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Performance Based Practical Design/Data Driven Safety Analysis

Module 2 – Michigan Safety Analysis Maps

Session Starts at 10 am

Welcome

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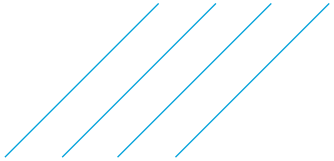
Agenda

- Welcome
- Intro from MDOT
- Review from Module 1
- Michigan Safety Crash Analysis Maps: Background
- Crash Modification Factors
- Break
- Michigan Safety Crash Analysis Maps: Planning Analysis vs Project Analysis
- Michigan Safety Crash Analysis Maps: Adjustment Factors
- Michigan Safety Crash Analysis Maps: Examples
- Wrap-up



Intro from MDOT

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Review from Module 1

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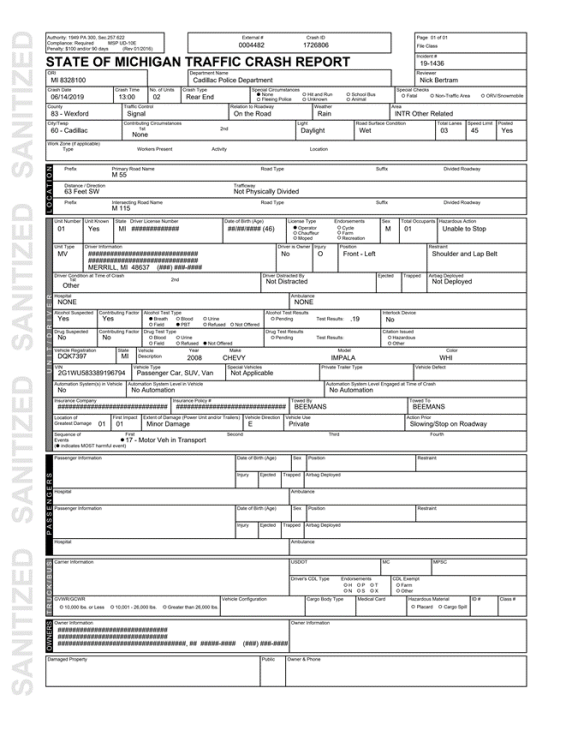
What is DDSA?

Using tools to analyze crash and roadway data to predict the safety impacts of highway projects allows agencies to target investments with more confidence and reduce severe crashes on the roadways.

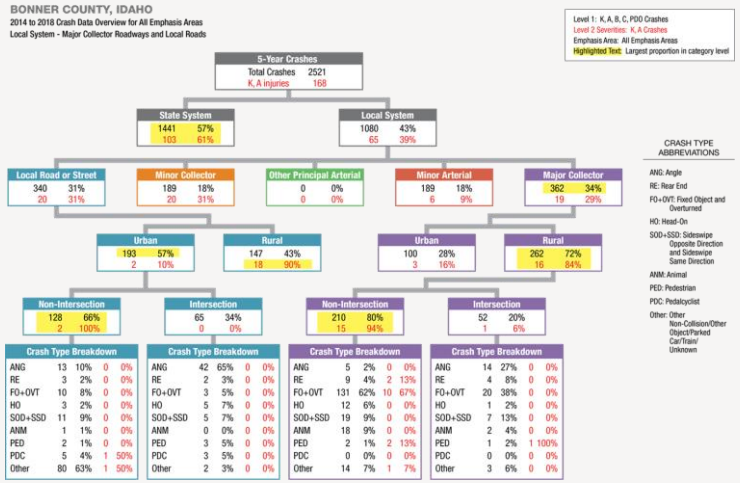
Source: FHWA

Safety Data Analysis

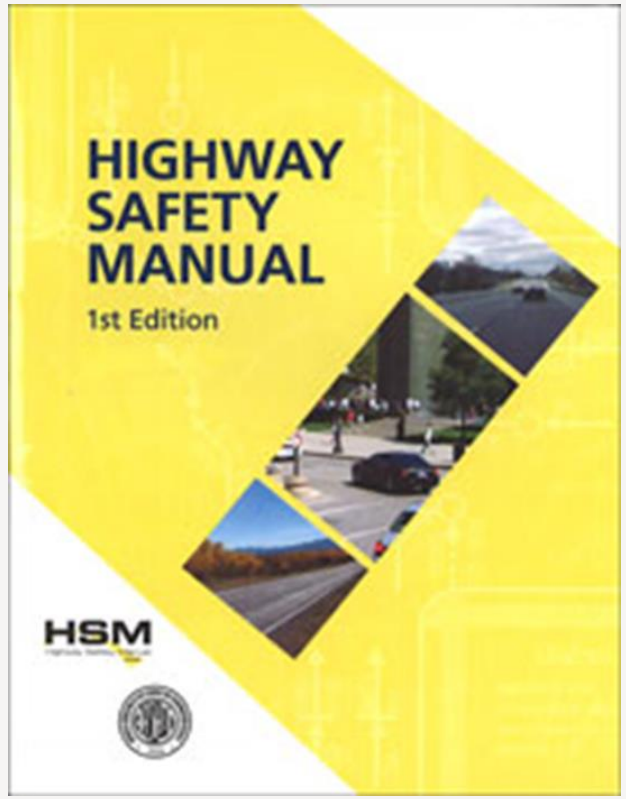


STATE OF MICHIGAN TRAFFIC CRASH REPORT

Crash Data Collection



Spot vs. Systemic



Predictive/HSM

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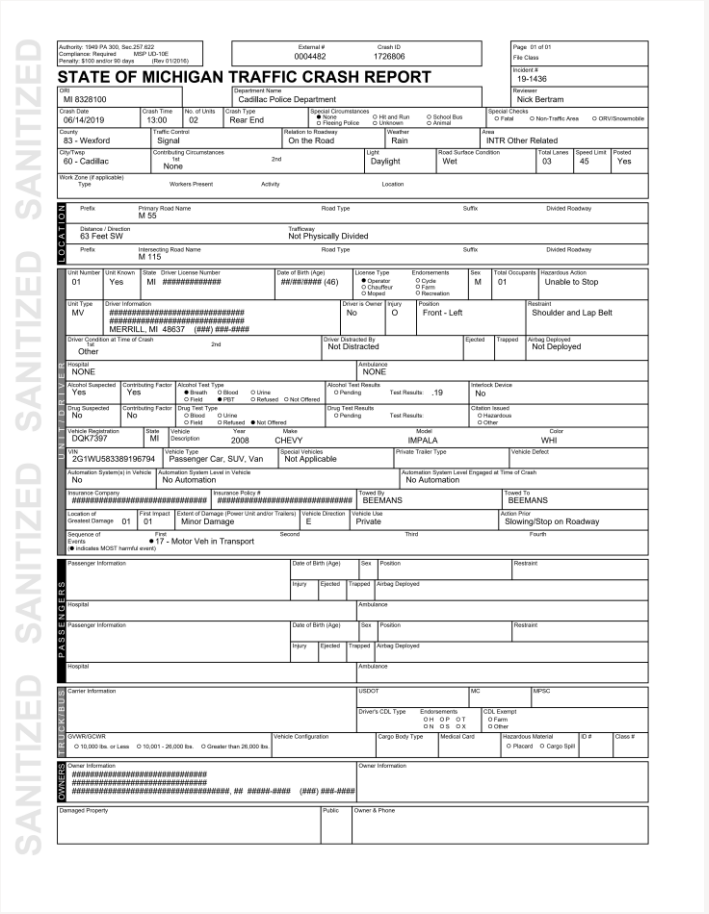
Issues with Traditional Crash Analysis

HSM Addresses:

- Quality & accuracy
- Reporting thresholds
- Frequency-severity
- Differences between jurisdictions
- Randomness and change



STATE OF MICHIGAN TRAFFIC CRASH REPORT

SANITIZED

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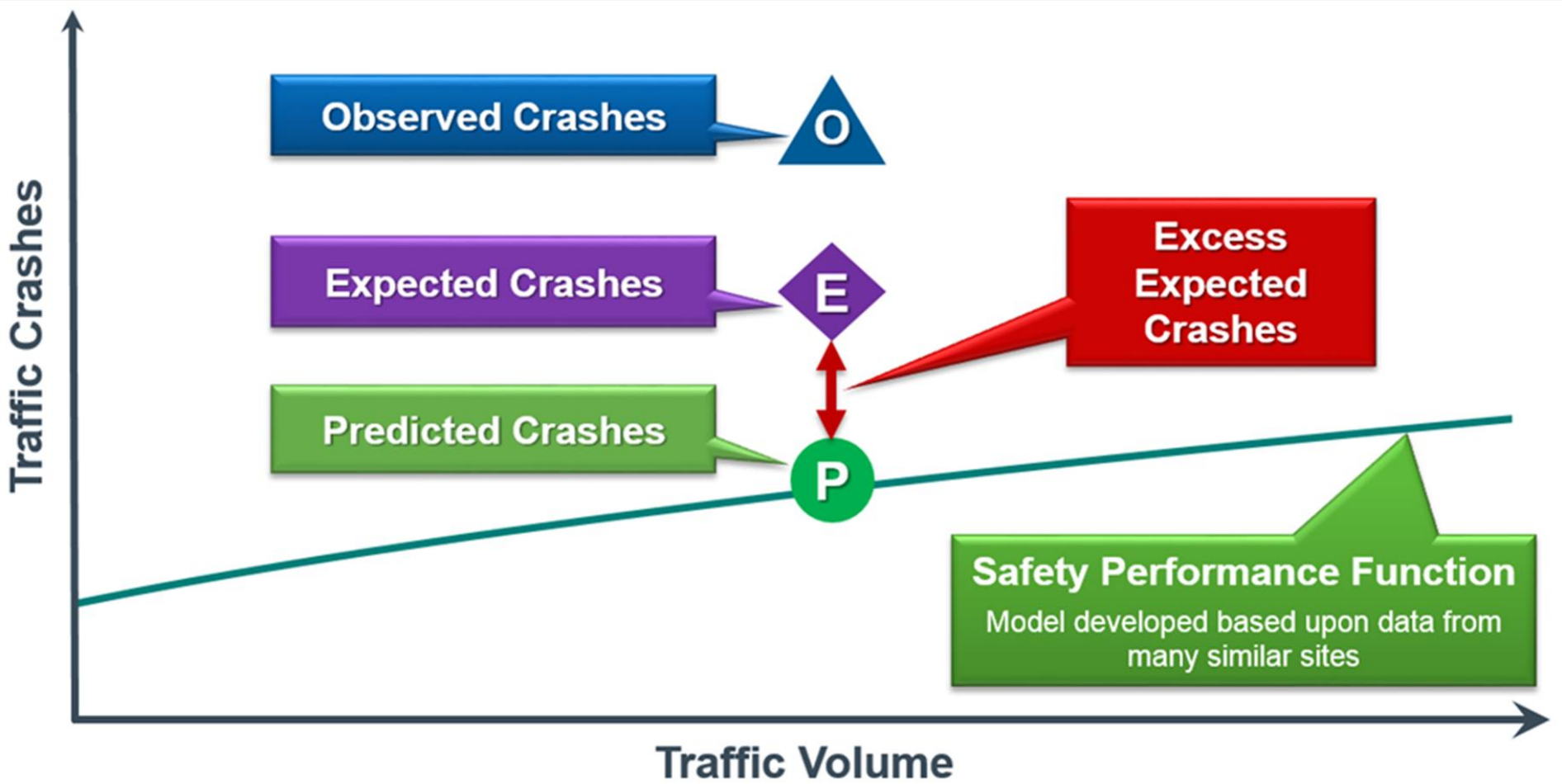
HSM Performance Measures



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Appropriate Level of Safety Analysis

Category Type	Program/Project Type	Project Examples	Crash Analysis Tier
Roadway Maintenance	Road Capital Preventive Maintenance (CPM) • Pavement Seal • Functional Enhancement	Micro-Surfacing, Ultra-Thin Overlay Overlay, Shoulder Ribbons	Tier I*
Roadway Maintenance	Freeway Resurfacing Program (FRP)	Single or Two Course Overlay	Tier I*
Roadway Maintenance	Non-Freeway Resurfacing Program (NFRP)	HMA Overlay	Tier I*
Safety – Non-Pavement	Guardrail	Cable barrier, guardrail, median barrier	Tier I*

Appropriate Level of Safety Analysis

Category Type	Program/Project Type	Project Examples	Crash Analysis Tier
3R – Resurfacing, Restoration and Rehabilitation	Bridge	Overlay, widen lanes, barrier/railing replacement	Tier II
	Road – Pavement	Resurfacing, milling, concrete overlays, inlays	
	Road – Operational	Passing relief lanes, turn lanes, thru lanes	
	Road – Safety	Minor alignment improvements, roadside safety improvements, lane or shoulder widening, intersection or rail-grade crossing upgrades	

Appropriate Level of Safety Analysis

Category Type	Program/Project Type	Project Examples	Crash Analysis Tier
3R – Resurfacing, Restoration and Rehabilitation	Road - Major Pavement Reconstruction	Full-Depth Replacement Only	Tier III
4R – Reconstruction or Replacement	Bridge	Bridge deck or superstructure replacement	Tier IV
	Roadway Reconstruction	Major alignment of geometric improvements, intermittent grade modifications (over 50%)	
	Roadway Operational Improvements	Adding lanes to increase capacity	
New Construction	Construction of new facility	Construction of additional miles of roadway or new bridge on new alignment	Tier IV

Michigan Safety Crash Analysis Maps: Background

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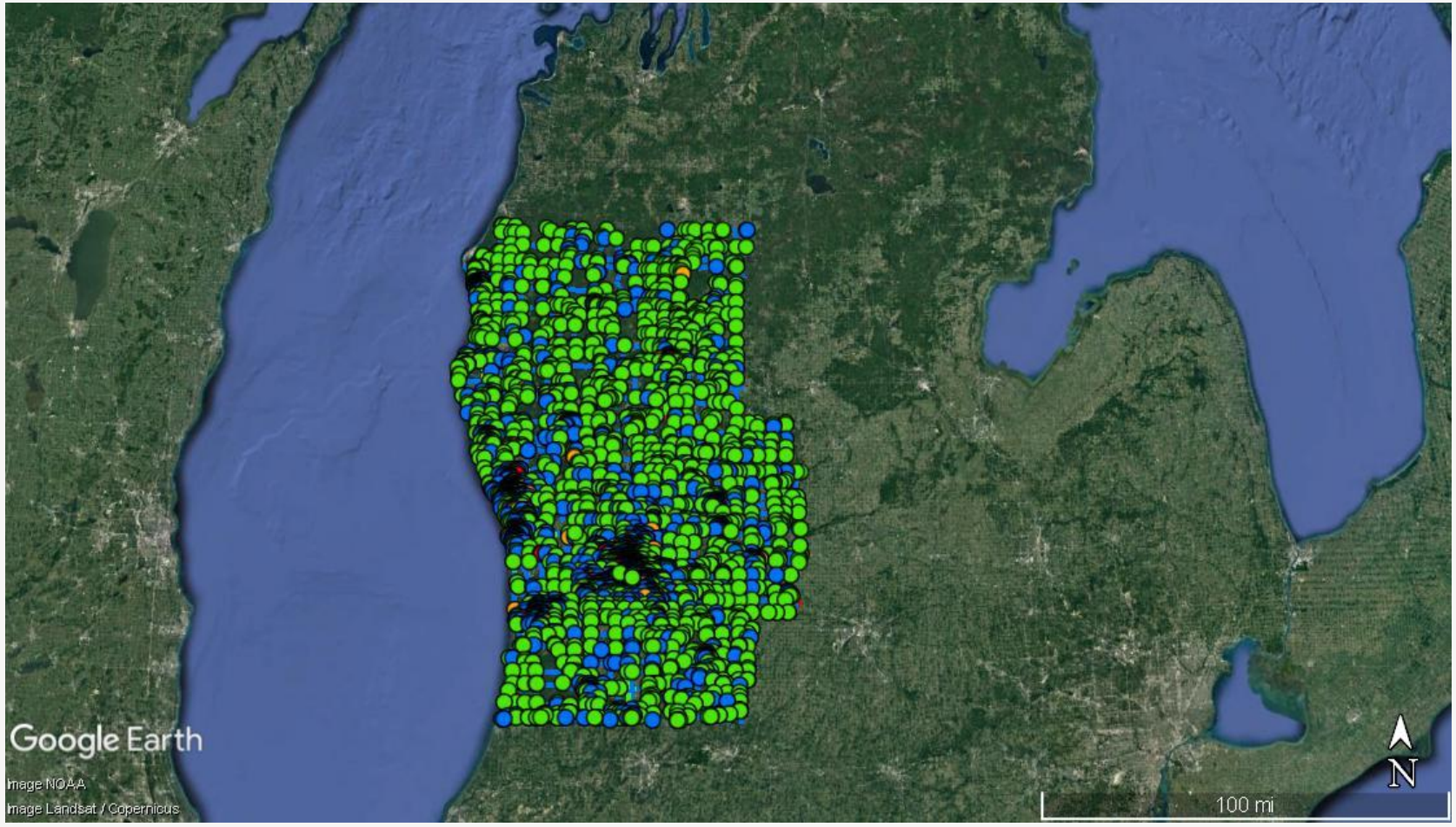
Crash Data Collection



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Acronyms

- CMF – Crash modification factor
- FI – Fatal and injury crashes
- EB – Empirical Bayes Approach
- HSM – Highway Safety Manual
- LOSS – Level of Service Safety
- PDO – Property damage only crashes
- SPF – Safety Performance Function

Analysis Background

Planning Level Analysis

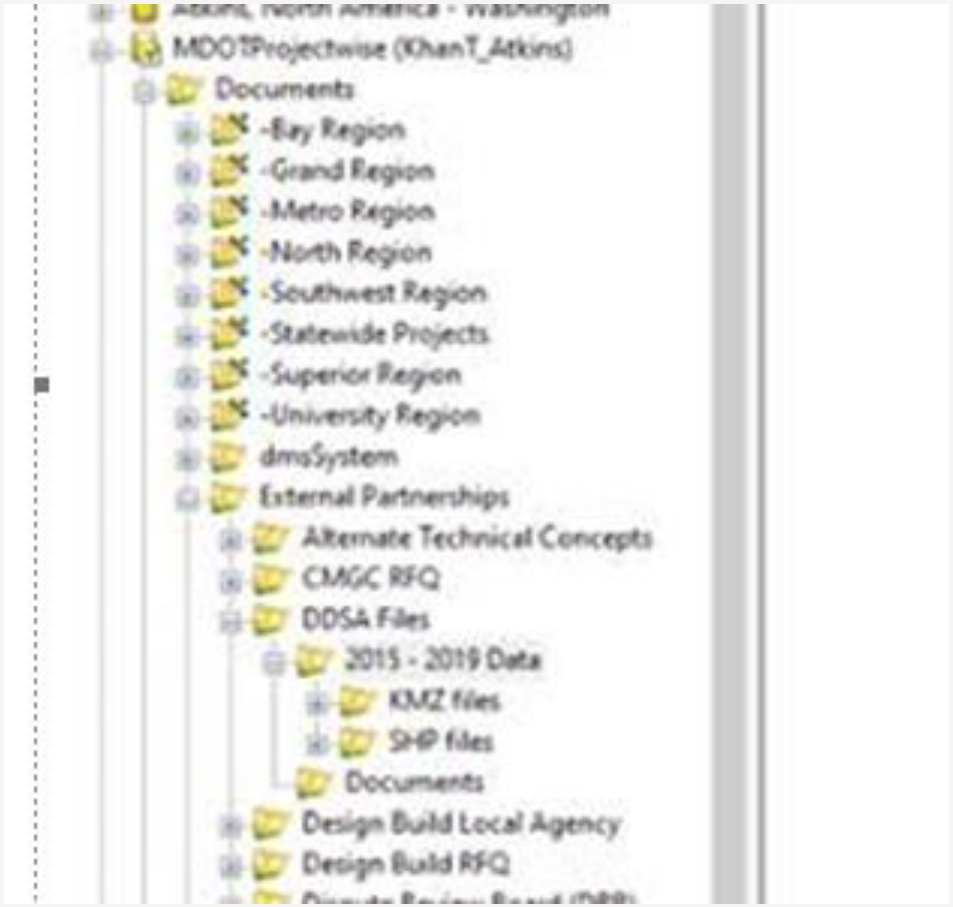
- Segmentation –FHWA Highway Performance Management System (HPMS)
- Safety Performance Functions
  - MDOT SPF's
  - HSM SPF's
- AADT and Roadway Characteristics – HPMS
- Adjustments needed in some cases
- KMZ and SHP

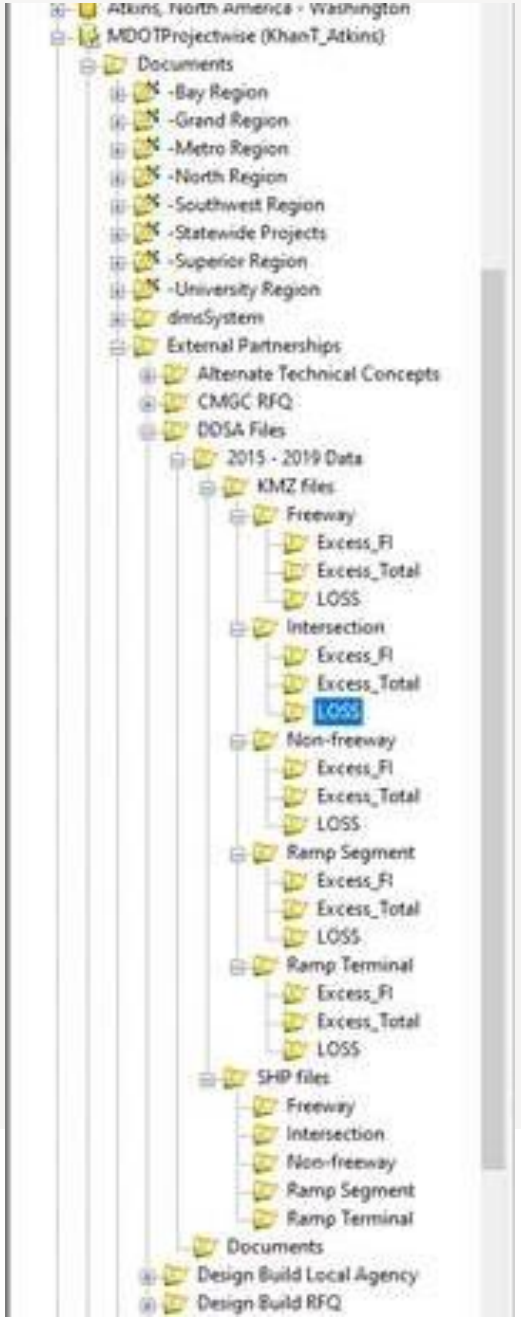
Available Files

For each region, the following files exist in KMZ and SHP format for:

- Total – Excess Expected Total Crashes
- FI – Excess Expected Fatal and Injury Crashes
- LOSS – Level of service safety

Available File - ProjectWise





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Roadway Network

- All federal-aid roadways (trunkline and local agency)
- Segmented using HPMS to increase network coverage from previous versions
- Intersections, segments, ramps, ramp terminals, freeway segments
- If intersection node not present, data is included within the adjacent segment

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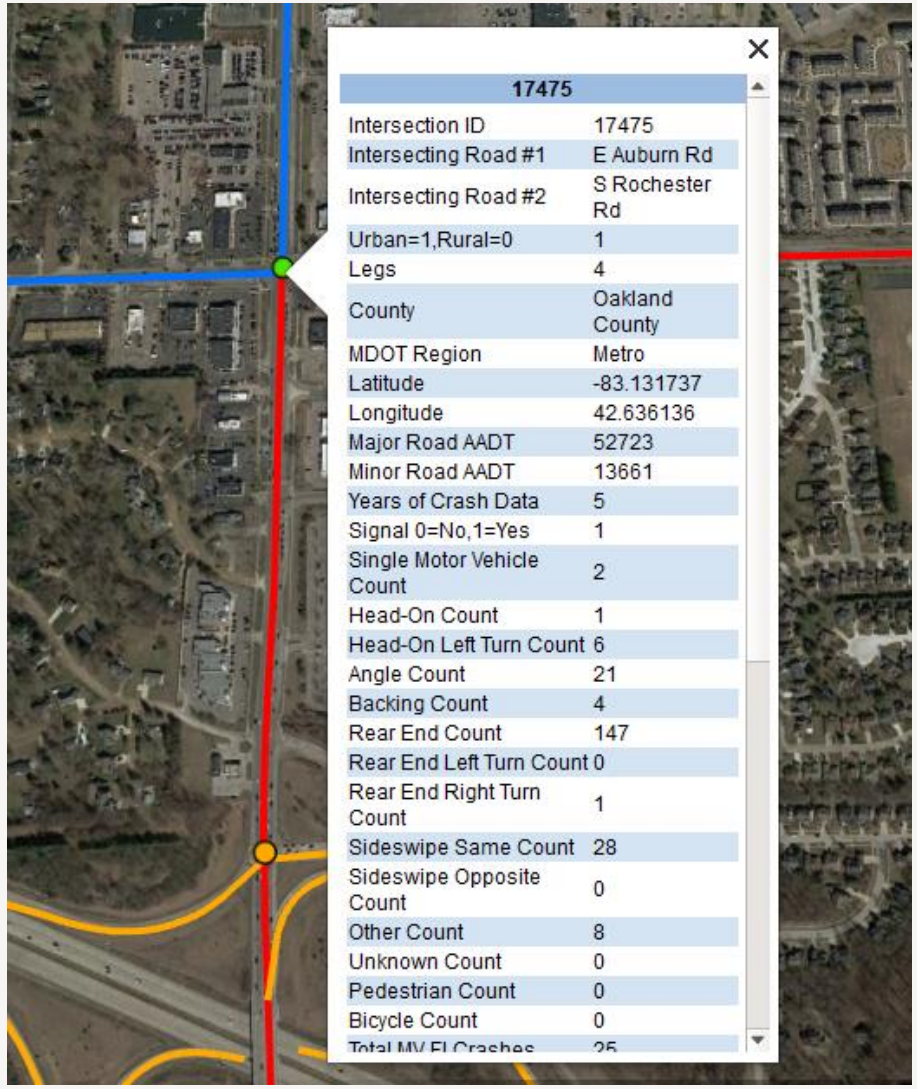
Data within each file (1 of 2)

- **Point ID** – unique ID for location
- **Estimated minor AADT** – used if no minor AADT in HPMS
- **Signal** – 1=yes, 0=no
- **Crash counts** – observed crash frequency totals for five years (2014-2018) by crash type from UD-10 coding
- **Predicted FI** – Average annual predicted fatal and injury crashes which is (predicted fatal crashes + predicted injury crashes)
- **Predicted PDO** – Average annual predicted PDO crashes
- **Predicted Total** - Average annual predicted total crashes which is (predicted fatal crashes + predicted injury crashes + predicted PDO crashes)



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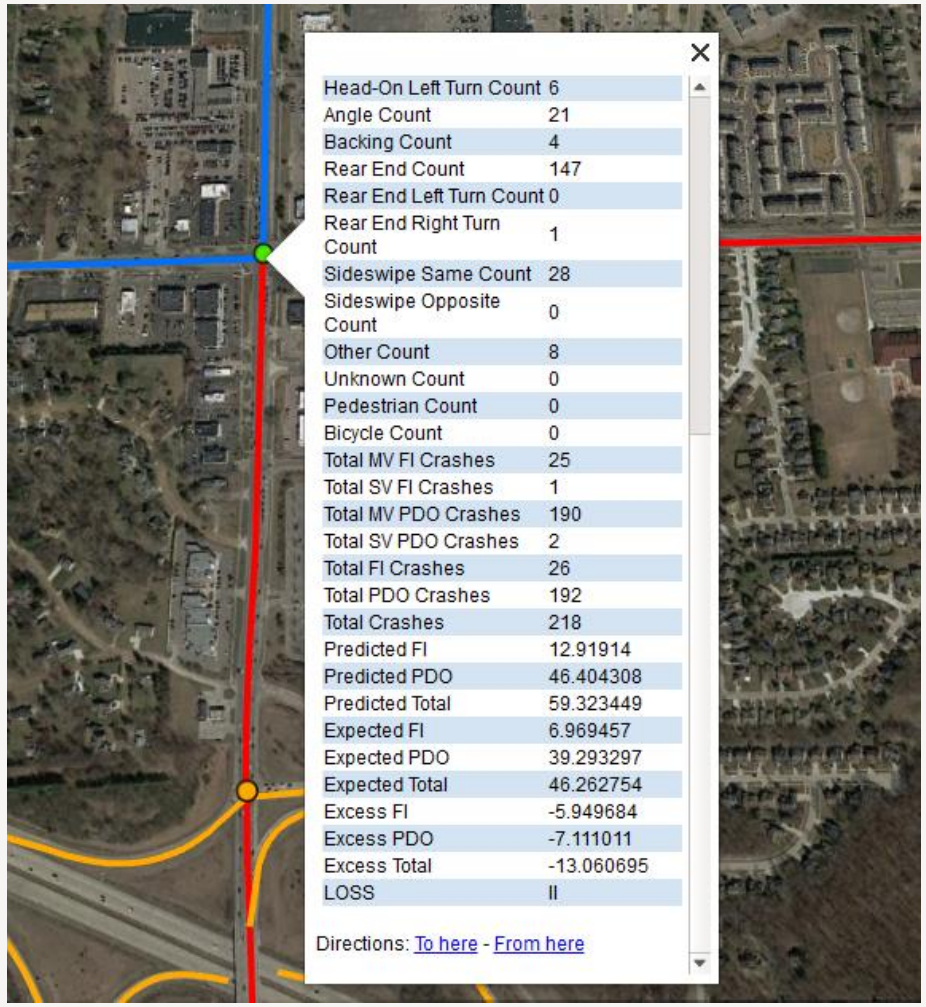
Data within each file (2 of 2)

- **Expected FI** – Average annual expected fatal and injury crashes which is (expected fatal crashes + expected injury crashes)
- **Expected PDO** – Average annual expected PDO crashes
- **Expected Total** - Average annual expected total crashes which is (expected fatal crashes + expected injury crashes + expected PDO crashes)
- **Excess FI.** Excess expected fatal and injury crashes which is (Expected FI – Predicted FI)
- **Excess PDO.** Excess expected PDO crashes which is (Expected PDO – Predicted PDO)
- **Excess Total.** Excess expected total crashes which is ((Expected FI + Expected PDO) – (Predicted FI + Predicted PDO))
- **LOSS.** Level of service safety



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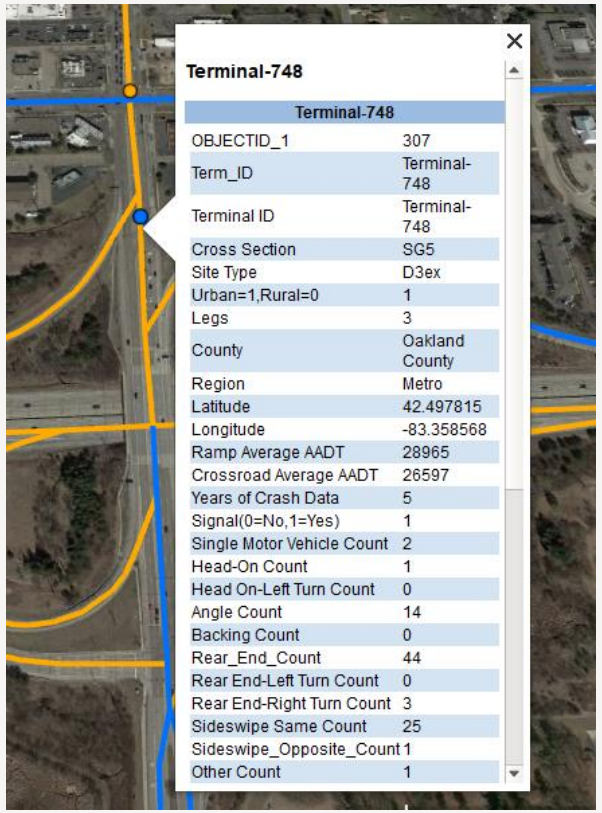
Non-Freeways

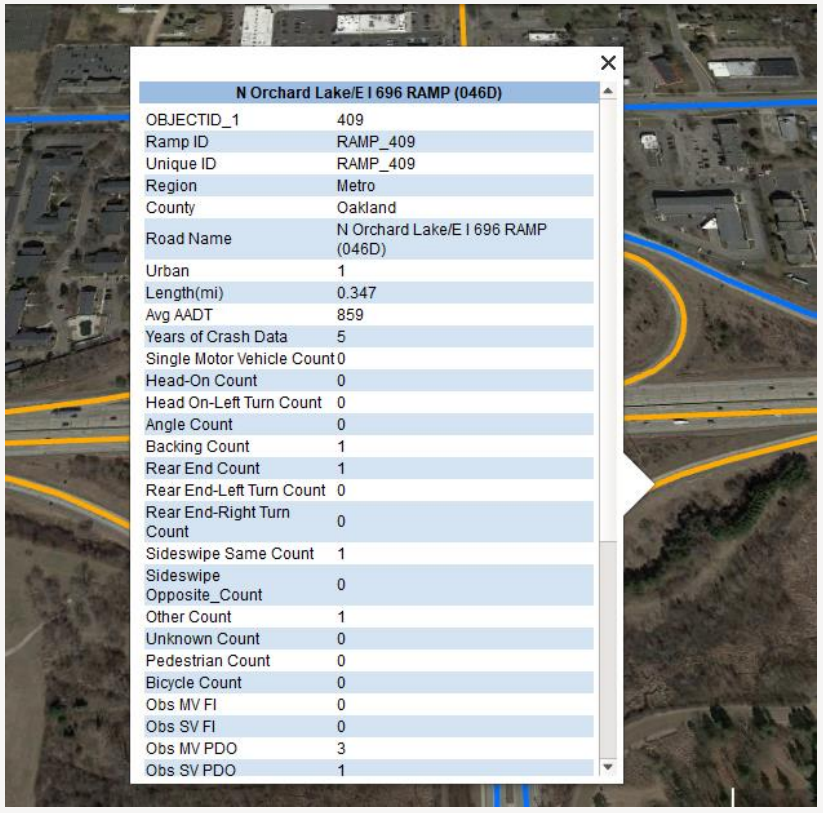
Segment Data Listing

Intersection Data Listing

Freeways



Ramp Terminal Data Listing



Ramp Segment Data Listing

Freeway Segment Data Listing

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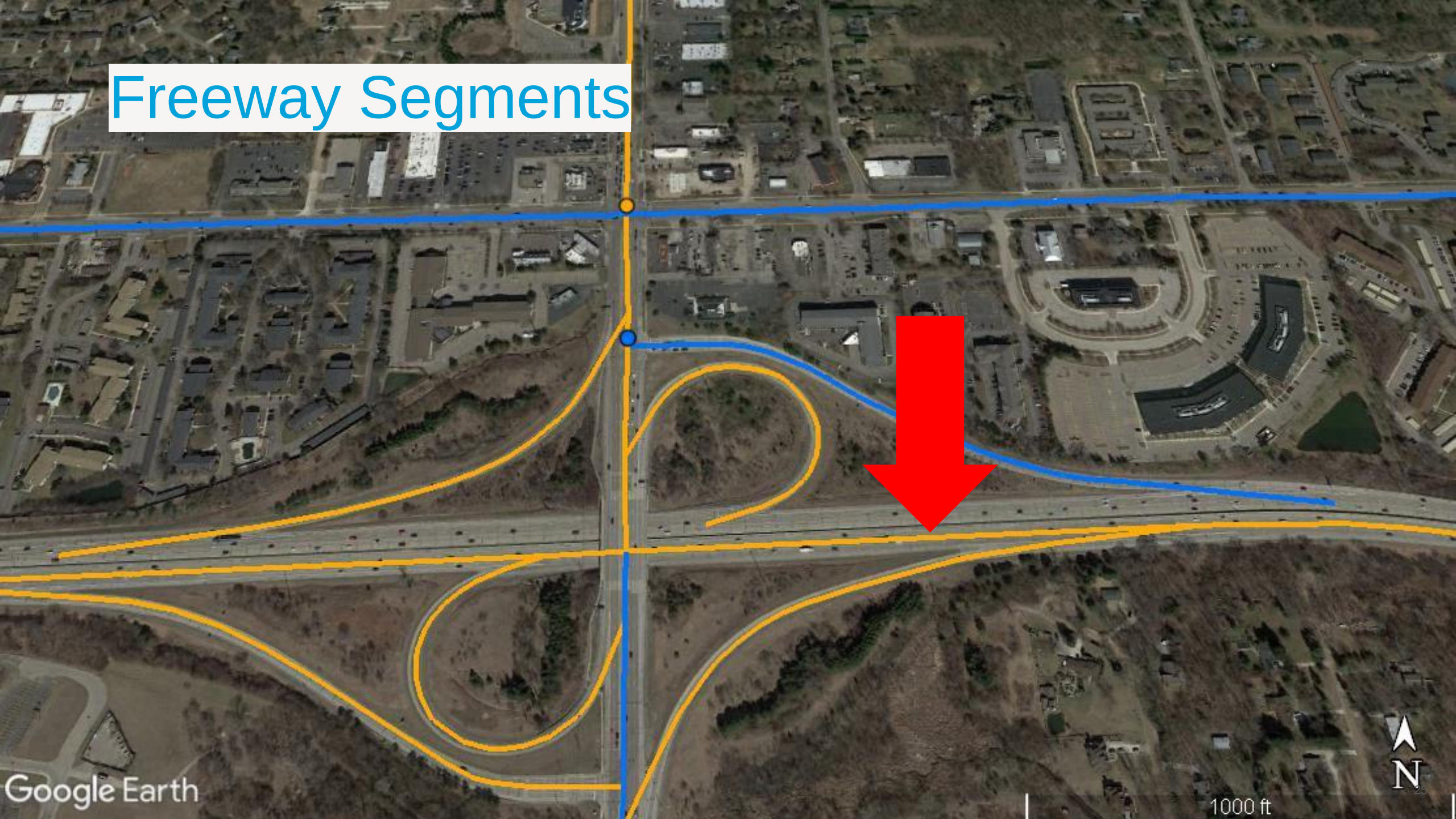
Freeway Segments



Rural Intersections

Show examples in Google Earth

Crash Modification Factors

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Crash Modification Factors (CMF)

$$CMF = \frac{\text{Expected Average Crash Frequency with Site Condition } b}{\text{Expected Average Crash Frequency with Site Condition } a}$$

Expressed as: CMF ± SE

SE is Standard Error

SE is used to determine low, medium, and high confidence interval for CMF

Crash Modification Factor

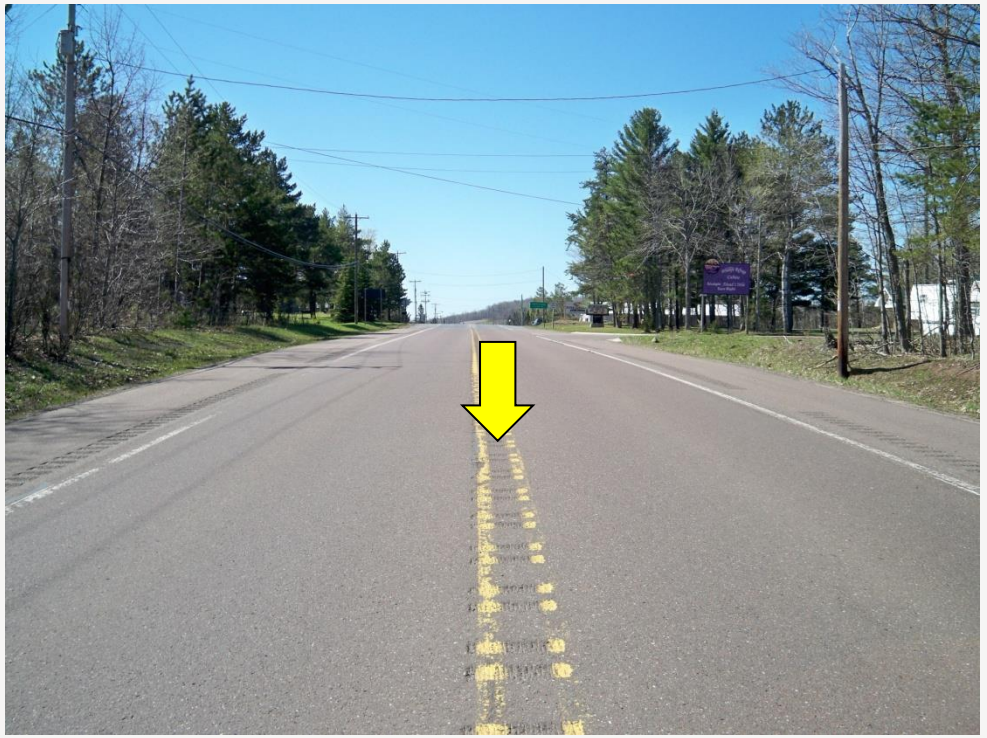
CMF = 0.88 for Total Crashes

Calculate Crash Reduction Factor (CRF)

CRF = 100 x (1.00 - CMF)

CRF = 100 X (1.00 – 0.88)

CRF = 12% reduction in total crashes



Centerline Rumble Strips

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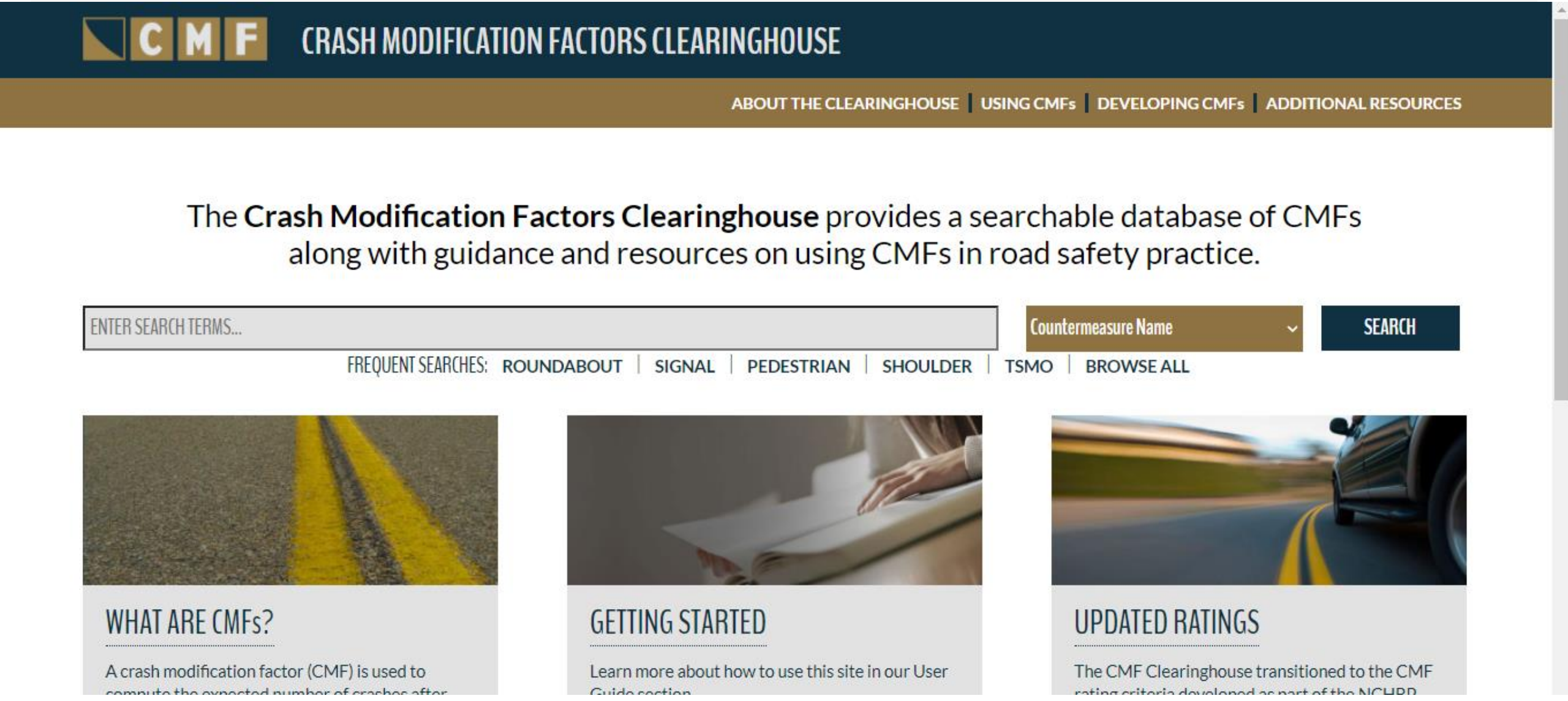
cmfclearinghouse.org



Crash Modification Factor

- [ ] 1 (0)
- [ ] 2 (3)
- [ ] 3 (0)
- [ ] 4 (1)
- [ ] 5 (1)

▸ COUNTRY

- [ ] U.S. & Canada (5)
- [ ] International (0)

▸ CRASH TYPE

▸ CRASH SEVERITY

▸ ROADWAY TYPE

▸ AREA TYPE

▸ INTERSECTION TYPE

▸ INTERSECTION GEOMETRY

▸ TRAFFIC CONTROL

▸ IN HSM

EXPORT ALL RESULTS TO EXCEL

▾ Category: Intersection traffic control (5)

▾ Subcategory: Traffic control visibility (5)

▸ Countermeasure: Add additional signal and upgrade to 12-inch lenses

▸ Countermeasure: Install larger signal lenses (12 inch)

▾ Countermeasure: Replace 8-inch red signal heads with 12-inch

Compare	CMF	CRF(%)	Quality	Crash Type	Crash Severity	Area Type	Reference	Comments
☐	0.58	42	★★★★★	Angle	All		SRINIVASAN ET AL., 2008	
☐	0.97	3	★★★★☆	All	All		SRINIVASAN ET AL., 2008	

Compare Reset Compare

*NOTE: You can compare CMFs across countermeasures, subcategories, and categories.

EXPORT ALL RESULTS TO EXCEL

Crash Modification Factor

CMF ID: 2333

REPLACE 8-INCH RED SIGNAL HEADS WITH 12-INCH

DESCRIPTION:

PRIOR CONDITION: *NO PRIOR CONDITION(S)*

CATEGORY: INTERSECTION TRAFFIC CONTROL

STUDY: *EVALUATION OF THE SAFETY EFFECTIVENESS OF SELECTED TREATMENTS AT URBAN SIGNALIZED INTERSECTIONS*, SRINIVASAN ET AL., 2008

Star Quality Rating:	★★★★★ [VIEW SCORE DETAILS]
Rating Points Total:	135

Crash Modification Factor (CMF)	
Value:	0.58
Adjusted Standard Error:	

Five Minute Break

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Michigan Safety Crash Analysis Maps: Planning vs. Project

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Planning Level vs. Project Level Analysis

Planning Level Analysis

- KMZ and SHP files are planning level analysis
- Network screening level with very few CMF's to adjust for geometric conditions

Project Level Analysis

- Quantify the safety impacts of geometric or traffic control modification
- Quantify the impacts of a design exception
- Need to apply additional CMF's to planning level analysis results to convert to a project level analysis

Planning Level → Project Level

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Equations

Project Level Expected FI = Expected FI * (CMF1 * CMF2 *CMF3 *….)

Project Level Expected PDO = Expected PDO * (CMF1 * CMF2 *CMF3 *….)

Project Level Expected Total = Project level Expected FI + Project level Expected PDO

Or

Project Level Expected Total = Expected Total * (CMF1 * CMF2 *CMF3 *….)

CMF Adjustments

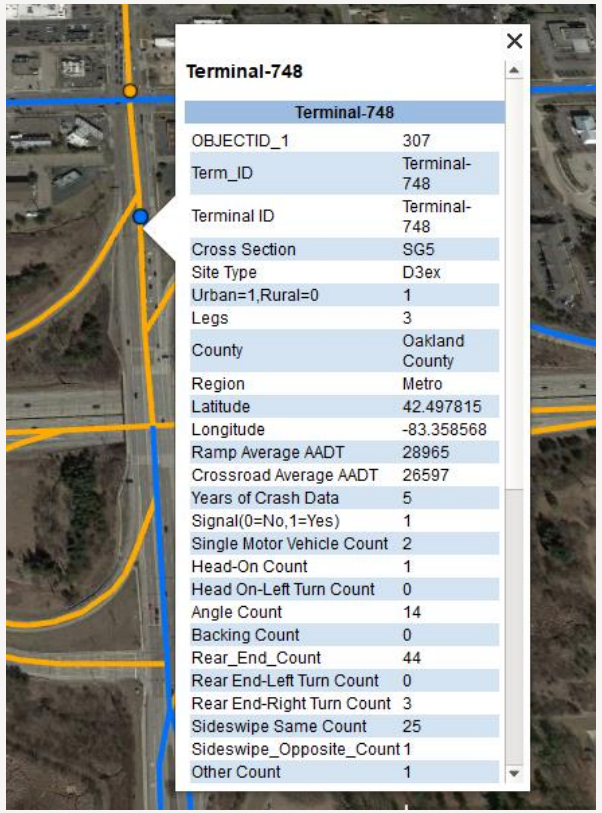
Intersections

- Lighting
- Right-turn on Red
- Median
- Number of lanes
- Speed Limit
- Traffic control

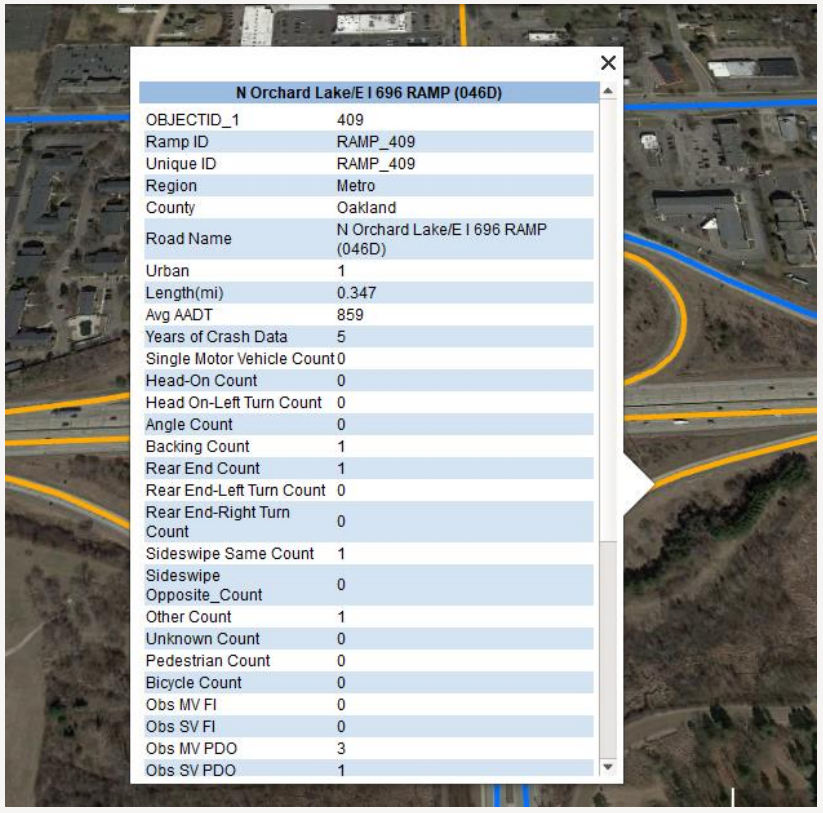
Segments

- Shoulder Width
- Driveways
- Horizontal Curve
- Terrain
- Passing Restrictions
- Lane width
- On-street parking
- Lighting
- Median
- Fixed objects

Freeways – No Adjustments Required



Ramp Terminals



Ramp Segments

Freeway Segments

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CMF Adjustments –Intersections

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CMF –Intersections (Two-way)

Attribute	CMF	Base Conditions
Lighting	No = 1.00 Yes = 0.74	Absence of lighting
Right-turn-on-red	Allowed = 1.00 Prohibited = 0.74	Right-turn-on-red is permitted

CMF –Intersections (Two-way Streets)

Median Presence

Median presence on major street	Median Presence on Minor Street	
	No	Yes
No	1.00	0.72
Yes	0.71	0.51

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CMF – Number of Lanes (Signalized)

Number of Major Street Through Lanes	Number of Minor Street Through Lanes				
	2	3	4	5	6
2	0.92	--	--	--	--
3	0.96	0.98	--	--	--
4	1.00	1.02	1.05	--	--
5	1.05	1.07	1.10	1.13	--
6	1.10	1.12	1.15	1.18	1.21

CMF – Number of Lanes (Stop Control)

Number of Major Street Through Lanes	Number of Minor Street Through Lanes				
	2	3	4	5	6
2	0.94	--	--	--	--
3	0.97	0.99	--	--	--
4	1.00	1.02	1.03	--	--
5	1.03	1.05	1.07	1.08	--
6	1.06	1.08	1.10	1.12	1.14

CMF –Intersections (Two-way Streets)

Speed limit

Major Posted Speed Limit (mph)	Intersection Control	
	Signalized	Unsignalized
25	0.76	0.86
30	0.83	0.90
35	0.91	0.95
40	1.00	1.00
45	1.10	1.05
50	1.20	1.11
55	1.32	1.16
60	1.45	1.22
65	1.59	1.29
70	1.74	--

CMF – Intersections (Two-way Streets)

Left-turn lanes

Intersection Type	Intersection Traffic Control	Number of approaches with left-turn lanes			
		One approach	Two approaches	Three approaches	Four approaches
Three Leg	Minor-road stop control	0.67	0.45	--	--
Three Leg	Traffic Signal	0.93	0.86	0.80	--
Four Leg	Minor-road stop control	0.73	0.53	--	--
Four Leg	Traffic Signal	0.90	0.81	0.73	0.66

Intersection Example

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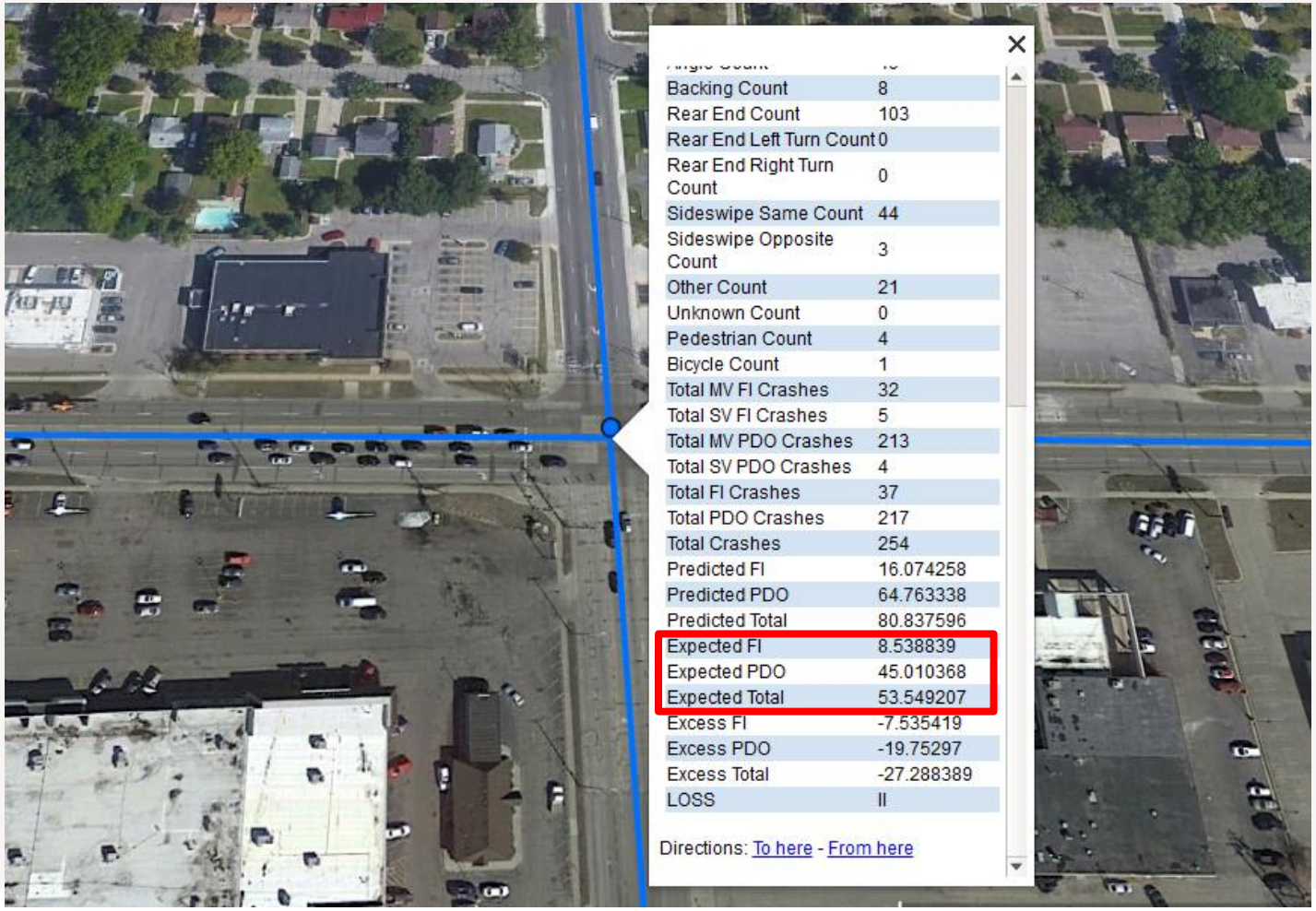
Intersection Example – M-11 & Eastern



From KMZ

- Expected FI = 8.54
- Expected PDO = 45.0

Objective

Calculate the project level Expected FI and Expected PDO. Also determine the impact of adding a median to 28th Street.

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Intersection Example – M-11 & Eastern

Expected FI Adjustment

FI Crashes: Project Level Expected FI = Expected FI * (Product of CMF's)

PDO Crashes: Project Level Expected PDO = Expected PDO * (Product of CMF's)

Step 1 – apply Expected FI value from KMZ

FI Crashes: Project Level Expected FI = **8.54** * (Product of CMF's)

PDO Crashes: Project Level Expected PDO = **45.0** * (Product of CMF's)

Intersection Example – M-11 & Eastern (Step 2)

Step 2 – Calculate product of CMF's

Item	Details	CMF
Lighting	Lighting Present	0.74
Right-turn-on-red	Not present on any approach	1.00
Median	Not present on any approach	1.00
Number of Lanes	4 Lanes on all approaches	1.05
Speed Limit on major street	40 mph	1.00
Left-turn Lane	Four approaches of a signalized intersection	0.66
Product of CMF's		**0.51**

Intersection Example – M-11 & Eastern (Steps 3 & 4)

Step 3 – apply product of CMF's from step 2

Project Level Expected FI = 8.54 * (**0.51**)

Project Level Expected PDO = 45.0 * (**0.51**)

Step 4 – Calculate the project level Expected FI and PDO

Project Level Expected FI = 8.54 * (0.51) = **4.36**

Project Level Expected PDO = 45.0 * (0.51) = **22.95**

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Intersection Example – M-11 & Eastern (Steps 5 & 6)

Step 5 – Determine impact of median – select CMF which is 0.71

Step 6 – Calculate the project level Expected FI and PDO with median

Project Level Expected FI = 4.36 * **0.71** = **3.10**

Project Level Expected PDO = 22.95* **0.71 = 16.30**

Summary	Before	After	Change
FI	4.36	3.10	1.26
PDO	22.95	16.30	6.65
Total	27.31	19.40	7.91

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CMF Adjustments - Segments

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CMF – Two Lane Rural Segments

Attribute	CMF	Variables	Base Conditions
Shoulder Width	$CMF_{sw} = e^{-0.024(Wsw-6.0)}$	W_{sw} = Shoulder Width	6.0 ft paved shoulder
Driveways	$CMF_{dw} = e^{0.021(n_{dw}-15)}$	n_{dw} = Number of driveways	15 driveways per mile
Horizontal Curve	$CMF_{hc} = e^{0.714(p_{hc})}$	p_{hc} = (length of curves under 0.297 miles / total length of segment)	When p_{hc} = 1.0, then the CMF is 2.0
Terrain	$CMF_{terrain\ (level)} = 1.0$ $CMF_{terrain(rolling)} = 1.07$		
Passing Restrictions	$CMF_{rstr} = e^{0.005(p_{rstr})}$	P_{rstr} = ((length of no passing areas / total length of segment) *100)	When p_{rstr} is 100%, then the CMF is 1.65

CMF – Four Lane Rural Segments

Attribute	CMF	Variables	Base Conditions
Right Shoulder Width	$CMF_{rsw} = e^{-0.037(W_{rsw}-6.0)}$	W_{rsw} = Shoulder Width	6.0 ft right paved shoulder
Left Shoulder Width	$CMF_{lsw} = e^{-0.064(W_{rsw}-2.0)}$	W_{lsw} = Shoulder Width	2.0 ft left paved shoulder
Driveways (undivided)	$CMD_{dw(undivided)} = e^{0.0136(n_{dw}-20)}$	$N_{dw(undivided)}$ = Number of driveways	20 driveways per mile
Driveways (divided)	$CMD_{dw(divided)} = e^{0.010(n_{dw}-20)}$	$N_{dw\ (divided)}$ = Number of driveways	20 driveways per mile
Horizontal Curve	$CMF_{hc} = e^{0.902(p_{hc})}$	p_{hc} = (length of curves under 0.5 miles / total length of segment)	No horizontal curves with radius less than 0.5 miles (2,640 ft)

Source: https://www.michigan.gov/documents/mdot/OR14-027_-_MDOT_Rural_SPF_-_FINAL_REPORT_May_11_2018_623286_7.pdf

CMF – Paved Federal Aid Rural County Segments

Attribute	CMF	Variables	Base Conditions
Shoulder Width	$CMF_{sw} = e^{-0.029(Wsw-6.0)}$	W_{sw} = Shoulder Width	6.0 ft paved shoulder
Driveways	$CMD_{dw} = e^{0.010(n_{dw}-15)}$	n_{dw} = Number of driveways	15 driveways per mile
Horizontal Curve	$CMF_{hc} = e^{0.869(p_{hc})}$	p_{hc} = (length of curves under 0.297 miles / total length of segment)	When p_{hc} = 1.0, then the CMF is 2.0

Source: https://www.michigan.gov/documents/mdot/OR14-027_-_MDOT_Rural_SPF_-_FINAL_REPORT_May_11_2018_623286_7.pdf

CMF – Two Way Urban Segments

Attribute	CMF	Variables	Base Conditions
Lane Width	$CMF_{lw} = e^{-0.0219(W_l-12)}$	W_l = Lane Width	12 ft lanes
Right Shoulder Width	$CMF_{rsw} = e^{-0.0285(W_{rsw}-1.5)}$	W_{rsw} = Shoulder Width	1.5 ft right paved shoulder
Left Shoulder Width	$CMF_{lsw} = e^{-0.022(W_{rsw}-1.0)}$	W_{lsw} = Shoulder Width	1.0 ft left paved shoulder
On-street Parking	$CMD_{pk} = 1+p_{pk}* (f_{pk}-1.0)$	p_{pk} = Proportion of curb lenth with on-street parking = $(0.5*L_{pk}/L)$ P_{pk} = See Table 1 L_{pk} = sum of curb length with on-street parking for both sides of the road combined (miles) L = length of roadway segment (miles).	Two way streets with five or fewer lanes

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CMF – Two Way Urban Segments

Attribute	CMF	Variables	Base Conditions
Roadside fixed objects	CMF_{fo} = See table 2	D_{fo} = Segment length (miles) O_{fo} = see table on next slide	Absence of roadside objects
Driveways	$CMF_{dw} = e^{-0.014(n_{dwc}-10)} * e^{-0.005(n_{dwi}-3)} * e^{-0.002(n_{dwr}-8)} * e^{-0.003(n_{dwo}-10)}$	n_{dwc} = Number of commercial driveways n_{dwi} = Number of industrial driveways n_{dwr} = Number of residential driveways n_{dwo} = Number of other driveways	• 10 commercial driveways per mile • 3 industrial driveways per mile • 8 residential driveways • 10 other driveways per mile
Lighting	$CMF_{lgt} = 1.0-(1.0*p_{inr}-0.83*p_{pnr})$	p_{inr} = proportion of total nighttime crashes for unlighted roadway segments that involve a fatality or injury (see table 3) p_{pnr} = proportion of total nighttime crashes for unlighted roadway segments that involve property damage only (see table 3)	• Roadway segments with five or fewer lanes • Lighting

CMF – Two Way Urban Segments

Attribute	CMF	Variables	Base Conditions
Median width	Restrictive medians: $CMF_{mw} = e^{-0.041(\sqrt{W_m}-\sqrt{16})}$ Non-restrictive medians: $CMF_{mw} = e^{-0.0255(W_m-12)}$	W_m=Median width (ft)	Restrictive medians = 16 ft Non-restrictive medians = 12 ft

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Table 1 - f_{pk} values for Urban Segments

Roadway Segment Type	Parallel Parking		Angle Parking	
	Residential or Other	Commercial or Industrial / Institutional	Residential or Other	Commercial or Industrial / Institutional
2U – Two Lane Undivided	1.465	2.074	3.428	4.853
3T – Two Lane with TWLTL	1.465	2.074	3.428	4.853
4U – Four Lane Undivided	1.1	1.709	2.574	3.999
4D – Four Lane Divided	1.1	1.709	2.574	3.999
5T – Five Lane with TWLTL	1.1	1.709	2.574	3.999

Source: https://www.michigan.gov/documents/mdot/SPR-1639_539388_7.pdf

Table 2 – Roadside Fixed Object CMF – Urban Segments

Offset to Fixed Objects (ft)	CMF
0	1.5
2	1.38
5	1.26
10	1.13
15	1.07
20	1.04
25	1.02
30	1.01

Source: https://www.michigan.gov/documents/mdot/SPR-1639_539388_7.pdf

Table 3 – Nighttime Crash Proportions for unlighted segments

Roadway Type	p_{inr}	p_{pnr}
2U – Two Lane Undivided	0.424	0.576
3T – Two Lane with TWLTL	0.429	0.571
4U – Four Lane Undivided	0.517	0.483
4D – Four Lane Divided	0.364	0.636
5T – Five Lane with TWLTL	0.432	0.568

Source: https://www.michigan.gov/documents/mdot/SPR-1639_539388_7.pdf

CMF – One Way Urban Segments

Attribute	CMF	Variables	Base Conditions
Right Shoulder Width	$CMF_{rsw} = e^{-0.0201(W_{rsw}-1.5)} / e^{0.0804}$	W_{rsw} = Shoulder Width	
On-street Parking	$CMF_{pk} = (1+(0.5*L_{pkpar}/L)* (b_{pkpar}-1.0)) * (1+(0.5*L_{pkang}/L)* (b_{pkang}-1.0)$	L_{pkpar} = sum of curb length with on-street parallel parking for both sides of road combined in miles L_{pkang} = sum of curb length with on-street angle parking for both sides of road combined in miles b_{pk} = See table 4 L = length of roadway segment (miles).	• Absence of parking • Multi-vehicle crashes only

Source: https://www.michigan.gov/documents/mdot/SPR-1639_539388_7.pdf

CMF – One Way Urban Segments

Attribute	CMF	Variables	Base Conditions
Roadside fixed objects	CMF_{fo} = See table 5	O_{fo} = Offset to fixed object	Absence of roadside objects
Driveways	$CMF_{dw} = e^{0.011(n_{dw}-10)}$	n_{dw} = Number of driveways	• 10 commercial driveways per mile

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Table 4 – factors used for CMF for on-street parking

Roadway Type	Parallel Parking b_{pkpar}	Angle Parking b_{pkang}
Two Lane One-Way Street	1.112	4.364
Three Lane One-Way Street	1.359	4.364
Four Lane One-Way Street	1.359	4.364

Source: https://www.michigan.gov/documents/mdot/SPR-1639_539388_7.pdf

Table 5 – Roadside Fixed Object CMF – Urban Segments

Offset to Fixed Objects (ft)	CMF
0	1.50
2	1.41
5	1.31
10	1.20
15	1.12
20	1.08
25	1.05
30	1.03

Source: https://www.michigan.gov/documents/mdot/SPR-1639_539388_7.pdf

Rural Segment Example

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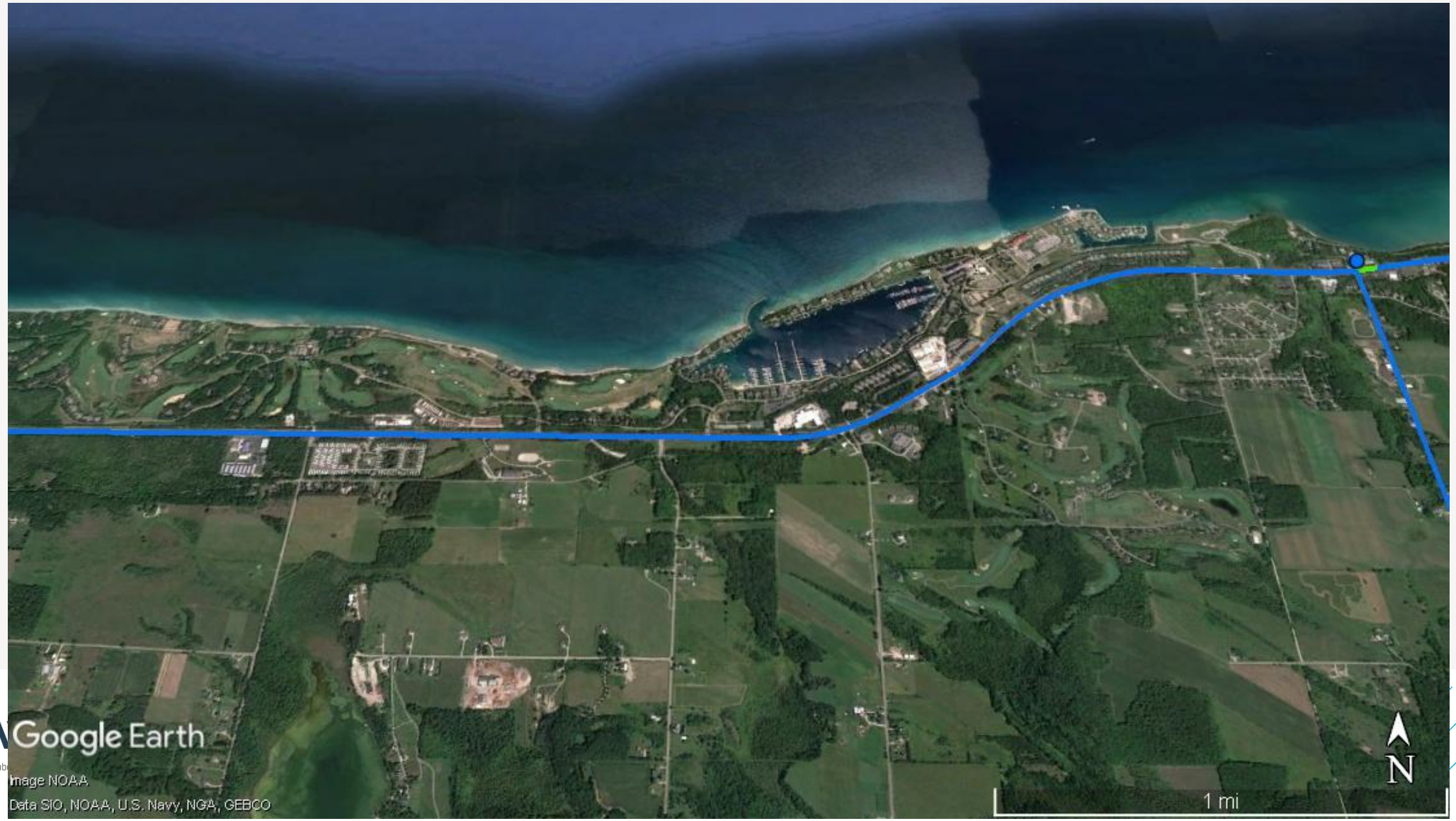
Segment Example – US-31 Emmet County



Segment Example – Gather HSM Data (Step 1)

ID	Length (mi)	Expected FI	Expected PDO
5885	0.20	0.50	1.80
5887	0.28	0.95	2.21
5881	1.00	2.02	6.12
5882	1.00	0.75	2.88
5883	1.00	0.99	1.16
Segment TOTAL	**3.48**	**5.21**	**14.17**
US-31 & Resort Pike Rd		0.85	1.56
TOTAL		**6.06**	**15.73**

Segment Example – Rural Segment CMF's (Step 2)

Attribute	CMF
Shoulder Width	0.91
Driveways	0.95
Horizontal Curve	1.36
Terrain (flat)	1.00
Passing Restrictions	1.65
TOTAL	1.94

Segment Example – Intersection CMF's (Step 2)

Attribute	CMF
Lighting	1.00
RTOR	1.00
Median	1.00
Speed Limit (55 mph)	1.32
LT Lanes (2 approaches)	0.86
TOTAL	1.14

Segment Example – Convert from planning to project level

	Planning Level Expected Value	Product of CMF's	Project Level Expected value
FI Segment	5.21	1.94	10.11
PDO Segment	14.17	1.94	27.49
FI Intersection	0.85	1.14	0.97
PDO Intersection	1.56	1.14	1.78
TOTAL	21.79		40.35

Proposed Improvements

- Add a median to US-31 (CMF = 0.71)
- Add lighting to US-31 & Resort Pike Rd intersection (CMF = 0.74)

	Project Level Expected value (existing)	CMF	Project Level Expected value (proposed)	% Change
FI Segment	10.11	0.71	7.18	
PDO Segment	27.49	0.71	19.52	
FI Intersection	0.97	0.74	0.72	
PDO Intersection	1.78	0.74	1.32	
TOTAL	**40.35**		**28.74**	**28.8%**

Design Exception Example

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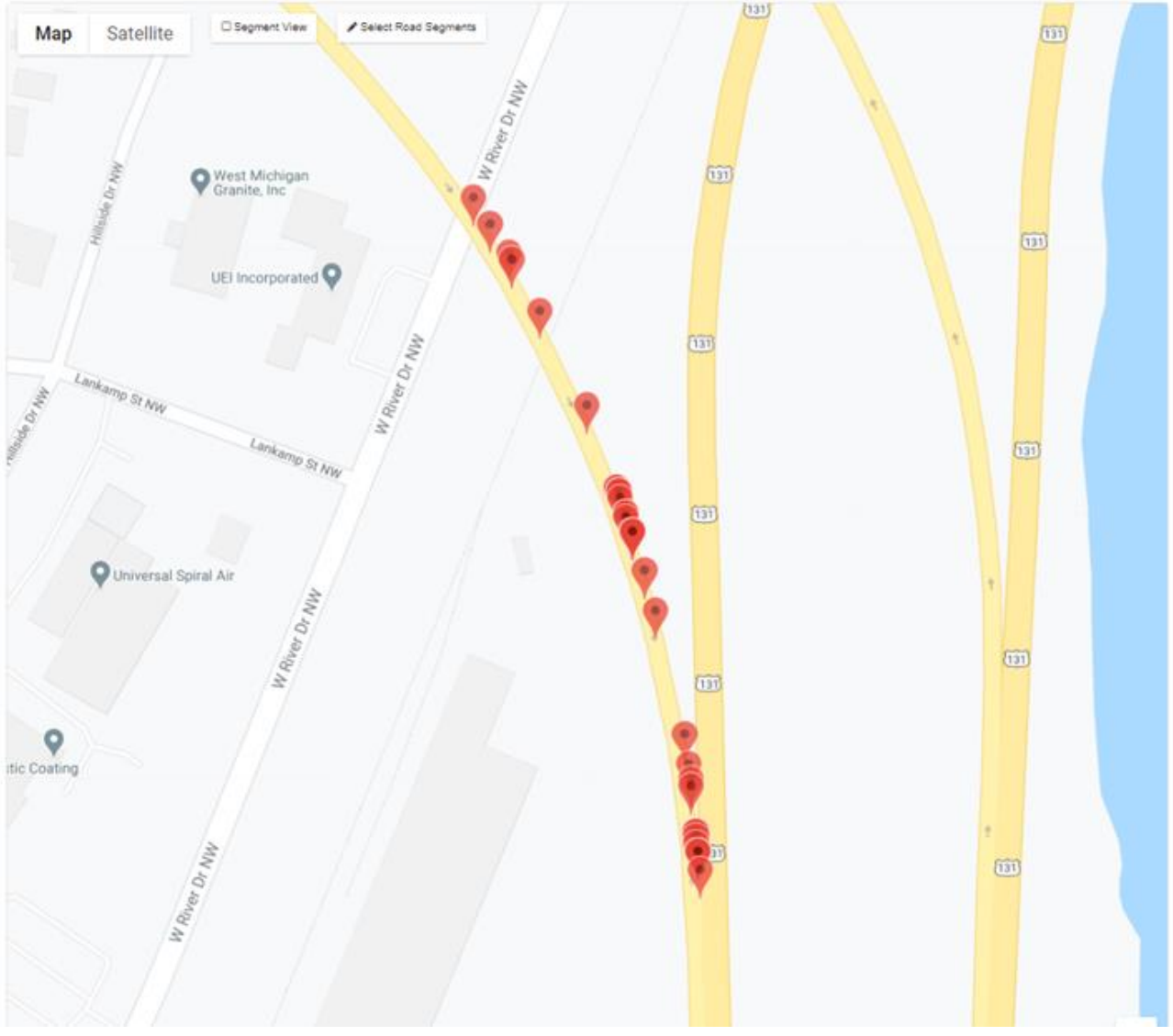
EB I-96 to SB US-131



Crash Severity	2015	2016	2017	2018	2019	Total
Fatalities	0	0	0	0	0	0
Injury	1		2	1	3	7
PDO	3	7	6	2	9	27
Total	4	7	8	3	12	34

Crash Type	2015	2016	2017	2018	2019	Total
Fixed Object/Single vehicle	1	5	5	2	3	16
Rear End	2	1	3	1	1	8
Sideswipe	1	1	-	-	4	6
Angle	-	-	-	-	1	1
Other	-	-	-	-	3	3
Total	4	7	8	3	12	34

Design Exception Comparison

Assumptions	Scenario 1: Requires Design Exception	Scenario 2: Meet Standards
Inside shoulder width	4 ft	6 ft
Outside shoulder width	4 ft	6 ft
Distance to face of barrier	6.4 ft	4 ft

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DDSA Analysis for Design Exception

Scenario	Total Predicted	FI Predicted	PDO Predicted
Scenario 1: Requires Design Exception	9.86	4.29	5.57
Scenario 2: Meet Standards	9.01	3.84	5.17
Difference	0.85	0.45	0.40
% Change	-9.4%	-11.7%	-7.7%
Variance	0.36	0.10	0.08
Standard Error	0.60	0.32	0.28
Significance	15.7%	36.6%	27.5%
Statistically Significant	No	No	No