Interchange Access Request Safety Procedure Webinar

Systems Implementation Office

March 8, 2018

FDOT

Discussion Topics

- Background
  - FHWA Policy
  - Interchange Access Request User's Guide
- Safety Analysis Methodology
  - Overview
  - Methodology Letter of Understanding Requirements
  - Existing Conditions
  - Interchange Operational Analysis Report
  - Interchange Modification Report
  - Interchange Justification Report
- Project Examples
  - I-4 at Saxon Boulevard IOAR
  - I-75 at Martin Luther King Boulevard IMR
  - I-75 at CR 514 IJR

Housekeeping

- Presentation Material
  - The presentation slides and projects spreadsheets will be available on the FDOT website
  - http://www.fdot.gov/planning/systems/training.shtm
- We encourage participation
  - Questions may be asked using the chat panel
  - Questions will be answered during the webinar and breaks
- PDH/AICP Credits
  - 1.5 Credits available

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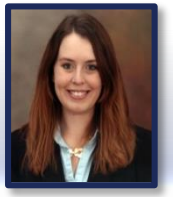

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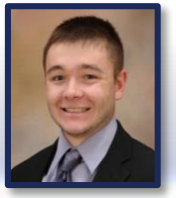

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Acronyms

Term	Acronym
Annual Average Daily Traffic	AADT
Benefit Cost Analysis	BCA
Collector-Distributor Roadway	C-D Roadway
Crash Modification Factor	CMF
Diverging Diamond Interchange	DDI
Empirical Bayes Method	EB Method
Federal Highway Administration	FHWA
Florida Department of Transportation	FDOT
Highway Safety Manual	HSM
Interchange Access Request	IAR
Interchange Access Request User's Guide	IARUG
Interchange Justification Report	IJR
Interchange Modification Report	IMR
Interchange Operational Analysis Report	IOAR
Methodology Letter of Understanding	MLOU
Safety Performance Factor	SPF

Background

Interchange Access Requests

- Requests for new or modified access to
  - Interstate Highway System
  - Non-interstate limited access facilities on the State Highway System (SHS)

- An Interchange Access Request (IAR) shows that a proposed interchange proposal is **Safety**, Operational and Engineering (SO&E) viable

FHWA's Interstate System Access Policy

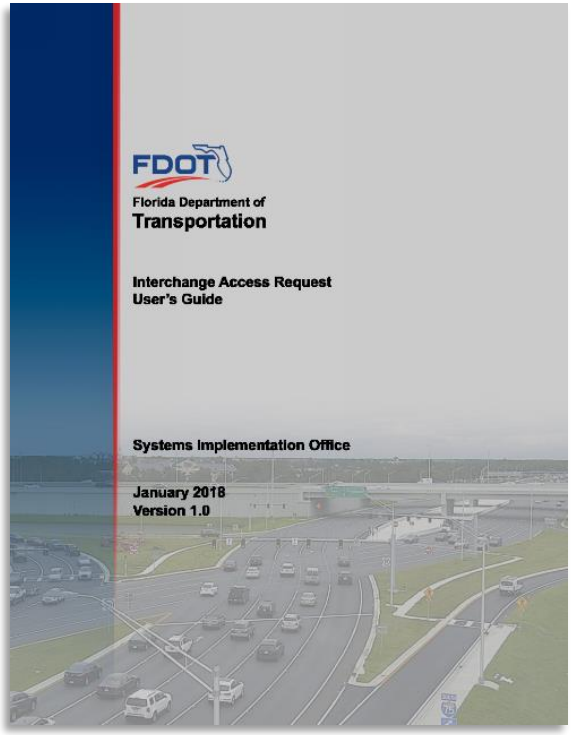
- The FHWA Policy statement entitled "Access to the Interstate System"
  - Published in Federal Register on October 22, 1990
  - Last modified May 22, 2017
  - Replaces the old August 2009 Policy

- The May 2017 FHWA Policy statement
  - Focuses on **Safety**, Operational and Engineering viability

- All new and ongoing IARs must adequately address the FHWA Policy Points
  - FHWA Policy Point 1: The request does not have a significant adverse impact on the operation and **safety** of the freeway system

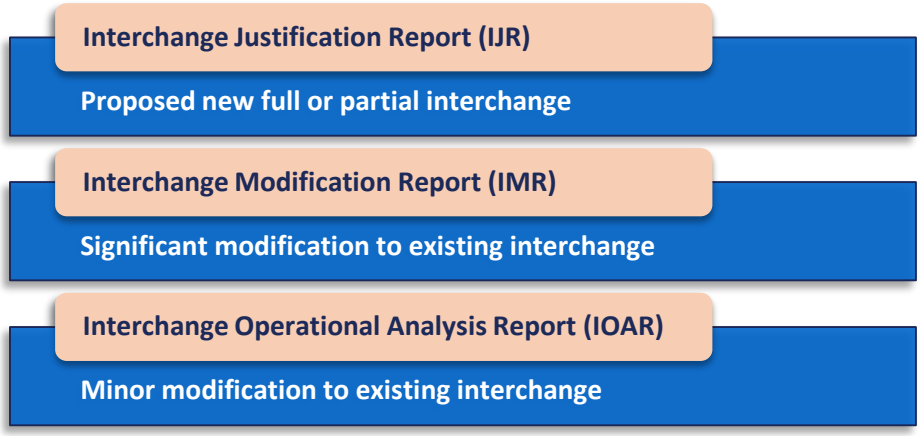
Interchange Access Request User's Guide

- First released in December 2002
  - Updated March 2015
- Current version released January 2018 includes updated
  - Safety analysis methodology
- The updated safety analysis methodology is summarized in Section 3.3 of the IARUG
  - Follows the safety analysis procedures based on HSM
- Available online at
  - http://www.fdot.gov/planning/systems/programs/sm/intjus/



Safety Analysis Overview

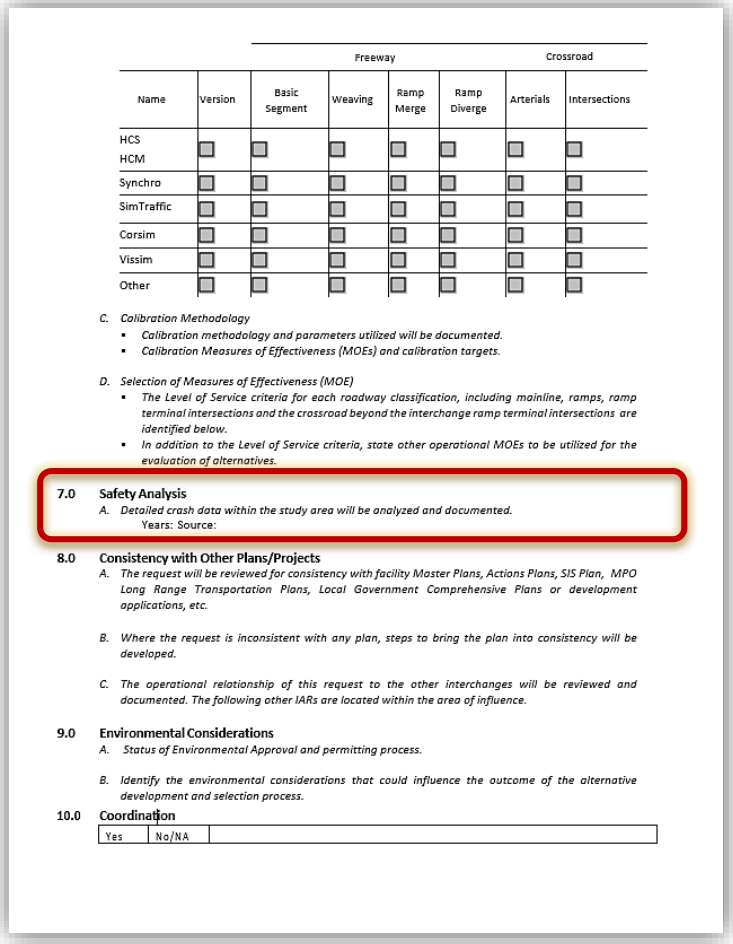
- The level of safety analysis performed is determined by the type of IAR
  - The type of IAR is specified in the MLOU
  - The safety analysis requirements must also be specified in the MLOU
- Three common IAR documents



- The study limits of safety analysis are the same as for operational analysis
- The safety analysis for proposed conditions should document how the access request proposal would improve the identified safety problems

Requirements in MLOU

- Section 7.0 in the MLOU
  - Safety Analysis
- The safety analysis methodology shall be documented and agreed to in the MLOU
- Minimum 5 years of historical crash data
- The MLOU shall state an understanding that either a quantitative analysis for an IOAR, IMR, or IJR will be required
- If the project will perform a Benefit Cost Analysis, it must be specified in the MLOU



		Freeway				Crossroad	
Name	Version	Basic Segment	Weaving	Ramp Merge	Ramp Diverge	Arterials	Intersections
HCS HCM	☐	☐	☐	☐	☐	☐	☐
Synchro	☐	☐	☐	☐	☐	☐	☐
SimTraffic	☐	☐	☐	☐	☐	☐	☐
Corsim	☐	☐	☐	☐	☐	☐	☐
Vissim	☐	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐	☐

C. *Calibration Methodology*
- *Calibration methodology and parameters utilized will be documented.*
- *Calibration Measures of Effectiveness (MOEs) and calibration targets.*

D. *Selection of Measures of Effectiveness (MOE)*
- *The Level of Service criteria for each roadway classification, including mainline, ramps, ramp terminal intersections and the crossroad beyond the interchange ramp terminal intersections are identified below.*
- *In addition to the Level of Service criteria, state other operational MOEs to be utilized for the evaluation of alternatives.*

7.0 Safety Analysis

A. *Detailed crash data within the study area will be analyzed and documented.*
Years: Source:

8.0 Consistency with Other Plans/Projects

A. *The request will be reviewed for consistency with facility Master Plans, Actions Plans, SIS Plan, MPO Long Range Transportation Plans, Local Government Comprehensive Plans or development applications, etc.*

B. *Where the request is inconsistent with any plan, steps to bring the plan into consistency will be developed.*

C. *The operational relationship of this request to the other interchanges will be reviewed and documented. The following other IARs are located within the area of influence.*

9.0 Environmental Considerations

A. *Status of Environmental Approval and permitting process.*

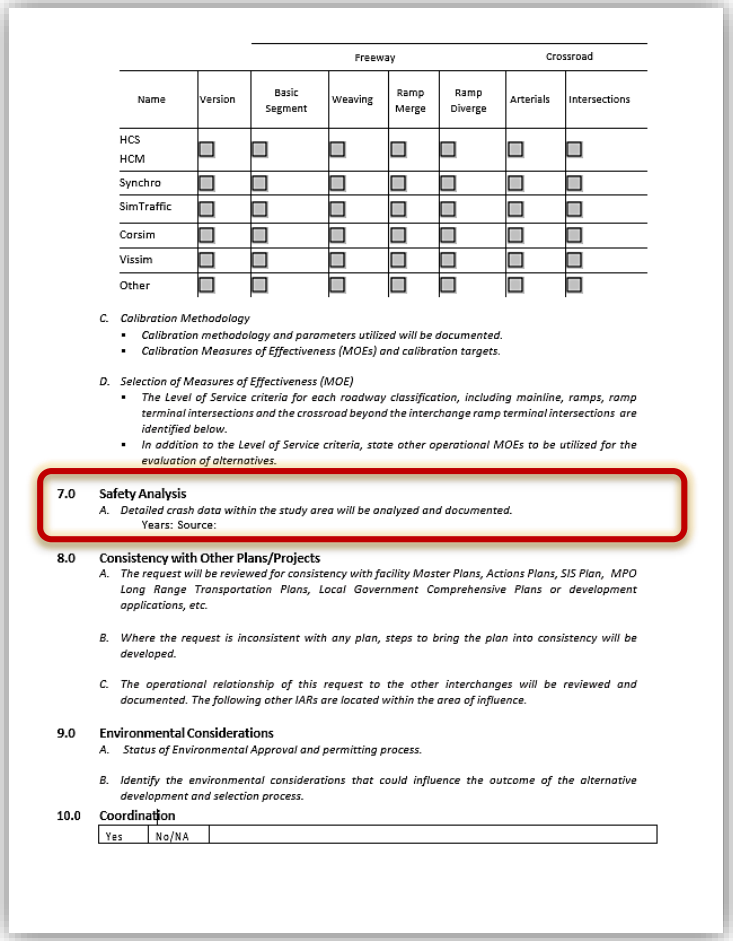
B. *Identify the environmental considerations that could influence the outcome of the alternative development and selection process.*

10.0 Coordination

Yes	No/NA	

Requirements in MLOU

- The following safety performance measures must be stated in the MLOU
  - Crash rate
  - Crash frequency
  - Reduction in crashes
  - Benefit Cost Ratio (as applicable)



		Freeway				Crossroad	
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Synchro	☐	☐	☐	☐	☐	☐	☐
SimTraffic	☐	☐	☐	☐	☐	☐	☐
Corsim	☐	☐	☐	☐	☐	☐	☐
Vissim	☐	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐	☐

C. *Calibration Methodology*
- *Calibration methodology and parameters utilized will be documented.*
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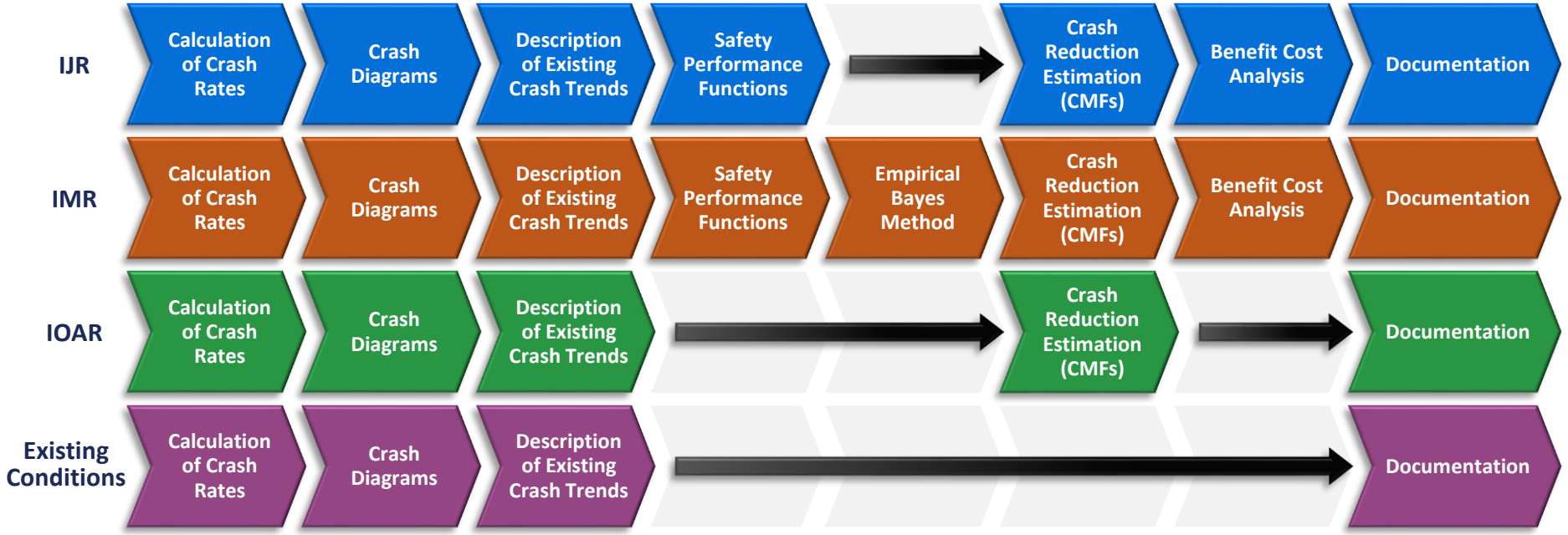
10.0 Coordination

Yes	No/NA	

Safety Analysis Methodology

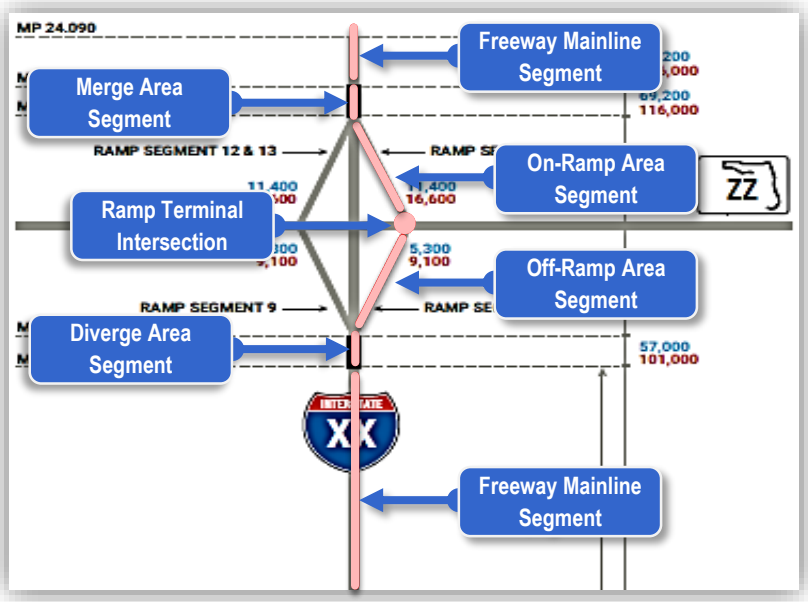
Safety Analysis Types



- Safety analysis based on the procedures in the Highway Safety Manual (HSM)

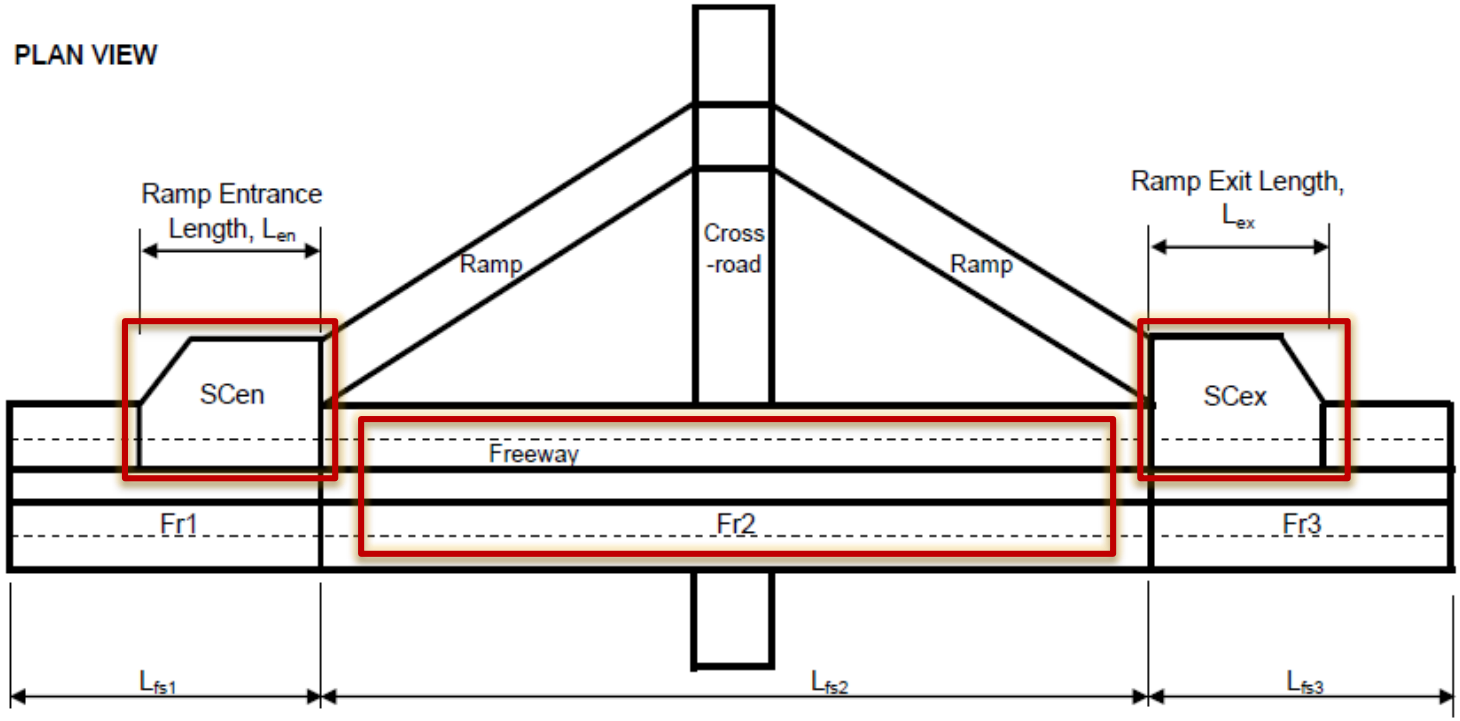
Segmentation Process

- Specify the Area of Influence for safety analysis
  - The study limits of safety analysis are the same as for operational analysis.
- Crash Data should be collected according to the segmentation of the project
- Rule: move along a reference line, begin new segment where there is a change in segment type
- Safety analysis should be specific to the proposed improvements



Segmentation Process

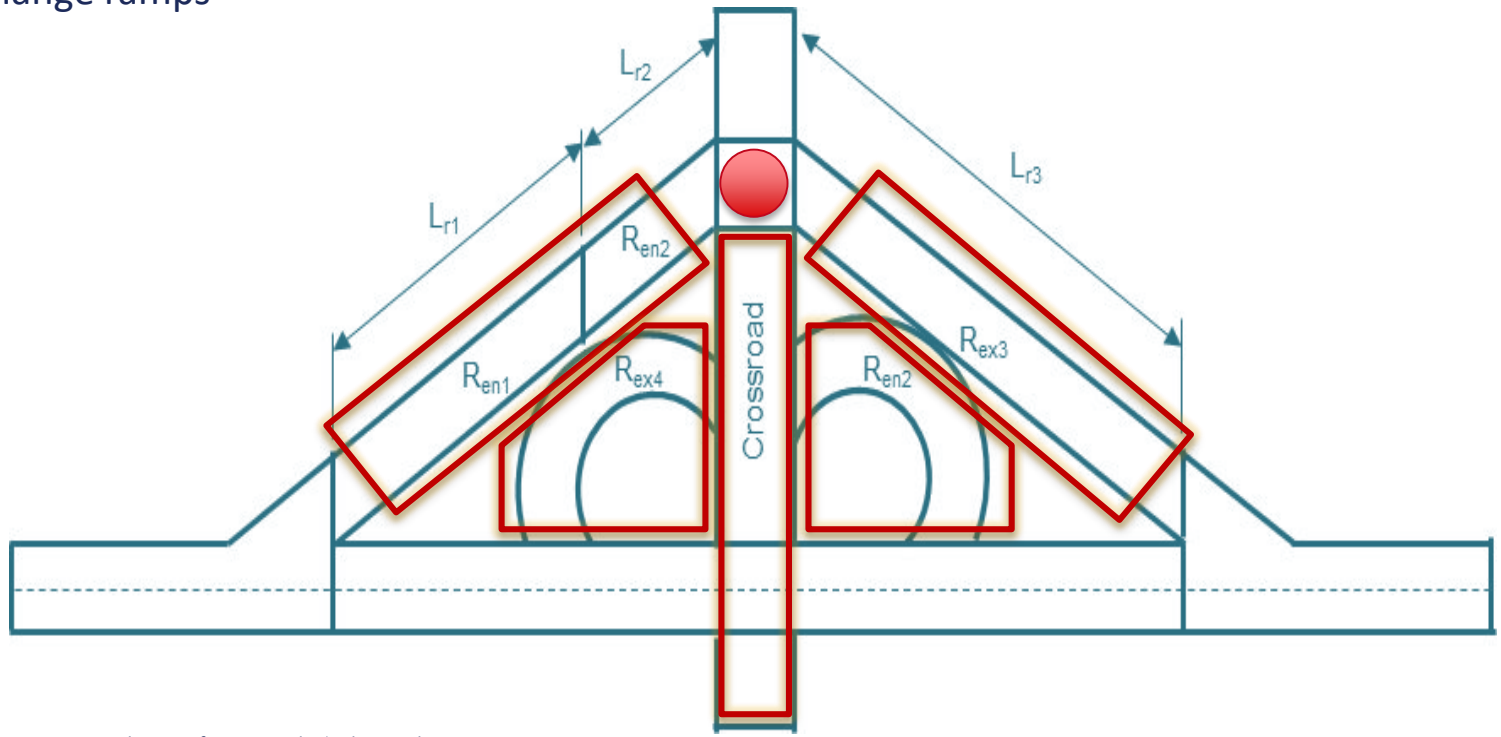
- Freeway segmentation process
  - Merge area
  - Freeway mainline
  - Diverge area



Source: Highway Safety Manual 1st Edition, Chapter 18, Figure 18-10

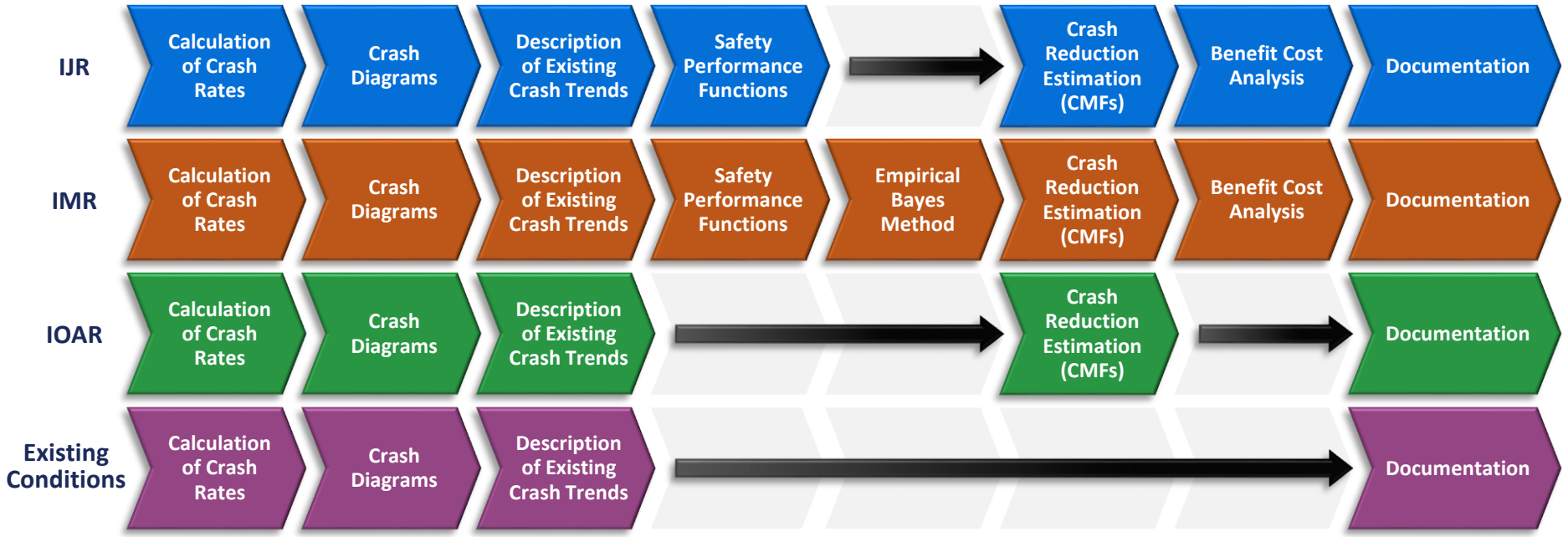
Segmentation Process

- Ramp segmentation process
  - Crossroad segment
  - Study intersections
  - Interchange ramps



Source: Highway Safety Manual 1st Edition, Chapter 19, Figure 19-10

Existing Conditions



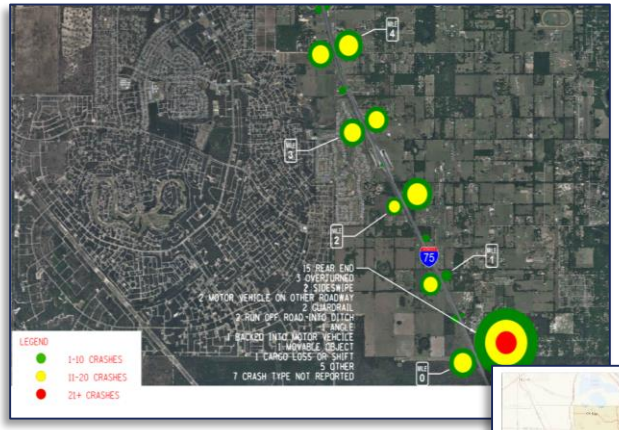
Calculation of Crash Rates

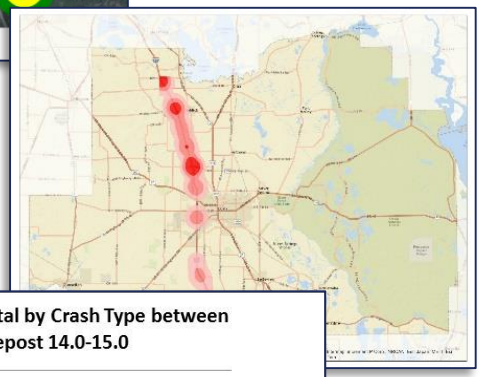
- Calculation of crash rates
  - Provides a qualitative data point
  - Compare across different locations

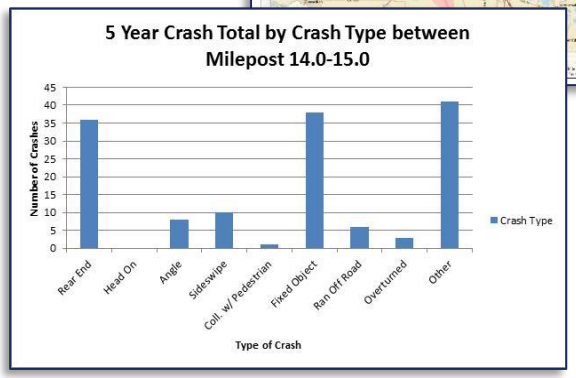
- Crash Frequency = $\frac{Total\ Crashes}{Years\ of\ Crash\ Data}$
  - Units: Crashes/Year
- Crash Rate (Intersections) = $\frac{Total\ Crashes * 1{,}000{,}000}{AADT * 365 * Years}$
  - Units: Crashes/Million Entering
- Crash Rate (Segments) = $\frac{Total\ Crashes * 1{,}000{,}000}{AADT * 365 * Years * Miles}$
  - Units: Crashes/Million Vehicle Miles Traveled

Crash Diagrams & Description of Existing Crash Trends

- Crash diagrams
  - Show crashes graphically
  - Can be performed by GIS or by hand
- Types of crash diagrams include
  - Heat maps
  - Bar charts
  - Pie charts
  - Other maps graphically showing the high crash locations along a system or at an interchange
- Provide a description of the existing crash trends observed using the historical crash data



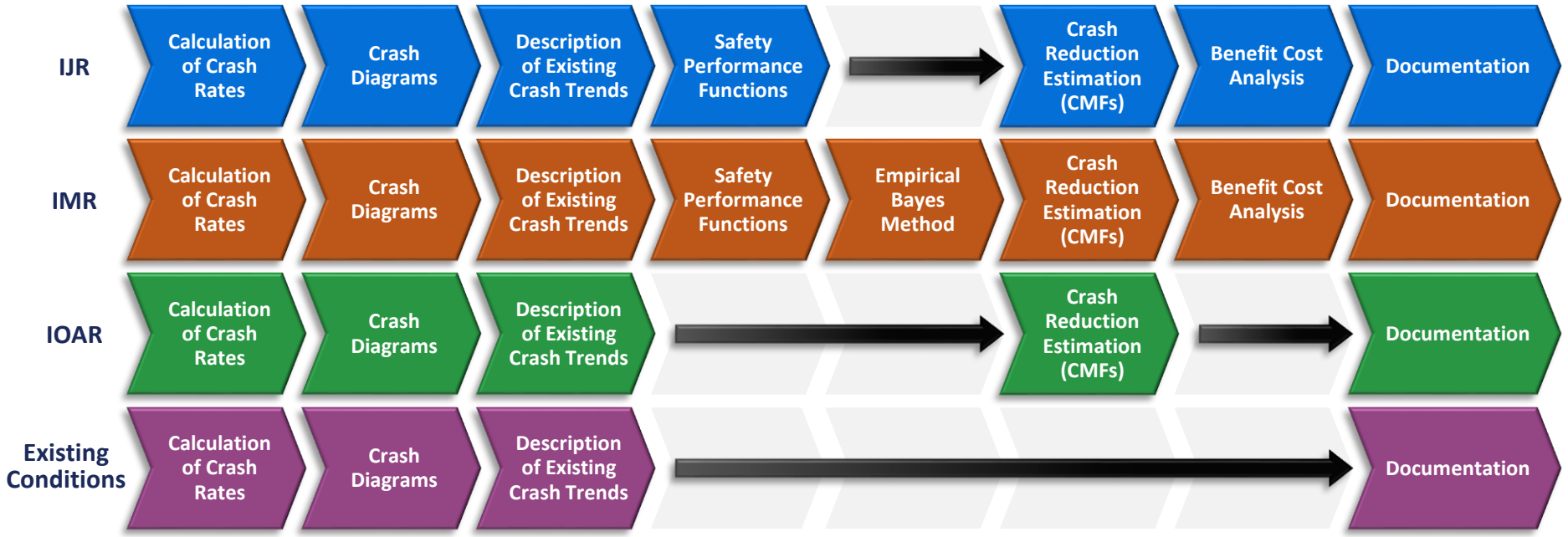




Documentation

- Include the following documentation when discussing the existing conditions crash analysis:

Interchange Operational Analysis Report (IOAR)



Crash Reduction Estimation (CMFs)

- Crash Modification Factors (CMFs) provide an estimated reduction in crashes for safety improvements

- CMFs are available via:
  - Crash Modification Factors Clearinghouse funded by FHWA
    - http://www.cmfclearinghouse.org/index.cfm
  - Highway Safety Manual (HSM)

- Some common CMFs that can be applied to IARs

Countermeasure	CMF
Add continuous auxiliary lane for weaving between entrance ramp and exit ramp	0.79
Change spacing between two ramp terminals at diamond interchange from X feet to Y feet	$= 100 * (1 - e^{0.014308(Y-X)})$
Convert diamond interchange to DDI or DCD	0.67
Design diamond, trumpet, or cloverleaf interchange with crossroad above freeway	0.96
Divided vs. undivided cross road at diamond interchange ramps	0.53
Install a traffic signal	0.61
Provide left turn on 1 approach	0.93
Provide right turn on 1 approach	0.96

- CMFs may not exist for each improvement

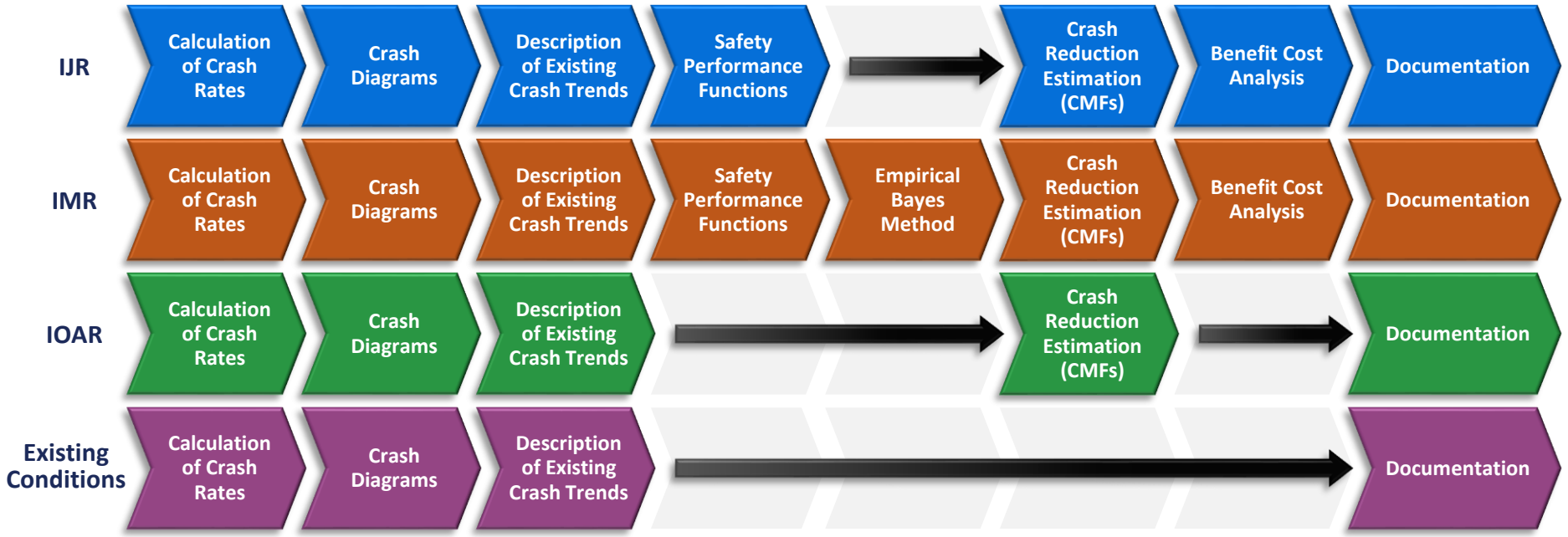
Crash Reduction Estimation (CMFs)

- Crash Modification Factors (CMFs) provide an estimated reduction in crashes for safety improvements
- Proposed Crash Frequency = $Existing\ Crash\ Frequency\ * (CMF_1 * CMF2 * \cdots CMFn)$
- Apply CMFs to specific areas where improvements are being implemented

Documentation

- Include the following documentation in the IOAR:

Interchange Modification Report (IMR)



Safety Performance Functions

- A safety performance function (SPF) is an equation used to calculate the expected number of crashes per year at a location as a function of exposure and, in some cases, roadway or intersection characteristics
  - Predicts crash frequency

- Safety Performance Functions equations incorporate
  - Annual Average Daily Traffic (AADT)
  - Sight Characteristics (i.e. Number of Lanes, Merge/Diverge Type, Intersection Type)
  - Existing Condition Crash Modification Factors (i.e. Turn Lanes, Presence of TWLTL, Flashing Yellow Arrow Indications)

- Needed only for facilities where alternatives are being considered

Safety Performance Functions

Predicted Crash Frequency

$$N_{predicted} =$$

$$SPF \times (CMF1 \times CMF2 \times \ldots.) \times C$$

where:

SPF = Safety Performance Function

CMF = Crash Modification Factors

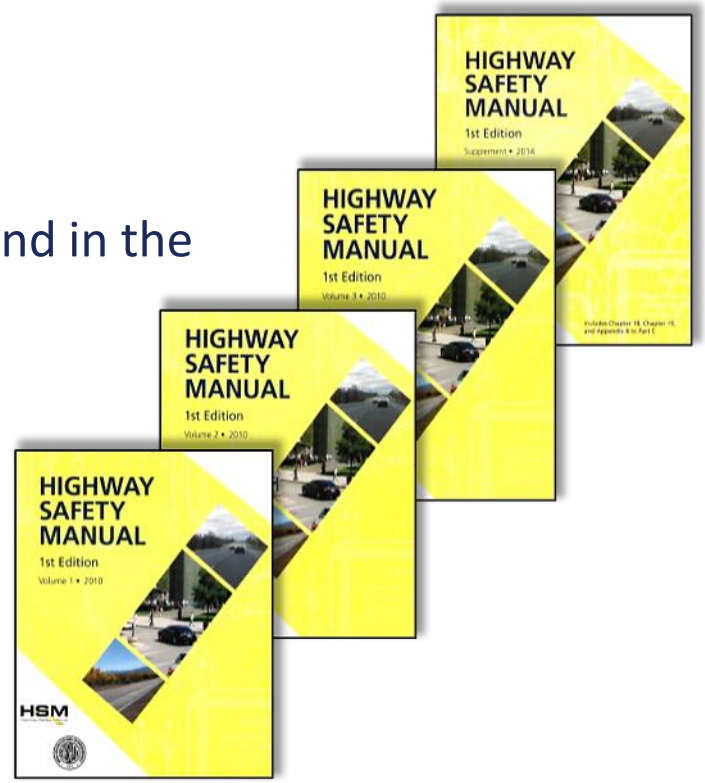
C = Local Calibration Factor

Safety Performance Functions

- Calculating the SPF for each facility crash type has 4 steps:
  1. Base Equation (N_{bimv}=…)
  2. SPF Coefficients (Total, FI, PDO Coefficients to use in Base Equation)
  3. Balancing Fatal-Injury and Property Damage Only
  4. Distribution of Crash Type

- SPF equations, CMFs and Coefficients can be found in the HSM Part 2

- SPF calculations performed using Spreadsheets
  - Will be available on the FDOT website
  - http://www.fdot.gov/planning/systems/training.shtm



Safety Performance Functions

- Step 1: Base Equation (N_{bimv}=…)
  - Crash/collision type: Intersection Multiple Vehicle Crashes

Multiple-Vehicle Collisions

SPFs for multiple-vehicle intersection-related collisions are applied as follows:

$$N_{bimv} = exp(a + b \times In(AADT_{maj}) + c \times In(AADT_{min})) \quad (12\text{-}21)$$

Where:

$AADT_{maj}$ = average daily traffic volume (vehicles/day) for major road (both directions of travel combined);

$AADT_{min}$ = average daily traffic volume (vehicles/day) for minor road (both directions of travel combined); and

a, b, c = regression coefficients.

Source: Highway Safety Manual 1st Edition, Chapter 12

Safety Performance Functions

- Step 2: SPF Coefficients (Total, FI, PDO Coefficients to use in Base Equation)
  - Crash/collision type: Intersection Multiple Vehicle Crashes

Table 12-10. SPF Coefficients for Multiple-Vehicle Collisions at Intersections

Intersection Type	Coefficients Used in Equation 12-21			Overdispersion Parameter (k)
	Intercept (a)	$AADT_{maj}$ (b)	$AADT_{min}$ (c)	
Total Crashes				
3ST	−13.36	1.11	0.41	0.80
3SG	−12.13	1.11	0.26	0.33
4ST	−8.90	0.82	0.25	0.40
4SG	−10.99	1.07	0.23	0.39
Fatal-and-Injury Crashes				
3ST	−14.01	1.16	0.30	0.69
3SG	−11.58	1.02	0.17	0.30
4ST	−11.13	0.93	0.28	0.48
4SG	−13.14	1.18	0.22	0.33
Property-Damage-Only Crashes				
3ST	−15.38	1.20	0.51	0.77
3SG	−13.24	1.14	0.30	0.36
4ST	−8.74	0.77	0.23	0.40
4SG	−11.02	1.02	0.24	0.44

Source: Highway Safety Manual 1st Edition, Chapter 12

Safety Performance Functions

- Step 2: SPF Coefficients (Total, FI, PDO Coefficients to use in Base Equation)
  - Crash/collision type: Intersection Multiple Vehicle Crashes

Table 12-10. SPF Coefficients for Multiple-Vehicle Collisions at Intersections

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4ST	−8.74	0.77	0.23	0.40
4SG	−11.02	1.02	0.24	0.44

Source: Highway Safety Manual 1st Edition, Chapter 12

Safety Performance Functions

- Step 3: Balancing Fatal/Injury and Property Damage Only crashes
  - Crash/collision type: Intersection Multiple Vehicle Crashes

$$N_{bimv(FI)} = N_{bimv(total)} * \left(\frac{N'_{bimv(FI)}}{N'_{bimv(FI)} + N'_{bimv(PDO)}}\right) \quad (12\text{-}22)$$

$$N_{bimv(PDO)} = N_{bimv(total)} - N_{bimv(FI)} \quad (12\text{-}23)$$

Source: Highway Safety Manual 1st Edition, Chapter 12

Safety Performance Functions

- Step 4: distribution of crash types
  - Crash/collision type: Intersection Multiple Vehicle Crashes

Table 12-11. Distribution of Multiple-Vehicle Collisions for Intersections by Collision Type

	Proportion of Crashes by Severity Level for Specific Intersections Types							
	3ST		3SG		4ST		4SG	
Manner of Collision	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Rear-end collision	0.421	0.440	0.549	0.546	0.338	0.374	0.450	0.483
Head-on collision	0.045	0.023	0.038	0.020	0.041	0.030	0.049	0.030
Angle collision	0.343	0.262	0.280	0.204	0.440	0.335	0.347	0.244
Sideswipe	0.126	0.040	0.076	0.032	0.121	0.044	0.099	0.032
Other multiple-vehicle collisions	0.065	0.235	0.057	0.198	0.060	0.217	0.055	0.211

Source: HSIS data for California (2002–2006)

Source: Highway Safety Manual 1st Edition, Chapter 12

Safety Performance Functions

- After completing the 4 steps, apply the Crash Modification Factors (CMFs)
- The CMF(s) is applied to the SPF in predicted crash frequency only for existing conditions
- Each SPF has certain CMFs that can be applied
- Calculations performed using Spreadsheets

$$N_{predicted} = SPF \times (CMF1 \times CMF2 \times ....) \times C$$

where:

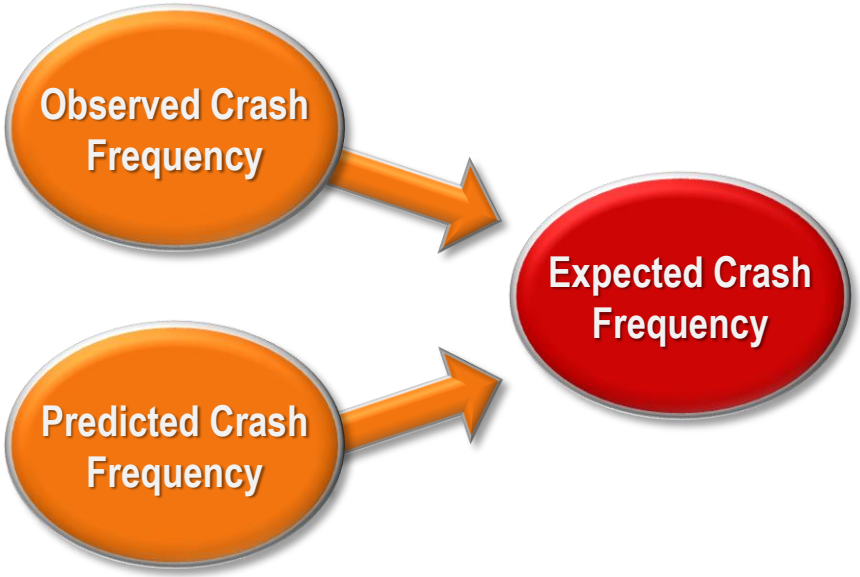
SPF = Safety Performance Function

CMF = Crash Modification Factors

C = Local Calibration Factor

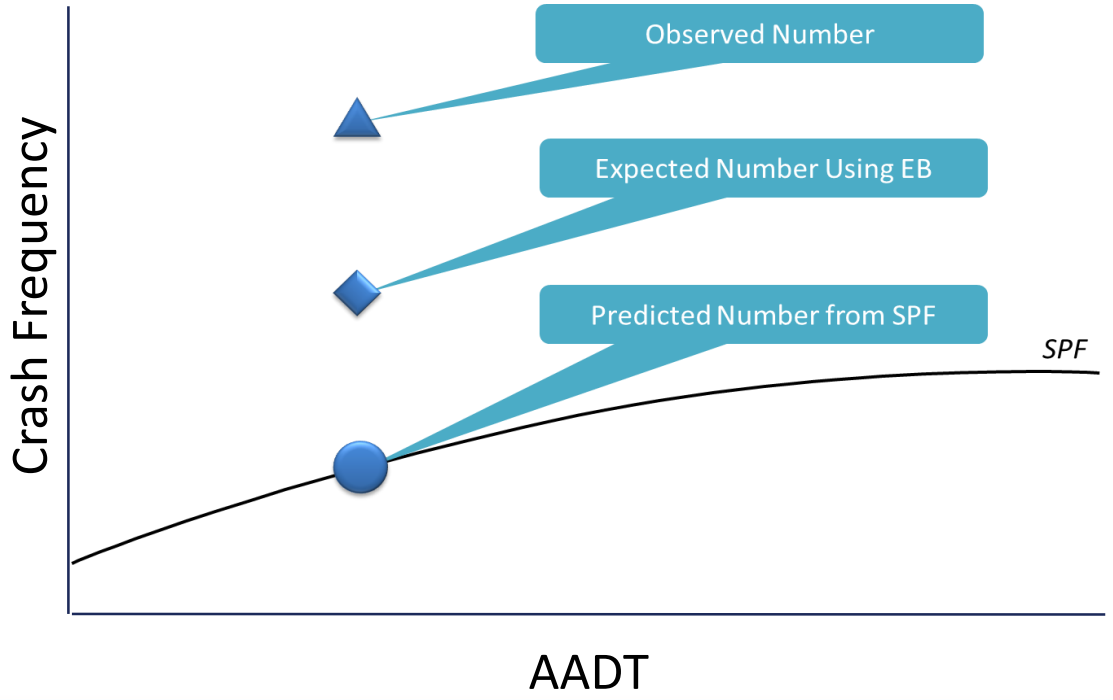
Empirical Bayes Method

- Empirical Bayes Method
  - Combines **Predicted** Crash Frequency with **Observed** Crash Frequency to determine **Expected** Crash Frequency
  - Improves the statistical reliability
- Observed Crash Frequency
  - Existing crash data collected
- Predicted Crash Frequency
  - Calculated using the Safety Performance Function (SPF)
- Expected Crash Frequency
  - Calculated from the **Observed** and **Predicted** crash frequency



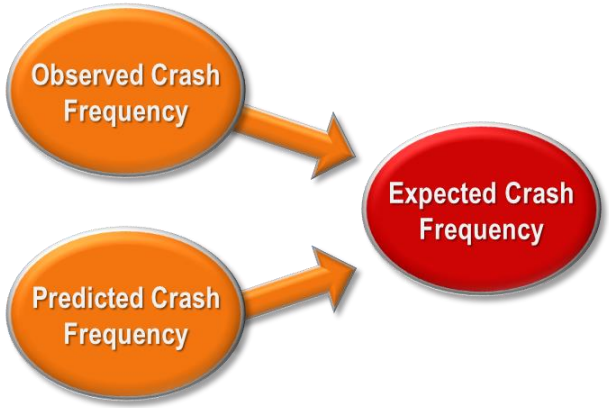
Empirical Bayes Method

- $Number\ of\ expected\ crashes = w * N_{predicted} + (1 - w) * N_{observed}$
  - Where: $w = \frac{1}{1 + k * (N_{predicted} * Study\ Years)}$
  - K = overdispersion parameter (associated with SPF) – can be found in HSM Part 2



Empirical Bayes Method

- Empirical Bayes Method Summary
  - The higher the weight value, the more confidence is put on Predicted Crashes compared to Observed Crashes
  - Longer Study Period (Higher $N_{predicted}$ Total) = More Confidence in Observed Crashes
  - Longer Study Areas (Higher $N_{predicted}$ Total) = More Confidence in Observed Crashes
  - Higher K Value, better SPF = More Confidence in Predicted Crashes



Benefit Cost Analysis

- Benefit Cost Analysis (BCA) requires Empirical Bayes Method
- Assign dollar value to crashes prevented
- Divide benefits by cost

FDOT KABCO Crash Costs 2011-2015

Cost Severity	Compressive Crash Cost
Fatal (K)	$10,560,000
Severe Injury (A)	$599,040
Moderate Injury (B)	$162,240
Minor Injury (C)	$100,800
Property Damage Only (O)	$7,600

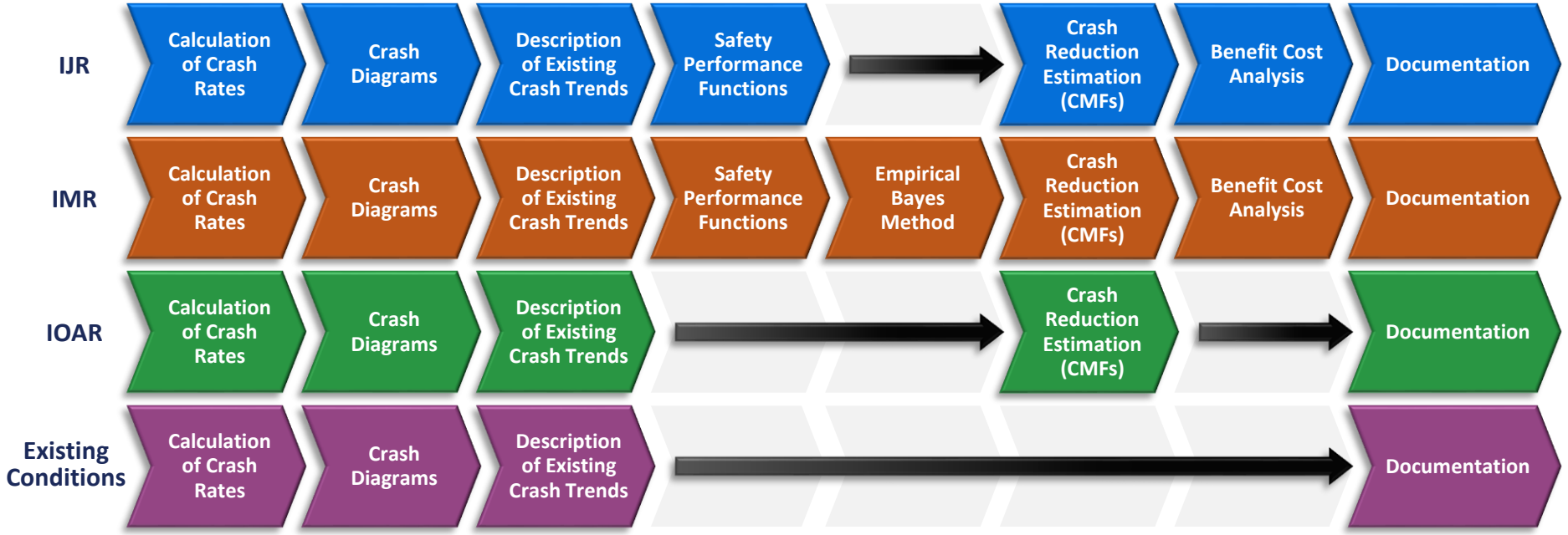
Source: Florida Department of Transportation State Safety Office's Crash Analysis Reporting (CAR) System, analysis years 2011 through 2015

Documentation

- Include the following documentation in the IMR:

Interchange Justification Report (IJR)

- Empirical Bayes method not required in an IJR



Questions?

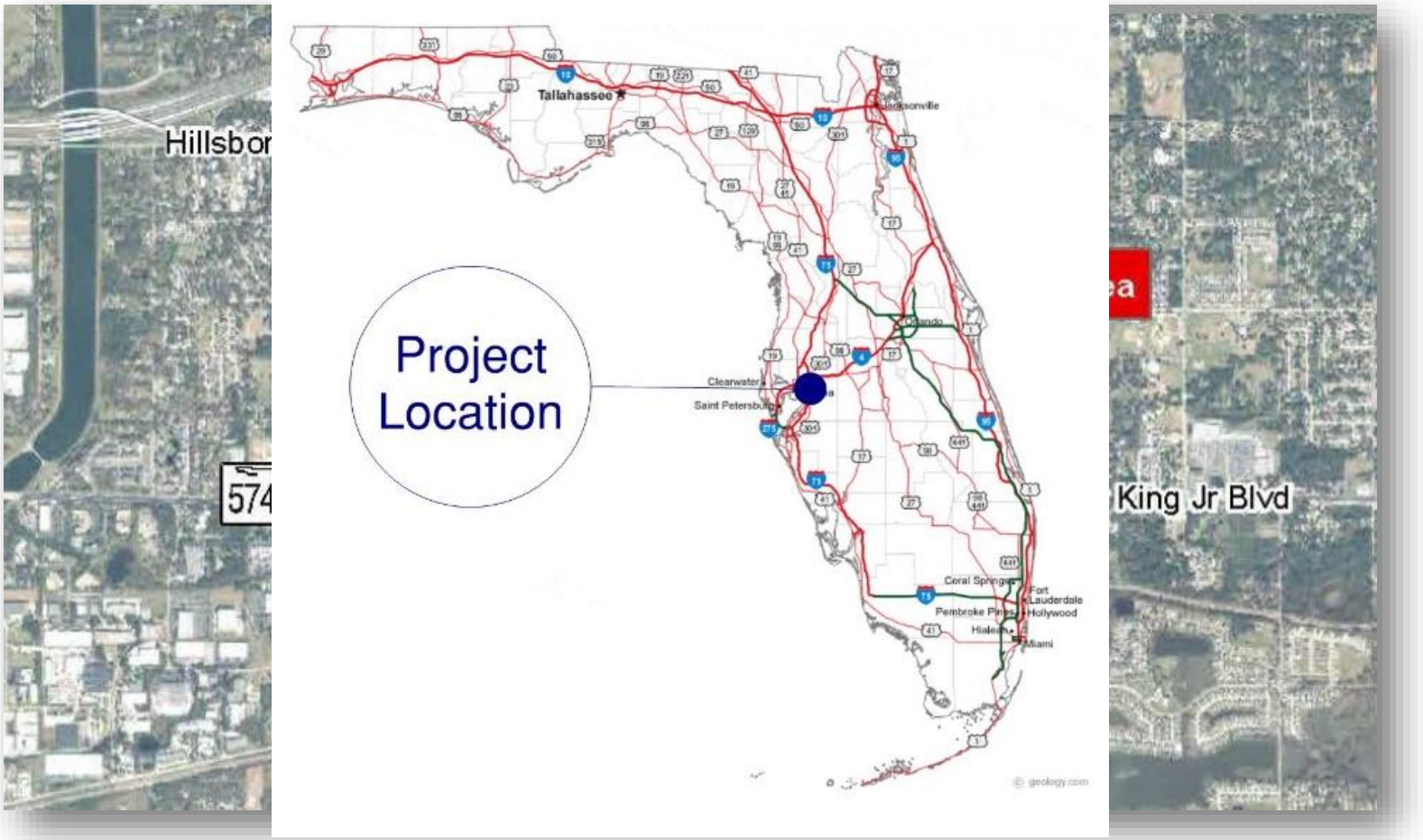
Project Examples

IOAR Example

- I-4 at Saxon Boulevard

IMR Example

- I-75 at Martin Luther King Boulevard



IJR Example

- I-75 at CR 514

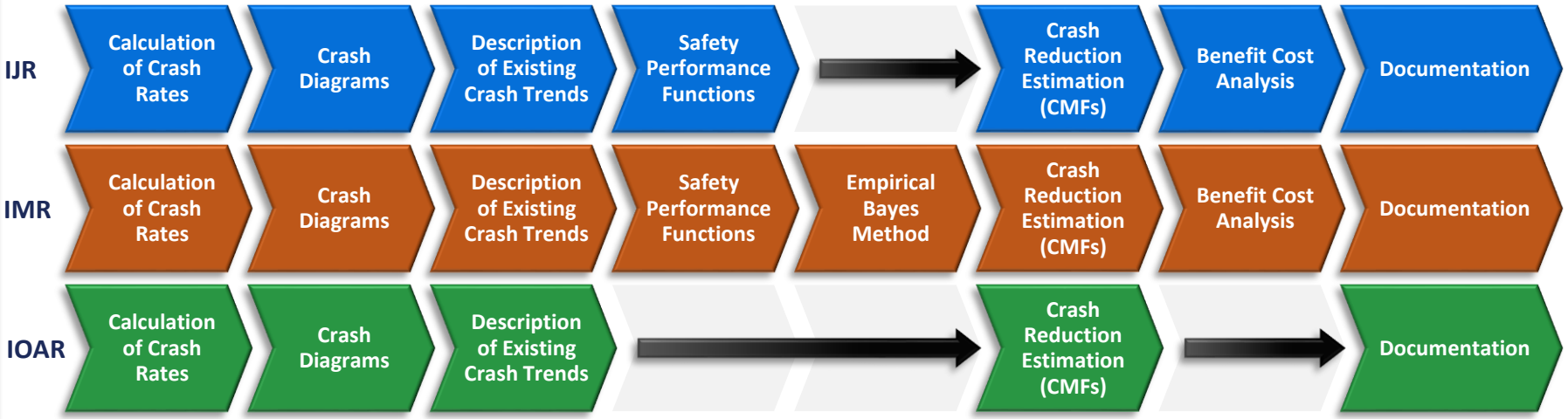
Example 1:
I-4 at Saxon Boulevard IOAR

Project Summary

- Project location
  - Volusia County
- Existing conditions
  - Partial Cloverleaf
  - Loop ramp in all quadrants except southeast quadrant
- Major recommended improvements
  - Signalize the I-4 eastbound off-ramp right turn movement
  - Additional eastbound through lane on Saxon Boulevard between the eastbound off-ramp and Normandy Boulevard

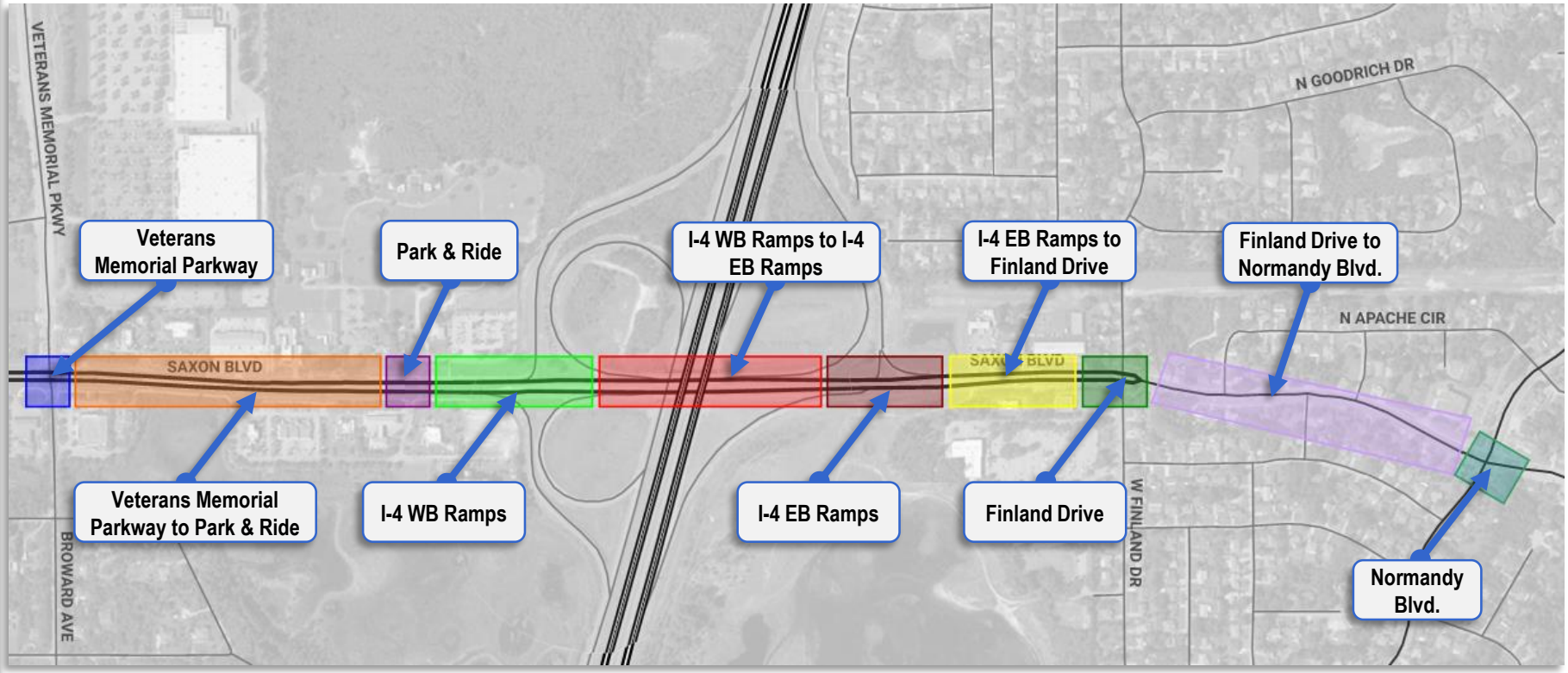
Tasks Required

- Benefit Cost Analysis is not required for this IOAR safety analysis



Segmentation Process

- This project focused primarily on the arterial capacity and I-4 eastbound off-ramp signalization
- Focus on project improvements only for safety analysis



Existing Crash Data

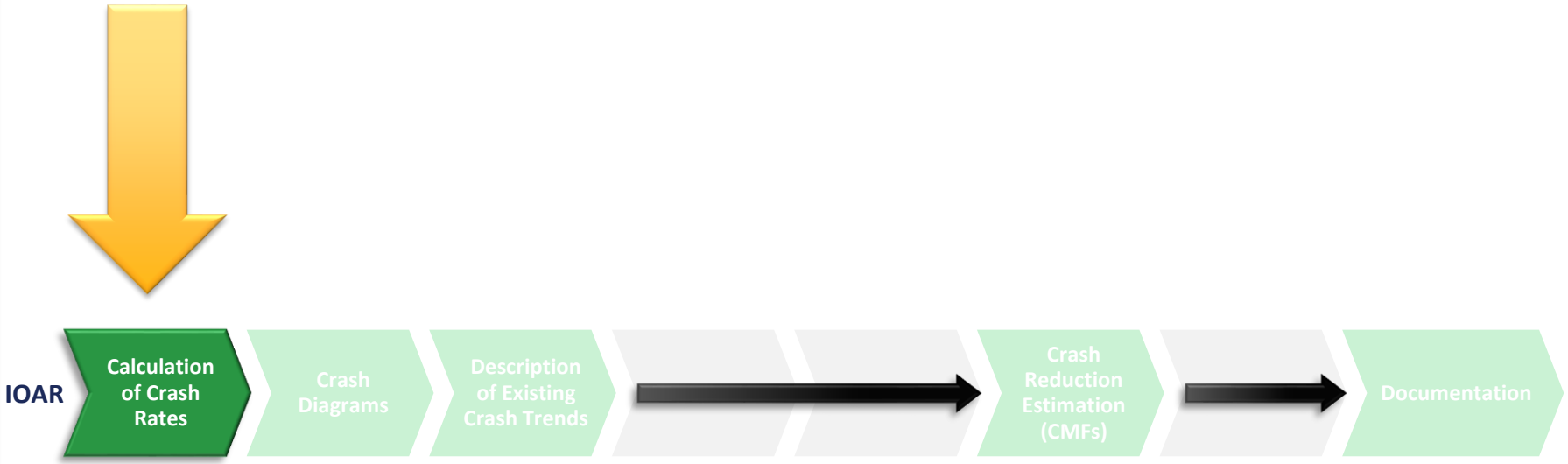
Crashes Divided by Location (Segmentation)

5-Year Crash History	Veterans Memorial Parkway	Veterans Memorial Parkway to Park&Ride	Park&Ride	I-4 WB Ramps	I-4 WB Ramps to I-4 EB Ramps	I-4 EB Ramps	I-4 EB Ramps to Finland Drive	Finland Drive	Finland Drive to Normandy Blvd.	Normandy Blvd.
Fatality	1	0	0	0	0	0	0	0	1	0
Injury	42	5	21	3	1	19	8	25	7	29
PDO	59	12	14	14	1	17	16	36	4	35
Total	**102**	**17**	**35**	**17**	**2**	**36**	**24**	**61**	**12**	**64**

3-5 Years of Crash Data Required

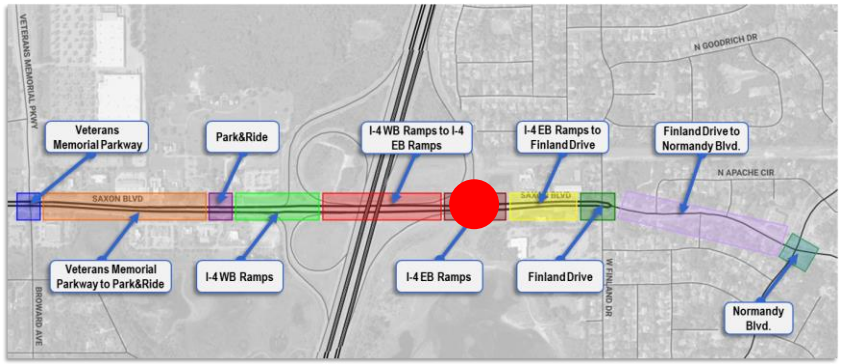
- Focus on project improvements only for safety analysis

Calculation of Crash Rates



Calculation of Crash Rates

- Calculation example
  - Intersection – Saxon Boulevard at I-4 eastbound ramps



- Crash Frequency =

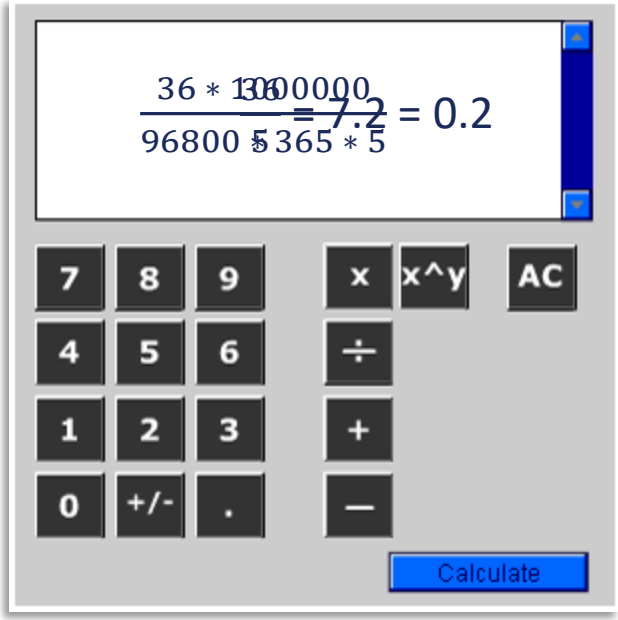
$$\frac{36\ Crashes}{5\ Years} =$$

7.2 Crashes/Year

- Crash Rate (Intersections) =

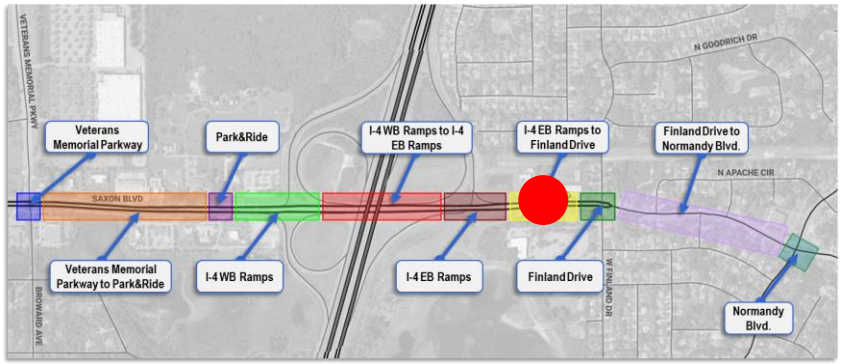
$$\frac{36\ Crashes\ *\ 1{,}000{,}000}{96{,}800\ Vehicles\ *\ 365\ *5\ Years} =$$

0.20 Crashes/Million Entering



Calculation of Crash Rates

- Calculation example
  - Segment – I-4 eastbound ramps to Finland Drive



- Crash Frequency =

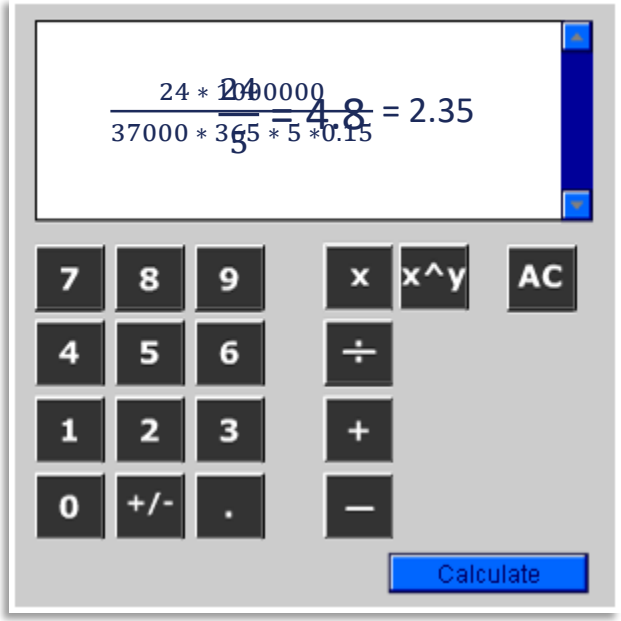
$$\frac{24\ Crashes}{5\ Years} =$$

4.8 Crashes/Year

- Crash Rate (Segments) =

$$\frac{24\ Crashes * 1{,}000{,}000}{37{,}000\ vehicles * 365 *\ 5\ Years * 0.15\ Miles} =$$

2.35 Crashes/Million Vehicle Miles Traveled

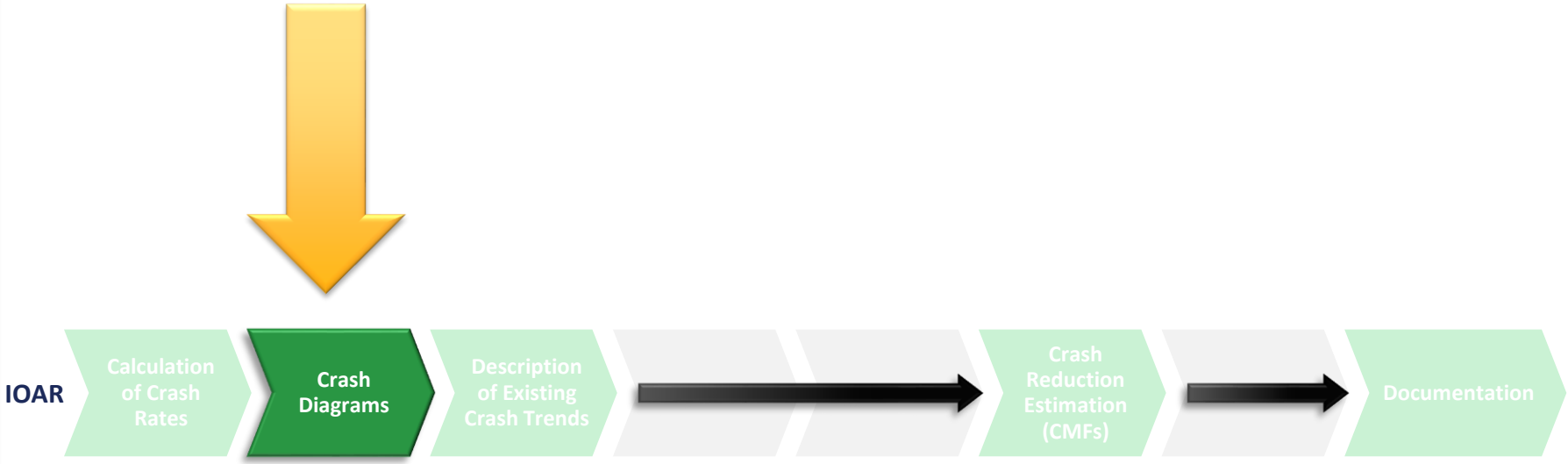


Calculation of Crash Rates

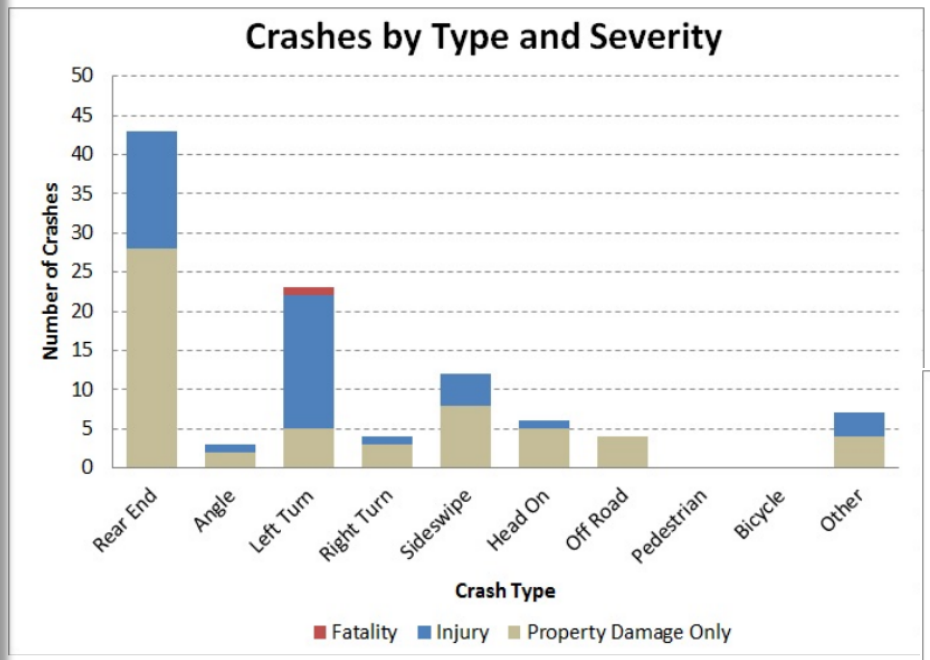
		Veterans Memorial Parkway	Veterans Memorial Parkway to Park&Ride	Park&Ride	I-4 WB Ramps	I-4 WB Ramps to I-4 EB Ramps	I-4 EB Ramps	I-4 EB Ramps to Finland Drive	Finland Drive	Finland Drive to Normany Blvd	Normandy Blvd
5-Year Crash History	Fatality	1	0	0	0	0	0	0	0	1	0
	Injury	42	5	21	3	1	19	8	25	7	29
	PDO	59	12	14	14	1	17	16	36	4	35
	Total	**102**	**17**	**35**	**17**	**2**	**36**	**24**	**61**	**12**	**64**
Daily Entering		50,800	41,000	41,400	46,300	41,000	96,800	37,000	39,500	37,000	49,300
Segment Length			1,700'			1,400'		800'		1,800'	
Crash Frequency		**20.4**	**3.4**	**7**	**3.4**	**0.4**	**7.2**	**4.8**	**12.2**	**2.4**	**12.8**
Crash Rate		**1.10**	**0.71**	**0.46**	**0.20**	**0.10**	**0.20**	**2.35**	**0.85**	**0.52**	**0.71**

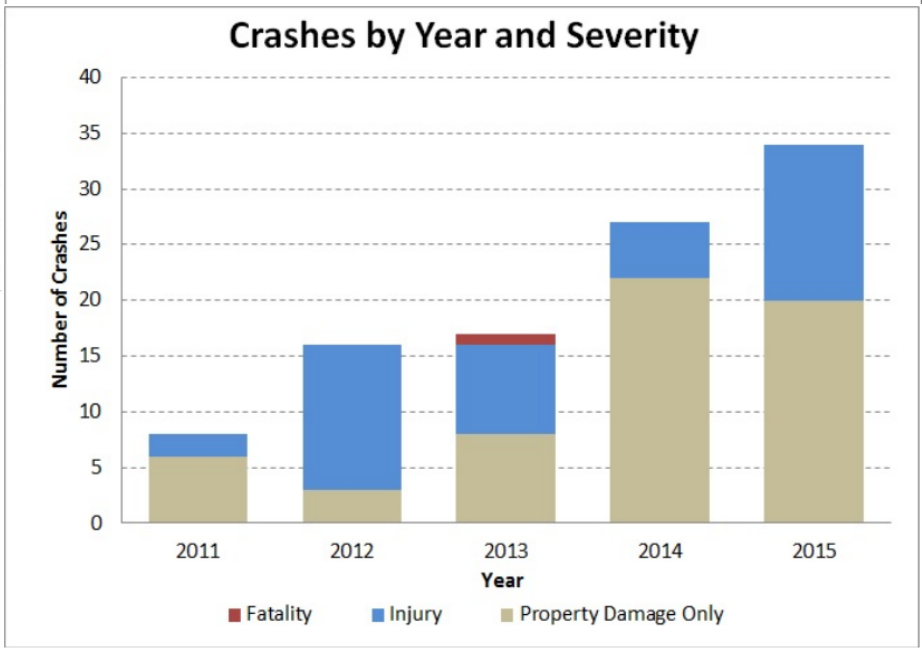
- Focus on project improvements only for safety analysis

Crash Diagrams

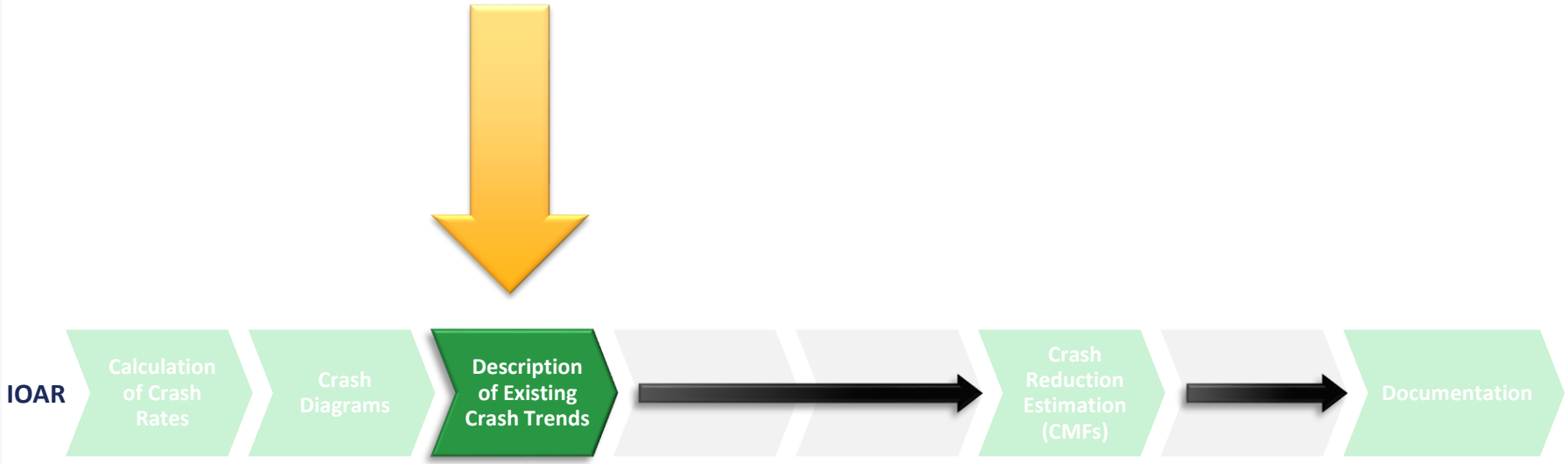


Crash Diagrams





Description of Existing Crash Trends

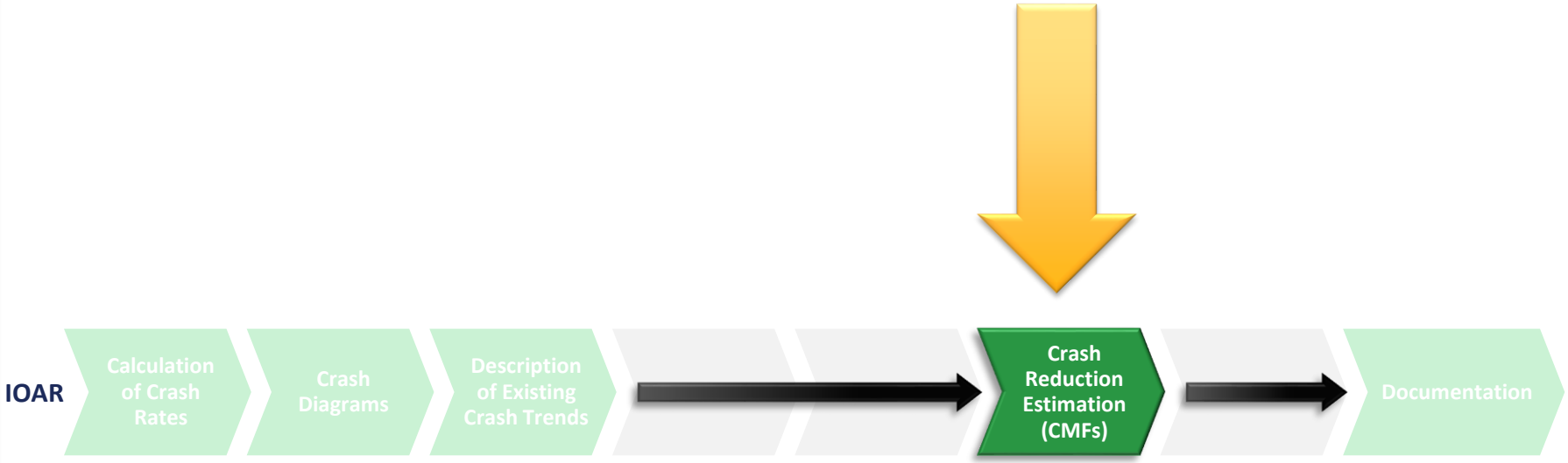


Description of Existing Crash Trends

- During the five-year crash analysis period (2011-2015), 102 crashes were reported at Saxon Boulevard at Veterans Memorial Parkway. Of the 102 crashes, 42 crashes (41 percent) were injury related and 59 crashes (58 percent) resulted in PDO. One (1) fatal crash was reported during the crash analysis period at this location. Other crash metrics at this intersection include:
  - Rear End was the highest crash types (43 crashes) – 15 being injury related;
  - Left Turn crashes were the second highest crash type (23 crashes) – 17 injury related and 1 fatality; and
  - 30 crashes (29 percent) occurred at night.

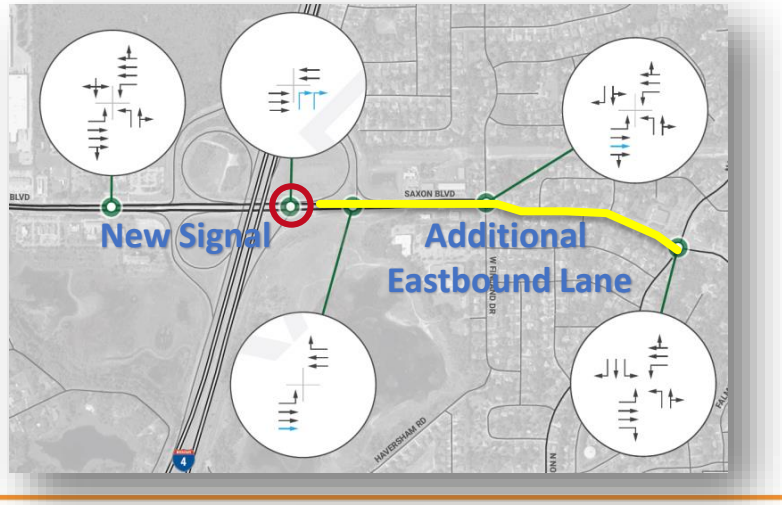
- During the five-year crash analysis period (2011-2015), 64 crashes were reported at Saxon Boulevard at Normandy Boulevard. Of the 64 crashes, 29 crashes (45 percent) were injury related and 35 crashes (5 percent) resulted in PDO. No fatal crashes were reported during the crash analysis period at this location. Other crash metrics at this intersection include:
  - Rear end crashes were the highest crash type (30 crashes) – 10 being injury related;
  - Left turn crashes were the second highest crash type (14 crashes) – 10 being injury related; and
  - 25 crashes (39 percent) occurred at night.

Crash Reduction Estimation (CMFs)



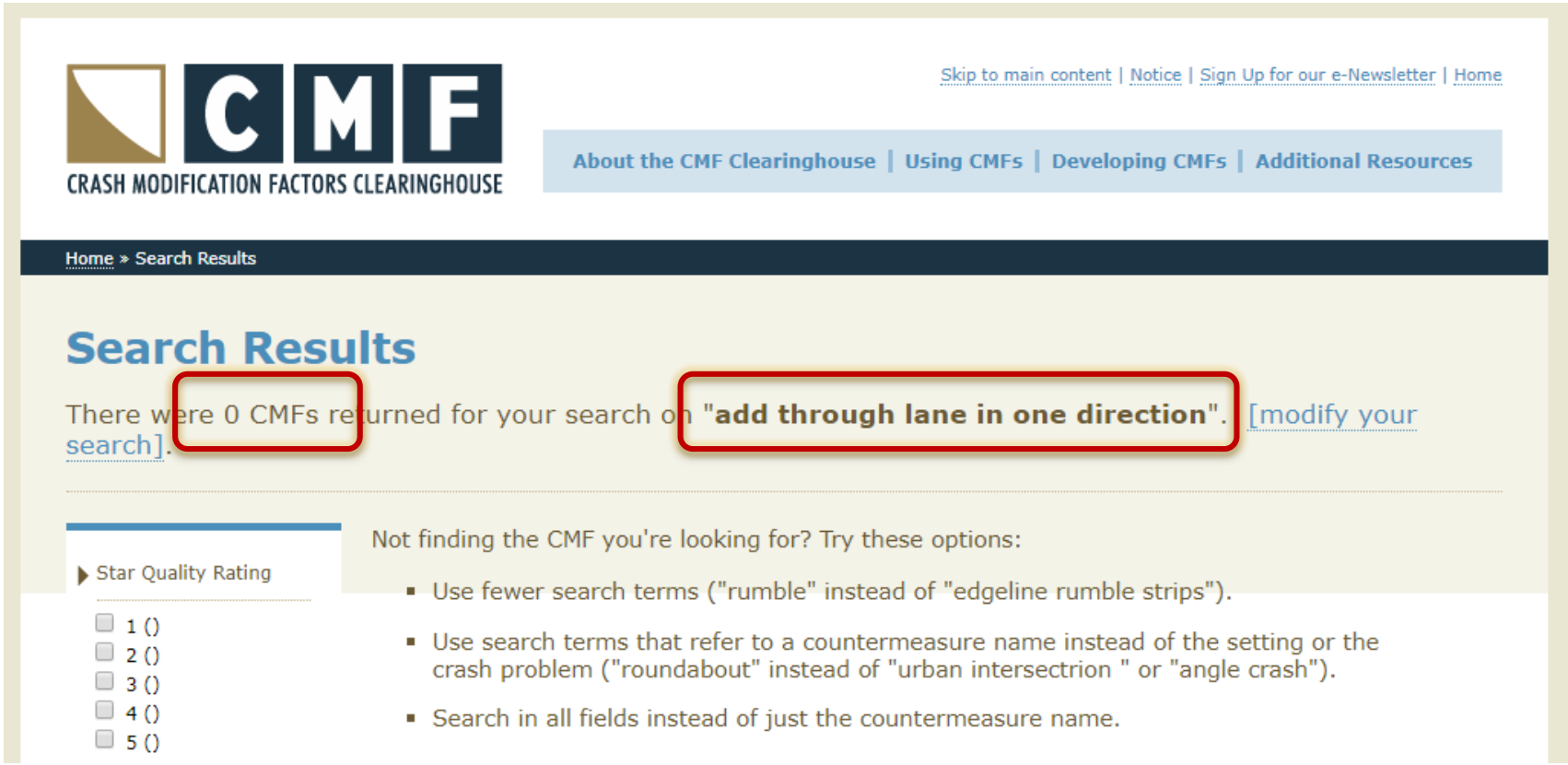
Crash Reduction Estimation (CMFs)

- Major recommended improvements
  - Signalize the I-4 eastbound off-ramp right turn movement
  - Additional eastbound through lane on Saxon Boulevard between the eastbound off-ramp and Normandy Boulevard
- Research CMFs for the recommended improvements
- Crash Modification Factors may not exist for each improvement



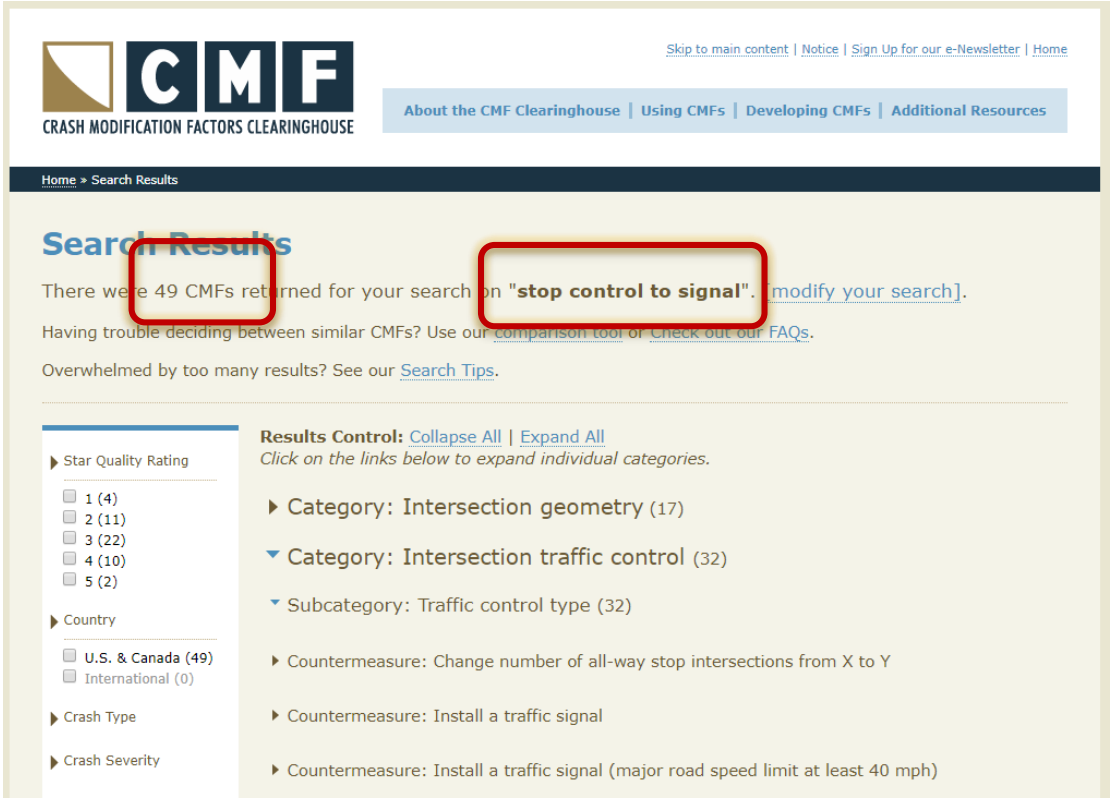
Crash Reduction Estimation (CMFs)

- Major recommended improvement
  - Additional eastbound through lane on Saxon Boulevard between the eastbound off-ramp and Normandy Boulevard



Crash Reduction Estimation (CMFs)

- Major recommended improvement
  - Signalize the eastbound off-ramp right turn movement
  - Selection of CMFs requires engineering judgement and knowledge of project area



Crash Reduction Estimation (CMFs)

- Recommended to use this CMF.

CMF / CRF Details

CMF ID: 322

Install a traffic signal (major road speed limit at least 40 mph)

Description: Install a traffic signal (major road speed limit at least 40 mph)

Prior Condition: No Prior Condition(s)

Category: Intersection traffic control

Study: Safety Effects of Left-Turn Phasing Schemes at High-Speed Intersections, Davis and Aul, 2007

Star Quality Rating:	★★★☆☆

Crash Modification Factor (CMF)	
Value:	0.95
Adjusted Standard Error:	0.09
Unadjusted Standard Error:	0.08

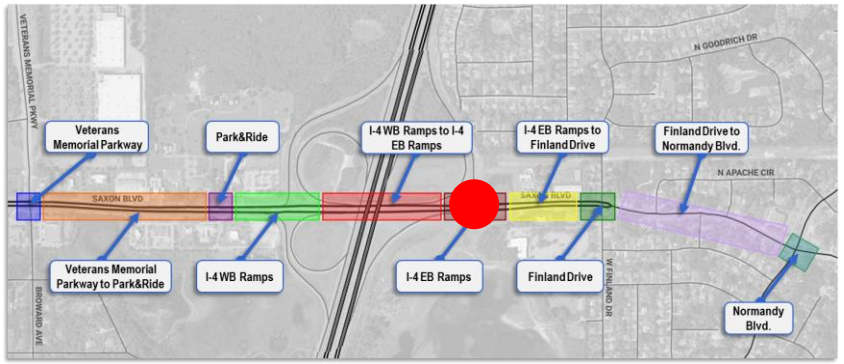
Crash Reduction Estimation (CMFs)

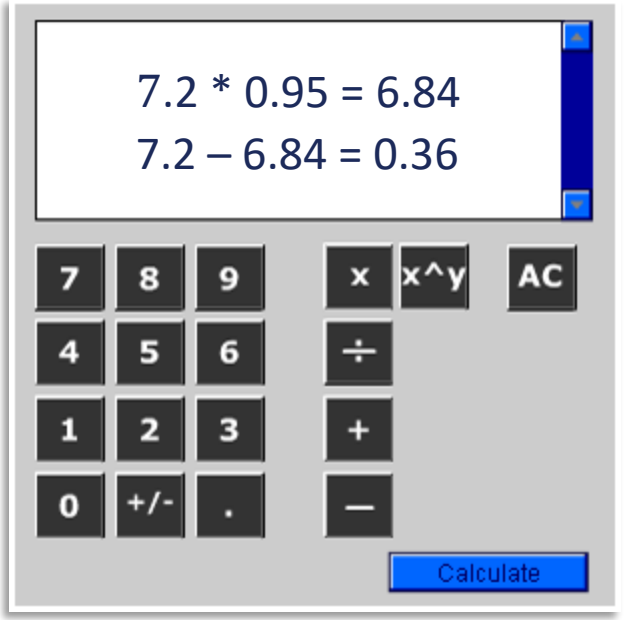
- Apply CMF to appropriate segment that is being improved

		Veterans Memorial Parkway	Veterans Memorial Parkway to Park&Ride	Park&Ride	I-4 WB Ramps	I-4 WB Ramps to I-4 EB Ramps	I-4 EB Ramps	I-4 EB Ramps to Finland Drive	Finland Drive	Finland Drive to Normany Blvd	Normandy Blvd
5-Year Crash History	Fatality	1	0	0	0	0	0	0	0	1	0
	Injury	42	5	21	3	1	19	8	25	7	29
	PDO	59	12	14	14	1	17	16	36	4	35
	Total	**102**	**17**	**35**	**17**	**2**	**36**	**24**	**61**	**12**	**64**
Daily Entering		50,800	41,000	41,400	46,300	41,000	96,800	37,000	39,500	37,000	49,300
Segment Length			1,700'			1,400'		800'		1,800'	
Crash Frequency		**20.4**	**3.4**	**7**	**3.4**	**0.4**	**7.2**	**4.8**	**12.2**	**2.4**	**12.8**
Crash Rate		**1.10**	**0.71**	**0.46**	**0.20**	**0.10**	**0.20**	**2.35**	**0.85**	**0.52**	**0.71**

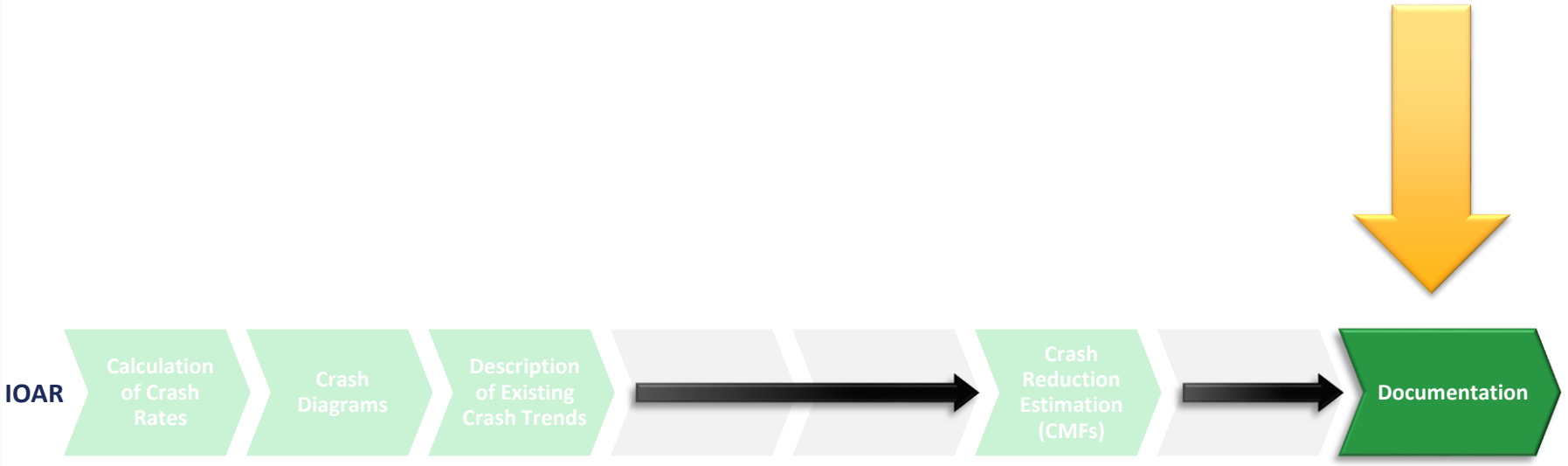
Crash Reduction Estimation (CMFs)

- CMF for Converting Stop Control to Signal Control is 0.95
- Existing Crash Frequency = 7.2 crashes/year
- Proposed Crash Frequency = Existing Crash Frequency * (CMF_1 * CMF_2*…CMF_n)
- Proposed Crash Frequency = 7.20 * 0.95 = 6.84 crashes/year
- Reduction in 0.36 crashes/year





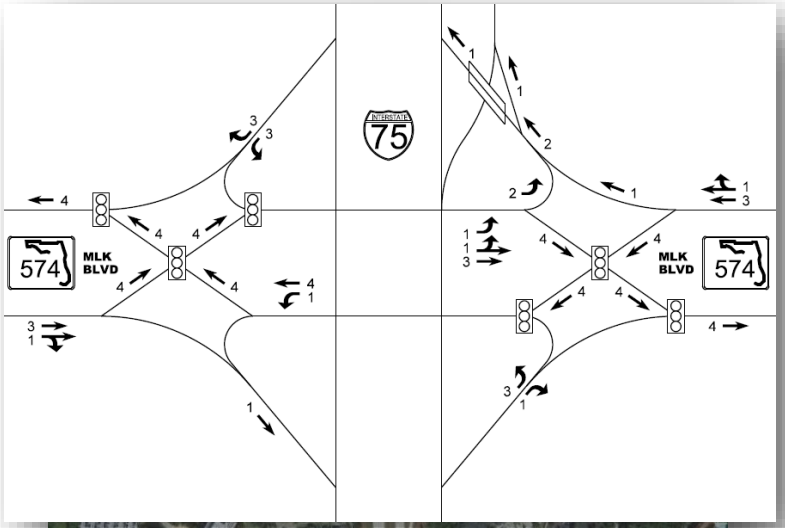
Documentation



Example 2:
I-75 at Martin Luther King Boulevard IMR

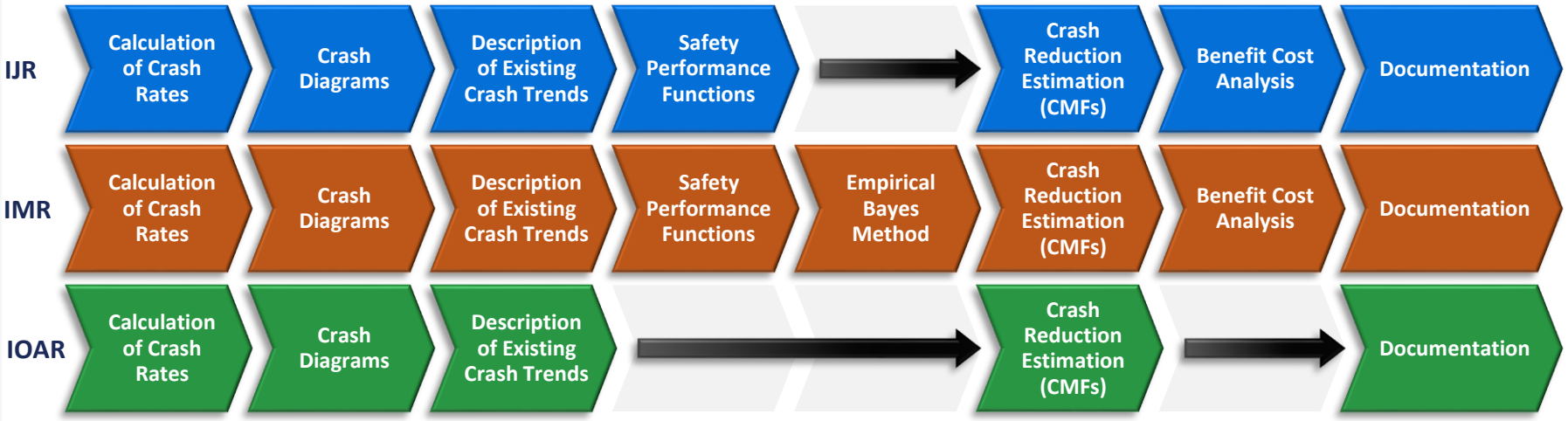
Project Summary

- Project location
  - Hillsborough County
- Existing conditions
  - Partial cloverleaf interchange
  - Ramp terminals are signalized
  - I-75 has 6 General Use Lanes
  - Martin Luther King Boulevard has 6 lanes
- Major recommended improvements
  - Convert to existing interchange to Diverging Diamond Interchange (DDI)
  - Build northbound Collector-Distributor (C-D) Road



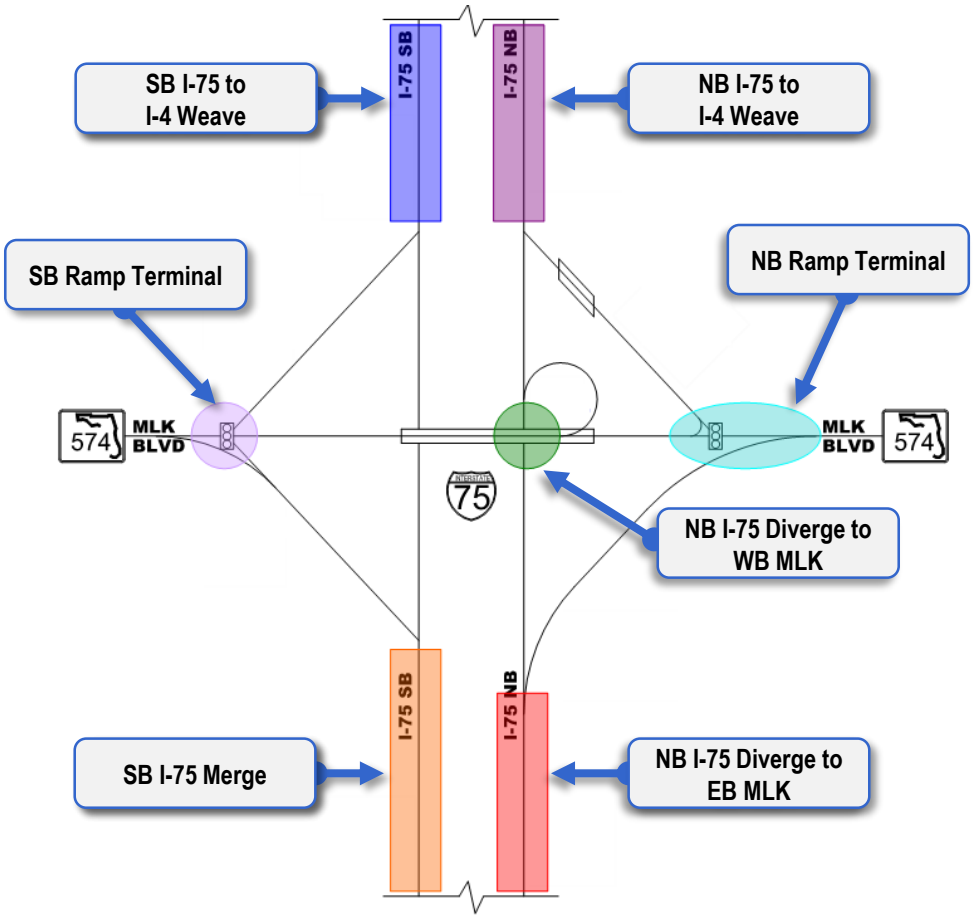
Tasks Required

- Benefit Cost Analysis is required for this IMR safety analysis



Segmentation Process

- Segment the interstate and ramp terminals
  - Northbound I-75 Diverge to Eastbound Martin Luther King Boulevard
  - Northbound I-75 Diverge to Westbound Martin Luther King Boulevard
  - Northbound Ramp Terminal
  - Northbound I-75 to I-4 Weave
  - Southbound I-75 to I-4 Weave
  - Southbound Ramp Terminal
  - Southbound I-75 Merge



Existing Crash Data

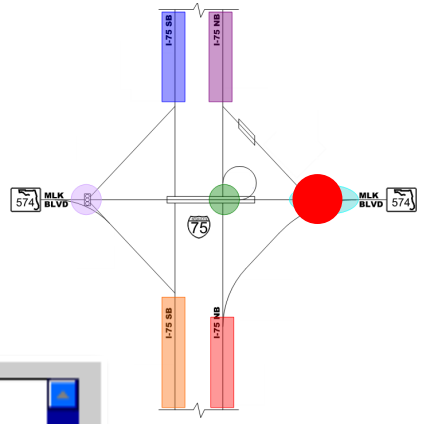
		5-Year Crash Total																			
		Occupant Fell From Vehicle	Rear End	Sideswipe	Angle	Cargo	Head On	Fire	Guardrail	Concrete Barrier	Median Crossover	Overturned	Tree	Moveable Object	Motor Vehicle	Sign	Parked Car	Ditch	All Other	Unknown	None	Total
NB I-75 Diverge to EB MLK	Total	0	15	2	3	0	2	0	5	0	1	1	0	0	1	0	1	1	2	1	0	35
	FI	0	5	1	1	0	2	0	2	0	0	1	0	0	0	0	0	0	1	0	0	13
	PDO	0	10	1	2	0	0	0	3	0	1	0	0	0	1	0	1	1	1	1	0	22
NB I-75 Diverge to WB MLK	Total	0	33	7	2	0	0	0	3	1	0	2	3	0	2	1	0	0	6	1	2	63
	FI	0	13	3	2	0	0	0	1	0	0	1	1	0	1	0	0	0	2	0	1	25
	PDO	0	20	4	0	0	0	0	2	1	0	1	2	0	1	1	0	0	4	1	1	38
SB I-75 Merge	Total	0	16	3	2	0	0	0	3	0	0	1	0	3	0	0	1	0	2	0	0	31
	FI	0	6	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	11
	PDO	0	10	2	1	0	0	0	2	0	0	1	0	2	0	0	1	0	1	0	0	20
NB I-75 to I-4 Weave	Total	0	74	3	10	1	1	0	8	0	0	2	0	2	1	0	0	0	2	2	0	106
	FI	0	28	1	4	0	0	0	3	0	0	1	0	1	0	0	0	0	1	1	0	40
	PDO	0	46	2	6	1	1	0	5	0	0	1	0	1	1	0	0	0	1	1	0	66
SB I-75 to I-4 Weave	Total	1	27	8	3	2	0	0	2	1	0	2	0	1	2	0	0	1	3	2	1	55
	FI	1	12	3	2	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1	0	23
	PDO	0	15	5	1	1	0	0	1	1	0	1	0	1	1	0	0	1	2	1	1	32
NB Ramp Terminal	Total	0	3	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	7
	FI		1		1																	2
	PDO		2											1						2		5
SB Ramp Terminal	Total	0	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
	FI		2																			2
	PDO		3		1																	4
Total	Total	1	173	23	22	3	3	0	21	2	1	8	3	7	6	1	2	2	15	8	3	303
	FI	1	67	9	11	1	2	0	8	0	0	4	1	2	2	0	0	0	6	2	1	116
	PDO	0	106	14	11	2	1	0	13	2	1	4	2	5	4	1	2	2	9	6	2	187

Calculation of Crash Rates

IMR | Calculation of Crash Rates | Crash Diagrams | Description of Existing Crash Trends | Safety Performance Functions | Empirical Bayes Method | Crash Reduction Estimation (CMFs) | Benefit Cost Analysis | Documentation

Calculation of Crash Rates

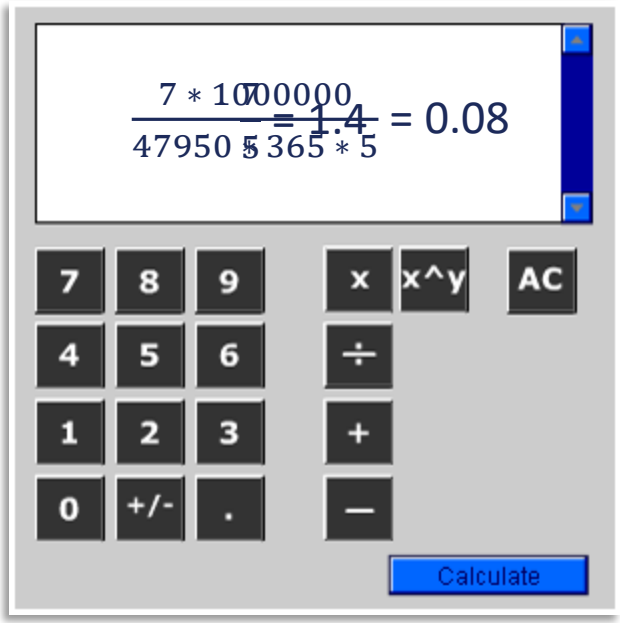
- Calculation example
  - Intersection – Martin Luther King Boulevard at Northbound Ramp Terminal



- Crash Frequency =

$$\frac{7\ Crashes}{5\ Years} =$$

1.4 Crashes/Year



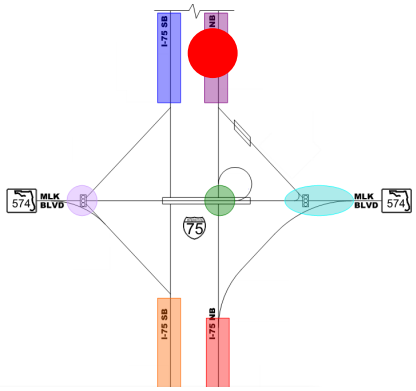
- Crash Rate (Intersections) =

$$\frac{7\ Crashes * 1{,}000{,}000}{47{,}950\ Vehicles * 365 * 5\ Years} =$$

0.08 Crashes/Million Entering

Calculation of Crash Rates

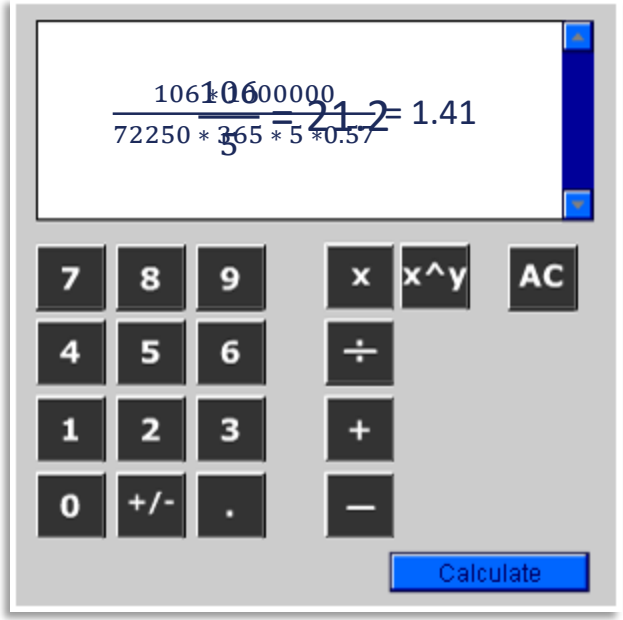
- Calculation example
  - Segment – Northbound I-75 to I-4 weave



- Crash Frequency =

$$\frac{106\ Crashes}{5\ Years} =$$

21.2 Crashes/Year



- Crash Rate (Segments) =

$$\frac{106\ Crashes * 1{,}000{,}000}{72{,}250\ vehicles * 365 *\ 5\ Years * 0.57\ Miles} =$$

1.41 Crashes/Million Vehicle Miles Traveled

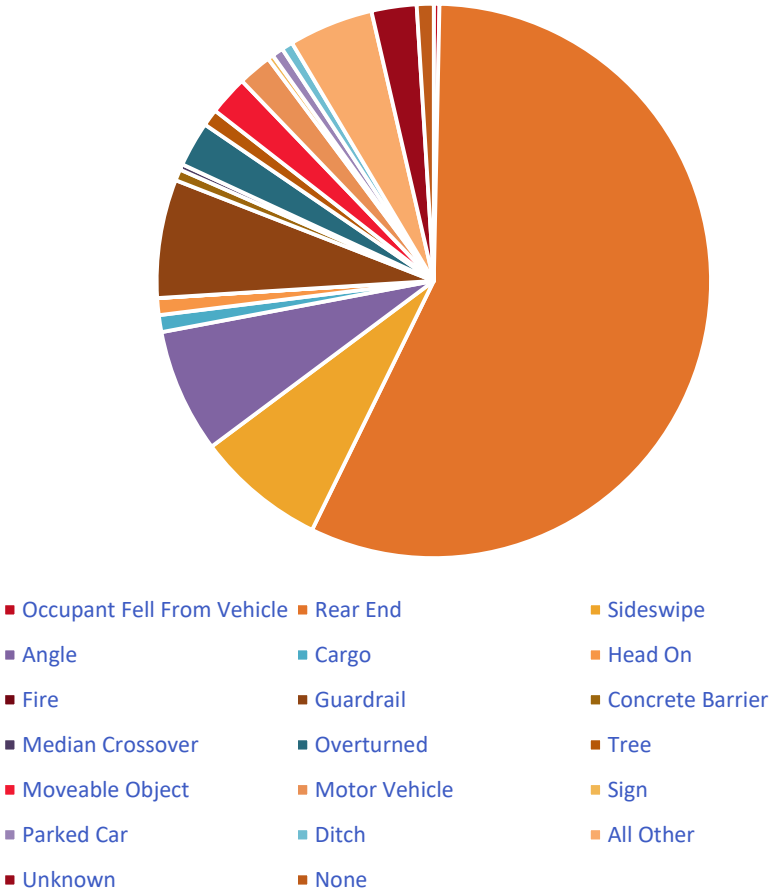
Calculation of Crash Rates

		5-Year Crash Total	Crash Rates			
		Total	Daily Entering	Segment Length	Crash Frequency	Crash Rate
NB I-75 Diverge to EB MLK	Total	**35**	69,750	1,500'	7	**0.97**
	FI	13				
	PDO	22				
NB I-75 Diverge to WB MLK	Total	**63**	65,850	1,500'	12.6	**1.85**
	FI	25				
	PDO	38				
SB I-75 Merge	Total	**31**	69,750	1,500'	6.2	**0.86**
	FI	11				
	PDO	20				
NB I-75 to I-4 Weave	Total	**106**	72,250	3,000'	21.2	**1.41**
	FI	40				
	PDO	66				
SB I-75 to I-4 Weave	Total	**55**	72,250	3,000'	11	**0.73**
	FI	23				
	PDO	32				
NB Ramp Terminal	Total	**7**	47,950		1.4	**0.08**
	FI	2				
	PDO	5				
SB Ramp Terminal	Total	**6**	46,050		1.2	**0.07**
	FI	2				
	PDO	4				
Total	Total	**303**				
	FI	116				
	PDO	187				

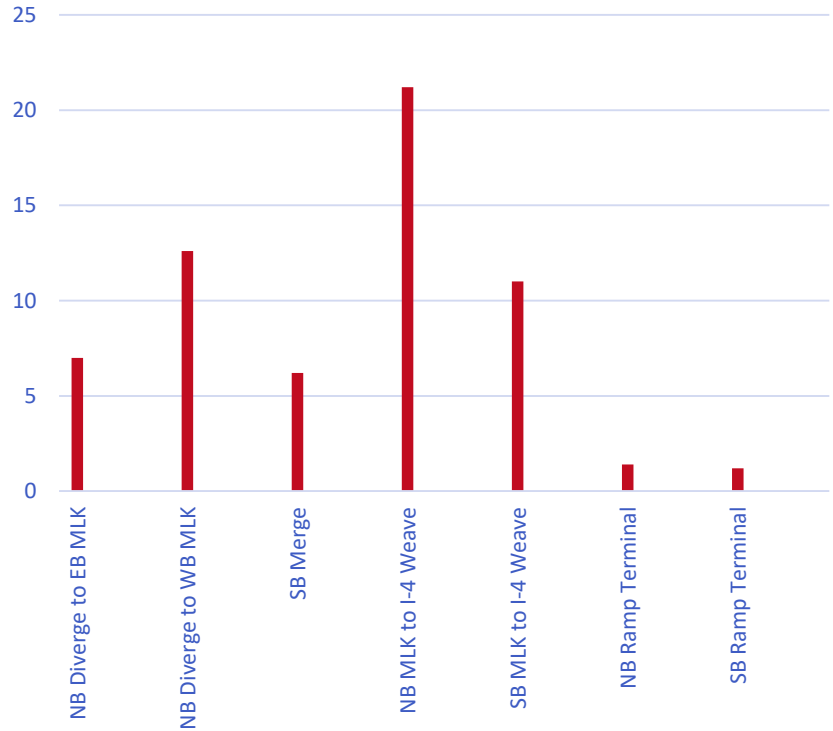
Crash Diagrams

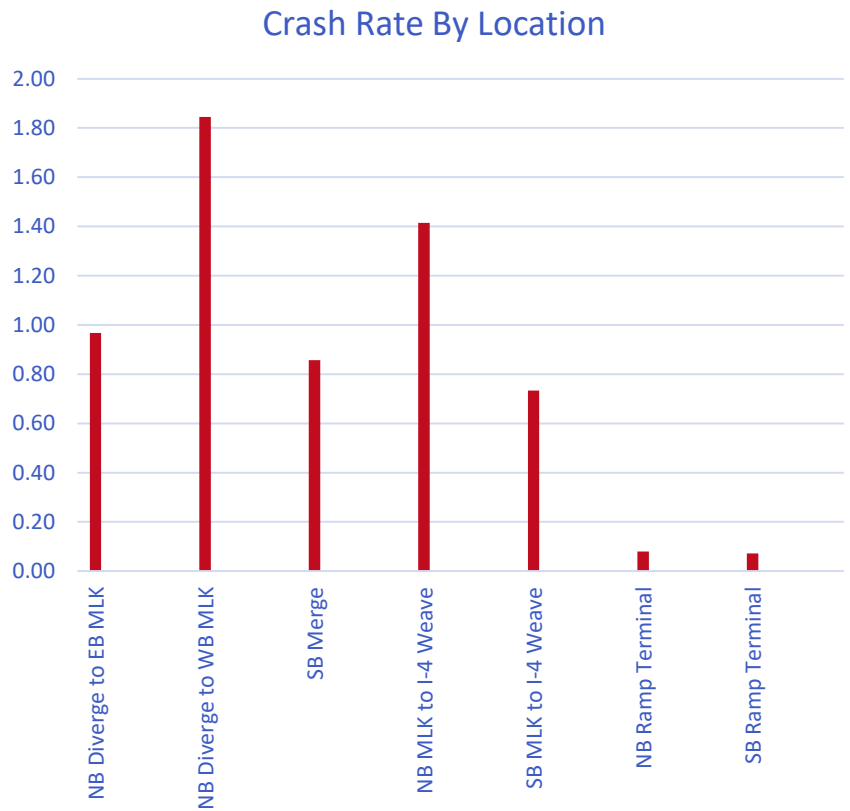
Crash Diagrams

Crash Type Frequency



Crash Diagrams





Description of Existing Crash Trends

IMR

- Calculation of Crash Rates
- Crash Diagrams
- **Description of Existing Crash Trends**
- Safety Performance Functions
- Empirical Bayes Method
- Crash Reduction Estimation (CMFs)
- Benefit Cost Analysis
- Documentation

Description of Existing Crash Trends

- "The majority of the crashes are rear end, sideswipe, and angle."
- "In terms of severity, four fatalities occurred along the I-75 northbound direction and three occurred in the southbound direction."
- "The proposed alternatives with the I-4 traffic being removed from I-75 and being moved to a C-D road, and removal of the loop ramp has a potential for reducing the weaving area, the severe fatal crashes, and also will help in reducing the rear-end and sideswipe crashes, which are the main crashes along the I-75 within the interchange area. "

Safety Performance Functions

Safety Performance Functions

NB Ramps
Ramp Terminal

Equation: N=exp(a+b*ln(c*AADTxrd)+d*ln(c*AADTex+c*AADTen)

$AADT_{xrd}$=	1700	Urban/Rural: Urban	Terminal Type: (4 Leg, 4 Quad ParClo, Loop Exit
$AADT_{ex}$=	1600		
$AADT_{en}$=	1500	Crossroad Through Lanes: 4	
$AADT_{in}$=	1500		
$AADT_{out}$=	1900	Control: Signalized	

	a	b	c	d
FI	-1.748	0.191	0.001	0.131
PDO	-2.755	0.741	0.001	0.845

Total Vehicle Crashes	0.469
FI Vehicle Crashes	0.223
PDO Vehicle Crashes	0.245

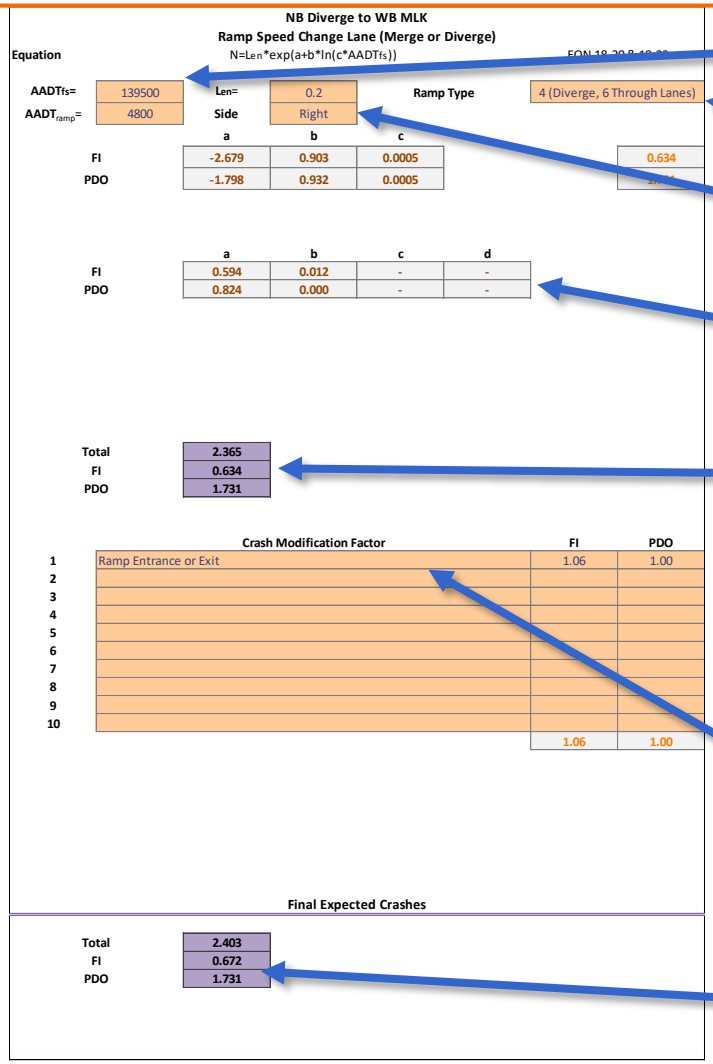
	Crash Modification Factor			FI	PDO
10	Exit Ramp Capacity	1 Lane(s)	Merge/Freeflow	1.03	1.03
11	Crossroad Left Turn Lanes (In)		Present	0.92	0.93
	Crossroad Left Turn Lanes (Out)		Not Present	1.00	1.00
12	Cross road Right Turn Lanes (In)		Not Present	1.00	1.00
	Crossroad Right Turn Lanes (Out)		Present	0.93	0.98
13	Access Control (Unsig Access within 250')	Driveways	Roadways	1.00	1.00
14	Segment Length	.3mi to Adj. Ramp	1mi to Public Rd	0.93	0.93
15	Median Width (In)	4' Median	12' Lane	1.00	1.00
	Median Width (Out)	22' Median	12' Lane	1.09	1.22
16	Protected Left Turn Operations (In)	2 Lanes Opposing	Protected Only	0.73	0.8
	Protected Left Turn Operations (Out)	2 Lanes Opposing	Permissive	1.00	1.00
17	Channelized Right Turn on Crossroad (In)		Not Channelized	1.00	1.00
	Channelized Right Turn on Crossroad (Out)		Channelized	1.17	1.17
18	Channelized Right Turn on Exit Ramp		Channelized	1.42	1.78
19	Non- Ramp Public Street Leg		Not Present	1.00	1.00
20	Skew Angle		'	1.00	1.00
				1.09	1.81

Final Expected Crashes

Total	0.685
FI	0.243
PDO	0.443

- Vehicle Inputs
- Terminal Type
- Terminal Type Inputs
- Vehicle SPF Coefficients
- Vehicle N_{spf} Results
- CMFs
- Final Expected Crash Frequency

Safety Performance Functions



NB Diverge to WB MLK

Ramp Speed Change Lane (Merge or Diverge)

Equation: N=Len*exp(a+b*ln(c*AADTfs))

AADTfs=	139500	Len=	0.2	Ramp Type	4 (Diverge, 6 Through Lanes)
$AADT_{ramp}$=	4800	Side	Right		

	a	b	c	
FI	-2.679	0.903	0.0005	0.634
PDO	-1.798	0.932	0.0005	

	a	b	c	d
FI	0.594	0.012	-	-
PDO	0.824	0.000	-	-

Total	2.365
FI	0.634
PDO	1.731

	Crash Modification Factor	FI	PDO
1	Ramp Entrance or Exit	1.06	1.00
2			
3			
4			
5			
6			
7			
8			
9			
10			
		1.06	1.00

Final Expected Crashes

Total	2.403
FI	0.672
PDO	1.731

Vehicle Inputs

Lane Change Type

Lane Change Type Inputs

SPF Coefficients

N_{spf} Results

CMFs

Final Expected Crash Frequency

Safety Performance Functions

- Safety Performance Function Summary

No Build Summary			
	FI	PDO	TOTAL
Segment from MLK to I-10	7.9	18.9	26.8
NB Diverge to EB MLK	0.2	0.4	0.6
NB Diverge to WB MLK	0.7	1.7	2.4
SB Merge from MLK	0.6	1.1	1.7
NB Ramps	0.2	0.4	0.7
SB Ramps	0.3	0.5	0.7
Total	9.9	23.1	33.0

Empirical Bayes Method

Empirical Bayes Method

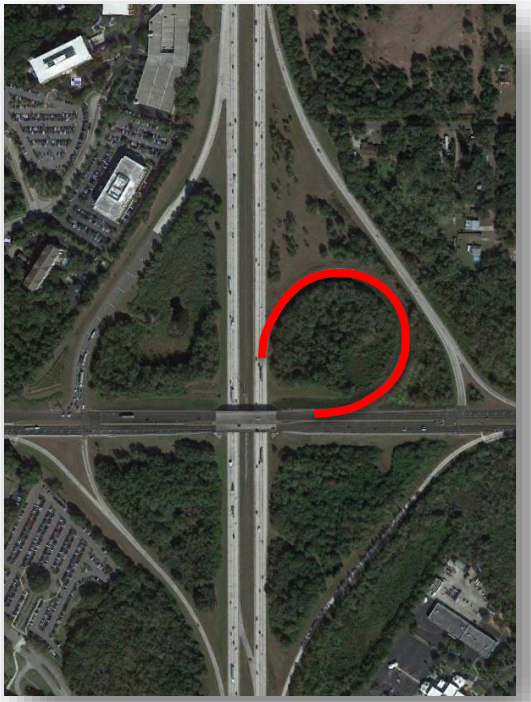
- Calculation example
  - Northbound diverge to westbound Martin Luther King property damage only (PDO) crashes

- $N_{expected} = w \times N_{predicted} + (1 - w) \times N_{observed}$

  Where:

  $$w = \frac{1}{1 + k \times (N_{Predicted} * Study\ Years)}$$

  k = overdispersion parameter (associated with SPF)



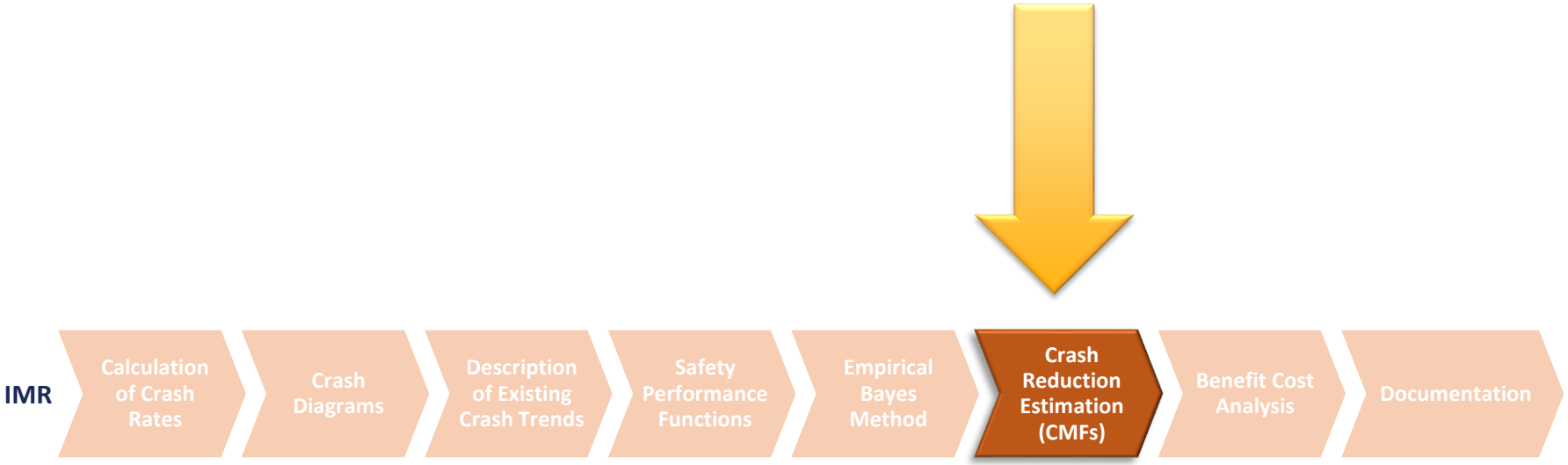
- $N_{expected} = \frac{1}{1 + 0.63 * (1.731 * 5)} * 1.731 +$

  $(1 - \frac{1}{1 + 0.63 * (1.731 * 5)}) * 7.6 = 6.69$ crashes/year

Empirical Bayes Method

	Predicted Crash Totals		k Value		Weight 5 Year Study Period		Observed Frequency		Expected Crash Frequency	
	FI	PDO	FI	PDO	FI	PDO	FI	PDO	FI	PDO
Freeway Segment (MLK to I-4)	**5.662**	**14.874**					**6.4**	**9.8**	**6.40**	**11.27**
Multiple-Vehicle	*3.752*	*10.059*	*0.09*	*0.09*	*0.36*	*0.18*	*5.4*	*8.4*	*4.81*	*8.70*
Single-Vehicle	*1.910*	*4.815*	*0.06*	*0.08*	*0.654*	*0.340*	*1.0*	*1.4*	*1.595*	*2.562*
NB Diverge to EB MLK	**0.159**	**0.433**	**0.56**	**0.63**	**0.692**	**0.422**	**2.6**	**4.4**	**4.61**	**9.97**
NB Diverge to WB MLK	**0.634**	**1.731**	**0.56**	**0.63**	**0.36**	**0.15**	**5.0**	**7.6**	**3.43**	**6.69**
SB Merge	**0.273**	**0.867**	**0.38**	**0.40**	**0.66**	**0.36**	**2.2**	**4.0**	**0.94**	**2.86**
NB Ramp Terminal	**0.223**	**0.245**	**0.11**	**0.25**	**0.89**	**0.77**	**0.4**	**1.0**	**0.24**	**0.42**
SB Ramp Terminal	**0.248**	**0.406**	**0.09**	**0.14**	**0.90**	**0.78**	**0.4**	**0.8**	**0.26**	**0.49**
Total	**7.20**	**18.56**					**17.0**	**27.6**	**15.88**	**31.71**

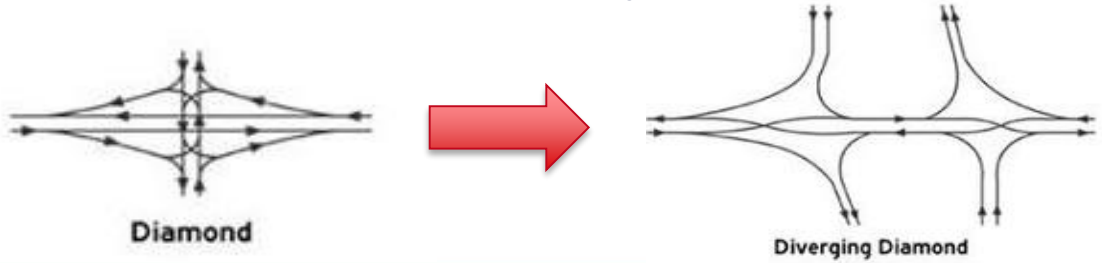
Crash Reduction Estimations (CMFs)



Crash Reduction Estimations (CMFs)

- Major recommended improvements
  - Convert to existing interchange to Diverging Diamond Interchange (DDI)
  - Build northbound Collector-Distributor (C-D) Road to I-4

- CMF Plan for converting to existing interchange to Diverging Diamond Interchange (DDI)
  - Need to convert the I-75 Northbound off-ramp into a diamond configuration so that the DDI CMF applies
  - $Future\ Crashes = Expected\ Crashes * CMF$
    - CMF converts Diamond Interchange to Diverging Diamond Interchange (DDI)
  - Conversion of northbound ramp terminal to diamond interchange
    - $Future\ Crashes = Expected\ Crashes\ x\ \frac{Predicted_{Proposed}}{Predicted_{Existing}}$



Crash Reduction Estimations (CMFs)

NB Ramps - Existing
Ramp Terminal

Equation: N=exp(a+b*ln(c*AADTxrd)+d*ln(c*AADTex+c*AADTen)

$AADT_{xrd}$=	1700
$AADT_{ex}$=	1600
$AADT_{en}$=	1500
$AADT_{in}$=	1500
$AADT_{out}$=	1900

Urban/Rural: Urban
Crossroad Through Lanes: 4
Control: Signalized
Terminal Type: 5 (4 Leg, 4 Quad ParClo, Loop Exit)

	a	b	c	d
FI	-1.748	0.191	0.001	0.131
PDO	-2.755	0.741	0.001	0.845

Total Vehicle Crashes	0.469
FI Vehicle Crashes	0.223
PDO Vehicle Crashes	0.245

NB Ramps - Diamond
Ramp Terminal

Equation: N=exp(a+b*ln(c*AADTxrd)+d*ln(c*AADTex+c*AADTen)

$AADT_{xrd}$=	1700
$AADT_{ex}$=	1600
$AADT_{en}$=	1500
$AADT_{in}$=	1500
$AADT_{out}$=	1900

Urban/Rural: Urban
Crossroad Through Lanes: 4
Control: Signalized
Terminal Type: 3 (4 Leg, Diagonal Entrance/Exit)

	a	b	c	d
FI	-2.335	1.191	0.001	0.131
PDO	-2.072	0.879	0.001	0.545

Total Vehicle Crashes	0.583
FI Vehicle Crashes	0.211
PDO Vehicle Crashes	0.372

Change Ramp Type in SPF Equations

Crash Modification Factor

				FI	PDO
10	Exit Ramp Capacity	1 Lane(s)	Merge/Freeflow	1.03	1.03
11	Crossroad Left Turn Lanes (In)		Present	0.92	0.93
	Crossroad Left Turn Lanes (Out)		Not Present	1.00	1.00
12	Crossroad Right Turn Lanes (In)		Not Present	1.00	1.00
	Crossroad Right Turn Lanes (Out)		Present	0.93	0.98
13	Access Control (Unsig Access within 250')	Driveways	Roadways	1.00	1.00
14	Segment Length	.3mi to Adj. Ramp	1mi to Public Rd	0.93	0.93
15	Median Width (In)	4' Median	12' Lane	1.00	1.00
	Median Width (Out)	22' Median	12' Lane	1.09	1.22
16	Protected Left Turn Operations (In)	2 Lanes Opposing	Protected Only	0.73	0.81
	Protected Left Turn Operations (Out)	2 Lanes Oppos			
17	Channelized Right Turn on Crossroad (In)				
	Channelized Right Turn on Crossroad (Out)				
18	Channelized Right Turn on Exit Ramp				
19	Non- Ramp Public Street Leg				
20	Skew Angle				

Crash Modification Factor

				FI	PDO
10	Exit Ramp Capacity	1 Lane(s)	Merge/Freeflow	1.03	1.03
11	Crossroad Left Turn Lanes (In)		Present	0.92	0.93
	Crossroad Left Turn Lanes (Out)		Not Present	1.00	1.00
12	Crossroad Right Turn Lanes (In)		Not Present	1.00	1.00
	Crossroad Right Turn Lanes (Out)		Present	0.93	0.98
13	Access Control (Unsig Access within 250')	Driveways	Roadways	1.00	1.00
14	Segment Length	.3mi to Adj. Ramp	1mi to Public Rd	0.93	0.93
15	Median Width (In)	4' Median	12' Lane	1.00	1.00
	Median Width (Out)	22' Median	12' Lane	1.09	1.22
16	Protected Left Turn Operations (In)	2 Lanes Opposing	Protected Only	0.73	0.81
	Protected Left Turn Operations (Out)	2 Lanes Opposing	Permissive	1.00	1.00
17	Channelized Right Turn on Crossroad (In)		Not Channelized	1.00	1.00
	Channelized Right Turn on Crossroad (Out)		Channelized	1.17	1.17
18	Channelized Right Turn on Exit Ramp		Channelized	1.42	1.78
19	Non- Ramp Public Street Leg		Not Present	1.00	1.00
20	Skew Angle		*	1.00	1.00
				1.09	1.81

$$CMF = \frac{Predicted_{Proposed}}{Predicted_{Existing}} = \frac{0.901}{0.685} = 1.315$$

Final Expected Crashes

Total	0.685
FI	0.243
PDO	0.443

$Predicted_{Existing} = 0.685$

Final Expected Crashes

Total	0.901
FI	0.229
PDO	0.672

$Predicted_{Proposed} = 0.901$

CMF
1.315
0.945
1.517

Crash Reduction Estimations (CMFs)

- Major recommended improvements
  - Convert to existing interchange to Diverging Diamond Interchange (DDI)

CMF / CRF Details

CMF ID: 9104

Convert diamond interchange to Diverging Diamond Interchange (DDI) or Double Crossover Diamond (DCD)

Description: Convert a diamond interchange to a Diverging Diamond Interchange (DDI) or a Double Crossover Diamond (DCD)

Prior Condition: Conventional diamond interchange

Category: Interchange design

Study: Safety Evaluation of Diverging Diamond Interchanges in Missouri, Claros et al., 2015

Star Quality Rating:	[View score details]

Crash Modification Factor (CMF)	
Value:	0.592
Adjusted Standard Error:	
Unadjusted Standard Error:	0.029

Crash Reduction Estimations (CMFs)

- Major recommended improvements
  - Build northbound Collector-Distributor (C-D) Road to I-4
- Need to estimate safety benefit of No-Build C-D Road
- First, complete SPF calculation for existing freeway segment – No C-D Road

Segment from MLK to I-10 - Existing Freeway Segment

Equation: $N = Lfs * \exp(a + b * \ln(c * AADTfs))$ — EQN 18-15 & 18-18

$AADT_{fs}$ = 144500 | L_{fs} = 0.6 | Number of Through Lanes: 06 Through Lanes

	a	b	c	
Multiple Vehicle FI	-5.587	1.492	0.001	3.752
Multiple Vehicle PDO	-6.809	1.936	0.001	10.059
Single Vehicle FI	-2.055	0.646	0.001	1.910
Single Vehicle PDO	-2.274	0.876	0.001	4.815

Multiple Vehicle Total	13.811
Multiple Vehicle FI	3.752
Multiple Vehicle PDO	10.059
Single Vehicle Total	6.725
Single Vehicle FI	1.910
Single Vehicle PDO	4.815

Total	20.536
FI	5.662
PDO	14.874

	Crash Modification Factor				FI	PDO
1	Horizontal Curve (Use EQN 18-24)				1.00	1.00
2	Lane Width			13' Lanes	0.96	1.00
3	Inside Shoulder Width			10' Shoulder	0.93	0.94
5	Median Barrier		100% Adj to Barrier	50' to Barrier	1.00	1.00
Other						
					0.90	0.94

	Crash Modification Factor (Multiple Vehicle Crashes)				FI	PDO
4	Median Width	85' Median	50% Adj to Barrier	50' to Barrier	1.03	1.03
6	High Volume	50% of AADT where vol>1000 veh/ln/hr			1.19	1.15
7	Weave (See Corresponding Template)				1.42	1.30
Other						
					1.75	1.54

	Crash Modification Factor (Single Vehicle Crashes)				FI	PDO
	Median Width	13' Median	50% Adj to Barrier	13' to Barrier	0.96	1.13
6	High Volume	30% of AADT where vol>1000 veh/ln/hr			0.98	0.83
8	Outside Shoulder Width			8' Shoulder	1.14	1.00
9	Shoulder Rumble Strip		0% Present on Inside	0% Present on Outside	1.00	1.00
10	Outside Clearance	0% Adj to Barrier	40' Clearzone	20' from Edge of Shoulder	1.00	1.00
11	Outside Barrier		100% Adj to Barrier	50' to Barrier	1.00	1.00
Other						
					1.07	0.94

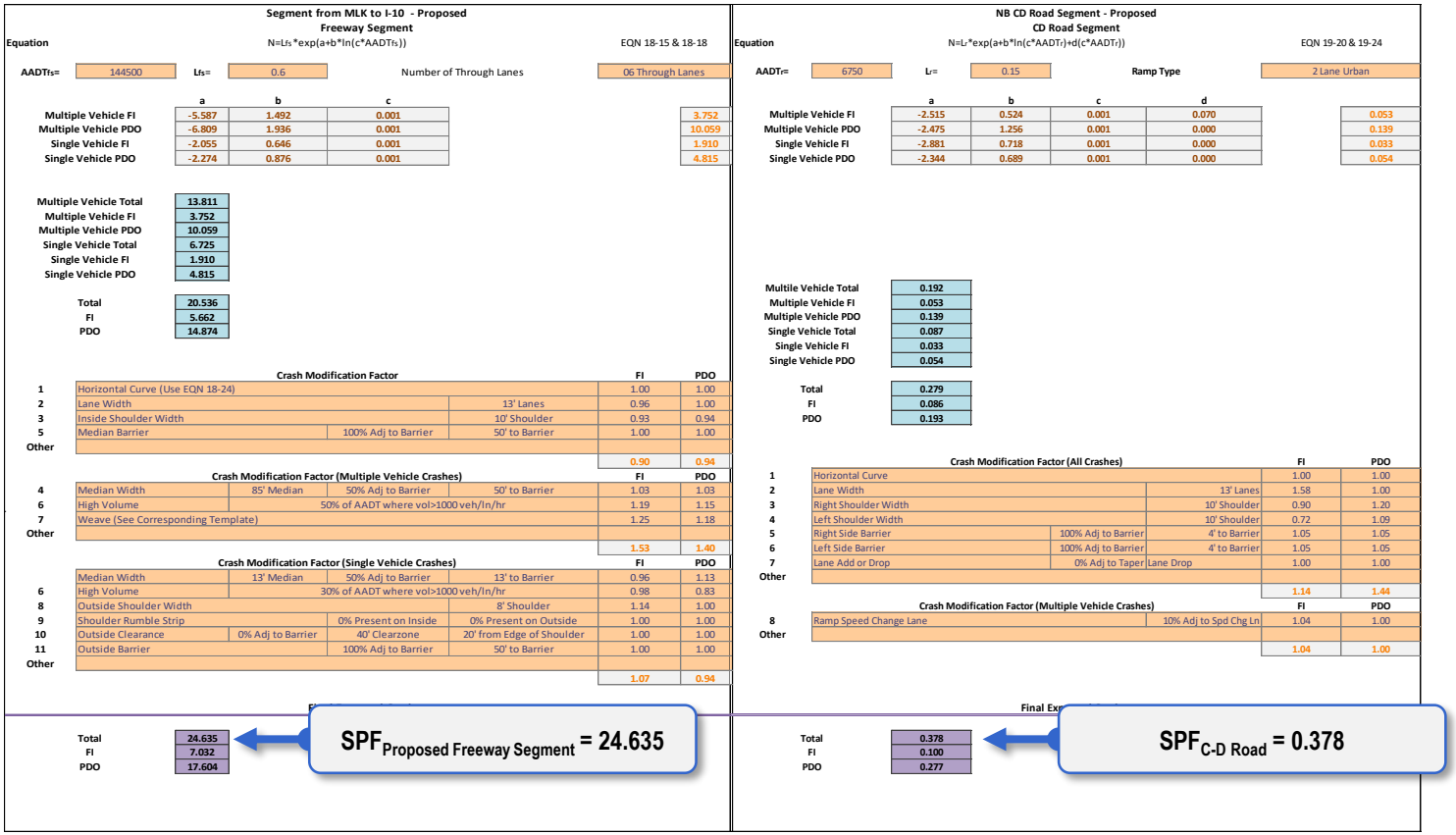
Final Expected Crashes

Total	26.645
FI	7.753
PDO	18.892

$SPF_{Existing\ Freeway\ Segment} = 26.645$

Crash Reduction Estimations (CMFs)

- Second, complete SPF calculation for proposed freeway segment (fewer lanes) and proposed C-D road



Segment from MLK to I-10 - Proposed Freeway Segment

Equation: $N = Lf_S * \exp(a + b*\ln(c*AADTf_S))$ — EQN 18-15 & 18-18

$AADTf_S$ = 144500 | Lf_S = 0.6 | Number of Through Lanes: 06 Through Lanes

	a	b	c	
Multiple Vehicle FI	-5.587	1.492	0.001	3.752
Multiple Vehicle PDO	-6.809	1.936	0.001	10.059
Single Vehicle FI	-2.055	0.646	0.001	1.910
Single Vehicle PDO	-2.274	0.876	0.001	4.815

Multiple Vehicle Total	13.811
Multiple Vehicle FI	3.752
Multiple Vehicle PDO	10.059
Single Vehicle Total	6.725
Single Vehicle FI	1.910
Single Vehicle PDO	4.815
Total	20.536
FI	5.662
PDO	14.874

Crash Modification Factor

				FI	PDO
1	Horizontal Curve (Use EQN 18-24)			1.00	1.00
2	Lane Width		13' Lanes	0.96	1.00
3	Inside Shoulder Width		10' Shoulder	0.93	0.94
5	Median Barrier	100% Adj to Barrier	50' to Barrier	1.00	1.00
Other					
				0.90	0.94

Crash Modification Factor (Multiple Vehicle Crashes)

				FI	PDO
4	Median Width	85' Median	50% Adj to Barrier / 50' to Barrier	1.03	1.03
6	High Volume	50% of AADT where vol>1000 veh/ln/hr		1.19	1.15
7	Weave (See Corresponding Template)			1.25	1.18
Other					
				1.53	1.40

Crash Modification Factor (Single Vehicle Crashes)

					FI	PDO
	Median Width	13' Median	50% Adj to Barrier	13' to Barrier	0.96	1.13
6	High Volume	30% of AADT where vol>1000 veh/ln/hr			0.98	0.83
8	Outside Shoulder Width			8' Shoulder	1.14	1.00
9	Shoulder Rumble Strip		0% Present on Inside	0% Present on Outside	1.00	1.00
10	Outside Clearance	0% Adj to Barrier	40' Clearzone	20' from Edge of Shoulder	1.00	1.00
11	Outside Barrier		100% Adj to Barrier	50' to Barrier	1.00	1.00
Other						
					1.07	0.94

Total	24.635
FI	7.032
PDO	17.604

$SPF_{Proposed\ Freeway\ Segment} = 24.635$

NB CD Road Segment - Proposed CD Road Segment

Equation: $N = Lr * \exp(a + b*\ln(c*AADTr) + d(c*AADTr))$ — EQN 19-20 & 19-24

$AADTr$ = 6750 | Lr = 0.15 | Ramp Type: 2 Lane Urban

	a	b	c	d	
Multiple Vehicle FI	-2.515	0.524	0.001	0.070	0.053
Multiple Vehicle PDO	-2.475	1.256	0.001	0.000	0.139
Single Vehicle FI	-2.881	0.718	0.001	0.000	0.033
Single Vehicle PDO	-2.344	0.689	0.001	0.000	0.054

Multile Vehicle Total	0.192
Multiple Vehicle FI	0.053
Multiple Vehicle PDO	0.139
Single Vehicle Total	0.087
Single Vehicle FI	0.033
Single Vehicle PDO	0.054
Total	0.279
FI	0.086
PDO	0.193

Crash Modification Factor (All Crashes)

				FI	PDO
1	Horizontal Curve			1.00	1.00
2	Lane Width		13' Lanes	1.58	1.00
3	Right Shoulder Width		10' Shoulder	0.90	1.20
4	Left Shoulder Width		10' Shoulder	0.72	1.09
5	Right Side Barrier	100% Adj to Barrier	4' to Barrier	1.05	1.05
6	Left Side Barrier	100% Adj to Barrier	4' to Barrier	1.05	1.05
7	Lane Add or Drop	0% Adj to Taper	Lane Drop	1.00	1.00
Other					
				1.14	1.44

Crash Modification Factor (Multiple Vehicle Crashes)

			FI	PDO
8	Ramp Speed Change Lane	10% Adj to Spd Chg Ln	1.04	1.00
Other				
			1.04	1.00

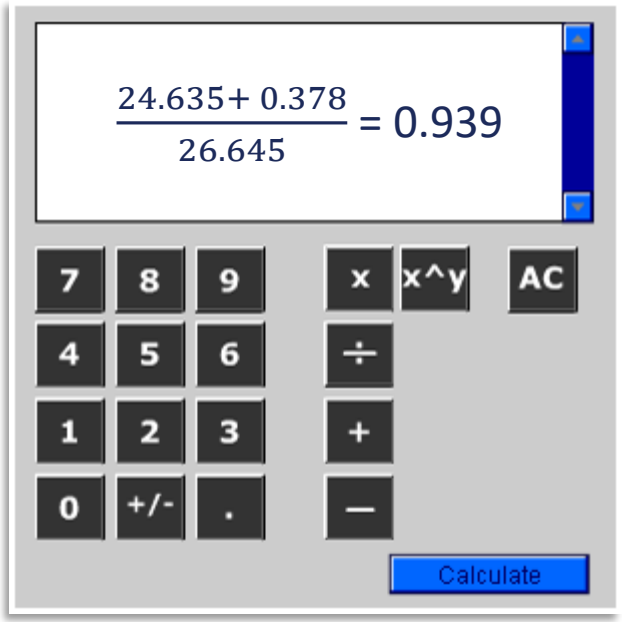
Final Ex

Total	0.378
FI	0.100
PDO	0.277

$SPF_{C\text{-}D\ Road} = 0.378$

Crash Reduction Estimations (CMFs)

- Third, divide proposed SPF by existing SPF to determine final CMF
- $$CMF = \frac{SPF_{Proposed\ Freeway\ Segment} + SPF_{C-D\ Road}}{SPF_{Existing\ Freeway\ Segment}}$$
- $$CMF = \frac{24.635 + 0.378}{26.645} = 0.939$$



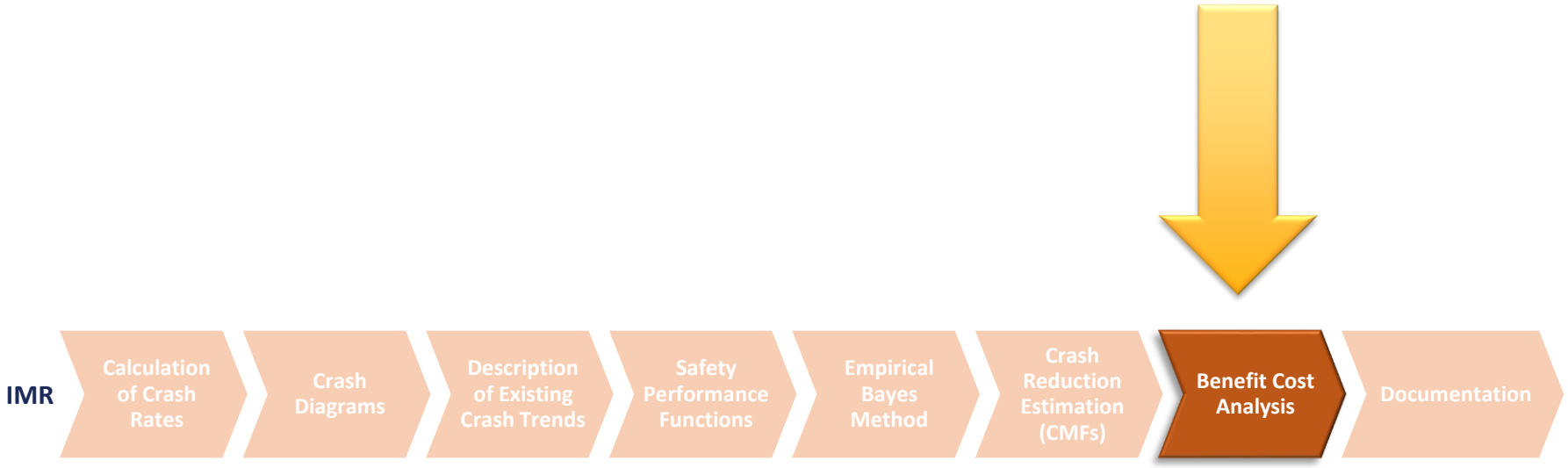
Crash Reduction Estimations (CMFs)

- Diamond to DDI CMF = 0.592
- Loop Ramp to Diamond CMF = 1.315
- Freeway to C-D Road CMF = 0.939

		MLK Interchange					I-75 CD Road	Total
		NB Diverge to EB MLK	NB Diverge to WB MLK	SB Merge	NB Ramp Terminal	SB Ramp Terminal	Freeway Segment	
Expected Crash Frequency	Fatal Injury	4.61	3.43	0.94	0.24	0.26	6.40	**15.88**
	PDO	9.97	6.69	2.86	0.42	0.49	11.27	**31.71**
	Total	**14.58**	**10.12**	**3.79**	**0.66**	**0.76**	**17.67**	**47.59**
CMF's	Fatal Injury	0.592	0.592	0.592	0.778	0.592	0.920	
	PDO	0.592	0.592	0.592	0.778	0.592	0.946	
Proposed Condition Expected Crash Frequency	Fatal Injury	2.73	2.03	0.55	0.19	0.16	5.89	**11.55**
	PDO	5.90	3.96	1.69	0.33	0.29	10.66	**22.84**
	Total	**8.63**	**5.99**	**2.25**	**0.52**	**0.45**	**16.55**	**34.39**

0.592 * 1.315

Benefit Cost Analysis



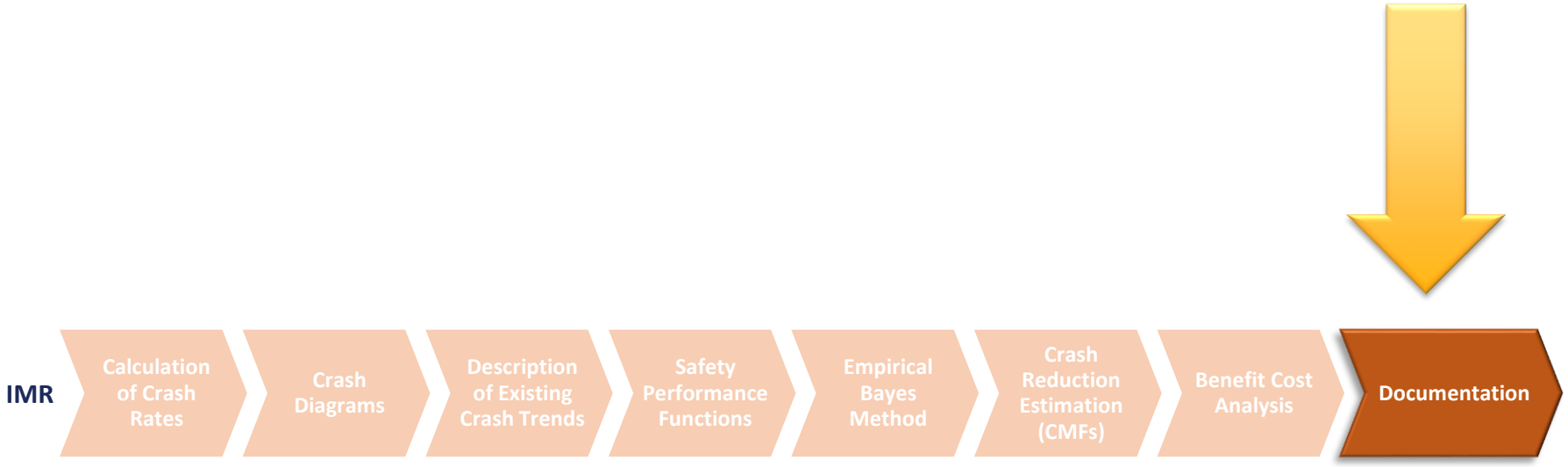
Benefit Cost Analysis

- Assign dollar amount to crash
  - $450,000 per Fatal/Injury Crash
  - $30,000 per Property Damage Only Crash

- This project is expected to decrease crash cost per year by $2,240,400
  - Fatal/Injury Crash Cost Reduction:
    $450,000 * (15.88 existing expected crashes – 11.55 proposed expected crashes) = $1,948,500
  - Property Damage Only Crash Cost Reduction:
    $30,000 * (31.71 existing expected crashes – 22.84 proposed expected crashes) = $266,100

- Include this benefit in benefit cost analysis

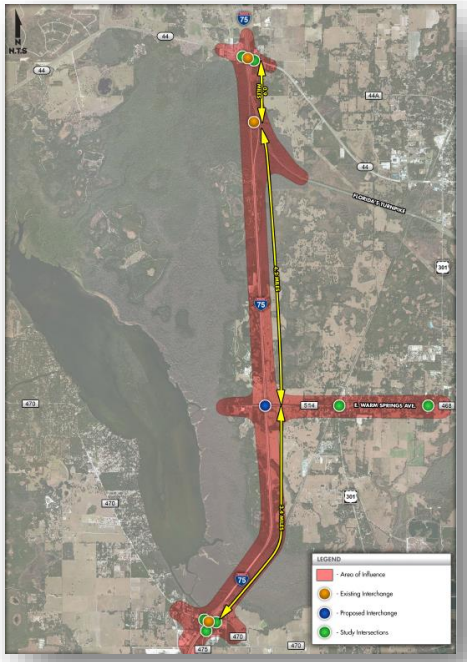
Documentation



Example 3:
I-75 at CR 514

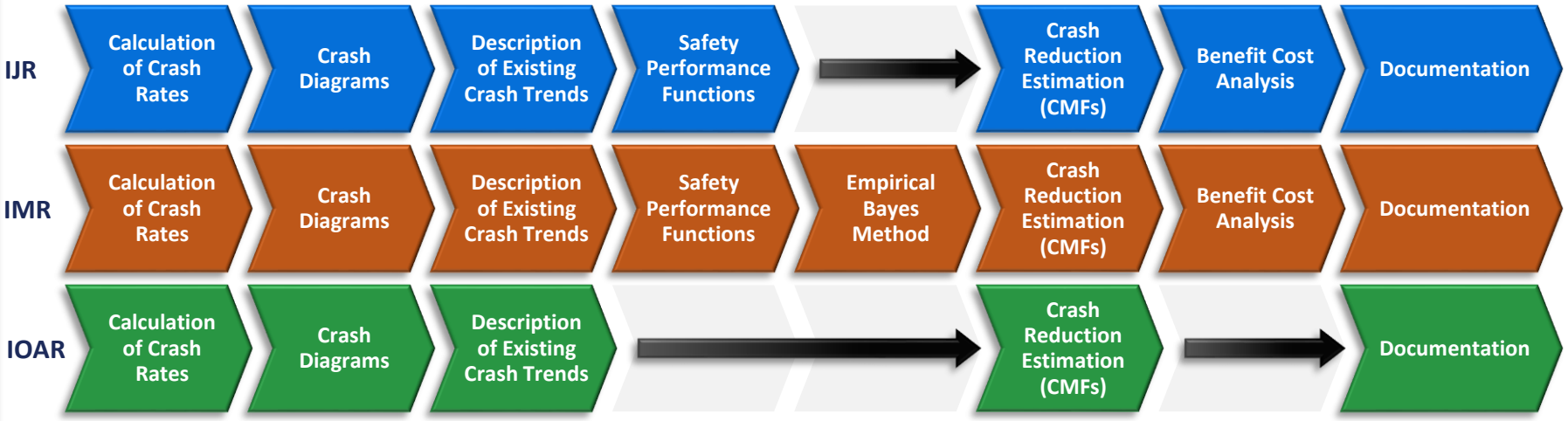
Project Summary

- Project location
  - Sumter County
- Existing conditions
  - I-75 has 4 General Use Lanes
  - Area of influence includes
    - I-75 at CR 470 interchange
    - I-75 at Florida's Turnpike interchange
    - I-75 at SR 44
- Major recommended improvements
  - New partial cloverleaf interchange between CR 470 and Florida's Turnpike along I-75



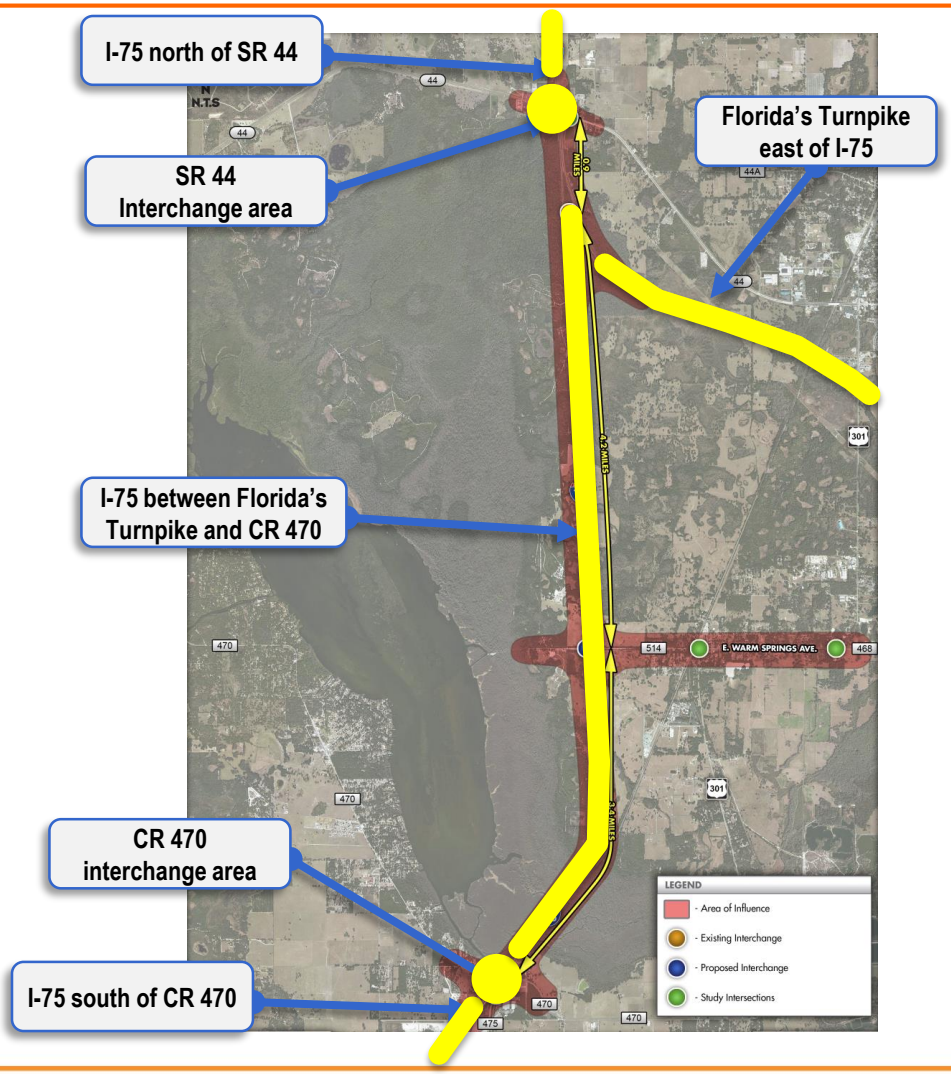
Tasks Required

- Benefit Cost Analysis is required for this IJR safety analysis

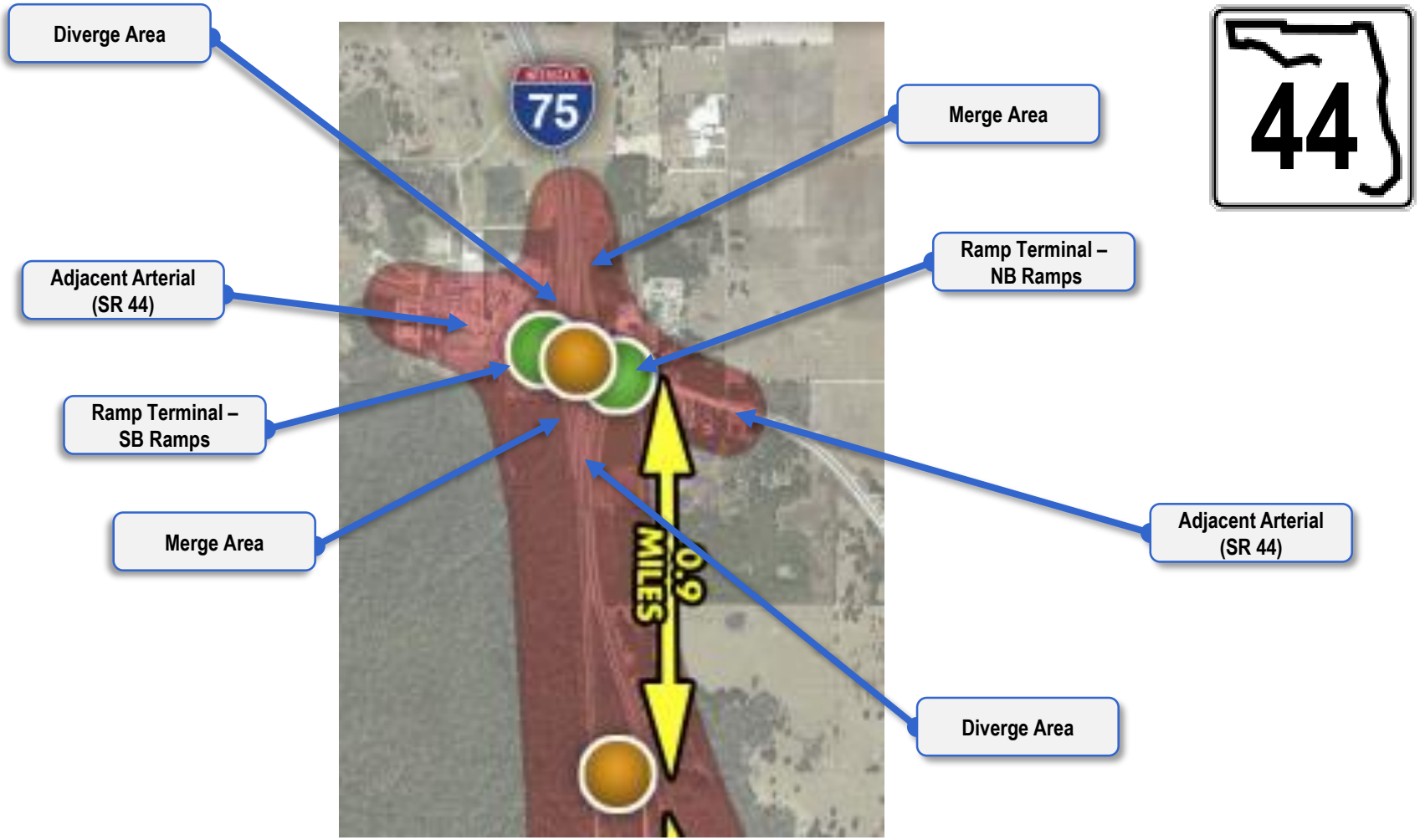


Segmentation Process

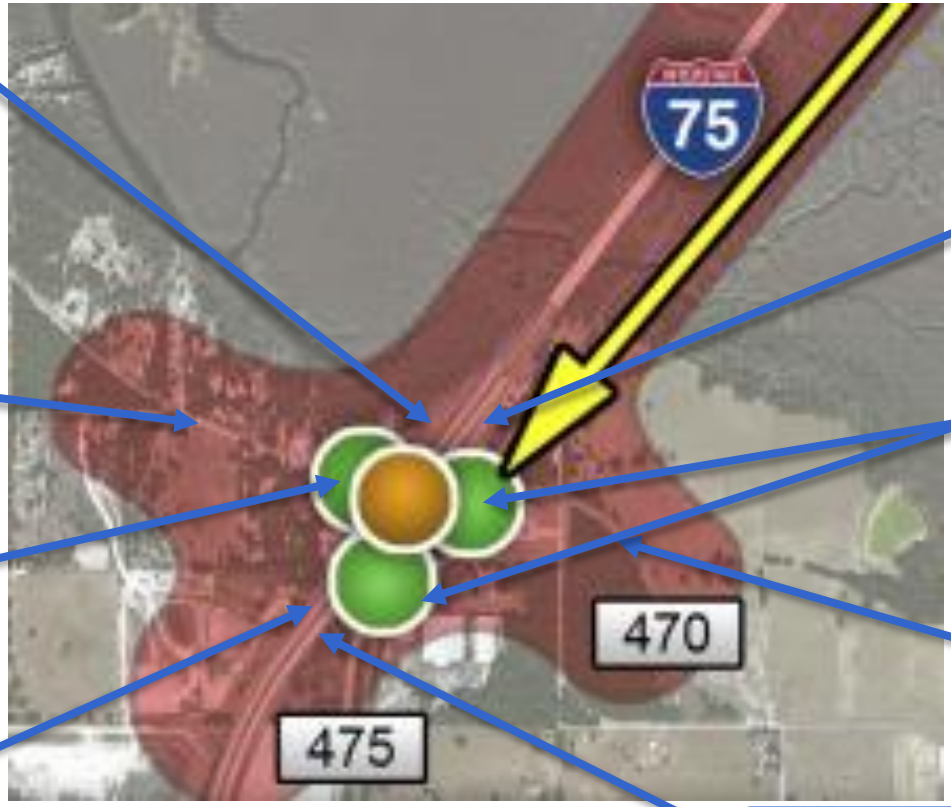
- Include surrounding arterials, interchanges and freeway segments
  - I-75 south of CR 470
  - CR 470 interchange area
  - I-75 between Florida's Turnpike and CR 470
  - Florida's Turnpike east of I-75
  - SR 44 interchange area
  - I-75 north of SR 44



Segmentation Process



Segmentation Process



470
COUNTY

Diverge Area

Adjacent Arterial (CR 470)

Ramp Terminal – SB Ramps

Merge Area

Merge Area

Ramp Terminal – NB Ramps

Adjacent Arterial (CR 470)

Diverge Area

Existing Crash Data

3 Year Crash Data (2010-2012)				
Roadway	Facility Type	Limits	Average AADT	# of Crashes
I-75	Interstate	1 mile S of CR 470	39,200	37
CR 470	Arterial	1/2 mile E & W of I-75	7,450	20
I-75	Interstate	CR 470 to SR 44	40,690	199
SR 44	Arterial	1/2 mile E & W of I-75	10,950	52
I-75	Interstate	1 mile north of SR 44	65,000	22

Calculation of Crash Rates

IJR

Calculation of Crash Rates | Crash Diagrams | Description of Existing Crash Trends | Safety Performance Functions → | Crash Reduction Estimation (CMFs) | Benefit Cost Analysis | Documentation

Calculation of Crash Rates

- Calculation example
  - Segment – SR 44 0.3 miles east and west of SR 44

- Crash Frequency =

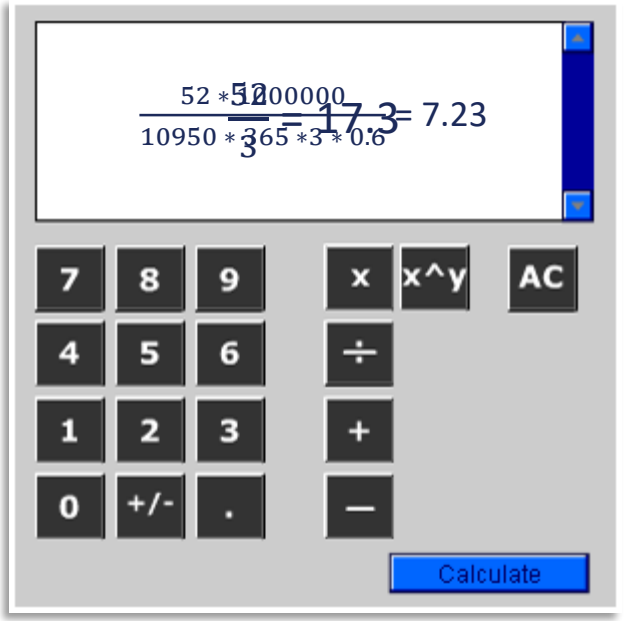
$$\frac{52\ Crashes}{3\ Years} =$$

17.3 Crashes/Year

- Crash Rate (Segments) =

$$\frac{52\ Crashes * 1{,}000{,}000}{10{,}950\ vehicles * 365 * \ 3\ Years * 0.60\ Miles} =$$

7.23 Crashes/Million Vehicle Miles Traveled

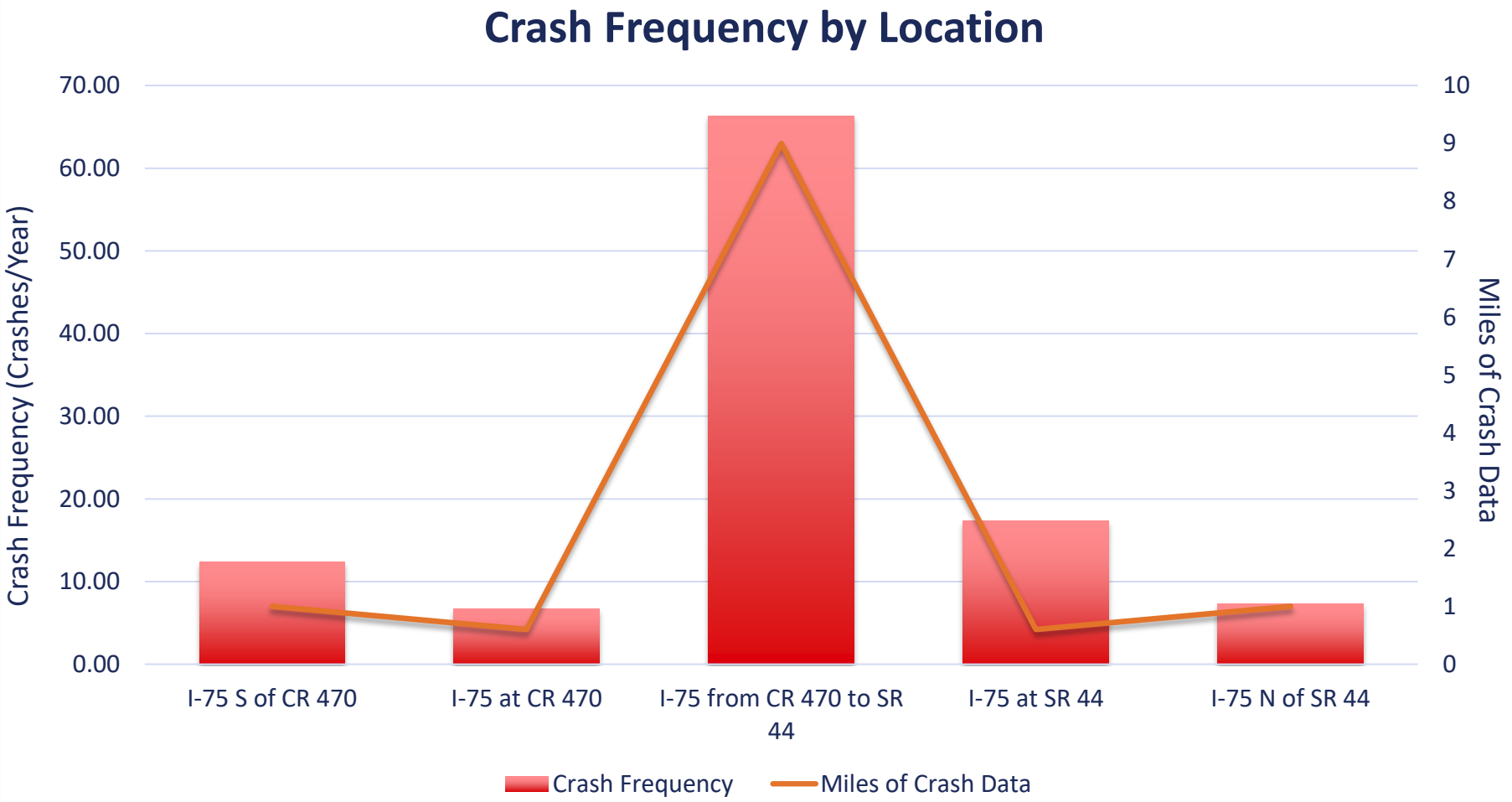


Calculation of Crash Rates

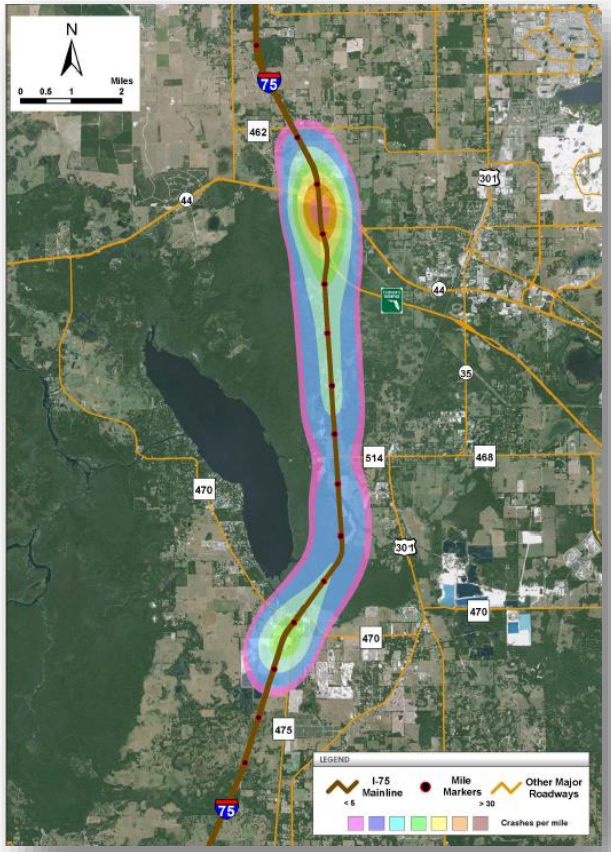
3 Year Crash Data (2010-2012)						
Roadway	Facility Type	Limits	Average AADT	# of Crashes	Crash Frequency	Crash Rate
I-75	Interstate	1 mile S of CR 470	39,200	37	12.3	0.86
CR 470	Arterial	0.3 miles E & W of I-75	7,450	20	6.7	4.09
I-75	Interstate	CR 470 to SR 44	40,690	199	66.3	0.50
SR 44	Arterial	0.3 miles E & W of I-75	10,950	52	17.3	7.23
I-75	Interstate	1 mile north of SR 44	65,000	22	7.3	0.31

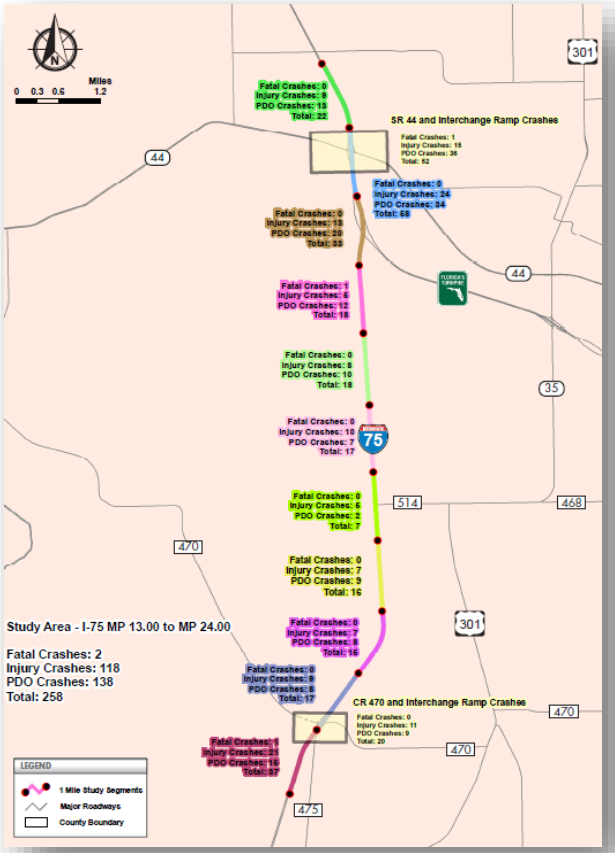
Crash Diagrams

Crash Diagrams



Crash Diagrams





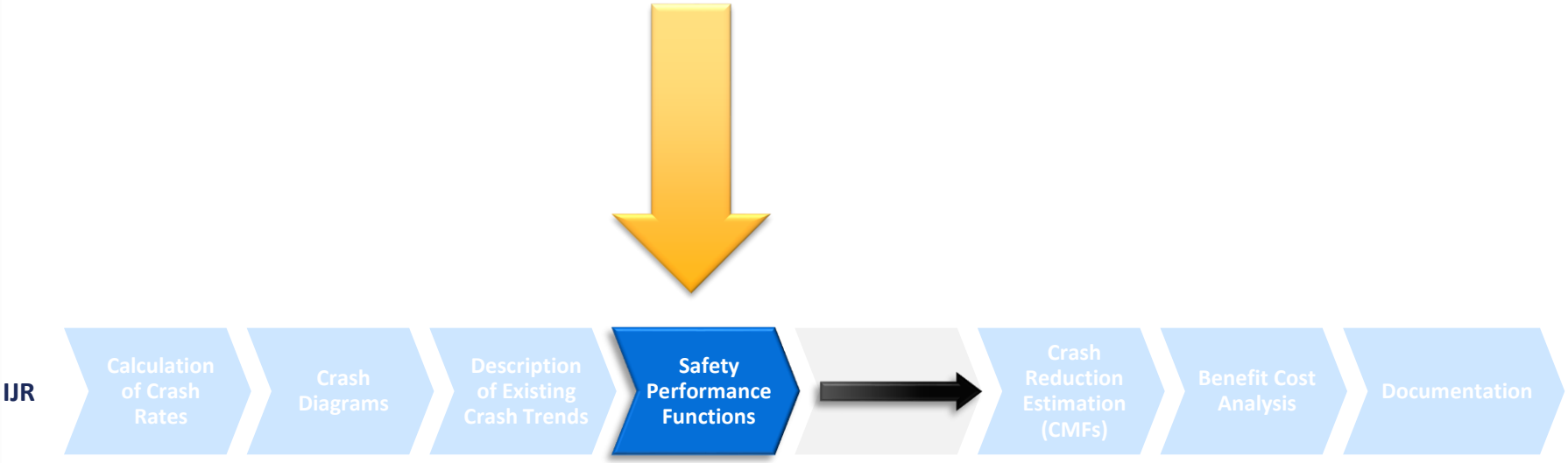
Description of Existing Crash Trends

Description of Existing Crash Trends

- "According to crash reports obtained from the FDOT CARS database and Signal Four Analytics, a total of 52 crashes occurred during the three year crash period between 2010 and 2012 along the study segment of SR 44 including I-75 ramps and ramp terminal intersections. One of the crashes resulted in a fatality."

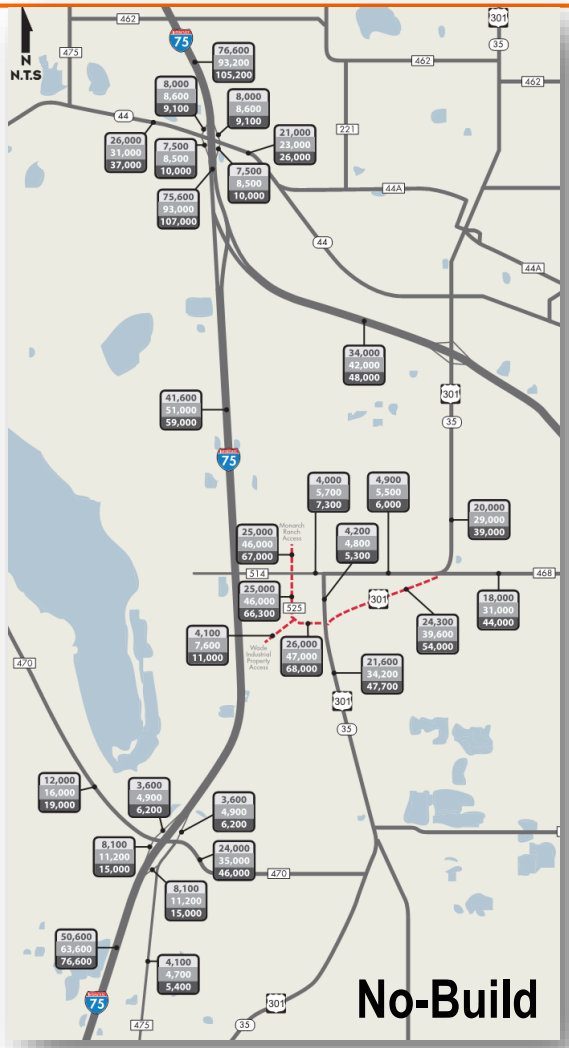
- "The majority of the crash types recorded are rear-end type crashes (41%), left-turn crashes (30%), and sideswipe crashes (16%). Majority of these crashes occurred at the ramp terminal intersections. The calculated crash rate of 7.23 crashes per million vehicles is higher than the statewide average crash rate for rural four-lane facilities of 0.555."

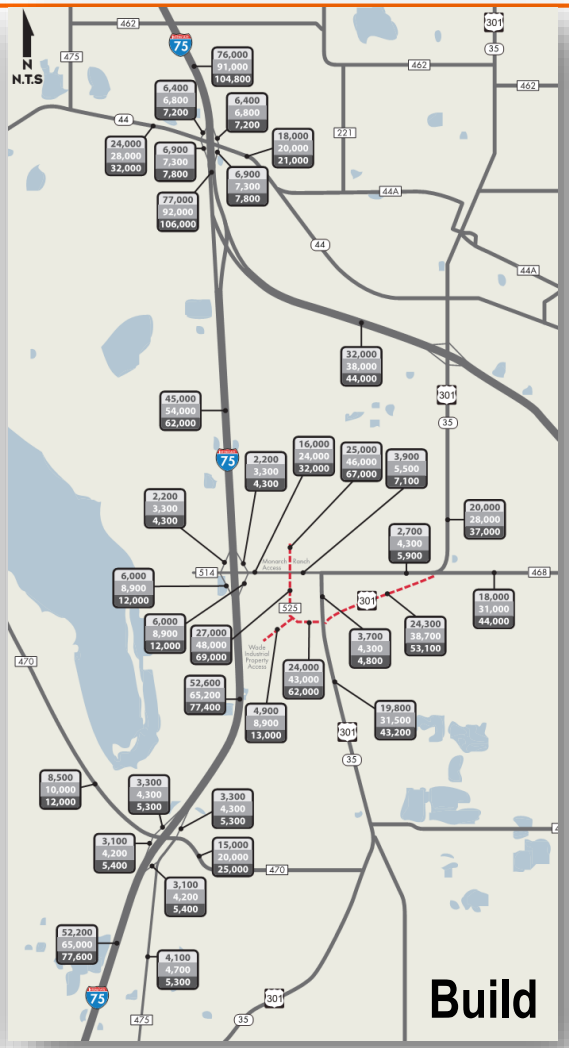
Safety Performance Functions



Safety Performance Functions

- Projected change in traffic patterns must now be analyzed in order to develop SPFs

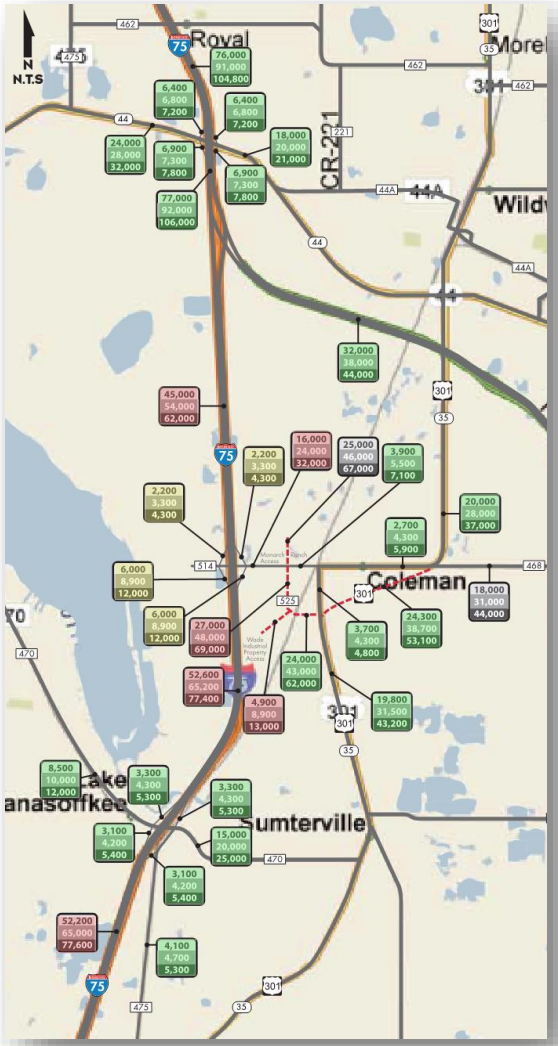




Safety Performance Functions

- **Green** locations indicate **DECREASE** in traffic between No-Build and Build Alternatives = **LOWER** SPF results

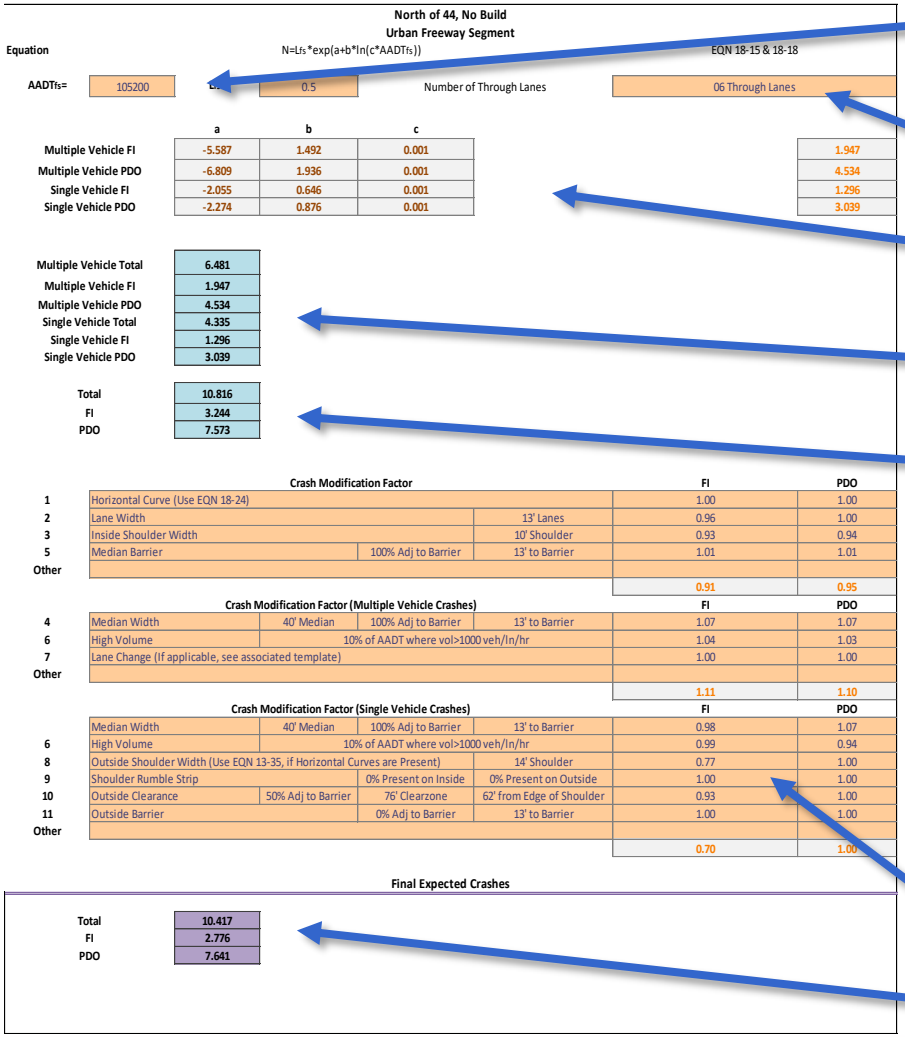
- **Red** locations indicate **INCREASE** in traffic between No-Build and Build Alternatives = **HIGHER** SPF results



Safety Performance Functions

- When developing SPFs for a new interchange
  - Use the Design Year traffic volumes
  - Calculate a SPF for each section that has traffic changing significantly (increasing or decreasing) between the No-Build and Build Alternatives
  - The study limits of safety analysis are the same as for operational analysis
  - In order to see complete safety benefits of proposed interchange, must analyze the safety conditions at the adjacent interchanges

Safety Performance Functions



North of 44, No Build
Urban Freeway Segment

Equation: $N=L_{fs}*\exp(a+b*\ln(c*AADT_{fs}))$ — EQN 18-15 & 18-18

AADTfs=	105200	Ls=	0.5	Number of Through Lanes	06 Through Lanes

	a	b	c	
Multiple Vehicle FI	-5.587	1.492	0.001	1.947
Multiple Vehicle PDO	-6.809	1.936	0.001	4.534
Single Vehicle FI	-2.055	0.646	0.001	1.296
Single Vehicle PDO	-2.274	0.876	0.001	3.039

Multiple Vehicle Total	6.481
Multiple Vehicle FI	1.947
Multiple Vehicle PDO	4.534
Single Vehicle Total	4.335
Single Vehicle FI	1.296
Single Vehicle PDO	3.039

Total	10.816
FI	3.244
PDO	7.573

	Crash Modification Factor				FI	PDO
1	Horizontal Curve (Use EQN 18-24)				1.00	1.00
2	Lane Width			13' Lanes	0.96	1.00
3	Inside Shoulder Width			10' Shoulder	0.93	0.94
5	Median Barrier		100% Adj to Barrier	13' to Barrier	1.01	1.01
Other						
					0.91	0.95

	Crash Modification Factor (Multiple Vehicle Crashes)				FI	PDO
4	Median Width	40' Median	100% Adj to Barrier	13' to Barrier	1.07	1.07
6	High Volume	10% of AADT where vol>1000 veh/ln/hr			1.04	1.03
7	Lane Change (If applicable, see associated template)				1.00	1.00
Other						
					1.11	1.10

	Crash Modification Factor (Single Vehicle Crashes)				FI	PDO
	Median Width	40' Median	100% Adj to Barrier	13' to Barrier	0.98	1.07
6	High Volume	10% of AADT where vol>1000 veh/ln/hr			0.99	0.94
8	Outside Shoulder Width (Use EQN 13-35, if Horizontal Curves are Present)			14' Shoulder	0.77	1.00
9	Shoulder Rumble Strip		0% Present on Inside	0% Present on Outside	1.00	1.00
10	Outside Clearance	50% Adj to Barrier	76' Clearzone	62' from Edge of Shoulder	0.93	1.00
11	Outside Barrier		0% Adj to Barrier	13' to Barrier	1.00	1.00
Other						
					0.70	1.00

Final Expected Crashes

Total	10.417
FI	2.776
PDO	7.641

Build Vehicle Inputs

Segment Type

Vehicle SPF Coefficients

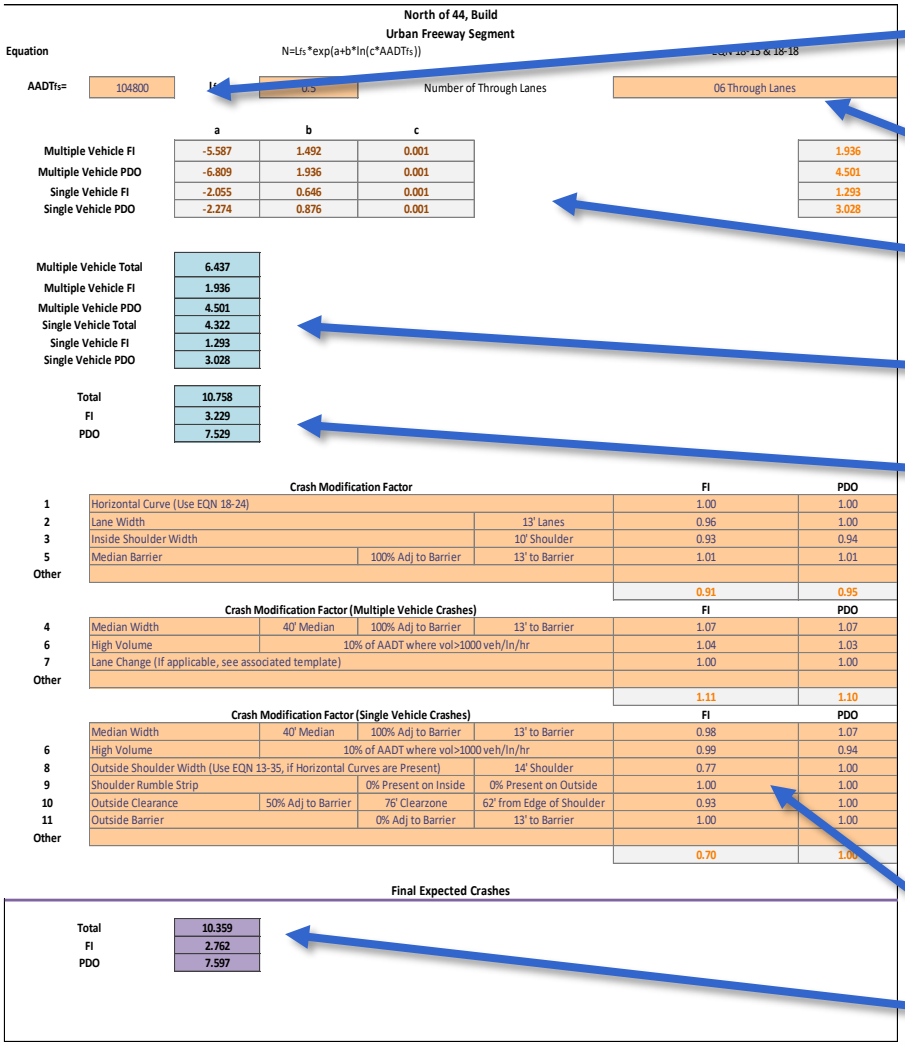
FI and PDO Vehicle N_{SPF} Results

Balanced Vehicle N_{spf} Results

CMFs

Final Expected Crash Frequency

Safety Performance Functions



North of 44, Build
Urban Freeway Segment

Equation: $N=Lf_S * \exp(a+b*\ln(c*AADT_{FS}))$ — Eqn 18-15 & 18-18

AADTfs=	104800	Lfs=	0.5	Number of Through Lanes	06 Through Lanes

	a	b	c	
Multiple Vehicle FI	-5.587	1.492	0.001	1.936
Multiple Vehicle PDO	-6.809	1.936	0.001	4.501
Single Vehicle FI	-2.055	0.646	0.001	1.293
Single Vehicle PDO	-2.274	0.876	0.001	3.028

Multiple Vehicle Total	6.437
Multiple Vehicle FI	1.936
Multiple Vehicle PDO	4.501
Single Vehicle Total	4.322
Single Vehicle FI	1.293
Single Vehicle PDO	3.028

Total	10.758
FI	3.229
PDO	7.529

	Crash Modification Factor				FI	PDO
1	Horizontal Curve (Use EQN 18-24)				1.00	1.00
2	Lane Width			13' Lanes	0.96	1.00
3	Inside Shoulder Width			10' Shoulder	0.93	0.94
5	Median Barrier		100% Adj to Barrier	13' to Barrier	1.01	1.01
Other						
					0.91	0.95

	Crash Modification Factor (Multiple Vehicle Crashes)				FI	PDO
4	Median Width	40' Median	100% Adj to Barrier	13' to Barrier	1.07	1.07
6	High Volume	10% of AADT where vol>1000 veh/ln/hr			1.04	1.03
7	Lane Change (If applicable, see associated template)				1.00	1.00
Other						
					1.11	1.10

	Crash Modification Factor (Single Vehicle Crashes)				FI	PDO
	Median Width	40' Median	100% Adj to Barrier	13' to Barrier	0.98	1.07
6	High Volume	10% of AADT where vol>1000 veh/ln/hr			0.99	0.94
8	Outside Shoulder Width (Use EQN 13-35, if Horizontal Curves are Present)			14' Shoulder	0.77	1.00
9	Shoulder Rumble Strip		0% Present on Inside	0% Present on Outside	1.00	1.00
10	Outside Clearance	50% Adj to Barrier	76' Clearzone	62' from Edge of Shoulder	0.93	1.00
11	Outside Barrier		0% Adj to Barrier	13' to Barrier	1.00	1.00
Other						
					0.70	1.00

Final Expected Crashes

Total	10.359
FI	2.762
PDO	7.597

No-Build Vehicle Inputs

Segment Type

Vehicle SPF Coefficients

FI and PDO Vehicle N_{SPF} Results

Balanced Vehicle N_{spf} Results

CMFs

Final Expected Crash Frequency

Safety Performance Functions

- Safety Performance Function Summary – No-Build vs. Build

No Build				
Location	SPF Type	FI	PDO	Total
North of 44, No Build	Urban Freeway Segment	2.8	7.6	**10.4**
Between Turnpike and 470, No Build	Urban Freeway Segment	18.9	45.0	**63.9**
South of 470, No Build	Urban Freeway Segment	1.9	4.8	**6.6**
Turnpike, East of I-75, No Build	Urban Freeway Segment	8.1	20.2	**28.2**
NB Diverge to 470, No Build	Diverge	0.5	1.2	**1.7**
NB Merge from 470, No Build	Merge	0.4	0.8	**1.2**
SB Diverge to 470, No Build	Diverge	0.4	1.0	**1.4**
SB Merge from 470, No Build	Merge	0.7	1.2	**1.8**
NB Diverge to 44, No Build	Diverge	0.7	1.7	**2.3**
NB Merge from 44, No Build	Merge	0.9	1.7	**2.6**
SB Diverge to 44, No Build	Diverge	0.6	1.7	**2.3**
SB Merge from 44, No Build	Merge	0.9	1.7	**2.6**
470 at SB Ramps, No Build	Ramp Terminal	8.3	18.1	**26.4**
470 at NB Ramps, No Build	Ramp Terminal	27.5	51.6	**79.1**
44 at SB Ramps, No Build	Ramp Terminal	9.8	15.2	**24.9**
44 at NB Ramps, No Build	Ramp Terminal	8.4	15.3	**23.7**
470, West of I-75, No Build	Urban Arterial	1.0	2.1	**3.1**
470, East of I-74, No Build	Urban Arterial	12.5	29.2	**41.7**
514, East of I-75, No Build	Urban Arterial	0.5	1.0	**1.5**
44, East of I-75, No Build	Urban Arterial	5.0	12.1	**17.1**
44, West of I-75, No Build	Urban Arterial	2.4	5.8	**8.2**
Total		**111.9**	**239.0**	**350.9**

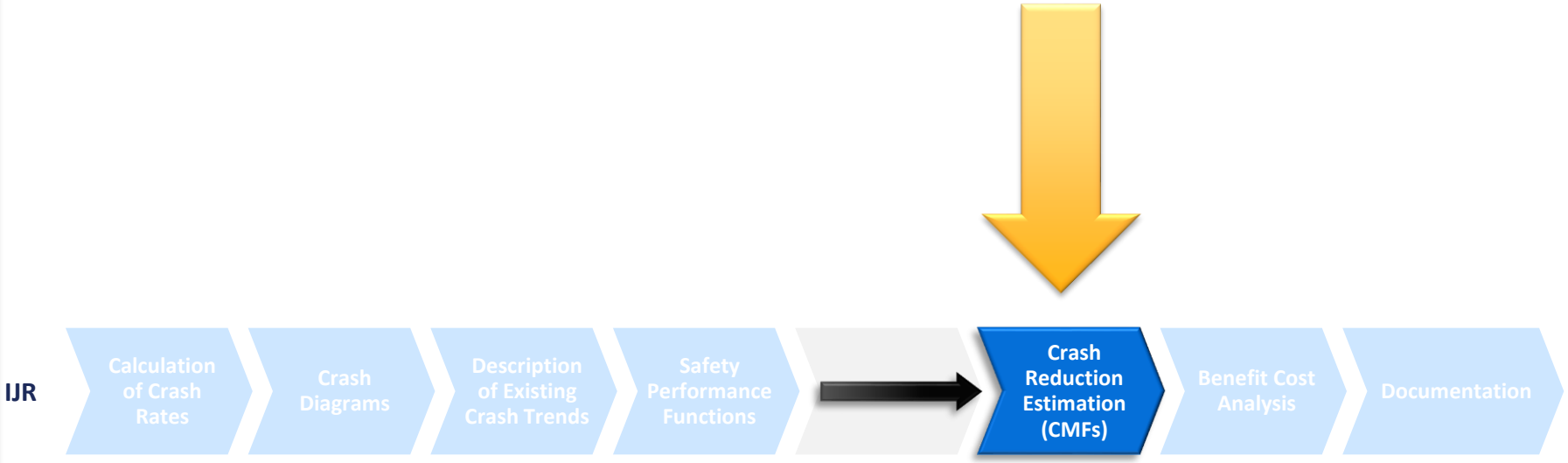
Build				
Location	SPF Type	FI	PDO	Total
North of 44, Build	Urban Freeway Segment	2.8	7.6	**10.4**
Between Turnpike and 514, Build	Urban Freeway Segment	9.9	23.6	**33.5**
Between 514 and 470, Build	Urban Freeway Segment	13.3	33.6	**46.8**
South of 470, Build	Urban Freeway Segment	1.9	4.8	**6.6**
Turnpike, East of I-75, Build	Urban Freeway Segment	7.3	17.9	**25.2**
NB Diverge to 470, Build	Diverge	0.5	1.3	**1.7**
NB Merge from 470, Build	Merge	0.5	1.2	**1.7**
SB Diverge to 470, Build	Diverge	0.5	1.2	**1.7**
SB Merge from 470, Build	Merge	0.6	1.2	**1.8**
NB Diverge to 514, Build	Diverge	0.5	1.2	**1.7**
NB Merge from 514, Build	Merge	0.4	0.9	**1.3**
SB Diverge to 514, Build	Diverge	0.4	1.0	**1.4**
SB Merge from 514, Build	Merge	0.6	1.2	**1.8**
NB Diverge to 44, Build	Diverge	0.1	0.2	**0.3**
NB Merge from 44, Build	Merge	0.8	1.7	**2.5**
SB Diverge to 44, Build	Diverge	0.6	1.7	**2.3**
SB Merge from 44, Build	Merge	0.1	0.1	**0.2**
470 at SB Ramps, Build	Ramp Terminal	4.3	8.9	**13.3**
470 at NB Ramps, Build	Ramp Terminal	20.2	31.2	**51.4**
514 at SB Ramps, Build	Ramp Terminal	2.7	2.8	**5.6**
514 at NB Ramps, Build	Ramp Terminal	1.2	3.7	**4.9**
44 at SB Ramps, Build	Ramp Terminal	7.6	12.3	**19.9**
44 at NB Ramps, Build	Ramp Terminal	6.0	11.6	**17.7**
470, West of I-75, Build	Urban Arterial	0.6	1.2	**1.8**
470, East of I-74, Build	Urban Arterial	6.1	13.4	**19.5**
514, East of I-75, Build	Urban Arterial	3.5	7.7	**11.2**
44, East of I-75, Build	Urban Arterial	4.2	10.3	**14.5**
44, West of I-75, Build	Urban Arterial	1.9	4.6	**6.5**
Total		**99.1**	**208.0**	**307.1**

Safety Performance Functions

- Safety Performance Function Summary
- No-Build
  - FI Crashes = 111.9 crashes
  - PDO Crashes = 239.0 crashes
  - Total = 350.9 crashes
- Build
  - FI Crashes = 99.1 crashes
  - PDO Crashes = 208.0 crashes
  - Total = 307.1 crashes
- Reduction
  - FI Crashes = 111.9 – 99.1 = 12.8 crashes
  - PDO Crashes = 239.0 – 208.0 = 31.0 crashes
  - Total = 350.9 – 307.1 = 43.8 crashes

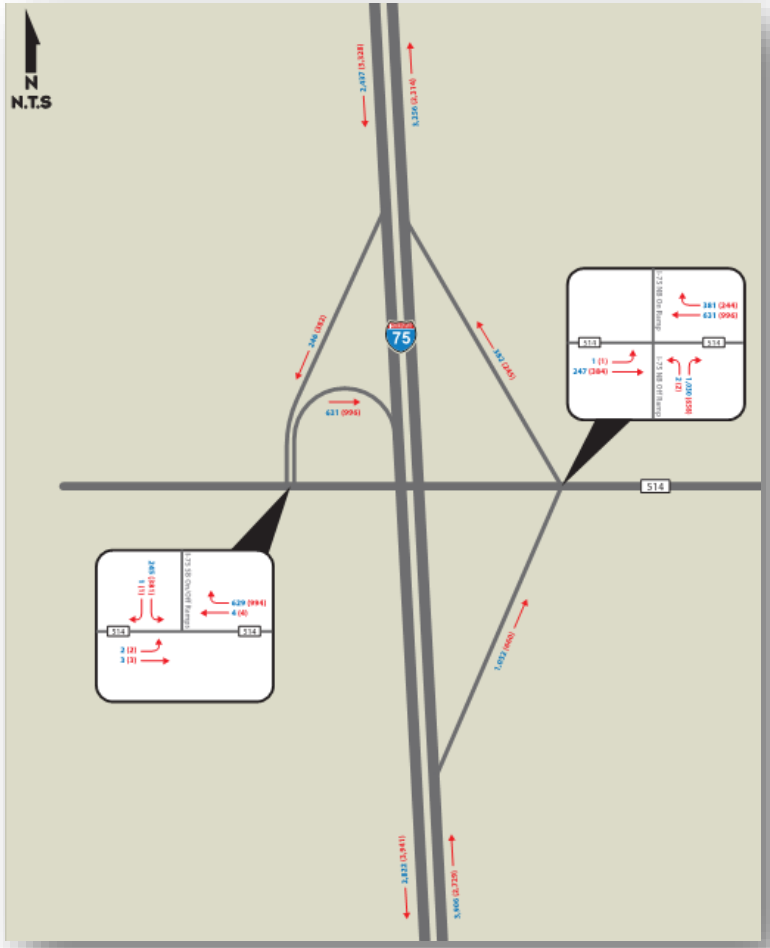
	FI	PDO	Total
Total REDUCTION in Crashes	**12.8**	**30.9**	**43.8**

Crash Reduction Estimations (CMFs)

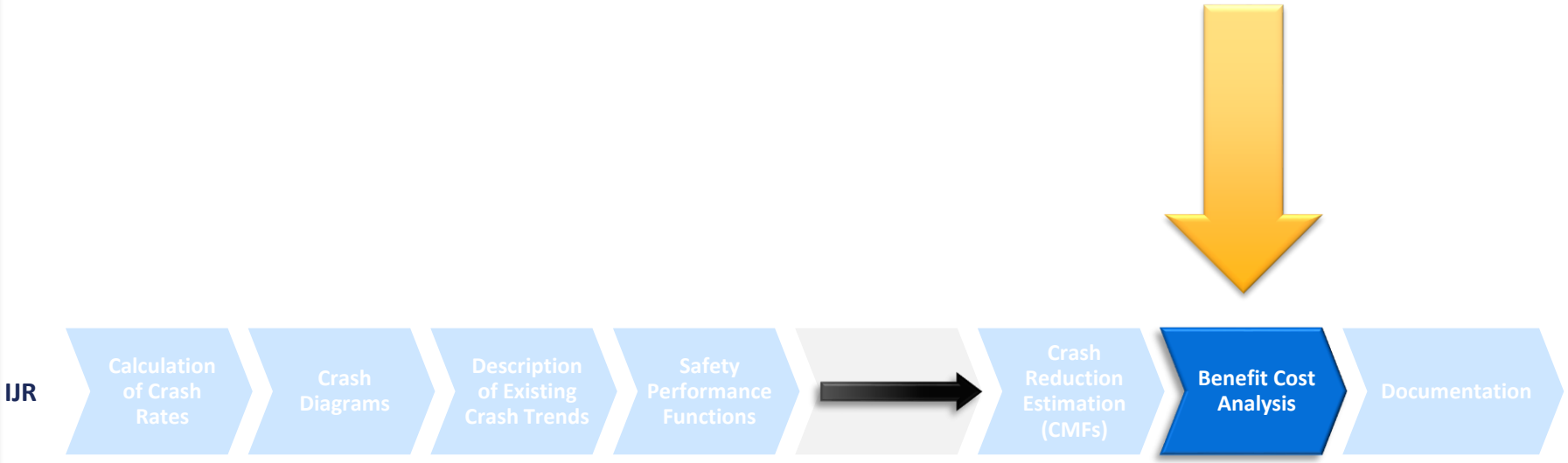


Crash Reduction Estimations (CMFs)

- Major recommended improvements
  - New interchange between CR 470 and SR 44 along I-75
- If any CMFs will be applied to the adjacent interchanges or freeway segments, they can be applied directly to the Predicted Crash Frequency
- No CMFs will be applied to the adjacent interchanges as a result of the new interchange at CR 514



Benefit Cost Analysis



Benefit Cost Analysis

- Assign dollar amount to crash
  - $450,000 per Fatal/Injury Crash
  - $30,000 per Property Damage Only Crash

- This project is expected to decrease crash cost per year by $1,593,000
  - Fatal/Injury Crash Cost Reduction:

    $450,000 * (111.9 existing expected crashes – 99.1 proposed expected crashes) = $5,760,000
  - Property Damage Only Crash Cost Reduction:

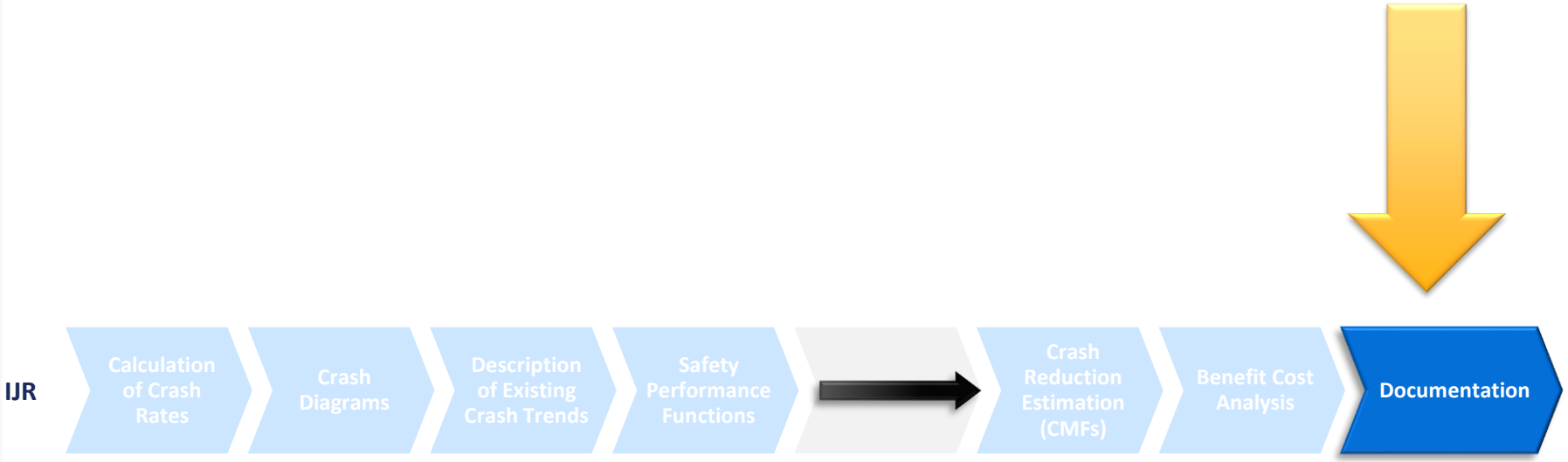
    $30,000 * (239.0 existing expected crashes – 208.0 proposed expected crashes) = $930,000

- Include this added benefit to mobility and development benefits.

Benefit Cost Analysis

- In some cases, additional access – especially if it attracts new trips - may result in additional crashes
- Any increase in crashes in the area needs to be balanced with other project objectives
  - Project Purpose and Need
  - Mobility and other project benefits
  - Impact to transportation network if new access is not granted
- Compare the added risk to the benefit in travel time and mobility

Documentation



Contact Information

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Thank You!