AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AASHTO

Exploring Highway Safety Manual Crash Prediction Tools

October 12, 2023 1:30 PM EST

Stephen Read, Virginia DOT & AASHTO Highway Safety Manual Steering Committee Chair

Bonnie Polin, Massachusetts DOT & AASHTO Highway Safety Manual Steering Committee Co-Chair

Kelly Hardy, AASHTO

Exploring Highway Safety Manual Crash Prediction Tools

This webinar features best practices and challenges in Highway Safety Manual crash prediction tool creation for State DOTs.

Stephen Read, Virginia DOT & AASHTO Highway Safety Manual Steering Committee Chair

Bonnie Polin, Massachusetts DOT & AASHTO Highway Safety Manual Steering Committee Co-Chair

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Kelly Hardy, AASHTO

Economic Crash Analysis Tool (ECAT) Overview

Ohio Department of Transportation

Brenton Bogard

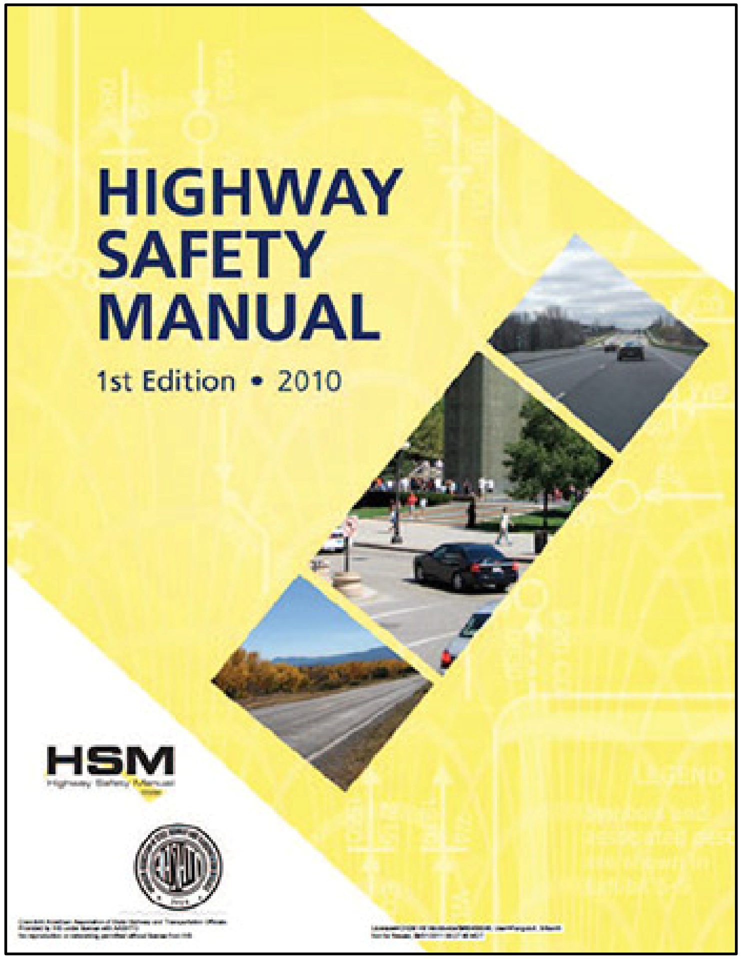
10/12/2023

What is ECAT?

ECONOMIC CRASH ANALYSIS TOOL

- ODOT's customized tool to complete Part C Predictive Method with Part C & D CMFs and Crash History as described in AASHTO's Highway Safety Manual

- Complete a benefit cost analysis as required for ODOT's Highway Safety Program



Overall Process

1. Define Project Elements (segments and/or intersections)
2. Collect and assign observed crashes to Each Project Element
3. Calculate the Highway Safety Manual Predicted and Expected Crash Frequency
4. Compare Existing Project Elements to Proposed Project Element Conditions
5. Summarize Project
6. Complete the Benefit-Cost Analysis

Define Project Elements

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6. Complete the Benefit-Cost Analysis (if required)

Project Information Worksheet

- Collect information about the overall project
- Identify homogenous segments and individual intersections for the entire project
- Select CMFs that are applicable to the entire project

Project Information Worksheet

- Gather general project and contact information
- Will you be performing a benefit-cost analysis?

Project Information			
General Information			
Project Name	LAK-90-4.00-14.69 (Variable Speed Limits)	Contact Email	brenton.bogard@dot.ohio.gov
Project Description	Variable Speed Limits	Contact Phone	867-5309
Reference Number		Date Performed	8/15/2023
Analyst	Brenton Bogard	Analysis Year	2023
Agency/Company	ODOT		
Perform Benefit Cost Analysis?	Yes		

Analysis Setup

- It is important to know if you are analyzing a project where the proposed conditions do not use the same Safety Performance Function (SPF) as the existing conditions.
- 3 analysis scenarios:

1

Do the proposed improvements fundamentally change the conditions of the base safety performance function (SPF), Or is crash data unavailable for the analysis condition, Or is only predicted (and not expected) analysis needed for the existing or proposed condition?	No
(Examples: unsignalized to signalized, undivided to divided, increase or decrease in the number of lanes, change the number of approaches to an intersection, significant realignment of the roadway)	

2

Do the proposed improvements fundamentally change the conditions of the base safety performance function (SPF), Or is crash data unavailable for the analysis condition, Or is only predicted (and not expected) analysis needed for the existing or proposed condition?	Yes
(Examples: unsignalized to signalized, undivided to divided, increase or decrease in the number of lanes, change the number of approaches to an intersection, significant realignment of the roadway)	
If Yes, are you analyzing the existing or proposed conditions?	Existing

3

Do the proposed improvements fundamentally change the conditions of the base safety performance function (SPF), Or is crash data unavailable for the analysis condition, Or is only predicted (and not expected) analysis needed for the existing or proposed condition?	Yes
(Examples: unsignalized to signalized, undivided to divided, increase or decrease in the number of lanes, change the number of approaches to an intersection, significant realignment of the roadway)	
If Yes, are you analyzing the existing or proposed conditions?	Proposed

Project Elements

Project Elements Description Table									
			Location Information						
Project Element ID (Must be Unique)	Site Type	Intersection Control Type	NLFID	Begin Logpoint/ Intersection Midpoint	End Logpoint *(Leave blank for Intersection)*	Length (mi) OR Intersection Radius Buffer (mi)	Cross Route NLFID(s)	Common Name	Remove Project Element
CR3; 13.75-13.92	Urban & Suburban Arterial Segment		CFRACR00003**C	13.75	13.92	0.17		Renner Road to Westpointe Plaza	
CR3; 13.93-14.05	Urban & Suburban Arterial Segment		CFRACR00003**C	13.93	14.05	0.12		Westpointe Plaza to Westchester	
CR3; 14.06-14.23	Urban & Suburban Arterial Segment		CFRACR00003**C	14.06	14.23	0.17		Westchester to Sam's Club	
CR3; 14.24-14.47	Urban & Suburban Arterial Segment		CFRACR00003**C	14.24	14.47	0.23		Sam's Club to Tanglewood	
CR3; 14.48-14.7	Urban & Suburban Arterial Segment		CFRACR00003**C	14.48	14.7	0.22		Tanglewood to Nike Dr	
CR3; 14.71-14.85	Urban & Suburban Arterial Segment		CFRACR00003**C	14.71	14.85	0.14		Nike Dr to Reebok Dr	
CR3; 14.86-15.16	Urban & Suburban Arterial Segment		CFRACR00003**C	14.86	15.16	0.3		Reebok Dr. to Avia	
CR3; 15.17-15.32	Urban & Suburban Arterial Segment		CFRACR00003**C	15.17	15.32	0.15		Avia to Roberts Rd.	
CR3; 13.75	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	13.75		0.05	CFRACR0002	Renner Road	
CR3; 13.93	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	13.93		0.05		Westpointe Plaza	
CR3; 14.06	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.06		0.05		Westchester	
CR3; 14.24	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.24		0.05		Sam's Club	
CR3; 14.48	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.48		0.05		Tanglewood	
CR3; 14.71	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.71		0.05	MFRAMR0151	Nike Dr.	
CR3; 14.86	Urban & Suburban Arterial Intersection	Unsignalized	CFRACR00003**C	14.86		0.05		Reebok Dr.	
CR3; 15.17	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	15.17		0.05		Kroger Dr.	
CR3; 15.32	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	15.32		0.05	CFRACR0002	Roberts Rd.	

Project Elements

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CR3; 13.93-14.05	Urban & Suburban Arterial Segment		CFRACR00003**C	13.93	14.05	0.12		Westpointe Plaza to Westchester	
CR3; 14.06-14.23	Urban & Suburban Arterial Segment		CFRACR00003**C	14.06	14.23	0.17		Westchester to Sam's Club	
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CR3; 14.71-14.85	Urban & Suburban Arterial Segment		CFRACR00003**C	14.71	14.85	0.14		Nike Dr to Reebok Dr	
CR3; 14.86-15.16	Urban & Suburban Arterial Segment		CFRACR00003**C	14.86	15.16	0.3		Reebok Dr. to Avia	
CR3; 15.17-15.32	Urban & Suburban Arterial Segment		CFRACR00003**C	15.17	15.32	0.15		Avia to Roberts Rd.	
CR3; 13.75	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	13.75		0.05	CFRACR0002	Renner Road	
CR3; 13.93	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	13.93		0.05		Westpointe Plaza	
CR3; 14.06	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.06		0.05		Westchester	
CR3; 14.24	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.24		0.05		Sam's Club	
CR3; 14.48	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.48		0.05		Tanglewood	
CR3; 14.71	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.71		0.05	MFRAMR0151	Nike Dr.	
CR3; 14.86	Urban & Suburban Arterial Intersection	Unsignalized	CFRACR00003**C	14.86		0.05		Reebok Dr.	
CR3; 15.17	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	15.17		0.05		Kroger Dr.	
CR3; 15.32	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	15.32		0.05	CFRACR0002	Roberts Rd.	

Project Elements

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CR3; 13.93	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	13.93		0.05		Westpointe Plaza	
CR3; 14.06	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.06		0.05		Westchester	
CR3; 14.24	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.24		0.05		Sam's Club	
CR3; 14.48	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.48		0.05		Tanglewood	
CR3; 14.71	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	14.71		0.05	MFRAMR0151	Nike Dr.	
CR3; 14.86	Urban & Suburban Arterial Intersection	Unsignalized	CFRACR00003**C	14.86		0.05		Reebok Dr.	
CR3; 15.17	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	15.17		0.05		Kroger Dr.	
CR3; 15.32	Urban & Suburban Arterial Intersection	Signalized	CFRACR00003**C	15.32		0.05	CFRACR0002	Roberts Rd.	

Traffic Volume Growth Rate

Enter in traffic volume growth for B/C analysis:

Traffic Volume Growth Rate Calculation For Benefit Cost Analysis			
	Year	AADT	
Present ADT (PADT)	2023	55,123	veh / day
Future ADT (FADT)	2043	60,600	veh / day
Annual Linear Growth Rate		0.0050	

CMF Table

5 CMF application scenarios: Severity, Crash Type, Wet-Related, Night-Related or User Defined:

Select Other Non-Site Characteristic Based Countermeasures For Entire Project						
CMF Nbr	Countermeasure	CMF KA Value	CMF B Value	CMF C Value	CMF O Value	CMF Valid for the Following Site Types
CMF 1	Increased pavement friction	Wet-Related	Wet-Related	Wet-Related	Wet-Related	1 / 3 / 4 / 6
CMF 2	Convert intersection with minor-road stop control to modern roundabout (Rural)	0.13	0.13	0.13	0.29	2 / 10
CMF 3	Install edgelines (curves) - Urban	By Crash Type	By Crash Type	By Crash Type	By Crash Type	6
CMF 4	Replace Night-Time Flash with Steady Operation	Night-Related	Night-Related	Night-Related	Night-Related	7 / 10
CMF 5	User Defined	Add Value	Add Value	Add Value	Add Value	Unknown

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Crash Data Worksheet

- The crash data tab is used to assign observed crashes to individual project elements
- It follows the basic template of ODOT's CAM Tool to allow users to use both tools without having to re-enter data
- The toolbox can be used to automatically assign crashes to segment and intersection based on information the analyst provided in the Project Elements Description Table on the Project Information Tab

Crash Data Worksheet

#VALUE!

Observed Crash Data

Load Crash Data from CAM Tool

Toolbox (ctrl+t)

Location ID	ntersection ID	Segment ID	Severity_5cd	FreewayRelated	HYPERLINK	DOC_NBR	Light Condition	Crash Type	Road Condition	Crash Location	Year	NLFID	Logp
IR90N; 9.464-14.69		IR90N; 9.464-14	A	Freeway Segment	Crash Report	20167053236	Daylight	Sideswipe	Dry	Not An Intersection	2016	SLAKIR00090**N	10.4
IR90N; 4-9.464		IR90N; 4-9.464	K	Freeway Segment	Crash Report	20164001599	Dark - Lighted Roadwa	Fixed Obje	Dry	Not An Intersection	2016	SLAKIR00090**N	5.36
IR90; 10.486-14.69		IR90; 10.486-14.	A	Freeway Segment	Crash Report	20214177497	Dark - Roadway Not Lig	Sideswipe	Dry	Not An Intersection	2021	SLAKIR00090**C	13.9
IR90N; 4-9.464		IR90N; 4-9.464	B	Freeway Segment	Crash Report	20196282799	Dark - Lighted Roadwa	Sideswipe	Dry	Not An Intersection	2019	SLAKIR00090**N	4.01
IR90; 4-10.486		IR90; 4-10.486	B	Freeway Segment	Crash Report	20157082669	Daylight	Sideswipe	Dry	Not An Intersection	2015	SLAKIR00090**C	4.69
IR90N; 4-9.464		IR90N; 4-9.464	A	Freeway Segment	Crash Report	20203052432	Daylight	Rear End	Dry	Not An Intersection	2020	SLAKIR00090**N	7.34
IR90; 10.486-14.69		IR90; 10.486-14.	K	Freeway Segment	Crash Report	20205099816	Daylight	Overturnin	Dry	Not An Intersection	2020	SLAKIR00090**C	12.4
IR90N; 4-9.464		IR90N; 4-9.464	B	Freeway Segment	Crash Report	20226257556	Dark - Lighted Roadwa	Sideswipe	Dry	Not An Intersection	2022	SLAKIR00090**N	5.28
IR90; 4-10.486		IR90; 4-10.486	K	Freeway Segment	Crash Report	20167066317	Dark - Roadway Not Lig	Fixed Obje	Dry	Not An Intersection	2016	SLAKIR00090**C	8.66
IR90N; 4-9.464		IR90N; 4-9.464	A	Freeway Segment	Crash Report	20216109596	Daylight	Angle	Dry	Not An Intersection	2021	SLAKIR00090**N	4.88
IR90N; 4-9.464		IR90N; 4-9.464	B	Freeway Segment	Crash Report	20186047671	Dark - Roadway Not Lig	Sideswipe	Dry	Not An Intersection	2018	SLAKIR00090**N	5.29
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20134006082	Dark - Roadway Not Lig	Parked Ve	Wet	Not An Intersection	2013	SLAKIR00090**C	5.08
IR90; 4-10.486		IR90; 4-10.486	K	Freeway Segment	Crash Report	20215222017	Dark - Roadway Not Lig	Fixed Obje	Dry	Not An Intersection	2021	SLAKIR00090**C	10.1
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20157052577	Daylight	Other Obje	Dry	Not An Intersection	2015	SLAKIR00090**C	6.28
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20186064675	Daylight	Fixed Obje	Wet	Not An Intersection	2018	SLAKIR00090**C	4.26
IR90N; 4-9.464		IR90N; 4-9.464	A	Freeway Segment	Crash Report	20213066982	Dawn/Dusk	Rear End	Dry	Not An Intersection	2021	SLAKIR00090**N	8.88
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20203010870	Dark - Roadway Not Lig	Rear End	Snow	Not An Intersection	2020	SLAKIR00090**C	9.28
IR90N; 4-9.464		IR90N; 4-9.464	B	Freeway Segment	Crash Report	20174015836	Other / Unknown	Sideswipe	Dry	Not An Intersection	2017	SLAKIR00090**N	6.08
IR90; 4-10.486		IR90; 4-10.486	B	Freeway Segment	Crash Report	20147051405	Daylight	Sideswipe	Dry	Not An Intersection	2014	SLAKIR00090**C	6.97
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20213105366	Dark - Unknown Roadw	Parked Ve	Dry	Not An Intersection	2021	SLAKIR00090**C	7.54
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20186100366	Dark - Roadway Not Lig	Head On	Dry	Not An Intersection	2018	SLAKIR00090**C	9.74
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20186006853	Daylight	Fixed Obje	Wet	Not An Intersection	2018	SLAKIR00090**C	4.80
IR90N; 9.464-14.69		IR90N; 9.464-14	A	Freeway Segment	Crash Report	20205039082	Dark - Lighted Roadwa	Parked Ve	Snow	Not An Intersection	2020	SLAKIR00090**N	10.7
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20226157656	Dark - Lighted Roadwa	Fixed Obje	Dry	Not An Intersection	2022	SLAKIR00090**C	4.89
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20193097155	Daylight	Rear End	Dry	Not An Intersection	2019	SLAKIR00090**C	9.45
IR90N; 4-9.464		IR90N; 4-9.464	A	Freeway Segment	Crash Report	20216045051	Daylight	Fixed Obje	Dry	Not An Intersection	2021	SLAKIR00090**N	6.04
IR90; 4-10.486		IR90; 4-10.486	A	Freeway Segment	Crash Report	20213224823	Dark - Roadway Not Lig	Fixed Obje	Wet	Not An Intersection	2021	SLAKIR00090**C	6.89
IR90N; 4-9.464		IR90N; 4-9.464	B	Freeway Segment	Crash Report	20186098742	Daylight	Sideswipe	Dry	Not An Intersection	2018	SLAKIR00090**N	7.14
IR90N; 9.464-14.69		IR90N; 9.464-14	C	Freeway Segment	Crash Report	20134016007	Daylight	Fixed Obje	Ice	Not An Intersection	2013	SLAKIR00090**N	10.1
IR90N; 4-9.464		IR90N; 4-9.464	A	Freeway Segment	Crash Report	20213023930	Dark - Roadway Not Lig	Fixed Obje	Wet	Not An Intersection	2021	SLAKIR00090**N	9.45
IR90; 4-10.486		IR90; 4-10.486	B	Freeway Segment	Crash Report	20216067864	Dark - Lighted Roadwa	Animal	Dry	Not An Intersection	2021	SLAKIR00090**C	4.90
IR90; 4-10.486		IR90; 4-10.486	B	Freeway Segment	Crash Report	20128045230	Daylight	Sideswipe	Dry	Not An Intersection	2012	SLAKIR00090**C	7.17

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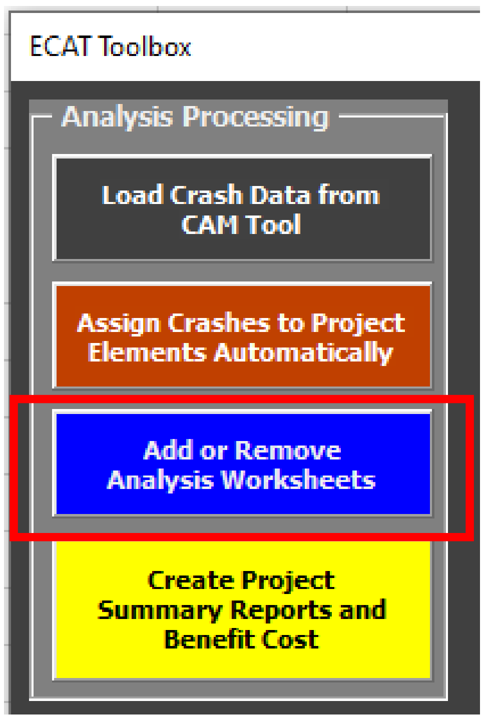
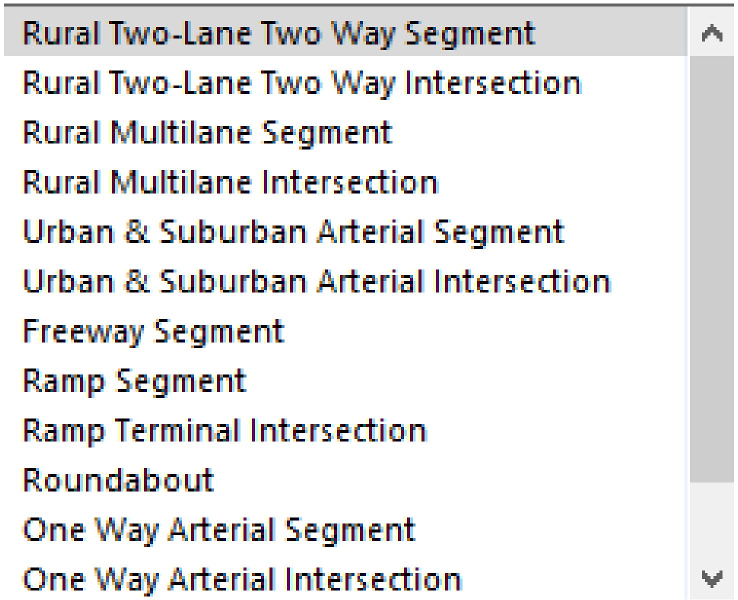
6. Complete the Benefit-Cost Analysis (if required)

Analysis Sheets

- There is a unique analysis sheet for every Site Type in the tool.
- These are created based on the information the analyst provided on the Project Information Worksheet
- Additionally, the analysis sheets will be formatted based on information the analyst provided on the Project Information Worksheet





Analysis Sheets

Project and Site Conditions Information

Existing Conditions: General Information and Data for Rural Two-Lane Two-Way Intersection						
General Information			**Location Information**			
Analyst			Route	#N/A		
Agency or Company			Logpoint	#N/A		
Date Performed			Common Name	#N/A		
Intersection	0		Analysis Year			
Signalized/Unsignalized	#N/A					
Input Data			**Existing Conditions**			**HSM Base Conditions**
Intersection type (3ST, 4ST, 4SG)						--
$AADT_{major}$ (veh/day)	$AADT_{MAX}$ = 25,200 (veh/day)					--
$AADT_{minor}$ (veh/day)	$AADT_{MAX}$ = 12,500 (veh/day)					--
Intersection skew angle (degrees) Skew Angle Help			Skew for Leg 1 (All):			0
						0
						0
Intersection lighting (present/not present)						Not Present
Calibration Factor, C_i			#N/A			1.00
Locality:						

Analysis Sheets

Existing Conditions: General Information and Data for Roundabout Intersection					
General Information				**Location Information**	
Analyst				Route	#N/A
Agency or Company				Logpoint	#N/A
Date Performed				Common Name	#N/A
Intersection	0			Analysis Year	
Signalized/Unsignalized	Unsignalized				

Input Data				**Existing Conditions**	**HSM Base Conditions**
Area Type (Rural, Urban)					--
Number of Legs (3 or 4)					--
Single-Lane or Multi-lane Roundabout					--
Total Entering AADT (veh/day)					--
					0
Presence of Outbound Only Leg (present/not present)					Not Present
Calibration Factor, C_i				Varies, See Below	1.00
Locality:					--
Leg 1	Leg 1 Entering AADT (veh/day)	$AADT_{MAX}$ = 28,927	(veh/day)		--
	Bypass lane (present/not present) - Leg 1				--
	Number of driveways or unsignalized access points - Leg 1				--
	Entry width (feet) - Leg 1				--
	Number of entering lanes (1 lane, 2 lanes) - Leg 1				--
Leg 2	Leg 2 Entering AADT (veh/day)	$AADT_{MAX}$ = 28,927	(veh/day)		--
	Bypass lane (present/not present) - Leg 2				--
	Number of driveways or unsignalized access points - Leg 2				--
	Entry width (feet) - Leg 2				--
	Number of entering lanes (1 lane, 2 lanes) - Leg 2				--
Leg 3	Leg 3 Entering AADT (veh/day)	$AADT_{MAX}$ = 28,927	(veh/day)		--
	Bypass lane (present/not present) - Leg 3				--
	Number of driveways or unsignalized access points - Leg 3				--
	Entry width (feet) - Leg 3				--
	Number of entering lanes (1 lane, 2 lanes) - Leg 3				--
Leg 4	Leg 4 Entering AADT (veh/day)	$AADT_{MAX}$ = N/A	(veh/day)		--
	Bypass lane (present/not present) - Leg 4				--
	Number of driveways or unsignalized access points - Leg 4				--
	Entry width (feet) - Leg 4				--
	Number of entering lanes (1 lane, 2 lanes) - Leg 4				--

Analysis Sheets

ECAT OVERVIEW

Project and Site Conditions Information

Basic Roadway Data					
Area Type			Copy From:		
Segment length L (mi)		#N/A			
Cross Section Data Cross Section Help					
Number of through lanes n					
Outside shoulder width W_s (ft)					10
Inside shoulder width W_{is} (ft)					6
Median width W_m (ft)					60
Depressed Median?					
Posted Speed Limit PSL (mph)					
Lighting Present?					
Freeway Segment Volume Data					
Freeway segment AADT, $AADT_{fs}$ (veh/day)			(Note: this is only for the one side of freeway being analyzed.)		
	Allowable AADT =		to		
Ramp Access Data			*Begin Station (feet)*	*End Station (Feet)*	
Entrance Ramp	Distance from begin milepost to upstream entrance ramp gore $X_{b,ent}$ (mi)				
	Length of s-c lane in segment $L_{en,seg}$ (mi)				
Exit Ramp	Distance from end milepost to downstream exit ramp gore $X_{e,ext}$ (mi)				
	Length of s-c lane in segment $L_{ex,seg}$ (mi)				
Weave	Type of Weaving Section Weave Help				

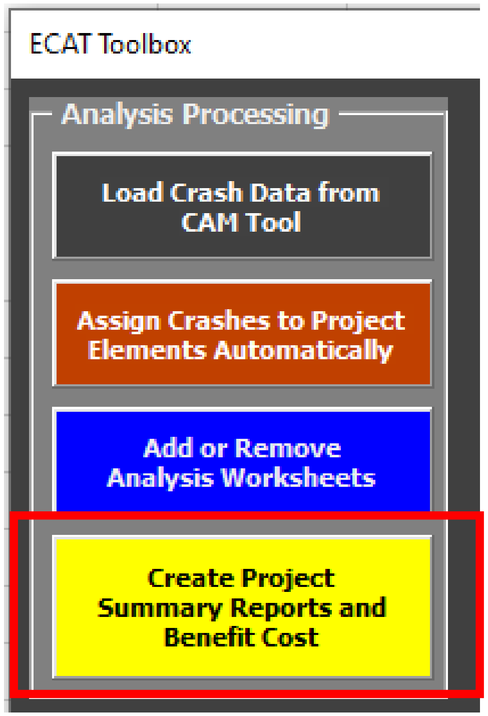
	Basic Freeway	S-C Entrance	S-C Exit		
Curve and Barrier Characteristics					
Horizontal Curve Data	Basic Freeway	S-C Entrance	S-C Exit	Add Curve Data	
Total Curve Length (mi)	0	0	0		Go to Curve Details
Median Barrier Summary					
Length of Median Barrier (mi)	0	0	0	Add Barrier Data	
Roadside Barrier Summary					
Length of Roadside Barrier (mi)	0	0	0		Go to Barrier Details

Overall Process

1. Define Project Elements (segments and/or intersections)
2. Collect and assign observed crashes to Each Project Element
3. Calculate the Highway Safety Manual Predicted and Expected Crash Frequency
4. Compare Existing Project Elements to Proposed Project Element Conditions
5. Summarize Project
6. Complete the Benefit-Cost Analysis (if required)

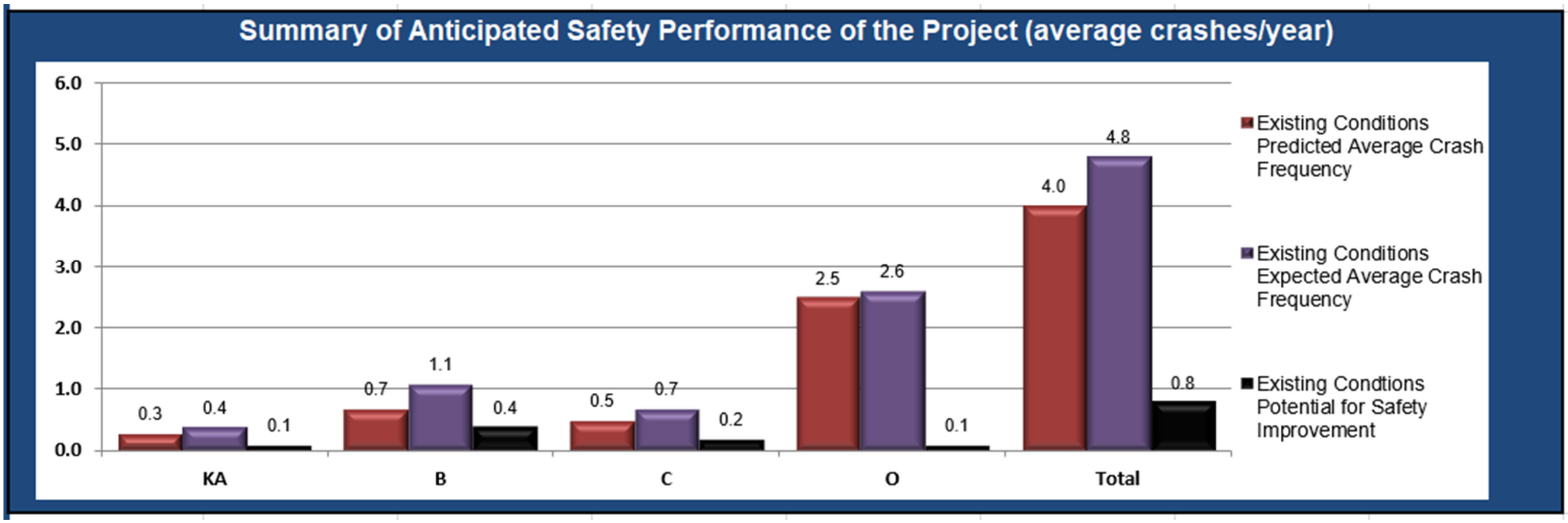
Create Reports

- Create Project Summary Reports will create all reports necessary based on the information provided by the analyst
- No data entry is required on the reports



HSM Summary Report

- The report tab summarizes all the Project Elements that are HSM site types
- Combines all the individual analysis into a Project Summary



HSM Summary Report

- Crash predictions broken out by element ID

Existing Conditions Project Element Predicted Crash Summary (Without Animal Crashes)						
Project Element ID	Common Name	Crash Severity Level				
		KA	B	C	O	Total
ASD-30; 3.90	SR 511	0.0831	0.1706	0.1007	0.8685	1.2229

Existing Conditions Project Element Expected Crash Summary (Without Animal Crashes)						
Project Element ID	Common Name	Crash Severity Level				
		KA	B	C	O	Total
ASD-30; 3.90	SR 511	0.1341	0.2756	0.1628	1.3267	1.8992

Existing Conditions Project Element Potential for Safety Improvement Summary (Without Animal Crashes)						
Project Element ID	Common Name	Crash Severity Level				
		KA	B	C	O	Total
ASD-30; 3.90	SR 511	0.051	0.105	0.0621	0.4582	0.6763

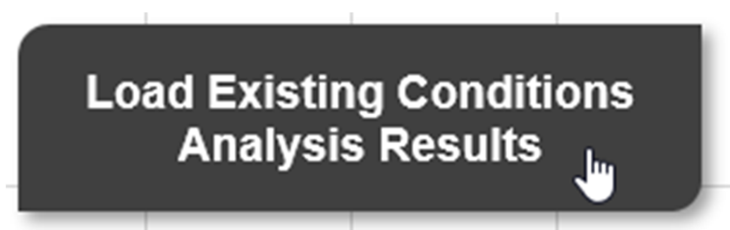
Proposed Conditions Project Element Expected Crash Summary (Without Animal Crashes)						
Project Element ID	Common Name	Crash Severity Level				
		KA	B	C	O	Total
ASD-30; 3.90	SR 511	0.0461	0.0971	0.0579	0.7153	0.9164

HSM Summary Report

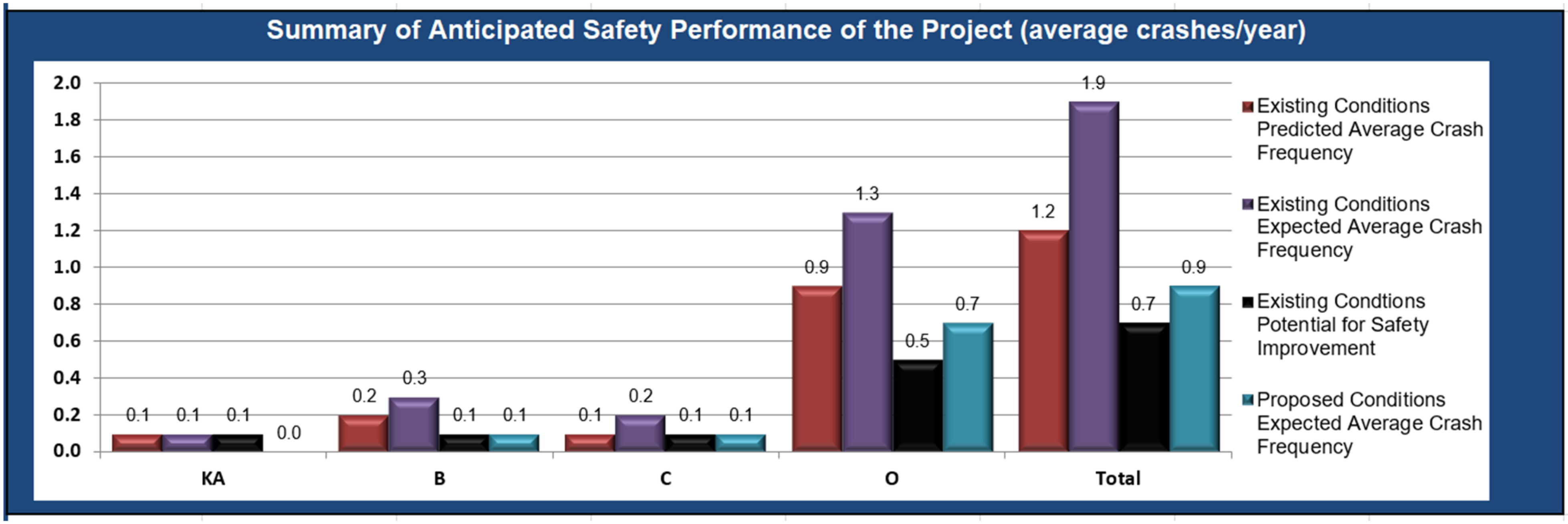
Summary by Crash Type				
Crash Type	Existing			Proposed
	Predicted Crash Frequency	Expected Crash Frequency	PSI	Expected Crash Frequency
Unknown	0.0006	0.0010	0.0004	0.0010
Head On	0.0121	0.0181	0.0060	0.0181
Rear End	0.1923	0.2857	0.0934	0.2857
Backing	0.0623	0.0929	0.0306	0.0929
Sideswipe - Meeting	0.0011	0.0016	0.0005	0.0016
Sideswipe - Passing	0.1204	0.1789	0.0585	0.1789
Angle	0.4225	0.6260	0.2035	0.6260
Parked Vehicle	0.0390	0.0580	0.0190	0.0580
Pedestrian	0.0040	0.0059	0.0019	0.0059
Animal	0.0000	0.0000	0.0000	0.0000
Train	0.0000	0.0000	0.0000	0.0000
Pedalcycles	0.0011	0.0016	0.0005	0.0016
Other Non-Vehicle	0.0000	0.0000	0.0000	0.0000
Fixed Object	0.2124	0.3162	0.1038	0.3162
Other Object	0.0066	0.0098	0.0032	0.0098
Overturning	0.0105	0.0155	0.0050	0.0155
Other Non-Collision	0.0242	0.0360	0.0118	0.0360
Left Turn	0.0740	0.1096	0.0356	0.1096
Right Turn	0.0398	0.0592	0.0194	0.0592

Change in SPF

- When there is a change in site conditions, the analyst will need to load the existing conditions analysis file into the proposed.
- This can be completed by clicking button and selecting the existing analysis results.



HSM Summary Report



HSM Summary Report

Project Summary Results (Without Animal Crashes)					
	KA	B	C	O	Total
$N_{predicted}$ - Existing Conditions	0.0831	0.1706	0.1007	0.8685	1.2229
$N_{expected}$ - Existing Conditions	0.1341	0.2756	0.1628	1.3267	1.8992
$N_{potential\ for\ improvement}$ - Existing Conditions	0.0510	0.1050	0.0621	0.4582	0.6763
$N_{expected}$ - Proposed Conditions	0.0461	0.0971	0.0579	0.7153	0.9164

Overall Process

1. Define Project Elements (segments and/or intersections)
2. Collect and assign observed crashes to Each Project Element
3. Calculate the Highway Safety Manual Predicted and Expected Crash Frequency
4. Compare Existing Project Elements to Proposed Project Element Conditions
5. Summarize Project
6. Complete the Benefit-Cost Analysis (if required)

Benefit-Cost Analysis

- Compare the estimated future safety benefits of the proposed improvements to the cost of constructing the same improvements

Countermeasure Service Lives, Costs, and Safety Benefits								
Countermeasures	Service Life (Years)	Initial Cost of Countermeasure	Annual Maintenance & Energy Costs	Salvage Value	Net Present Cost of Countermeasure	Total Cost of Countermeasures	Summary of Annual Crash Modifications	Net Present Value of Safety Benefits
Roundabout	20	$2,724,108.00			$2,724,108.00	$2,724,108.00	-5.579	$5,398,996
Lighting	10	$250,000.00			$500,000.00	$620,061.07		
Site Characteristic Improvements (Please add description about improvements i.e. Signal Phasing)					$0.00	$0.00		
Site Characteristic Improvements (Please add description about improvements i.e. Added Right Turn Lane)					$0.00	$0.00		
					$0.00	$0.00	0.000	$0

Benefit-Cost Analysis

- Discount rate of 4% is used
- Crash costs are updated annually

Benefit - Cost Calculator	
Net Present Value of Project	$3,224,108.00
Net Present Value of Safety Benefits	$5,398,995.96
Net Benefit	$2,174,887.96
Benefit / Cost Ratio	1.67

Expected Annual Crash Adjustment	
Number of Fatal & Incapacitating Injury Crashes	-0.527
Number of Injury Crashes	-2.537
Number of Total Crashes	-5.579

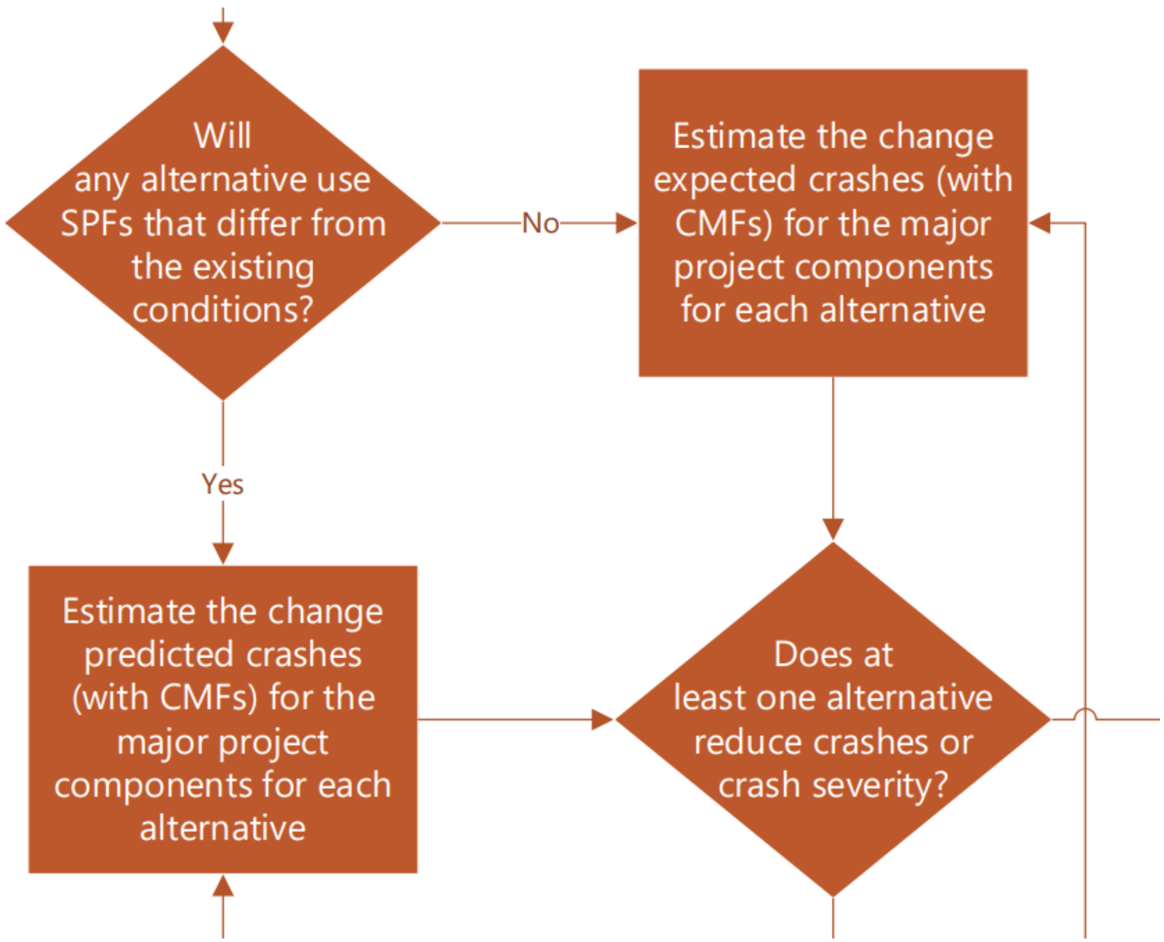
Customization

- Ability to analyze any site type, multiple site types as a whole project in 1 file
- Observed crash importing
- Site type analysis sheets
- Safety Performance Functions (SPF's)
- Calibration Factors
- Crash Modification Factors (CMF's)
- Benefit Cost Analysis
- Integrated into funding requests

Rural Two-Lane, Two-Way Roads		Total		
Segments	T2U	1.20		
Three-Leg Minor Stop-Controlled Intersection	T3ST	0.91		
Three-Leg Turning Intersection	T3STT	1.00	*	
Three-Leg Signalized Intersection	T3SG	1.00	*	
Four-Leg Minor Stop-Controlled Intersection	T4ST	1.01		
Four-Leg All-Way Stop-Controlled Intersection	T4aST	1.00	*	
Four-Leg Signalized Intersection	T4SG	1.68		
Rural Multilane Highways		Total	FI	PDO
Divided Highways Segments	M4D	1.31	0.42	2.25
Undivided Highways Segments	M4U	1.61	0.71	2.58
Three-Leg Minor Stop-Controlled Intersection	M3ST	1.30	1.08	1.48
Three-Leg Signalized Intersection	M3SG	1.00	1.00	1.00
Four-Leg Minor Stop-Controlled Intersection	M4ST	1.20	0.9	1.55
Four-Leg Signalized Intersection	M4SG	1.17	0.76	1.48
Urban & Suburban Arterial Highways - Segments		Total	FI	PDO
Two-Lane Undivided Segments	2U	0.74	0.58	0.8
Three-Lane With Center Two-Way Left-Turn Lanes Segments	3T	0.63	0.51	0.67
Four-Lane Divided Segments	4D	0.93	0.77	0.99
Four-Lane Undivided Segments	4U	0.24	0.19	0.27
Five-Lane With Center Two-Way Left-Turn Lanes Segments	5T	0.38	0.37	0.38
Two-Lane One-Way Segments	2O	1.00	1.00	1.00
Three-Lane One-Way Segments	3O	1.00	1.00	1.00
Four-Lane One-Way Segments	4O	1.00	1.00	1.00
Urban & Suburban Arterial Highways - Intersections		Total	FI	PDO
Three-Leg Minor Stop-Controlled Intersection	3ST	0.69	0.53	0.78
Three-Leg Minor Stop-Controlled Intersection (High Speed)	3ST (HS)	1.00	1.00	1.00
Three-Leg All-Way Stop-Controlled Intersection	3aST	1.00	1.00	1.00
Three-Leg Turning Intersection	3STT	1.00	1.00	1.00
Three-Leg Signalized Intersection	3SG	1.92	1.05	2.55

Program Integration

- Estimating the change in predicted/expected crashes is required for any project that isn't maintenance related
- Projects with "improving safety" as part of the purpose and need must reduce crashes or crash severity
- Safety Analysis Guidelines referenced in other important guidance documents



Crash Data Users

- **Internal - ~250**
  - Central Office – Highway Safety, Engineering
  - Districts – Planners, Designers & Project Managers

- **External ~1,500 users**
  - Consultants
  - MPO's
  - Local agencies
  - News agencies
  - Public

Pros and Cons

Pros

- Integrated into planning/project development process
- Analyze an entire project in one file
- Sped up analysis
- Able to customize

Cons

- We own it
- Methodology/Application issues
- Maintenance
- Training
- Personnel

EVERY MOVE YOU MAKE

TOWARD ZERO DEATHS

Brenton Bogard

Ohio Department of Transportation

Brenton.Bogard@dot.ohio.gov

NORTH CAROLINA
Department of Transportation

NCDOT Predictive Safety Analysis

Brian Murphy, NCDOT

AASHTO Webinar: Exploring Highway Safety Manual Crash Prediction Calculation Tools, 10/12/23

Predictive Safety Analysis at NCDOT

- Who is doing predictive safety analysis?
  - Currently only internal staff: Safety Planning Group of the Traffic Safety Unit
  - Soon to expand to contractors who are prequalified to conduct predictive safety analysis
- What is it being used for?
  - Mostly performed for alternatives analysis on TIP (capital improvement) projects
  - Exploring the use of SPFs in network screening

Predictive Safety Analysis at NCDOT

- What "level" of SPFs do we use?
  - Mostly project-level (detailed predictions)
  - Explored used planning-level (Type 1, AADT only)
- What SPFs do we use?
  - HSM1 SPFs
  - SPFs from NCHRP projects intended for the HSM
    - Roundabouts (17-70)
    - One-way and 6-8 lane arterials (17-58)
    - New intersection types (17-68)

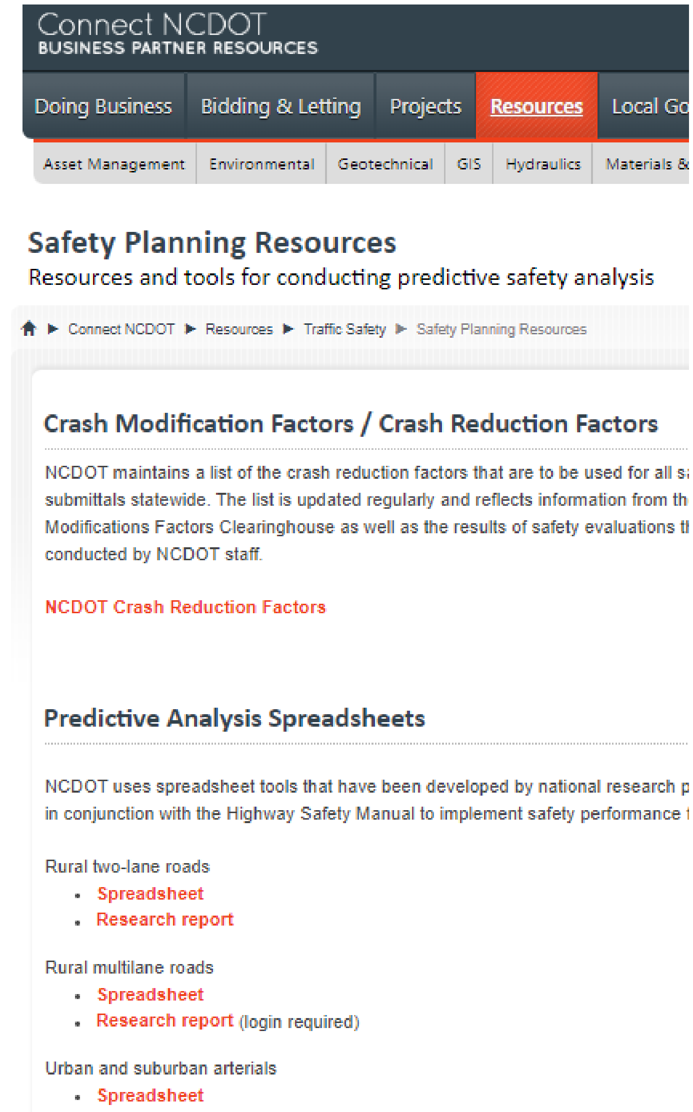
Predictive Safety Analysis at NCDOT

- How do we implement SPFs?
  - Spreadsheet tools
- Why spreadsheets?
  - Customizable
  - Can verify calculations are being done correctly
  - Can “reach in” and grab interim values for alternate calculations
- Other resources:
  - SPF calibration factors for NC conditions
  - CMFs from an NCDOT-specific list and from the CMF Clearinghouse

Safety Planning Resources Webpage

https://connect.ncdot.gov/resources/safety/Pages/Safety-Planning-Resources.aspx

Resource page intended for anyone conducting predictive safety analysis in NC



Resources posted:

- NCDOT state CMF list
- Spreadsheet tools (with links to original research reports)
- Compilation of NC calibration factors
- Crash proportion tables
- Intersection control selection tools and resources
- Training resources for Predictive Safety Analysis

NCDOT Spreadsheet Tools

- Can accommodate multiple segments or intersections in a single sheet
- Flat file arrangement – site characteristics and calculations all in one row
- Not macro-driven – all calculations can be followed

Site ID	Site Characteristics				CMF/AF Values			SPF Prediction Results		

Tools We Use by Facility Type

- **Rural undivided** – NCDOT custom spreadsheet
- **Rural multilane** – NCDOT custom spreadsheet
- **Urb/suburb arterials** – NCDOT custom spreadsheet (incorporates HSM1 SPFs and 17-58 SPFs for one-way and 6+ lanes)
- **Freeways** – iSatE spreadsheet tool
- **Roundabouts** – we have the 17-70 spreadsheets but have not yet used them

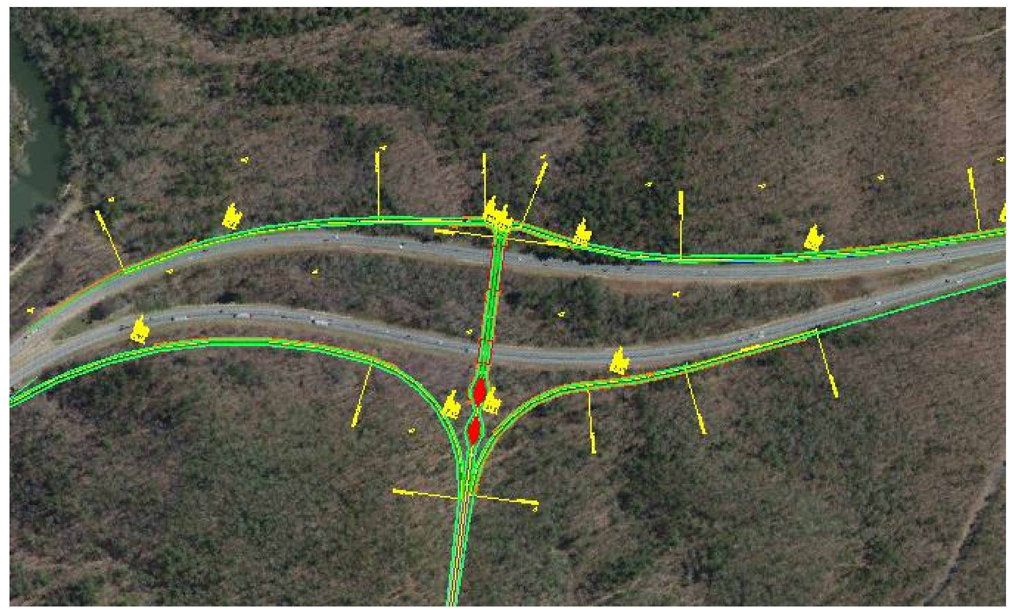
Example Use Cases of Predictive Safety Analysis at NCDOT

Example: HE-0001

- New proposed interchange
- Two alternatives for interchange design

Left side ramps

Right side ramps



Example: HE-0001

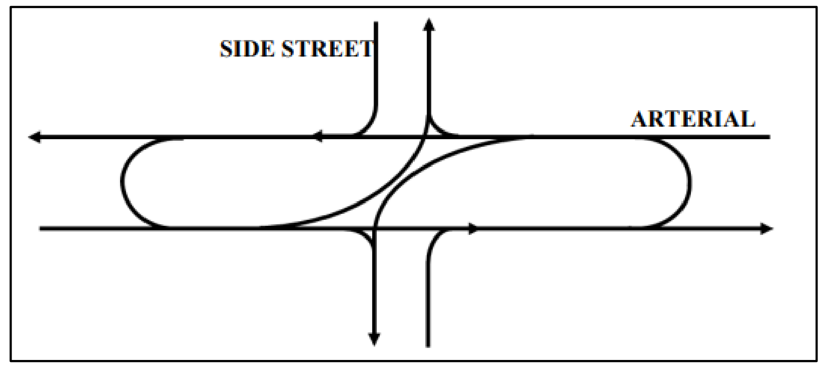
- Tool used: iSatE spreadsheet tool
- Right side design yielded fewer crashes
  - The left-side exit was a factor in increased predicted crashes, but also influential were the ramp length and curves in the left side alternative.

Example: R-4045

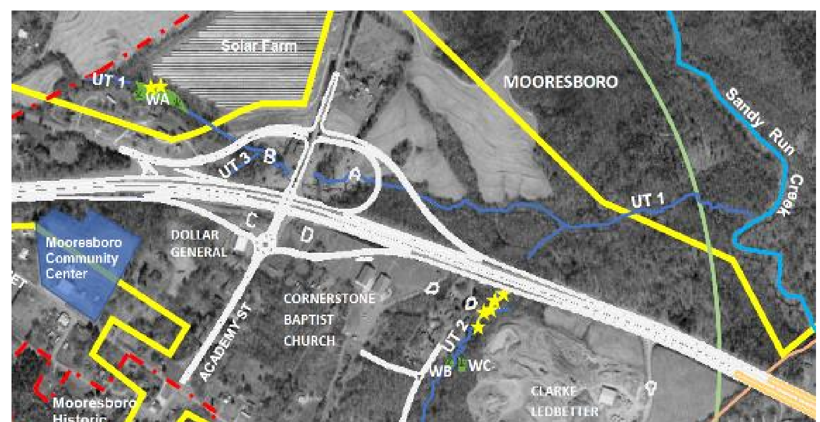
- Intersection rebuild
- Three alternatives considered
- Focused only on frontal impact crashes

No Build
Minor road stop-controlled

Alternative 1
Reduced conflict intersection (RCI)



Alternative 2
Interchange



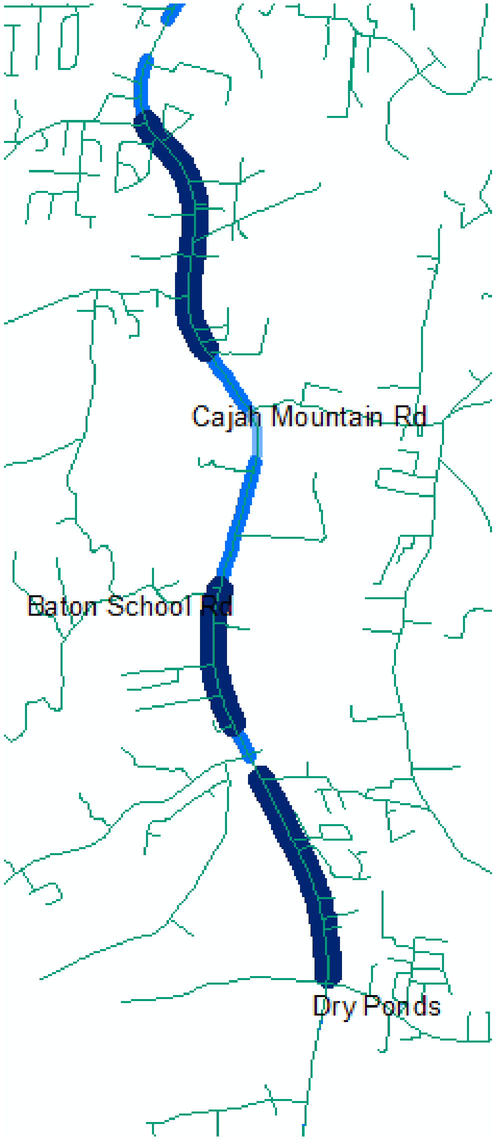
Example: R-4045

- Tools used:
  - NCDOT custom spreadsheet tool of HSM SPFs (rural multilane divided)
  - iSatE spreadsheet tool
- Other resources used:
  - Crash proportions for NC facilities (to estimate frontal impact crashes)
  - CMF for roundabout (because iSatE does not predict for roundabouts at ramp terminal intersections)

Example: R-3430

Proposed: Widen 2-lane rural road to a 3-lane cross section (2 through lanes plus TWLTL)

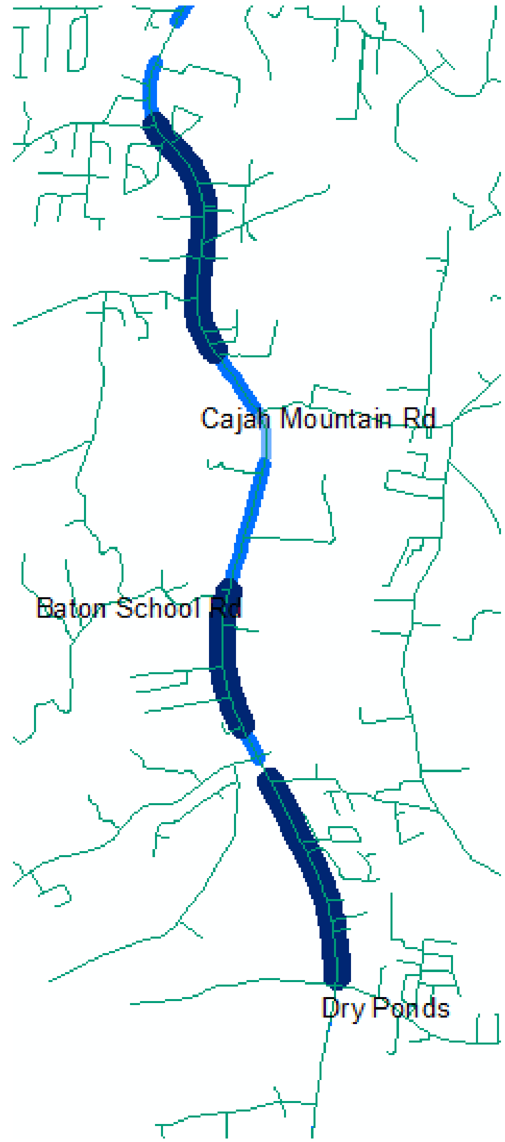
What we provided: Identified sections where 3-lane cross section would be most beneficial (higher predicted crashes)



Example: R-3430

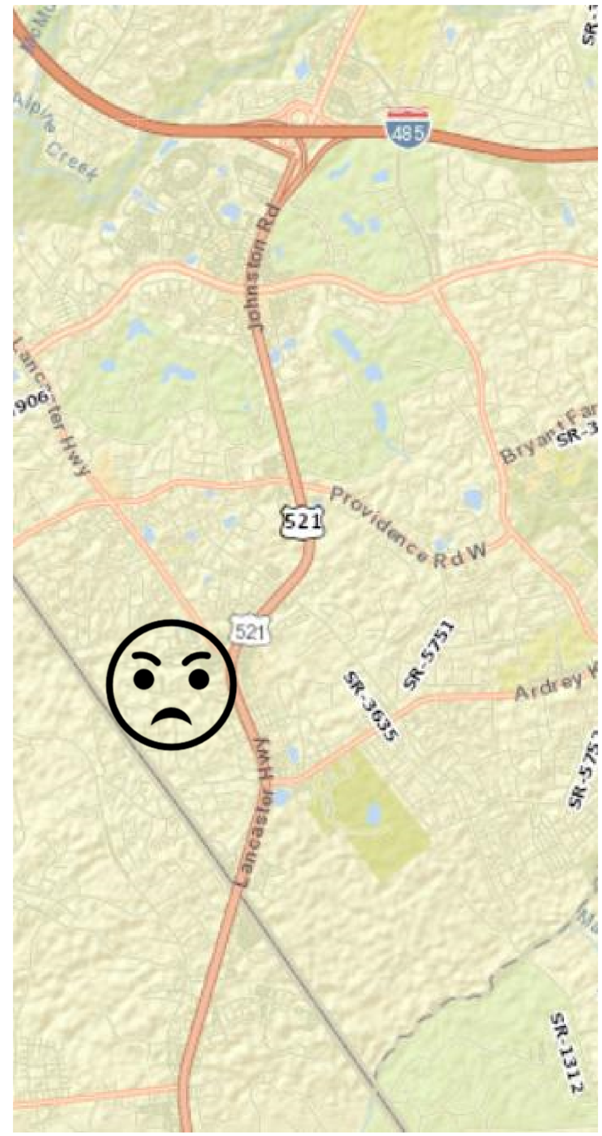
Tools used:

- NCDOT custom spreadsheet tool of HSM SPFs (rural 2U)



Example: U-6109

- Proposed: Widen 4-lane urban arterial
  - Alternative 1: Widen to 6-lanes with traditional intersections
  - Alternative 2: Widen to 6-lanes with RCI concept
  - Alternative 3: Widen to 8-lanes with traditional intersections
- Significant resistance from neighborhood group and legislator



Example: U-6109

- Tools used:
  - NCDOT custom spreadsheet tool developed to implement new SPFs from NCHRP 17-58 (6+ lane urban arterials)
- Other resources used:
  - CMFs to adjust predicted crashes for non-traditional intersection designs (RCI, MUT, CFI) in Alternative 2
- Special note: NC calibration factors were not available for the 6+ lane models, so we had to couch the results as *relative* comparisons

PENNDOT ICE TOOL

AASHTO
EXPLORING HIGHWAY SAFETY MANUAL CRASH PREDICTION MODELS CALCULATION TOOLS

JASON HERSHOCK

OCTOBER 12, 2023

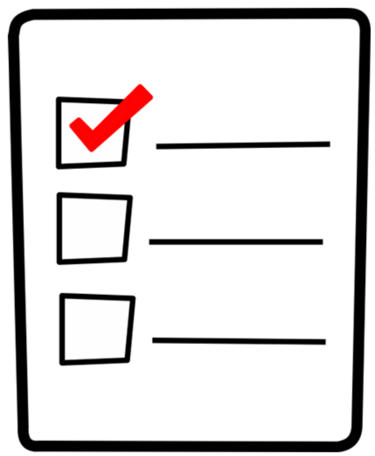
pennsylvania
DEPARTMENT OF TRANSPORTATION

TODAY'S AGENDA

- PennDOT uses of the HSM
- Staff Involved
- Other DDSA Tools
- The new web-based ICE Tool

HSM USES IN PENNSYLVANIA

- Highway Safety Network Screening
- Design Alternatives Analysis
- Design Exceptions
- Traffic Engineering Studies
- Project Performance Assessments

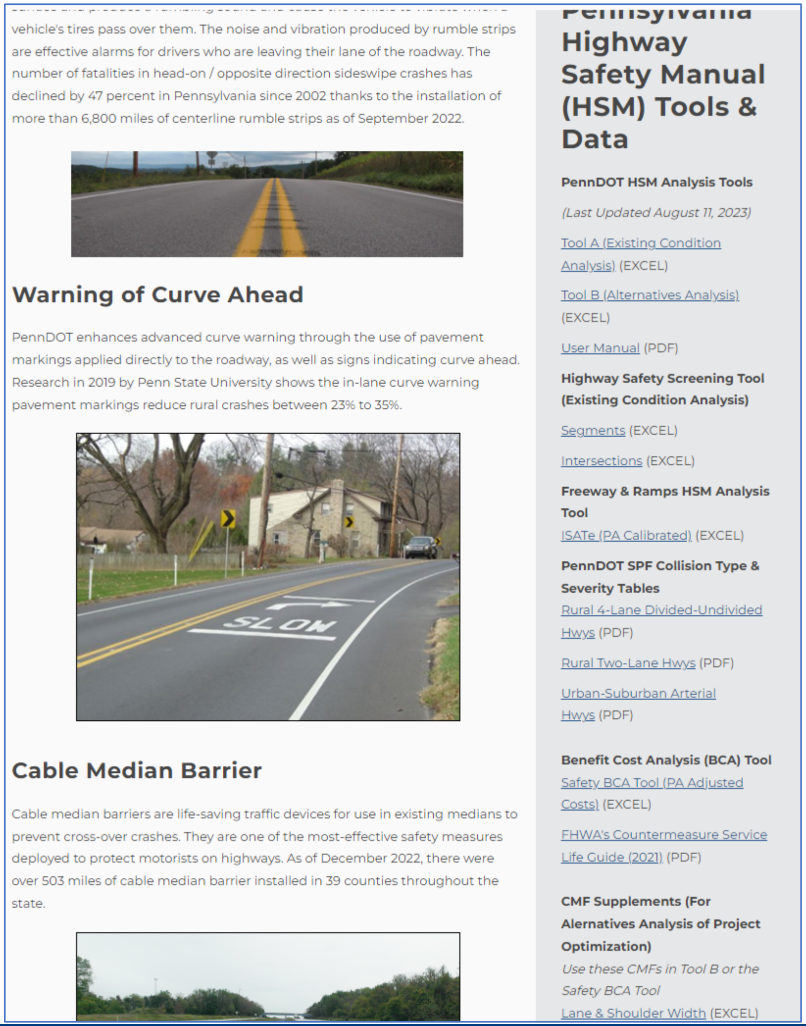


STAFF INVOLVED

- Engineering Districts
  - Planning
  - Design
  - Traffic Ops and Safety Eng.
- Central Office
  - Highway Safety Network Screening
  - HSIP assessments
  - Countermeasure studies
  - Analysis Tools
  - Policy development

- Regional Planning Partners
  - MPOs and RPOs
    - Prioritize HSIP funded projects
- Consultants
  - Purpose and Need (PAN)
  - Point of Access (POAs)
  - Traffic Impact Studies
  - Roadway Design
- Municipalities
  - Limited use so far

OTHER DDSA TOOLS



vehicle's tires pass over them. The noise and vibration produced by rumble strips are effective alarms for drivers who are leaving their lane of the roadway. The number of fatalities in head-on / opposite direction sideswipe crashes has declined by 47 percent in Pennsylvania since 2002 thanks to the installation of more than 6,800 miles of centerline rumble strips as of September 2022.

Warning of Curve Ahead

PennDOT enhances advanced curve warning through the use of pavement markings applied directly to the roadway, as well as signs indicating curve ahead. Research in 2019 by Penn State University shows the in-lane curve warning pavement markings reduce rural crashes between 23% to 35%.

Cable Median Barrier

Cable median barriers are life-saving traffic devices for use in existing medians to prevent cross-over crashes. They are one of the most-effective safety measures deployed to protect motorists on highways. As of December 2022, there were over 503 miles of cable median barrier installed in 39 counties throughout the state.

Pennsylvania Highway Safety Manual (HSM) Tools & Data

PennDOT HSM Analysis Tools

(Last Updated August 11, 2023)

Tool A (Existing Condition Analysis) (EXCEL)

Tool B (Alternatives Analysis) (EXCEL)

User Manual (PDF)

Highway Safety Screening Tool (Existing Condition Analysis)

Segments (EXCEL)

Intersections (EXCEL)

Freeway & Ramps HSM Analysis Tool

ISATe (PA Calibrated) (EXCEL)

PennDOT SPF Collision Type & Severity Tables

Rural 4-Lane Divided-Undivided Hwys (PDF)

Rural Two-Lane Hwys (PDF)

Urban-Suburban Arterial Hwys (PDF)

Benefit Cost Analysis (BCA) Tool

Safety BCA Tool (PA Adjusted Costs) (EXCEL)

FHWA's Countermeasure Service Life Guide (2021) (PDF)

CMF Supplements (For Alernatives Analysis of Project Optimization)

Use these CMFs in Tool B or the Safety BCA Tool

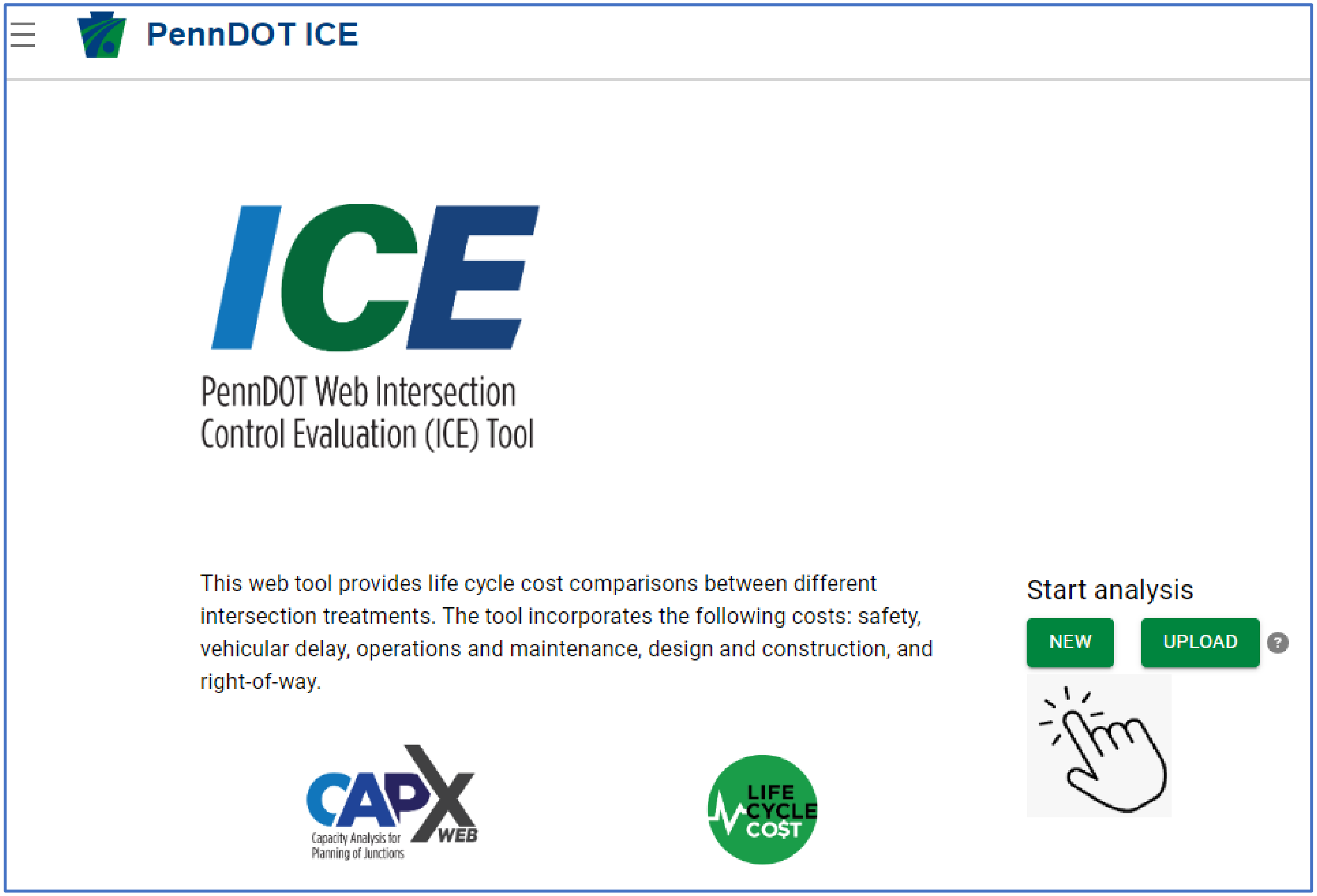
Lane & Shoulder Width (EXCEL)

We have several tools for highway safety analysis

- https://www.penndot.pa.gov/TravelInPA/Safety/Pages/Safety-Infrastructure-Improvement-Programs.aspx

OUR NEW ICE WEB TOOL

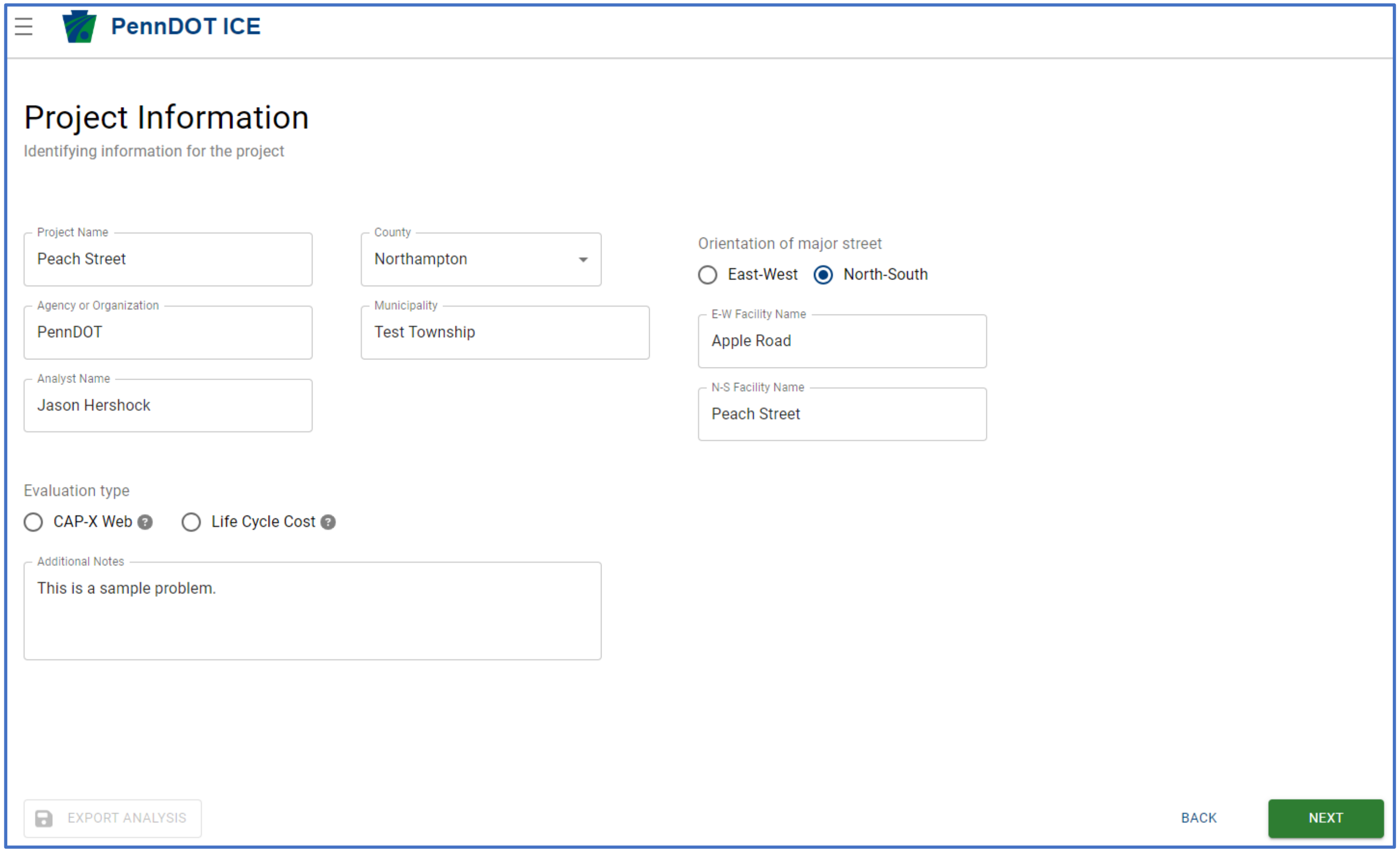
OUR NEW ICE WEB TOOL



Opening Screen

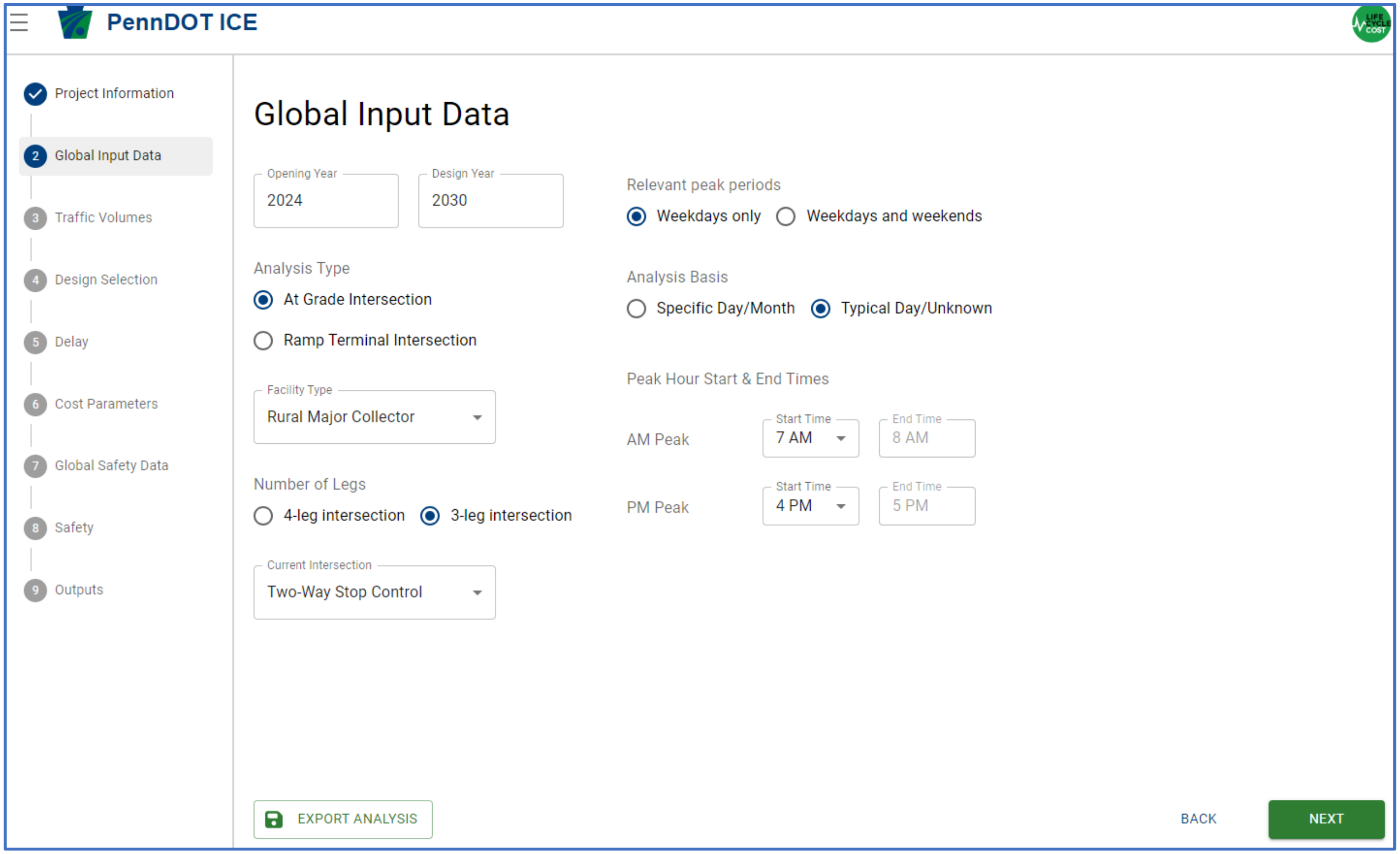
- Includes Capacity Analysis
- Safety Benefit Cost Analysis
- Can start **new** or **upload** previous analysis

SPICE/ICE WEB ANALYSIS TOOL



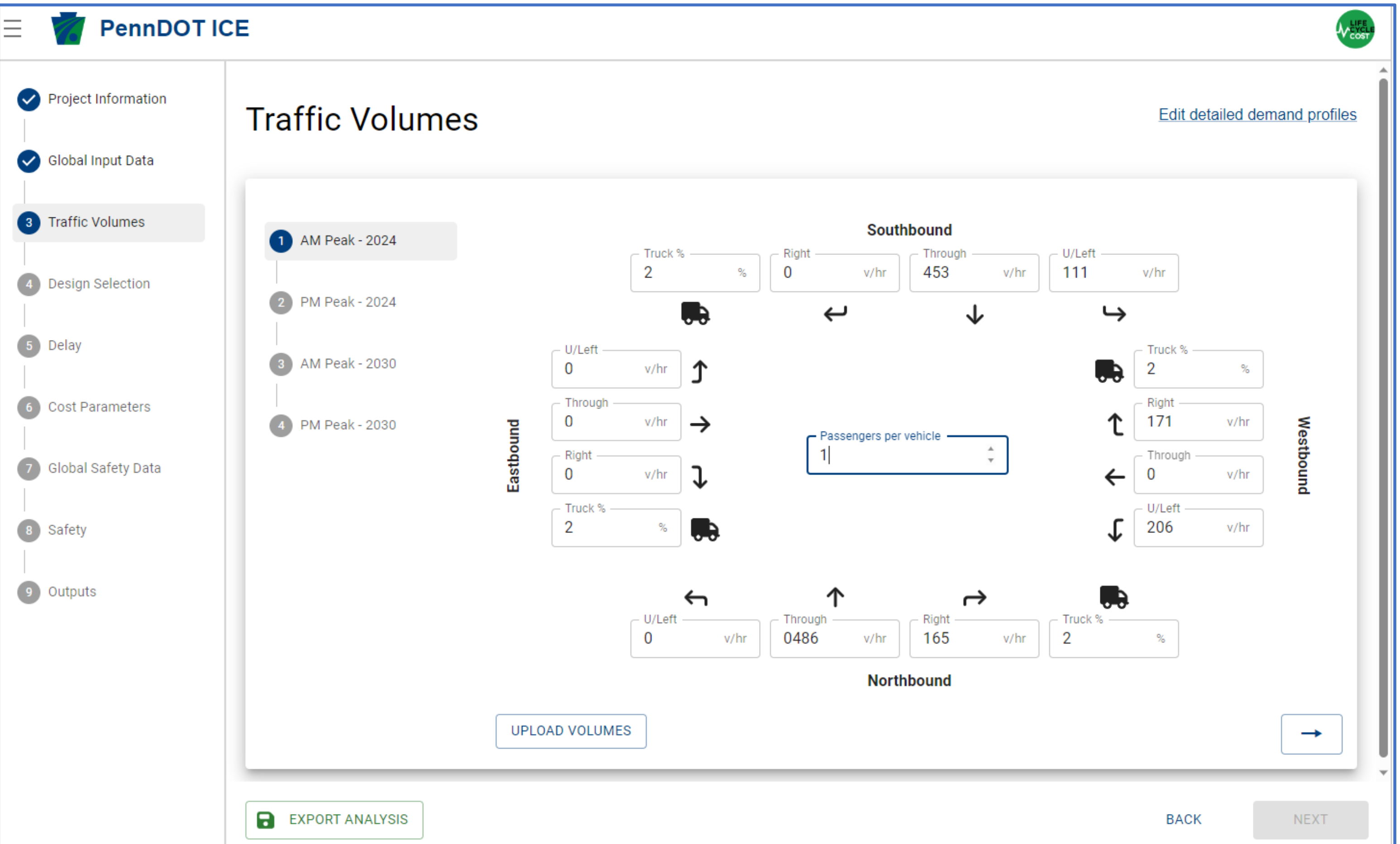
- Enter Project Information
- Select
  - Capacity analysis or
  - Combined capacity & safety analysis (Life Cycle)

SPICE/ICE WEB ANALYSIS TOOL



- **<u>Global Input Data</u>**
  - Analysis years
  - Peak periods
  - Analysis type
  - Facility type
  - Peak hours
  - Number of legs
  - Traffic Control

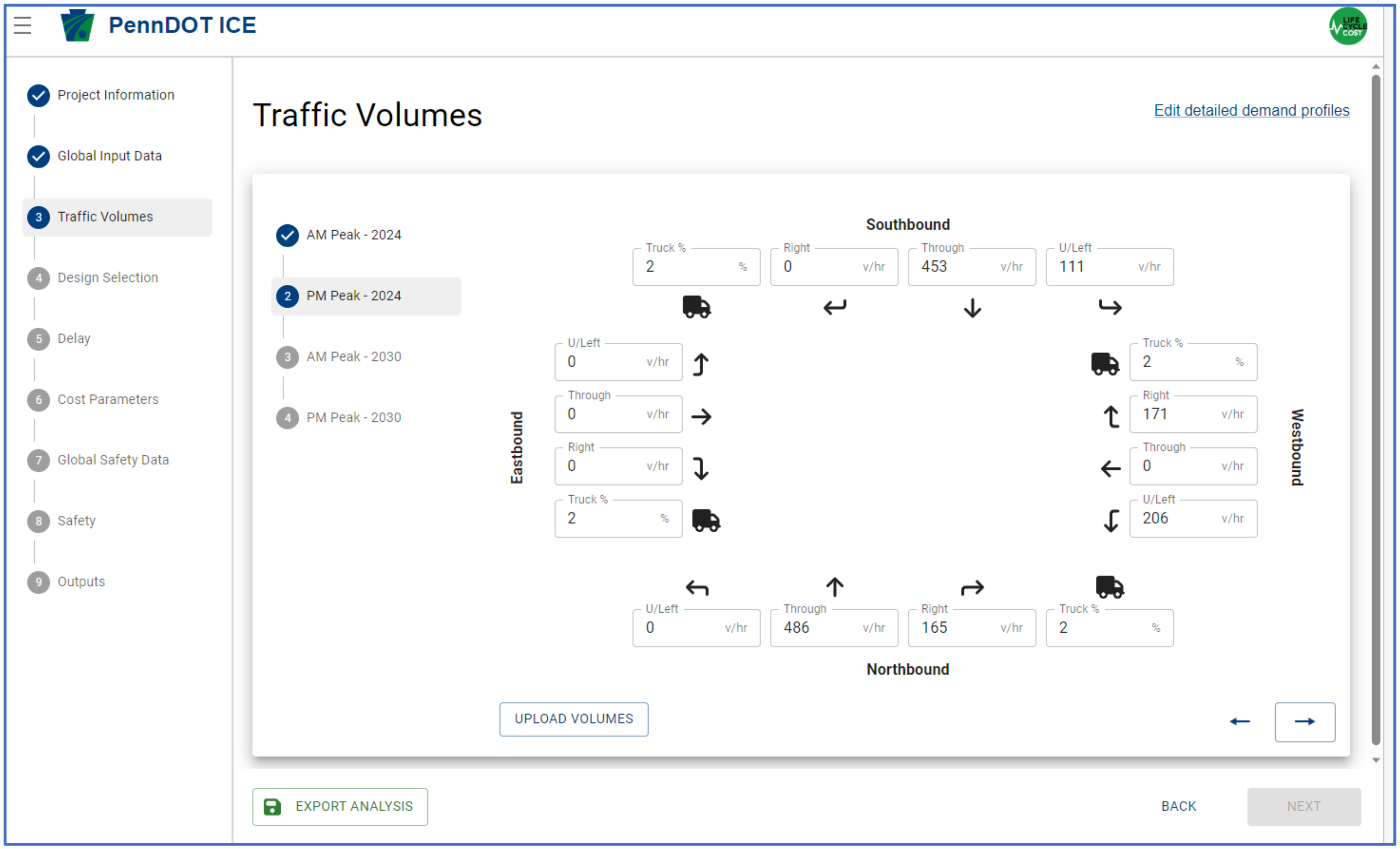
SPICE/ICE WEB ANALYSIS TOOL



Enter Traffic Volumes

- Opening year AM and PM Peak Counts
  - Option to upload traffic counts
- Forecast AM and PM peak counts

SPICE/ICE WEB ANALYSIS TOOL



Enter Traffic Volumes

- Opening Year AM and PM Peak Counts
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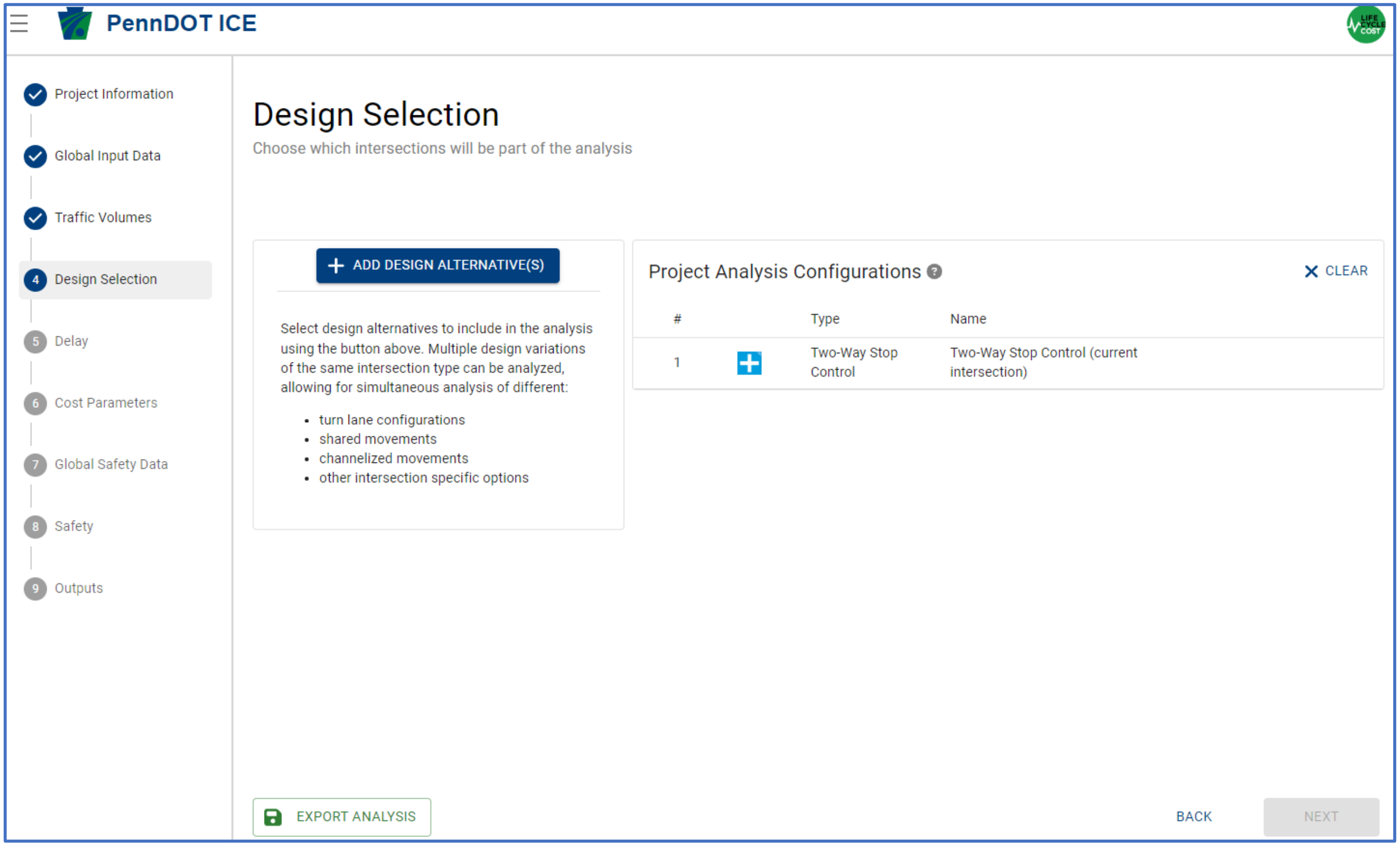
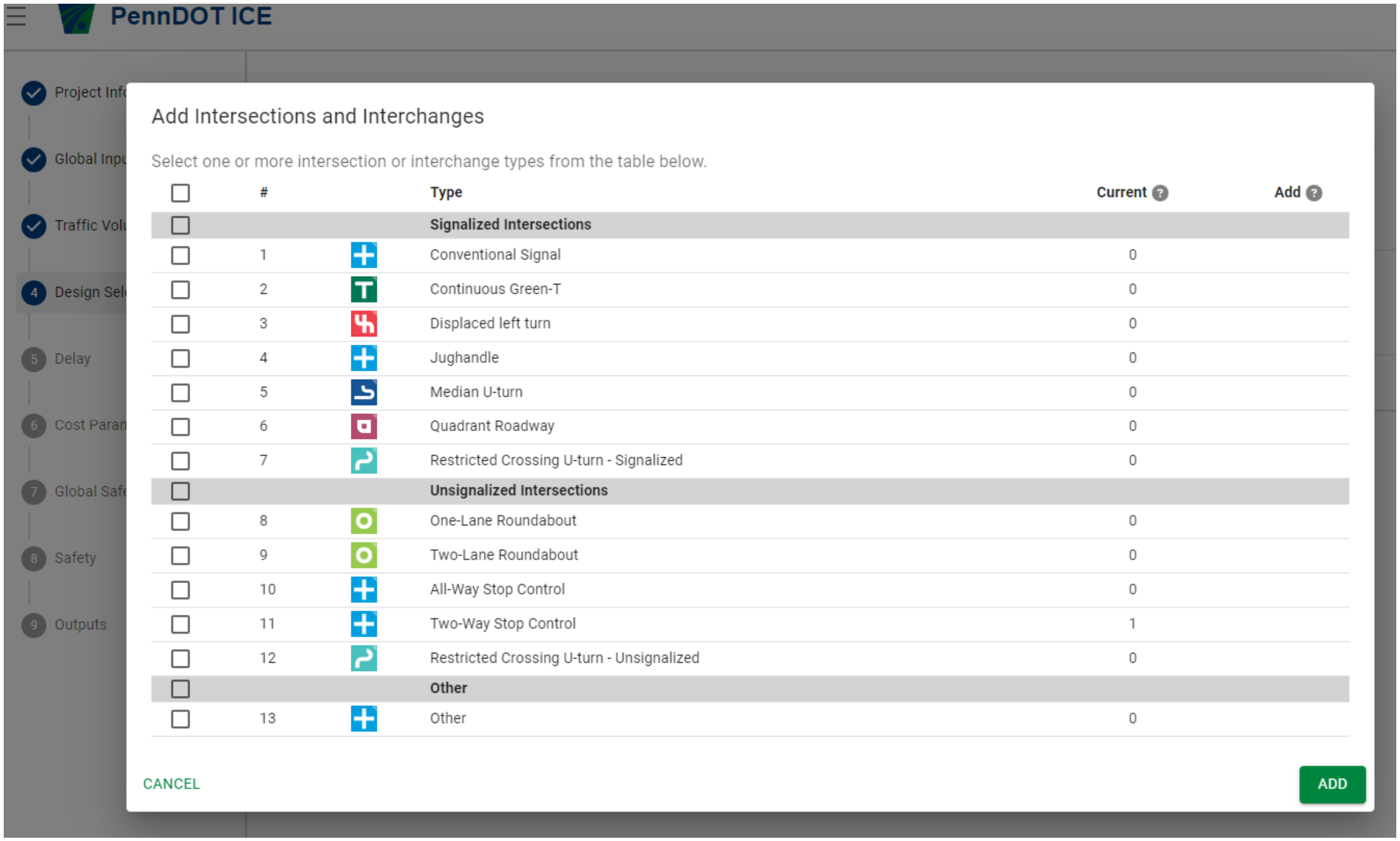
SPICE/ICE WEB ANALYSIS TOOL



Design Selection

- Select intersection configuration options
- Defaults to current intersection type

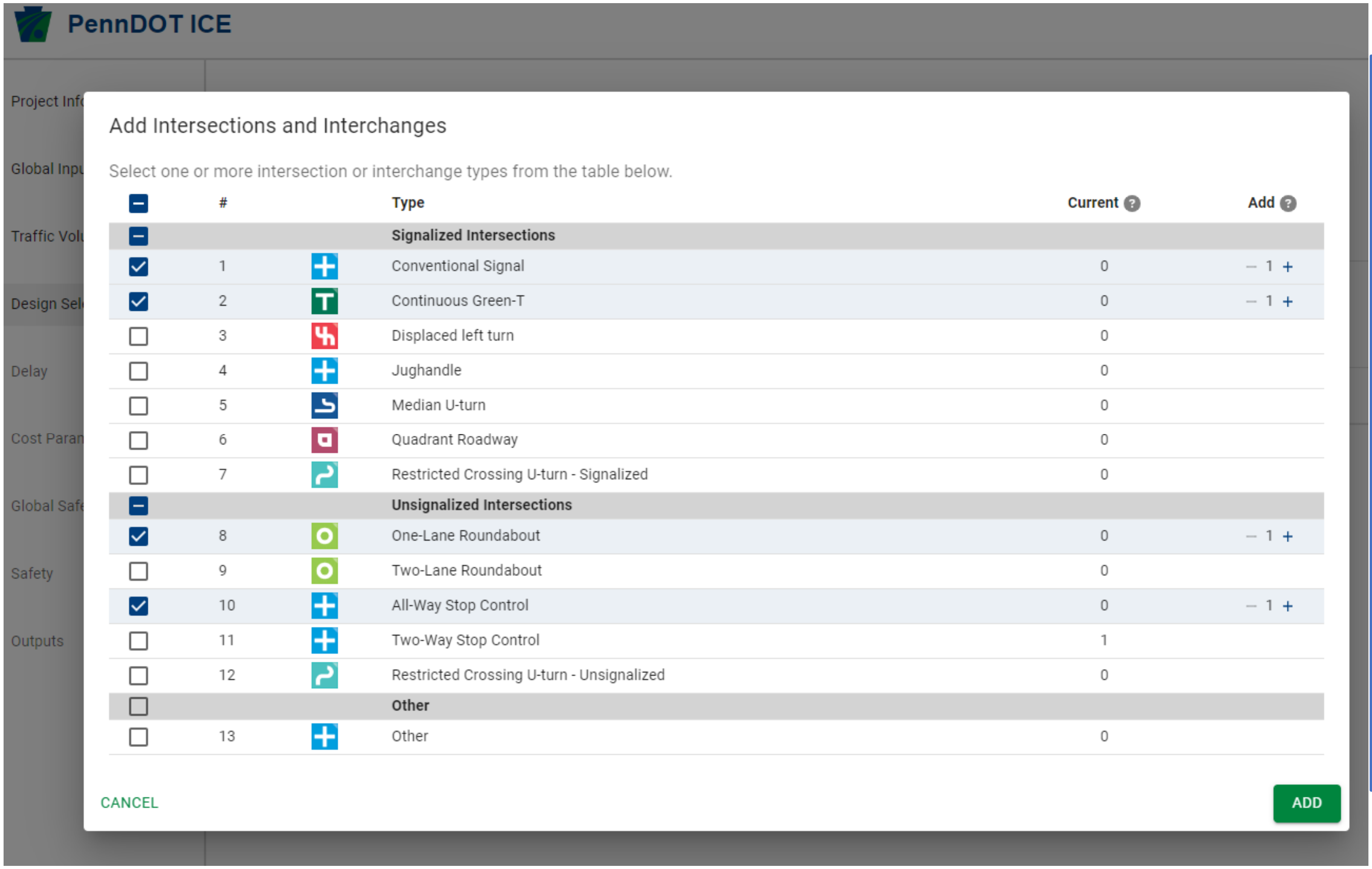
SPICE/ICE WEB ANALYSIS TOOL



Design Selection

- Select intersection configuration options
- Defaults to current intersection type
- Select alternatives
  - Click add

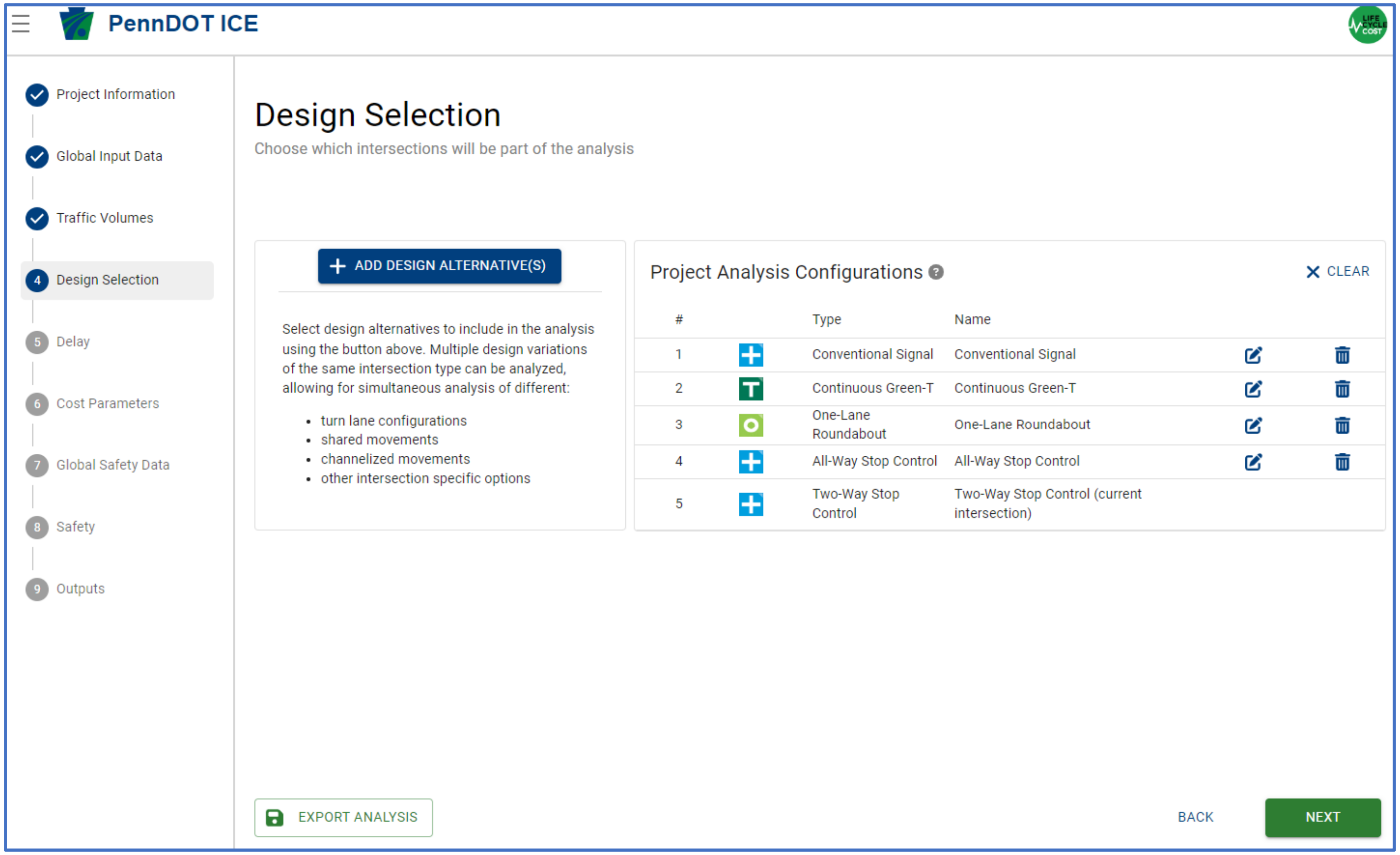
SPICE/ICE WEB ANALYSIS TOOL



Design Selection

- Select intersection configuration options
- Defaults to current intersection type
- Select alternatives
  - Click add

SPICE/ICE WEB ANALYSIS TOOL



- Options selected
- Move onto delay analysis

SPICE/ICE WEB ANALYSIS TOOL

PennDOT ICE

1. Project Information
2. Global Input Data
3. Traffic Volumes
4. Design Selection
5. Delay
6. Cost Parameters
7. Global Safety Data
8. Safety
9. Outputs

Delay

Enter average vehicle delay for each of the intersections

		Opening Year Average Vehicle Delay		Design Year Average Vehicle Delay	
Control Strategy	**Units**	**AM Peak**	**PM Peak**	**AM Peak**	**PM Peak**
Conventional Signal	sec/vehicle	22.5	42.0	23	43
Continuous Green-T	sec/vehicle	16	29.5	17.5	30.5
One-Lane Roundabout	sec/vehicle	15	26	16	28
All-Way Stop Control	sec/vehicle	19	31	20	34
Two-Way Stop Control (current intersection)	sec/vehicle	16	28.2	17	29

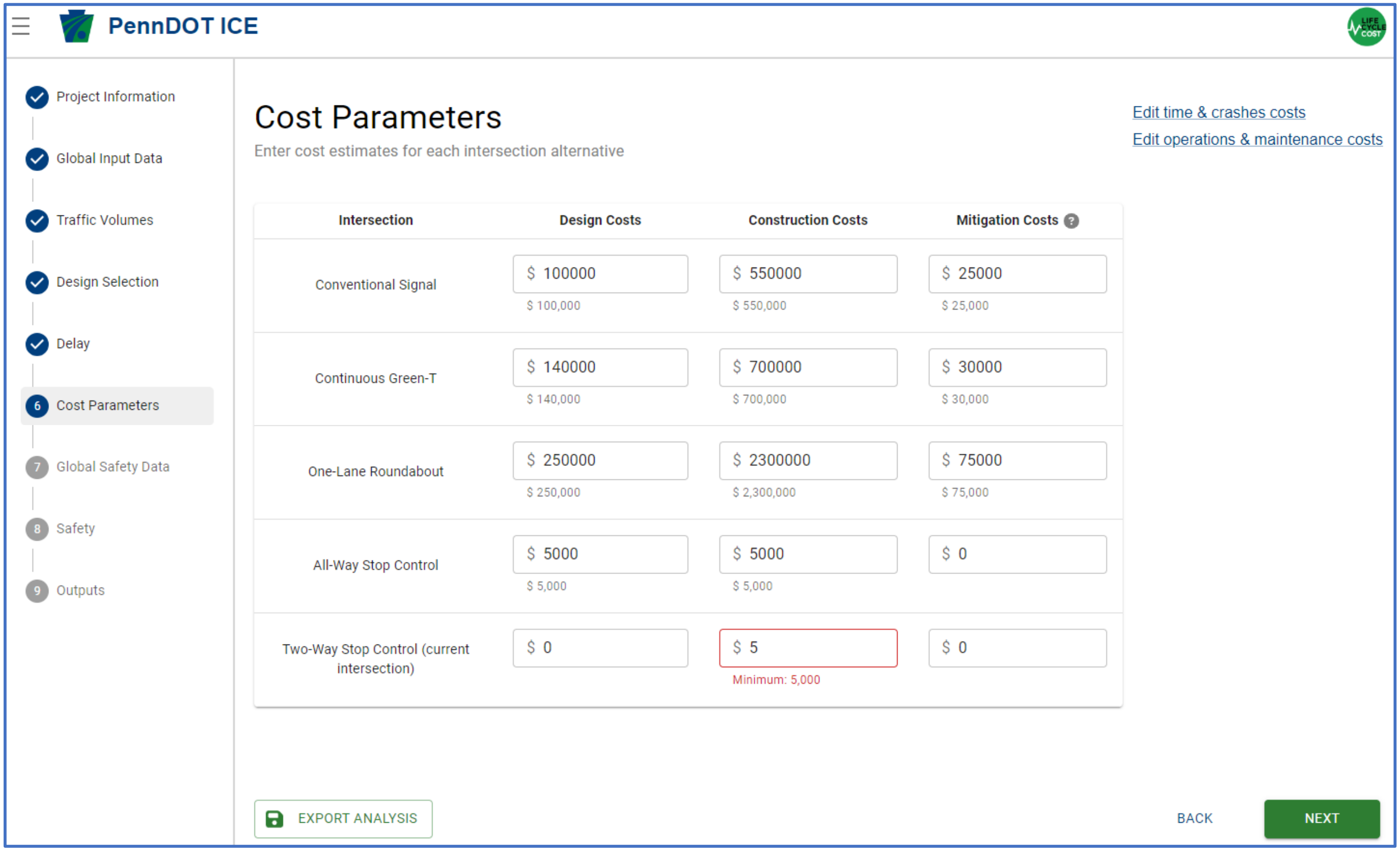
Where should I find my delay data?

Delay should be determined using PennDOT-approved software as specified in Publication 46 or with the NCHRP Project 17-98 PPEAG ICE Spreadsheet Tool. It is recognized that analysis of innovative intersections consisting of multiple nodes is challenging with conventional traffic analysis software and the planning-level delay values from the PPEAG ICE Spreadsheet Tool are

EXPORT ANALYSIS | BACK | NEXT

- Enter **delay** for each design option
- Help window at the bottom

SPICE/ICE WEB ANALYSIS TOOL



Cost Parameters

- Enter costs for each option
  - Design
  - Construction
  - Mitigation
- Cost check shown below entry area
- Notice the $5K minimum for Construction costs

SPICE/ICE WEB ANALYSIS TOOL

PennDOT ICE

- Project Information
- Global Input Data
- Traffic Volumes
- Design Selection
- Delay
- 6 Cost Parameters
- 7 Global Safety Data
- 8 Safety
- 9 Outputs

Cost Parameters

Enter cost estimates for each intersection alternative

Edit time & crashes costs
Edit operations & maintenance costs

Intersection	Design Costs	Construction Costs	Mitigation Costs
Conventional Signal	$ 100000 ($ 100,000)	$ 550000 ($ 550,000)	$ 25000 ($ 25,000)
Continuous Green-T	$ 140000 ($ 140,000)	$ 700000 ($ 700,000)	$ 30000 ($ 30,000)
One-Lane Roundabout	$ 250000 ($ 250,000)	$ 2300000 ($ 2,300,000)	$ 75000 ($ 75,000)
All-Way Stop Control	$ 5000 ($ 5,000)	$ 5000 ($ 5,000)	$ 0
Two-Way Stop Control (current intersection)	$ 0	$ 5000 ($ 5,000)	$ 0

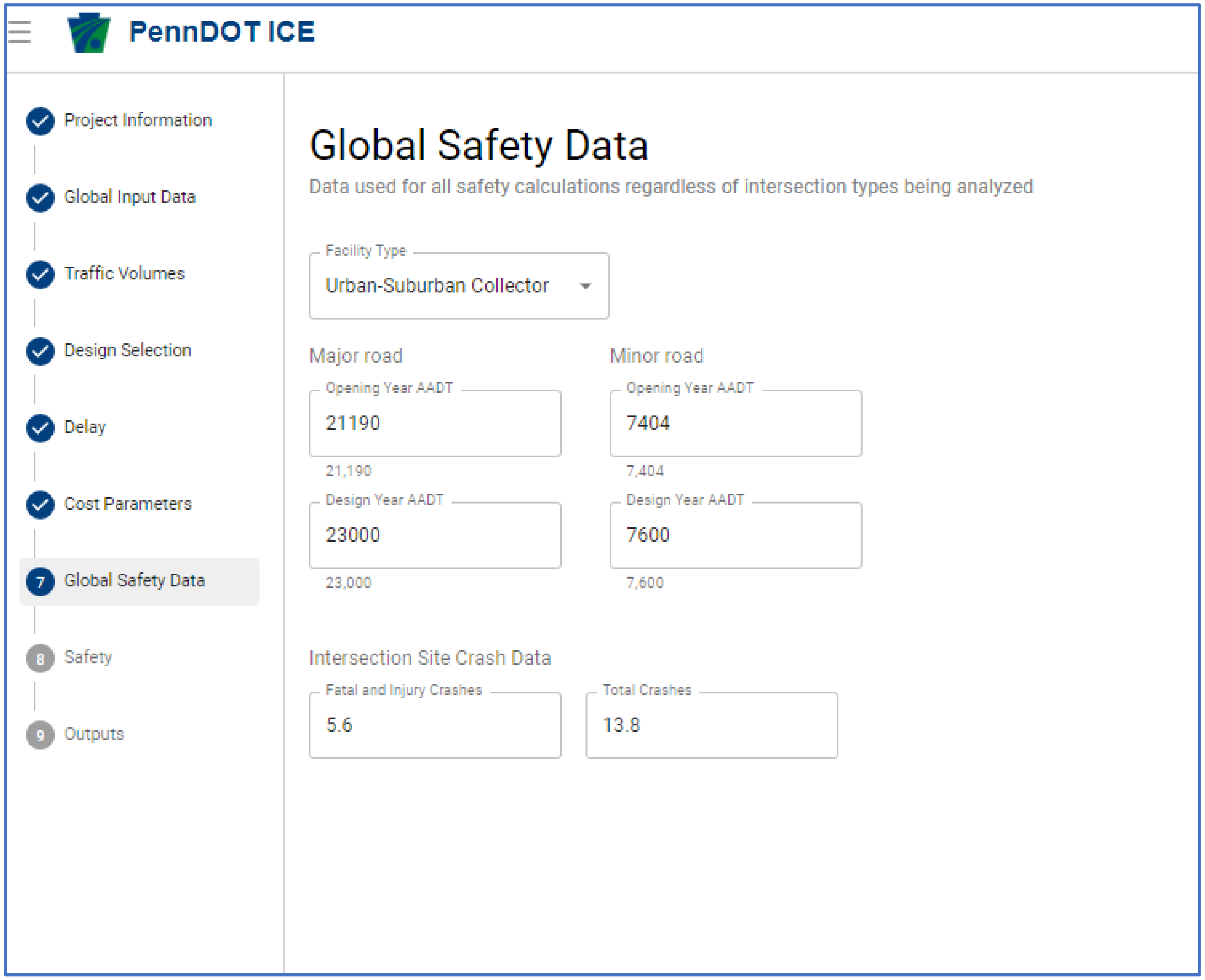
EXPORT ANALYSIS

BACK NEXT

Cost Parameters

- Enter costs for each option
  - Design
  - Construction
  - Mitigation
- Notice the $5K minimum for Construction costs

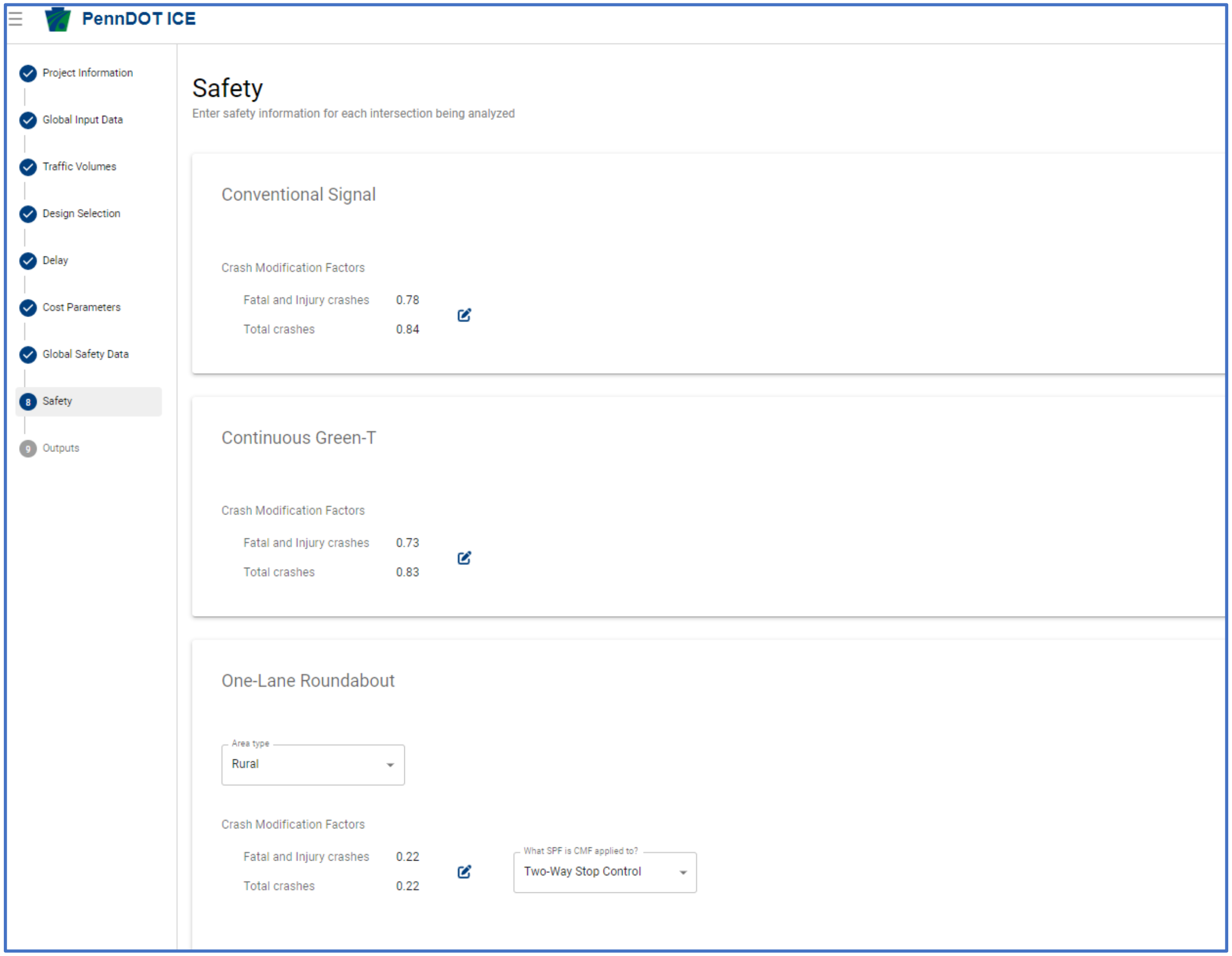
SPICE/ICE WEB ANALYSIS TOOL



Global Safety Data

- Enter Each intersecting road AADT
- Enter intersection crash data
  - Based 5 years of crash data
  - Use observed data or can use predicted crash data from an SPF for existing condition

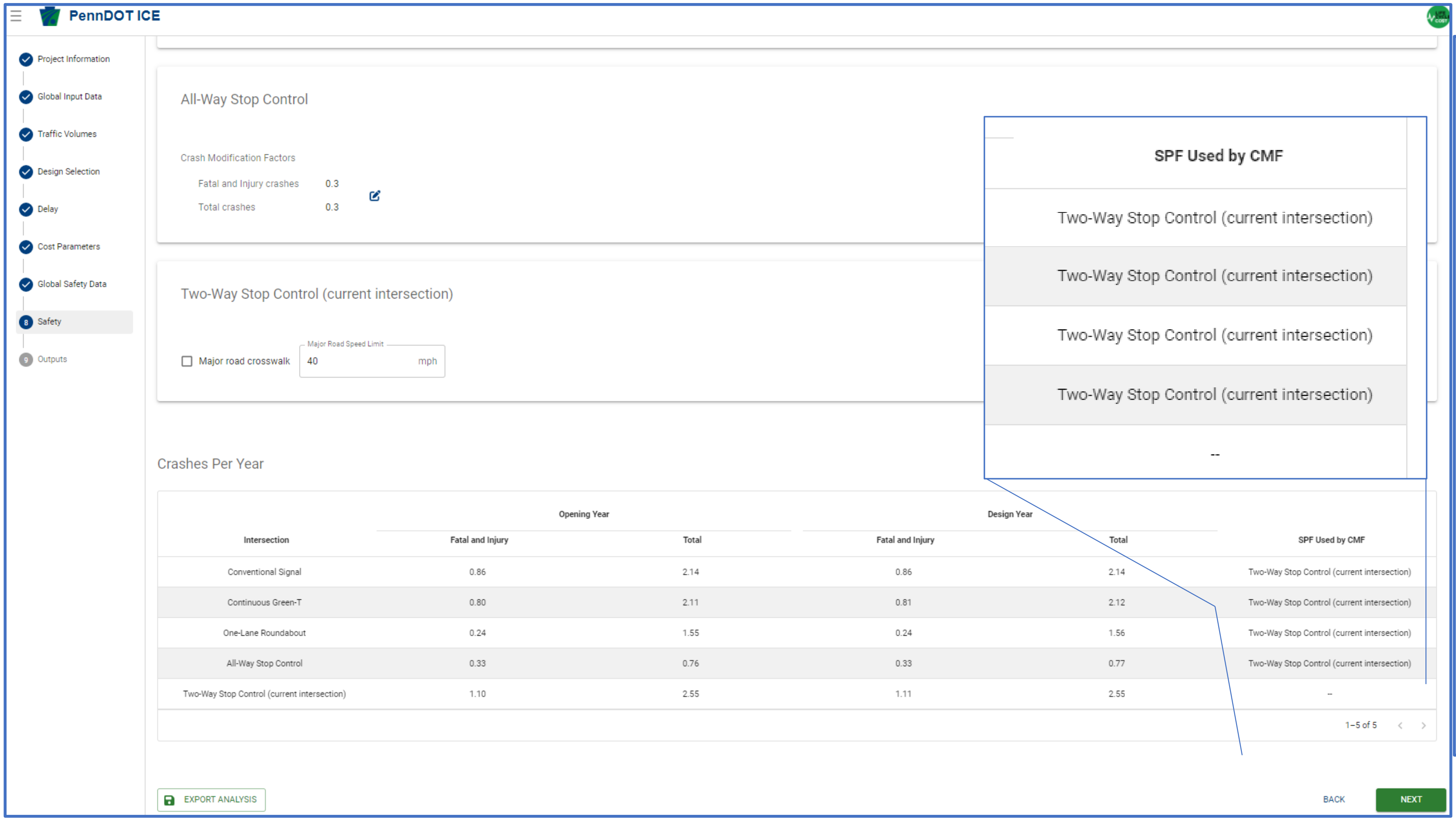
SPICE/ICE WEB ANALYSIS TOOL



Safety Analysis Summary

- Review each design option
- Enter speed limit for major road

SPICE/ICE WEB ANALYSIS TOOL



Safety Analysis Summary

- Review each design option
- Crosswalks?
- Enter posted speed limit for major road

SPICE/ICE WEB ANALYSIS TOOL

PennDOT ICE

Safety Defaults

Allows override of default crash modification factors for selected intersections

	Crash Severity	Override Value	Clearinghouse ID / Notes
Conventional Signal	Fatal and Injury		
	Total		
Continuous Green-T	Fatal and Injury		
	Total		
One-Lane Roundabout	Fatal and Injury		
	Total		
All-Way Stop Control	Fatal and Injury		
	Total		
Two-Way Stop Control	Uses safety performance function (SPF)		

EXPORT ANALYSIS

CANCEL

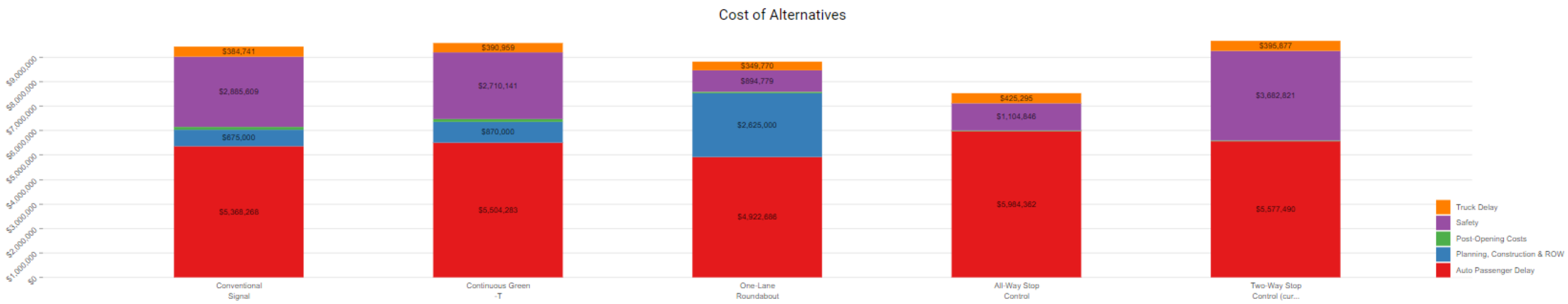
SAVE

Safety Analysis Summary

- Allows you to override default CMFs for a state specific CMF or some other analysis modification factoring

SPICE/ICE WEB ANALYSIS TOOL

Outputs



Intersection	Planning, Construction & ROW	Post-Opening Costs	Auto Passenger Delay	Truck Delay	Safety	Total Cost
Conventional Signal	$675,000	$112,183	$5,368,268	$384,741	$2,885,609	**$9,425,802**
Continuous Green-T	$870,000	$112,183	$5,504,283	$390,959	$2,710,141	**$9,587,566**
One-Lane Roundabout	$2,625,000	$36,673	$4,922,686	$349,770	$894,779	**$8,828,907**
All-Way Stop Control	$10,000	$12,097	$5,984,362	$425,295	$1,104,846	**$7,536,601**
Two-Way Stop Control (current intersection)	$5,000	$12,097	$5,577,490	$395,877	$3,682,821	**$9,673,285**

1–5 of 5

Benefit/Cost Ratio

Intersection	Auto Passenger Delay	Truck Delay	Safety	Net Present Value of Benefits	Net Present Value of Costs	Benefit/Cost (B/C) Ratio	Delay B/C	Safety B/C
Conventional Signal	$209,221	$11,136	$797,212	$1,017,569	$770,085	**1.32**	0.29	1.04
Continuous Green-T	$73,206	$4,918	$972,680	$1,050,804	$965,085	**1.09**	0.08	1.01
One-Lane Roundabout	$654,804	$46,108	$2,788,042	$3,488,954	$2,644,575	**1.32**	0.27	1.05
All-Way Stop Control	$ (406,873)	$ (29,418)	$2,577,975	$2,141,684	$5,000	**428.34**	Not Preferred	515.59

EXPORT ANALYSIS

BACK

GENERATE REPORT

Output - Benefit Cost Analysis

- Costs of each Alternative
- Net Present Values (NPV)
- Benefit Cost Ratios
  - Total
  - Delay
  - Safety

SPICE/ICE WEB ANALYSIS TOOL

Generate Report

PennDOT ICE

Life Cycle Cost Report

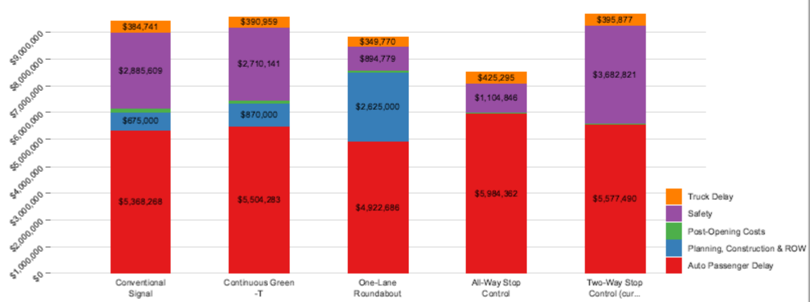
10/2/2023 - 7:35:21 AM

General Information

Project Name	Peach Street
Project Agency	PennDOT
Project Analyst	Jason Hershock
County	NORTHAMPTON
City	Test Township
Major Facility	NORTH_SOUTH
East-West Facility Name	Apple Road
North-South Facility Name	Peach Street
Evaluation Type	LIFE_CYCLE_COST
Additional Project Notes	This is a sample problem.

Net Costs

Cost of Alternatives



Intersection	[illegible]	Post-Opening Costs	Auto Passenger Delay	Truck Delay	Safety	Total Cost
Conventional Signal	$675,000	$112,183	$5,368,268	$384,741	$2,885,609	**$9,425,802**
Continuous Green-T	$870,000	$112,183	$5,504,283	$390,959	$2,710,141	**$9,587,566**
One-Lane Roundabout	$2,625,000	$36,673	$4,922,686	$349,770	$894,779	**$8,828,907**
All-Way Stop Control	$10,000	$12,097	$5,984,362	$425,295	$1,104,846	**$7,536,601**
[illegible]	$5,000	$12,097	$5,577,490	$395,877	$3,682,821	**$9,673,285**

1–5 of 5

Benefit Cost Analysis

Intersection	Auto Passenger Delay	Truck Delay	Safety	[illegible]	Net Present Value of Costs	Benefit/Cost (B/C) Ratio	Delay B/C	Safety B/(
Conventional Signal	$209,221	$11,136	$797,212	$1,017,569	$770,085	**1.32**	0.29	1.04
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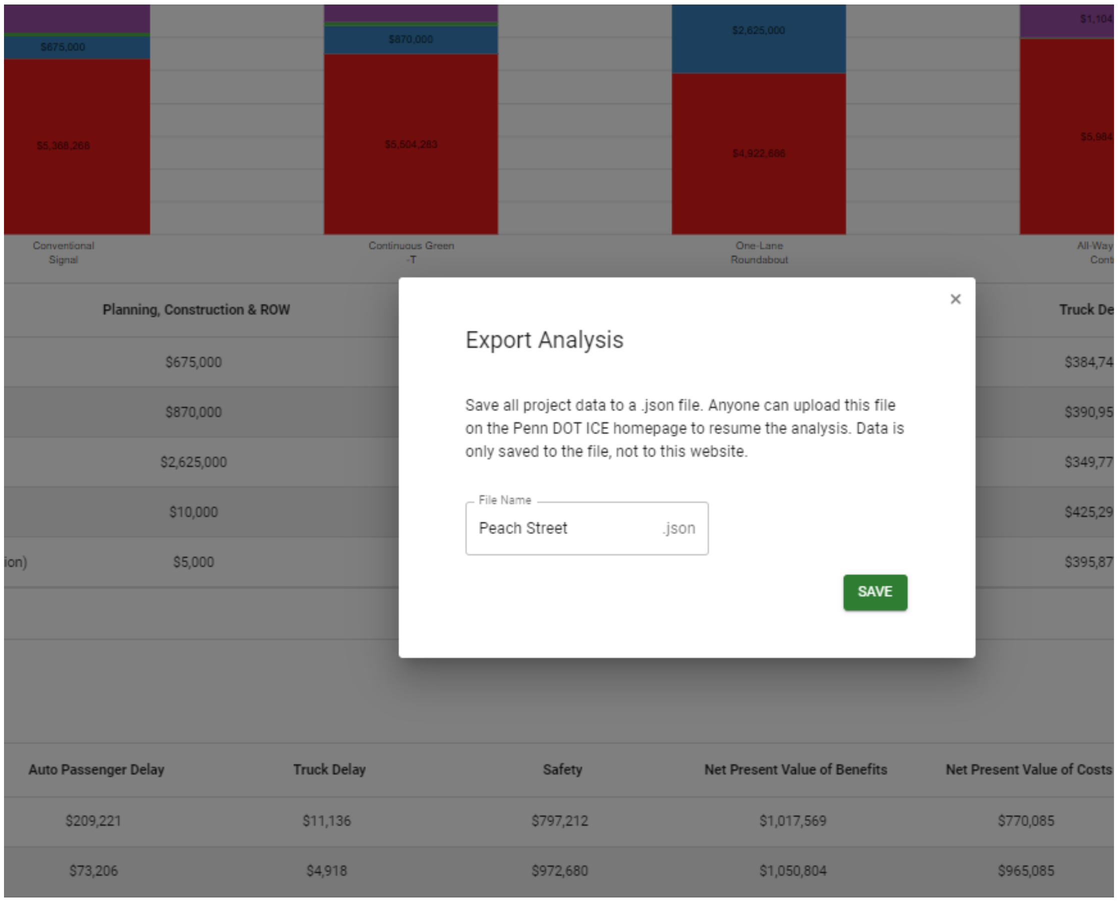
One-Lane Roundabout	$654,804	$46,108	$2,788,042	$3,488,954	$2,644,575	**1.32**	0.27	1.05
All-Way Stop Control	$ (406,873)	$ (29,418)	$2,577,975	$2,141,684	$5,000	**428.34**	Not Preferred	515.59

1–4 of 4

Default values edited

None

ICE TOOL



That's it….

- Save your file
  - Click **Export** button in bottom left corner
- Print a report
  - 2-page summary
- Create PDF summary file
  - Print to Adobe PDF

Thank you

HSM + Python = hsmpy

Challenging today.
Reinventing tomorrow.

Agenda

- Background
- hsmpy
- Why Python?
- Next Steps

Background – Current Tools

Current Tools for Comprehensive HSM Part C calculations based on AASHTO website:

- IHSDM
- HSM Spreadsheet Tools
- ISATe

PART C – Predictive Method

IHSDM
Interactive Highway Safety Design Model

The HSM Part C provides a predictive method for estimating expected average crash frequencies at individual sites. This method relies on safety performance functions (SPF) that estimate predicted average crash frequency as a function of traffic volume and roadway characteristics (e.g., number of lanes, median type, intersection control, number of approach legs). To support the use of the HSM predictive methods, FHWA has developed a freely available software program called the Interactive Highway Safety Design Model (IHSDM). IHSDM's crash prediction module (CPM) – which incorporates the latest analytical methods included in Part C including the freeway analysis supplement. It can be used to:

- Predict crash frequency for highway segments, intersections, and interchanges;
- Evaluate the safety effects of highway improvements and treatments;
- Compare relative safety performance of design alternatives; and
- Assess the safety and cost-effectiveness of design decisions.

IHSDM contains five additional modules: Design Consistency, Intersection Review, Policy Review, Traffic Analysis, and Driver/Vehicle.

- Learn More
- Download IHSDM (free)

HSM Spreadsheet Tools

In addition to IHSDM, NCHRP research studies have developed a number of spreadsheet tools which assist with the implementation of HSM Part C predictive methods. Primarily, there are spreadsheets for the rural roadways and urban arterial segments and intersections and for freeway segments and interchange elements. The non-freeway spreadsheets are named for the chapters: rural two-lane two-way roads (HSM Chapter 10), rural multilane highways (HSM Chapter 11), and urban and suburban arterials (HSM Chapter 12). The Enhanced Interchange Safety Analysis Tool (ISATe) are for freeway segments and speed-change lanes (HSM Chapter 18) and ramps and ramp terminals (HSM Chapter 19).

- Rural Two-Lane Roads Spreadsheet v3.1 (Updated July, 2020)
- Rural Multilane Highways Spreadsheet v3.1 (Updated July, 2020)
- Urban and Suburban Arterials Spreadsheet v3.2 (Updated April, 2020)
- Enhanced Interchange Safety Analysis Tool (ISATe) and User Manual

Background – More Advanced Tools

At Jacobs, we perform a lot of HSM part C calculations and for several reasons, including the following, we decided to develop our internal tool to perform predicted crash analysis:

- Easier integration with input data (GIS)
- Capable of adjusting and incorporating more complex models (HSM2)
- Easy application for larger projects (multiple sites, HSM calibration efforts)
- Ability to be incorporated in project automation.

```
[9]  rtl_seg.how()
```

```
HOW-TO
------
To perform a prediction, call the model's predict method and pass all

MODEL PARAMETERS
----------------
aadt
- range=[1.0 to 17800.0], dtype=float, enforce=warn
ase
- values={0, 1}, enforce=strict
  - Automated speed enforcement
  - 0: not present; 1: present
curve_length
- range=[0.0 to 100.0], dtype=float, enforce=strict
  - Length of the horizontal curve in miles
curve_radius
- range=[0.0 to 100000.0], dtype=float, enforce=strict
  - Radius of the horizontal curve in feet
dwy_density
- range=[0.0 to 100.0], dtype=float, enforce=warn
  - Number of driveways per mile
grade
- range=[-20.0 to 20.0], dtype=float, enforce=strict
lane_width
- range=[6.0 to 24.0], dtype=float, enforce=strict
...
- values={0, 1}, enforce=strict
  - Two-way left-turn lane
  - 0: not present; 1: present
```

What is hsmpy?

- hsmpy = HSM + Python
- hsmpy is an internal Python package that includes HSM part C calculations.
- It was first developed in 2013 as part of a HSM calibration project and has been used/modified/QCed/Appended is multiple projects since then.
- Specifically, it has been QCed against HSM and AASHTO spread sheets.
- hsmpy provides core HSM calculations which can be easily adjusted, upgraded, and used.

```python
###############
# DEFINE SPFS #
###############

model.add_layer()

def spf(aadt=None, length=None, a=None, b=None, cf=None, **kwargs):
    """
    Based on HSM Equation 10-7.
    """
    # Perform calculation
    n = a * aadt * length * 365 * 1e-6 * math.exp(b) * cf
    return n

@model.add_spf(refs={'spf':{'severity':'kabco'}})
def spf_kabco(aadt=None, length=None, **kwargs):
    return spf(aadt=aadt, length=length, **kwargs)


##############
# DEFINE AFS #
##############

@model.add_af()
def af_lane_width(lane_width=None, aadt=None, **kwargs):
    """
    Lane Width
    Based on Table 10-8, Equation 10-11.
    """
    # Compute type-specific AF
    if lane_width < 10:
        if aadt < 400:
            af = 1.05
        elif aadt > 2000:
            af = 1.50
        else:
            af = 1.05 + 2.81 * 1e-4 * (aadt - 400)
    elif lane_width < 11:
        if aadt < 400:
            af = 1.02
        elif aadt > 2000:
            af = 1.30
        else:
            af = 1.02 + 1.75 * 1e-4 * (aadt - 400)
```

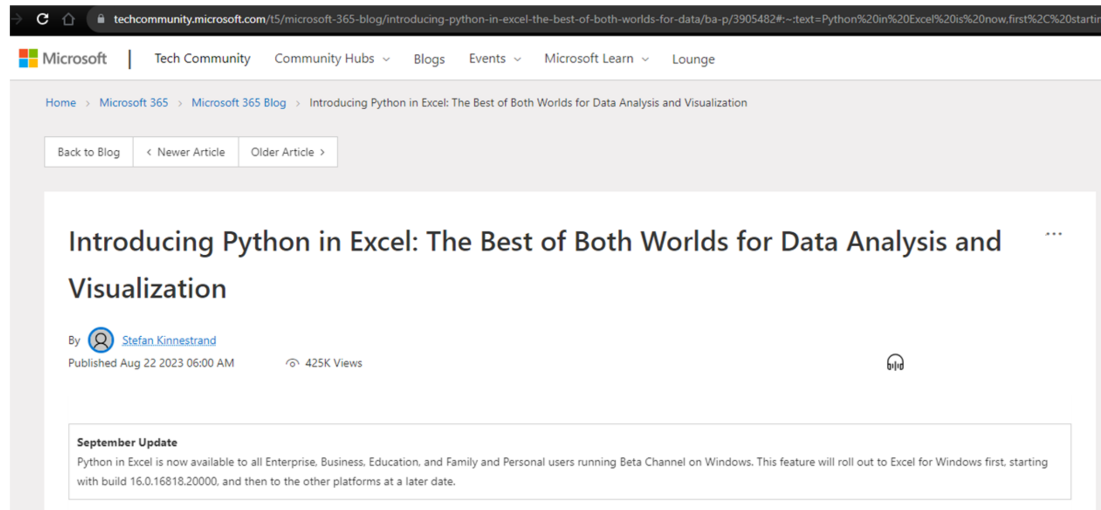
Why Python – Backend

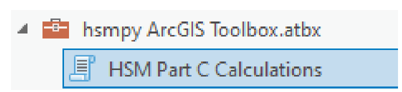
- Roadway, Intersection and Crash data are main datasets that are used for HSM calculations
- These datasets have geometry components and are usually represented in GIS format
- GIS data is usually stored/published/viewed as Esri geometry or open-source GIS solutions (shapely, geojson, etc.) which are easily accessible in Python.
- Providing a reference for HSM calculations that can be easily integrated and used by agencies, contractors, and practitioners.

Why Python – Front end (User Interface)

The hsmpy package can be used in different ways:

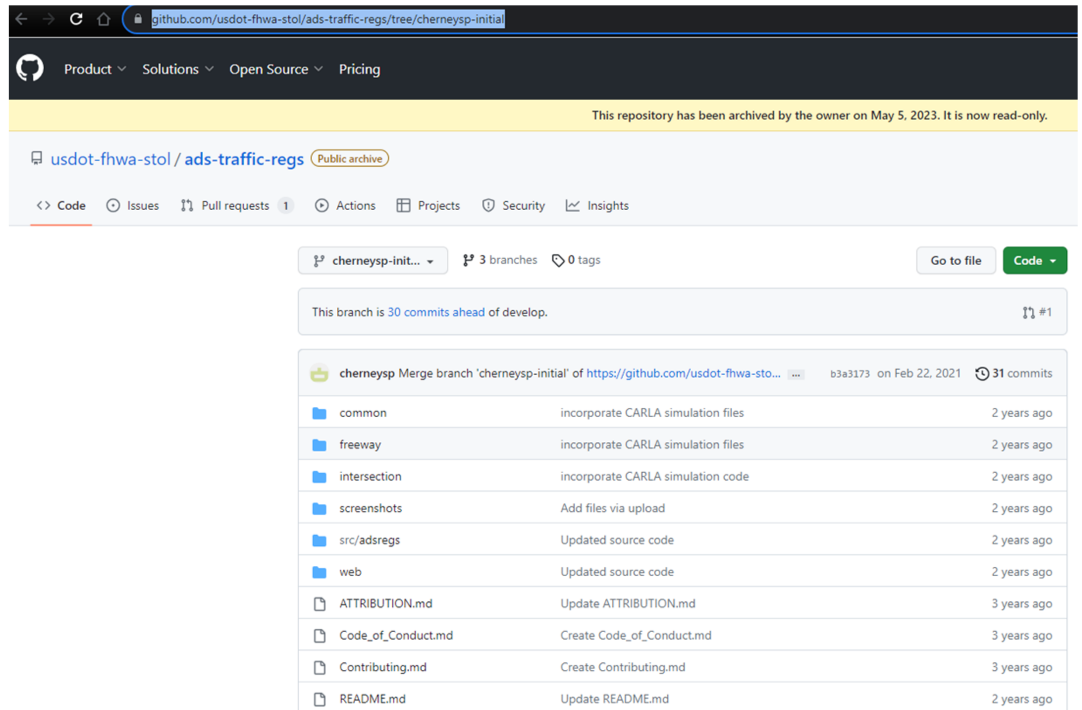
- Web-based applications
- Stand-alone applications
- Excel-Based Tools
- Esri-based Tools





Applications – Next Steps

- A Github repo for HSM
- An open-source Python version of HSM1 and HSM2
- Potentially adding sample problems and their solutions in Python format, solved using hsmpy
- Having one reference (QCed) version of HSM calculations that can be used by developers and advanced users to either perform analysis or to build easy-to-use applications for practitioners.



https://ops.fhwa.dot.gov/publications/fhwahop21040/ch1.htm
https://github.com/usdot-fhwa-stol/ads-traffic-regs/tree/cherneysp-initial

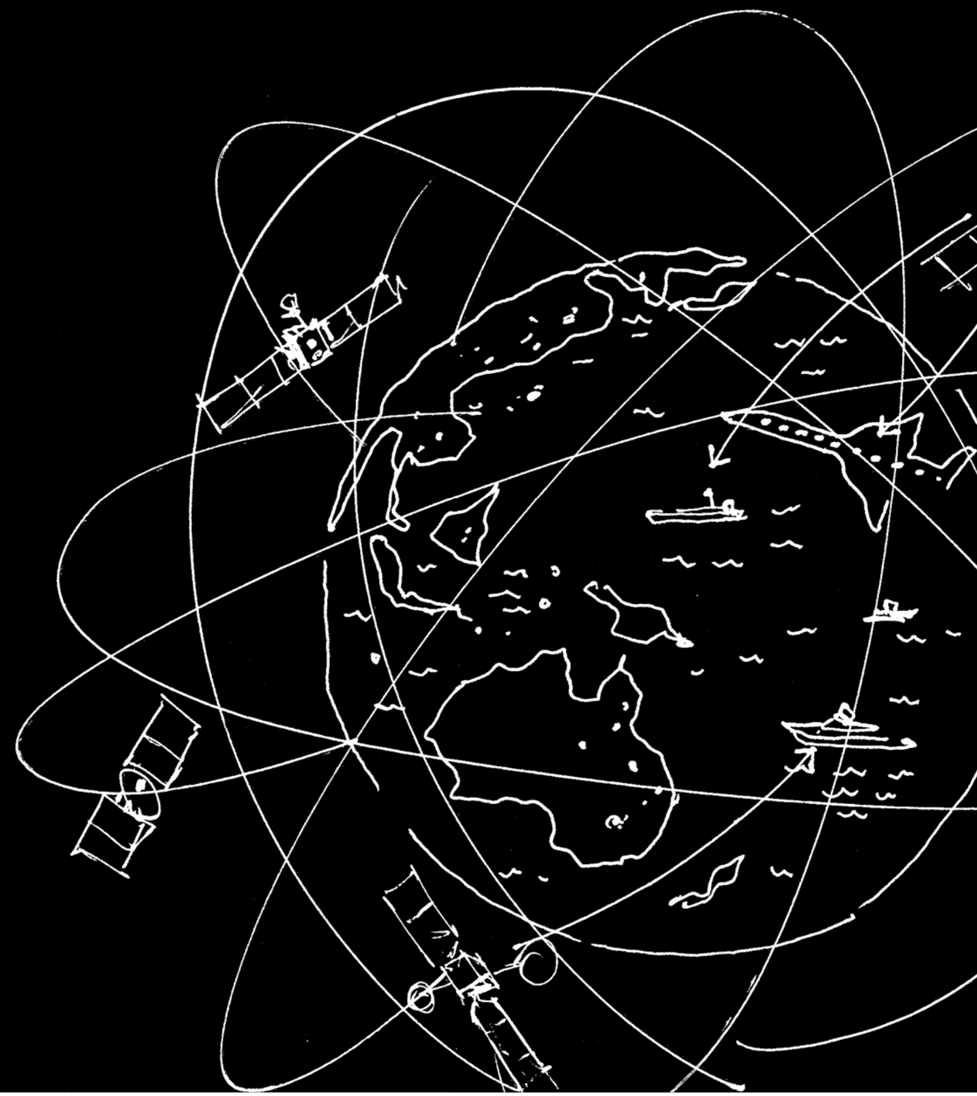
Credits - Acknowledgements

Credit to all that have contributed to develop this package:

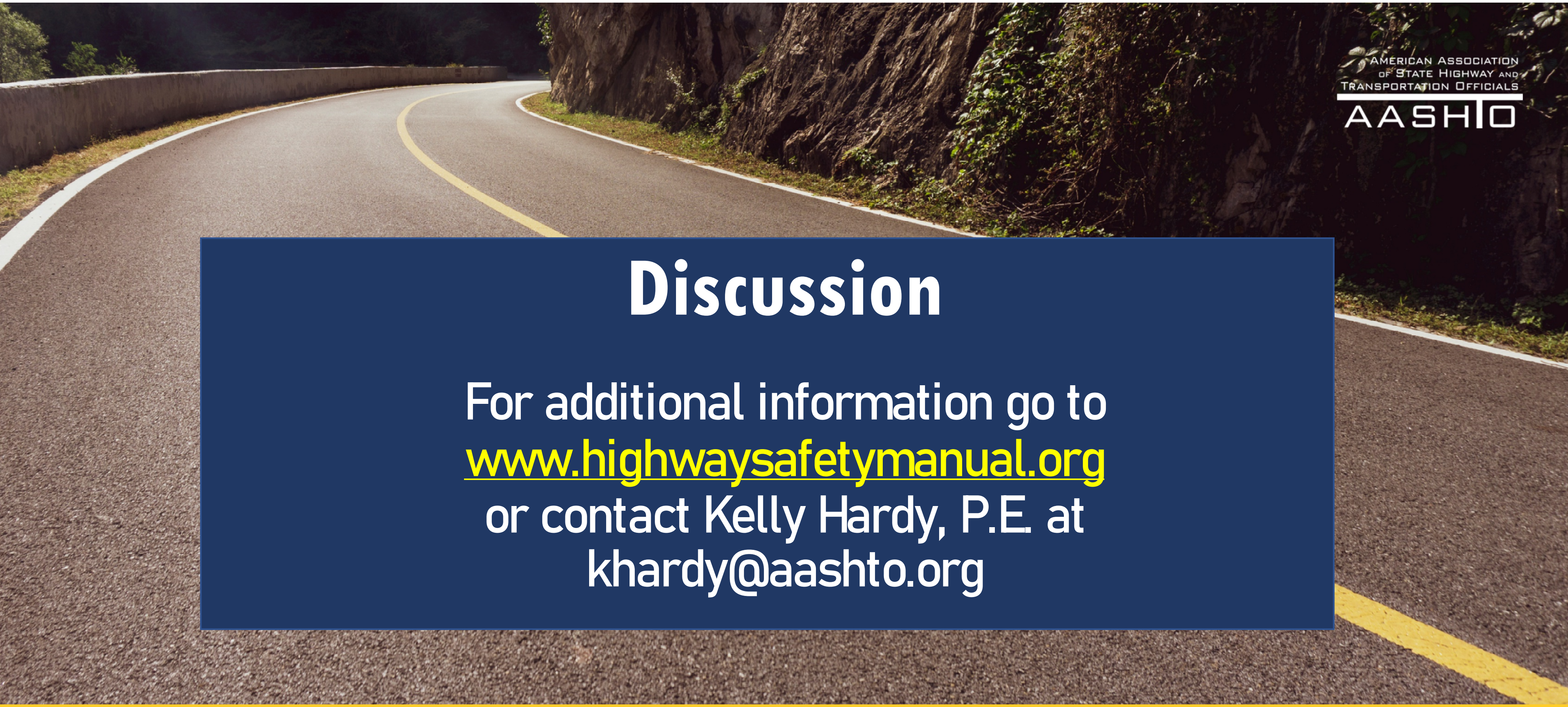
```
ACKNOWLEDGEMENTS
----------------

Model coding and validation performed by:
- Tariq Shihadah, RSP (Jacobs)
- Kyle Baumann (Jacobs)
- Minh Truong, RSP (Jacobs)
- Brianna Lawton (Jacobs)
- Mahdi Rajabi, RSP (Jacobs)
"""
```

Copyright notice

Important



Challenging today.
Reinventing tomorrow.



Discussion

For additional information go to
www.highwaysafetymanual.org
or contact Kelly Hardy, P.E. at
khardy@aashto.org