



ATKINS

Member of the SNC-Lavalin Group

Performance Based Practical Design/Data Driven Safety Analysis

Module 2 – Michigan Safety
Analysis Maps

Session Starts at 10 am

Welcome

Instructors



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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

Review from Module 1

What is DDSA?

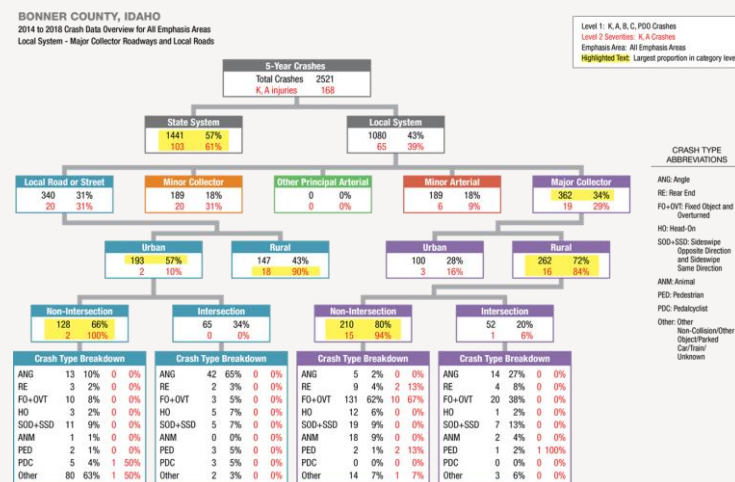


Using tools to analyze crash and roadway data to predict the safety impacts of highway projects allows agencies to target investments with more confidence and reduce severe crashes on the roadways.



[illegible]

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Spot vs. Systemic



Predictive/HSM

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

Authority: 9409 PA 305, Sec. 207 822
Compliance: Required - MSP LD-10E
Penalty: \$100 and/or 60 days - (Pen 110105)

External # 0004482
Crash ID 1726806
Page: 01 of 01
File Class
Report # 19-1438
Reviewer Nick Bertram

City MI 8329100
Department Name Cadillac Police Department
Crash Date 06/14/2019
Crash Time 13:00
No. of Lanes 62
Crash Type Rear End
Signal
County 83 - Westford
Traffic Control Signal
Location On the Road
Weather Rain
Road Surface Condition Wet
Total Lanes 63
Speed Limit 45
Posted Yes

Crash Type 60 - Cadillac
Contributing Circumstances None
2nd
Light Daylight
Road Surface Condition Wet
Total Lanes 63
Speed Limit 45
Posted Yes

Block Size (if applicable) Type Workers Present Activity Location

Primary Road Name M 55
Road Type Gully
Shoulder/Ditch 63 Feet SW
Not Physically Divided
Shoulder/Ditch 63 Feet SW
Not Physically Divided
Shoulder/Ditch 63 Feet SW
Not Physically Divided

Crash Number 01
Unit Known Yes
MI 8329100
Date of Birth (Age) 06/14/2019 (46)
License Type Operator
Employment Operator
Employment M
Yield Occupants 01
Incapacitated Unable to Stop

Unit Type MV
Other Information
MERRILL MI 45537 (888) 888-8888
Driver's License No
Position Front - Left
Shoulder and Lap Belt
Driver's License Not Distracted
Incapacitated Not Deployed

Vehicle Registration DQK7397
Size MI
Vehicle Description 2008 CHEVY
Model IMPALA
Color WHI
VIN 2G1WU583389196794
Vehicle Type Passenger Car, SUV, Van
Special Vehicle Not Applicable
Vehicle Defect

Activation System Level in Vehicle No
Activation System Level Engaged at Time of Crash No
Activation System Level Engaged at Time of Crash No

Insurance Company
Insurance Policy #
Insured By BEEMANS
Insured To BEEMANS
Greatest Damage 01
01 Minor Damage
Vehicle Use Private
Cause of Crash Slowing/Stopping on Roadway

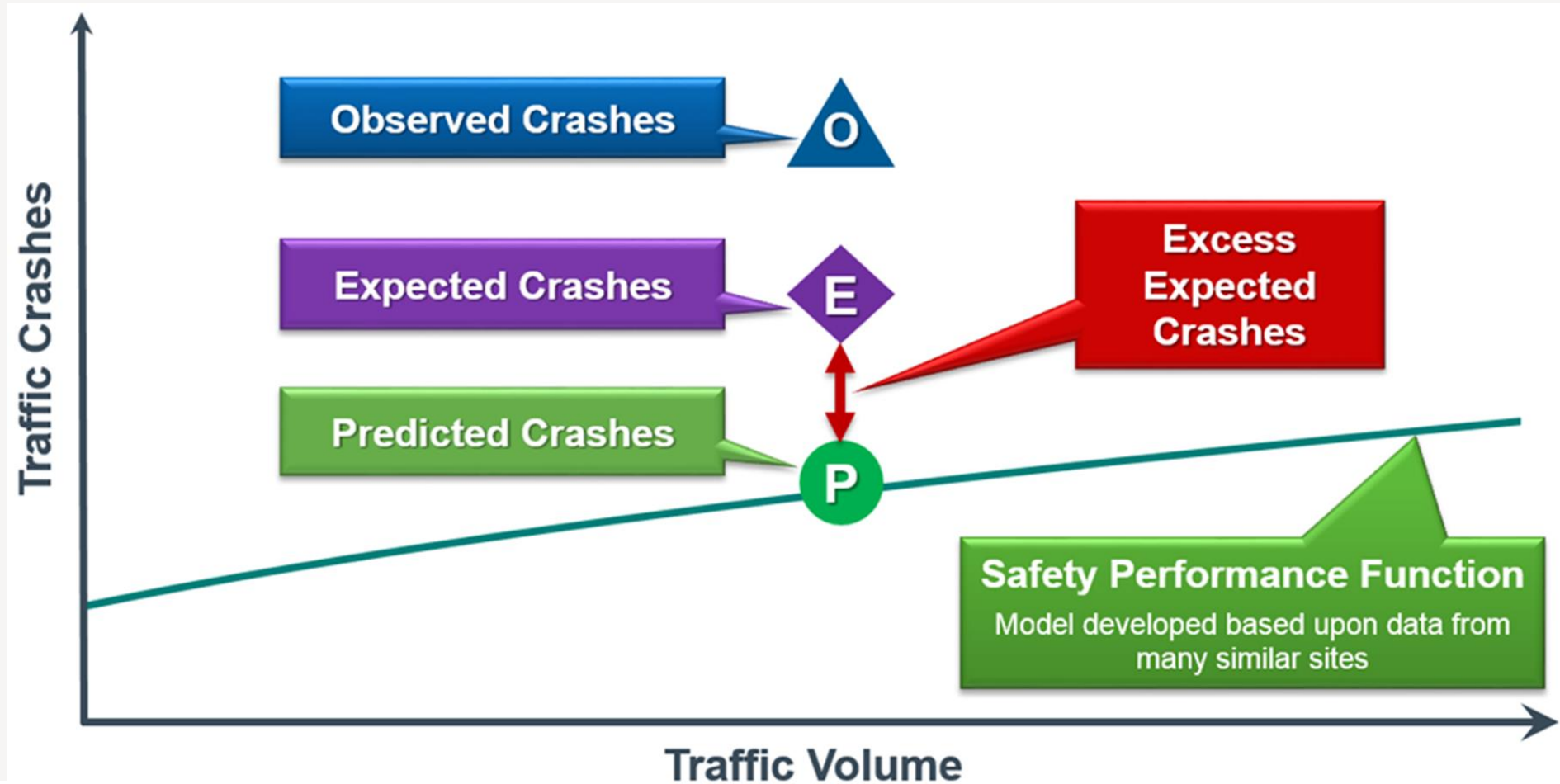
Sequence of Events
1st - Motor Veh in Transport
2nd
3rd
4th

Passenger Information
Date of Birth (Age)
Sex
Position
Injury
Ejected
Trapped
Airbag Deployed
Ambulance
Hospital

Passenger Information
Date of Birth (Age)
Sex
Position
Injury
Ejected
Trapped
Airbag Deployed
Ambulance
Hospital

Driver Information
Driver's COL Type
Ends - 01 - 02 - 03 - 04 - 05 - 06 - 07 - 08 - 09 - 10 - 11 - 12 - 13 - 14 - 15 - 16 - 17 - 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34 - 35 - 36 - 37 - 38 - 39 - 40 - 41 - 42 - 43 - 44 - 45 - 46 - 47 - 48 - 49 - 50 - 51 - 52 - 53 - 54 - 55 - 56 - 57 - 58 - 59 - 60 - 61 - 62 - 63 - 64 - 65 - 66 - 67 - 68 - 69 - 70 - 71 - 72 - 73 - 74 - 75 - 76 - 77 - 78 - 79 - 80 - 81 - 82 - 83 - 84 - 85 - 86 - 87 - 88 - 89 - 90 - 91 - 92 - 93 - 94 - 95 - 96 - 97 - 98 - 99 - 100 - 101 - 102 - 103 - 104 - 105 - 106 - 107 - 108 - 109 - 110 - 111 - 112 - 113 - 114 - 115 - 116 - 117 - 118 - 119 - 120 - 121 - 122 - 123 - 124 - 125 - 126 - 127 - 128 - 129 - 130 - 131 - 132 - 133 - 134 - 135 - 136 - 137 - 138 - 139 - 140 - 141 - 142 - 143 - 144 - 145 - 146 - 147 - 148 - 149 - 150 - 151 - 152 - 153 - 154 - 155 - 156 - 157 - 158 - 159 - 160 - 161 - 162 - 163 - 164 - 165 - 166 - 167 - 168 - 169 - 170 - 171 - 172 - 173 - 174 - 175 - 176 - 177 - 178 - 179 - 180 - 181 - 182 - 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HSM Performance Measures



Appropriate Level of Safety Analysis

Category Type	Program/Project Type	Project Examples	Crash Analysis Tier
Roadway Maintenance	Road Capital Preventive Maintenance (CPM) <ul style="list-style-type: none"> • 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	



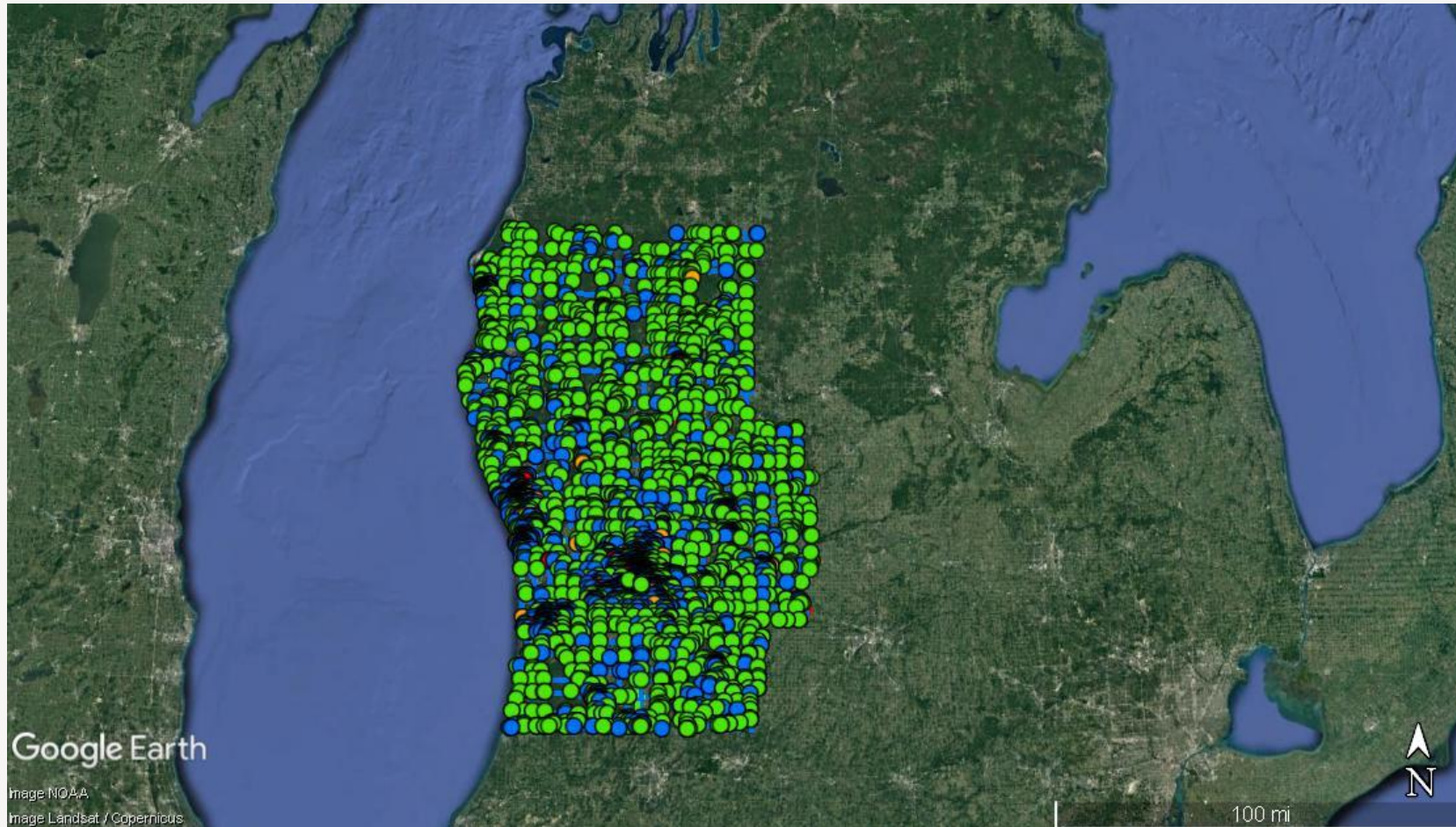
Appropriate Level of Safety Analysis

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
	Bridge	Bridge deck or superstructure replacement	Tier IV
4R – Reconstruction or Replacement	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

Crash Data Collection



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



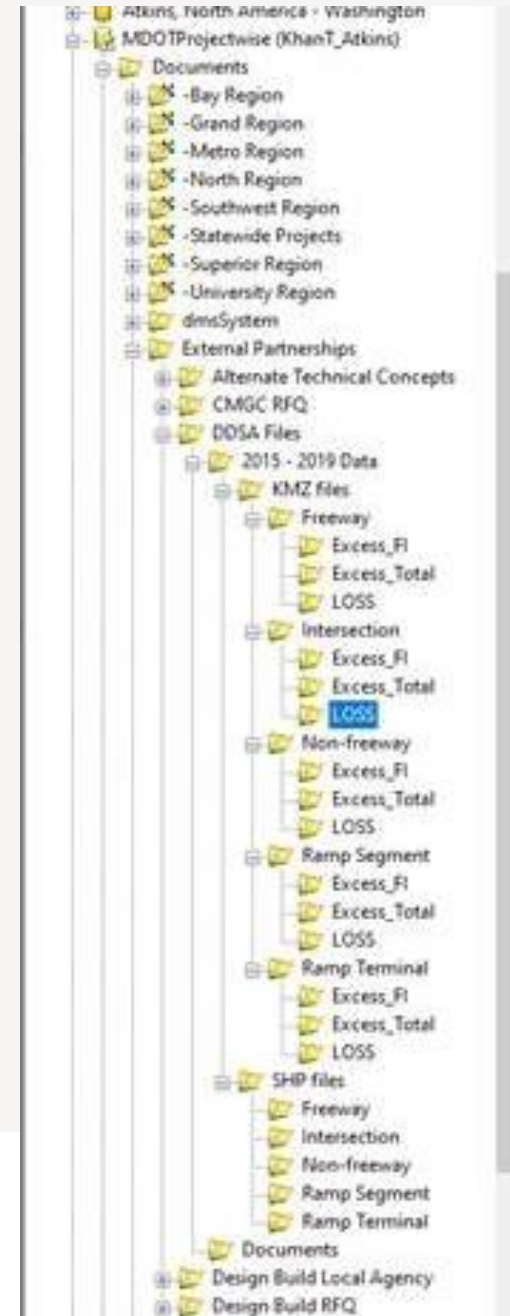
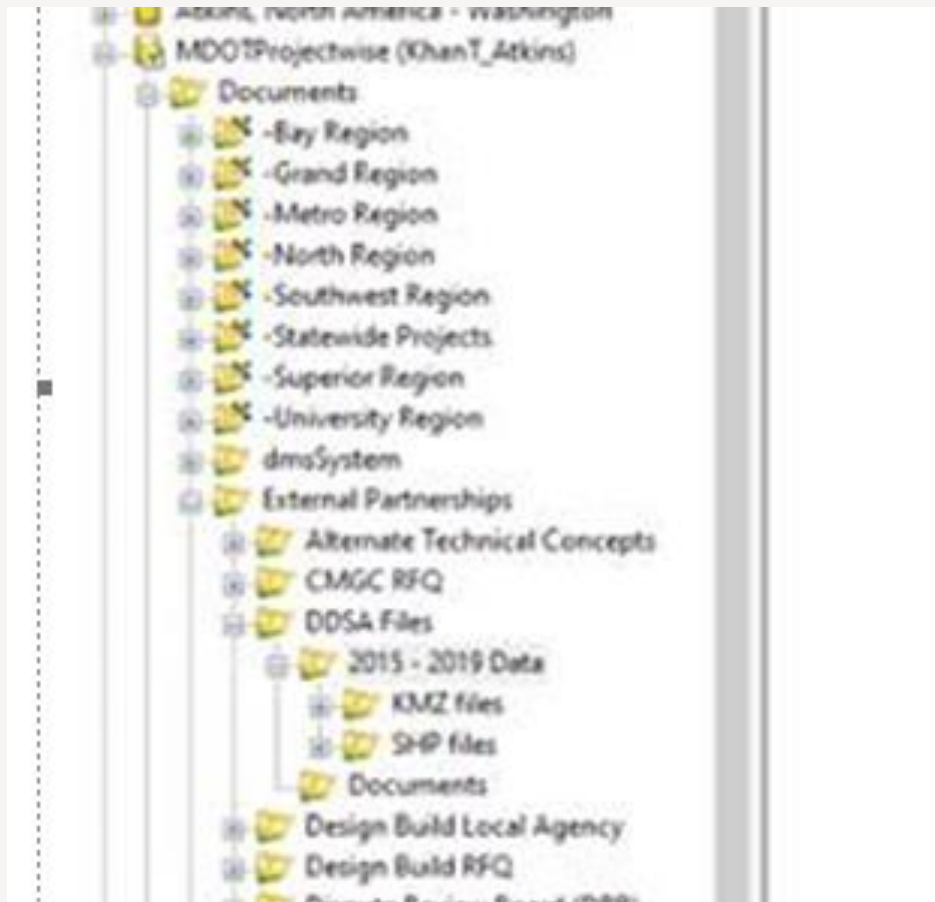
Available Files

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

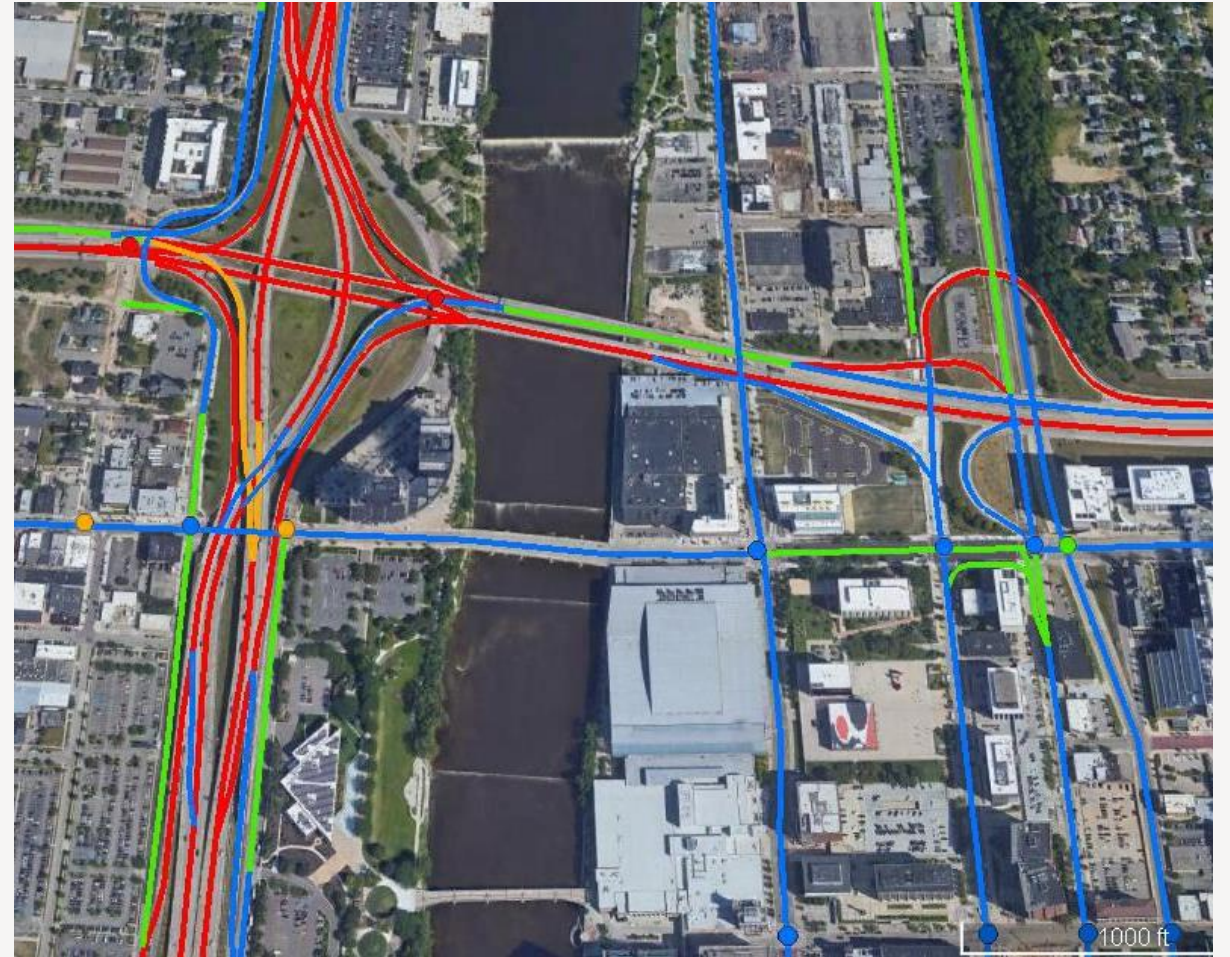


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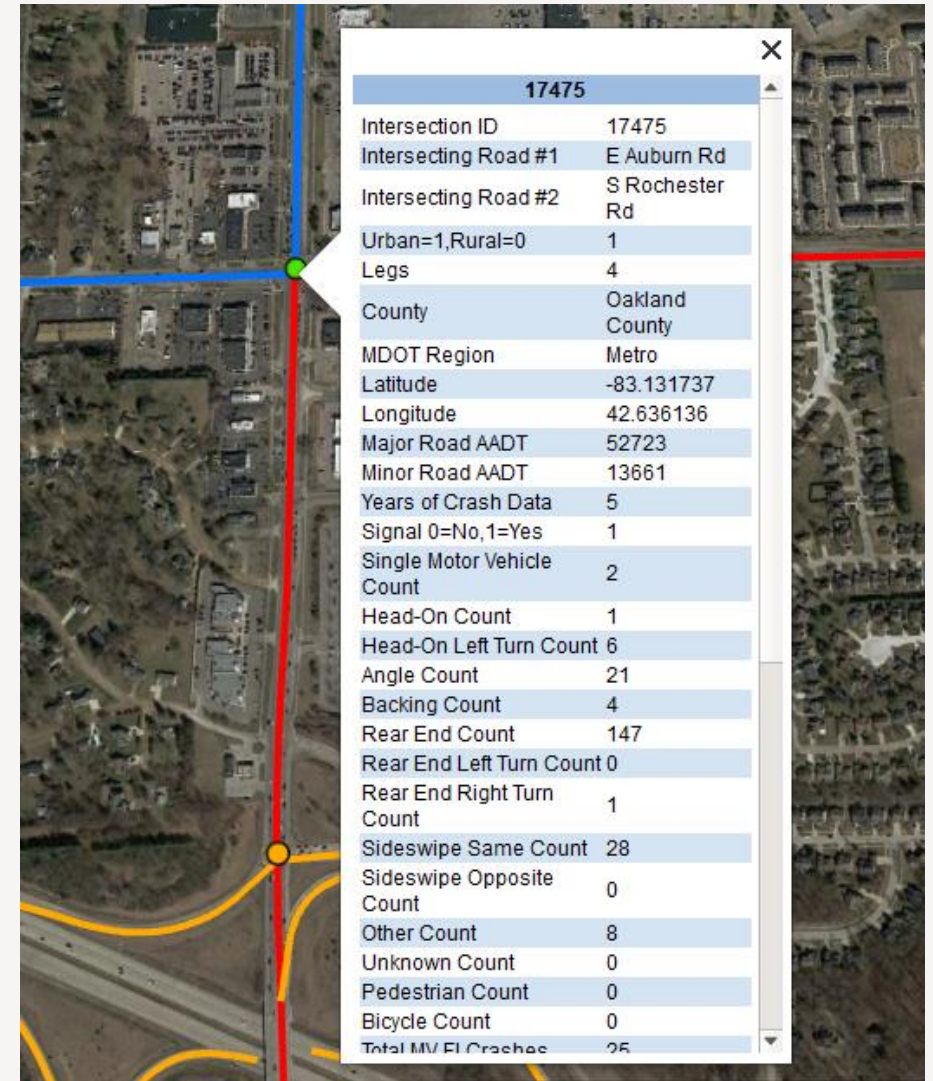
Roadway Network

- › 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



Data within each file (1 of 2)

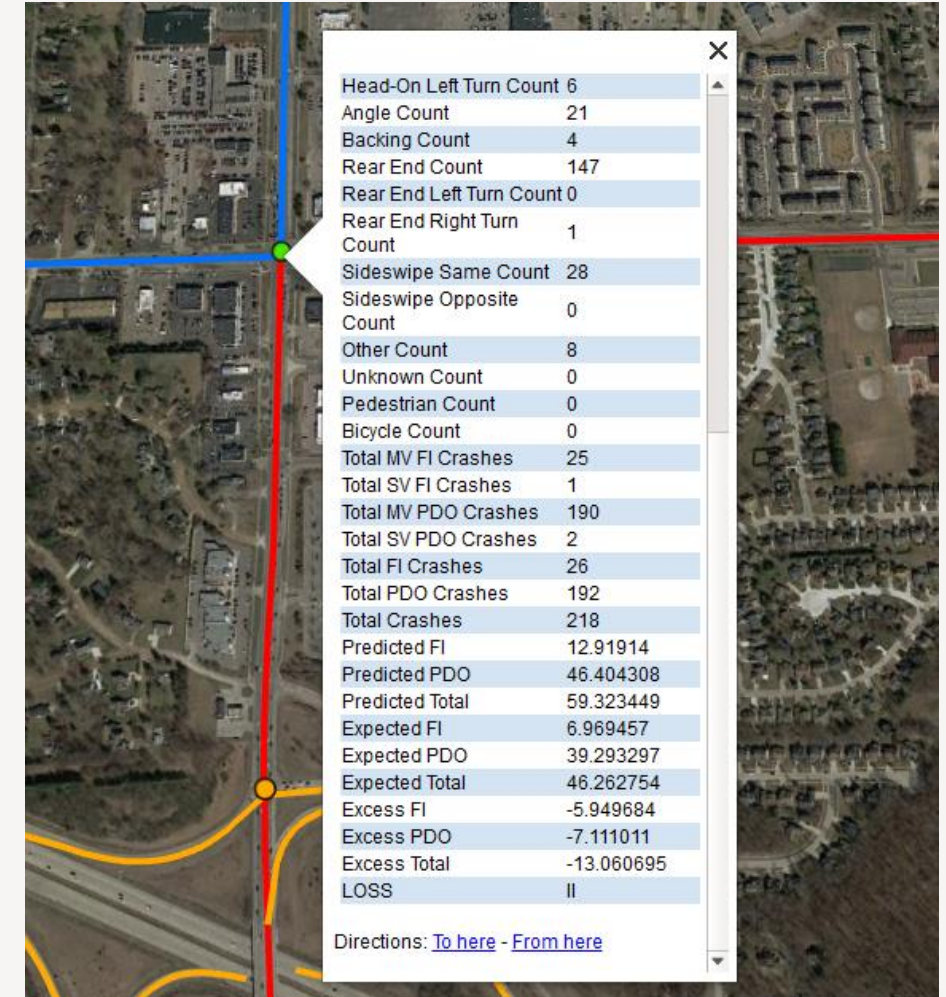
- › **Point ID** – unique ID for location
- › **Estimated minor AADT** – used if no minor AADT in HPMS
- › **Signal** – 1=yes, 0=no
- › **Crash counts** – observed crash frequency totals for five years (2014-2018) by crash type from UD-10 coding
- › **Predicted FI** – Average annual predicted fatal and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



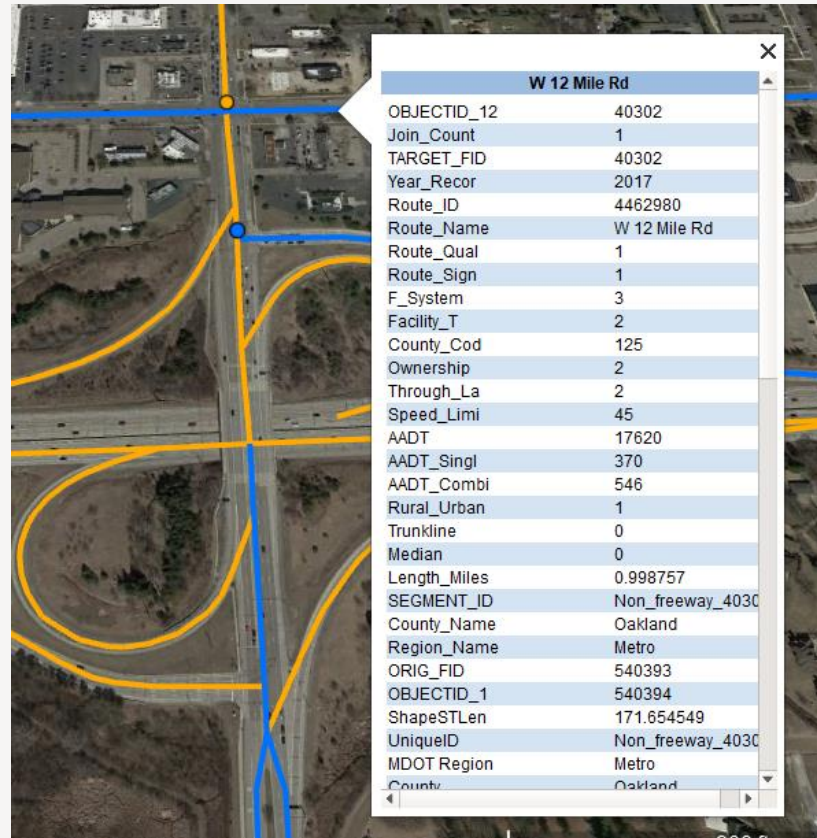
17475	
Intersection ID	17475
Intersecting Road #1	E Auburn Rd
Intersecting Road #2	S Rochester Rd
Urban=1,Rural=0	1
Legs	4
County	Oakland County
MDOT Region	Metro
Latitude	-83.131737
Longitude	42.636136
Major Road AADT	52723
Minor Road AADT	13661
Years of Crash Data	5
Signal 0=No,1=Yes	1
Single Motor Vehicle Count	2
Head-On Count	1
Head-On Left Turn Count	6
Angle Count	21
Backing Count	4
Rear End Count	147
Rear End Left Turn Count	0
Rear End Right Turn Count	1
Sideswipe Same Count	28
Sideswipe Opposite Count	0
Other Count	8
Unknown Count	0
Pedestrian Count	0
Bicycle Count	0
Total MV FI Crashes	25

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



Non-Freeways

An aerial photograph of a road intersection. A blue line represents the road segment being viewed. A yellow line indicates a nearby road. A data popup window is overlaid on the map, displaying various attributes for the selected road segment.

W 12 Mile Rd	
OBJECTID_12	40302
Join_Count	1
TARGET_FID	40302
Year_Recor	2017
Route_ID	4462980
Route_Name	W 12 Mile Rd
Route_Qual	1
Route_Sign	1
F_System	3
Facility_T	2
County_Cod	125
Ownership	2
Through_La	2
Speed_Limi	45
AADT	17620
AADT_Singl	370
AADT_Combi	546
Rural_Urban	1
Trunkline	0
Median	0
Length_Miles	0.998757
SEGMENT_ID	Non_freeway_4030
County_Name	Oakland
Region_Name	Metro
ORIG_FID	540393
OBJECTID_1	540394
ShapeSTLen	171.654549
UniquelD	Non_freeway_4030
MDOT Region	Metro
County	Oakland

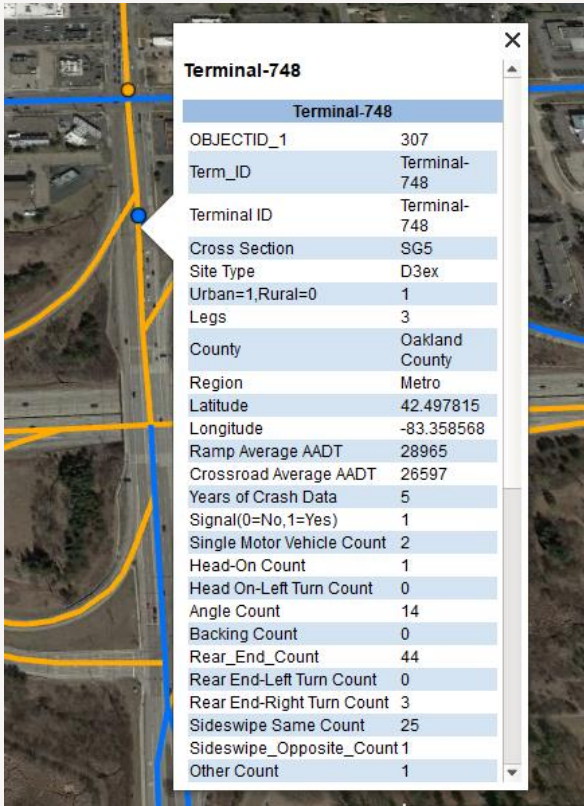
Segment Data Listing

An aerial photograph of a road intersection. A blue line represents the road segment being viewed. A yellow line indicates a nearby road. A data popup window is overlaid on the map, displaying various attributes for the selected intersection.

15692	
Intersection ID	15692
Intersecting Road #1	W 12 Mile Rd
Intersecting Road #2	Orchard Lake Rd
Urban=1,Rural=0	1
Legs	4
County	Oakland County
MDOT Region	Metro
Latitude	-83.35867
Longitude	42.499221
Major Road AADT	36393
Minor Road AADT	17620
Years of Crash Data	5
Signal 0=No,1=Yes	1
Single Motor Vehicle Count	5
Head-On Count	1
Head-On Left Turn Count	6
Angle Count	80
Backing Count	5
Rear End Count	152
Rear End Left Turn Count	2
Rear End Right Turn Count	3
Sideswipe Same Count	69
Sideswipe Opposite Count	3
Other Count	29
Unknown Count	0
Pedestrian Count	0
Bicycle Count	0

Intersection Data Listing

Freeways



Terminal-748

Terminal-748	
OBJECTID_1	307
Term_ID	Terminal-748
Terminal ID	Terminal-748
Cross Section	SG5
Site Type	D3ex
Urban=1,Rural=0	1
Legs	3
County	Oakland County
Region	Metro
Latitude	42.497815
Longitude	-83.358568
Ramp Average AADT	28965
Crossroad Average AADT	26597
Years of Crash Data	5
Signal(0=No, 1=Yes)	1
Single Motor Vehicle Count	2
Head-On Count	1
Head On-Left Turn Count	0
Angle Count	14
Backing Count	0
Rear_End_Count	44
Rear End-Left Turn Count	0
Rear End-Right Turn Count	3
Sideswipe Same Count	25
Sideswipe_Opposite_Count	1
Other Count	1

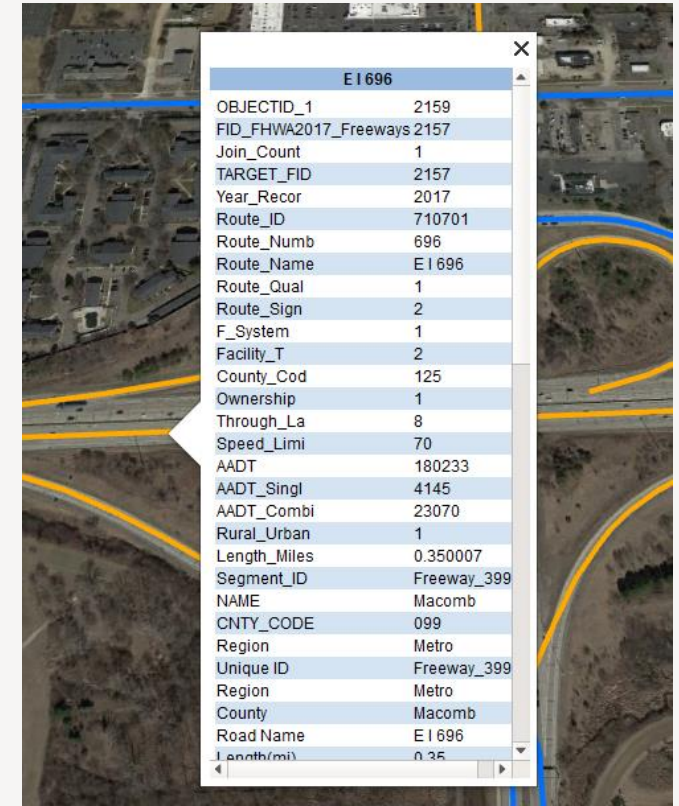
Ramp Terminal Data Listing



N Orchard Lake/E I 696 RAMP (046D)

OBJECTID_1	409
Ramp ID	RAMP_409
Unique ID	RAMP_409
Region	Metro
County	Oakland
Road Name	N Orchard Lake/E I 696 RAMP (046D)
Urban	1
Length(mi)	0.347
Avg AADT	859
Years of Crash Data	5
Single Motor Vehicle Count	0
Head-On Count	0
Head On-Left Turn Count	0
Angle Count	0
Backing Count	1
Rear End Count	1
Rear End-Left Turn Count	0
Rear End-Right Turn Count	0
Sideswipe Same Count	1
Sideswipe Opposite_Count	0
Other Count	1
Unknown Count	0
Pedestrian Count	0
Bicycle Count	0
Obs MV FI	0
Obs SV FI	0
Obs MV PDO	3
Obs SV PDO	1

Ramp Segment Data Listing

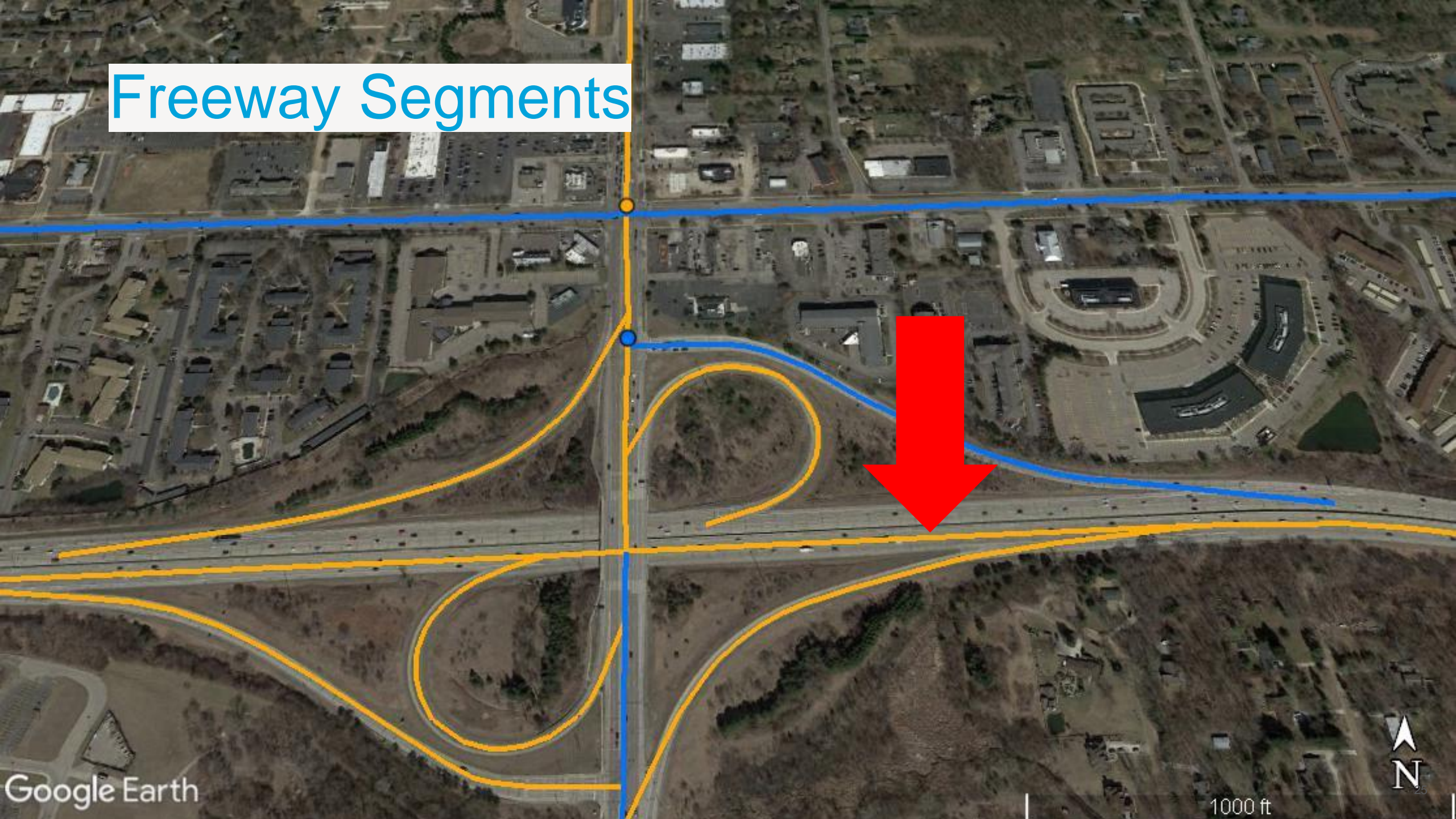


E I 696

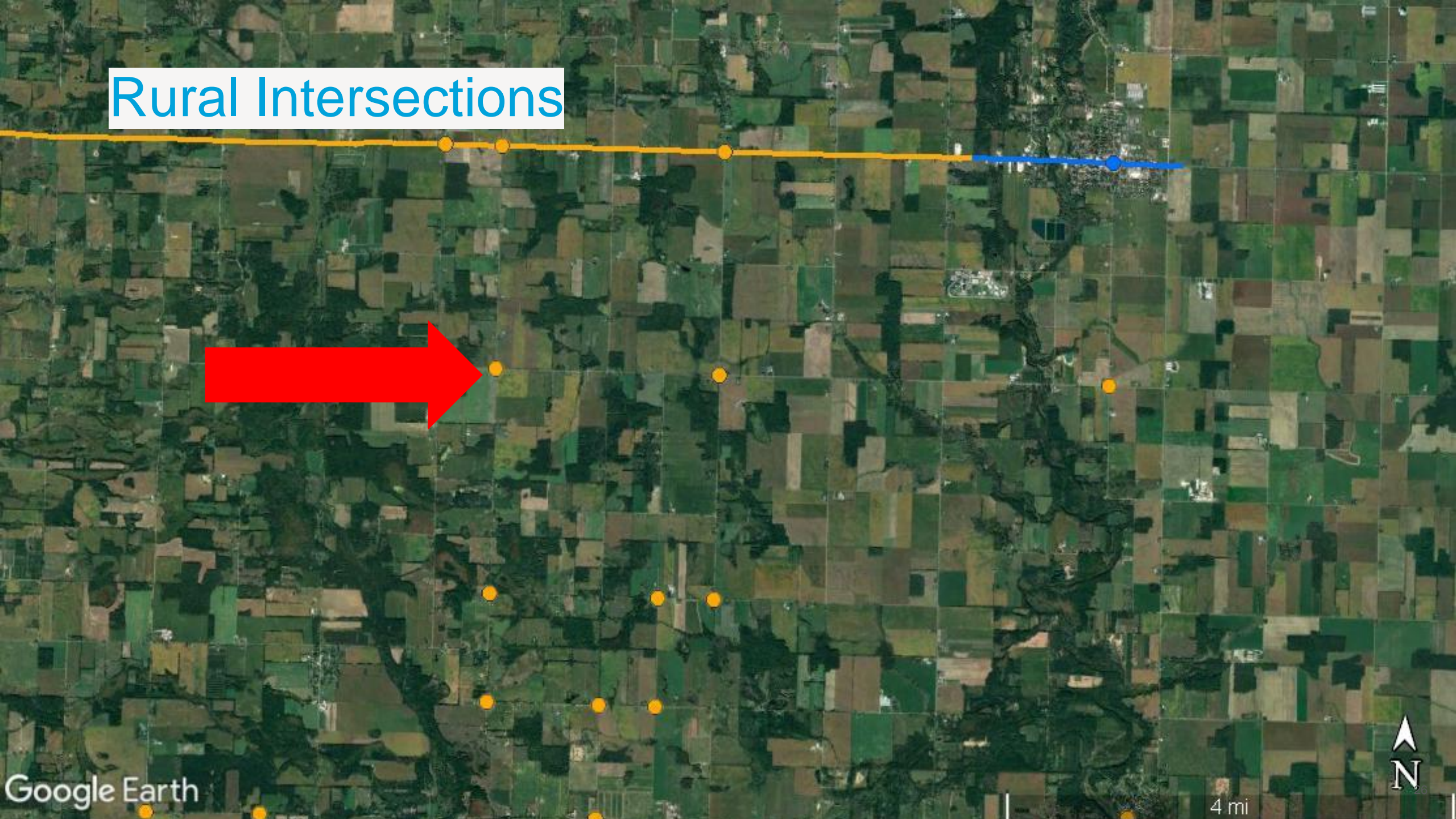
OBJECTID_1	2159
FID_FHWA2017_Freeways	2157
Join_Count	1
TARGET_FID	2157
Year_Recor	2017
Route_ID	710701
Route_Numb	696
Route_Name	E I 696
Route_Qual	1
Route_Sign	2
F_System	1
Facility_T	2
County_Cod	125
Ownership	1
Through_La	8
Speed_Limi	70
AADT	180233
AADT_Singl	4145
AADT_Combi	23070
Rural_Urban	1
Length_Miles	0.350007
Segment_ID	Freeway_399
NAME	Macomb
CNTY_CODE	099
Region	Metro
Unique ID	Freeway_399
Region	Metro
County	Macomb
Road Name	E I 696
Length(mi)	0.35

Freeway Segment Data Listing

Freeway Segments



Rural Intersections



Show examples in Google Earth



Crash Modification Factors

Crash Modification Factors (CMF)

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

Expressed as: $\text{CMF} \pm \text{SE}$

SE is Standard Error

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

Crash Modification Factor

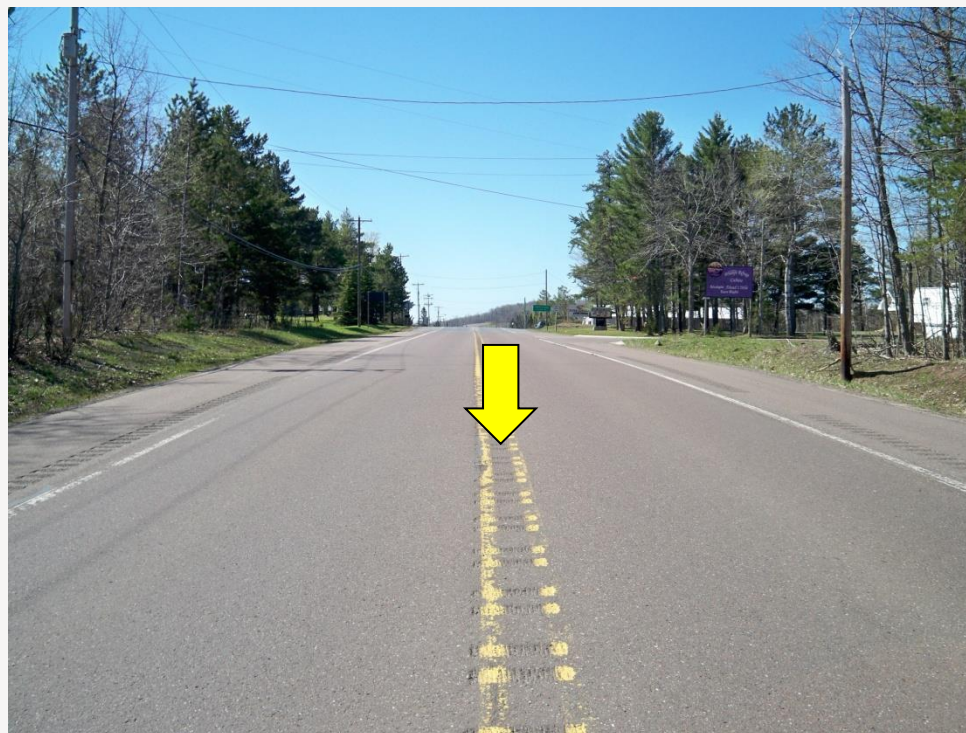
CMF = 0.88 for Total Crashes

Calculate Crash Reduction
Factor (CRF)

$$\text{CRF} = 100 \times (1.00 - \text{CMF})$$

$$\text{CRF} = 100 \times (1.00 - 0.88)$$

CRF = 12% reduction in total
crashes



Centerline Rumble Strips

cmfclearinghouse.org



CRASH MODIFICATION FACTORS CLEARINGHOUSE

[ABOUT THE CLEARINGHOUSE](#) | [USING CMFs](#) | [DEVELOPING CMFs](#) | [ADDITIONAL RESOURCES](#)

The **Crash Modification Factors Clearinghouse** provides a searchable database of CMFs along with guidance and resources on using CMFs in road safety practice.

Countermeasure Name



SEARCH

FREQUENT SEARCHES: [ROUNDAABOUT](#) | [SIGNAL](#) | [PEDESTRIAN](#) | [SHOULDER](#) | [TSMO](#) | [BROWSE ALL](#)



WHAT ARE CMFs?

A crash modification factor (CMF) is used to compute the expected number of crashes after



GETTING STARTED

Learn more about how to use this site in our User Guide section



UPDATED RATINGS

The CMF Clearinghouse transitioned to the CMF rating criteria developed as part of the NCHRP

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
<input type="checkbox"/>	0.58	42	★★★★★	Angle	All		SRINIVASAN ET AL., 2008	
<input type="checkbox"/>	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

Michigan Safety Crash Analysis Maps: Planning vs. Project

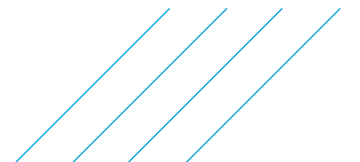
Planning Level vs. Project Level Analysis

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



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

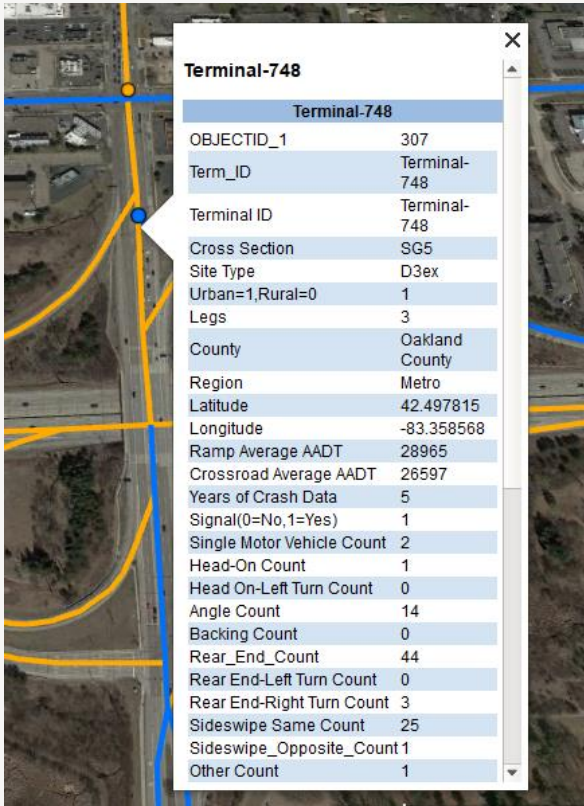
- Lighting
- Right-turn on Red
- Median
- Number of lanes
- Speed Limit
- Traffic control

Segments

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



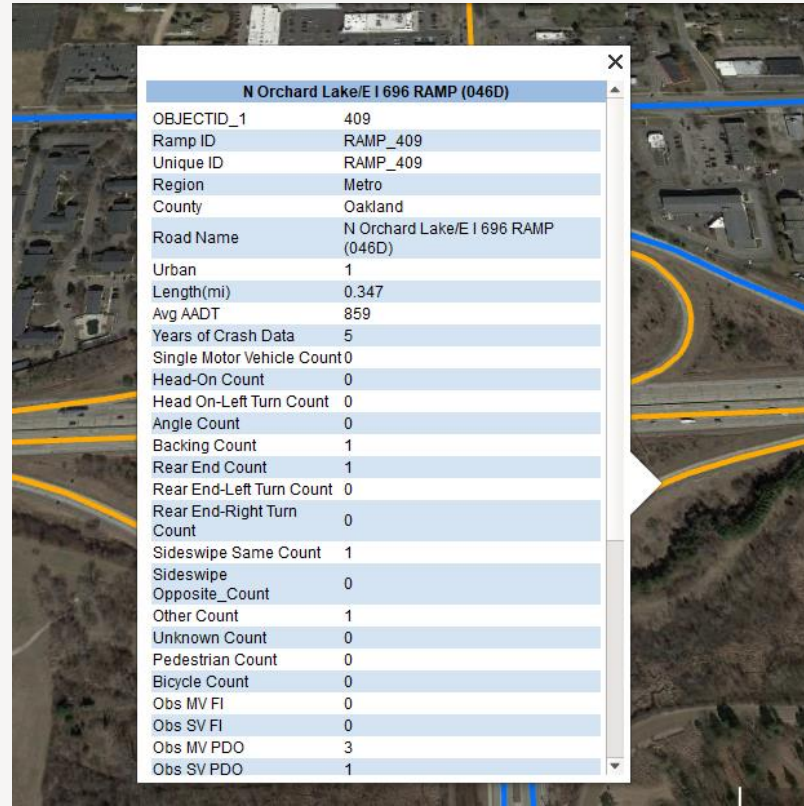
Freeways – No Adjustments Required



Terminal-748

Terminal-748	
OBJECTID_1	307
Term_ID	Terminal-748
Terminal ID	Terminal-748
Cross Section	SG5
Site Type	D3ex
Urban=1,Rural=0	1
Legs	3
County	Oakland County
Region	Metro
Latitude	42.497815
Longitude	-83.358568
Ramp Average AADT	28965
Crossroad Average AADT	26597
Years of Crash Data	5
Signal(0=No, 1=Yes)	1
Single Motor Vehicle Count	2
Head-On Count	1
Head-On-Left Turn Count	0
Angle Count	14
Backing Count	0
Rear_End_Count	44
Rear End-Left Turn Count	0
Rear End-Right Turn Count	3
Sideswipe Same Count	25
Sideswipe_Opposite_Count	1
Other Count	1

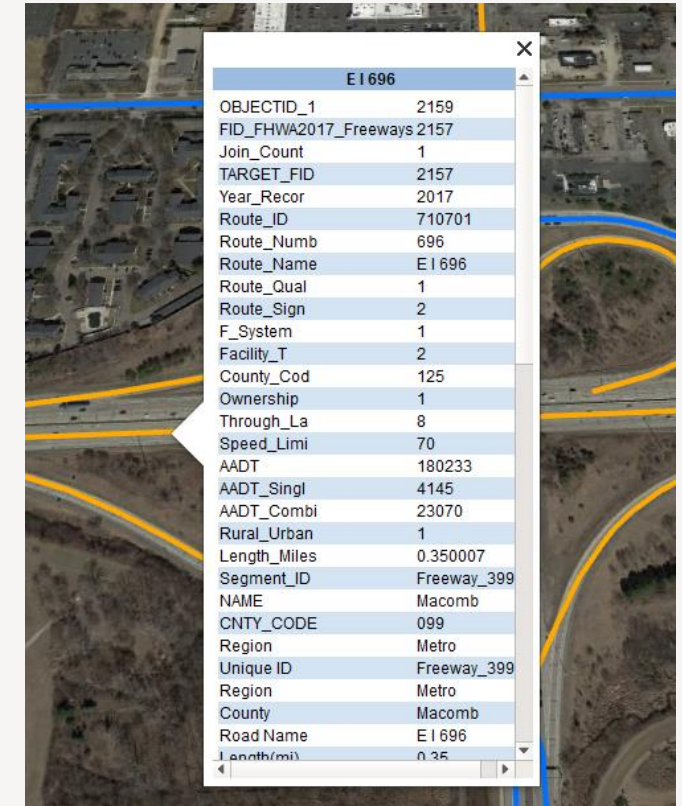
Ramp Terminals



N Orchard Lake/E I 696 RAMP (046D)

OBJECTID_1	409
Ramp ID	RAMP_409
Unique ID	RAMP_409
Region	Metro
County	Oakland
Road Name	N Orchard Lake/E I 696 RAMP (046D)
Urban	1
Length(mi)	0.347
Avg AADT	859
Years of Crash Data	5
Single Motor Vehicle Count	0
Head-On Count	0
Head-On-Left Turn Count	0
Angle Count	0
Backing Count	1
Rear End Count	1
Rear End-Left Turn Count	0
Rear End-Right Turn Count	0
Count	0
Sideswipe Same Count	1
Sideswipe Opposite_Count	0
Other Count	1
Unknown Count	0
Pedestrian Count	0
Bicycle Count	0
Obs MV FI	0
Obs SV FI	0
Obs MV PDO	3
Obs SV PDO	1

Ramp Segments



E I 696

OBJECTID_1	2159
FID_FHWA2017_Freeways	2157
Join_Count	1
TARGET_FID	2157
Year_Recor	2017
Route_ID	710701
Route_Numb	696
Route_Name	E I 696
Route_Qual	1
Route_Sign	2
F_System	1
Facility_T	2
County_Cod	125
Ownership	1
Through_La	8
Speed_Limi	70
AADT	180233
AADT_Singl	4145
AADT_Combi	23070
Rural_Urban	1
Length_Miles	0.350007
Segment_ID	Freeway_399
NAME	Macomb
CNTY_CODE	099
Region	Metro
Unique ID	Freeway_399
Region	Metro
County	Macomb
Road Name	E I 696
Length(mi)	0.35

Freeway Segments

CMF Adjustments –Intersections

CMF –Intersections (Two-way)

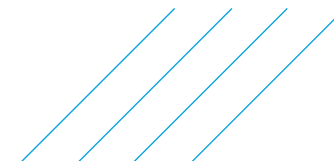
Attribute	CMF	Base Conditions
Lighting	No = 1.00 Yes = 0.74	Absence of lighting
Right-turn-on-red	Allowed = 1.00 Prohibited = 0.74	Right-turn-on-red is permitted



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



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)

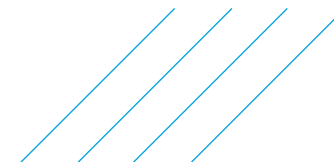
Number of Major Street Through Lanes	Number of Minor Street Through Lanes				
	2	3	4	5	6
2	0.94	--	--	--	--
3	0.97	0.99	--	--	--
4	1.00	1.02	1.03	--	--
5	1.03	1.05	1.07	1.08	--
6	1.06	1.08	1.10	1.12	1.14



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	--



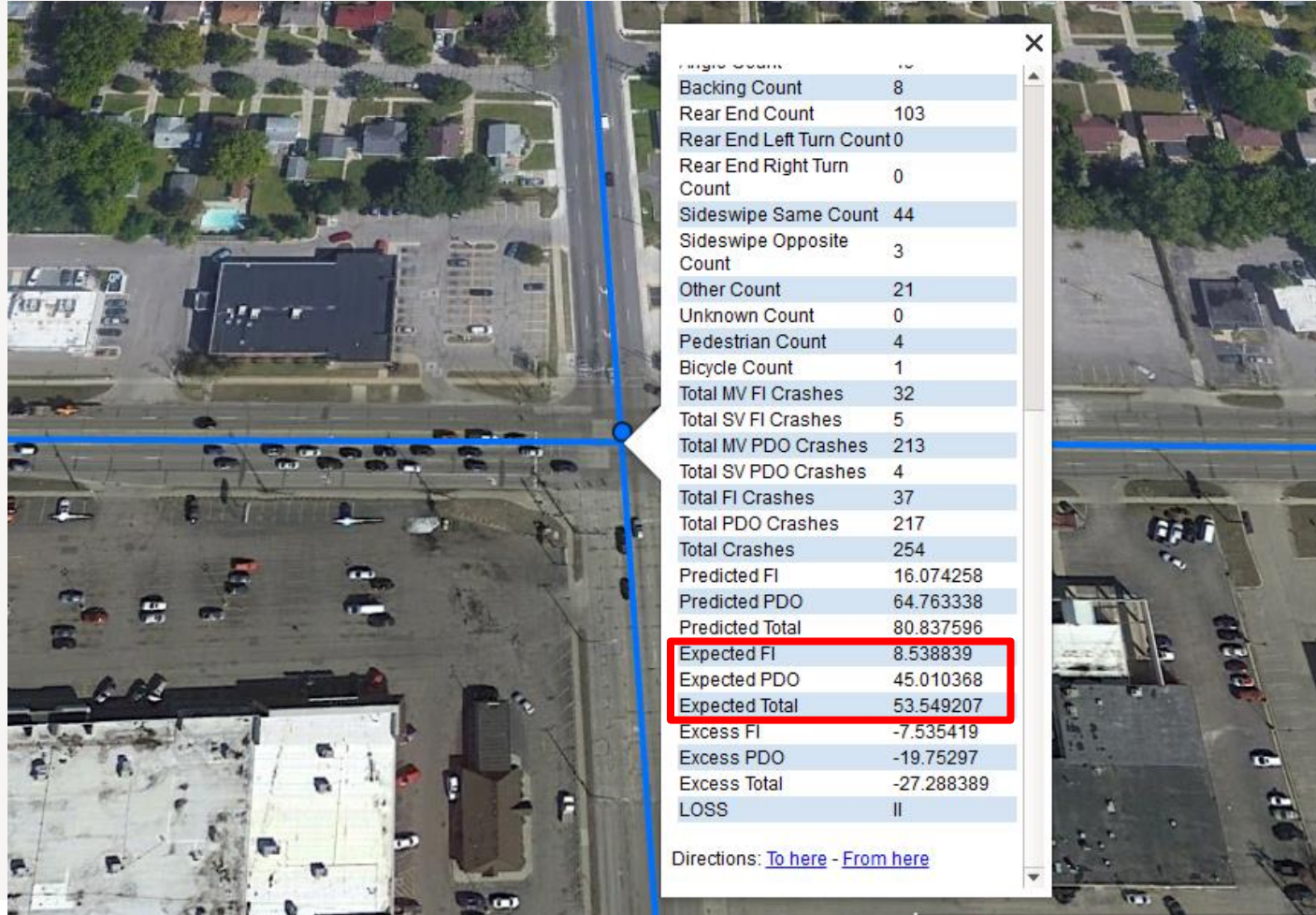
CMF – Intersections (Two-way Streets)

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

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.



Intersection Example – M-11 & Eastern

Expected FI Adjustment

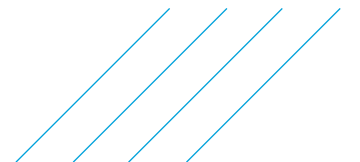
FI Crashes: Project Level Expected FI = Expected FI * (Product of CMF's)

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

$$\text{Project Level Expected FI} = 8.54 * (\mathbf{0.51})$$

$$\text{Project Level Expected PDO} = 45.0 * (\mathbf{0.51})$$

Step 4 – Calculate the project level Expected FI and PDO

$$\text{Project Level Expected FI} = 8.54 * (0.51) = \mathbf{4.36}$$

$$\text{Project Level Expected PDO} = 45.0 * (0.51) = \mathbf{22.95}$$



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



CMF Adjustments - Segments

CMF – Two Lane Rural Segments

Attribute	CMF	Variables	Base Conditions
Shoulder Width	$CMF_{sw} = e^{-0.024(W_{sw}-6.0)}$	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



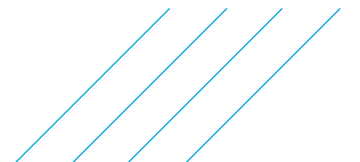
CMF – Four Lane Rural Segments

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	$CMF_{lsw} = e^{-0.064(W_{lsw}^{-2.0})}$	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)



CMF – Paved Federal Aid Rural County Segments

Attribute	CMF	Variables	Base Conditions
Shoulder Width	$CMF_{sw} = e^{-0.029(W_{sw}-6.0)}$	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



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	$CMF_{lsw} = e^{-0.022(W_{lsw}^{-1.0})}$	W_{lsw} = Shoulder Width	1.0 ft left paved shoulder
On-street Parking	$CMD_{pk} = 1 + p_{pk} * (f_{pk} - 1.0)$	<p>p_{pk} = Proportion of curb length with on-street parking = $(0.5 * L_{pk} / L)$</p> <p>P_{pk} = See Table 1</p> <p>L_{pk} = sum of curb length with on-street parking for both sides of the road combined (miles)</p> <p>L = length of roadway segment (miles).</p>	Two way streets with five or fewer lanes



CMF – Two Way Urban Segments

Attribute	CMF	Variables	Base Conditions
Roadside fixed objects	$CMF_{fo} = \text{See table 2}$	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	<ul style="list-style-type: none"> • 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>p_{inr} = proportion of total nighttime crashes for unlighted roadway segments that involve a fatality or injury (see table 3)</p> <p>p_{pnr} = proportion of total nighttime crashes for unlighted roadway segments that involve property damage only (see table 3)</p>	<ul style="list-style-type: none"> • 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

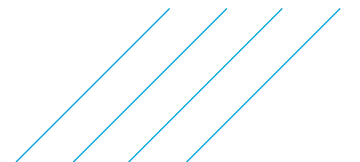


Table 1 - f_{pk} values for Urban Segments

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



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

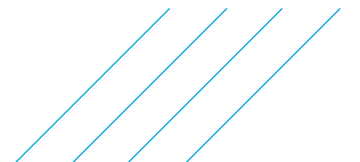


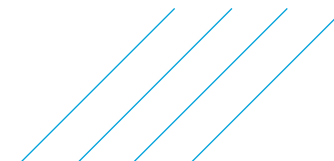
Table 3 – Nighttime Crash Proportions for unlighted segments

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



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	$CMF_{pk} = (1 + (0.5 * L_{pkpar} / L) * (b_{pkpar} - 1.0)) * (1 + (0.5 * L_{pkang} / L) * (b_{pkang} - 1.0))$	<p>L_{pkpar} = sum of curb length with on-street parallel parking for both sides of road combined in miles</p> <p>L_{pkang} = sum of curb length with on-street angle parking for both sides of road combined in miles</p> <p>b_{pk} = See table 4</p> <p>L = length of roadway segment (miles).</p>	<ul style="list-style-type: none"> Absence of parking Multi-vehicle crashes only



CMF – One Way Urban Segments

Attribute	CMF	Variables	Base Conditions
Roadside fixed objects	$CMF_{fo} = \text{See table 5}$	$O_{fo} = \text{Offset to fixed object}$	Absence of roadside objects
Driveways	$CMF_{dw} = e^{0.011(n_{dw} - 10)}$	$n_{dw} = \text{Number of driveways}$	<ul style="list-style-type: none"> 10 commercial driveways per mile



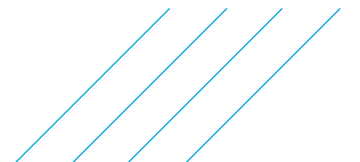
Table 4 – factors used for CMF for on-street parking

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



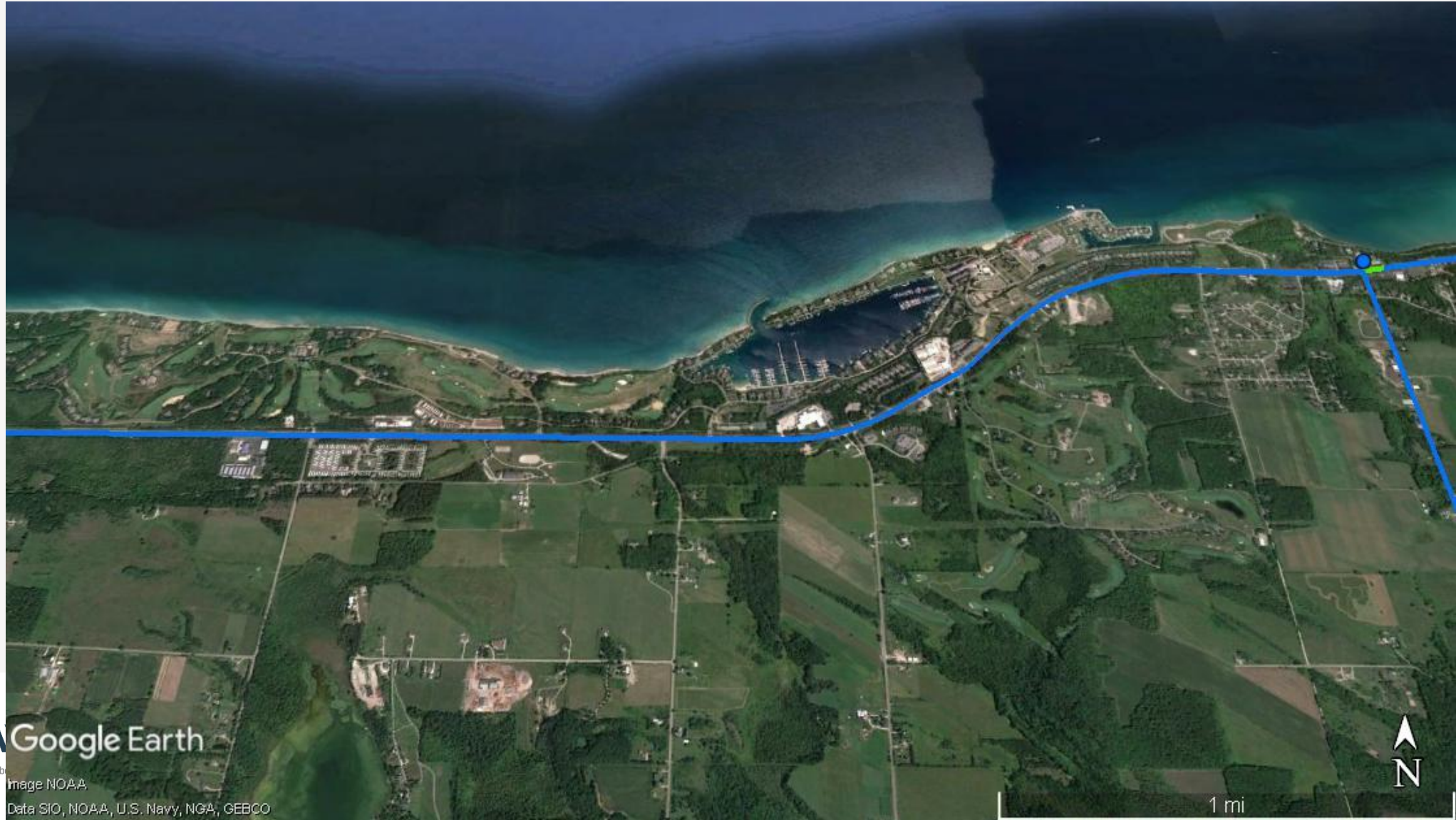
Table 5 – Roadside Fixed Object CMF – Urban Segments

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



Rural Segment Example

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

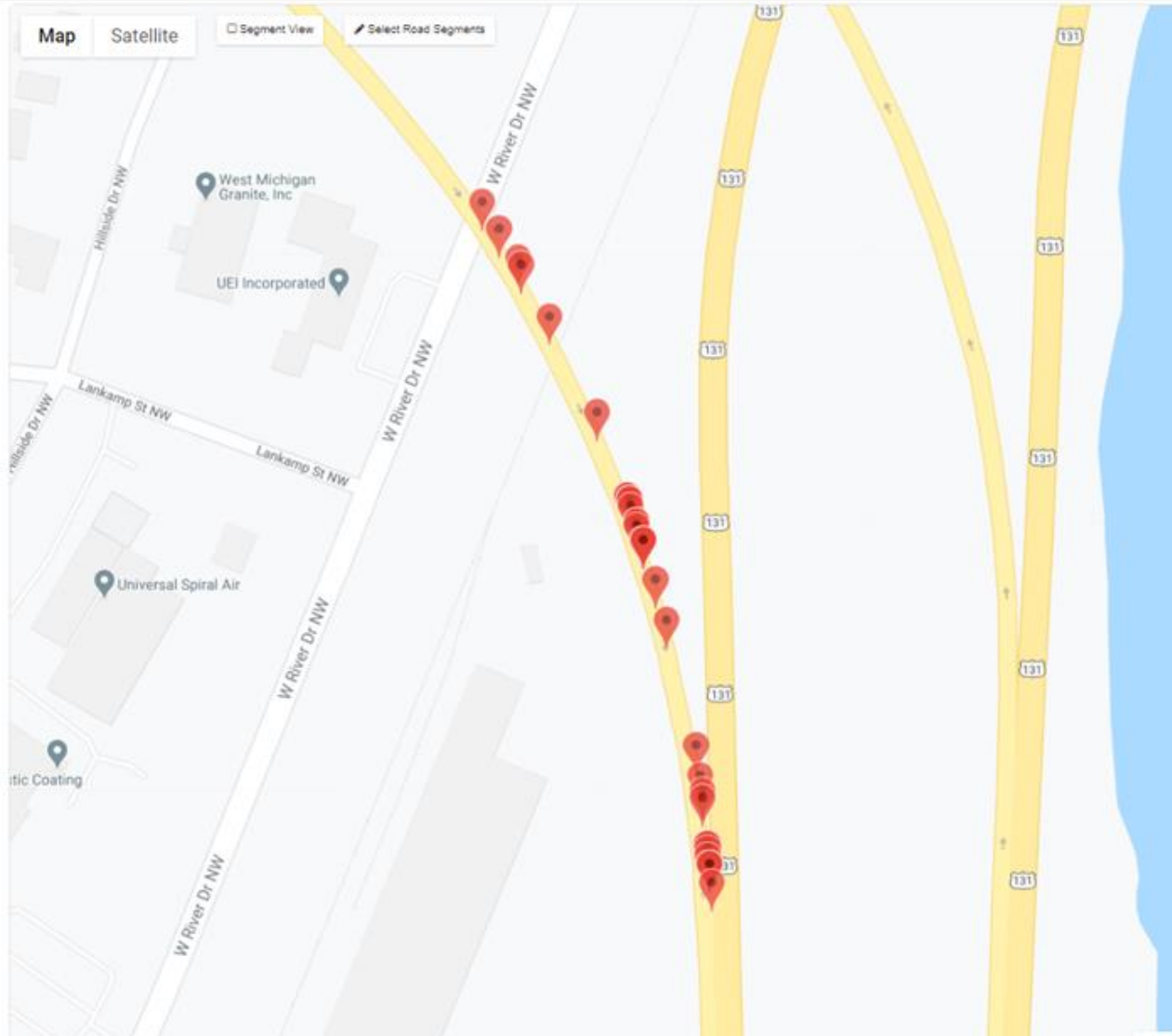
- › Add a median to US-31 (CMF = 0.71)
- › Add lighting to US-31 & Resort Pike Rd intersection (CMF = 0.74)

	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

EB I-96 to SB US-131

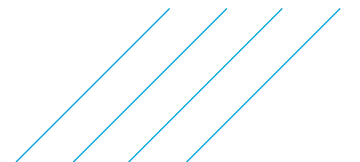


Crash Severity	2015	2016	2017	2018	2019	Total
Fatalities	0	0	0	0	0	0
Injury	1		2	1	3	7
PDO	3	7	6	2	9	27
Total	4	7	8	3	12	34

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



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