

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	Project Information								
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:

Do the proposed in Or is crash data un Or is only predicted		Νο					
(Examples: unsignalized realignment of the roadwa	to signalized, undivided to divided, ay)	, increase or decrease in the	e number of lanes, change the n	number of approaches	to an intersection	n, significant	

Do the proposed improvements fundamentally change the condit 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)		
	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 existing	s n
	(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 Description Table											
					Loc	ation Informatio	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.			

Project Elements

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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; 14.24	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		
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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					



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

1	Load Crach Data		#VALUE!				
Observed Crash Data	from CAM Tool	Toolly our (stalet)					
						o 1.1	Y 11515
Location ID	ntersection ID Segment ID	Severity_5cd FreewayRelated	HYPERLINK DOC_NBR	Light Condition	Crash Type Road Condition	n Crash Location	Year NLFID Log
IR90N; 9.464-14.69	IR90N; 9.464-14	A Freeway Segment	Crash Report 2016/053236	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 202141/7497	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 2015/082669	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 Veł 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 Roadv	Parked Veł 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 Veł 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

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

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 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



Ę		_	Existing Condi	itions: Gen	eral Informatio	on and Data f	or Rural Two	o-Lane Two-	Way Intersection	on
Ĭ	General Information						nation			
ŭ	Analyst			Route			#N/A			
0	Agency or Company					Logpoint			#N/A	
2	Date Performed					Common Name			#N/A	
S	Intersection 0				Analysis Year					
o	Signalized/Unsignalized #N/A									
i i i	Input Data			Existing Conditions			HSM Base Conditions			
ŭ	Intersection type (3ST, 4ST, 4SG)									
ບັ	AADT _{major} (veh/day)		AADT _{MAX} =	25,200	(veh/day)				-	
କ	AADT _{minor} (veh/day)		AADT _{MAX} =	12,500	(veh/day)					-
5	Intersection skew angle (degrees)					Skew for Leg				0
פ	Skew Angle Help					1 (All):				Ŭ
ar										0
ដ										0
oje	Intersection lighting (present/not pres	ent)							Not Present	
L.	Calibration Factor, Ci					#N/A			1.00	
_	Locality:									



	Existing Conditions: General Information and Data for Roundabout Intersection										
	General Inform	ation				Location Informat	ion				
Analyst					Route	#N/A					
Agency or Compan	у				Logpoint	#N/A					
Date Performed	0				Common Name	#N/A					
Intersection Signalized/Unsigna	U lized				Analysis Year						
Signalized/Onsigna	Input Data	1			Existing Conditions		HSM Base Conditions				
Area Type (Rural, U	Jrban)				Entrang contantono						
Number of Legs (3	or 4)										
Single-Lane or Mult	i-lane Roundabout										
Total Entering AAD	T (veh/day)										
							0				
Presence of Outbou	und Only Leg (present/not present)						Not Present				
Calibration Factor,	Ci				Varies, See Below		1.00				
Locality:							-				
	Leg 1 Entering AADT (veh/day)	AADT _{MAX} =	28,927	(veh/day)			-				
	Bypass lane (present/not present) - L	.eg 1									
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) - L	.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) - l	.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 lanes) - Leg 3					-						
	Leg 4 Entering AADT (veh/day)	AADT _{MAX} =	N/A	(veh/day)			-				
	Bypass lane (present/not present) - L	.eg 4					-				
Leg 4	Number of driveways or unsignalized	access points	- Leg 4				-				
	Entry width (feet) - Leg 4						-				
	Number of entering lanes (1 lane, 2 la	anes) - Leg 4									



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	olume Data									
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	ost to upstream ent	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	st to downstream	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							
TTCurc .	Type of Weaving Section		wea	venep						
Curve and Barrier C	haracteristics									
Horizontal Curve Data	1			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	ary									
	Length of Median Barrie	er (mi)		0	0	0	Add Barr	ier Data		
Roadside Barrier Sum	nmary			0	0	0				On the Destring Date "In
	Length of Roadside Ba	rrier (mi)		U	U	U				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)				
Brainet Floment ID	Common Name		Crash Severity Level							
Project Element ID			KA B		C O		Total			
<u>ASD-30; 3.90</u>	SR 511		0.0831	0.1706	0.1007	0.8685	1.2229			
	Existing Conc	litions Project E	Element Expecte	ed Crash Summ	ary (Without Ar	nimal Crashes)				
Ducio et Element ID				Crash Severity Level						
Project Element ID Comr	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 \$	Safety Improver	ment Summary	Without Animal Cra	ishes)			
Brainet Floment ID	Commo	n Nomo	Crash Severity Level							
Project Element ID	Commo	on 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 Sumn	nary (Without A	nimal Crashes)				
Broiget Flowent ID	Commo	n Nama			Crash Severity Level					
Project Element ID	Commo	JII Manie	KA	В	С	0	Total			
ASD-30; 3.90	SR 511		0.0461	0.0971	0.0579	0.7153	0.9164			



	Sum	mary by Crash	Туре	
		Existing		Proposed
Crash Type	Predicted Crash	Expected Crash	PCI	Expected Crash
	Frequency	Frequency	гы	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	mmary 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

Ca	unterme	easure Service	Lives, Costs, an	d Safety Benefi	ts			
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 5 70	ÉE 208.006
Site Characteristic Improvements (Please add description about improvements i.e. Signal Phasing)					\$0.00	\$0.00	-5.579	\$2,398,990
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
					40.00	<u>Å0.00</u>	0.000	4.0



Benefit-Cost Analysis

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

	Ber	efit - Co	ost Calcula	tor		
	Net Presen	t Value (of Project	\$3,224	,108.00	
Net Pres	ent Value o	of Safety	Benefits	\$5,398	,995.96	
		Ne	et Benefit	\$2,174	,887.96	
	Be	nefit / (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
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments	2U	Total 0.74	FI 0.58	PDO 0.8
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments Three-Lane With Center Two-Way Left-Turn Lanes Segments	2U 3T	Total 0.74 0.63	Fl 0.58 0.51	PDO 0.8 0.67
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments	2U 3T 4D	Total 0.74 0.63 0.93	Fl 0.58 0.51 0.77	PDO 0.8 0.67 0.99
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Divided Segments Four-Lane Undivided Segments	2U 3T 4D 4U	Total 0.74 0.63 0.93 0.24	Fl 0.58 0.51 0.77 0.19	PDO 0.8 0.67 0.99 0.27
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments 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	2U 3T 4D 4U 5T	Total 0.74 0.63 0.93 0.24 0.38	Fl 0.58 0.51 0.77 0.19 0.37	PDO 0.8 0.67 0.99 0.27 0.38
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments 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	2U 3T 4D 4U 5T 20	Total 0.74 0.63 0.93 0.24 0.38 1.00	Fl 0.58 0.51 0.77 0.19 0.37 1.00	PDO 0.8 0.67 0.99 0.27 0.38 1.00
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments 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	2U 3T 4D 4U 5T 20 30	Total 0.74 0.63 0.93 0.24 0.38 1.00 1.00	Fl 0.58 0.51 0.77 0.19 0.37 1.00 1.00	PDO 0.8 0.67 0.99 0.27 0.38 1.00 1.00
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments 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	2U 3T 4D 4U 5T 20 30 40	Total 0.74 0.63 0.93 0.24 0.38 1.00 1.00 1.00	Fl 0.58 0.51 0.77 0.19 0.37 1.00 1.00 1.00	PDO 0.8 0.67 0.27 0.38 1.00 1.00
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments 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 Four-Lane One-Way Segments Urban & Suburban Arterial Highways - Intersections	2U 3T 4D 4U 5T 20 30 40	Total 0.74 0.63 0.93 0.24 0.38 1.00 1.00 1.00 Total	Fl 0.58 0.51 0.77 0.19 0.37 1.00 1.00 1.00 Fl	PDO 0.8 0.67 0.27 0.38 1.00 1.00 1.00 PDO
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Undivided Segments Four-Lane Undivided Segments Five-Lane With Center Two-Way Left-Turn Lanes Segments Two-Lane One-Way Segments Four-Lane One-Way Segments Four-Lane One-Way Segments Urban & Suburban Arterial Highways - Intersections Three-Leg Minor Stop-Controlled Intersection	2U 3T 4D 4U 5T 20 30 40 3ST	Total 0.74 0.63 0.93 0.24 0.38 1.00 1.00 Total 0.69	Fl 0.58 0.51 0.77 0.19 0.37 1.00 1.00 1.00 Fl 0.53	PDO 0.8 0.67 0.27 0.38 1.00 1.00 PDO 0.78
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Undivided 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)	2U 3T 4D 4U 5T 20 30 40 3ST 3ST (HS)	Total 0.74 0.63 0.93 0.24 0.38 1.00 1.00 1.00 Total 0.69 1.00	Fl 0.58 0.51 0.77 0.19 0.37 1.00 1.00 1.00 Fl 0.53 1.00	PDO 0.8 0.67 0.99 0.27 0.38 1.00 1.00 PDO 0.78 1.00
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Undivided Segments Four-Lane Undivided Segments Tive-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) Three-Leg All-Way Stop-Controlled Intersection	2U 3T 4D 4U 5T 20 30 40 3ST 3ST (HS) 3aST	Total 0.74 0.63 0.93 0.24 0.38 1.00 1.00 Total 0.69 1.00 1.00	Fl 0.58 0.51 0.77 0.19 0.37 1.00 1.00 Fl 0.53 1.00 1.00	PDO 0.8 0.67 0.99 0.27 0.38 1.00 1.00 PDO 0.78 1.00 1.00
Urban & Suburban Arterial Highways - Segments Two-Lane Undivided Segments Three-Lane With Center Two-Way Left-Turn Lanes Segments Four-Lane Undivided 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 Three-Lane One-Way Segments Three-Leg Minor Stop-Controlled Intersection Three-Leg Minor Stop-Controlled Intersection (High Speed) Three-Leg All-Way Stop-Controlled Intersection Three-Leg Turning Intersection	2U 3T 4D 4U 5T 20 30 40 330 40 335T 35T (HS) 3aST 35TT	Total 0.74 0.63 0.93 0.24 0.38 1.00 1.00 Total 0.69 1.00 1.00 1.00	Fl 0.58 0.51 0.77 0.19 0.37 1.00 1.00 Fl 0.53 1.00 1.00 1.00	PDO 0.8 0.67 0.99 0.27 0.38 1.00 1.00 PDO 0.78 1.00 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 N(business partne	CDOT er resources					
Doing Business	Bidding & Let	Projects		<u>Resources</u>	Local Go	
Asset Management	Environmental Geote		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>
 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

Project Info	∆dd Inte	ersections	and Inter	changes		
	Add Into	.1500110115		enanges		
Global Inpu	Select one	e or more int	ersection or	interchange types from the table below.		
		#		Туре	Current 😨	Add 😮
Traffic Volu				Signalized Intersections		
		1	+	Conventional Signal	0	- 1 +
Design Sel		2	Т	Continuous Green-T	0	- 1 +
		3	ч	Displaced left turn	0	
Delay		4	+	Jughandle	0	
		5	ک	Median U-turn	0	
Cost Paran		б		Quadrant Roadway	0	
		7	دم ا	Restricted Crossing U-turn - Signalized	0	
Global Safe				Unsignalized Intersections		
		8	0	One-Lane Roundabout	0	- 1 +
Safety		9	0	Two-Lane Roundabout	0	
		10		All-Way Stop Control	0	- 1 +
Outputs		11	+	Two-Way Stop Control	1	
		12	`مے	Restricted Crossing U-turn - Unsignalized	0	
				Other		
		13	+	Other	0	
						_
	CANCEL					ADI

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 A	Analysis Cor	nfigurations 🛛	1		× CLEAR	
	Select design alternatives to include in the analysis	#	Ту	/pe	Name			
5 Delay	using the button above. Multiple design variations of the same intersection type can be analyzed,	1	+ Co	onventional Signal	Conventional Signal	Ľ	Ū	
6 Cost Parameters	allowing for simultaneous analysis of different:	2	T Co	ontinuous Green-T	Continuous Green-T	Ľ	ā	
	 turn lane configurations shared movements 	3	Or Ro	ne-Lane oundabout	One-Lane Roundabout	Ľ	Ē	
7 Global Safety Data	channelized movements other intersection specific options	4	AI	l-Way Stop Control	All-Way Stop Control	Ľ	Ū	
8 Safety		5	Tv Co	vo-Way Stop ontrol	Two-Way Stop Control (current intersection)			
9 Outputs								
	EXPORT ANALYSIS					ВАСК	NEXT	



	Delay					
lobal Input Data	Enter average vehicle delay for ea	ch of the interse	ctions			
raffic Volumes			Ope Average	ning Year Vehicle Delay	De Average	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
Clobal 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 h the PPEAG ICE	roved software as speci PPEAG ICE Spreadsheet sections consisting of mi alysis software and the Spreadsheet Tool are	ried in Tool. Jltiple		

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

✓ Project Information Cost Parameters Edit time & crashes costs Edit acceptions & maintenance of the cost of the	eters					
	-					
Global Input Data Enter cost estimates for each intersection alternative	; for					
✓ Traffic Volumes Intersection Design Costs Construction Costs Mitigation Costs ()	1					
• Design						
Conventional Signal S 100,000 S 550,000 S 25,000 Construct	tion					
Continuous Green-T \$ 140000 \$ 700000 \$ 30000 • IVILIGATION	1					
6 Cost Parameters \$ 140,000 \$ 700,000 \$ 30,000	shown					
Image: Construction of the construc	/ area					
\$ 250,000 \$ 2,300,000 \$ 75,000	aica					
Safety All-Way Stop Control \$ 5000 \$ 5000 \$ 0	\$5K					
Outputs S 5,000 S 5,000 S 5,000 minimum for	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	section alternative			Edit operations & maintenance costs	Enter costs for
Traffic Volumes	Intersection	Design Costs	Construction Costs	Mitigation Costs 👔		each option
Design Selection	Conventional Signal	\$ 100000	\$ 550000	\$ 25000		 Design Construction
Oelay	Continuous Cross T	\$ 140000	\$ 700000	\$ 30000		 Mitigation
6 Cost Parameters	Continuous Green-1	\$ 140,000	\$ 700,000	\$ 30,000		• Notico tha \$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	

oject 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	Total 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				Two-Way Stop Contr	ol (current intersection)	design option	
Cost Parameters Global Safety Data	Two-Way Stop Control (current intersection)				Two-Way Stop Contr	 Crosswalks? 		
Safety	Major Road Speed Limit				Two-Way Stop Control (current intersection)			
Uniputs	Major road crosswalk 40 mph				Two-Way Stop Contr	ol (current intersection)	speed limit for	
	Crashes Per Year					-	major road	
	Intersection	Opening Fatal and Iniury	Year Total	Des Fatal and Injury	ign Year	SPF Lleed 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		

E 👘 PennDOT ICE

Safety Defaults

EXPORT ANALYSIS

Allows override of default crash modification factors for selected intersections

	Crash Seventy	Override value	Clearinghouse ID / Notes			
Conventional Signal	Fatal and Injury					
Conventional Signal	Total					
Orationary Cores T	Fatal and Injury					
Continuous Green-1	Total					
One Lone Reundahaut	Fatal and Injury					
one-carle Roundabout	Total					
All May Ober Overteel	Fatal and Injury					
All-way stop control	Total					
Two-Way Stop Control	Uses safety performance function (SPF)					

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

V EXST

 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)

\$ (29.41

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

						BACK
\$ (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

\$112,183 \$112,183	\$5,368,268 \$5,504,283	\$384,74 1 \$390,959	\$2,885,609 \$2,710,141	\$9,425,802
\$112,183	\$5,504,283	\$390,959	\$2,710,141	\$9,587,566
\$36,673	\$4,922,686	\$349,770	\$894,779	\$8,828,90
\$12,097	\$5,984,362	\$425,295	\$1,104,846	\$7,536,60
\$12,097	\$5,577,490	\$395,877	\$3,682,821	\$9,673,28
	\$12,097	\$12,097 \$5,577,490	\$12,097 \$5,577,490 \$395,877	\$12,097 \$5,577,490 \$395,877 \$3,682,821

Benefit Cost Analysis

Intersection	Auto Passenger Delay	Truck Delay	Safety	™at Process ™ator at ™ana	Net Present Value of Costs	Benefit/Cost (B/C) Ratio	Delay B/Č	Safety B/0
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	Sav on t	e all project data to a .jsor he Penn DOT ICE homepa	n file. Anyone can upload thi ge to resume the analysis. E	s file Data is	\$390,95
	\$2,625,000	only	saved to the file, not to th	nis website.		\$349,77
	\$10,000	Pe	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)

	Worksheet 34 - General Information	and Robot Data for Ford Two	ni, ana Teo Way Brashasy Interventions
	General Information		Location Information
Analyst Agency or Company Cate Performed	(unter name) (unter Apancy) (anter date)	Readway Harsectori Jurisdictori Analysis Year	(enter nachosy name) (enter retursoritos name) (enter juridictor) 2019
	Input Data	Base Conditions	Site Constitute
renewalking top (197, 497, 496)			MT
AAOT, ago (whitey)	AADTmix = 19.500 (with day)		
AAOTaur (retrite)	AADT_ax = 4.500 (vehicley)		
intersection skew angle (degrees)	r 431, does skew after for minor legity		(any for Leg 1 (A)
liamber of signalized or uncombined of	ppriseches with a left-law tana (D. 1, 2, 3, 4)	. 0	
Namber of signalized or uncontrolled in	pproaches with a right-turn lane (0. 4, 2, 3, 4)	0	2015 B 2015 B 2015
Hersel for lighting presented prese	rb.	Hot Present	NJ Protect
Catholica Earlier ()		1.00	1.0

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.

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a o Issue 1 Pull requests • Actions Projects • Security Image: Im	ot-fhwa-stol / ads-traffic-regs	5 (Public archive)		
P cherneysp-init P 3 branche © 0 tags Go to file Code • This branch is 30 commits ahead of develop. I) #1 I herneysp Merge branch 'cherneysp-initial' of https://github.com/usdot-fhwa-sto b3a3173 on Feb 22.2021 I) 31 commits I common incorporate CARLA simulation files 2 years ago I freeway incorporate CARLA simulation files 2 years ago I intersection incorporate CARLA simulation files 2 years ago I screenshots Add files via upload 2 years ago I screenshots Updated source code 2 years ago I web Updated source code 2 years ago I ATTRIBUTION.md Update ATTRIBUTION.md 3 years ago I Code_of_Conduct.md Create Code_of_Conduct.md 3 years ago I Contributing.md Create Contributing.md 3 years ago I README.md Update README.md 2 years ago	e 💿 Issues 👫 Pull requests 🚺	⊙ Actions ☐ Projects ① Security	└─ Insights	
This branch is 30 commits ahead of develop.		🐉 cherneysp-init 👻 🐉 3 branches	🛇 0 tags	Go to file Code 🔻
Image: commonincorporate CARLA simulation files2 years agoImage: commonincorporate CARLA simulation files2 years agoImage: freewayincorporate CARLA simulation files2 years agoImage: intersectionincorporate CARLA simulation files2 years agoImage: screenshotsAdd files via upload2 years agoImage: screenshotsVupdated source code2 years agoImage: screenshotsUpdated source code3 years agoImage: screenshotsUpdate ATTRIBUTION.md3 years agoImage: screenshotsCreate Code_of_Conduct.md3 years agoImage: screenshotsCreate Contributing.md3 years agoImage: screens		This branch is 30 commits ahead of develop.		រូ <u>រ</u> #1
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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		📄 web	Updated source code	2 years ago
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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

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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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Important

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