



2024 Minnesota Toward Zero Deaths Conference

# Safety Analysis for the Northbound Highway 52 at I-94 Improvement Project

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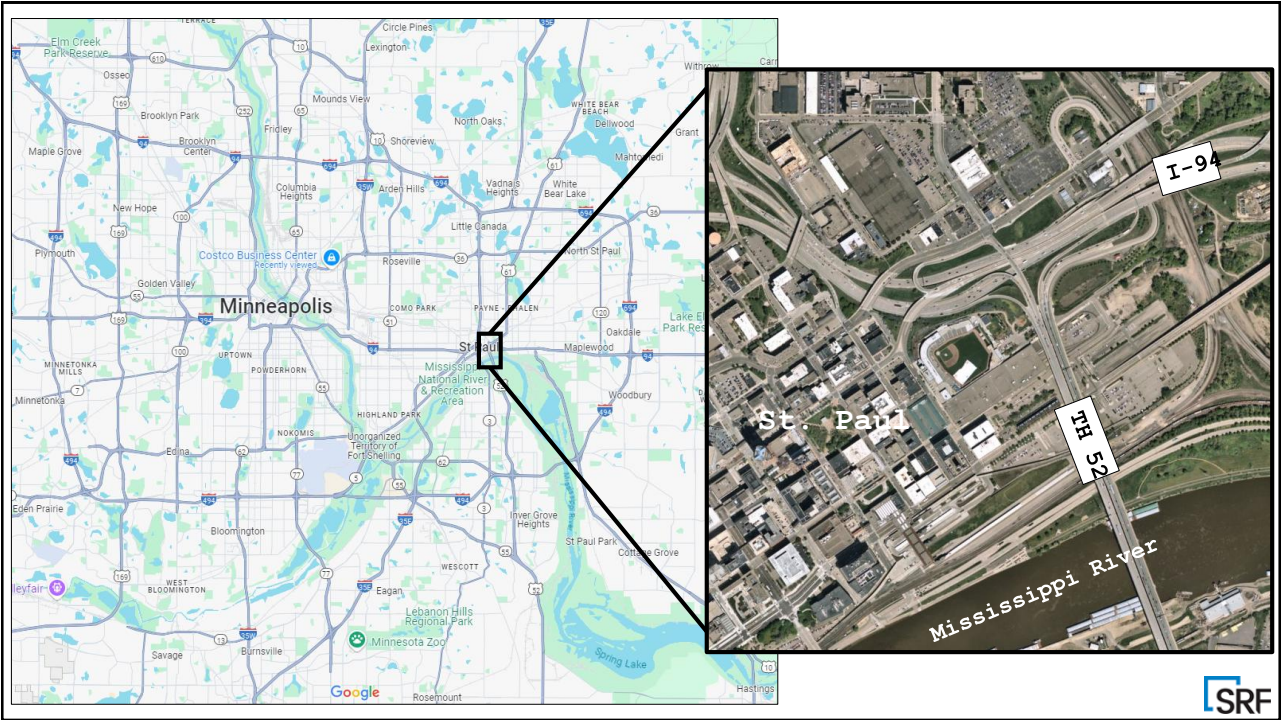
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Traffic Engineering Lead  
SRF Consulting Group



## Agenda

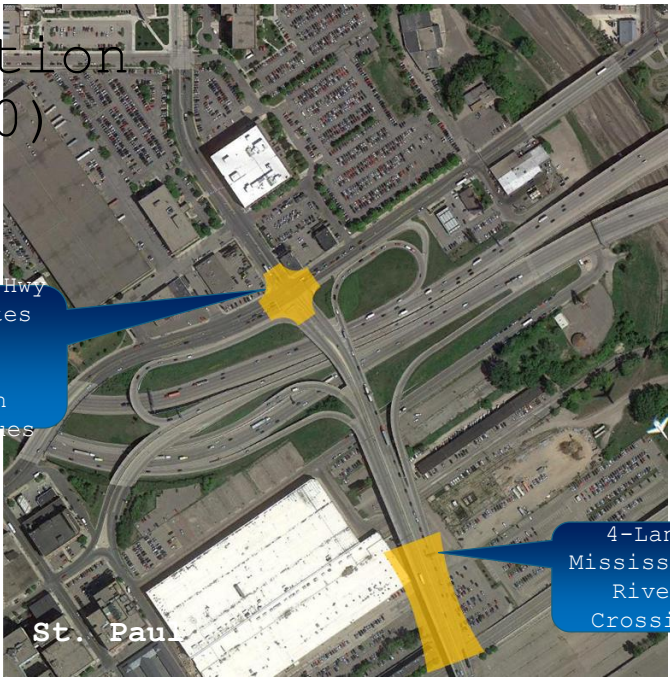
- Project Background
- Existing Conditions
- Alternatives
- Evaluation Criteria
- Findings





# Pre-Construction (up to 2010)

NORTHBOUND Hwy 52 terminates at signal  
• Major congestion  
• Crash issues



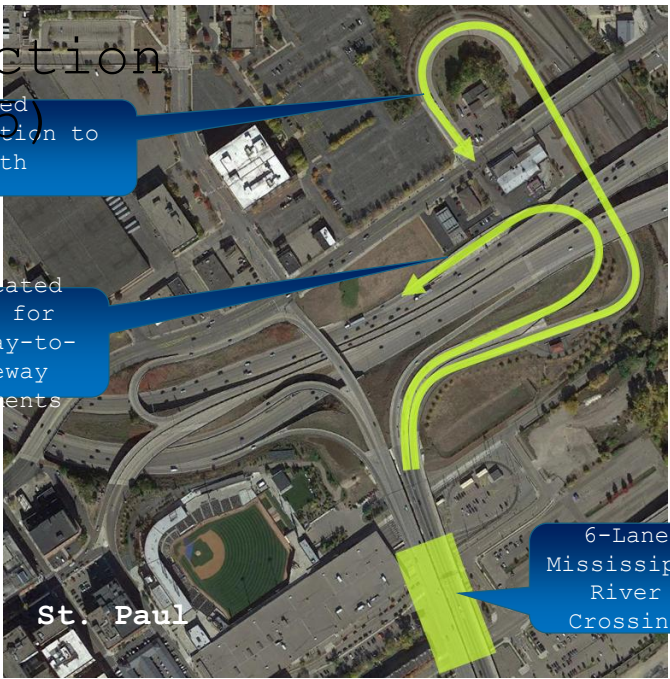
4-Lane Mississippi River Crossing

# Post-Construction (since 2010)

Retouted connection to East 7th Street

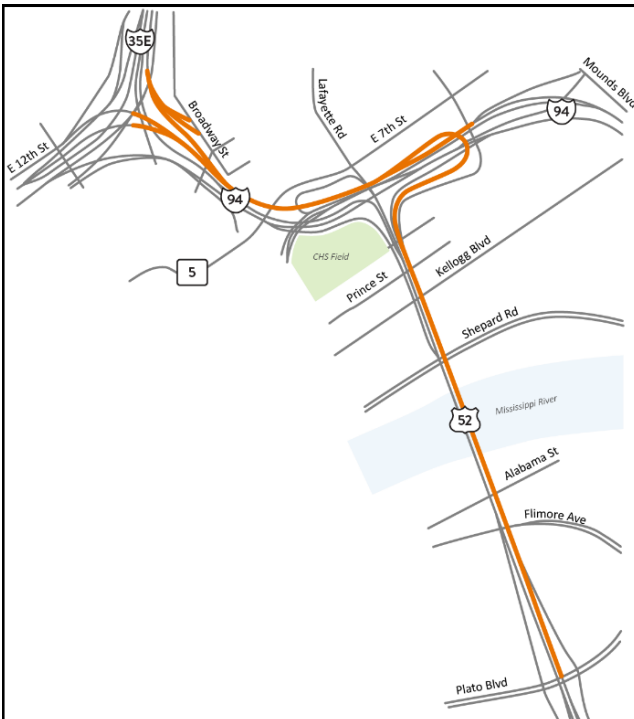
Dedicated ramp for freeway-to-freeway movements

6-Lane Mississippi River Crossing



## Changed Context

- CHS Field
- LRT Maintenance Facility
- Disconnected local roadways



## Project Overview & Background

### Analysis Segments:

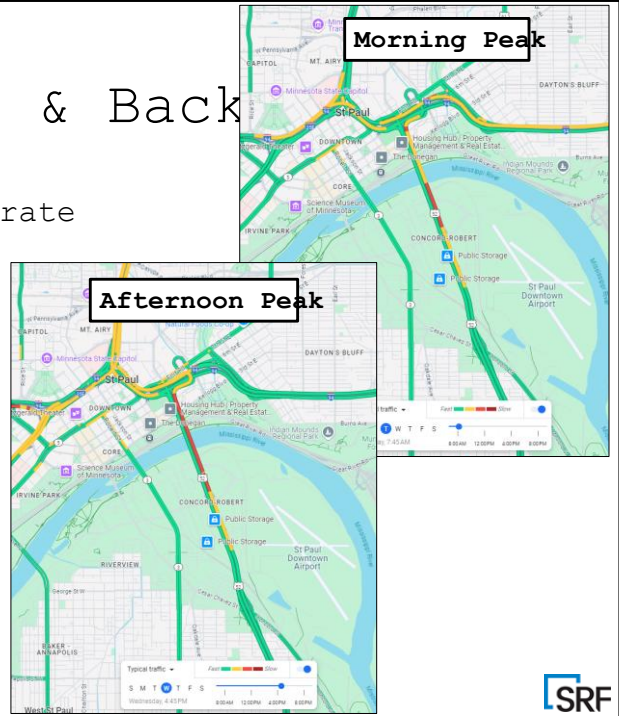
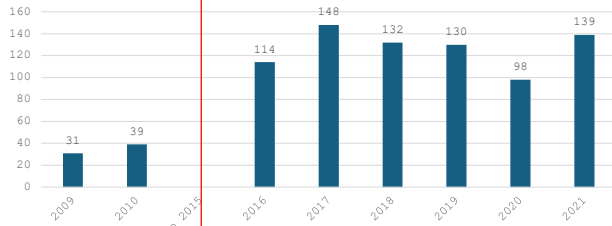
- Northbound TH 5 ←
- Westbound I-94 ←
- Northbound I-35E



# Project Overview & Back

- Historically elevated crash rate
- Significant congestion
- Concepts to improve safety &

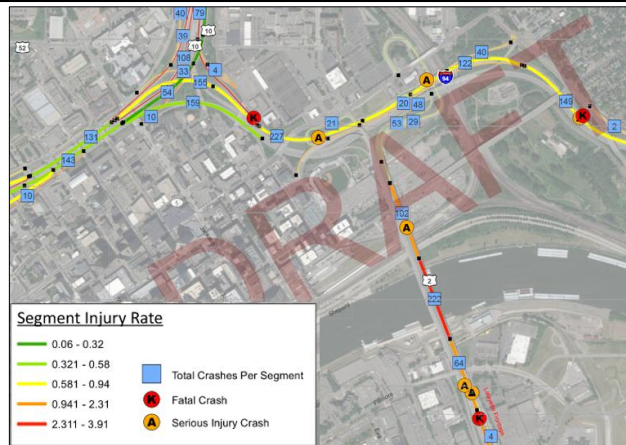
Total Number of Crashes on TH 52 NB from Plato to I-94



## Existing Crash Analysis

- Nearly all segments exceeded the Critical Crash Rate
- Six segments exceeded the Fatal + Serious Injury (KA) Critical Crash Rate

- Two on WB I-94
- One on NB I-35E



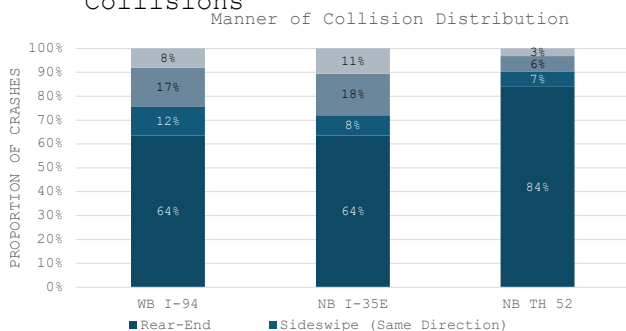
Segments		Crash Rate Range		Exceeds Critical	
Highway	No.	Total	K + A	Total	K + A
WB I-94	16	0.89 - 3.52	0.0 - 5.2	16	2
NB I-35E	11	0.57 - 4.58	0.0 - 2.9	11	1
<b>NB TH</b>		<b>0.32 -</b>	<b>0.0 -</b>		

# Existing Crash Analysis

## Collision Type

### NB TH 52

- 84% Rear-End Collisions
- 93% Injury Crashes are Rear-End Collisions



## Rear-End Crashes

### Study Area:

26% Injury

0.3% Fatal and Serious Injury

### NB TH 52 (Plato to I-94):

35% Injury

1.2% Fatal and Serious Injury



# Existing Crash Analysis

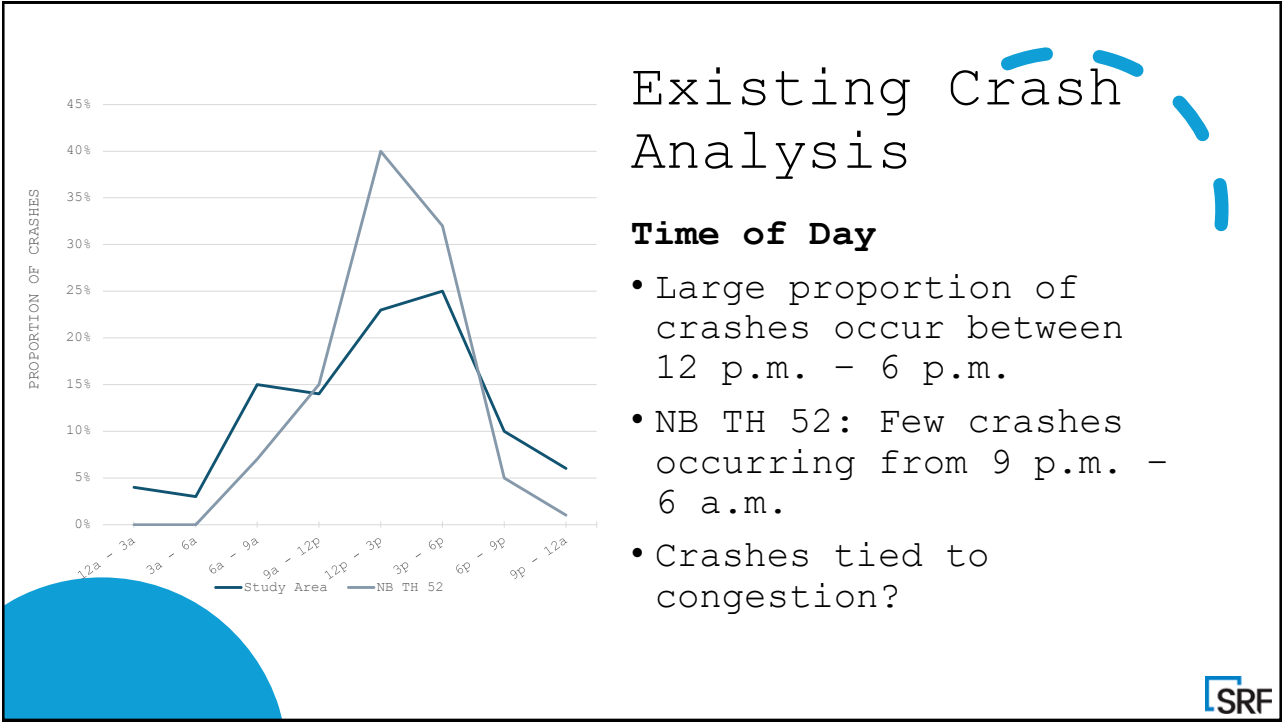
## External Conditions

### NB TH 52: Plato to I-94

- 95% Clear or Cloudy weather conditions
- 90% Occur under Daylight conditions
- 24% Cite "Congestion Backup" road circumstance

Surface Condition	Study Area	NB TH 52
Dry	73.5%	86.9%
Wet	12.8%	10.5%
Ice/Frost, Snow, Slush	13.4%	2.6%
Other/Unknown	0.3%	0.0%



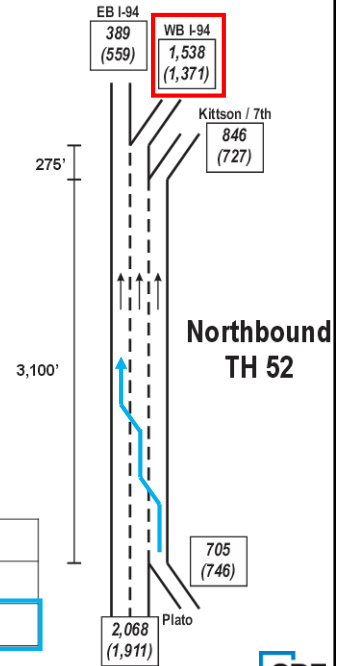


# Existing Operations

- Lane Utilization
  - 50-55% to WB I-94/NB I-35E

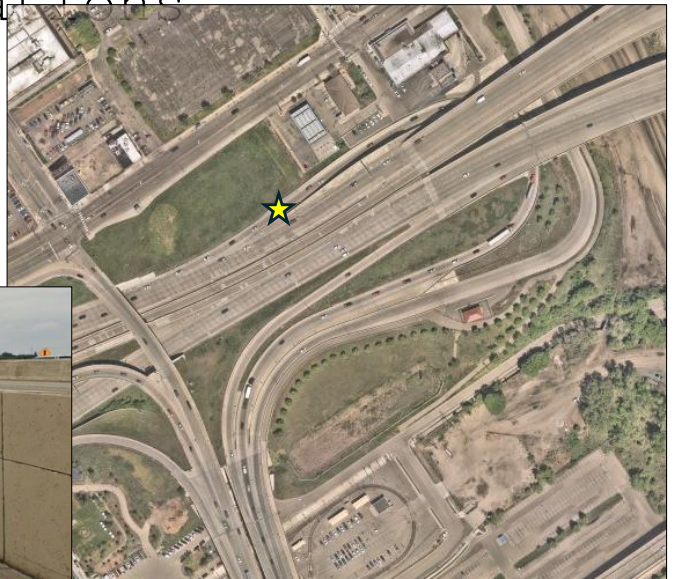


	Kittson / 7th	WB I-94	EB I-94
Start	711 (573)	1,152 (1,040)	205 (298)
Plato	135 (154)	386 (331)	183 (281)

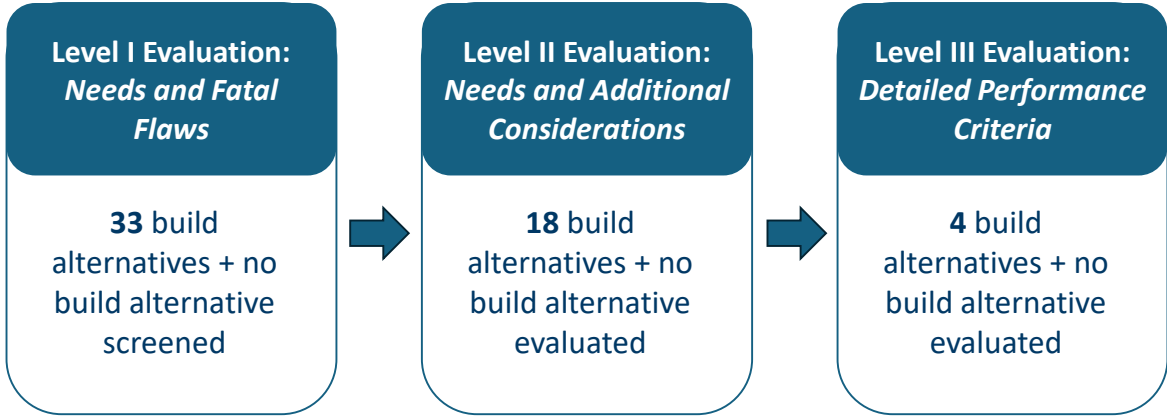


# Existing Operations

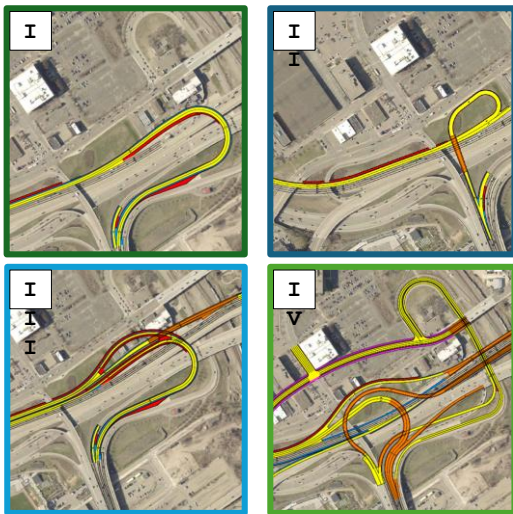
- Ramp Curvature
- Heavy Vehicles
- Vertical Grade



# Alternatives



# Alternatives



- Level 1** Evaluates against needs and fatal flaws
- Level 2** Evaluates against needs and additional considerations
- Level 3** Evaluates performance against detailed criteria





# Evaluation Criteria

## Vehicle Safety

- Reduces Risk of Fatal + Injury Crashes
- Reduces Risk of Total Crashes
- Number of Weaving Maneuvers
- Speed Shear & Speed Gradient

## Vehicle Mobility

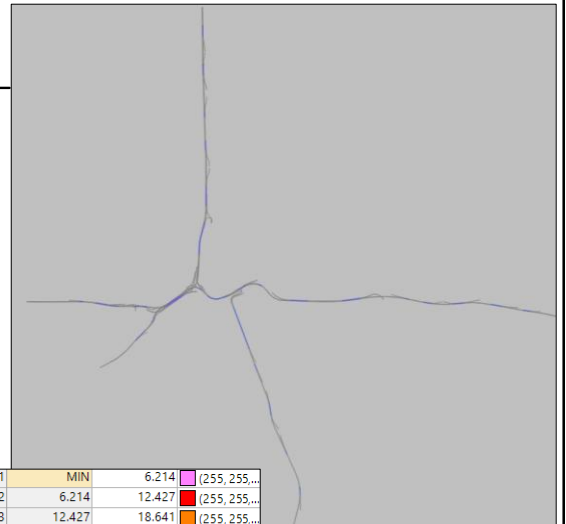
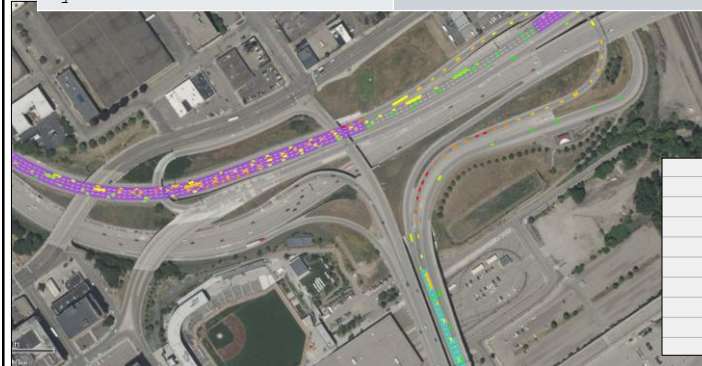
- Corridor Measures of Effectiveness (MOEs)
  - Level-of-Service
  - Travel Times
- System Vehicle Hours Traveled (VHT)



# Evaluation Criteria

## Vehicle Mobility

Performance Measure	Methodology
Corridor Measures of Effectiveness	VISSIM Model Output
System Travel Time	



1	MIN	6.214	(255, 255, ...)
2		6.214	(255, 255, ...)
3		12.427	(255, 255, ...)
4		18.641	(255, 255, ...)
5		24.855	(255, 255, ...)
6		31.069	(255, 198, ...)
7		37.282	(255, 128, ...)
8		49.710	(255, 0, 2, ...)
9		62.137	(255, 0, 1, ...)
10		74.565	(255, 0, 1, ...)



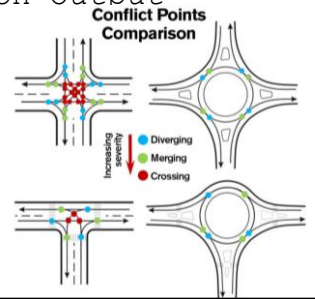
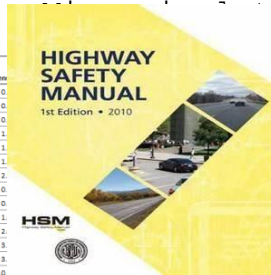
# Evaluation Criteria

## Vehicle Safety

- Crash Modification Factors (CMFs)
- Crash Rates
- Highway Safety Manual (HSM)
  - Predicted Crashes/Safety
- Conflict Points
- Interactive Highway Safety Design Model (IHSDM)

Statewide Crash Densities by Critical Rate Category  
Minnesota, 2017 through 2021 Crashes

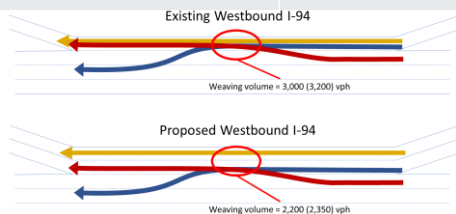
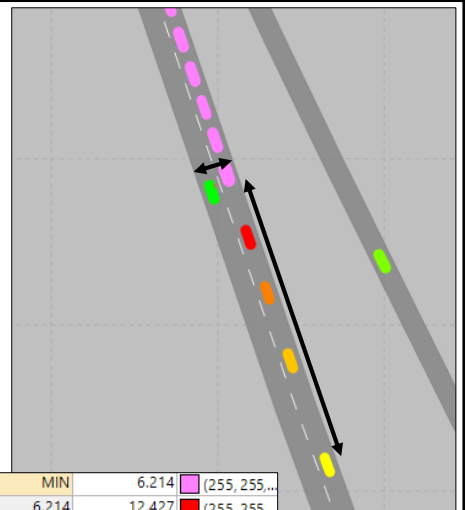
Miles	VMT	Junction and Non-Junction Crashes				Non-Junction Crashes Only				
		K/A Crashes	Total Crashes	KA Dens.	TOT Dens.	K/A Crashes	Total Crashes	KA Dens.	TOT Dens.	
Rural 2-Lane AADT 1-1499	3,475.0	5,405,305,241	213	2,723	0.012	0.157	168	2,182	0.010	0
Rural 2-Lane AADT 1500-4999	3,751.7	18,564,262,295	469	8,039	2.526	0.433	329	5,896	0.018	0
Rural 2-Lane AADT 5000-7999	545.7	6,060,891,464	150	2,894	2.475	0.478	101	1,924	0.037	0
Rural 2-Lane AADT 8000+	206.6	4,012,184,319	96	2,153	2.393	0.537	66	1,337	0.064	1
Rural 4-Lane Divided	40.2	747,615,656	7	552	0.936	0.738	3	321	0.015	1
Rural Expressway	753.9	15,771,470,815	212	7,374	1.344	0.468	130	4,961	0.034	1
Rural Freeway	654.1	20,672,883,497	154	10,547	0.745	0.510	136	9,172	0.042	2
Urban 2-Lane AADT 1-1499	158.9	280,720,489	18	219	6.412	0.780	11	113	0.014	0
Urban 2-Lane AADT 1500-4999	494.5	2,782,752,330	80	2,311	2.875	0.830	39	1,025	0.016	0
Urban 2-Lane AADT 5000-7999	208.3	2,416,363,897	58	2,613	2.814	1.081	36	1,101	0.035	1
Urban 2-Lane AADT 8000+	205.1	4,632,615,461	104	6,489	2.245	1.185	52	2,128	0.051	2
Urban 4-Lane Divided	166.9	6,035,733,616	175	11,085	2.899	1.837	48	3,135	0.058	3
Urban Expressway	324.4	13,246,226,356	293	13,093	1.910	0.988	89	5,470	0.055	3
Urban Freeway	416.4	48,142,982,112	270	44,768	0.561	0.930	154	21,249	0.074	10
Other	0.0	0	0	0	N/A	N/A	0	0	N/A	N/A
<b>All Trunk Highway Sections</b>	<b>11,401.6</b>	<b>148,771,807,538</b>	<b>2,269</b>	<b>111,860</b>	<b>1.525</b>	<b>0.765</b>	<b>1,362</b>	<b>60,014</b>	<b>0.024</b>	<b>1,053</b>



# Evaluation Criteria

## Vehicle Safety

Performance Measure	Methodology
Reduces Risk of Fatal and Injury Crashes	Surrogate Safety Assessment Model (SSAM)
Reduces Risk of All Crashes	
Number of Weaving Maneuvers	O-D Volumes & VISSIM Model Output
Speed Shear and Speed Gradient	VISSIM Model Output



2	6.214	12.427	18.641	24.855	31.069	37.282	49.710	62.137	74.565	124.274
3	12.427	18.641	24.855	31.069	37.282	49.710	62.137	74.565	124.274	
4	18.641	24.855	31.069	37.282	49.710	62.137	74.565	124.274		
5	24.855	31.069	37.282	49.710	62.137	74.565	124.274			
6	31.069	37.282	49.710	62.137	74.565	124.274				
7	37.282	49.710	62.137	74.565	124.274					
8	49.710	62.137	74.565	124.274						
9	62.137	74.565	124.274							
10	74.565	124.274								



# Surrogate Safety Assessment Model (SSAM)



- Use alongside traffic microsimulation
- Vehicle trajectories to evaluate potential conflicts
- Conflict Types:
  - Rear-End
  - Lane Change
  - Crossing
- Conflict Severity
  - Time To Collision (TTC)
  - Post-Encroachment Time (PET)
  - Max speed differential (MaxDeltaV)
  - Probability of Unsuccessful Evasive Action (P(UEA))

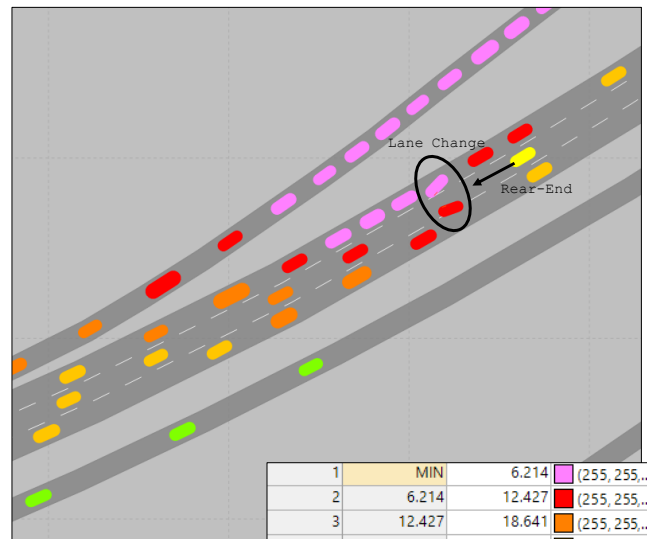
Surrogate Safety Assessment Model (SSAM) | FHWA (dot.gov)



## SSAM - Step 1

### Convert to crashes per year

- Probability of Unsuccessful Evasive Action (P(UEA))
- Coefficients determined based on calibrating to existing data



$$\frac{\text{Crashes}}{\text{Year}} = 71.1 * \left( \frac{\sum P(\text{Unsuccessful Evasive Action for Each Conflict})}{\text{Hour}} \right)^{0.24}$$

# SSAM - Step 2

## Estimate Maximum Abbreviated Injury Scale (MAIS)

• National Highway Traffic Safety Administration (NHTSA) Research

- MAIS 0 - No Injury
- MAIS 5 - Critical Injury

• Maximum Speed Differential, D

$$P(MAIS\ 1) = \frac{e^{-1.3925+0.0815 \cdot D}}{1 + e^{-1.3925+0.0815 \cdot D}} - \frac{e^{-5.1331+0.1479 \cdot D}}{1 + e^{-5.1331+0.1479 \cdot D}}$$

$$P(MAIS\ 2) = \frac{e^{-5.1331+0.1479 \cdot D}}{1 + e^{-5.1331+0.1479 \cdot D}} - \frac{e^{-6.9540+0.1637 \cdot D}}{1 + e^{-6.9540+0.1637 \cdot D}}$$

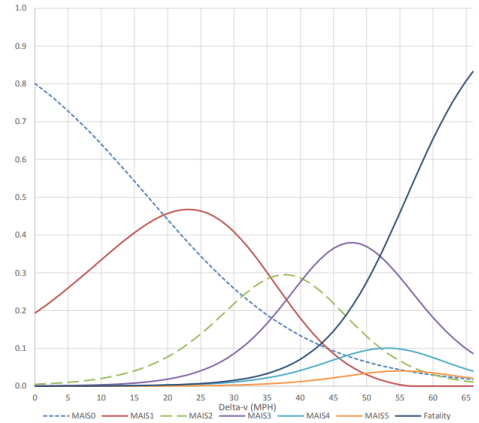
$$P(MAIS\ 3) = \frac{e^{-6.9540+0.1637 \cdot D}}{1 + e^{-6.9540+0.1637 \cdot D}} - \frac{e^{-8.2070+0.1564 \cdot D}}{1 + e^{-8.2070+0.1564 \cdot D}}$$

$$P(MAIS\ 4) = \frac{e^{-8.2070+0.1564 \cdot D}}{1 + e^{-8.2070+0.1564 \cdot D}} - \frac{e^{-8.7927+0.1598 \cdot D}}{1 + e^{-8.7927+0.1598 \cdot D}}$$

$$P(MAIS\ 5) = \frac{e^{-8.7927+0.1598 \cdot D}}{1 + e^{-8.7927+0.1598 \cdot D}} - \frac{e^{-8.9819+0.1603 \cdot D}}{1 + e^{-8.9819+0.1603 \cdot D}}$$

$$P(Fatal) = \frac{e^{-8.9819+0.1603 \cdot (D+k_{fac})}}{1 + e^{-8.9819+0.1603 \cdot (D+k_{fac})}}$$

$$P(MAIS\ 0) = 1 - P(MAIS\ 1) - P(MAIS\ 2) - P(MAIS\ 3) - P(MAIS\ 4) - P(MAIS\ 5) - P(Fatal)$$



MAIS(05/08) Injury Probability Curves as Functions of Delta V (dot.gov)

# SSAM - Step 3

## MAIS to KABCO

• National Highway Traffic Safety Administration (NHTSA) Research

	K	A	B	C	O
<b>MAIS 0</b>	0.00	0.01	0.08	0.30	0.88
<b>MAIS 1</b>	0.00	0.05	0.40	0.40	0.11
<b>MAIS 2</b>	0.00	0.17	0.27	0.15	0.01
<b>MAIS 3</b>	0.00	0.23	0.14	0.09	0.00
<b>MAIS 4</b>	0.00	0.25	0.10	0.05	0.00
<b>MAIS 5</b>	0.00	0.28	0.01	0.02	0.00
<b>Fatal</b>	1.00	0.00	0.00	0.00	0.00

Probability of A for some Conflict

$$Prob(A) = 0.01 * P(MAIS\ 0) + 0.05 * P(MAIS\ 1) + 0.17 * P(MAIS\ 2) + 0.23 * P(MAIS\ 3) + 0.25 * P(MAIS\ 4) + 0.28 * P(MAIS\ 5) + 0 * P(Fatal)$$

KABCO-to-MAIS Translators - 2022 Update (dot.gov)



# SSAM - Step 4

## Estimate crash severity per year

- KABCO distribution for each conflict
- Measure sum of all conflicts to determine the overall KABCO distribution
- Apply distribution to the crashes per year identified in Step 1

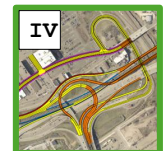
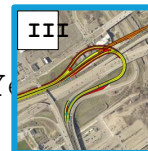
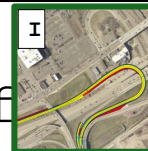
$$\left. \begin{matrix} \sum Prob(K) \\ \sum Prob(A) \\ \sum Prob(B) \\ \sum Prob(C) \\ \sum Prob(O) \end{matrix} \right\} \frac{Crashes}{Year}$$



# Findings - Vehicle Safety

## Crash Risk

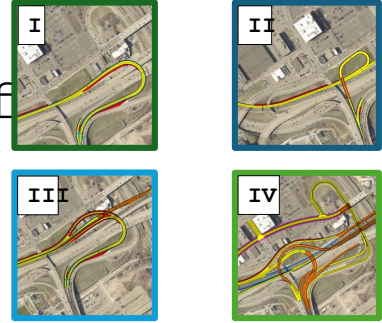
- Predicted Crashes/Year - Future Year 2055
- NB TH 52: Entire segment
- WB I-94: From Mounds Blvd to NB I-35E



Severity	No Build	Alternative I	Alternative II	Alternative III	Alternative IV
Fatal (K)	0.80	1.08	0.54	0.64	0.53
Serious Injury (A)	2.05	1.51	1.18	1.41	1.25
Minor Injury (B)	22.59	16.43	12.92	15.55	13.75
Possible Injury (C)	111.26	75.33	62.71	75.60	67.18
Non-Injury/Injury	385.26	248.57	215.10	259.58	231.48

# Findings - Vehicle Safety

- Risk of Fatal + Injury Crashes
- Risk of Total Crashes



	No Build	Alternative I	Alternative II	Alternative III	Alternative IV
Fatal + Injury Crashes	136.7	94.4	77.4	93.2	82.7
	-	- 31.0%	- 43.4%	- 31.8%	- 39.5%
Total Crashes	522.0	342.9	292.5	352.8	314.2
	-	- 34.3%	- 44.0%	- 32.4%	- 39.8%

- Metrics are represented as crashes/year for year 2045
- Metrics are represented as % change from the No Build Alternative

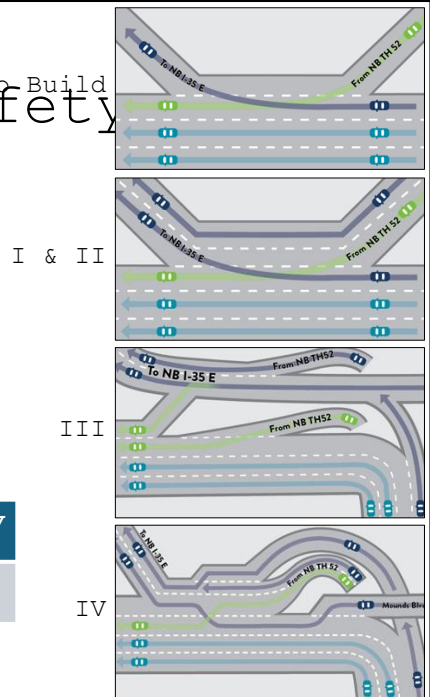


# Findings - Vehicle Safety

## Number of Weaving Maneuvers

- Focused on WB I-94 weaving section influence area
  - NB TH 52 Entrance to NB I-35E Exit
- Recorded Lane Changes from VISSIM
  - Ramp to Freeway
  - Freeway to Ramp

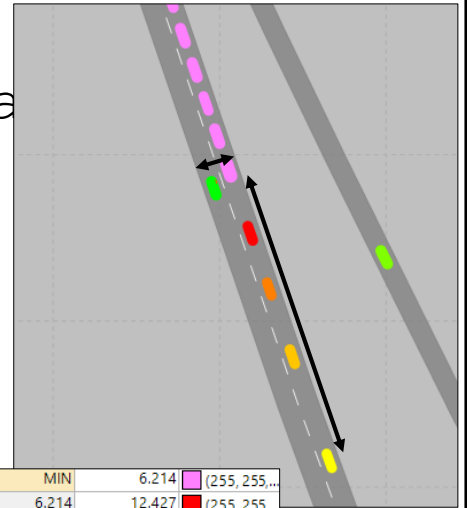
Total Lane Changes	Alternative I	Alternative II	Alternative III	Alternative IV
Percent Change from No Build	- 17.7%	- 18.7%	- 52.6%	- 55.0%



# Findings - Vehicle Safety

## Speed Shear & Speed Gradient

- Lane-by-lane speeds recorded every 500'
  - NB TH 52: Entire segment
  - WB I-94: From Mounds Blvd to NB I-35E
- Measure the sum of all maximum speed gradients & shears



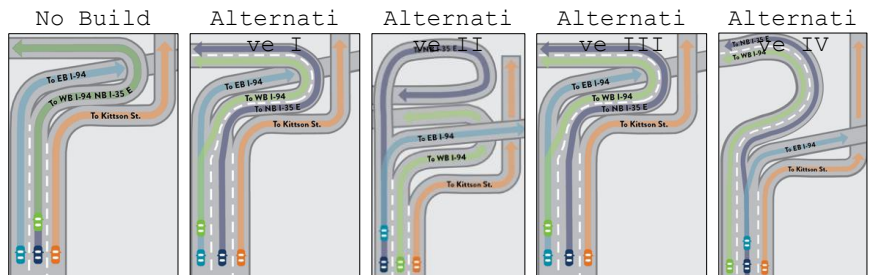
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8	49.710	62.137	(255, 0, 2...
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# Findings - Vehicle Safety

## Speed Shear & Speed Gradient

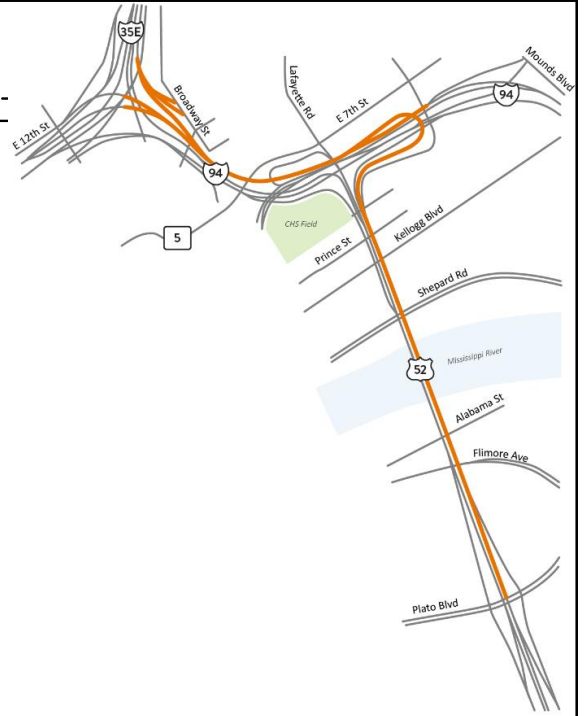
- NB TH 52



	No Build	Alternative I	Alternative II	Alternative III	Alternative IV
Sum of Max Speed Shears (mph)	500	341	401	340	349
	-	- 32%	- 20%	- 32%	- 30%
Sum of Max Speed Gradients	159	115	125	116	117
• Metrics are the AM and PM Peak Hours Combined	-	- 28%	- 22%	- 27%	- 26%

## Future Opportunity:

- Application of SSAM
  - Complex transportation networks
  - Crashes related to congestion
- More research:
  - Calibration
  - Vehicle headings
  - Vehicle types



## Questions?

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