applicable or Unsure
On-Street Parking	○	○	○	○
Roadway Lighting	○	○	○	○
Transit	○	○	○	○
Design Speed	○	○	○	○
Target Speed	○	○	○	○
Free Flow Speed	○	○	○	○
Average Speed (All Vehicles)	○	○	○	○
50th Percentile Speed	○	○	○	○
85th Percentile Speed	○	○	○	○
Standard Deviation (or Variance) of Speed	○	○	○	○
10-mph Pace	○	○	○	○
Crash History (All Crashes)	○	○	○	○
Fatal and Injury Crash History	○	○	○	○

Please list any additional factor(s) that should be considered when setting speed limits:

Written feedback

→

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Speed Limit Setting Case Review

- 100 total speed limit setting case example corridors were identified by the project team for subsequent review by panelists
  - Distributed to ensure coverage of a broad range of roadway characteristics
  - At least one case from all 50 states and Washington, D.C.
  - Content is developed such that the panelist was not given the “actual” location or the existing posted speed limit
- Each case developed in into unique Qualtrics survey and provided to panelists via email with complete pre-survey data

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Distribution of Speed Limit Setting Cases (N=100)

Distribution of Sites		Roadway Context				
		Rural	**Rural Town**	**Urban/Suburban**	**Urban Core**	**All Contexts**
Roadway Type	**Freeway**	5		5	5	**15**
	Multilane Divided Arterial	5	2	10	3	**20**
	Multilane Undivided Arterial	5	7	10	6	**28**
	Two-Lane Arterial	2	7	10	3	**22**
	Two-Lane Collector	3	2	5	5	**15**
	All Types	**20**	**18**	**40**	**22**	**100**

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Corridor Characteristics Collected for Each Case

- Roadway Type and Context
- Corridor Length
- AADT and Heavy Vehicle Percentage
- Functional Classification
- Current Posted Speed (Hidden)
- Roadside Development Type
- Number of Horizontal Curves with a Design Speed below the Speed Limit (per mile)
- Lane Width
- Shoulder Width/Type
- Median Width/Type
- Rumble Strip Presence
- Pedestrian and Bicycle Facilities
- Pedestrian and Bicycle Activity Level
- Terrain
- Access Point Density
- Signal Density
- All-Way Stop Density
- Interchange Density
- Lighting Presence
- Transit Presence
- On-Street Parking Presence
- Other Relevant Site Notes

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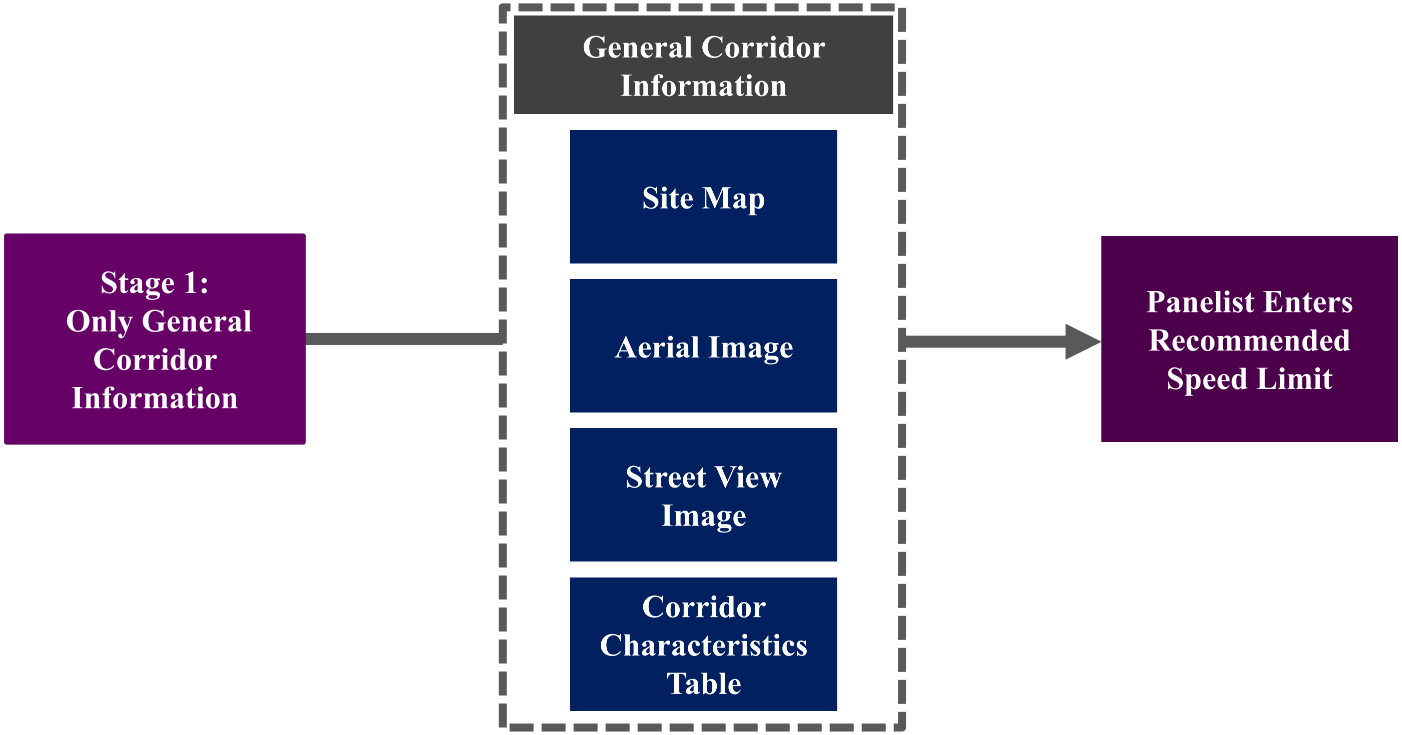
Stage 1: General Corridor Information Only



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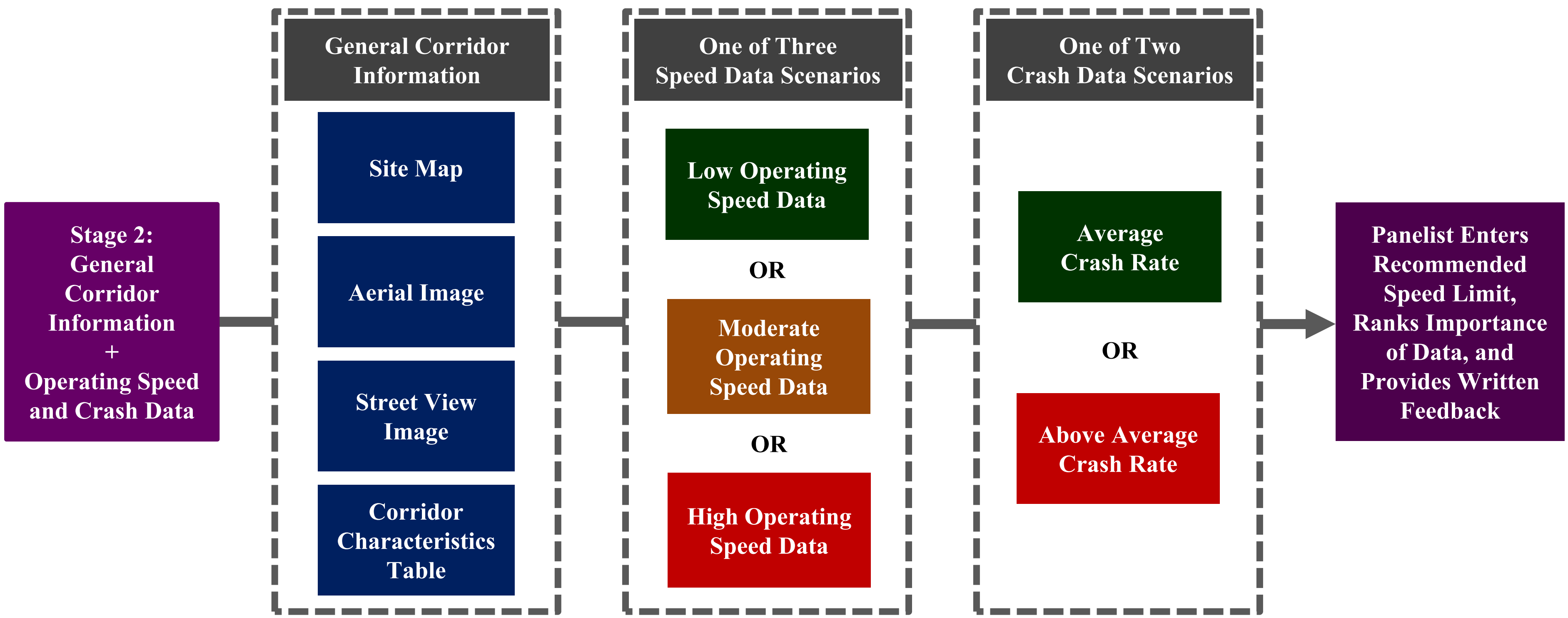
Stage 2: General Information + Randomized Speed/Crash Data



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Example Speed Data Scenarios for Case with 65 MPH Speed Limit

Posted Speed	Iteration	Operating Speed Presented 15th	50th	85th
65 MPH	Low	51	60	66
		52	61	67
		53	62	68
	Moderate	54	63	69
		55	64	70
		56	65	71
		57	66	72
		58	67	73
	High	59	68	74
		60	69	75
		61	70	76

Operating Speed Percentile	Speed Measured on This Corridor
15th Percentile	51 mph
50th Percentile	60 mph
85th Percentile	66 mph

Operating Speed Percentile	Speed Measured on This Corridor
15th Percentile	55 mph
50th Percentile	64 mph
85th Percentile	70 mph

Operating Speed Percentile	Speed Measured on This Corridor
15th Percentile	60 mph
50th Percentile	69 mph
85th Percentile	75 mph

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Development of Stage 2 Iterations: Crash Data Scenarios

- After selecting one of three operating speed scenarios, either **"Average"** or **"Significantly Above Average"** crash rate scenarios randomly selected

Crash Category	Crash Rate on This Corridor Compared to Similar Roadways
All Crashes	Average
Fatal and Injury Crashes	Average

Crash Category	Crash Rate on This Corridor Compared to Similar Roadways
All Crashes	Significantly Above Average
Fatal and Injury Crashes	Significantly Above Average

Stage One Block (General Roadway Info Only)

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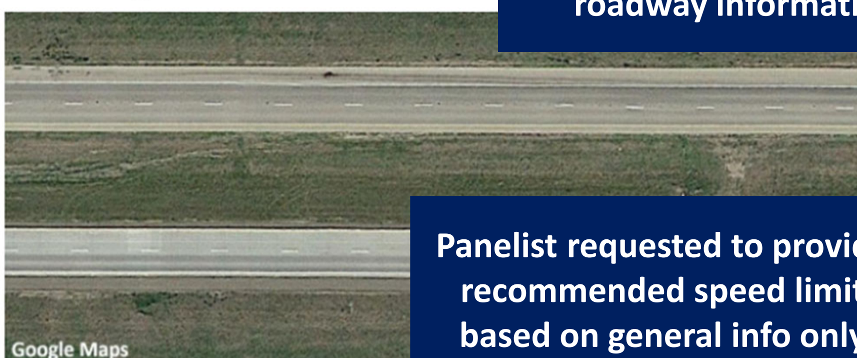
General Site Description: Four-Lane Freeway Corridor in Rural Area

Site Map

Aerial Image



Panelist provided standardized set of general roadway information

Panelist requested to provide recommended speed limit based on general info only

Street View of Corridor

Corridor Characteristics

Characteristic	Description
Segment Length	20.0 Miles
Traffic Volume	10,000 Vehicles per Day 20.0% Heavy Vehicles
Roadside Development Type	Farm
Number of Horizontal Curves with a Design Speed below the Speed Limit (per mile)	0.0 Horizontal Curves per Mile
Roadway Cross Section	Four 12' Travel Lanes 5' Paved Left Shoulder 12' Paved Right Shoulder 50' Median with No Barrier

Characteristic	Description
Rumble Strips	Shoulder
Ped/Bike Facilities	Limited Access
Ped/Bike Activity Level	Limited Access
Terrain	Rolling
Access Point Density	Limited Access
Signal Density	Limited Access
Stop Sign Density	Limited Access
Interchange Density	0.25 Interchanges per Mile
Lighting	None
Transit	None
On-Street Parking	None
Other Notes	-

What posted speed limit (in miles per hour) do you recommend for the study corridor?

50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90

Stage 2 Instruction Block

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Thank you. Your initial response has been recorded.

You will now be provided with traffic speed and crash data for the study corridor. This data is being provided in addition to the prior information, which remains unchanged.

You will be again requested to recommend a speed limit for the corridor considering this additional information.

After making this recommendation, you will be asked to rank the relative importance of each of the data categories in making your speed limit recommendation. You will also be asked to note any other information that may have been helpful towards making your speed limit recommendation.

→

New set of instructions provided to panelist specific to stage 2

Stage 2 Block (General Info + Speed/Crash Data)

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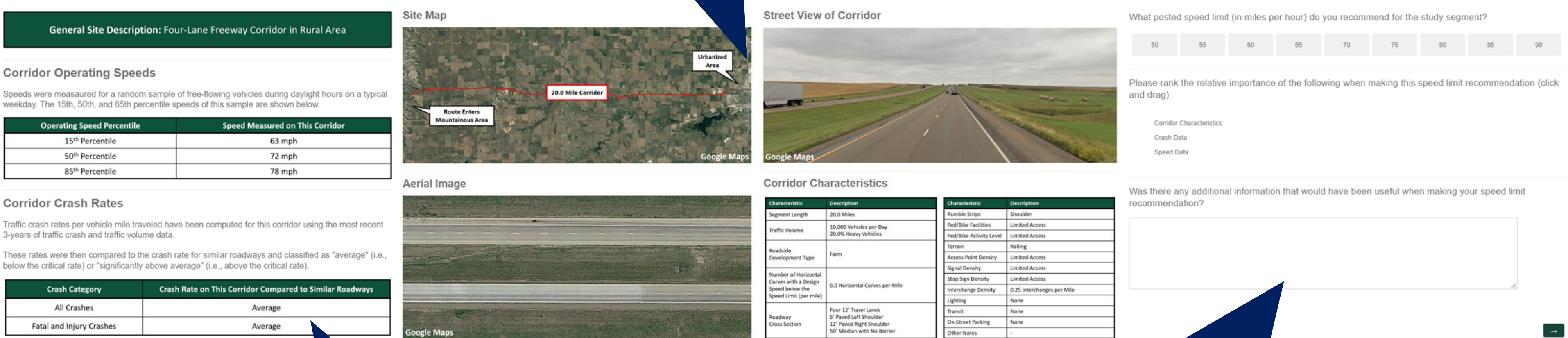
Same set of general roadway information



One of three randomly selected speed/crash data iterations

Panelist requested to provide recommended speed limit, rank the importance of data, and include written feedback

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Pre-Survey
Preliminary Results

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Pre-Survey Results: Number of Panelists by Employer Category

Employer Category	Expert	Expanded	All Panelists
Small (< 50,000 Pop.) City or Other Municipality	1	5	**6**
Medium (50,000 to 249,999 Pop.) City or Other Municipality	0	7	**7**
Large (> 250,000 Pop.) City or Other Municipality	4	20	**24**
Consultant	1	18	**19**
County Road Agency	5	27	**32**
FHWA	1	2	**3**
Law Enforcement	2	9	**11**
Other Transportation Agency or Entity	0	6	**6**
Other	0	3	**3**
Research/Education	0	12	**12**
State DOT	13	88	**101**
All Panelists	**27**	**197**	**224**

Pre-Survey Results: Map of All Panelists (N=224) by State*

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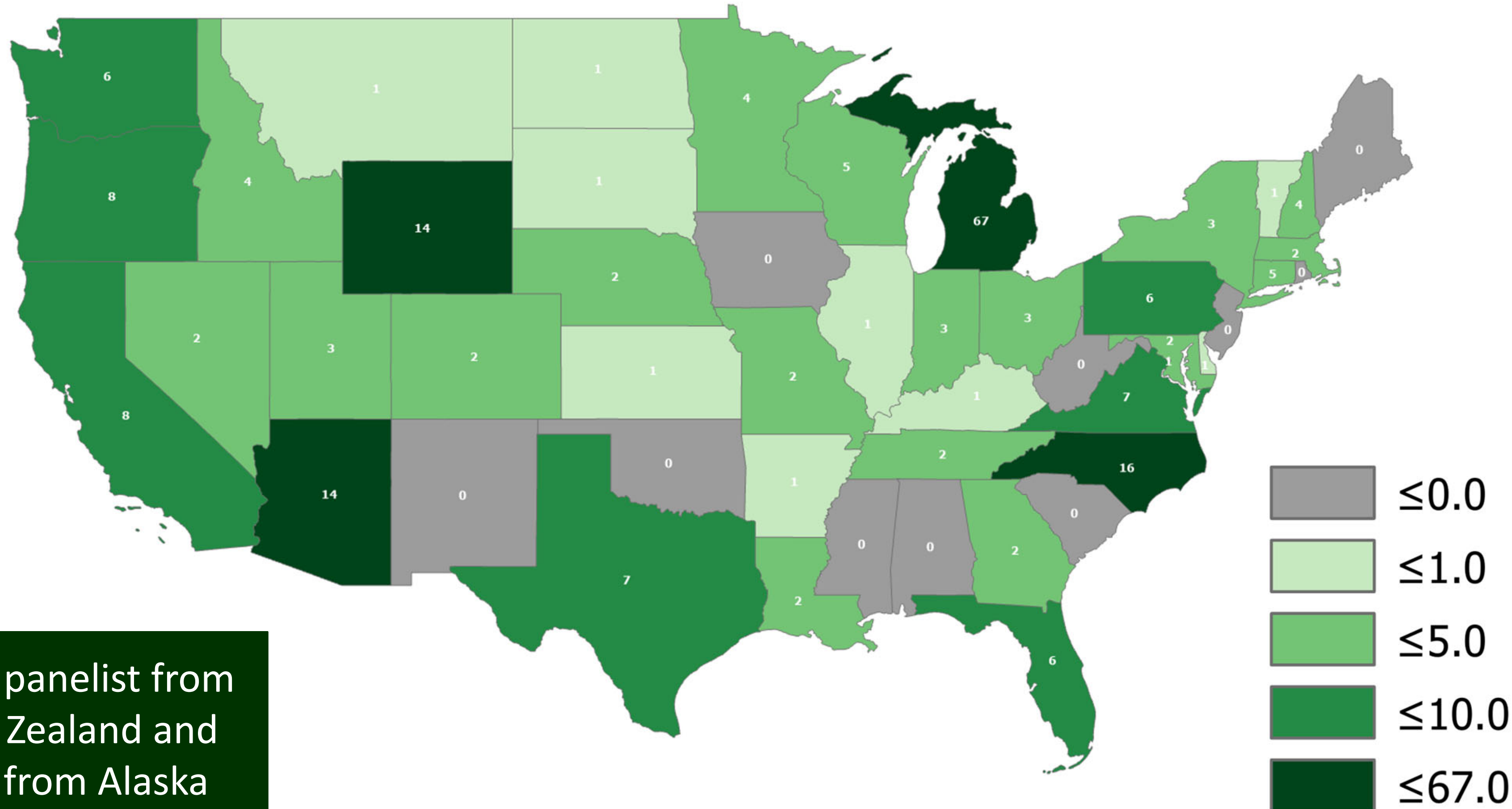

*One panelist from New Zealand and two from Alaska

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Pre-Survey Results: Panelist Experience

Experience	Expert	Expanded	Total
Setting Speed Limits	96.3%	69.0%	**72.3%**
Performing Speed Studies	77.8%	69.0%	**70.1%**
Speed Management	88.9%	79.2%	**80.4%**
Laws/Statutes	70.4%	34.5%	**38.8%**
Speed Enforcement	18.5%	13.7%	**14.3%**
Geometric Design	88.9%	69.5%	**71.9%**
Research	44.4%	28.4%	**30.4%**
Other	22.2%	8.1%	**9.8%**
None	0.0%	6.1%	**5.4%**

Pre-Survey Results: Years of Speed Limit Setting Experience

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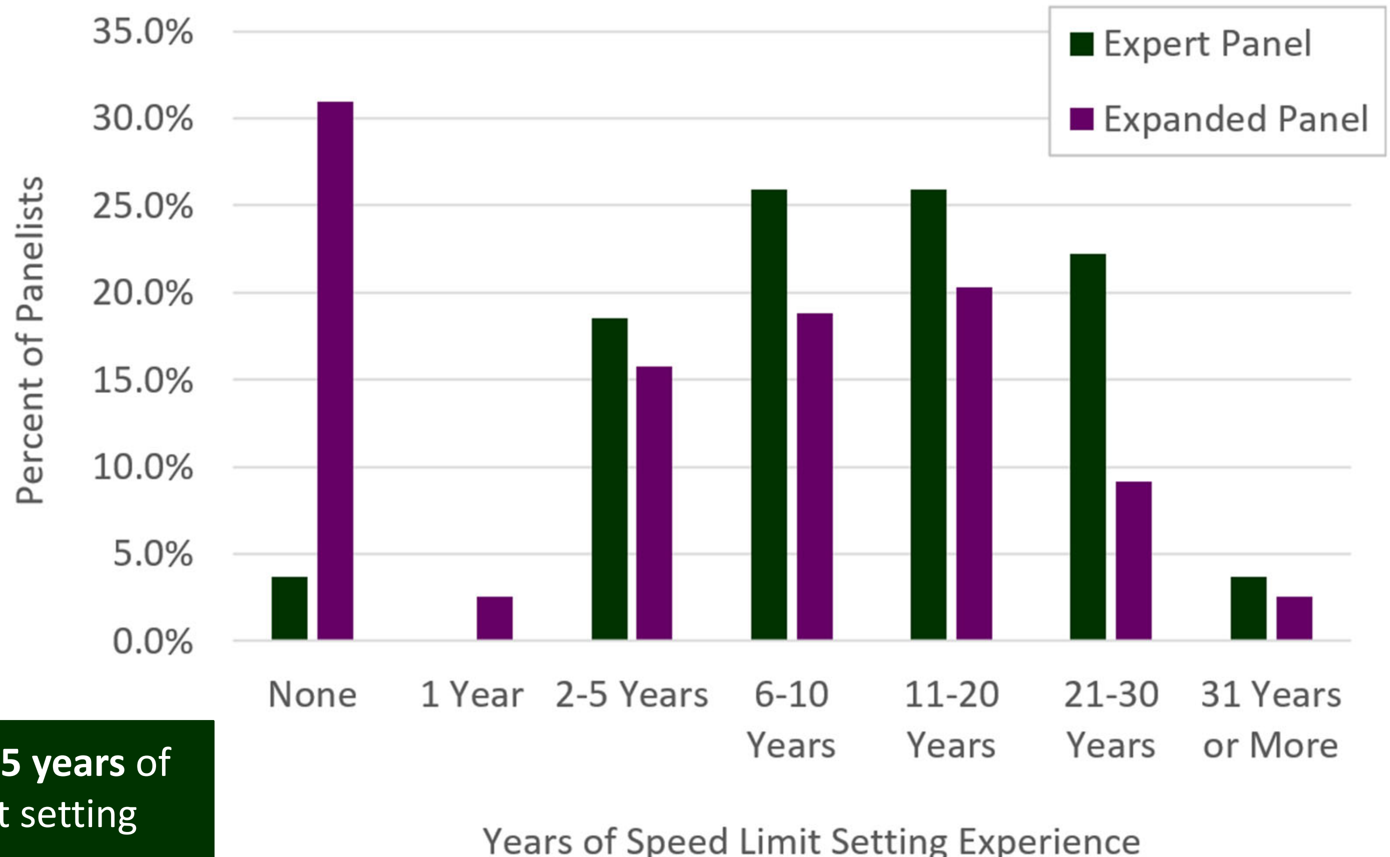

Total of **2,095 years** of speed limit setting experience in pre-survey

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Pre-Survey Results: Experience by Roadway Type/Context

Expert Panelists		Roadway Context			
		Rural	Rural Town	Urban/Suburban	Urban Core
Roadway Type	Limited Access Freeways	34.6%		34.6%	34.6%
	Multilane Divided Roadways	38.5%	38.5%	73.1%	46.2%
	Multilane Undivided Roadways	50.0%	50.0%	80.8%	61.5%
	Two-Lane Roadways	69.2%	65.4%	73.1%	65.4%

**Only includes panelists who responded that they have experience setting speed limits*

Expanded Panelists		Roadway Context			
		Rural	Rural Town	Urban/Suburban	Urban Core
Roadway Type	Limited Access Freeways	35.3%		37.5%	25.0%
	Multilane Divided Roadways	48.5%	39.0%	63.2%	36.8%
	Multilane Undivided Roadways	56.6%	48.5%	78.7%	47.8%
	Two-Lane Roadways	80.1%	64.0%	79.4%	50.0%

**Only includes panelists who responded that they have experience setting speed limits*

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Pre-Survey Results: Agency Speed Limit Setting Approach

Approaches	Expert	Expanded	Total
Engineering Approach	88.9%	79.2%	**80.4%**
Road Risk Approach	22.2%	26.9%	**26.3%**
Injury Minimization or Safe Systems Approach	29.6%	14.7%	**16.5%**
Citywide or Default Approach	25.9%	24.4%	**24.6%**
USLIMITS2	37.0%	25.9%	**27.2%**
NCHRP Report 966/Project 17-76 Tool	14.8%	7.6%	**8.5%**
Other Method	33.3%	12.7%	**15.2%**
Other Tool	3.7%	2.5%	**2.7%**
Unsure	0.0%	5.6%	**4.9%**
None	3.7%	7.6%	**7.1%**

Pre-Survey Results: Expert Panelists - Factor Level of Importance

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Factor	Not Important	Somewhat Important	Very Important	Not Applicable or Unsure
Roadway Type/Functional Class	0.0%	29.6%	70.4%	0.0%
Area Type/Context	3.7%	18.5%	77.8%	0.0%
Traffic Volume	11.1%	59.3%	29.6%	0.0%
Truck Volume	33.3%	55.6%	11.1%	0.0%
Roadside Development Type	0.0%	22.2%	77.8%	0.0%
Horizontal/Vertical Curvature	11.1%	40.7%	48.1%	0.0%
Available Sight Distance	0.0%	37.0%	63.0%	0.0%
Grade/Terrain	7.4%	66.7%	25.9%	0.0%
Number of Lanes	18.5%	55.6%	25.9%	0.0%
Lane Width	18.5%	55.6%	22.2%	3.7%
Shoulder Characteristics	7.4%	70.4%	18.5%	3.7%
Median Type	22.2%	55.6%	14.8%	7.4%
Median Width	25.9%	55.6%	11.1%	7.4%
Rumble Strips	29.6%	44.4%	3.7%	22.2%
Roadside Objects/Clear Zone	11.1%	33.3%	51.9%	3.7%
Number of Access Points	7.4%	37.0%	55.6%	0.0%
Number of Traffic Signals or Stop Signs	7.4%	63.0%	25.9%	3.7%
Sidewalk or Shared-Use Path	14.8%	40.7%	40.7%	3.7%
On-Road Bicycle Lane	0.0%	44.4%	51.9%	3.7%
Pedestrian Activity Level	3.7%	22.2%	74.1%	0.0%
Bicycle Activity Level	3.7%	25.9%	70.4%	0.0%
On-Street Parking	7.4%	37.0%	55.6%	0.0%
Roadway Lighting	25.9%	55.6%	14.8%	3.7%
Transit	22.2%	48.1%	25.9%	3.7%
Design Speed	14.8%	37.0%	40.7%	7.4%
Target Speed	14.8%	33.3%	44.4%	7.4%
Free Flow Speed	11.1%	18.5%	66.7%	3.7%
Average Speed of All Vehicles	7.4%	37.0%	55.6%	0.0%
50th Percentile Speed	3.7%	40.7%	55.6%	0.0%
85th Percentile Speed	7.4%	18.5%	74.1%	0.0%
Standard Deviation of Speed	11.1%	44.4%	37.0%	7.4%
10-mph Pace	14.8%	37.0%	40.7%	7.4%
Crash History (All Crashes)	0.0%	7.4%	92.6%	0.0%
Fatal and Injury Crash History	0.0%	7.4%	92.6%	0.0%

Pre-Survey Results: Expanded Panelists - Factor Level of Importance

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Factor	Not Important	Somewhat Important	Very Important	Not Applicable or Unsure
Roadway Type/Functional Class	1.0%	22.3%	75.1%	1.5%
Area Type/Context	1.5%	23.4%	73.6%	1.5%
Traffic Volume	11.7%	50.8%	34.5%	3.0%
Truck Volume	18.3%	59.4%	18.3%	4.1%
Roadside Development Type	2.5%	26.9%	66.0%	4.6%
Horizontal/Vertical Curvature	5.1%	36.0%	55.3%	3.6%
Available Sight Distance	5.1%	29.9%	60.9%	4.1%
Grade/Terrain	8.6%	56.3%	32.5%	2.5%
Number of Lanes	14.7%	61.4%	20.3%	3.6%
Lane Width	13.2%	54.8%	28.4%	3.6%
Shoulder Characteristics	10.7%	57.9%	27.4%	4.1%
Median Type	20.3%	52.8%	18.3%	8.6%
Median Width	26.4%	53.3%	12.2%	8.1%
Rumble Strips	44.2%	38.6%	4.1%	13.2%
Roadside Objects/Clear Zone	8.1%	53.3%	34.5%	4.1%
Number of Access Points	1.5%	32.0%	64.5%	2.0%
Number of Traffic Signals or Stop Signs	10.2%	52.8%	33.0%	4.1%
Sidewalk or Shared-Use Path	14.2%	42.6%	38.6%	4.6%
On-Road Bicycle Lane	8.6%	39.6%	47.7%	4.1%
Pedestrian Activity Level	4.6%	28.4%	62.9%	4.1%
Bicycle Activity Level	5.1%	35.5%	55.3%	4.1%
On-Street Parking	7.1%	49.7%	37.1%	6.1%
Roadway Lighting	30.5%	51.3%	12.7%	5.6%
Transit	25.4%	45.7%	17.3%	11.7%
Design Speed	8.1%	35.5%	52.8%	3.6%
Target Speed	12.2%	29.4%	46.2%	12.2%
Free Flow Speed	7.1%	33.0%	54.8%	5.1%
Average Speed of All Vehicles	11.2%	46.2%	36.5%	6.1%
50th Percentile Speed	15.2%	54.8%	23.9%	6.1%
85th Percentile Speed	7.6%	19.8%	69.0%	3.6%
Standard Deviation of Speed	9.6%	48.2%	32.0%	10.2%
10-mph Pace	13.7%	40.1%	25.4%	20.8%
Crash History (All Crashes)	2.0%	34.5%	61.4%	2.0%
Fatal and Injury Crash History	2.0%	26.4%	69.0%	2.5%

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Pre-Survey Results: Other Factors or Considerations Noted by Panelists
Laws, policies, ordinances, or statutes
Enforcement
Animal presence or crash history
Local stakeholder/political influence
Location or type of non-motorized activity beyond just volume count
Many factors are potentially related, level of importance may vary by facility type or characteristics
Consistency to enhance driver behavior
School presence
Statutory definitions and limits
Speeds along adjacent facilities
Historical crash patterns or trends directly related to speed (as opposed to all crashes)
The interelationship between many of these factors and operating speeds should be considered
Equity
Weather considerations
Corridor length
Horse and buggy presence
Signal timing and cordination
Vehicles exceeding the current limit
Sunrise and sunset
Micromobility systems
Elder care facility proximity
Pavement condition
Adjacent highway network considerations, minimizing vehicles migrating to undesired routes
Driver behavior beyond operating speed
Impacts on adjacent recurring congestion or queueing
Optimizing overall delay or travel time versus point operating speeds
Fuel efficiency

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Speed Limit Setting Case Reviews
Preliminary Results

Case Review Results: Map of Panelists (181) by State*

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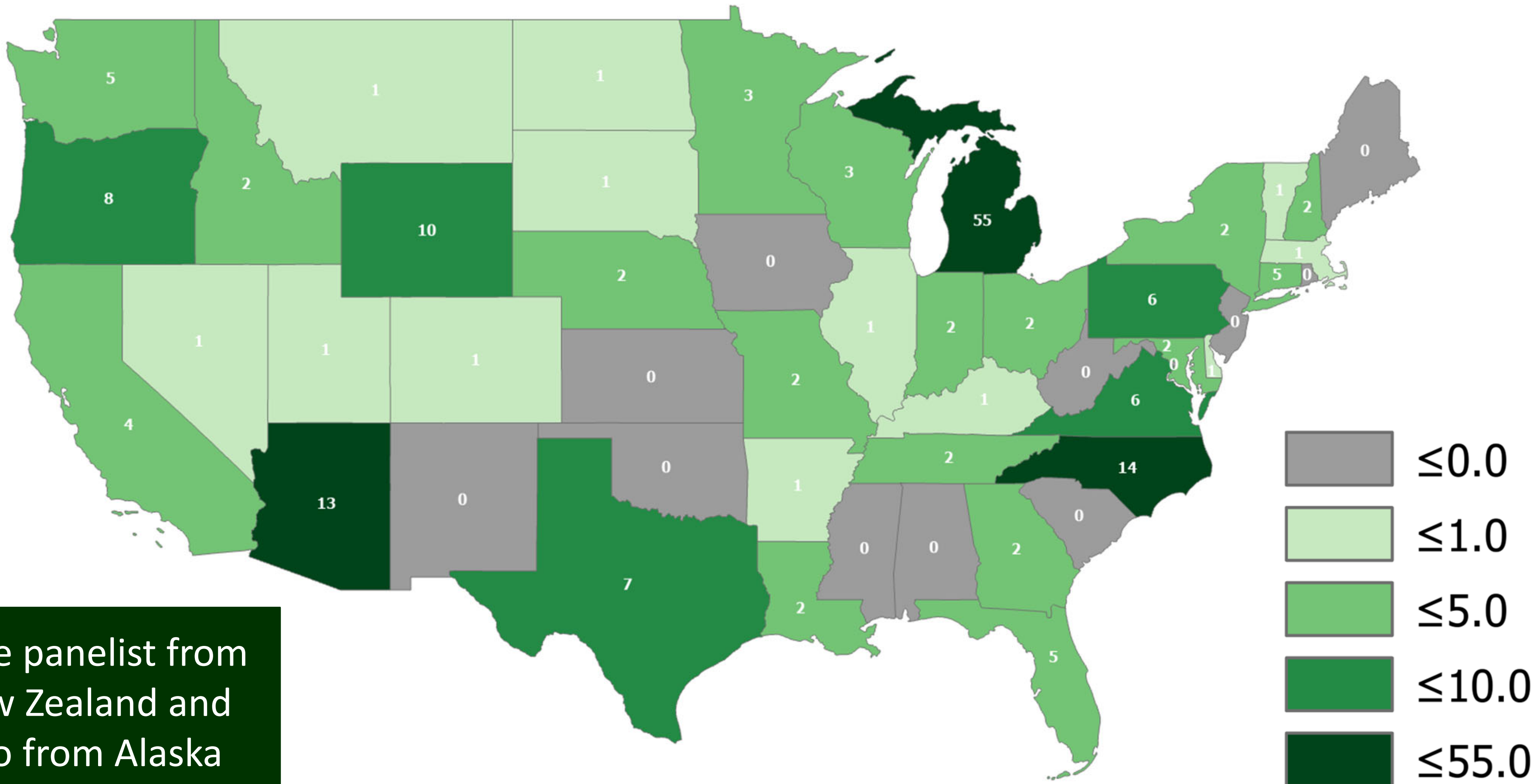

*One panelist from New Zealand and two from Alaska

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Case Review Results: Completed Reviews by Roadway Type/Context

Cases Completed by Panelists		Roadway Context				
		Rural	Rural Town	Urban/Suburban	Urban Core	All Contexts
Roadway Type	Freeway	84		97	99	**280**
	Multilane Divided Arterial	104	33	211	63	**411**
	Multilane Undivided Arterial	102	149	221	124	**596**
	Two-Lane Arterial	53	131	219	57	**460**
	Two-Lane Collector	66	41	119	98	**324**
	All Types	**409**	**354**	**867**	**441**	**2,071**

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Example Data: Case #25 (Rural Multilane Undivided Arterial)

23 Total Reviews

Actual Posted Speed Limit = 55 MPH
(Not Shown to Panelists)

Case #25 (Rural Multilane Undivided Arterial) Recommended Speed Limit Results

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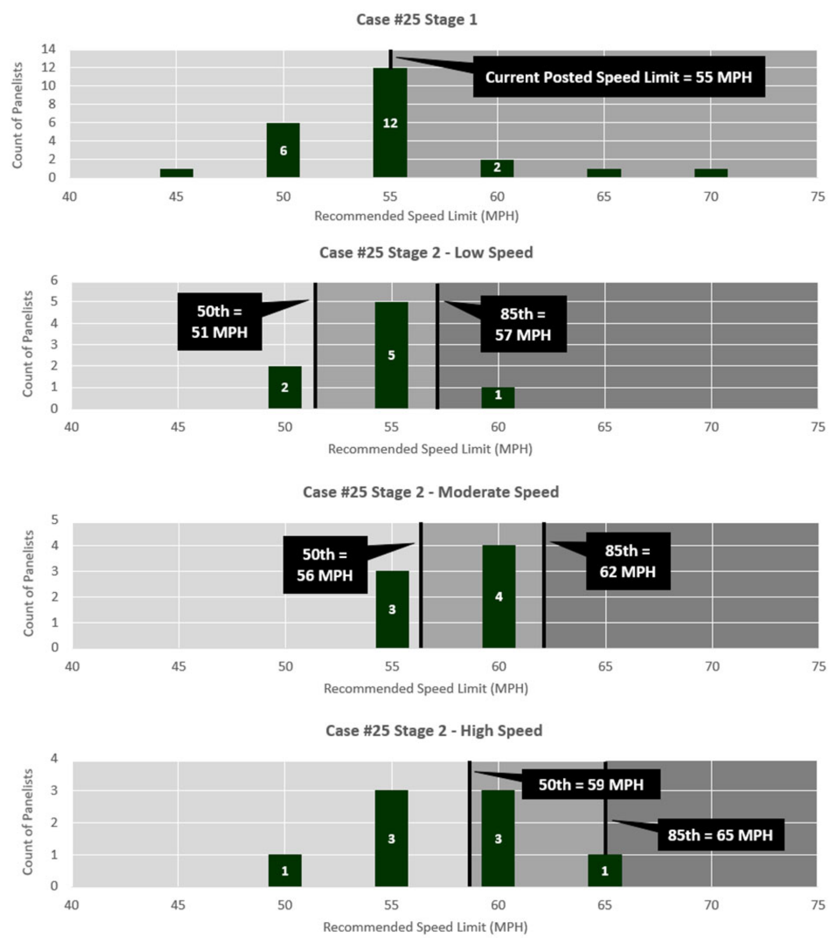
Note Case #25
All Three Crash
Iterations = Average



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Case #25 (Rural Multilane Undivided Arterial) Recommended Speed Limits by Speed Iteration

Iteration	Other - Low	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th	Other - High
Low Speed	0.0%	25.0%	0.0%	62.5%	0.0%	12.5%
Moderate Speed	0.0%	42.9%	0.0%	57.1%	0.0%	0.0%
High Speed	12.5%	37.5%	37.5%	12.5%	0.0%	0.0%
All Iterations	**4.3%**	**34.8%**	**13.0%**	**43.5%**	**0.0%**	**4.3%**

Note Case #25
All Three Crash Iterations = Average

NCHRP 17-85
Development and Application of Crash Severity Models for the Highway Safety Manual

Presentation to Committee on Safety Performance and Analysis – August 16, 2022

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NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Acknowledging the Project Team

Project Team	Team Members
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Project Objectives (From RFP)

- Assess the current HSM approaches for estimating and predicting crash count by severity
- Identify gaps and opportunities in the current prediction/estimation procedures
- Develop and validate new severity models to address the gaps and opportunities
- Develop a guidance document to apply the new models in a format suitable for possible adoption in the HSM

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Presentation Outline

- Recap of New Methodologies Considered
- Data Sources Used for Estimation and Validation
- Recommended Methodologies by Facility Type
- QIE Estimation of Input Variables
- Example Applications of each Methodology
- Implementation Guidance and Software
- Questions

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1. Recap of New Methodologies Considered

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Distinctive Feature of these Approaches

Inclusion of driver and vehicle variables as predictors

- Most important variables in most severity prediction models
- Usually only available in crash data – not segment data

Quasi-induced Exposure translates crash involvement to segment-level population proportions

- Not at fault drivers assumed to appear randomly in crashes
- Necessary to aggregate groups of segments and intersections to get sufficient observations by involvement group

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Method 1 Negative Binomial - Ordered Probit Fractional Split Modeling Framework

Dataset Overview

ID	Total Crash	PDO	Injury	Fatal	PDO	Injury	Fatal
1	10	6	4	0	0.6	0.4	0
2	12	6	5	1	0.5	0.42	0.08
3	8	5	2	1	0.63	0.25	0.12
4	4	0	3	1	0	0.75	**0.25**

Crash counts by severity level (PDO, Injury, Fatal, first group)

Crash proportions by severity level (PDO, Injury, Fatal, second group)

Total Fatal Crash =1
Total Crash =4
Fatal Proportion = ¼

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Method 1 Negative Binomial - Ordered Probit Fractional Split Modeling Framework

Model Prediction

ID	Total Crash	PDO	Injury	Fatal	PDO	Injury	Fatal
1	10	6	4	0	0.6	0.4	0
2	12	6	5	1	0.5	0.42	0.08
3	8	5	2	1	0.63	0.25	0.12
4	4	0	3	1	0	0.75	**0.25**

NB Model

Predicted
Total Crash Counts

X

Predicted
Severity Counts

Ordered Fractional Split Model

Predicted
Severity Proportions

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Estimation of Ordered Fractional Split Models

- For proportional variables, a conventional Maximum likelihood approach is not applicable. Hence a quasi-likelihood model estimation process is employed that maximizes the proportion observed in each category
- The approach while maximizing the observed proportion likelihood recognizes that
  - Proportion for each severity category is between 0 and 1
  - Sum of the proportions across all categories adds up to 1
- For the joint model (that connects total crash count and proportion) a combination likelihood function is developed (mathematical details in Yasmin and Eluru, 2018)

Method 2 Univariate Count Modeling Framework

Univariate count models to be estimated

(Negative Binomial)

$$\mu_i = Years * Length * AADT_i^{\beta_1} * e^{\beta_2 * x_{site\_features,i} + \boldsymbol{\beta_3 * P_{older,i} + \beta_4 * P_{male,i} + \beta_5 * P_{truck,i}} + \cdots + \boldsymbol{\beta_k x_{k,i}}}$$

Average crash frequency at this site i (each crash severity level has its own model)

Proportions of certain drivers and vehicles at this site i (obtained from quasi-induced exposure analysis)

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Method 3 Multilevel Discrete Outcome Modeling Framework

Models to be estimated

Total Crash Count Model (at segment and intersection level, using Negative Binomial)
Crash Severity Discrete Outcome Model (at crash level, using PPO & ML)
Driver Group Estimation (at segment and intersection level, using Quasi-Induced Exposure)

Model Prediction

Crash count by severity = (Predicted total crash count)
× (Predicted driver group proportion)
× (Predicted crash severity probability by driver group)

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2. Data Sources Used for Estimation and Validation

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Rural Roadways

Facilities	Estimation Data			Validation Data		
	State	Site Counts	Total Mileage	State	Site Counts	Total Mileage
2-lane 2-way undivided segments	WA	5,271	1784	CT	7,083	1080
2-lane 2-way UnSig. 3-leg Ints.	MN	1,619	-	CT	238	-
2-lane 2-way UnSig. 4-leg Ints.	MN	2,212	-	CT	97	-
2-lane 2-way Sig. 4-leg Ints.	MN	68	-	CT	31	-
4-lane undivided segments	CA	176	76	CT	76	5
4-lane divided Segments	CA	1,072	596	MN	542	485
4-lane UnSig. 3-leg intersections	CA	409	-	MN	209	-
4-lane UnSig. 4-leg intersections	CA	275	-	MN	269	-
4-lane Sig. 4-leg intersections	CA	71	-	MN	54	-

Urban & Suburban Arterials

Facilities	Estimation Data			Validation Data		
	State	Site Counts	Total Mileage	State	Site Counts	Total Mileage
2-lane undivided arterials	OH	3,608	2526	NC	2,605	1688
3-lane arterials (with center 2-way left)	OH	141	45	NC	74	17
4-lane undivided arterials	OH	1,663	923	NC	935	487
4-lane divided arterials	OH	862	485	NC	1,332	550
5-lane arterials (with center 2-way left)	OH	50	17	NC	14	2
UnSig. 3-leg intersections	CT	798	-	MN	794	-
Sig. 3-leg intersections	CT	498	-	MN	67	-
UnSig. 4-leg intersections	CT	262	-	MN	528	-
Sig. 4-leg intersections	CT	986	-	MN	632	-

Freeway Segments

Facilities	Estimation Data			Validation Data		
	State	Site Counts	Total Mileage	State	Site Counts	Total Mileage
Rural 4-lane divided segments	CA	1,286	1187	OH	391	432
Rural 6-lane divided segments	CA	197	109	OH	174	201
Rural 8-lane divided segments	CA	144	96	-	-	-
Urban 4-lane divided segments	CA	1,393	613	OH	1,612	777
Urban 6-lane divided segments	CA	1,191	504	OH	781	438
Urban 8-lane divided segments	CA	1,519	514	OH	245	112
Urban 10-lane divided segments	CA	889	254	OH	25	13

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3. Recommended Methodologies by Facility Type

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Performance Measures

Mean Absolute Deviation (MAD)
- sum of the absolute value of predicted validation observations minus observed validation observations, divided by the number of validation observations.

Mean Squared Prediction Error (MSPE)
- sum of squared differences between observed and predicted crash frequencies, divided by sample size.

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Recommendation Criteria

Models with lower MAD or MSPE across different severity levels and for both estimation and validation datasets were preferred.

Consistency within the same facility group was preferred. For example, we preferred to recommend the same best model for Rural two-lane highway segments and Rural two-lane highway 3ST, 4ST, and 4SG intersections.

We preferred to recommend models from the three new approaches, unless the HSM or NCHRP 17-62 models strongly outperformed them.

We verified our final recommendations using an overall model performance metric that aggregates the performance measures over all severity levels for both the estimation and validation datasets.

Recommended Approach by Facility Type

Facility Type Group	Approach
Two-lane Rural Highways (all types)	Univariate severity count modeling
Multilane Rural Highways:	
All except 4SG intersections	Multilevel discrete outcome modeling
4SG intersections	Current (1st edition) HSM approach
Urban/Suburban Arterial Segments and Intersections	Negative Binomial Ordered Probit Fractional Split
Urban and Rural Freeway Segments	Current (1st edition) HSM approach

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4. QIE Estimation of Input Variables

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HSM Highway Safety Manual — Task 4: Methodology Consolidation — NCHRP National Cooperative Highway Research Program

Development of Algorithm for Creating Aggregate-Level Data

Challenge in getting statistically stable estimates of driving population distributions by characteristics at site-level.

Overall idea is aggregating adjacent sites that are similar.

$$p_{d,j,i} = \frac{c_{d,j,i}}{n_i}$$

Meeting condition $\sum n_i \, p_{d,j,i} \geq 5$, equivalently $\sum c_{d,j,i} \geq 5$,

$$p_{d,j,I} = \frac{\sum_{i=1}^{I} c_{d,j,i}}{\sum_{i=1}^{I} n_i}$$

d denotes the demographic variable $(d = 1, \ldots, D)$ with j levels $(j = 1, \ldots, J)$. i be a site (segment or intersection).

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Task 4: Methodology Consolidation

Sample Data Analysis For Aggregation

Data:

Description	Frequency
Roadway segments (total length=532.4 miles)	1264
Not at fault drivers (two or more vehicle crashes)	22,240
Not at fault drivers-male	12,594
Not at fault drivers-female	9646
Not at fault drivers-PC	17,182
Not at fault drivers-truck/bus	3708
Not at fault drivers-other vehicles	1350
Not at fault drivers-age below 20	1220
Not at fault drivers-age 20-69	19,838
Not at fault drivers-age above 69	1182
Total crashes	16,762
K crashes	202
A crashes	327
B crashes	1469
C crashes	3718
O (PDO) crashes	11,046

HSM Highway Safety Manual

Task 4: Methodology Consolidation

NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Step 1: Calculate frequencies

ID	CNTYRTE	BEGMP	ENDMP	Not at Fault Drivers/Vehicles								
				Total	Age15-19	Age20-69	Age70+	PC	Truck/Bus	Other	Male	Female
1	01001 23 D	59.862	59.926	1	0	1	0	0	0	1	1	0
2	01001 23 D	60.047	60.048	0	0	0	0	0	0	0	0	0
3	01001 23 D	60.049	60.125	2	1	1	0	2	0	0	1	1
4	01001 23 D	60.231	60.397	0	0	0	0	0	0	0	0	0
5	01001 23 D	60.4	60.457	2	0	1	1	1	1	0	2	0
6	01001 23 D	60.68	60.725	2	0	2	0	2	0	0	0	2
7	01001 23 D	61.05	61.126	1	0	1	0	0	0	1	0	1
8	01001 23 D	61.7	61.838	7	1	5	1	4	2	1	5	2
9	01053 17 D	1.047	1.051	0	0	0	0	0	0	0	0	0
10	01053 17 D	1.089	1.195	0	0	0	0	0	0	0	0	0
11	01053 17 D	1.47	2.78	14	1	12	1	10	3	1	8	6
12	01101 08 D	26.102	26.183	0	0	0	0	0	0	0	0	0
13	01101 08 D	27.104	27.28	3	1	1	1	2	0	1	2	1
14	01101 08 D	27.281	27.48	5	1	3	1	4	1	0	2	3
15	01101 08 D	31.188	31.27	5	0	5	0	3	1	1	3	2
16	01101 08 RD	27.564	27.774	2	1	1	0	2	0	0	1	1

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Task 4: Methodology Consolidation

Step 2: Aggregate frequencies

Within the same route (partitioned by county route number (CNTYRTE)), each site is examined sequentially to check against the condition of $c_{d,j,i} \geq 5$

Once met, the cumulative count is reset to zero from the next row. Repeat until the end of the road.

If there are not enough sites at the end, add them to the previous aggregation.

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Task 4: Methodology Consolidation

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Step 3: Calculate percentages (vehicle types)

ID	CNTYRTE	BEGMP	ENDMP	NF Driver	NF Driver sum	NF PC	NF PC sum	NF PC/ Total	NF Truck/Bus	NF Truck/Bus sum	(Truck/Bus)/ Total
1	01001 23 D	59.862	59.926	1	15	0	9	0.600	0	3	0.200
2	01001 23 D	60.047	60.048	0	15	0	9	0.600	0	3	0.200
3	01001 23 D	60.049	60.125	2	15	2	9	0.600	0	3	0.200
4	01001 23 D	60.231	60.397	0	15	0	9	0.600	0	3	0.200
5	01001 23 D	60.4	60.457	2	15	1	9	0.600	1	3	0.200
6	01001 23 D	60.68	60.725	2	15	2	9	0.600	0	3	0.200
7	01001 23 D	61.05	61.126	1	15	0	9	0.600	0	3	0.200
8	01001 23 D	61.7	61.838	7	15	4	9	0.600	2	3	0.200
13	01101 08 D	27.104	27.28	3	8	2	6	0.750	0	1	0.125
14	01101 08 D	27.281	27.48	5	8	4	6	0.750	1	1	0.125
15	01101 08 D	31.188	31.27	5	7	3	5	0.714	1	1	0.143

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5. Example Applications of Each Methodology

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Method 1
Ordered Fractional Split Approach

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NB-OPFS Model Results (Urban 4ST Intersections)

Variable Names	NB Model Component		OPFS Model Component	
	Estimate	t-stat	Estimate	t-stat
Constant	-8.499	-10.088	---	---
Threshold Parameters	---	---	---	---
Threshold between O and C	---	---	-0.231	-0.761
Threshold between C and B	---	---	0.326	1.059
Threshold between B and A	---	---	1.416	4.097
Threshold between A and K	---	---	2.091	5.145
Independent Variable				
Speed 10-25 mph	-0.300	-2.414	-0.243	-1.965
Presence of Major Driveways	-0.445	-3.356	---	---
Presence of Lighting	---	---	-0.223	-2.161
Ln(Major AADT)	0.634	7.192	---	---
Ln(Minor AADT)	0.455	7.338	-0.089	-2.325
Over-dispersion	0.430	8.941	---	---

Urban 4-leg Stop Controlled Intersections

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NB-OPFS Model Prediction (Urban 4ST Intersections)

Intersection	Speed Limit *(mph)*	Major Driveways	Presence of Lighting	Major AADT	Minor AADT
1	40	No	No	6,100	4,800
2	25	No	Yes	3,100	2,300
3	45	Yes	Yes	8,300	1,400

Example Scenarios

NB-OPFS Model Prediction (Urban 4ST Intersections)

Intersection	Speed Limit *(mph)*	Major Driveways	Presence of Lighting	Major AADT	Minor AADT
1	40	No	No	6,100	4,800
2	25	No	Yes	3,100	2,300
3	45	Yes	Yes	8,300	1,400

Inter-section	Predicted Crash Counts (NB Model)
	Total Crash
1	12.099
2	4.176
3	5.381

$$\text{Crash Count} = Year * (Major\ AADT^{0.634})(Minor\ AADT^{0.455}) * e^{z}$$

where $z = -8.499 - 0.300 * (10 \le \text{speed limit} \le 25\text{mph}) - 0.445 * (\text{Presence of Major Driveway})$

For intersection 1:

$$\text{Crash Count} = 5 * (6100^{0.634})(4800^{0.455}) * e^{-8.499 - 0.300*0 - 0.445*0} = 12.099$$

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NB-OPFS Model Prediction (Urban 4ST Intersections)

Intersection	Speed Limit *(mph)*	Major Driveways	Presence of Lighting	Major AADT	Minor AADT
1	40	No	No	6,100	4,800
2	25	No	Yes	3,100	2,300
3	45	Yes	Yes	8,300	1,400

Calculation for severity category C for intersection 1:

$$\Lambda(C) = \varphi\{0.326 - (q)\} - \varphi\{-0.231 - (q)\}$$

where q = - 0.243* (10 ≤ speed limit ≤ 25mph) - 0.223* (Presence of Lighting) -0.089* Ln (Minor AADT)

= -0.243 * 0 - 0.223*0 – 0.089*ln(4800) = -0.754

φ is standard normal cumulative distribution function = {1/1+exp (-x)}

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NB-OPFS Model Prediction (Urban 4ST Intersections)

Intersection	Speed Limit *(mph)*	Major Driveways	Presence of Lighting	Major AADT	Minor AADT
1	40	No	No	6,100	4,800
2	25	No	Yes	3,100	2,300
3	45	Yes	Yes	8,300	1,400

Intersection	Predicted Severity Category C Proportions (OLFS Model)
	C
1	0.160
2	0.108
3	0.146

Calculation for severity category C for intersection 1:

Upper limit = $0.326 - (q = -0.754)$
=1.080

Lower limit = $-0.231 - (q = -0.754)$
=0.523

$\Lambda(C)$ = $\varphi\{1.080\} - \varphi\{0.523\}$
= 0.160

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NB-OPFS Model Prediction (Urban 4ST Intersections)

Intersection	Predicted Crash Counts (NB Model)	Predicted Severity Proportions (OPFS Model)				
	Total Crash	***O***	***C***	***B***	***A***	***K***
1	12.099	0.700	0.160	0.125	0.013	0.002
2	4.176	0.822	0.108	0.064	0.004	0.001
3	5.381	0.738	0.146	0.105	0.010	0.002

Intersection	Predicted Crash Counts (NB Model)	Predicted Severity Count (OPFS Model)				
	Total Crash	***O***	***C***	***B***	***A***	***K***
1	12.099	8.465	1.940	1.512	0.155	0.027
2	4.176	3.433	0.453	0.268	0.019	0.002
3	5.381	3.970	0.785	0.565	0.052	0.008

C_{count}
= 12.099*0.160
= 1.940

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Method 2
Univariate Count Model Approach

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Univariate Count Model Results (Rural two-lane segments)

Variables	KABCO (2651)		KABC (2484)		KAB (975)		KA (299)		K (97)	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	-7.428*	0.153	-8.701*	0.217	-8.487*	0.280	-10.536*	0.575	-11.797*	1.002
Ln(AADT)	0.937*	0.020	0.940*	0.027	0.838*	0.036	0.845*	0.066	0.781*	0.113
LW<12’	0.070*	0.034	0.216*	0.049	0.180*	0.064	-	-	-	-
SW	-0.056*	0.007	-0.055*	0.010	-0.047*	0.014	-	-	-	-
Presence of Light	0.071**	0.042	-	-	-	-	-0.292**	0.159	-	-
Deg. Curve	0.086*	0.009	0.114*	0.012	0.119*	0.016	0.155*	0.029	0.222*	0.047
Female	0.278*	0.116	0.307**	0.181	0.375**	0.225	1.485*	0.462	2.268*	0.812
HV	-	-	-	-	-	-	1.006**	0.628	3.332*	0.901
MCO	-0.819*	0.440	-	-	-	-	-	-	-	-
Young	-	-	0.508**	0.285	-	-	-	-	-	-
Gamma#	0.135*	0.008	0.159*	0.017	0.205*	0.031	0.514*	0.136	1.241*	0.574
-2LL	14373.0		8390.5		5890.6		2321.4		924.7	
AIC	14391.0		8406.5		5904.6		2335.4		936.7	
BIC	14450.0		8459.0		5950.6		2381.4		976.1	

*Significant at α=0.05 **Significant at α=0.10 #Overdispersion=Gamma/L
Numbers in the parentheses represent number of segments with non-zero crashes

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Univariate Count Model Prediction (Rural two-lane segments)

Seg-ment	Length (mile)	AADT	LW<12’	SW (feet)	Lighting	Deg. of Curv.	Prop. of Male	Prop. of Female	Prop. of PC	Prop. of HV	Prop. of MCO	Prop. of Young	Prop. of Middle	Prop. of Senior
1	0.16	26543	No	8	Yes	1.91	0.66667	0.33333	0.88679	0.11321	0.00000	0.15615	0.82392	0.01993
2	0.27	25257	No	8	Yes	0	0.64286	0.35714	0.98696	0.01087	0.00217	0.15615	0.82392	0.01993
3	0.13	25257	Yes	6	Yes	0	0.58333	0.41667	0.97917	0.01736	0.00347	0.26316	0.60526	0.13158

$$\text{Crash Count} = \exp[-intercept + \ln(year) + \ln(seg.length) + b_1 * \ln(AADT) + b_2 * LW + b_3 * SW + b_4 * Presence\ of\ light + b_5 * Deg.of\ Curv. + b_6 * Prop.female + b_7 * Prop.HV + b_8 * Prop.of\ MCO + b_9 * Prop.of\ Young + b_{10} * Prop.of\ Senior]$$

<u>For segment 1:</u>

$$\text{Crash Count(KABCO)} = \exp(-7.428 + \ln(5) + \ln(0.16) + 0.937 * \ln(26543) - 0.056 * 8 + 0.071 * 1 + 0.086 * 1.91 + 0.278 * 0.33333)$$

= 5.892

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Univariate Count Model Prediction (Rural two-lane segments)

For segment 1 (Contd.):

Crash Count(KABC) =
$\exp(-8.701 + \ln(5) + \ln(0.16) + 0.940 * \ln(26543) - 0.055 * 8 + 0.114 * 1.91 + 0.307 * 0.33333 + 0.508 * 0.15615)$ = *1.842*

Crash Count(KAB) =
$\exp(-8.487 + \ln(5) + \ln(0.16) + 0.838 * \ln(26543) - 0.047 * 8 + 0.119 * 1.91 + 0.375 * 0.33333)$ = *0.821*

Crash Count(KA) =
$\exp(-10.536 + \ln(5) + \ln(0.16) + 0.845 * \ln(26543) - 0.292 * 1 + 0.155 * 1.91 + 1.485 * 0.33333 + 1.006 * 0.11321)$ = *0.215*

Crash Count(K) =
$\exp(-11.797 + \ln(5) + \ln(0.16) + 0.781 * \ln(26543) + 0.222 * 1.91 + 2.268 * 0.33333 + 3.332 * 0.11321)$
= *0.081*

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Univariate Count Model Prediction (Rural two-lane segments)

Predicted Crash Counts by Severity

Segment	KABCO	KABC	KAB	KA	K	A	B	C	O
1	5.892	1.842	0.821	0.215	0.081	0.133	0.606	1.021	4.050
2	8.092	2.403	1.068	0.241	0.065	0.177	0.826	1.335	5.689
3	3.535	1.282	0.531	0.098	0.029	0.069	0.433	0.751	2.252

$$\text{Crash Count(O)} = \text{Crash Count(KABCO)} - \text{Crash Count(KABC)} = 5.892 - 1.842 = 4.050$$

$$\text{Crash Count(C)} = \text{Crash Count(KABC)} - \text{Crash Count(KAB)} = 1.842 - 0.821 = 1.021$$

$$\text{Crash Count(B)} = \text{Crash Count(KAB)} - \text{Crash Count(KA)} = 0.821 - 0.215 = 0.606$$

$$\text{Crash Count(A)} = \text{Crash Count(KA)} - \text{Crash Count(K)} = 0.215 - 0.081 = 0.133$$

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Method 3
Multilevel Discrete Outcome Model Approach

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Multilevel Model Results (Rural multilane 3ST intersections) Step 1: Univariate Total Crash Count Model

Variables	KABCO (158)	
	Estimate	SE
Intercept	-10.998*	1.154
Ln(AADT1)	0.816*	0.107
Ln(AADT2)	0.584*	0.066
Speed <=55 mph	0.400**	0.214
Presence of light	-	-
Proportion of HV	-1.711*	0.778
Proportion of Young	-	-
dispersion	1.043	0.186
-2LL	924.0	
AIC	936.0	
BIC	960.1	

*Significant at α=0.05 **Significant at α=0.10
Numbers in the parentheses represent number of segments with non-zero crashes

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Multilevel Model Results (Rural multilane 3ST intersections) Step 2: Proportional Regression Connection Model

Response Variables	Definition
G1 (pc-m-mid)	Passenger Car, Male, Middle
G2 (pc-f-mid)	Passenger Car, Female, Middle
G3 (pc-mf-mid)	Passenger Car, Male & Female, Middle
G4 (pc-m-yngmid)	Passenger Car, Male, Young & Middle
G5 (pc-f-yngmid)	Passenger Car, Female, Young & Middle
G6 (pc-mf- yngmid)	Passenger Car, Male & Female, Young & Middle
G7 (pchv-m-mid)	Passenger Car & Heavy Vehicle, Male, Middle
G8 (pc-m-snrmid)	Passenger Car, Male, Senior & Middle
G9 (pc-mf-snrmid)	Passenger Car, Male & Female, Senior & Middle
G10 (other)	All other groups

Explanatory Variables	Definition
Facility Indicator	4ST / 4SG
Ln(AADT1)	Natural log of Major AADT
Ln(AADT2)	Natural log of Minor AADT
Light	1 indicates presence of light
SPD<=55mph	1 indicates speed limit <=55 mph
p_female	Proportion of female drivers
p_hv	Proportion of heavy vehicles
p_mco	Proportion of motorcycle and other vehicles
p_yng	Proportion of young drivers
p_snr	Proportion of senior drivers

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Multilevel Model Results (Rural multilane 3ST intersections) Step 2: Proportional Regression Connection Model (2)

	G1	G2	G3	G4	G5	G6	G7	G8	G9	Other	Precision
(Intercept)	1.529	2.399#	0.887	2.163	2.528#	1.571	2.093	2.165#	2.286	0	-0.845*
4SG Indicator	0.051	-0.192	-0.033	-0.129	-0.173	-0.007	-0.112	-0.254	-0.19	0	0.112#
4ST Indicator	0.121	-0.081	0.166	0.045	-0.088	-0.008	-0.096	-0.064	-0.034	0	0.096*
Ln(AADT1)	-0.093	-0.205	-0.012	-0.171	-0.222#	-0.144	-0.18	-0.172	-0.203	0	0.102*
Ln(AADT2)	0	-0.042	-0.012	-0.025	-0.049	0.024	-0.024	-0.034	-0.023	0	0.054*
Light	-0.091	-0.195	-0.116	-0.078	-0.121	-0.119	-0.117	-0.108	-0.072	0	0.01
SPD<=55mph	0.011	0.099	0.039	-0.034	-0.059	0.121	-0.002	-0.003	0.068	0	0.011
p_female	-0.745	0.151	-0.675	-0.572	0.019	-0.465	-0.458	-0.626	-0.448	0	-0.042
p_hv	-1.235#	-1.808*	-2.348*	-2.041*	-1.85*	-1.974*	-1.223#	-1.871*	-1.907	0	0.282
p_mco	-1.845	-1.96	-1.523	-1.465	-1.762	-1.71	-1.72	-1.813	-1.767	0	0.193
p_yng	-2.004*	-1.723#	-1.972*	-1.502	-1.522	-1.066	-1.35	-1.327	-1.443	0	0.213
p_snr	-2.171	-1.38	-1.938	-1.949	-0.93	-1.887	-1.767	-1.186	-0.3	0	0.016

*significant at α=0.05 #significant at α=0.10

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Multilevel Model Results (Rural multilane 3ST intersections) Step 3: Discrete Outcome Crash Severity Model

Variables	OL (Reduced)	
	Estimate	SE
Intercept_5	-2.948*	0.942
Intercept_4	-1.793*	0.932
Intercept_3	-0.569	0.930
Intercept_2	0.649	0.930
G1 (pc-m-mid)	-0.073	0.174
G2 (pc-f-mid)	-0.058	0.253
G3 (pc-mf-mid)	0.182	0.179
G4 (pc-m-yngmid)	0.096	0.235
G5 (pc-f-yngmid)	0.408	0.306
G6 (pc-mf- yngmid)	-0.037	0.209
G7 (pchv-m-mid)	-0.410	0.287
G8 (pc-m-snrmid)	0.140	0.297
G9 (pc-mf-snrmid)	0.252	0.280

Variables	OL (Reduced)	
	Estimate	SE
LnAADT1	-0.060	0.091
LnAADT2	-0.036	0.043
Light	-	-
SPD <=55mph	-0.448*	0.167
Facility 4ST Indicator	0.555*	0.140
Facility 4SG Indicator	0.239	0.172
-2LL	2816.7	
AIC	2852.7	

*Significant at α=0.05
Intercept_5 is threshold between severity level K and A
Intercept_4 is threshold between severity level A and B
Intercept_3 is threshold between severity level B and C
Intercept_2 is threshold between severity level C and O

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Multilevel Model Prediction (Rural multilane 3ST intersections)

Example Scenarios

Inter-section	AADT1	AADT2	Light	SPD<= 55 mph	Prop. of Male	Prop. of Female	Prop. of PC	Prop. of HV	Prop. of MCO	Prop. of Young	Prop. of Middle	Prop. of Senior
1	10,600	210	No	Yes	0.375	0.625	0.947	0.035	0.018	0.136	0.793	0.071
2	9,550	220	No	Yes	0.375	0.625	0.947	0.035	0.018	0.136	0.793	0.071
3	16,939	51	No	Yes	0.333	0.667	1	0	0	0.175	0.75	0.075

Step-1/Univariate Total Crash Count Model: For intersection 1,

Total Crash Count =

$$\exp(-10.998 + 0.816 * \ln(10600) + 0.504 * \ln(9550) + 0.400 * 1 - 1.711 * 0.035)$$

= *1.028*

Inter-section	Predicted Total Crash Count
1	1.028
2	0.970
3	0.701

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Multilevel Model Prediction (Rural multilane 3ST intersections)

Step-2/Connection Model:

Predicted Proportion of a group, $\mu_{ij} = \frac{\exp(x_{i.}b_{.j})}{\sum_{j=1}^{j=10}\exp(x_{i.}b_{.j})}$

where i is the observation, j is the group, b is estimated coefficient for parameter x

For intersection 1 and group 1, $\mu_{11} = \frac{\exp(x_{1.}b_{.1})}{\sum_{j=1}^{j=10}\exp(x_{1.}b_{.j})}$

$$\exp(x_{1.}b_{.1}) = \exp(1.529 - 0.093 * \ln(10600) + 0 * \ln(210) - 0.091 * 0 + 0.011 * 1 - 0.745 * 0.625 - 1.235 * 0.035 - 1.845 * 0.018 - 2.004 * 0.136 - 2.171 * 0.071) = 0.748$$

$$\sum_{j=1}^{j=10} \exp(x_{1.}b_{.j}) = 8.099$$

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Multilevel Model Prediction (Rural multilane 3ST intersections)

Step-2/Connection Model (Cont.): For intersection 1,

For group 1, $\mu_{11} = \frac{0.748}{8.099} = 0.092$

Inter-section	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
1	0.092	0.128	0.102	0.084	0.100	0.103	0.085	0.085	0.096	0.123
2	0.092	0.129	0.101	0.084	0.101	0.103	0.085	0.086	0.097	0.122
3	0.087	0.131	0.106	0.083	0.103	0.098	0.083	0.086	0.095	0.127

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Multilevel Model Prediction (Rural multilane 3ST intersections)

Step-3/Discrete Outcome Crash Severity Model): For intersection 1 and G1,

$\pi_k = \frac{\exp(z_k)}{1+\exp(z_k)}$; $z_k = a_k + x_i b_j$ where, k is the crash severity, b_j is estimated coefficient for parameter x_i; π_k is the probability of a crash be on severity k or higher.

$p_1 = 1 - \pi_2$; p_1 is the probability of severity level 1

$p_k = \pi_k - \pi_{k+1}$ *where* $k = 2, 3, 4$

$p_5 = \pi_5$

$$z_2 = 0.649 - 0.073 - 0.060 * \ln(10600) - 0.036 * \ln(210) - 0.448 * 1 = -0.621$$
$$z_3 = -0.563 - 0.073 - 0.060 * \ln(10600) - 0.036 * \ln(210) - 0.448 * 1 = -1.833$$
$$z_4 = -1.793 - 0.073 - 0.060 * \ln(10600) - 0.036 * \ln(210) - 0.448 * 1 = -3.063$$
$$z_5 = -2.948 - 0.073 - 0.060 * \ln(10600) - 0.036 * \ln(210) - 0.448 * 1 = -4.218$$

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Multilevel Model Prediction (Rural multilane 3ST intersections)

Step-3/Discrete Outcome Crash Severity Model(Cont.):

For intersection 1 and G1,

$$\pi_2 = \frac{\exp(z_2)}{1+\exp(z_2)} = \frac{\exp(-0.621)}{1+\exp(-0.621)} = 0.350$$

Similarly, $\pi_3 = 0.138, \pi_4 = 0.045; \pi_5 = 0.015$

$$p_1 = 1 - \pi_2 = 1 - 0.350 = 0.650$$
$$p_2 = \pi_2 - \pi_3 = 0.350 - 0.138 = 0.212$$
$$p_3 = \pi_3 - \pi_4 = 0.138 - 0.045 = 0.093$$
$$p_4 = \pi_4 - \pi_5 = 0.045 - 0.015 = 0.030$$
$$p_5 = \pi_5 = 0.015$$

	O	C	B	A	K
G1	0.650	0.212	0.093	0.030	0.015
G2	0.647	0.214	0.094	0.031	0.015
G3	0.590	0.239	0.113	0.038	0.019
G4	0.611	0.231	0.106	0.035	0.017
G5	0.535	0.261	0.134	0.047	0.023
G6	0.642	0.216	0.095	0.031	0.015
G7	0.723	0.175	0.070	0.022	0.010
G8	0.601	0.235	0.110	0.037	0.018
G9	0.573	0.246	0.120	0.041	0.020
G10	0.634	0.220	0.098	0.032	0.016

$$p_1 + p_2 + p_3 + p_4 + p_5 = 0.650 + 0.212 + 0.093 + 0.030 + 0.015 = 1$$

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Multilevel Model Prediction (Rural multilane 3ST intersections)

Inter-section	Predicted Total Crash Count
1	1.028
2	0.970
3	0.701

	O	C	B	A	K
G1	0.650	0.212	0.093	0.030	0.015
G2	0.647	0.214	0.094	0.031	0.015
G3	0.590	0.239	0.113	0.038	0.019
G4	0.611	0.231	0.106	0.035	0.017
G5	0.535	0.261	0.134	0.047	0.023
G6	0.642	0.216	0.095	0.031	0.015
G7	0.723	0.175	0.070	0.022	0.010
G8	0.601	0.235	0.110	0.037	0.018
G9	0.573	0.246	0.120	0.041	0.020
G10	0.634	0.220	0.098	0.032	0.016

Inter-section	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
1	0.092	0.128	0.102	0.084	0.100	0.103	0.085	0.085	0.096	0.123
2	0.092	0.129	0.101	0.084	0.101	0.103	0.085	0.086	0.097	0.122
3	0.087	0.131	0.106	0.083	0.103	0.098	0.083	0.086	0.095	0.127

Severity	*Count of Crashes for Intersection 1 by Groups*										
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	Total
O	0.061	0.085	0.062	0.053	0.055	0.068	0.063	0.053	0.057	0.080	0.637
C	0.020	0.028	0.025	0.020	0.027	0.023	0.015	0.021	0.024	0.028	0.231
B	0.009	0.012	0.012	0.009	0.014	0.010	0.006	0.010	0.012	0.012	0.106
A	0.003	0.004	0.004	0.003	0.005	0.003	0.002	0.003	0.004	0.004	0.035
K	0.001	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.017

Step-4/Combine three models: For intersection 1,
Count of O crashes for G1=1.028*0.092*0.650 = 0.061

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6. Implementation Guidance and Software

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Implementation Guidance

- The guidance provides instructions for implementing the crash severity models as recommended in NCHRP Project 17-85
- Facility types covered in this guidance are the same as shown in "Recommended Methodologies by Facility Type", including
    - rural two-lane two-way roadways
    - rural multilane highways
    - urban and suburban arterials

Implementation Guidance

The guidance includes the following sections

- Summary of the model recommendation by facility types
- Data requirements and preparation
- Introduction of the web-based implementation tool
- Discussions and summaries
- Appendix

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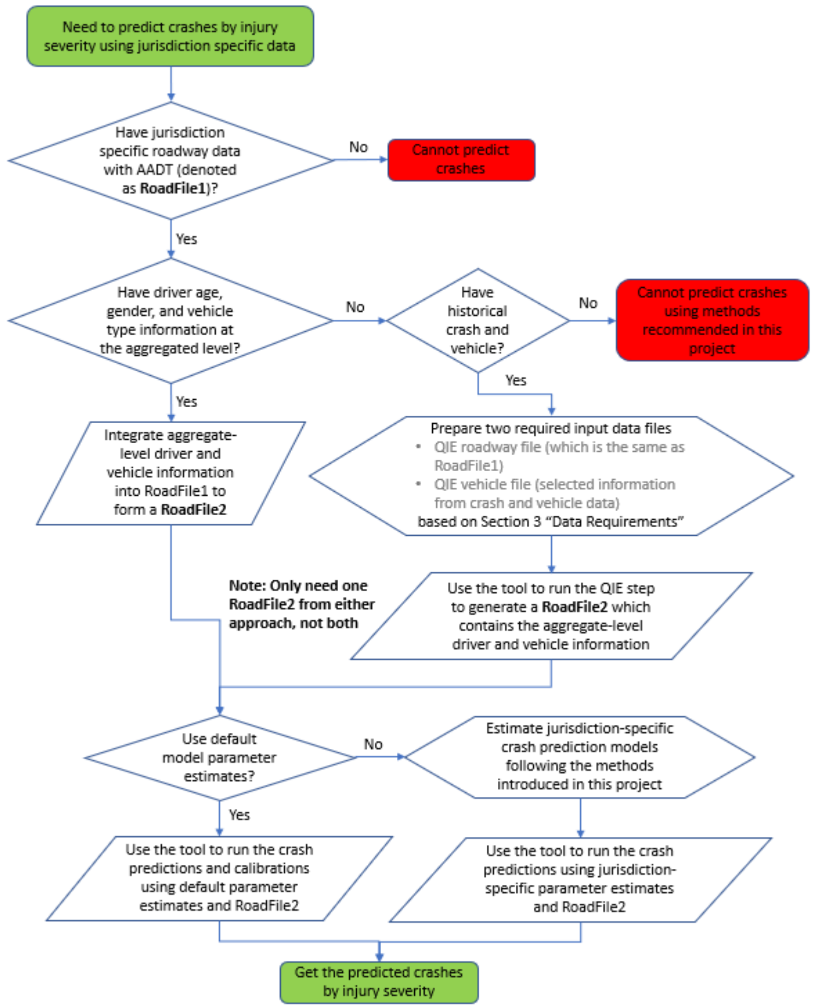
Decision Flow to Use the Tool



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Data Requirements Discussed in the Guidance

- Applicable AADT ranges for segments and intersections
- Data requirements for generating the demographic and vehicle composition variables using the QIE method
  - QIE roadway file
  - QIE driver file
- Data requirements for predicting the crash counts by severity
  - Lists of variables required for different facility types if default parameter estimates are to be used

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Introduction of the Web-Based Application

- The team developed an R Shiny web-based application for generating the QIE variables and predicting crashes by severity using one of the three new modeling approaches
- Shiny is an open-source R package that provides an elegant and powerful web framework for building web applications using R
- The application can be accessed at https://nchrp17-85.shinyapps.io/nchrp1785/

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Excel versus R

Excel	R	Solution: R Shiny
• **Pro:** Universal familiarity, seeming transparency • **Con:** Complicated to implement iterative QIE procedure	• **Pro:** All-in-one solution for both QIE generation and crash prediction • **Con:** Lack of familiarity for some potential users	• Standalone executable app • All data imports and exports are in CSV format

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HSM
Highway Safety Manual

NCHRP
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Home Page

NCHRP 17-85 Development and Application of Crash Severity Models for the Highway Safety Manual

NCHRP 17-85 | Generate QIE Variables | Predict Crashes By Severity | Read More - Model Specifications

This application is developed for the NCHRP project 17-85 Development and Application of Crash Severity Models for the Highway Safety Manual. It allows practitioners to easily implement the project findings, including generating quasi-induced-exposure (QIE) data and predicting crashes by injury severity levels.

For more information check the NCHRP page

The first edition of the Highway Safety Manual *(AASHTO, 2010)* has provided methods and procedures in estimating total crashes, crashes by type and crashes by severity at the site-level, project-level and corridor level. Crash prediction models are critical in the entire safety management system recommended by HSM, including network screening, economic analysis, safety effectiveness evaluation, and so on. Using statistical count models to estimate total crashes is the prevailing method and the method used by the current HSM. Such count models are usually estimated using negative binomial regression, which accounts for commonly observed over-dispersion in the crash data. Crash counts are assumed to be related to traffic volumes and roadway geometric features in those models. Crashes by severity are often estimated similarly, with the potential issue that different crash severities may not be independent *(Ma et al., 2008)* sample sizes may not always be significant enough to carry out individual count models, and the models may not be consistent from state to state, year to year. Multivariate count models *(Ma et al., 2008; Ma and Kockelman, 2006; Wang et al., 2017)* or simultaneous equations models *(Ye et al., 2013)* are also used to deal with the potential correlations between crash counts due to the presence of shared unobserved factors across crash severities.

The objectives of the project were to:

(1) Identify gaps and opportunities in the current severity prediction/estimation procedures within the HSM

To this end, the team evaluated the efficacy of the current HSM procedures for predicting crash severity. Procedures developed by NCHRP Project 17-62 were also evaluated. An extensive literature review of crash severity prediction methods was conducted to identify potential for improving upon the HSM and NCHRP 17-62 methods. Two notable avenues for improvement were identified: including personal demographic (sex and age) and vehicle attributes as predictor variables and estimating crash severity separately from crash incidence.

(2) Develop and validate new severity models to address the gaps and opportunities

Considering these two avenues, the team first derived a method using quasi-induced exposure to estimate personal demographic and vehicle type exposure for all road segment and intersection observations in the estimation and validation datasets. The resulting driver sex and age and vehicle type proportions were then used as predictor variables in three different approaches for predicting crash severity counts: univariate negative binomial severity count prediction models as were estimated for NCHRP 17-62 (but including these new variables along with other covariates), a second approach combining negative binomial count prediction with ordered probit fractional split severity prediction, and a third approach combining negative binomial count prediction, ordered logit severity prediction, and a fractional model to translate aggregate count prediction by segment or intersection into disaggregate input for crash severity models.

(3) Develop a guidance document that includes protocols for the use and application of severity-based models in a format suitable for possible adoption in the HSM

Crash severity counts were predicted for estimation and validation datasets using the three new approaches along with the HSM and NCHRP 17-62 approaches. The team reviewed the predictive performance of all these models and recommended a set for each facility type for implementation, which were approved by the project panel. Software tools were developed to implement the recommended models and an implementation document was prepared to describe how to use the software tools as well to implement the models manually. This implementation guide is provided in a companion volume titled 'User Implementation Guidance'.

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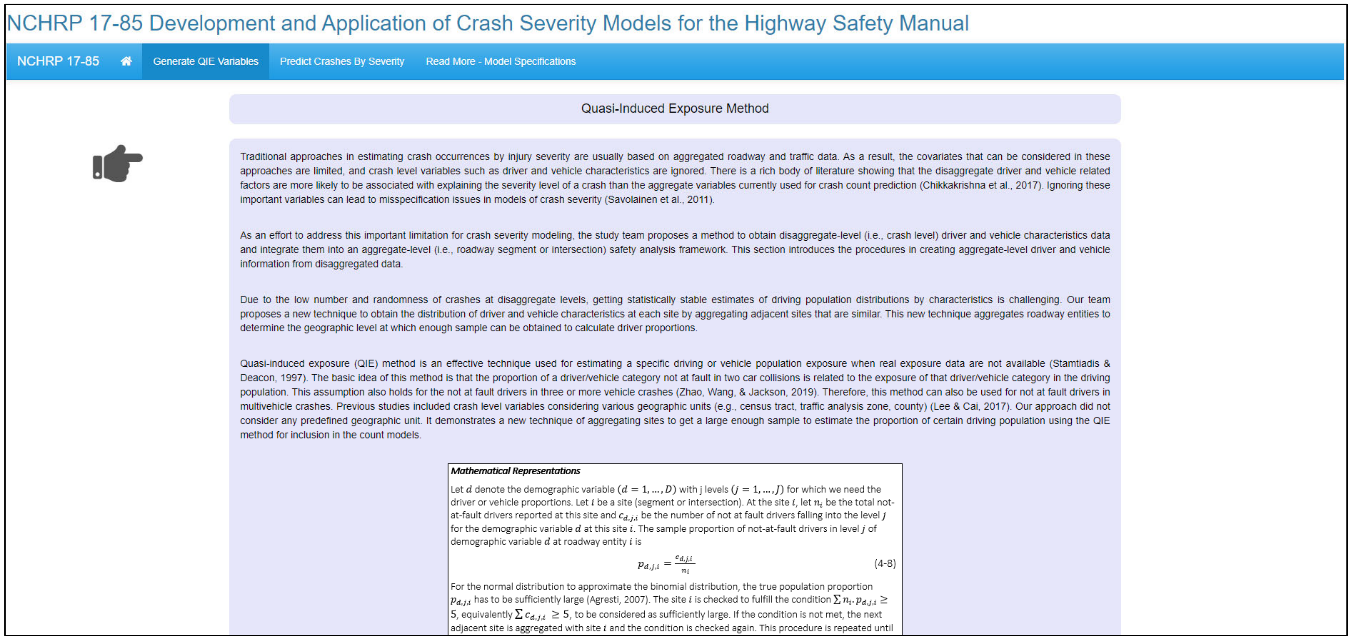
Generate QIE Variables Page



NCHRP 17-85 Development and Application of Crash Severity Models for the Highway Safety Manual

NCHRP 17-85 | Generate QIE Variables | Predict Crashes By Severity | Read More - Model Specifications

Quasi-Induced Exposure Method

Traditional approaches in estimating crash occurrences by injury severity are usually based on aggregated roadway and traffic data. As a result, the covariates that can be considered in these approaches are limited, and crash level variables such as driver and vehicle characteristics are ignored. There is a rich body of literature showing that the disaggregate driver and vehicle related factors are more likely to be associated with explaining the severity level of a crash than the aggregate variables currently used for crash count prediction (Chikkakrishna et al., 2017). Ignoring these important variables can lead to misspecification issues in models of crash severity (Savolainen et al., 2011).

As an effort to address this important limitation for crash severity modeling, the study team proposes a method to obtain disaggregate-level (i.e., crash level) driver and vehicle characteristics data and integrate them into an aggregate-level (i.e., roadway segment or intersection) safety analysis framework. This section introduces the procedures in creating aggregate-level driver and vehicle information from disaggregated data.

Due to the low number and randomness of crashes at disaggregate levels, getting statistically stable estimates of driving population distributions by characteristics is challenging. Our team proposes a new technique to obtain the distribution of driver and vehicle characteristics at each site by aggregating adjacent sites that are similar. This new technique aggregates roadway entities to determine the geographic level at which enough sample can be obtained to calculate driver proportions.

Quasi-induced exposure (QIE) method is an effective technique used for estimating a specific driving or vehicle population exposure when real exposure data are not available (Stamtiadis & Deacon, 1997). The basic idea of this method is that the proportion of a driver/vehicle category not at fault in two car collisions is related to the exposure of that driver/vehicle category in the driving population. This assumption also holds for the not at fault drivers in three or more vehicle crashes (Zhao, Wang, & Jackson, 2019). Therefore, this method can also be used for not at fault drivers in multivehicle crashes. Previous studies included crash level variables considering various geographic units (e.g., census tract, traffic analysis zone, county) (Lee & Cai, 2017). Our approach did not consider any predefined geographic unit. It demonstrates a new technique of aggregating sites to get a large enough sample to estimate the proportion of certain driving population using the QIE method for inclusion in the count models.

Mathematical Representations

Let d denote the demographic variable $(d = 1, \ldots, D)$ with j levels $(j = 1, \ldots, J)$ for which we need the driver or vehicle proportions. Let i be a site (segment or intersection). At the site i, let n_i be the total not-at-fault drivers reported at this site and $c_{d,j,i}$ be the number of not at fault drivers falling into the level j for the demographic variable d at this site i. The sample proportion of not-at-fault drivers in level j of demographic variable d at roadway entity i is

$$p_{d,j,i} = \frac{c_{d,j,i}}{n_i} \quad (4\text{-}8)$$

For the normal distribution to approximate the binomial distribution, the true population proportion $p_{d,j,i}$ has to be sufficiently large (Agresti, 2007). The site i is checked to fulfill the condition $\sum n_i . p_{d,j,i} \geq 5$, equivalently $\sum c_{d,j,i} \geq 5$, to be considered as sufficiently large. If the condition is not met, the next adjacent site is aggregated with site i and the condition is checked again. This procedure is repeated until

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Predict Crash Page

NCHRP 17-85 Development and Application of Crash Severity Models for the Highway Safety Manual

NCHRP 17-85 | Generate QIE Variables | Predict Crashes By Severity | Read More - Model Specifications

Crash Count Prediction Models By Severity

In this project, we have implemented three different modeling frameworks for estimating crash counts by injury severity, they are

* the Univariate Count Modeling framework, which covers
  - Rural Two-Lane Two-Way Highways
  - Rural Two-Lane Three-Leg Stop-Controlled Intersections
  - Rural Two-Lane Four-Leg Stop-Controlled Intersections
  - Rural Two-Lane Four-Leg Signalized Intersections
* the Negative Binomial - Ordered-Probit Fractional Split Modeling framework, which covers
  - Urban Two-Lane Undivided Roads
  - Urban Three-Lane With A Centerline Two-Way Left-Turn-Lane Roads
  - Urban Four-Lane Undivided Roads
  - Urban Four-Lane Divided Roads
  - Urban Five-Lane With A Centerline Two-Way Left-Turn-Lane Roads
  - Urban Three-Leg Stop-Controlled Intersections
  - Urban Three-Leg Signalize Intersections
  - Urban Four-Leg Stop-Controlled Intersections
  - Urban Four-Leg Signalized Intersections
* the Multi-level Discrete Outcome Modeling framework, which covers
  - Rural Four-Lane Undivided Roads
  - Rural Four-Lane Divided Roads
  - Rural Multi-Lane Three-Leg Stop-Controlled Intersections
  - Rural Multi-Lane Four-Leg Stop-Controlled Intersections

7. Questions

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NCHRP 17-89 SAFETY PERFORMANCE OF PART-TIME SHOULDER USE ON FREEWAYS

TRB Safety Performance and Analysis Committee (ACS 20) Midyear Meeting

August 16, 2022

KITTELSON & ASSOCIATES

PennState

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Project Team Members

Panel Members

- Ida Van Schalkwyk, Chair
- Steven Buckley
- Casey Emoto
- Bryan Katz
- Peter Martin
- Bonnie Polin
- Julius Rinosa
- Guohui Zhang
- Kelly Hardy, AASHTO Rep
- George Merritt, FHWA Rep

NCHRP Staff

- Ed Harrigan

Core Research Team

- Pete Jenior, PI
- James (Jim) Bonneson
- Wayne Kittelson
- Laura Zhao
- Eric Donnell (Penn State)
- Vikash Gayah (Penn State)

Other Team Members

- Dr. Fred Mannering
- Irwin Writing and Editing

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What is Part-time Shoulder Use (PTSU)?

- Use of the left or right shoulders of an existing roadway for travel during certain hours of the day.
  - Preserves shoulder as shoulder during most hours of day
- Other names
  - Hard shoulder running
  - “Branded” names such as Flex Lane, Smart Lane, etc.
- Open to all vehicles or open to buses

NCHRP Project 17-89 Overview

- Sought to fill gap in Highway Safety Manual (HSM)
  - 2014 HSM Supplement has procedure for freeways, but not with PTSU
- Collected data from five states – GA, HI, MN, OH, VA
- Data Collected
  - Crashes
  - Roadway geometry/infrastructure
  - PTSU hours of operation
- Site characteristics
  - PTSU sites and comparison sites
  - Right and left-side PTSU (mostly right)
  - Urban
- CPMs are for PTSU open to all vehicles
  - Bus-on-shoulder did not have statistically significant difference in crash frequency and CPMs were not created

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Presentation Overview

- **Crash Prediction Models**
- Research Questions
- Research Products, Applications, and Next Steps

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17-89 Crash Prediction Models

- Crash prediction models (CPMs) for freeways w/ PTSU
  - Single-direction models
  - Variables identify PTSU presence, so models can be used on freeways with or without PTSU
- All CPMs developed used negative binomial regression
  - Fixed parameter – ultimately used in project
  - Random parameter – initially explored
  - Latent class – initially explored
- All CPMs developed for F+I crashes and PDO crashes
- CPMs account for site type

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CPMs used in Project 17-89

- Fixed Parameter (FP) CPMs used in Project
  - Similar to current HSM/HSM Supplement CPMs
- 6 CPMs Developed
  - Basic freeway segment FI
  - Entrance speed-change lane FI
  - Exit speed-change lane FI
  - Basic freeway segment PDO
  - Entrance speed-change lane PDO
  - Exit speed-change lane PDO
- Unique Overdispersion Parameters Developed
  - FI CPMs
  - PDO CPMs
- Non-linearities in some AFs

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Crash Prediction Model Form

General form of HSM Crash Prediction Model (CPM)

$$N_p = C \times N_{SPF} \times (AF_1 \times \ldots \times AF_n)$$

where

N_p = predicted average crash frequency, crashes/yr;

C = local calibration factor;

N_{SPF} = predicted crash frequency for site with base conditions;

AF_i = adjustment factor for geometric design element, or traffic control feature i (i = 1 to n); and

n = total number of AFs.

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Adjustment Factors

Adjustment Factor	Variables Included
Horizontal Curvature	Curve radius (ft)
Inside Shoulder Width	Number of lanes, inside shoulder width (ft)
Rumble Strip Presence on Inside Shoulder	Number of lanes, proportion of segment with inside rumble strips
Lane Changes	AADT of upstream entrance ramp, AADT of downstream exit ramp, distance from beginning of segment to upstream entrance ramp gore, distance from end of segment to downstream exit ramp gore, length of segment
Lane Width	Lane width (ft)
Median Width	Proportion of segment with median barrier present, number of lanes, width of median not including shoulders (ft), distance from edge of inside shoulder to barrier face (ft)
Median Barrier	Proportion of segment with median barrier present, number of lanes, distance from edge of inside shoulder to barrier face (ft)
Outside Shoulder Width	Number of lanes, width of outside shoulder (ft)
PTSU Operation	Proportion of time during average day that PTSU operates, number of lanes, width of shoulder allocated to PTSU, proportion of PTSU in site that is a PTSU transition zone

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Adjustment Factors Con't

Adjustment Factor	Variables Included
Rumble Strip Presence on Outside Shoulder	Number of lanes, outside shoulder width (ft)
Roadside Barrier	Proportion of segment with outside barrier present, number of lanes, distance from edge of outside shoulder to barrier face (ft)
Turnout Presence	Proportion of segment with turnout present, number of lanes
Speed Change Lane Length	Length of exit or entrance speed change lane (mi)

- Not all AFs appear in all CPMs

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Adjustment Factor Example

- AF for horizontal curvature (non-linear):

$$AF_{hc,fi} = 1.0 + \exp(b_{hc,fi}) \times \left(\frac{5{,}730}{R}\right)^2$$

Where $b_{hc,fi}$ is a regression coefficient and R is the radius of the curve in feet

$b_{hc,fi} = -4.888$

PTSU Adjustment Factor

$$AF_{ptsu|agg,fs,fi} = (1.0 - P_{t,ptsu}) \times \exp(f_{w,closed}) + P_{t,ptsu} \times \exp(f_{ptsu,open} + f_{near,open} + f_{w,open})$$

$$f_{w,closed} = (b_{s,ast,fi}/n \times \min\{W_{ptsu}, 12\}) \times I_{ptsuLane}$$

$$f_{w,open} = (b_{s,ast,fi} \times \min\{W_{ptsu}, 13\} - 12) \times I_{ptsuLane}$$

$$f_{ptsu,open} = b_{ptsuOpen,ast,fi} \times I_{ptsuLane}$$

$$f_{near,open} = b_{nearOpen,ast,fi} \times (1 - I_{ptsuLane}) \times P_{transition,fs}$$

$$P_{transition,fs} = L_{transition,site}/L_{fs}$$

Where

n = number of lanes

$P_{t,ptsu}$ = proportion of time during average day that PTSU operates

W_{ptsu} = width of shoulder allocated to part-time vehicular traffic use (i.e., as an additional travel lane) (ft)

$I_{ptsuLane}$ = indicator variable (= 1.0 if PTSU lane [or tapered transition] is present, 0.0 otherwise)

$P_{transition,fs}$ = proportion of segment length with PTSU transition zone present upstream, downstream, or both

$L_{transition,site}$ = total length of PTSU transition zones within site (i.e., between site begin and end mileposts) (mi)

L_{fs} = length of freeway segment (mi)

“b” terms are regression coefficients

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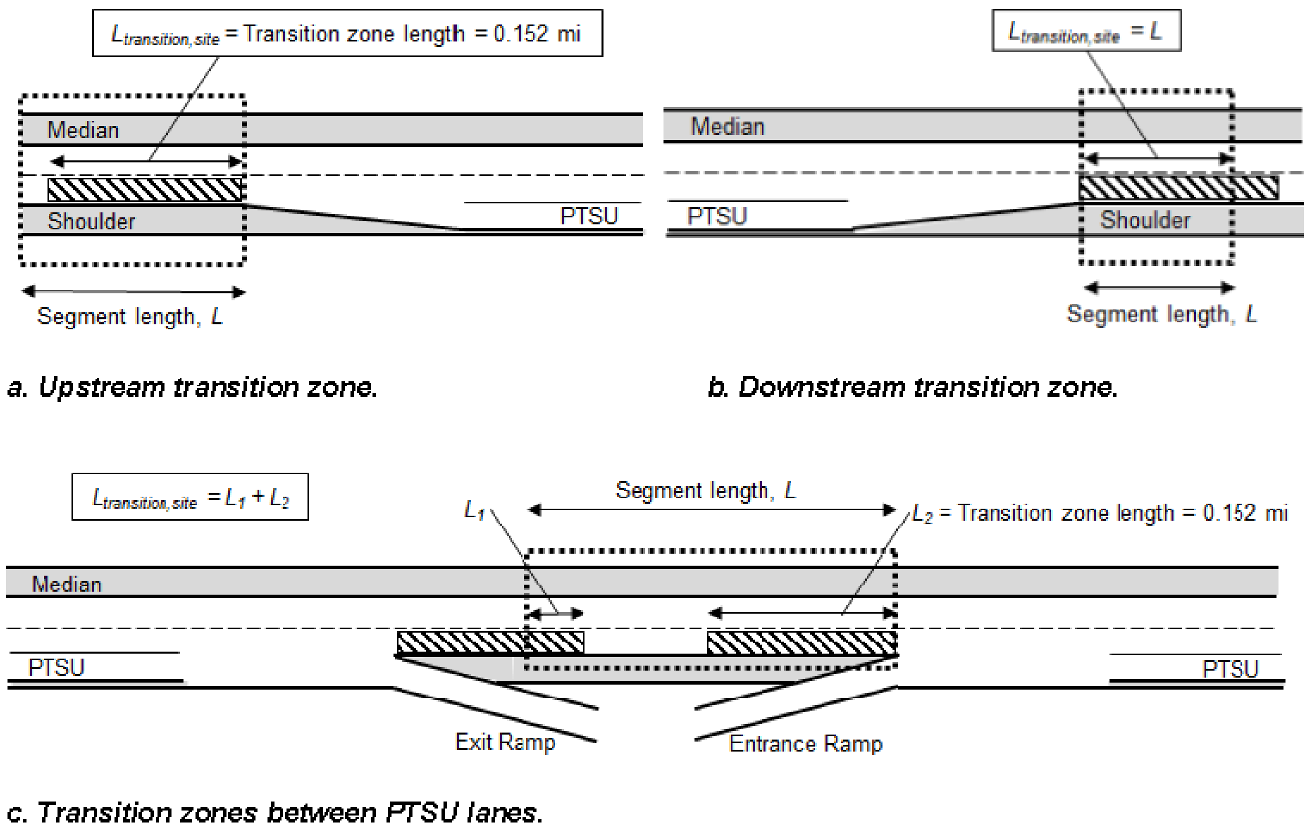
PTSU Transition Zone Defintion



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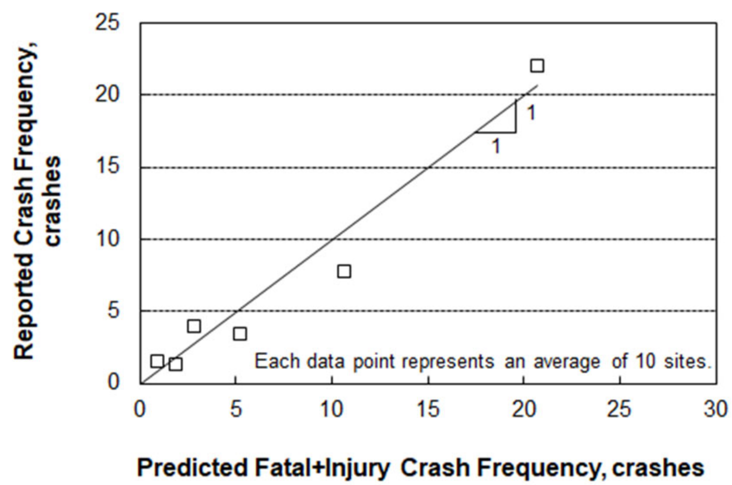
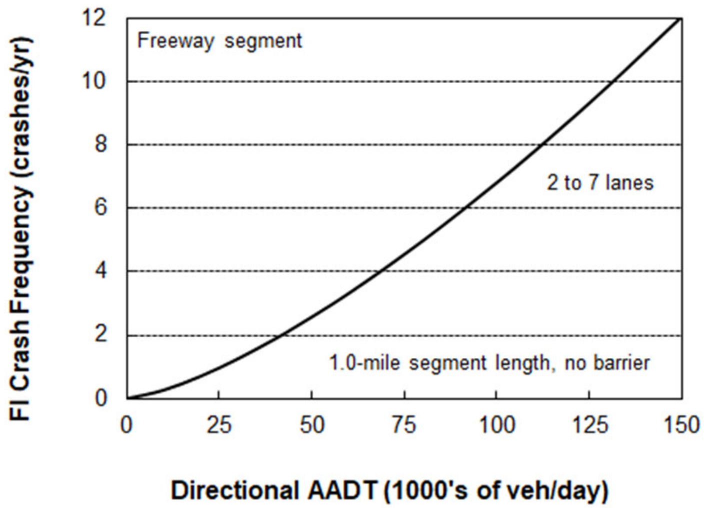
Validation

- Held out data from one state, then applied models to that state's data

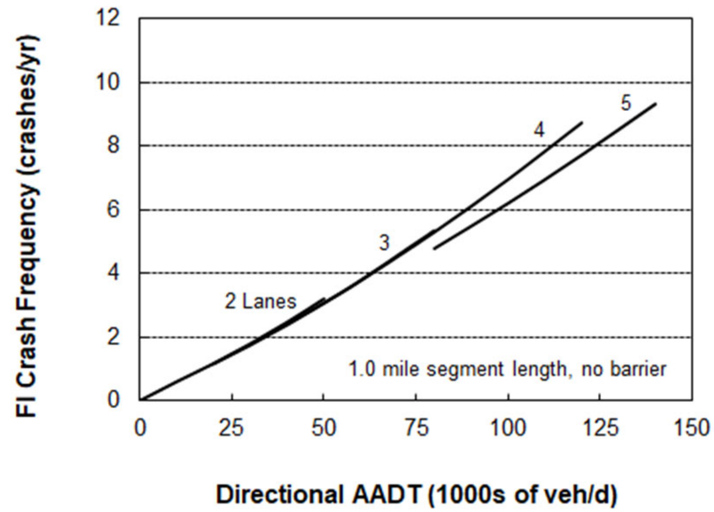


- Compared AFs with CMFs in the literature, especially NCHRP 17-45

Comparison of FP FI and HSM FI Models



17-89 Fixed Parameter Model



HSM Supplement Model

Severity and Type

- Severity Distribution Functions (SDFs)
  - Predicts the percent ("distribution") of K, A, B, and C crashes at a site within the frequency of FI crashes
  - Separate SDFs for each site type
- Crash Type Distribution Default Tables
  - Provides percent ("distribution") of 10 crash types at a site within the frequency of FI crashes and PDO crashes
  - Separate distributions for each site type
- Both can be applied to the CPMs results

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Effect of PTSU on FI Crash Frequency

PTSU Type	PTSU Lane Width (ft)	Proportion Time PTSU Operating[1]	AF Value by Number of Lanes		
			2	4	6
PTSU Lane (no turnouts)	11	0.1	1.11	1.19	1.22
		0.2	1.42	1.49	1.52
		0.3	1.73	1.79	1.82
		0.4	2.04	2.09	2.11
	12	0.1	1.08	1.17	1.20
		0.2	1.37	1.45	1.48
		0.3	1.67	1.74	1.77
		0.4	1.96	2.03	2.05
PTSU lane (turn-out every 0.5 mi)	11	0.1	1.00	1.13	1.18
		0.2	1.28	1.41	1.46
		0.3	1.56	1.70	1.75
		0.4	1.84	1.98	2.04
	12	0.1	0.97	1.11	1.16
		0.2	1.24	1.38	1.43
		0.3	1.51	1.65	1.70
		0.4	1.77	1.92	1.97
PTSU transition zone[2]	Any	0.1	1.11	1.11	1.11
		0.2	1.22	1.22	1.22
		0.3	1.33	1.33	1.33
		0.4	1.43	1.43	1.43

1 – Proportion time PTSU operating = (weekday hours × 5/7 + weekend hours × 2/7)/24
2 – Segment length is 0.27 miles.

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Effect of PTSU on Crash Severity and Cost

PTSU Type	Proportion Time PTSU Operating	AF Value by Severity[1]		Severity Distribution				Relative Crash Cost ($)[2]	Proportion Change in Cost[3]
		FI	PDO	K	A	B	C		
PTSU lane (no turnouts	Base cond.[4]	1.00	1.00	0.004	0.042	0.313	0.641	31,118	
	0.05	1.10	1.17	0.004	0.042	0.313	0.641	33,255	1.07
	0.1	1.27	1.39	0.003	0.039	0.317	0.641	37,594	1.21
	0.2	1.62	1.83	0.002	0.037	0.320	0.642	46,078	1.48
	0.3	1.97	2.27	0.001	0.034	0.323	0.642	54,486	1.75
	0.4	2.31	2.71	0.001	0.032	0.326	0.641	62,925	2.02
PTSU lane (turnout every 0.5 mi)	Base cond.[4]	1.00	1.00	0.004	0.042	0.313	0.641	31,118	
	0.05	0.99	1.02	0.004	0.042	0.313	0.641	29,842	0.96
	0.1	1.15	1.21	0.003	0.039	0.317	0.641	33,726	1.08
	0.2	1.46	1.60	0.002	0.037	0.320	0.642	41,319	1.33
	0.3	1.77	1.98	0.001	0.034	0.323	0.642	48,843	1.57
	0.4	2.09	2.36	0.001	0.032	0.326	0.641	56,395	1.81

1 – Product of PTSU operation, turnout presence, and outside shoulder width AFs. PTSU design conditions include two through lanes, PTSU lane width of 12 feet, and paved outside shoulder width of 2 feet. AF values for FI crashes are from Table 1. AF values for PDO crashes from Table 5-12 of the *NCHRP Project 17-89 Final Report*. AF values for outside shoulder width are also from the *NCHRP Project 17-89 Final Report*.
2 – Societal crash costs from Table 7-1 of the HSM (AASHTO 2010).
3 – Proportion change in crash cost equals the crash cost for the subject row divided by the crash cost for the base condition.
4 – Base condition: no PTSU lane, no PTSU operation, no turnout, and 10 foot outside shoulder width.

Key Findings

- **Sites with PTSU associated with increased fatal and injury crashes on annual basis, although they are also associated with decrease in proportion of fatal and severe injury crashes**
  - Led to decrease in monetized crash costs if PTSU used for very short periods of the day
  - Wider shoulder lanes and presence of emergency turnouts result in a lesser increase of fatal and injury crashes

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Presentation Overview

- Crash Prediction Models
- **Research Questions**
- Research Products, Applications, and Next Steps

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Research Questions

Question 1: What is the overall effect of a proposed shoulder use design on total and severe crash frequency?

Question 2a: What is the difference in safety performance when the shoulder is open or closed?

Question 2b: When the shoulder is closed, is there a difference in safety performance between a freeway with shoulder use and a freeway without shoulder use?

Question 3: What is the safety effect of converting shoulder use eligibility from bus-only to all vehicles?

Question 4: Are there differences in safety between using the left shoulder versus using the right shoulder?

Question 5a: What is the safety effect of adding dynamic signs in replacement of static signs?

Question 5b: What is the safety effect of converting static operation to dynamic operation?

Question 6: What is the safety effect of changing the width of the shoulder?

Question 7: Are fatal and severe injury crashes over-represented during overnight hours like a typical urban freeway, or does shoulder use change this relationship?

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Q1 – Overall Effect of PTSU

- Bus-on-Shoulder (BOS) – Presence of BOS does not have significant effect on total or FI crash frequency
- CPMs created for this project show
  - PTSU (open to all vehicles) significantly increases FI and PDO crash frequency
  - Increase in proportion of day that PTSU operates increases FI and PDO crashes

Q2a/2b – Shoulder Open vs. Closed

- Sites analyzed by hour: 24 weekday hours + 24 weekend hours = 48 observations per site
- Opening shoulder associated with significant increase in crash frequency
  - 137.5% greater if open for the full hour
- If PTSU is open 0% of an hour, crash frequency is not significantly different than freeway without PTSU

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Q4 – Left Shoulder vs. Right Shoulder

- Model created for Q4 found no significant difference between left-side and right-side PTSU crash frequency.
- Some evidence left-side PTSU may have fewer crashes than right-side
- *Dataset had limited number of left side sites. More research needed*

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Q5a – Dynamic vs. Static Signs

- No significant difference between sites with dynamic signs and sites with static signs

Static sign

Dynamic sign

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Q5b – Dynamic vs. Static Operation

- 2 study facilities converted from static to dynamic
  - I-66 Virginia – 48 sites, change to gantries/lane control signals over all lanes
  - I-85 Georgia – 6 sites, no changes to field devices
- Before/after study
- 7.3% decrease in total crash freq. after conversion

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Presentation Overview

- Crash Prediction Models
- Research Questions
- **Research Products, Applications, and Next Steps**

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17-89 Final Products

- NCHRP Web-only Report 309
  - Volume 1
    - PTSU Informational Guide
    - PTSU Safety Evaluation Guidelines (including draft HSM text)
  - Volume 2
    - Research Report
- Spreadsheet Tool to perform crash prediction

17-89 Spreadsheet Tool

General Information and Input Data

General Information		Location Information	
Analyst	PMJ	Freeway	
Agency or Company	Kittelson & Associates, Inc.	Direction	
Date Performed	08/16/22	Location Description	
		Jurisdiction	
		Analysis Year	

Input Data		Base Conditions	Site Conditions	Input Checks	
Site type (Basic Segment, Ramp Entrance Speed-Change Lane, Ramp Exit Speed-Change Lane)		--		-	
Length of freeway segment, L_{fs} (mi)		--		-	
Directional freeway AADT ($AADT_{fs}$), veh/day	$AADT_{MAX}$ = ? (veh/day)	--		OK	
Entrance ramp AADT ($AADT_{en}$), veh/day:	$AADT_{MAX}$ = N/A (veh/day)	--		OK	
Number of lanes, n		--		-	
Horizontal Alignment					
Curve radius (ft)		0		OK	
Cross Section Data					
Through lane width (W_l), ft:		12		out of range	
Outside shoulder width (W_s), ft:		10		N/A	
Inside shoulder width, **subject** direction of travel ($W_{is,s}$), ft:		6		out of range	x
Inside shoulder width, **opposite** direction of travel ($W_{is,o}$), ft:		6		-	x
Median width (W_m), ft:		60		out of range	x
Length of rumble strips on outside shoulder (mi)		0		N/A	
Length of rumble strips on inside shoulder (mi)		0		OK	
Length of median barrier, barrier piece 1		0		OK	
Distance from edge of travelled way to barrier face, barrier piece 1		N/A		N/A	x
Length of median barrier, barrier piece 2		0		OK	
Distance from edge of travelled way to barrier face, barrier piece 2		N/A		N/A	
Length of median barrier, barrier piece 3		0		OK	
Distance from edge of travelled way to barrier face, barrier piece 3		N/A		N/A	
Length of median barrier, barrier piece 4		0		OK	
Distance from edge of travelled way to barrier face, barrier piece 4		N/A		N/A	
Length of median barrier, barrier piece 5		0		OK	

Summary and EB Analysis

Observed and Expected Crashes

Perform Emperical Bayes (EB) analysis?	
Years of crash data used?	

	Type	Description	Analyze?	Predicted Average Crash Frequency FI	Predicted Average Crash Frequency PDO	Overdispersion Parameter, k FI	Overdispersion Parameter, k PDO	Observed Crashes, All Years FI	Observed Crashes, All Years PDO	Weighted Adjustment, w FI	Weighted Adjustment, w PDO	Expected Average Crash Frequency FI	Expected Average Crash Frequency PDO
Site 1	0	0	Yes	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 2	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 3	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 4	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 5	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 6	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 7	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 8	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 9	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 10	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 11	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 12	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 13	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 14	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 15	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 16	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 17	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 18	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 19	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
Site 20	0	0	No	0.00	0.00	#DIV/0!	#DIV/0!			-	-	-	-
			Project Totals:	0.00	0.00	-	-	0	0	-	-	-	-

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Uses for 17-89 vs. existing HSM

- At this time, CPMs in Ch. 18 of HSM Supplement remain "default" for freeway analysis
- Situations where 17-89 CPMs are more appropriate include:
  - A project where PTSU is provided or being considered for implementation.
  - A project that includes some sites or alternatives with PTSU.
  - A freeway where six or seven lanes in one direction are being analyzed.
  - A project in a jurisdiction that has calibrated the 17-89 CPMs but not the current HSM freeway CPMs.
  - The analysis results will be compared with prior analysis results from 17-89 CPMs.

Known Applications to Date

- I-80 Borman Expressway in Northwest Indiana
- Likely others

Inclusion in HSM2

- HSM2 team plans to include PTSU analysis capability
- Options include:
  - Multiple freeway models (current HSM, 17-89, 17-89A HOV/HOT?)
  - Single freeway model incorporating PTSU

Future Research Topics

- Extend 17-89 CPMs to rural areas
- Differences between left-side and right-side PTSU
- Single-source calibration
  - HSM Supplement
  - 17-89
  - 17-89A

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Questions?

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HOV/HOT Freeway Crash Prediction Method for the Highway Safety Manual

Scott Himes, PhD, PE
2021 Transportation Engineering Safety Conference

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2

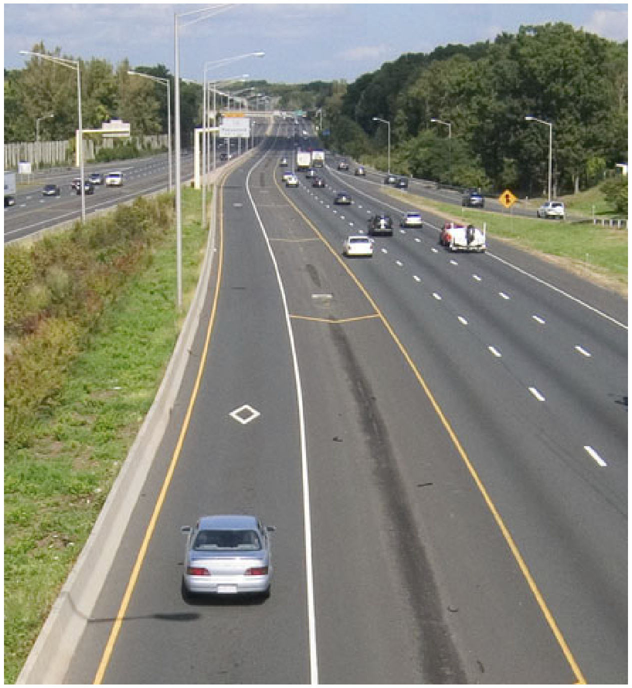
Presentation Overview

- Project Background
- The Predictive Method
- Application Scope
- Implementation Spreadsheet
- Takeaways and Conclusions

3

High Occupancy Vehicle (HOV) and Toll (HOT) Facilities

- Intended to relieve highway congestion
- Incentivize person throughput
  - 2 or more persons per vehicle eligibility
  - 3 or more persons per vehicle eligibility
- HOT has electronic toll component for vehicles not meeting eligibility requirement
- Restrict periods vary
  - 24 hours
  - Directional peak period
  - AM and PM peak periods



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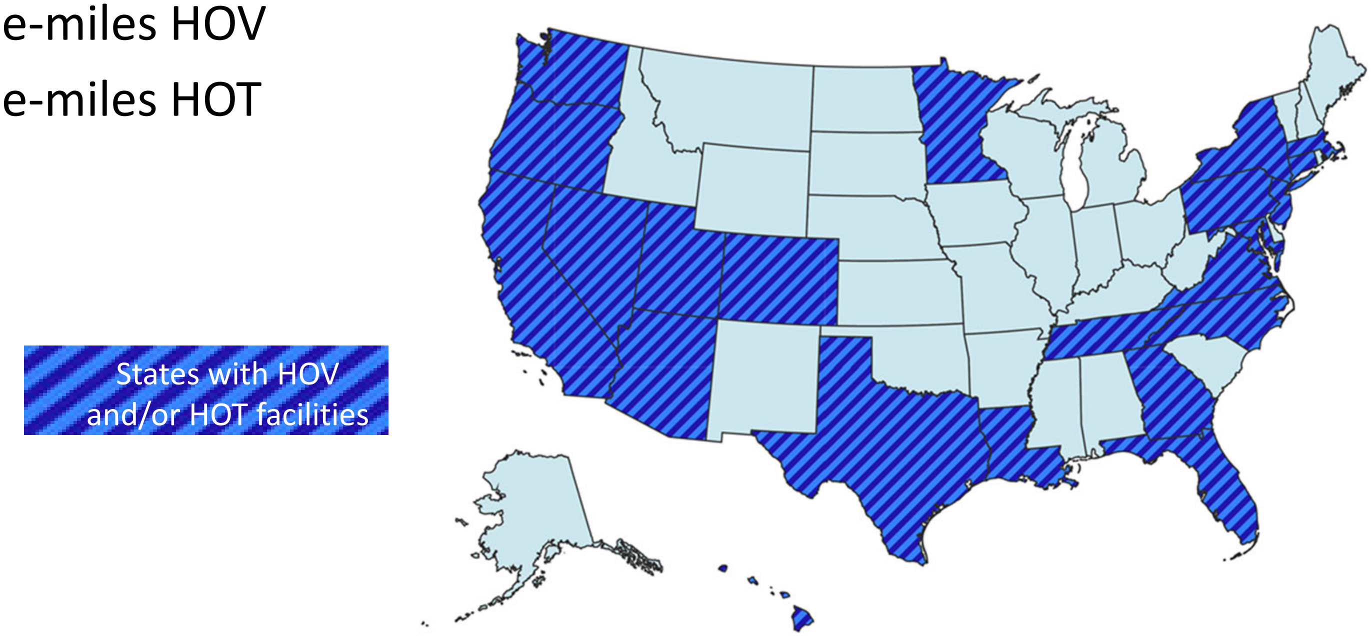
Installation of High-Occupancy (HO) Facilities

Mileage of facilities steadily increasing, as of 2021

- 2,875 lane-miles HOV
- 1,141 lane-miles HOT



HSM Predictive Method for Freeway Facilities

- Chapter 18 of the HSM Supplement provides predictive method for freeway facilities
- Existing crash prediction methodology does not include safety impacts of managed lanes
- Methodology asks users to ignore presence of those facilities
- Further research was needed to address managed lane facilities
    - NCHRP Project 17-89: Safety Performance of Part-Time Shoulder Use on Freeways
    - NCHRP Project 17-89A: HOV/HOT Crash Prediction Method for the HSM

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Project Purpose

- Develop a predictive method for freeway facilities with HOV/HOT lanes
  - Predict total crash frequency and multiple-vehicle crash frequency
  - Develop severity distribution functions to predict crash severity
  - Focus on directional freeway segments
- Develop proposed text for inclusion in the HSM
- Develop an implementation tool for the predictive method

The Predictive Method (PM)

PM includes:

- 18-step procedure for estimating average crash frequency
- *Predictive model* for freeway segments and speed-change lane sites

Site types addressed by PM:

- One direction basic freeway segment with two to seven general-purpose through lanes and one to four concurrent HOV/HOT lanes in the subject travel direction.
- Speed-change lane site (and adjacent through lanes) providing right-side freeway access for an entrance ramp or an exit ramp.

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Applicable Freeways

HOV and HOT lane design configurations and application frequency.

Lateral Separation	HOV and HOT Access Type	HOV and HOT Application Frequency by Lane Orientation [a, b]			
		Concurrent Lane	Separate Roadway	Reversible Lane	Contraflow Lane
Lane line	Continuous (dashed)	Often used; addressed by method	—	—	—
	At-grade entrance and exit zones	Often used; addressed by method	—	—	—
Flush buffer	Continuous (dashed)	Occasionally used	—	—	—
	At-grade entrance and exit zones	Often used; addressed by method	—	—	—
Pylon buffer	Grade-separated entrance and exit points	—	Often used	—	—
	At-grade entrance and exit zones	Often used; addressed by method	—	—	Often used
Barrier	Grade-separated entrance and exit points	—	Often used	Often used	—
	At-grade entrance and exit zones	Often used; addressed by method	—	Often used	Often used

[a] Predictive method addresses combinations associated with a cell having a white background.
[b] "—" identifies combinations not used (or rarely used).

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Applicable Freeways

HOV and HOT lane design configurations and application frequency.

Pylon Separated At-Grade Access HOV/HOT Lane

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How to use the Predictive Method

- Evaluate freeway facilities with/without HO lanes provided jurisdiction has calibration factors for both predictive methods
- Evaluates sites serving *one direction of travel*
- PM applies to basic freeway segments, entrance speed-change lanes, and exit speed-change lanes. Consists of:
  - Base safety performance functions (SPFs)
  - Adjustment factors (AFs)
  - Severity distribution functions (SDFs)

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Data Needs Comparison to Existing Freeway Predictive Method

SPF Adjustment Factor	Freeway Segments	Speed-Change Segments	Unique to this Method
Lateral separation and access type	✓	✓	✓
Freeway AADT	✓	✓	
Entrance or exit ramp AADT		✓	
Inside shoulder width	✓	✓	
Outside shoulder width	✓	✓	
Median width	✓	✓	
Median barrier	✓	✓	
Outside barrier	✓	✓	
Type C weaving section	✓		✓
Average speed differential	✓	✓	✓
High-volume hours	✓		✓
Number of HO lanes		✓	✓

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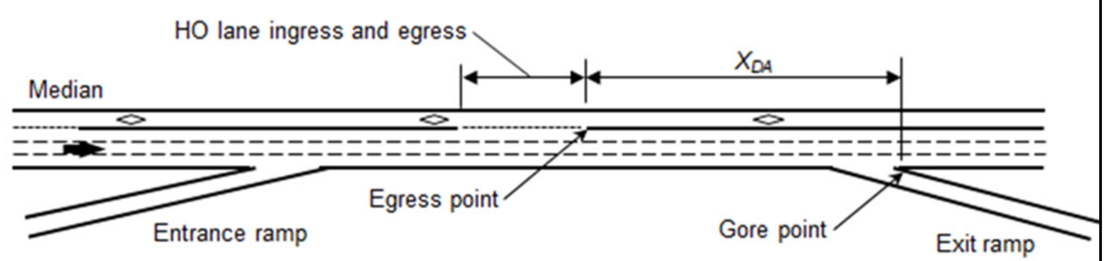
Lateral Separation and Access Type

- At-grade access or continuous access apply
- Lane line, buffer, barrier, or pylon separation
- Distance from HO lane egress to downstream exit ramp also applies

Distance from last HO lane egress point to next exit ramp
- Not necessary for continuous access
- Limited to values between 0 and 0.25 miles or more per lane



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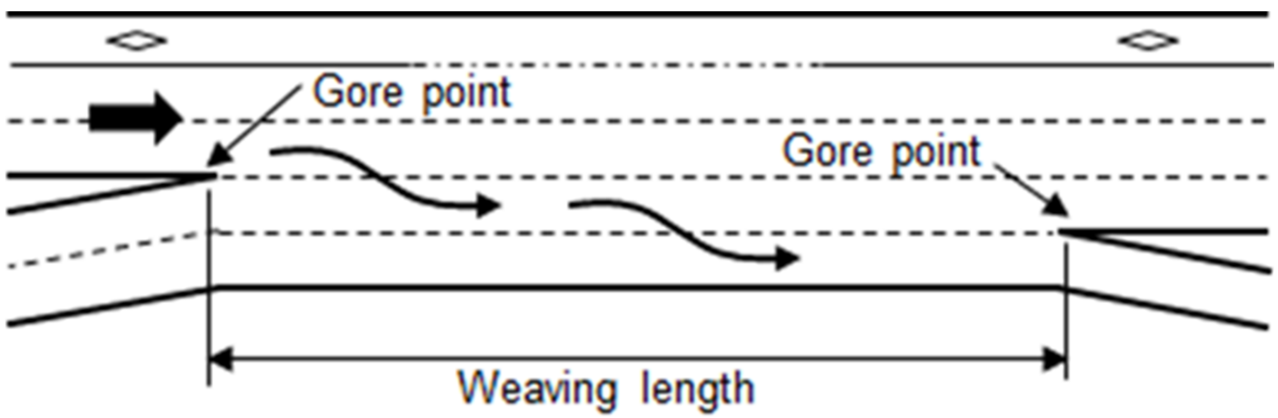
Type C Weaving Section



Presence of Type C Weaving Section
- Both entrance and exit ramps on right-side
- Only applies if Type C weave less than 0.85 miles in length

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Traffic Flow Characteristics

Proportion of hours in average day with lane volume exceeding 1,000 veh/hr/lane

- Can be obtained from traffic counting station
- Equation for default value provided based on major road AADT and number of GP lanes
- Note that Chapter 18 uses proportion of AADT rather than hours

Average speed differential between inside GP lane and the HO lane(s)

- Only applies to facilities with lane line or buffer lateral separation
- Represents average of the course of the year
- Can be obtained from measured spot speeds
- Equation for default value provided based on major road AADT and number of GP lanes

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Data Needs for Assessing Crash Severity

SPF Adjustment Factor	Freeway Segments	Speed-Change Segments
AADT	✓	✓
Posted speed limit	✓	✓
Number of GP lanes	✓	✓
HO lane access and separation type	✓	✓
Outside barrier	✓	✓
Median barrier	✓	✓
Outside barrier	✓	✓
Restriction period	✓	✓
Horizontal curvature	✓	✓
High-volume hours	✓	✓
Upstream entrance distance and AADT	✓	✓
Downstream exit distance and AADT	✓	✓

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Application Scope

1. Applicable to Urban Freeways with Concurrent HO Lanes
2. Projects Adding HOV or HOT Lanes
3. Weaving Section Analysis
4. Alternative Cross Section Analysis
5. Not Applicable to Left-Side Ramps
6. Not Able to Predict HOV- or HOT-Related Crash Frequency

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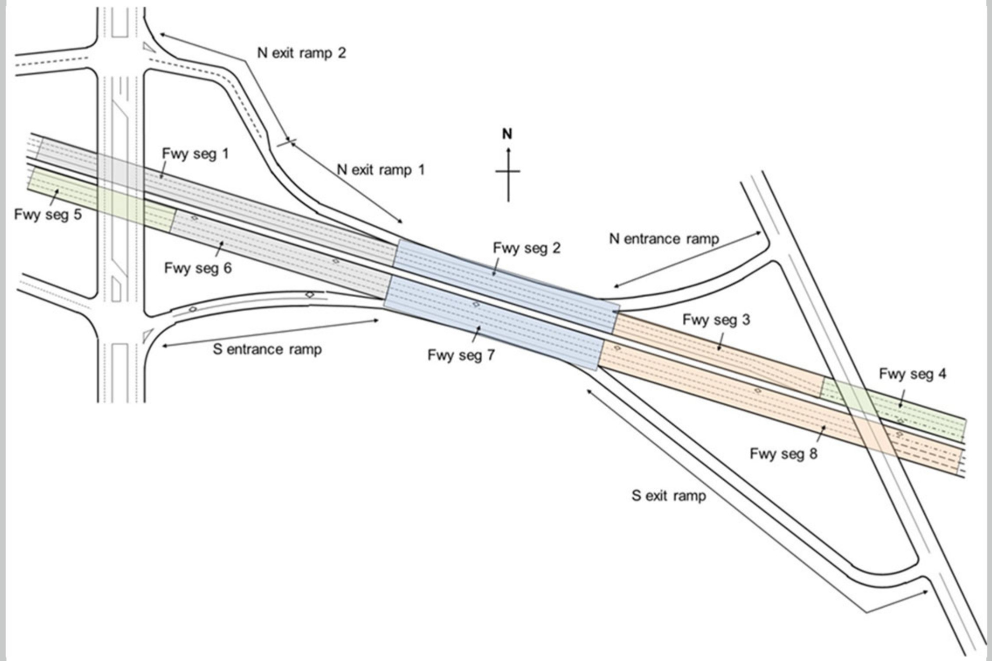
Potential Applications

- Freeways with Toll Facilities
- Evaluation of Freeway Facilities without HOV or HOT Lanes
    A. HO Lanes in Only One Direction
    B. Existing Freeway Does Not Have HO Lanes



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Predictive Method Limitations

Does not address

- Freeways in rural areas
- Freeways with other managed lane types
- Freeways with eight or more directional GP through lanes
- Freeways where HO lanes accommodated
    - Separate roadway
    - Reversible lane
    - Contraflow lane
- Ramp metering
- Toll plazas
- Left-side speed-change lanes

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Implementation Spreadsheet

Segment 1 through **Segment 20** contains input data for:

- crash frequency and severity models for basic freeway segments
- Entrance and exit speed-change lanes
- Detailed calculations and results by crash type and severity from the predictive method

General Information and Input Data

General Information		Location Information	
Analyst	SCH	Freeway	
Agency or Company	VHB	Direction	
Date Performed	5/24/2021	Location Description	
		Jurisdiction	
		Analysis Year	2021

Input Data		Base Condition	Site Conditions	Input Checks
Site type (Basic Segment, Ramp Entrance Speed-Change Lane, Ramp Exit Speed-Change Lane):		--	Basic Freeway Segment (FS)	-
Segment Length (L_s), mi:		--	1	-
Directional freeway AADT ($AADT_{fs}$), veh/day:	$AADT_{MAX}$ = 121,000 (veh/day)	--	65,000	OK
	$AADT_{MIN}$ = 0 (veh/day)	--		OK
Entrance ramp AADT ($AADT_{en}$), veh/day:	$AADT_{MAX}$ = 79,000 (veh/day)	--		N/A
Exit ramp AADT ($AADT_{ex}$), veh/day:	$AADT_{MAX}$ = 91,000 (veh/day)	--		N/A
Number of general purpose lanes, n_{gp}:		--	2	-
Number of HOV/HOT lanes, n_{HO}:		--	1	N/A
Cross Section Data				
Lateral separation type:		Continuous Access	Continuous Access	-
HOV/HOT buffer separation width (W_B), ft:		0		N/A
Distance to downstream exit from closest access (X), (mi)		0		N/A
Inside shoulder width (W_{IS}), ft:		2	2	OK
Outside shoulder width (W_{OS}), ft:		10	10	OK
Median width (W_M), ft:		22	22	OK
Segment length with inside median barrier (L_{IB}), mi:		0	0.1	OK
Segment length with outside barrier (L_{OB}), mi:		0	0	OK
Ramp Access Data				
Presence of type of Type C weaving section (I_C):		Not Present	No	-
Operational Data				
Is the percent of hours that are high volume hours available?		-	No - Use Default Value	-
Proportion of high volume hours (P_{HV}):		-	0	N/A
Is the average speed differential between HOV/HOT lane and leftmost GPL available?		-	No - Use Default Value	-
Average speed differential (X), mph:		0	3	N/A
Additional Severity Distribution Function Data				
Posted speed limit (X), mph:		-	65 MPH	-
Distance from begin milepost to upstream entrance ramp gore ($X_{b,ent}$), mi:			0.25	OK

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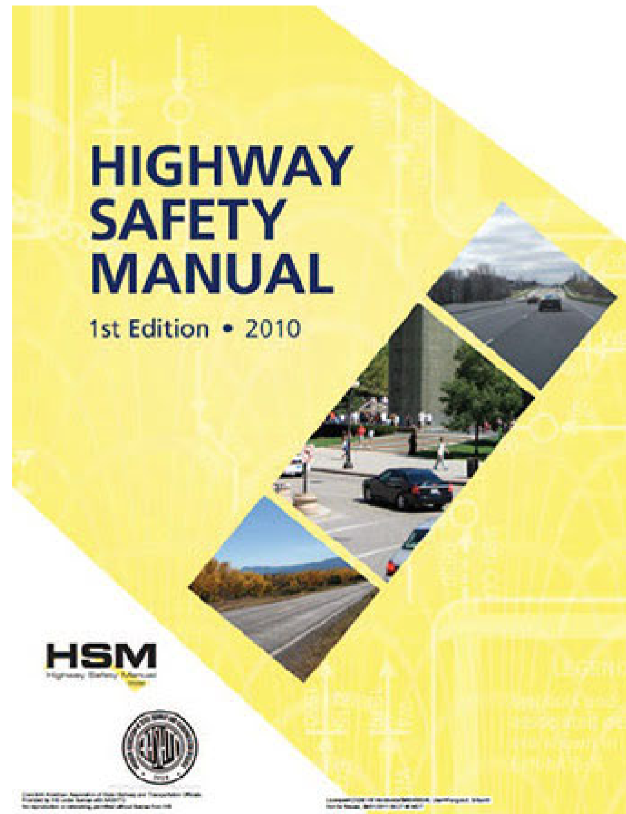
Other Deliverables

- Proposed text for HSM Chapter
- Safety Implementation Guide (User Guide for application and Spreadsheet Tool)
- Informational Guide



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Questions??

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