

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

## Development of Revised Speed Limit Expert System

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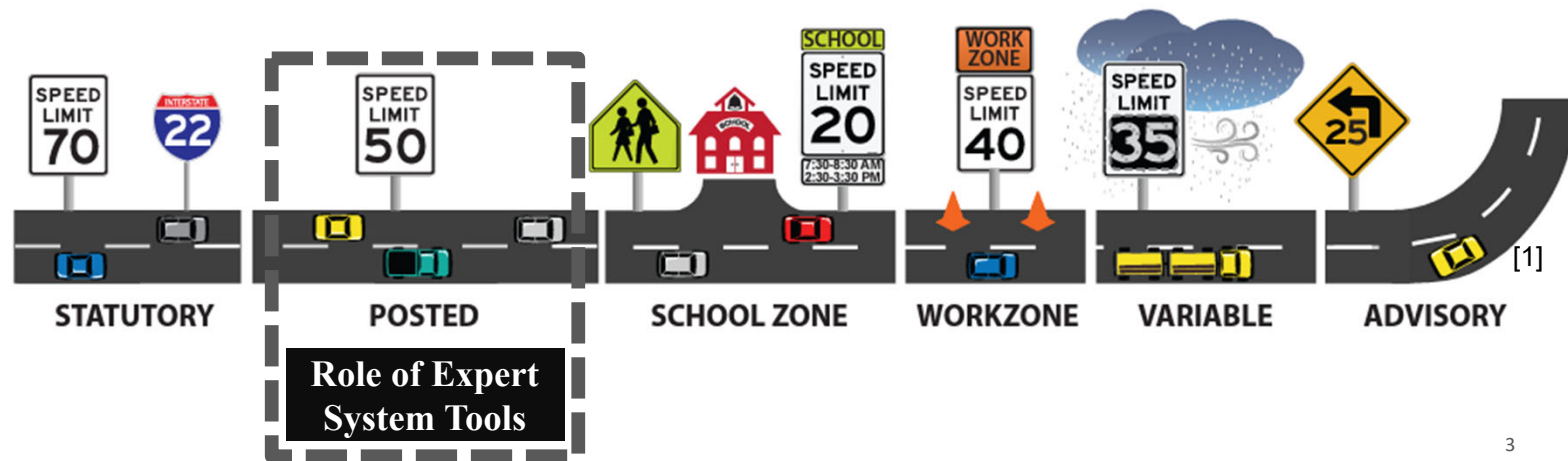


## Project Team

- UNC Highway Safety Research Center
  - Lead Agency
  - Software development
- Michigan State University
  - Lead for developing the decision rules
  - These slides were developed by the MSU team
- Toxcel
  - Project support

## Speed Limit Setting Expert Systems


- Developed based on surveys of experts, supplemented by research findings, current practice
- Purpose: Supplement engineering studies for setting posted speed limits



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[1] - Federal Highway Administration (2017). Speed Limit Basics (FHWA-SA-16-076).

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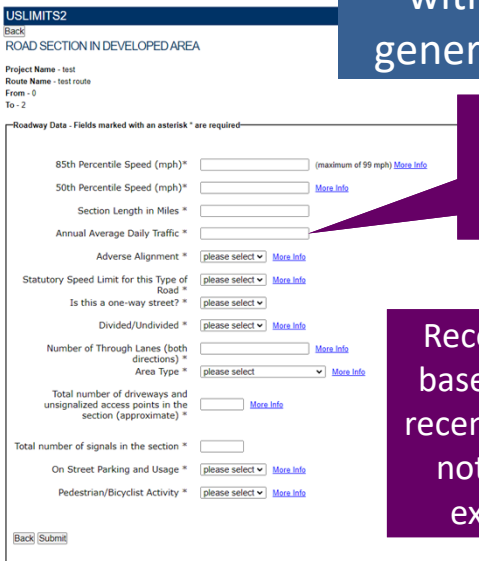

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## Common Speed Limit Setting Tools

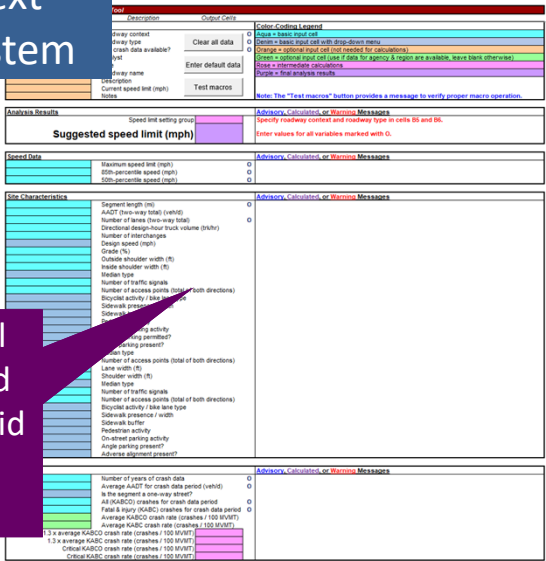
### USLIMITS2 (2000)

### NCHRP 03-139 is charged with creating the next generation Expert System

### NCHRP 17-76 Tool (2021) [2]



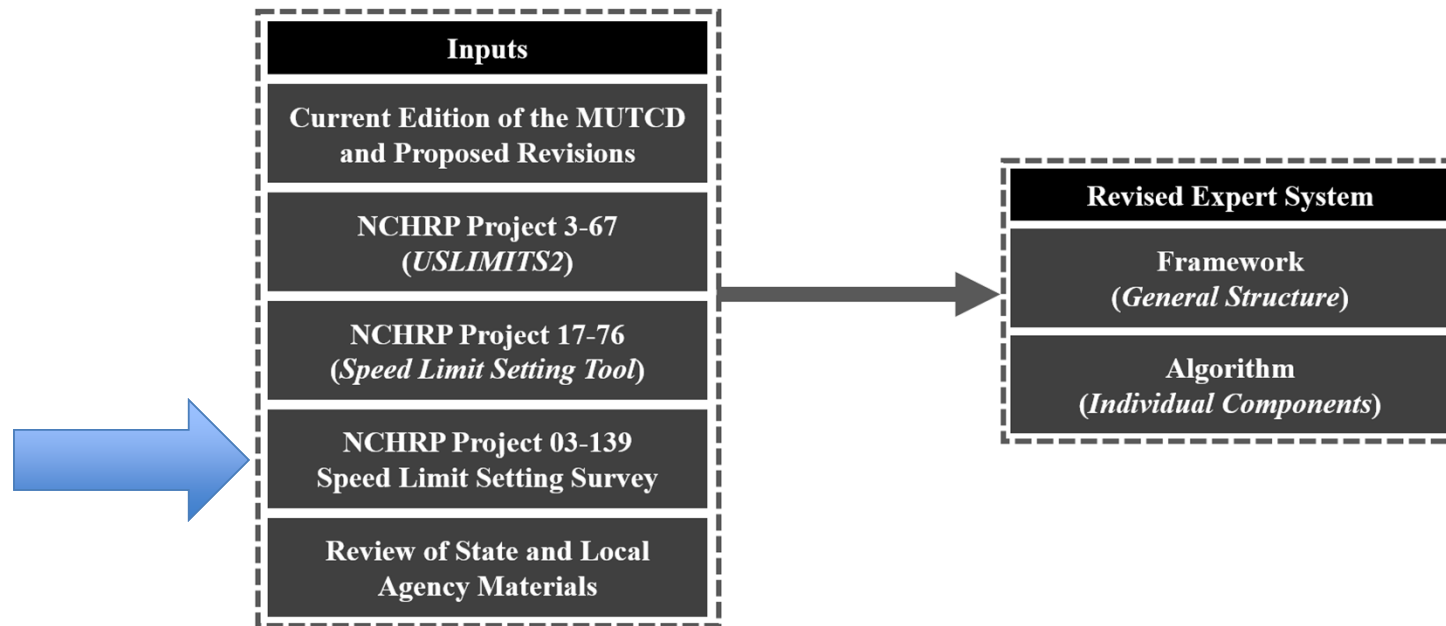
**Original Expert System currently hosted by FHWA**



**Recent Engineering Tool based on USLIMITS2 and recent safety research (did not update underlying expert opinion data)**

[1] - Federal Highway Administration (2020). USLIMITS2 – A Tool to Aid Practitioners in Determining Appropriate Speed Limit Recommendations.  
 [2] - Fitzpatrick, K., S. Das, M.P. Pratt, K. Dixon, and T. Gates (2021). NCHRP Web-Only Document 291: Development of a Posted Speed Limit Setting Procedure and Tool. Washington

## Resources Used to Develop Revised Expert System



# Summary of Speed Limit Setting Expert Panel Survey

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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
  - Included a broad range of roadway characteristics
  - At least one case from all 50 states and Washington, D.C.
  - Panelists were not given the “actual” location or the existing posted speed limit
- Each case developed in into unique Qualtrics survey
- A unique set of roadways were provided to each panelist base on pre-survey response

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## Survey Procedure

- Two Components:
  - **Pre-survey** initially provided via email to collect panelist information (speed limit experience, employer type, importance of various factors for speed limits)
  - **Speed limit setting case reviews** were then provided to panelists for review
    - Types of roadway contexts sent to each panelist were based on pre-survey response
    - Panelists reviewed each case study twice (giving a recommended speed limit each time):
      - **First, with only roadway data (map, aerial, street view, and characteristics table)**
      - **Then again with operating speed and crash data added**
- Two Groups:
  - **Expert steering panel** (20 members recommended by project team and panel)
  - **Expanded expert panel** (additional recruited survey-takers)

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## Panelists by Employer Category (N = 295)

Employer Category	Expert	Expanded	All Panelists
Small (< 50,000 Pop.) City or Other Municipality	1	25	26
Medium (50,000 to 249,999 Pop.) City or Other Municipality	0	13	13
Large (> 250,000 Pop.) City or Other Municipality	4	22	26
Consultant	1	25	26
County Road Agency	5	37	42
FHWA	1	2	3
Law Enforcement	2	22	24
Other Transportation Agency or Entity	0	6	6
Other	0	3	3
Research/Education	0	13	13
State DOT	13	100	113
<b>All Panelists</b>	<b>27</b>	<b>268</b>	<b>295</b>

**25 case reviews assigned to each expert panelist**  
**10 case reviews assigned to each expanded panelist**

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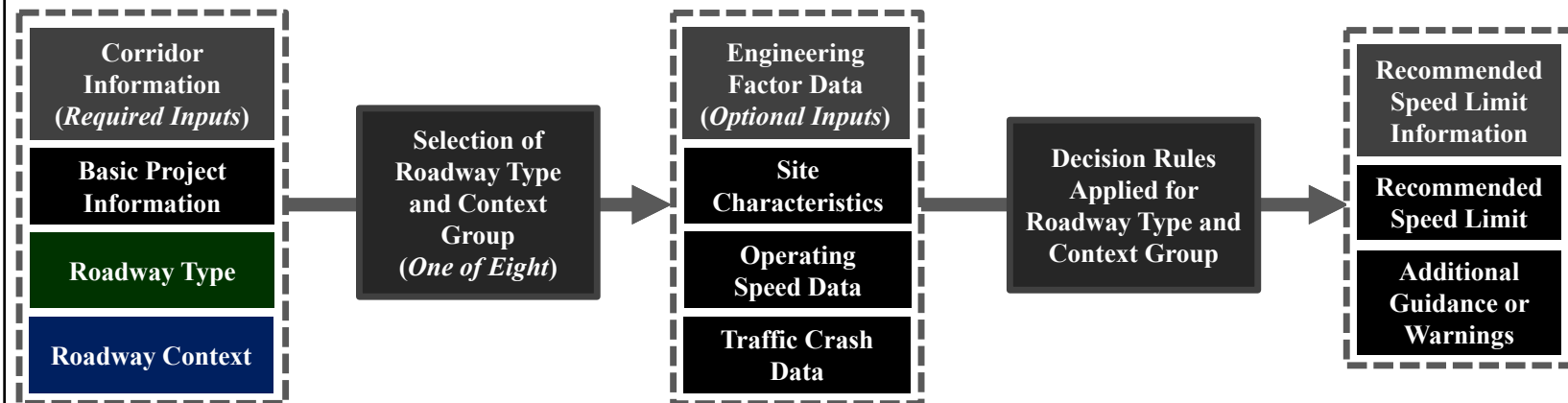
## Completed Reviews by Roadway Type/Context (N = 2,419)

Completed Case Reviews		Roadway Context				
		Rural	Rural Town	Urban/Suburban	Urban Core	All Contexts
Roadway Type	Freeway	105	0	117	107	329
	Multilane Divided Arterial	114	41	242	70	467
	Multilane Undivided Arterial	121	170	249	131	671
	Two-Lane Arterial	64	169	275	60	568
	Two-Lane Collector	83	56	142	103	384
	All Types	487	436	1,025	471	2,419

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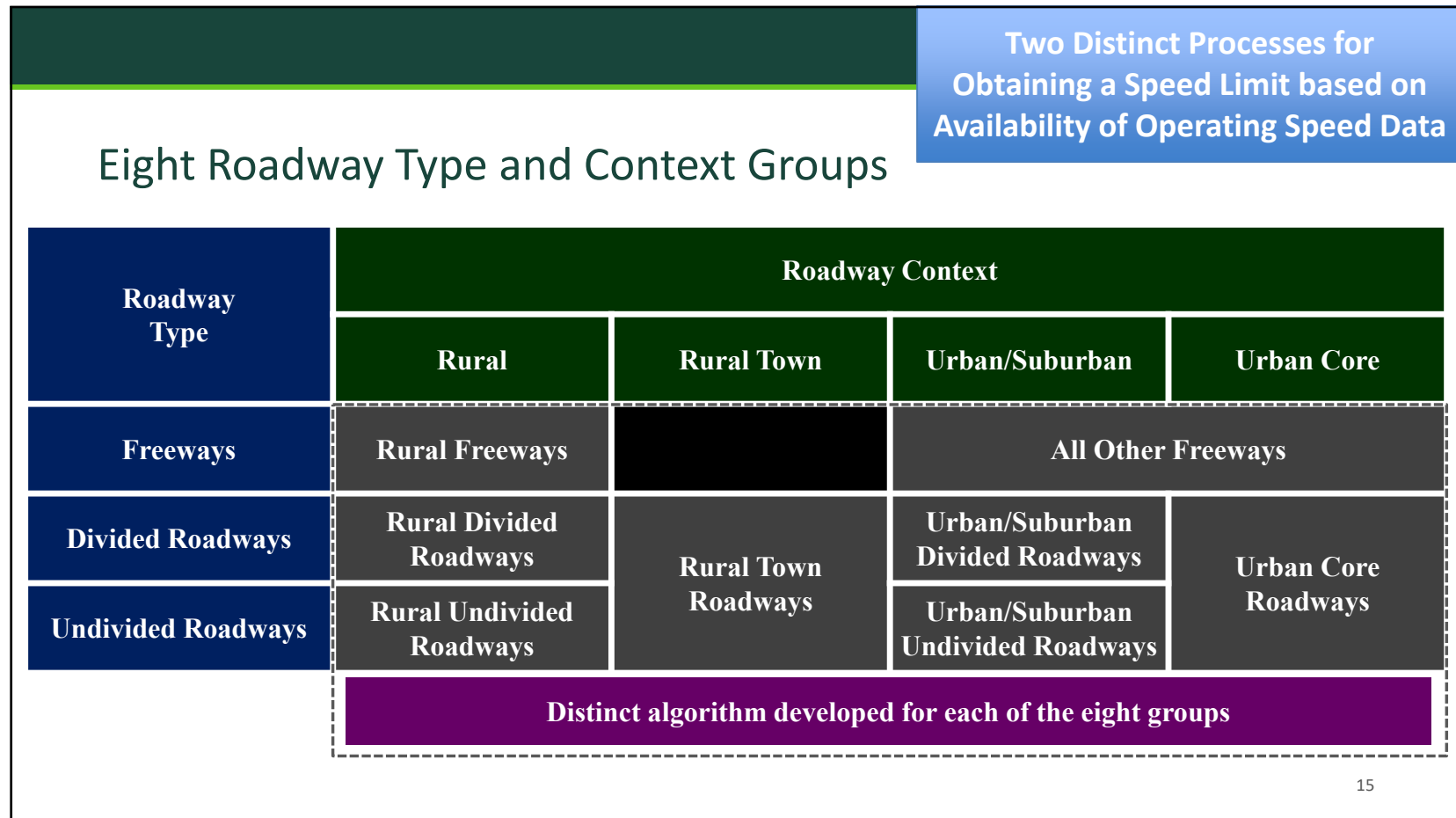
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## Structure of Revised Expert System



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## Speed Limit Decision Process Without Operating Speed Data

- If operating speed data **is not provided** by the user, the algorithm will begin with the range of values obtained from the expert panel survey
  - Including the typical range of values for the group and a median value
- Recommended speed limit will be identified by shifting the value within the typical range based on the engineering data provided by user
  - Including site characteristics and traffic crash data

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### Expert Panel Survey Data: Recommended Speed Limit without Operating Speed Data

Roadway Type and Context Group	Recommended Posted Speed Limit (MPH)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Rural Freeways	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.9%	27.6%	27.6%	28.6%	13.3%
All Other Freeways	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.3%	13.8%	39.7%	20.5%	4.0%	0.4%
Rural Divided Roadways	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	3.5%	1.0%	33.3%	14.9%	32.5%	7.9%	2.6%	0.0%
Rural Undivided Roadways	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	6.3%	10.8%	48.5%	15.3%	14.6%	3.0%	0.4%	0.0%
Rural Town Roadways	0.0%	2.8%	17.0%	21.3%	29.1%	11.0%	13.1%	2.1%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Urban/Suburban Divided Roadways	0.0%	0.8%	5.8%	7.9%	20.7%	12.8%	25.2%	11.6%	9.5%	0.4%	0.0%	0.0%	0.0%	0.0%
Urban/Suburban Undivided Roadways	0.0%	0.8%	11.7%	17.7%	31.7%	13.2%	13.7%	5.4%	5.0%	0.5%	0.0%	0.0%	0.0%	0.0%
Urban Core Roadways	1.4%	13.5%	48.6%	21.7%	14.6%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

**Median value** (Red callout pointing to 48.5% for Rural Undivided Roadways)

**Typical range for group** (Purple callout pointing to the range between 10.8% and 15.3% for Rural Undivided Roadways)

## Speed Limit Decision Process With Operating Speed Data

- If operating speed data **is provided**, the algorithm will begin with the range of values obtained from the expert panel survey
  - Including the distribution of responses
- Recommended speed limit will be identified by selecting one of four operating speed metrics based on the available engineering data:
  - Rounded Down 50<sup>th</sup> Percentile Operating Speed
  - Closest 50<sup>th</sup> Percentile Operating Speed
  - Rounded Down 85<sup>th</sup> Percentile Operating Speed
  - Closest 85<sup>th</sup> Percentile Operating Speed

Similar to  
USLIMITS2 and  
NCHRP 17-76

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### Expert Panel Survey Data: Recommended Speed Limit with Operating Speed Data

Roadway Type and Context Group	Recommended Posted Speed Limit (MPH)															
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
Rural Freeways	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.0%	16.2%	31.4%	34.3%	12.4%	2.9%	1.0%
All Other Freeways	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	6.7%	24.1%	19.2%	28.6%	12.9%	7.6%	0.0%	0.0%	0.0%
Rural Divided Roadways	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	12.3%	33.3%	23.7%	15.8%	12.3%	1.8%	0.0%	0.0%	0.0%
Rural Undivided Roadways	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	11.6%	49.6%	12.7%	14.2%	6.0%	3.4%	0.7%	0.0%	0.0%
Rural Town Roadways	0.2%	2.8%	15.4%	24.3%	30.3%	17.7%	8.7%	0.5%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Urban/Suburban Divided Roadways	0.0%	0.8%	6.6%	8.7%	19.8%	11.2%	22.7%	14.5%	9.5%	2.1%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Urban/Suburban Undivided Roadways	0.0%	1.4%	9.8%	21.2%	27.5%	14.4%	11.7%	6.0%	6.0%	2.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
Urban Core Roadways	2.7%	16.8%	50.0%	20.1%	9.3%	0.8%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Typical range for group



### Expert Panel Survey Data: Recommended Speed Limit in Relation to Operating Speed

Roadway Type and Context Group	Recommended Posted Speed Limit					
	Less than 50th Percentile	50th Percentile		85th Percentile		Greater than 85th Percentile
		Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th	
Rural Freeways	27.6%	18.1%	21.9%	37.1%	20.0%	4.8%
All Other Freeways	9.4%	25.9%	29.0%	44.6%	33.5%	11.6%
Rural Divided Roadways	23.7%	32.5%	36.8%	19.3%	22.8%	6.1%
Rural Undivided Roadways	23.9%	32.8%	32.8%	31.0%	23.5%	1.5%
Rural Town Roadways	10.8%	29.1%	34.2%	39.9%	36.5%	5.3%
Urban/Suburban Divided Roadways	13.6%	24.0%	33.5%	39.7%	34.3%	2.9%
Urban/Suburban Undivided Roadways	15.5%	29.9%	34.7%	41.4%	32.6%	2.9%
Urban Core Roadways	19.8%	33.2%	39.6%	34.1%	22.0%	1.3%

Typical range for group

Note that overlap exists across categories (rows add up to greater than 100%)

### Speed Limit Range for Each Group – **Without** Operating Speed Data

Roadway Type and Context Group	Range of Recommended Speed Limits from Expert Panel Surveys (MPH)		
	Minimum*	Default Value**	Maximum*
Rural Freeways	65	70	80
All Other Freeways	55	65	70
Rural Divided Roadways	55	60	70
Rural Undivided Roadways	50	55	65
Rural Town Roadways	25	35	45
Urban/Suburban Divided Roadways	25	45	55
Urban/Suburban Undivided Roadways	25	35	55
Urban Core Roadways	20	25	35

\* Represents range of speed limits that may be recommended when operating speed data is not available

\*\* Represents median speed limit recommendation from expert panel surveys

## Speed Limit Range for Each Group – **With** Operating Speed Data

Roadway Type and Context Group	Range of Speed Limit Recommendations in Relation to Operating Speed		
	Minimum	Default Value	Maximum
Rural Freeways	RD50	RD85	C85
All Other Freeways	RD50	RD85	C85
Rural Divided Roadways	RD50	RD85	C85
Rural Undivided Roadways	RD50	RD85	C85
Rural Town Roadways	RD50	RD85	C85
Urban/Suburban Divided Roadways	RD50	RD85	C85
Urban/Suburban Undivided Roadways	RD50	RD85	C85
Urban Core Roadways	RD50	C50	C85

Note:

- RD50 = 50<sup>th</sup> percentile operating speed rounded down to the nearest 5 MPH
- C50 = 50<sup>th</sup> percentile operating speed rounded to the closest 5 MPH
- RD85 = 85<sup>th</sup> percentile operating speed rounded down to the nearest 5 MPH
- C85 = 85<sup>th</sup> percentile operating speed rounded to the closest 5 MPH

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## Engineering Factor Index for Obtaining Recommended Speed Limit

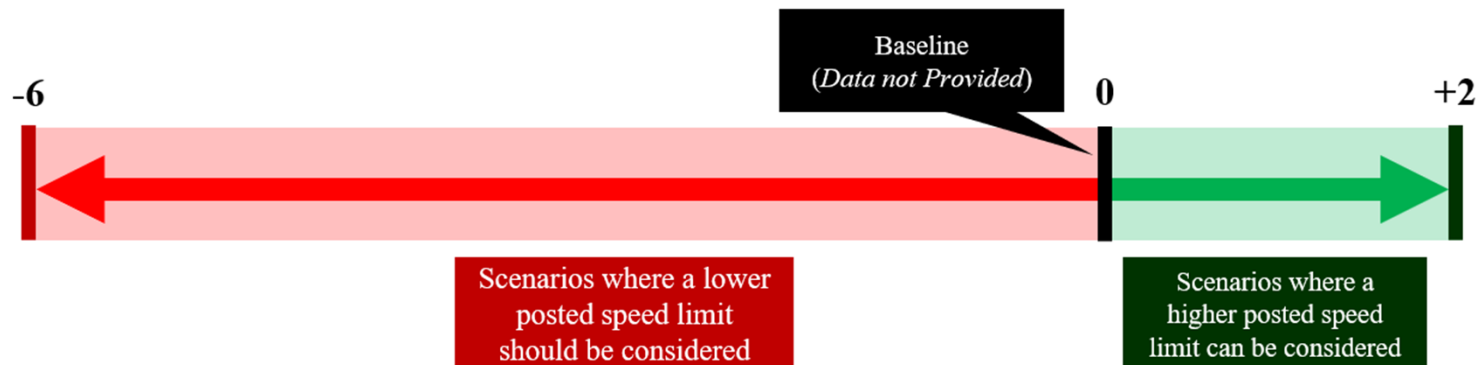
- Individual weight assigned to each engineering factor to calculate engineering factor index
  - Roadway type and context are required inputs
  - Everything else is **optional** but helps to refine the speed limit recommendation
- The index shifts speed limit recommendation away from default value:
  - Without operating speed data: recommended speed limit shifted up or down from default
  - With operating speed data: recommended speed limit = RD50, C50, RD85, or C85
- In order to ensure that the algorithm does not recommend higher speed limits where there is a factor that represents a potential safety concern
  - If **any negative condition** is present, the engineering factor index is determined by summation of only the negative values (*suboptimal conditions*)
  - If **no negative conditions** are present, the engineering factor index is determined by the summation of only the positive values (*optimal conditions*)

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## Calculation of the Engineering Factor Index

- Each factor is assigned a weight for calculating the engineering factor index
  - Roadway type and context are required inputs
  - Everything else is **optional** but helps to refine the speed limit recommendation
- The index shifts speed limit recommendation away from default value:
  - Without operating speed data: recommended speed limit shifted up or down from default
  - With operating speed data: recommended speed limit = RD50, C50, RD85, or C85



<h2 style="margin: 0;">Safety Performance Categories</h2>	
Safety Performance Category	Description
<b>High</b>	<ul style="list-style-type: none"> <li>The fatal and injury crash rate exceeds the critical crash rate using the average rate for similar facilities <b>OR</b></li> <li>There are agency-specific crash data analysis procedures that suggest potential safety concerns <b>OR</b></li> <li><u>There are specific Safe System or risk-based concerns present</u> (that have not already been accounted for in other decision rules).</li> </ul>
<b>Medium</b>	<ul style="list-style-type: none"> <li>The fatal and injury crash rate exceeds 1.3 x the average rate for similar facilities but not the critical rate <b>AND</b></li> <li>There are no agency-specific crash data analysis procedures that suggest potential safety concerns <b>AND</b></li> <li>There are no specific Safe System or risk-based concerns present (that have not already been accounted for in other decision rules).</li> </ul>
<b>Baseline</b>	<ul style="list-style-type: none"> <li>No safety performance information is provided.</li> </ul>
<b>Low</b>	<ul style="list-style-type: none"> <li>The fatal and injury crash rate does not exceed 1.3 x the average rate for similar facilities <b>AND</b></li> <li>There are no agency-specific crash data analysis procedures that suggest potential safety concerns <b>AND</b></li> <li>There are no specific Safe System or risk-based concerns present (that have not already been accounted for in other decision rules).</li> </ul>

## Statutory or Maximum Speeds

- Expert system intended to provide support for conducting speed limit engineering studies for specific speed zones
  - However, critical to ensure users are warned to select value that falls within statutory or other minimum/maximum limits that are set by policy
- The revised expert system will request a jurisdiction-specific maximum limit for the selected roadway type from the user
  - This value will be compared to the recommendation from the algorithm
  - Warning messages will be provided to ensure appropriate guidance is included
  - **Recommendations that are above this maximum limit can be obtained from the system, but with warning messages to notify the user**

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## Project Status

- Developing the case examples and conducting the survey of expert and expanded panel took much longer than expected
- Filed for no-cost extension with NCHRP, and waiting for a decision from NCHRP

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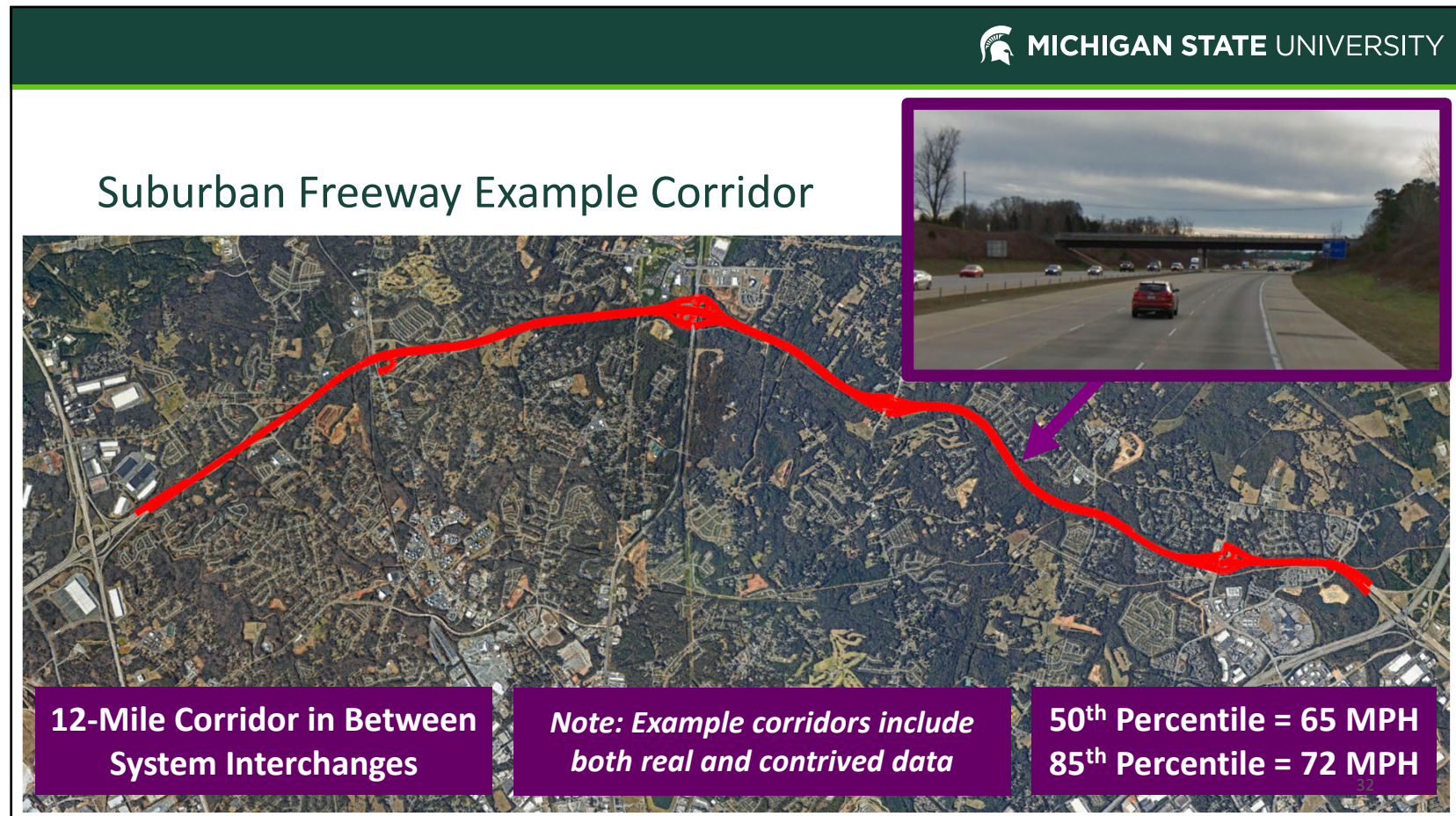
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# Questions?

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Suburban Freeway Example Corridor: Engineering Factor Index Calculation				
Input	Unit	Data	Weight (No Operating Speed)	Weight (With Operating Speed)
Safety Performance	Category	Low	+1	+1
Adverse Alignment or Available Sight Distance Concern	Presence	None	+1	+1
Mountainous Terrain	Presence	Flat Terrain	+1	+1
Interchange Spacing	Miles per Interchange	2.4	+1	+1
Truck Volume	Percent	6%	+1	+1
Median Width	Feet/Barrier Presence	Cable Barrier Present	0	0
Left Shoulder Width	Feet	9'	+1	+1
Right Shoulder Width	Feet	12'	+1	+1
<b>Engineering Factor Index</b>			<b>+7</b>	<b>+7</b>

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### Suburban Freeway Example Corridor: Recommended Speed Limit

#### +7 INDEX WITHOUT OPERATING SPEED

Urban/Suburban Freeways without Operating Speed Data	Recommended Posted Speed Limit (MPH)			
	55	60	65	70
Engineering Factor Index	Less than -3	-3	-2 to +5 (Default)	Greater than +5

70 MPH  
Recommended

#### +7 INDEX WITH OPERATING SPEED

Urban/Suburban Freeways with Operating Speed Data	Speed Limit Recommendation in Relation to Operating Speed			
	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Engineering Factor Index	Less than -3	-3	-2 to +6 (Default)	Greater than +6


Closest 85<sup>th</sup> Percentile  
Recommended (70 MPH)

Current Posted Speed Limit = 70 MPH  
(State Statutory Limit)

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### Urban Undivided Roadway Example Corridor


3-Mile Corridor in Urban Area




Note: Example corridors include both real and contrived data

50<sup>th</sup> Percentile = 28 MPH  
85<sup>th</sup> Percentile = 34 MPH

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Urban Undivided Example Corridor: Engineering Factor Index Calculation				
Input	Unit	Data	Weight (No Operating Speed)	Weight (With Operating Speed)
Safety Performance	Category	Moderate	-1	-1
Number of Lanes and Median Type	Combination	Two-Lane with Two-Way Left-Turn Lane	-1	0
Paved Shoulder Present	Presence	No Shoulder	0	0
Access Point Density	Access Points per Mile	56.0	0	0
Pedestrian Activity	Level	High Activity and Sidewalks with Buffer	0	-1
Bicycle Activity	Level	High without Separated Facilities	-3	-3
On-Street Parking	Presence	Parallel	-1	-1
Traffic Signal Density	Signals per Mile	3.3	0	0
Adverse Alignment or Available Sight Distance Concern	Presence	None	+1	+1
<b>Engineering Factor Index</b>			<b>-6</b>	<b>-6</b> 36

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### Urban Undivided Roadway Example Corridor: Recommended Speed Limit

**-6 INDEX  
WITHOUT OPERATING SPEED**

Urban/Suburban Undivided Roadways without Operating Speed Data	Recommended Posted Speed Limit (MPH)						
	25	30	35	40	45	50	55
Engineering Factor Index	Less than -5	-5 to -4	-3 to +6 (Default)	+7 to +9	+10 to +13	+14 to +15	Greater than +15

**25 MPH Recommended**

**-6 INDEX  
WITH OPERATING SPEED**

Urban/Suburban Undivided Roadways with Operating Speed Data	Speed Limit Recommendation in Relation to Operating Speed			
	Rounded Down 50th	Closest 50th	Rounded Down 85th	Closest 85th
Engineering Factor Index	Less than -4	-4 to -3	-2 to +6 (Default)	Greater than +6

**Rounded Down 50<sup>th</sup> Percentile Recommended (25 MPH)**

**Current Posted Speed Limit = 25 MPH**

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