

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.

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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



ECAT OVERVIEW



Overall Process



Define Project Elements



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?

ECAT	ECAT								
Economic Crash Analysis Tool	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:

Or is crash data una	nprovements fundamentally available for the analysis co I (and not expected) analysi	ndition,	·		nction (SPF),		No
(Examples: unsignalized realignment of the roadwa	to signalized, undivided to divided, ir ay)	ncrease or decrease in th	e number of lanes, change the	number of approache	s to an intersection	on, significant	

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

ECAT O	Do the proposed improvements fundamentally change the conditions Or is crash data unavailable for the analysis condition, Or is only predicted (and not expected) analysis needed for the existin	
	(Examples: unsignalized to signalized, undivided to divided, increase or decrease in the nur realignment of the roadway)	n

If Yes, are you analyzing the existing or proposed conditions?

If Yes, are you analyzing the existing or proposed condition?

Proposed conditions?

Proposed conditions?

Proposed conditions?

Proposed

Project Elements

Project Elements	Project Elements Description Table								
					Loc	ation Information	on		
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.	

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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.	

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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 Calcula	ation For Bene	fit Cost Analysi	s
	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							
	/IF br	Countermeasure	CMF KA Value	CMF B Value	CMF C Value	CMF O Value	CMF Valid for the Following Site Types	
СМ	F 1	Increased pavement friction	Wet-Related	Wet-Related	Wet-Related	Wet-Related	1/3/4/6	
СМ	F 2	Convert intersection with minor-road stop control to modern roundabout (Rural)	0.13	0.13	0.13	0.29	2 / 10	
СМ	F 3	Install edgelines (curves) - Urban	By Crash Type	By Crash Type	By Crash Type	By Crash Type	6	
СМ	F 4	Replace Night-Time Flash with Steady Operation	Night-Related	Night-Related	Night-Related	Night-Related	7 / 10	
СМ	F 5	User Defined	Add Value	Add Value	Add Value	Add Value	Unknown	



Overall Process



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

	Load Crash Data		#VALUE!			
Observed Crash Data	from CAM Tool	Toolbox (ctrl+t)				
Location ID	ntersection ID Segment ID	Severity_5cd FreewayRelate	HYPERLINK DOC_NBR Light Condition	Crash Type Road Condition C	rash Location	Year NLFID Log
IR90N; 9.464-14.69	IR90N; 9.464-14	· ·	Crash Report 20167053236 Daylight	· · · · ·	Not An Intersection	2016 SLAKIR00090**N 10.4
IR90N; 4-9.464	IR90N; 4-9.464	K Freeway Segmer	Crash Report 20164001599 Dark - Lighted Roadwa	y Fixed Obje Dry 🛛 🛛 🕅	Not An Intersection	2016 SLAKIR00090**N 5.36
IR90; 10.486-14.69	IR90; 10.486-14	A Freeway Segmer	Crash Report 20214177497 Dark - Roadway Not Lig	g Sideswipe Dry 🛛 🔊 🛚	Not An Intersection	2021 SLAKIR00090**C 13.9
IR90N; 4-9.464	IR90N; 4-9.464	B Freeway Segmer	Crash Report 20196282799 Dark - Lighted Roadwa	Sideswipe Dry N	Not An Intersection	2019 SLAKIR00090**N 4.01
IR90; 4-10.486	IR90; 4-10.486	B Freeway Segmer	Crash Report 20157082669 Daylight	Sideswipe Dry N	Not An Intersection	2015 SLAKIR00090**C 4.69
IR90N; 4-9.464	IR90N; 4-9.464	A Freeway Segmer	Crash Report 20203052432 Daylight	Rear End Dry N	Not An Intersection	2020 SLAKIR00090**N 7.34
IR90; 10.486-14.69	IR90; 10.486-14	. K Freeway Segmer	Crash Report 20205099816 Daylight	Overturnin Dry N	Not An Intersection	2020 SLAKIR00090**C 12.4
IR90N; 4-9.464	IR90N; 4-9.464	B Freeway Segmer	Crash Report 20226257556 Dark - Lighted Roadwa	Sideswipe Dry N	Not An Intersection	2022 SLAKIR00090**N 5.28
IR90; 4-10.486	IR90; 4-10.486	K Freeway Segmer	Crash Report 20167066317 Dark - Roadway Not Lig	g Fixed Obje Dry 🛛 🛛 🛛 🛛	Not An Intersection	2016 SLAKIR00090**C 8.66
IR90N; 4-9.464	IR90N; 4-9.464	A Freeway Segmer	Crash Report 20216109596 Daylight	Angle Dry N	Not An Intersection	2021 SLAKIR00090**N 4.88
IR90N; 4-9.464	IR90N; 4-9.464	B Freeway Segmen	Crash Report 20186047671 Dark - Roadway Not Lig	g Sideswipe Dry 🛛 🔊 🛚	Not An Intersection	2018 SLAKIR00090**N 5.29
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmer	Crash Report 20134006082 Dark - Roadway Not Lig	g Parked Veł Wet 🛛 🔊 🛚	Not An Intersection	2013 SLAKIR00090**C 5.08
IR90; 4-10.486	IR90; 4-10.486	K Freeway Segmer	t Crash Report 20215222017 Dark - Roadway Not Lig	g Fixed Obje Dry 🛛 🛛 🕅	Not An Intersection	2021 SLAKIR00090**C 10.1
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmen	Crash Report 20157052577 Daylight	Other Obje Dry N	Not An Intersection	2015 SLAKIR00090**C 6.28
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmer	Crash Report 20186064675 Daylight	Fixed Obje Wet N	Not An Intersection	2018 SLAKIR00090**C 4.26
IR90N; 4-9.464	IR90N; 4-9.464	A Freeway Segmer	Crash Report 20213066982 Dawn/Dusk	Rear End Dry N	Not An Intersection	2021 SLAKIR00090**N 8.88
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmer	Crash Report 20203010870 Dark - Roadway Not Lig	g Rear End Snow 🛛 🔊	Not An Intersection	2020 SLAKIR00090**C 9.28
IR90N; 4-9.464	IR90N; 4-9.464	B Freeway Segmen	Crash Report 20174015836 Other / Unknown	Sideswipe Dry N	Not An Intersection	2017 SLAKIR00090**N 6.08
IR90; 4-10.486	IR90; 4-10.486	B Freeway Segmen	Crash Report 20147051405 Daylight	Sideswipe Dry N	Not An Intersection	2014 SLAKIR00090**C 6.97
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmen	Crash Report 20213105366 Dark - Unknown Roadv	Parked Veł Dry N	Not An Intersection	2021 SLAKIR00090**C 7.54
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmer	Crash Report 20186100366 Dark - Roadway Not Lig	g Head On Dry 🛛 🔊	Not An Intersection	2018 SLAKIR00090**C 9.74
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmer	Crash Report 20186006853 Daylight	Fixed Obje Wet N	Not An Intersection	2018 SLAKIR00090**C 4.80
IR90N; 9.464-14.69	IR90N; 9.464-14	A Freeway Segmer	Crash Report 20205039082 Dark - Lighted Roadwa	Parked Veł Snow N	Not An Intersection	2020 SLAKIR00090**N 10.7
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmer	Crash Report 20226157656 Dark - Lighted Roadwa	Fixed Obje Dry N	Not An Intersection	2022 SLAKIR00090**C 4.89
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmer	Crash Report 20193097155 Daylight	Rear End Dry N	Not An Intersection	2019 SLAKIR00090**C 9.45
IR90N; 4-9.464	IR90N; 4-9.464	A Freeway Segmer	Crash Report 20216045051 Daylight	Fixed Obje Dry N	Not An Intersection	2021 SLAKIR00090**N 6.04
IR90; 4-10.486	IR90; 4-10.486	A Freeway Segmen	Crash Report 20213224823 Dark - Roadway Not Lig	Fixed Obje Wet N	Not An Intersection	2021 SLAKIR00090**C 6.89
IR90N; 4-9.464	IR90N; 4-9.464	B Freeway Segmen	Crash Report 20186098742 Daylight	Sideswipe Dry N	Not An Intersection	2018 SLAKIR00090**N 7.14
IR90N; 9.464-14.69	IR90N; 9.464-14	C Freeway Segmer	Crash Report 20134016007 Daylight	Fixed Obje Ice N	Not An Intersection	2013 SLAKIR00090**N 10.1
IR90N; 4-9.464	IR90N; 4-9.464	A Freeway Segmen	Crash Report 20213023930 Dark - Roadway Not Lig	g Fixed Obje Wet N	Not An Intersection	2021 SLAKIR00090**N 9.45
IR90; 4-10.486	IR90; 4-10.486		Crash Report 20216067864 Dark - Lighted Roadwa		Not An Intersection	2021 SLAKIR00090**C 4.90
IR90; 4-10.486	IR90; 4-10.486	· · ·	Crash Report 20128045230 Daylight	· · ·	Not An Intersection	2012 SLAKIR00090**C 7.17

ECAT OVERVIEW

Overall Process



- 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

ECAT OVERVIEW

17

 Additionally, the analysis sheets will be formatted based on information the analyst provided on the Project Information Worksheet



Rural Two-Lane Two Way Segment Rural Two-Lane Two Way Intersection Rural Multilane Segment Rural Multilane Intersection Urban & Suburban Arterial Segment Urban & Suburban Arterial Intersection Freeway Segment Ramp Segment Ramp Terminal Intersection Roundabout One Way Arterial Segment One Way Arterial Intersection



General Information			Location Information			
Analyst			Route		#N/A	
Agency or Company			Logpoint		#N/A	
Date Performed			Common Name		#N/A	
ntersection 0			Analysis Year			
Signalized/Unsignalized #N/A						
nput Data			Ex	isting Conditions		HSM Base Conditions
ntersection type (3ST, 4ST, 4SG)						
AADT _{major} (veh/day)	AADT _{MAX} = 25,200	(veh/day)				
AADT _{minor} (veh/day)	AADT _{MAX} = 12,500	(veh/day)				
ntersection skew angle (degrees) Skew Angle Help			Skew for Leg 1 (All):			0
					•	0
						0
ntersection lighting (present/not present)						Not Present
Calibration Factor, Ci				#N/A		1.00



	General Inform	ation			Location Informat	ion
nalyst				Route	#N/A	
gency or Compa	ny			Logpoint	#N/A	
ate Performed				Common Name	#N/A	
tersection	0			Analysis Year		
ignalized/Unsign	alized Unsignalized Input Data			Existing Conditions		HSM Base Conditions
rea Type (Rural,				Existing Conditions	•	HSM base conditions
umber of Legs (3	-					
<u> </u>	Iti-lane Roundabout					
•						
otal Entering AAI	DT (ven/day)					
10.1						0
	ound Only Leg (present/not present)					Not Present
alibration Factor,	, C _i			Varies, See Below		1.00
ocality:						
	Leg 1 Entering AADT (veh/day)	AADT _{MAX} = 28,927	(veh/day)			
	Bypass lane (present/not present) - L	•				
Leg 1	Number of driveways or unsignalized	access points - Leg 1				
	Entry width (feet) - Leg 1					
	Number of entering lanes (1 lane, 2 la	anes) - Leg 1				
	Leg 2 Entering AADT (veh/day)	AADT _{MAX} = 28,927	(veh/day)			
	Bypass lane (present/not present) - I	.eg 2				
Leg 2	Number of driveways or unsignalized	access points - Leg 2				
	Entry width (feet) - Leg 2					
	Number of entering lanes (1 lane, 2 la	anes) - Leg 2				
	Leg 3 Entering AADT (veh/day)	AADT _{MAX} = 28,927	(veh/day)			
	Bypass lane (present/not present) - I	.eg 3				
Leg 3	Number of driveways or unsignalized	access points - Leg 3				
-	Entry width (feet) - Leg 3					
	Number of entering lanes (1 lane, 2 la	anes) - Leg 3				
	Leg 4 Entering AADT (veh/day)	AADT _{MAX} = N/A	(veh/day)			
	Bypass lane (present/not present) - L					
Leg 4	Number of driveways or unsignalized	•				
3 -	Entry width (feet) - Leg 4					
	Number of entering lanes (1 lane, 2 la					



Basic Roadway Data	1									
Area Type	-					Copy From:				
Segment length L (mi)					#N/A					
Cross Section Data		Cross Section	Help							
Number of through lanes	n									
Outside shoulder width V	N _s (ft)									10
Inside shoulder width Wi	_s (ft)									6
Median width W _m (ft)										60
Depressed Median?										
Posted Speed Limit PSL	. (mph)									
Lighting Present?										
Freeway Segment V										
Freeway segment AADT	, AADT _{fs} (veh/day)					(Note: this is only fo	or the one side of freeway be	ing analyzed.)		
				Allowable AADT =		to				
Ramp Access Data						Begin	Station (feet)	End Station	(Feet)	
Entrance Ramp	Distance from begin milepo		rance ramp gore X _{b,c}	_{rt} (mi)						
	Length of s-c lane in segn	nent L _{en,seg} (mi)								
Exit Ramp	Distance from end milepos		exit ramp gore X _{e.e}	_d (mi)						
	Length of s-c lane in segn	nent L _{ex,seg} (mi)								
Weave	Type of Weaving Section		Maa	ve Help						
Trouto	Type of Weaving Section		wea	venep						
Curve and Barrier C	haracteristics									
Horizontal Curve Data				Basic Freeway	S-C Entrance	S-C Exit		- Data		
	Total Curve Length (mi)		0	0	0	Add Curv	le Data		Go to Curve Details
Median Barrier Summ										
	Length of Median Barrie	er (mi)		0	0	0	Add Barr	ier Data		
Roadside Barrier Sum				0	0	0				On the Destring Date "In
	Length of Roadside Ba	rrier (mi)		U	U	0				Go to Barrier Details

Overall Process



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

ECAT Toolbox
Analysis Processing ———
Load Crash Data from CAM Tool
Assign Crashes to Project Elements Automatically
Add or Remove Analysis Worksheets
Create Project Summary Reports and Benefit Cost



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



• Crash predictions broken out by element ID

	Existing Cond	litions Project E	Element Predicte	ed Crash Summ	ary (Without Ar	nimal Crashes)					
Project Flowent ID	Commo	n Nama			Crash Severity Level						
Project Element ID	Common Name		KA B		С	0	Total				
<u>ASD-30; 3.90</u>	SR 511		0.0831	0.1706	0.1007	0.8685	1.2229				
	Existing Cond	litions Project E	Element Expecte	d Crash Summ	ary (Without An	nimal Crashes)					
Project Flowent ID	Commo	on Name		Crash Severity Level							
Project Element ID	Commo	on Name	KA	В	С	0	Total				
<u>ASD-30; 3.90</u>	SR 511		0.1341	0.2756	0.1628	1.3267	1.8992				
Exis	ting Conditions	Project Elemer	nt Potential for S	Safety Improven	nent Summary (Without Animal Cra	shes)				
Ducia et Element ID	0		Crash Severity Level								
Project Element ID	Common Name		KA	В	С	0	Total				
<u>ASD-30; 3.90</u>	SR 511		0.051	0.105	0.0621	0.4582	0.6763				
	Proposed Con	ditions Project	Element Expect	ed Crash Summ	nary (Without A	nimal Crashes)					
Ducia of Element ID	Comme	n Nama			Crash Severity Level						
Project Element ID	Commo	on Name	KA	В	С	0	Total				
	SR 511		0.0461	0.0971	0.0579	0.7153					



	Sum	mary by Crash	Туре	
		Existing		Proposed
Crash Type	Predicted Crash	Expected Crash	PSI	Expected Crash
	Frequency	Frequency	FSI	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.

Load Existing Conditions Analysis Results



Summary of Anticipated Safety Performance of the Project (average crashes/year)



Project Su	immary Results	(Without Anima	al Crashes)		
	KA	В	С	0	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



Benefit-Cost Analysis

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

	Co	unterme	easure Service I	ives, Costs, and	d Safety Benefi	its			
	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		
	Lighting	10	\$250,000.00			\$500,000.00	\$620,061.07	5 570	és 200.000
	Site Characteristic Improvements (Please add description about improvements i.e. Signal Phasing)					\$0.00	\$0.00	-5.579	\$5,398,996
	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
)						<u>Å0.00</u>	Å0.00	0.000	Á0



Benefit-Cost Analysis

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

	Be	enefit - Co	ost Calcula	tor		
	Net Prese	nt Value (of Project	\$3,224,	108.00	
Net Pres	ent Value	of Safety	/ Benefits	\$5,398,	995.96	
		Ne	et Benefit	\$2,174,	887.96	
	B	enefit / C	Cost Ratio	1.	67	

Expected /	Annual	Crash Adjustment	
Number of Fatal & Incapao Injury C	citating Crashes	-0.527	
Number of Injury C	Crashes	-2.537	
Number of Total C	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
			0.00	
Three-Lane With Center Two-Way Left-Turn Lanes Segments	3T	0.63		0.67
	3T 4D	0.63 0.93	0.51	
Three-Lane With Center Two-Way Left-Turn Lanes Segments			0.51 0.77	0.99
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments	4D	0.93	0.51 0.77 0.19	0.99 0.27
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments	4D 4U	0.93 0.24	0.51 0.77 0.19	0.99 0.27 0.38
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments	4D 4U 5T	0.93 0.24 0.38	0.51 0.77 0.19 0.37	0.99 0.27 0.38
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments Two-Lane One-Way Segments	4D 4U 5T 20	0.93 0.24 0.38 1.00	0.51 0.77 0.19 0.37 1.00	0.99 0.27 0.38 1.00 1.00
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments Two-Lane One-Way Segments Three-Lane One-Way Segments	4D 4U 5T 20 30	0.93 0.24 0.38 1.00 1.00	0.51 0.77 0.19 0.37 1.00 1.00	0.99 0.27 0.38 1.00 1.00
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments Two-Lane One-Way Segments Three-Lane One-Way Segments Four-Lane One-Way Segments	4D 4U 5T 20 30	0.93 0.24 0.38 1.00 1.00 1.00	0.51 0.77 0.19 0.37 1.00 1.00 1.00 Fl	0.99 0.27 0.38 1.00 1.00 1.00
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments Two-Lane One-Way Segments Three-Lane One-Way Segments Four-Lane One-Way Segments Urban & Suburban Arterial Highways - Intersections	4D 4U 5T 2O 30 40	0.93 0.24 0.38 1.00 1.00 1.00 Total	0.51 0.77 0.19 0.37 1.00 1.00 1.00 Fl	0.99 0.27 0.38 1.00 1.00 PDO 0.78
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments Two-Lane One-Way Segments Three-Lane One-Way Segments Four-Lane One-Way Segments Urban & Suburban Arterial Highways - Intersections Three-Leg Minor Stop-Controlled Intersection	4D 4U 5T 20 30 40 3ST	0.93 0.24 0.38 1.00 1.00 1.00 Total 0.69	0.51 0.77 0.19 0.37 1.00 1.00 1.00 Fl 0.53	0.99 0.27 0.38 1.00 1.00 PDO 0.78 1.00
Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments Two-Lane One-Way Segments Three-Lane One-Way Segments Four-Lane One-Way Segments Urban & Suburban Arterial Highways - Intersections Three-Leg Minor Stop-Controlled Intersection (High Speed)	4D 4U 5T 2O 30 40 3ST 3ST (HS)	0.93 0.24 0.38 1.00 1.00 1.00 Total 0.69 1.00	0.51 0.77 0.19 0.37 1.00 1.00 1.00 Fl 0.53 1.00	0.99 0.27 0.38 1.00 1.00 PDO 0.78 1.00 1.00

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

<u>Pros</u>

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

<u>Cons</u>

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





Brenton Bogard

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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

Connect NCDOT business partner resources								
Doing Business	Bidding & Let	Projec	ts	<u>Resources</u>	Local Go			
Asset Management	Environmental	Geot	echnical	GIS	Hydraulics	Materials &		

Safety Planning Resources

Resources and tools for conducting predictive safety analysis

♠ ► Connect NCDOT ► Resources ► Traffic Safety ► Safety Planning Resources

Crash Modification Factors / Crash Reduction Factors

NCDOT maintains a list of the crash reduction factors that are to be used for all si submittals statewide. The list is updated regularly and reflects information from th Modifications Factors Clearinghouse as well as the results of safety evaluations the conducted by NCDOT staff.

NCDOT Crash Reduction Factors

Predictive Analysis Spreadsheets

NCDOT uses spreadsheet tools that have been developed by national research p in conjunction with the Highway Safety Manual to implement safety performance t

Rural two-lane roads

- Spreadsheet
- Research report

Rural multilane roads

- Spreadsheet
- Research report (login required)

Urban and suburban arterials

- Spreadsheet
- Desearch report (login required

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.

ncdot.gov

Example: R-4045

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

No Build Minor road stopcontrolled

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

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.



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)

Freeway & Ramps HSM Analysis

ISATe (PA Calibrated) (EXCEL)
PennDOT SPF Collision Type &
Severity Tables
Rural 4-Lane Divided-Undivided

<u>Hwys</u> (PDF) <u>Rural Two-Lane Hwys</u> (PDF)

<u>Urban-Suburban Arterial</u> <u>Hwys</u> (PDF)

Benefit Cost Analysis (BCA) Tool Safety BCA Tool (PA Adjusted

Costs) (EXCEL) <u>FHWA's Countermeasure Service</u> 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

 <u>https://www.penndot.pa.gov/Travel</u> <u>InPA/Safety/Pages/Safety-</u> <u>Infrastructure-Improvement-</u> <u>Programs.aspx</u>

OUR NEW ICE WEB TOOL

Planning of Junctic



OUR NEW ICE WEB TOOL

PennDOT ICE



This web tool provides life cycle cost comparisons between different intersection treatments. The tool incorporates the following costs: safety, vehicular delay, operations and maintenance, design and construction, and right-of-way.







Opening Screen

- Includes Capacity Analysis
- Safety Benefit Cost Analysis
- Can start <u>new</u> or <u>upload</u> previous analysis

E PennDOT ICE				Enter Project
Project Information Identifying information for the project	٦			Information
Project Name Peach Street Agency or Organization PennDOT Analyst Name Jason Hershock Evaluation type CAP-X Web C Life Cycle Co Additional Notes This is a sample problem.	County Northampton Municipality Test Township	Orientation of major street C East-West C North-South E-W Facility Name Apple Road N-S Facility Name Peach Street		 Select Capacity analysis or Combined capacity & safety analy (Life Cycle)
EXPORT ANALYSIS			BACK	EXT



safety analysis

😑 🏾 🗑 PennDOT I	CE			A State
✓ Project Information	Global Input Data			• <u>Global Input</u> Data
 2 Global Input Data 3 Traffic Volumes 4 Design Selection 5 Delay 6 Cost Parameters 7 Global Safety Data 8 Safety 9 Outputs 	Opening Year 2030 Analysis Type 2030 Analysis Type At Grade Intersection Ramp Terminal Intersection Ramp Terminal Intersection Facility Type Tural Major Collector Number of Legs 3-leg intersection Current Intersection Intersection Two-Way Stop Control Image: Control Contro	Relevant peak periods Image: Start		 Analysis years Peak periods Analysis type Facility type Peak hours Number of legs Traffic Control
	EXPORT ANALYSIS		BACK	



Enter Traffic Volumes

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



😑 🍟 PennDOT	ICE					AV COST	
✓ Project Information	Design Selection						Design Selection
Global Input Data	Choose which intersections will be part of the analys	sis					 Select
Traffic Volumes							intersection
4 Design Selection	+ ADD DESIGN ALTERNATIVE(S)	Project Analysis	Configurations	• •		× CLEAR	configuration
	Select design alternatives to include in the analysis	#	Туре	Name			-
5 Delay	using the button above. Multiple design variations of the same intersection type can be analyzed, allowing for simultaneous analysis of different:	1	Two-Way Stop Control	Two-Way Stop Control (current intersection)			options
6 Cost Parameters	turn lane configurations						Defaults to current
7 Global Safety Data	 shared movements channelized movements other intersection specific options 						intersection type
8 Safety							
9 Outputs							
	EXPORT ANALYSIS				BACK	NEXT	

	Add Inte	ersections	and Inte	rchanges		
Global Inpu	Select on	e or more int	ersection o	r interchange types from the table below.		
		#		Туре	Current 😨	Add 🔞
Traffic Volu				Signalized Intersections		
		1	+	Conventional Signal	0	
Design Sele		2	T	Continuous Green-T	0	
		3	ቴ	Displaced left turn	0	
Delay		4	+	Jughandle	0	
		5	5	Median U-turn	0	
Cost Paran		б	D	Quadrant Roadway	0	
		7	`م	Restricted Crossing U-turn - Signalized	0	
Global Safe				Unsignalized Intersections		
		8	O	One-Lane Roundabout	0	
Safety		9	0	Two-Lane Roundabout	0	
		10	+	All-Way Stop Control	0	
Outputs		11	+	Two-Way Stop Control	1	
		12	آ ہے۔	Restricted Crossing U-turn - Unsignalized	0	
				Other		
		13	+	Other	0	

Design Selection

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

SPICE/ICE WEB ANALYSIS TOOL PennDOT ICE

			rchanges	
Select on	e or more int	ersection o	or interchange types from the table below.	
	#		Туре	Current 😰
			Signalized Intersections	
\checkmark	1	-	Conventional Signal	0
\checkmark	2	T	Continuous Green-T	0
	3	ጜ	Displaced left turn	0
	4	+	Jughandle	0
	5	ک	Median U-turn	0
	б		Quadrant Roadway	0
	7	آھے۔	Restricted Crossing U-turn - Signalized	0
			Unsignalized Intersections	
\checkmark	8	0	One-Lane Roundabout	0
	9	0	Two-Lane Roundabout	0
\checkmark	10	+	All-Way Stop Control	0
	11	+	Two-Way Stop Control	1
	12	`مے	Restricted Crossing U-turn - Unsignalized	0
			Other	
	13	+	Other	0

Design Selection

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

Project Information	Design Selection						 Options selected
Global Input Data	Choose which intersections will be part of the analys	is					Move onto delay
Traffic Volumes							analysis
4 Design Selection	+ ADD DESIGN ALTERNATIVE(S)	Project Ana	lysis Configurations 🛛			× CLEAR	
	Select design alternatives to include in the analysis	#	Туре	Name			
5 Delay	using the button above. Multiple design variations of the same intersection type can be analyzed,	1		Conventional Signal	Ľ	Ū	
6 Cost Parameters	allowing for simultaneous analysis of different:	2		Continuous Green-T	Ľ	ŵ	
	 turn lane configurations shared movements 	3	One-Lane Roundabout	One-Lane Roundabout	C	Ē	
7 Global Safety Data	 channelized movements other intersection specific options 	4	All-Way Stop Control	All-Way Stop Control	Ľ	Ē	
8 Safety	- other intersection specific options	5	Two-Way Stop Control	Two-Way Stop Control (current intersection)			
9 Outputs							
	EXPORT ANALYSIS				ВАСК	NEXT	



oject Information	Delay					
lobal Input Data	Enter average vehicle delay for ea	ch of the interse	ctions			
raffic Volumes			· · · · · · · · · · · · · · · · · · ·	ning Year Vehicle Delay		sign Year 9 Vehicle Delay
Design Selection	Control Strategy	Units	AM Peak	PM Peak	AM Peak	PM Peak
Delay	Conventional Signal	sec/vehicle	22.5	42.0	23	43
Cost Parameters	Continuous Green-T	sec/vehicle	16	29.5	17.5	30.5
Global Safety Data	One-Lane Roundabout	sec/vehicle	15	26	16	28
Global Salety Data	All-Way Stop Control	sec/vehicle	19	31	20	34
Safety	Two-Way Stop Control (current intersection)	sec/vehicle	16	28.2	17	29
Outputs	Where should I find my delay da Delay should be determined usi Publication 46 or with the NCHF It is recognized that analysis of nodes is challenging with conve planning-level delay values from	ng PennDOT-app RP Project 17-98 innovative inters entional traffic ar	PPEAG ICE Spreadsheet sections consisting of me nalysis software and the	Tool.		

- Enter <u>delay</u> for each design option
- Help window at the bottom

♦ Project Information Cost Parameters Edit time & crashes costs	eters					
	c					
✓ Global Input Data Edit operations & maintenance costs ■ Enter cost estimates for each intersection alternative						
Intersection Design Costs Construction Costs Mitigation Costs @	1					
• Design						
Conventional Signal S 100000 S 550,000 S 550,000 S 25000 S 25000 Construct	tion					
	_					
Continuous Green-T \$ 140000 \$ 700000 \$ 30000 • Mitigation]					
6 Cost Parameters § 140,000 \$ 700,000 \$ 30,000 • Cost check	shown					
Image: Constant of the second about \$ 250000 \$ 75000 Image: Constant of the second about \$ 250000 \$ 75000						
	, area					
Safety All-Way Stop Control \$ 5000 \$ 5000 \$ 0	-					
Outputs Image: Outputs Image: S 5,000 Image: S 5,000 Image: S 5,000	or					
Two-Way Stop Control (current \$ 0 \$ 5 \$ 0 Construction)	on costs					
Minimum: 5,000						
BACK NEXT						
📃 🎆 PennDOT	ICE				AV-LIVELU	
----------------------	--	--------------------------------	-----------------------------------	------------------------------	-------------------------------------	---
Project Information	Cost Parameters	3			Edit time & crashes costs	Cost Parameters
Global Input Data	Enter cost estimates for each inter				Edit operations & maintenance costs	Enter costs for
Traffic Volumes	Intersection	Design Costs	Construction Costs	Mitigation Costs 👔		each option
Design Selection	Conventional Signal	\$ 100000 \$ 100,000	\$ 550000	\$ 25000 \$ 25,000		DesignConstruction
Oelay	Continuous Green-T	\$ 140000	\$ 700000	\$ 30000		 Mitigation
6 Cost Parameters	Continuous Green-1	\$ 140,000	\$ 700,000	\$ 30,000		Notice the \$5K
7 Global Safety Data	One-Lane Roundabout	\$ 250000 \$ 250,000	\$ 2300000 \$ 2,300,000	\$ 75000 \$ 75,000		minimum for
8 Safety	All-Way Stop Control	\$ 5000	\$ 5000	\$ 0		Construction costs
9 Outputs		\$ 5,000	\$ 5,000			
	Two-Way Stop Control (current intersection)	\$ 0	\$ 5000 \$ 5,000	\$ 0		
	EXPORT ANALYSIS				BACK NEXT	

roject Information	Global Safet	y Data
lobal Input Data	Data used for all safety ca	Iculations regardless of intersection types being
raffic Volumes	Facility Type Urban-Suburban Collect	or 💌
esign Selection	Major road	Minor road
	Opening Year AADT	Opening Year AADT
elay	21190	7404
	21,190	7,404
Cost Parameters	- Design Year AADT	Design Year AADT
	23000	7600
Global Safety Data	23,000	7,600
Safety	Intersection Site Crash Da	ta
	- Fatal and Injury Crashes	
Outputs	5.6	13.8

Global Safety Data

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

 Project Information Global Input Data 	Safety Enter safety information for each intersection being analyzed	Safety Analysis Summary
Traffic Volumes Design Selection Delay	Conventional Signal Crash Modification Factors	Review each design option
Cost Parameters	Fatal and Injury crashes 0.78 Total crashes 0.84	Enter speed limit for
Safety Outputs	Continuous Green-T	major road
	Crash Modification Factors Fatal and Injury crashes 0.73 Total crashes 0.83	
	One-Lane Roundabout	
	Area typeRural	
	Crash Modification Factors Fatal and Injury crashes 0.22 Total crashes 0.22 Total crashes 0.22	

	CE						
Project Information Global Input Data	All-Way Stop Control						<u>Safety Analysis</u> Summary
Traffic Volumes Design Selection	Crash Modification Factors Fatal and Injury crashes 0.3				SPF Us	ed by CMF	Review each
Oelay	Total crashes 0.3	8			Two-Way Stop Contr	ol (current intersection)	design option
Cost Parameters Global Safety Data	Two-Way Stop Control (current intersection)				Two-Way Stop Contr	ol (current intersection)	 Crosswalks?
Safety	Major Road Speed Limit				Two-Way Stop Contr	ol (current intersection)	 Enter posted
Uniputs	Outputs I Major road crosswalk 40 mph				Two-Way Stop Contr	ol (current intersection)	speed limit for
	Crashes Per Year					-	major road
	Intersection	Opening Fatal and Injury	Year Total	Des Fatal and Injury	ign Year Total	SPF Used by CMF	
	Conventional Signal	0.86	2.14	0.86	2.14	Two-Way Stop Control (current intersection)	
	Continuous Green-T	0.80	2.11	0.81	2.12	Two-Way Stop Control (current intersection)	
	One-Lane Roundabout	0.24	1.55	0.24	1.56	Two-Way Stop Control (current intersection)	
	All-Way Stop Control	0.33	0.76	0.33	0.77	Two-Way Stop Control (current intersection)	
	Two-Way Stop Control (current intersection)	1.10	2.55	1.11	2.55	-	
						1-5 of 5 < >	
	EXPORT ANALYSIS					BACK NEXT	

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Safety Defaults

EXPORT ANALYSIS

Allows override of default crash modification factors for selected intersections

	Crash Severity	Override Value	Clearinghouse ID / Notes
Conventional Signal	Fatal and Injury		
Conventional Signal	Total		
Continuous Green-T	Fatal and Injury		
Continuous Green-1	Total		
One-Lane Roundabout	Fatal and Injury		
one-carle Roundabout	Total		
All-Way Stop Control	Fatal and Injury		
All-way stop control	Total		
Two-Way Stop Control		Uses safety performance function (SPF)	

<u>Safety Analysis</u> <u>Summary</u>

AV EXE

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

CANCEL



Continuous Green-T

One-Lane Roundabout

All-Way Stop Control

EXPORT ANALYSIS

\$73,206

\$654,804

\$ (406,873)

Output - Benefit **Cost Analysis**

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

1.01

1.05

515.59

GENERATE REPOR

- Delay ٠
- · Safety

\$ (29,418)	\$2,577,975	\$2,141,684	\$5,000	428.34	Not Preferred 🕢	
\$ (29,418)	\$2,577,975	\$2,141,684	\$5,000	428.34	Not Preferred 🔞	
\$46,108	\$2,788,042	\$3,488,954	\$2,644,575	1.32	0.27	
\$4,918	\$972,680	\$1,050,804	\$965,085	1.09	0.08	

V COST

PennDOT ICE Generate Life Cycle Cost Report 10/2/2023 - 7:35:21 AM Report 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 5.368.2 One-Lane Roundabout All-Way Stop Control Conventional Signal Cantinuous Green -T

Intersection		Post-Öpening Costs	Auto Passenger Delay	Truck Dellay	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
Öne-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
المنظومين ا المنظومين المنظومين ال	\$5,000	\$12,097	\$5,577,490	\$395,877	\$3,682,821	\$9,673,285
					1-50	f5 < >

Benefit Cost Analysis

Intersection	Auto Passenger Delay	Truck Dellay	Safety	na n	Net Present Value of Costs	Benefit/Cost (B/Č) Ratio	Dellay B/Ĉ	Safety B/
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
							1-4 of 4	< >

Default values edited

None

Truck Delay Safety Post-Opening Costs Planning Construction

Two-Way Stop Control (cur...

ICE TOOL

\$675,000		\$870,000		\$2,625,000		\$1,104
\$5,368,268		\$5,604,283		54.922.606		55,984
Conventional Signal		Continuous Green -T		One-Lane Roundabout		All-Way Cont
Plannir	ng, Construction & ROW				×	Truck De
	\$675,000	Ex	port Analysis			\$384,74
	\$870,000			n file. Anyone can upload thi ge to resume the analysis. E		\$390,95
	\$2,625,000		saved to the file, not to th			\$349,77
	\$10,000		e Name	son		\$425,29
ion)	\$5,000				SAVE	\$395,87
Auto Passenger De	lay Truc	k Delay	Safety	Net Present Value of Ben	fits Net Presen	t Value of Costs
\$209,221	\$1	1,136	\$797,212	\$1,017,569	\$7	70,085
\$73,206	\$4	1,918	\$972,680	\$1,050,804	\$9	65,085

That's it....

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

PENNDOT WEB-BASED ICE TOOL

Thank you





Challenging today. Reinventing tomorrow.

HSM + Python = hsmpy

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



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)

	General Information		Location Information	
knalyd Ngency or Company Date Pertanned	(antikr name) (antikr agency) (antikr date)	Reading Histocheri Andyna Year	(infer nachosy name) (infer infersionities name) (infer (united train) 2016	
	Input Data	Base Conditions	Site Conditions	
tersector type (257. 437. 495)			MT	
(white)	AADT_mix = 19:500 (with day)			
MOTerr (retrize)	AADToxx = 4.500 (vehicity)			
tiersection skew angle (degrees) [1	437, does skew differ for minor legiting		Same for Leg 1 (Al)	
	prosectives with a left-have lana (D. 1, 2, 5, 4)	- 0		
	proteches with a right-turn later (0. 1. 2. 3. 4)	0	and the second	
denotion lighting general religious	6	Hut Present	NJ Present	
Calibration Factor ().		1.00	1.00	

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.

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

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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.

```
89
      90
      # DEFINE SPFS #
 91
      92
 93
      model.add_layer()
 94
 95
      def spf(aadt=None, length=None, a=None, b=None, cf=None, **kwargs):
 96
 97
          Based on HSM Equation 10-7.
 98
 99
          # Perform calculation
          n = a * aadt * length * 365 * 1e-6 * math.exp(b) * cf
100
101
          return n
102
103
      @model.add spf(refs={'spf':{'severity':'kabco'}})
      def spf_kabco(aadt=None, length=None, **kwargs):
104
          return spf(aadt=aadt, length=length, **kwargs)
105
106
107
108
      ************
109
      # DEETNE AES #
110
      111
112
      @model.add_af()
113
      def af_lane_width(lane_width=None, aadt=None, **kwargs):
114
115
          Lane Width
116
          Based on Table 10-8, Equation 10-11.
117
          .....
118
          # Compute type-specific AF
119
          if lane_width < 10:
120
              if aadt < 400:
121
                  af = 1.05
122
              elif aadt > 2000:
123
                  af = 1.50
124
              else:
125
                  af = 1.05 + 2.81 * 1e-4 * (aadt - 400)
126
          elif lane_width < 11:
127
              if aadt < 400:
128
                  af = 1.02
129
              elif aadt > 2000:
130
                  af = 1.30
131
              else:
132
                  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

7



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.

C 🗅 🗎 github.com/usdot-fhwa-stol	l/ads-traffic-regs/tree/cherneysp-initial		
roduct × Solutions × Open Sourc	e ∨ Pricing		
		This repository has been archived by the owner on May 5,	2023. It is now read-only.
dot-fhwa-stol / ads-traffic-regs	S Public archive		
de 🕑 Issues 👔 Pull requests 🚺	⊙ Actions ☐ Projects ① Security	∠ Insights	
	^{₽,9} cherneysp-init ▼ ^{₽,9} 3 branches	𝕎 0 tags	Go to file Code -
	This branch is 30 commits ahead of develop.		۱ #۱
	👌 cherneysp Merge branch 'cherneysp-init	ial' of https://github.com/usdot-fhwa-sto	22, 2021 31 commits
	Common	incorporate CARLA simulation files	2 years ago
	freeway	incorporate CARLA simulation files	2 years ago
	intersection	incorporate CARLA simulation code	2 years ago
	screenshots	Add files via upload	2 years ago
	src/adsregs	Updated source code	2 years ago
	🖿 web	Updated source code	2 years ago
	ATTRIBUTION.md	Update ATTRIBUTION.md	3 years ago
	Code_of_Conduct.md	Create Code_of_Conduct.md	3 years ago
	Contributing.md	Create Contributing.md	3 years ago
	README.md	Update README.md	2 years ago

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

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Credits - Acknowledgements

Credit to all that have contributed to develop this package:

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- Tariq Shihadah, RSP (Jacobs)
- Kyle Baumann (Jacobs)
- Minh Truong, RSP (Jacobs)
- Brianna Lawton (Jacobs)
- Mahdi Rajabi, RSP (Jacobs)

.....



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