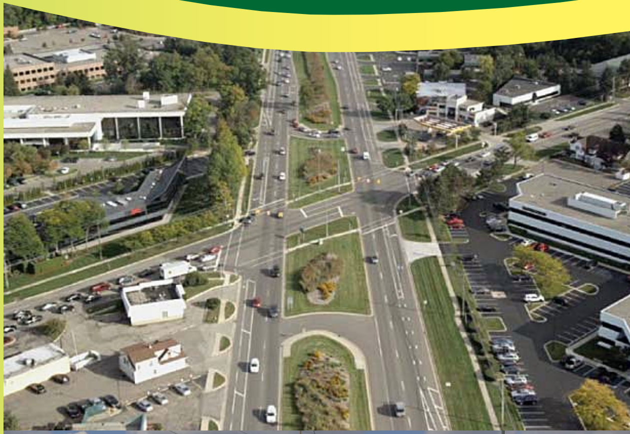
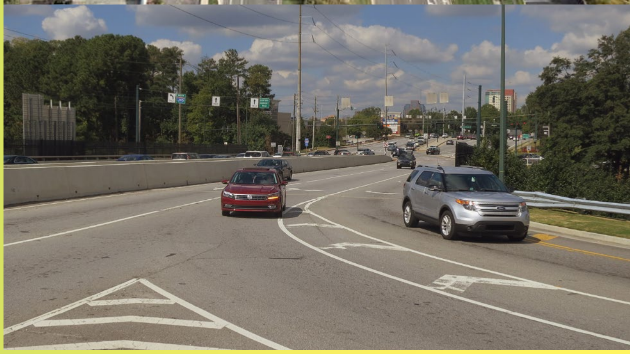
Safety Performance for Intersection Control Evaluation (SPICE) Tool User Manual





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NOTICE

QUALITY ASSURANCE STATEMENT

TECHNICAL REPORT DOCUMENTATION PAGE

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16. Abstract

The Safety Performance for Intersection Control Evaluation (SPICE) Tool is intended to aid in the determination of a preferred alternative for a given intersection project by providing an objective, quantifiable basis to compare the safety performance of different intersection types. This tool may be of use to traffic safety researchers and practitioners, transportation planners and engineers, and highway and street designers. This document provides information and guidance on how to use the SPICE Tool, a macro-based, Microsoft Excel spreadsheet, to assess the safety performance of a variety of intersection geometry and control scenarios in terms of predicted crash frequency and severity.

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Intersection safety, highway safety, alternative intersections, intersection control evaluation, intersection screening, intersection crashes, Highway Safety Manual, HSM, Crash Modification Factor, CMF	**No restrictions.**

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Unclassified	**Unclassified**	**52**	**N/A**

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

FOREWORD

This document is a user manual for the Safety Performance for Intersection Control Evaluation (SPICE) Tool, a macro-based, Microsoft Excel format spreadsheet. This user manual provides instructions and guidance on how to use this spreadsheet tool to perform safety performance analysis for a variety of intersection geometry and control scenarios. The SPICE Tool provides an objective, quantifiable basis for comparing the safety performance of different intersection types that will help users determine a preferred alternative for a given intersection project. This tool may be of use to traffic safety researchers and practitioners, transportation planners and engineers, and highway and street designers.

Michael S. Griffith
Director, Office of Safety Technologies
Federal Highway Administration

DISCLAIMER

The Safety Performance for Intersection Control Evaluation (SPICE) Tool is intended to assist planners and engineers with safety analysis. This analysis forms one component of a comprehensive intersection control evaluation (ICE) or alternatives analysis. As such, the results of the SPICE Tool – predicted crashes for different intersection and interchange forms – should not be the sole basis of choosing a given intersection or interchange form for implementation. The SPICE Tool is not intended to be an intersection/interchange form selection tool. Furthermore, the intersection forms contained within the SPICE Tool are not endorsed or preferred over other intersection forms not contained in the SPICE Tool.

COVER PHOTO CREDITS

Left: Lee Rodergerdts, Kittelson & Associates, Inc

Top Right: Federal Highway Administration

Bottom Right: Pete Jenior, Kittelson & Associates, Inc

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INTRODUCTION

WHAT IS INTERSECTION CONTROL EVALUATION (ICE)?

The primary intent of any transportation project, whether new construction or retrofitting existing infrastructure, should be to promote a sustainable transportation system that safeguards the mobility and safety of all users. Perhaps the greatest opportunity for realizing this goal lies at at-grade intersections and ramp terminals, where crossing traffic patterns potentially place users of various modes in conflict with each other and create delay. Therefore, transportation practitioners should work to deploy the most prudent intersection control type at each intersection. Though engineering judgement is often required when selecting the most 'appropriate' intersection design, engineers, researchers, and designers are able to evaluate a multitude of quantifiable factors and help facilitate an informed decision-making process.

To aid in this effort, many States have implemented Intersection Control Evaluation (ICE) policies/procedures, which provide practitioners with a consistent framework to evaluate and screen the applicability of proven combinations of geometry and traffic-control strategies at intersections. The goal of ICE is to better inform the decision making of the road agency to identify and select an alternative that meets the project purpose and reflects the overall best value, in terms of specific performance-based criteria within available resources. While the evaluation criteria may vary between specific ICE polices/procedures, they typically encourage practitioners to consider both qualitative (e.g., project purpose, multimodal needs, land use, community goals) and quantitative (e.g., traffic operations, safety performance, right-of-way impacts, etc.) factors and foster a holistic evaluation of a wide set of control strategies.

As with most transportation studies, ICE is scalable, meaning the corresponding level of effort for screening and analysis should be commensurate with the magnitude and nature of the project – less effort for simple, more effort for complex. The premise of an ICE policy or evaluation is the same whether it involves new intersections or modification to existing intersections. **Figure 1** illustrates the decision making process, and the ICE role in it.

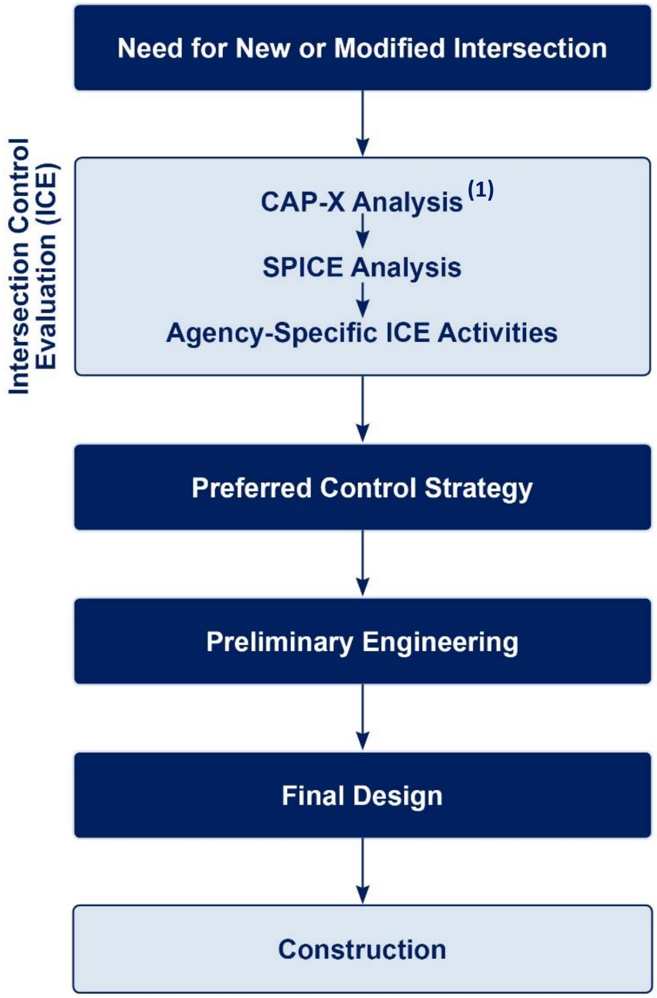


Figure 1. Decision Making Process.

ROLE OF THE SPICE TOOL

For ICE to promote the equitable and comprehensive assessment of potential intersection control strategies, the evaluation framework and the performance criteria employed must facilitate consistency and objectivity. With respect to safety performance, this requires a quantifiable comparison between control strategies that assess crash frequency and severity. Currently, the safety performance functions (SPFs) developed in Part C of the *Highway Safety Manual* (HSM) [and automated/expanded upon in the NCHRP Project 17-38 spreadsheets, Interactive Highway Safety Design Module (IHSDM), and SafetyAnalyst] provide relatively straightforward means of predicting crashes. However, the first edition of the HSM only provides SPFs for a few of the potential intersection-control strategies. Developing crash frequency predictions for control strategies without HSM SPFs requires considerable effort, including identifying and considering appropriate crash modification factors (CMFs), evaluating their quality and applicability, determining the types of crashes to apply them, and deciding whether or not to apply the Empirical Bayes method.

The Safety Performance for Intersection Control Evaluation (SPICE) tool was developed to provide practitioners with a means of evaluating the anticipated safety performance of control strategies within a single tool. The SPICE Tool uses the SPFs in Part C of the HSM (and subsequent NCHRP Reports) to select high-quality CMFs from Part D of the HSM and CMF Clearinghouse to predict crash frequency and severity for a variety of intersection control strategies. By prompting users for basic inputs, the tool automates many of the decisions required for selecting the appropriate SPF or CMF to apply.

Based on the input parameters, the tool is able to specify the predicted crash frequency and crash severity for each control strategy selected for evaluation. Practitioners can conduct analysis for a single year or the lifespan of a project.

RANGE OF HSM ANALYSES

Just as the ICE process is scalable, so too is the application of the SPICE Tool. When conducting a planning-level analysis of alternatives at the early stages of the project, the tool allows the user to quickly apply the HSM SPFs and CMFs with minimal data input (e.g., AADTs, presence of left-turn lanes) by using default values for many of the detailed inputs (e.g., intersection skew angle, number of lanes with protected left-turn phasing, levels of pedestrian activity). The results of the planning-level analysis, while not comprehensive, will still provide a relative comparison between control strategies. Results will vary as more detailed information is input into the tool.

Once more details of the project are known and alternative control strategies have been further developed, practitioners can conduct a more tailored HSM analysis. This is done by overriding many of the default values provided for Part C CMFs with actual values.

RELATIONSHIP TO OTHER TOOLS

While serving as a means of evaluating a wide range of control strategies in a consistent and reproducible manner, the SPICE Tool is not intended to replace the functionality of other tools, including the National Cooperative Highway Research Program (NCHRP) 17-38 spreadsheets, Enhanced Interchange Safety Analysis Tool (ISATe), or the Interactive Highway Safety Design Module (IHSDM). The SPICE Tool only provides predicted crash frequencies and severities for intersections, which can be input into more comprehensive ICE tools, such as the NCHRP Project 3-110 tool, to consider a wide range of performance measures (traffic operations, emissions, etc.) and their associated economic costs.

USING THE SPICE TOOL

FUNCTIONALITY AND REQUIREMENTS

The SPICE Tool is an Excel-based macro workbook. To facilitate the full functionality of the tool, it is important for the user to e*nable* macros (use the prompt dialog at the top of the workbook) upon opening the spreadsheet. These macros serve several purposes within the tool, including:

- Transferring user inputs/selections between Excel tabs to prevent the need for repetitive input/selections.
- Applying user inputs/selections to the appropriate SPF or CMF-selection algorithm.
- Hiding/displaying tabs and drop-down menus where appropriate based on user inputs.

Many of the tabs within the SPICE tool are connected by macros, which rely on user inputs/selections where prompted. As **Table 1** below illustrates, fields requiring user inputs are shown in yellow. Optional data entry fields are shown in gold and yellow; users should only enter inputs into these fields if they would like to override the default values used within the tool. Gold cells are a specific category of optional inputs related to the computation of Part C CMFs.

Table 1. SPICE Tool Data Field Input Legend.

Input Legend	
(light yellow)	Required data entry field
(gold)	Planning-Level default input
(light blue)	Optional data entry field
(gray)	Data entry field not used

To prevent erroneous inputs, overriding of cell descriptions, or breaking of macro functionality, cells not requiring/permitting user inputs are locked. These cells can only be overridden by unlocking the Excel spreadsheet and using the password: kai123

INTRODUCTION TAB

The *Introduction* tab provides an overview of the purpose, intent, and functionality of the SPICE Tool. While no user input is required on this tab, users should review the information on this tab prior to getting started in the SPICE tool. This tab also provides maintenance and contact information regarding the specific version of the SPICE Tool.

DISCLAIMER TAB

The *Disclaimer* tab provides the SPICE Tool disclaimer, limited warranty and limitation of remedies, and notice to the user. No user inputs are required; the tab is for informational purposes only

PROJECT INFORMATION TAB

The *Project Information* tab allows the user to enter general information about the project to which the SPICE Tool is being applied. Data entered on this tab has no bearing on the results of the analysis; rather, it provides an opportunity to *label* a file and provide project-specific information to be displayed on the printable *Results* tab. **Table 2** illustrates the user inputs on the tab.

Table 2. Example Inputs on the Project Information Tab.

Project Name:	E. Passyunk Ave./9th Ave. Intersection Improvements
Intersection:	E. Passyunk Ave./9th Ave.
Agency:	State Department of Transportation
Project Reference:	XX-####-XXXX
City:	Franklin
State:	XXXX
Date:	11/1/2017
Analyst:	AJB
Use this button to clear all inputs/outputs and reset the tool to its initial defaults	Load Cap-X Reset SPICE Tool

Clicking the *Load Cap-X* button allows the user to select a Microsoft Excel CAP-X file from which to load and automatically populate the project information cells. Clicking the *Reset SPICE Tool* button allows the user to remove all user inputs/outputs and resets all values to their defaults.

DEFINITIONS TAB

The *Definitions* tab provides definitions for some of the more complex terms and inputs used within the SPICE Tool. No user inputs are required; the tab is for informational purposes only.

CONTROL STRATEGY SELECTION TAB

The *Control Strategy Selection* tab allows users to establish the basic parameters of the SPICE analysis and determine which control strategies are to be included in the analysis. Most importantly, it allows users to select whether the analysis is being conducted for an at-grade intersection or a ramp-terminal intersection. This selection affects the required inputs for the remainder of the SPICE analysis. Additionally, users may choose to analyze a single year (the opening year), or a range of years (the opening year, the design year, and all years in between). When conducting analysis of a range of years, SPICE interpolates ADT for years between the opening year and design year and predicts crashes for each intermediate year. **Table 3** illustrates the initial user inputs on the tab.

Table 3. Example Inputs on the Control Strategy Selection Tab.

Intersection Type	At-grade Intersections
Analysis Year	Opening and Design Year
Opening Year	2017
Design Year	2037

- The remaining user input fields displayed on the *Control Strategy* tab depend on the selection of *Intersection Type*. **Table 4** illustrates user inputs if conducting a SPICE analysis for an ***at-grade*** intersection. These inputs enable SPICE to choose the appropriate SPF.

Table 4. Example Inputs on the Control Strategy Selection Tab for an At-grade Intersection Analysis.

Facility Type	On Urban and Suburban Arterial
Number of Legs	4-leg
Opening Year − Major Road AADT	20,000
Opening Year − Minor Road AADT	10,000
Design Year − Major Road AADT	25,000
Design Year − Minor Road AADT	12,500

Table 5 illustrates user inputs if conducting a SPICE analysis for a ***ramp terminal*** intersection.

Table 5. Example Inputs on the Control Strategy Selection Tab for Ramp-Terminal Intersection Analysis.

Freeway Orientation	North-South	
Area Type	Urban	
Opening Year AADT	NB Ramp Terminal	SB Ramp Terminal
Crossroad – Inside Leg	25,000	25,000
Crossroad – Outside Leg	25,000	25,000
Exit Ramp	4,500	4,500
Entrance Ramp	3,000	3,000
Design Year AADT	NB Ramp Terminal	SB Ramp Terminal
Crossroad – Inside Leg	30,000	30,000
Crossroad – Outside Leg	30,000	30,000
Exit Ramp	5,000	5,000
Entrance Ramp	3,000	3,250

The SPICE tool only analyzes diamond interchanges with 4-leg ramp terminals (i.e., the exit and entrance ramps meet at the same intersection). This is referred to as a D4 ramp terminal in Chapter 19 of the HSM Supplement, which contains ramp-terminal intersection SPFs. SPICE analyzes both ramp terminals simultaneously, and users are required to enter data for each ramp terminal. Other ramp terminal configurations - such as intersections involving loop ramps and 3-leg intersections - are not included in SPICE because there are other established analysis tools, for example ISTAe and IHSDM. Also, ICE studies typically consider roundabouts or alternative intersections (such as the crossover signal of a diverging diamond interchange) at D4 ramp terminals.

At the bottom of the *Control Strategies tab*, select the control strategies to be included in the SPICE analysis. The intersection control strategies shown vary depending on the intersection type being evaluated. **Table 6** illustrates the user inputs for at-grade intersections and **Table 7** illustrates the user inputs for ramp-terminal intersections. The *Base Intersection* column identifies the type of intersection, which is a Part D CMF and is applied by the SPICE Tool when predicting crashes.

If desired, users can manually enter additional intersection control strategies by overriding the *Other 1* and *Other 2* control strategy cells. When choosing these, the user must enter a CMF in a subsequent tab of the spreadsheet; on this spreadsheet the user must choose which control type SPF the CMF is applied to (traffic signal, minor road stop, etc.).

Should either the opening year or design year AADTs exceed the range of data used to develop the safety performance functions (SPFs) for each control strategy, a note will appear in red next to the respective control strategy. The SPICE Tool will still analyze the control strategy; however, use the results with caution. This is also indicated on the *Results* tab.

Table 6. Example Control Strategies in At-Grade Intersection Analysis.

Control Strategy	Include	Base Intersection
Traffic Signal	Yes	--
Traffic Signal (Alternative Configuration)	Yes	--
Minor Road Stop	Yes	--
All-way Stop	Yes	--
1-Lane Roundabout	Yes	User Selection
2-Lane Roundabout	Yes	User Selection
Displaced Left-Turn (DLT)	Yes	Traffic Signal
Median U-Turn (MUT)	Yes	Traffic Signal
Signalized Restricted Crossing U-Turn (RCUT)	Yes	Traffic Signal
Unsignalized Restricted Crossing U-Turn (RCUT)	Yes	Minor Road Stop
Continuous Green-T (CGT) Intersection	No	Traffic Signal
Jughandle	Yes	Traffic Signal
Other 1	No	Traffic Signal
Other 2	No	Minor Road Stop

Table 7. Example Control Strategies in Ramp Terminal Intersection Analysis.

Control Strategy	Include	Base Intersection
Conventional Traffic Signal	Yes	--
Conventional Traffic Signal (Alt)	Yes	--
Crossover Traffic Signal (of DDI)	Yes	--
Minor Road (ramp) Stop	Yes	--
1-Lane Roundabout	Yes	User Selection
2-Lane Roundabout	Yes	User Selection
Other 1	No	Conventional Traffic Signal
Other 2	No	Minor Road (ramp) Stop

AT-GRADE INPUTS TAB

Note: The *At-Grade Inputs* tab will only be visible when the user selects *At-Grade Intersections* for the *Intersection Type* on the *Control Strategy Selection* tab.

The *At-Grade Inputs* tab allows the user to enter pertinent information relating to the at-grade study intersection for the SPICE analysis. The top section allows the user to override AADT information (optional), as well as information regarding the number of turn lanes for the stop-controlled and signalized control strategies. Although they are associated with Part C CMFs, turn lane inputs were placed in the top portion of the spreadsheet and are required for planning-level analysis because they have a relatively large effect on crash prediction values and it is a basic aspect of an intersection that is likely to be known even at a planning stage. **Table 8** illustrates the user inputs in the top section of the *At-Grade Inputs* tab.

Table 8. Example User Inputs on the At-Grade Inputs Tab

Control Strategy													
Input		**Traffic Signal**	**Traffic Signal (Alt)**	**Minor Road Stop**	**All Way Stop**	**1-lane Round-about**	**2-lane Round-about**	**Displaced Left Turn**	**Median U-Turn**	**Signalized RCUT**	**Un-signalized RCUT**	**Jug-handle**	
Number of Approaches with Left-Turn Lanes	Additional Required Control Strategy Inputs	2	2		0								Do not include stop controlled approaches for minor stop
Number of Approaches with Right-Turn Lanes		2	2		0								
Number of Uncontrolled Approaches with Left-Turn Lanes				2									
Number of Uncontrolled Approaches with Right-Turn Lanes				2									

The bottom section of the *At-Grade Inputs* tab allows the user to override the default CMF-related inputs from Part C of the HSM. If conducting a planning-level analysis, these default values can be left alone. If conducting a more detailed HSM analysis, these inputs should be modified to match the anticipated conditions under each applicable control strategy. **Table 9** illustrates the user inputs in the bottom section of the *At-Grade Inputs* tab. To reset the default CMF inputs, select the *Reset Planning Input Defaults* button at the top left of the section.

Table 9. Default HSM Part C CMF Inputs on the At-Grade Inputs Tab.

Keep default values below here for planning-level analysis, override with actual values for full HSM Analysis													
Reset Planning Inputs to Defaults	Highway Safety Manual Part C CMF Inputs												
		Traffic Signal	Traffic Signal (Alt)	Minor Road Stop	All Way Stop	1-Lane Round-about	2-Lane Round-about	Displaced Left-Turn	Median U-Turn	Signalized RCUT	Un-signalized RCUT	Jug-handle	
Skew Angle	A yellow cell indicates the value may be used in the SPF computation	N/A	N/A	0	N/A	CMF - No Inputs Required	CMF - No Inputs Required	CMF - No Inputs Required	CMF - No Inputs Required	CMF - No Inputs Required	CMF - No Inputs Required	CMF - No Inputs Required	All yellow cells will be automatically populated by a macro. If users want to do a planning-level analysis, they can leave the automatic inputs as-is
Lighting Present		Yes	Yes	Yes	No								
# of Approaches Permissive LT Signal Phasing		0	0										
# of Approaches Perm/Protected LT Signal Phasing		0	0										
# of Approaches Protected LT Signal Phasing		0	0										
Number of Approaches with Right-Turn-on-Red Prohibited		0	0										
Red Light Cameras Present		No	No										
Pedestrian Volume by Activity Level		Low (50)	Low (50)										
User-Specified Sum of all daily pedestrian crossing volumes		50	50										
Max # of Lanes Crossed by Pedestrians		5	5										
Number of Bus Stops within 1,000 ft of Intersection		0	0										
Schools within 1,000 ft of intersection		No	No										
Number of Alcohol Sales Establishments within 1,000 ft of Intersection		0	0										

RAMP TERMINAL INPUTS TAB

Note: The *Ramp Terminal Inputs* tab will only be visible if the user selects *Ramp Terminal Intersections* for the *Intersection Type* on the *Control Strategy Selection* tab.

The *Ramp Terminal Inputs* tab allows the user to enter pertinent information relating to the ramp terminal study intersection for the SPICE analysis. The top section allows the user to override AADT information for the ramp and crossroad approaches (optional), as well as information regarding the number of lanes on the crossroad. **Table 10** illustrates the user inputs in the top section of the *Ramp Terminal Inputs* tab.

Table 10. Example User Inputs on the Ramp Terminal Inputs Tab.

Alternative	**Traffic Signal**		**Traffic Signal (Alt)**		**Minor Road (Ramp) Stop**	
	4-Leg Terminal w/ Diagonal Ramps (D4)		**4-Leg Terminal w/ Diagonal Ramps (D4)**		**4-Leg Terminal w/ Diagonal Ramps (D4)**	
Ramp Terminal	**NB Ramp Terminal**	**SB Ramp Terminal**	**NB Ramp Terminal**	**SB Ramp Terminal**	**NB Ramp Terminal**	**SB Ramp Terminal**
Number of Crossroad Lanes	4	4	4	4	4	4
Number of through traffic lanes that oppose the left-turn movement on the inside crossroad leg	2	2	2	2	N/A	N/A
Number of through traffic lanes that oppose the left-turn movement on the outside crossroad leg	2	2	2	2	N/A	N/A

The bottom section of the *Ramp Terminal Inputs* tab allows the user to override the default CMF-related inputs from Part C of the HSM. If conducting a planning-level analysis, these default values can be left alone. If conducting a more detailed HSM analysis, users should modify these inputs to match the anticipated conditions under each applicable control strategy. **Table 11** illustrates the user inputs in the bottom section of the *Ramp Terminal Inputs* tab.

Table 11. Default CMF Inputs on the Ramp Terminal Inputs Tab.

CMF Inputs	Part C CMFs Optional For Stage 1 ICE, Required for Stage 2 ICE					
	Traffic Signal		Traffic Signal (Alt)		Minor Road (Ramp) Stop	
	4-Leg Terminal w/ Diagonal Ramps (D4)		4-Leg Terminal w/ Diagonal Ramps (D4)		4-Leg Terminal w/ Diagonal Ramps (D4)	
	NB Ramp Terminal	SB Ramp Terminal	NB Ramp Terminal	SB Ramp Terminal	NB Ramp Terminal	SB Ramp Terminal
Exit Ramp Skew Angle	N/A	N/A	N/A	N/A	0	0
Is a non-ramp public street leg present?	No	No	No	No	N/A	N/A
Exit ramp right-turn control	Signal/ Stop/ yield-control	Signal/ Stop/ yield-control	Signal/ Stop/ yield-control	Signal/ Stop/ yield-control	Signal/ Stop/ yield-control	Signal/ Stop/ yield-control
Effective number of lanes serving exit ramp	1	1	1	1	1	1
Number of unsignalized driveways on outside crossroad leg within 250 ft of the interchange	0	0	0	0	N/A	N/A
Distance (mi) to the adjacent ramp terminal	0.10	0.10	0.10	0.10	0.10	0.10
Distance (mi) to the next public street intersection on outside crossroad leg	0.15	0.15	0.15	0.15	0.15	0.15
# of unsignalized public street approaches on outside crossroad leg within 250 ft (<0.05 mi) of interchange	1	1	1	1	1	1
Median Width (ft)	12.00	12.00	12.00	12.00	12.00	12.00
Presence of right-turn lane/bay on outside crossroad leg	Yes	Yes	Yes	Yes	Yes	Yes
Presence of left-turn lane/bay on inside crossroad leg	Yes	Yes	Yes	Yes	Yes	Yes
Left-turn lane/bay Width for inside crossroad leg	12.00	12.00	12.00	12.00	12.00	12.00
Protected Left-turn operation for inside crossroad leg	No	No	No	No	N/A	N/A
Right-turn channelization for outside crossroad leg	No	No	No	No	N/A	N/A
Right-turn channelization for exit ramp	No	No	No	No	N/A	N/A

CALIBRATION TAB

The *Calibration* tab allows the user to provide calibration factors for SPFs and override the default CMFs with locally developed values. By default, all SPF calibration factors use a value of 1.0. To override a specific SPF calibration factor, enter the value into the appropriate data field (blue cells). **Table 12** illustrates entering a locally derived calibration factor for traffic signals on rural two-lane highways.

Table 12. Example of Overriding Default SPF Calibration Factors.

Optional - Input locally-developed calibration factors for SPFs.							
At-Grade Intersection SPFs							
Traffic Control	**Facility Type**	**# legs**	**1-way/ 2 way**	**# of lanes on arterial**	**Default Calibration Factor**	**Optional User Override**	**Use Value**
Traffic Signal	On Rural 2-Lane Highway	3-leg	-	-	1.00	0.98	0.98
		4-leg	-	-	1.00	0.95	0.95

Crash prediction computations will automatically use any calibration factors or local CMFs entered on this sheet.

To override CMF values with locally derived values, enter the desired value into the appropriate data field (blue cells). For example, if research conducted by the State department of transportation illustrated Displaced Left-Turn intersections were more effective at reducing fatal-injury crashes than the CMFs in SPICE, enter the local CMF value. **Table 13** illustrates entering a locally derived CMF value for fatal-injury crashes for Displaced Left-Turn (DLT) intersections.

Table 13. Example of Overriding Default CMFs.

Optional – Override default CMFs with locally developed or new CMFs				
Control	**Type of Crashes**	**Default CMF**	**Optional User Override**	**Use Value**
Displaced Left-Turn (DLT)	Total	0.88		0.88
	Fatal-Injury	0.88	0.80	0.80
Median U-Turn (MUT)	Total	0.85		0.85
	Fatal-Injury	0.70		0.70

To enter CMFs for the two user-selected control strategies (i.e., the *Other 1* and *Other 2* control strategies), enter values in the provided cells, as **Table 14** shows.

Table 14. Example of Applying CMFs for Other Intersection Types.

Optional - Override default CMFs with locally-developed or new CMFs				
Control	**Type of Crashes**	**Default CMF**	**Optional User Override**	**Use Value**
Other Intersection #1	Total	1.00	0.85	0.85
	Fatal-Injury	1.00	0.92	0.92
Other Intersection #2	Total	1.00	0.72	0.72
	Fatal-Injury	1.00	0.85	0.85

To return all SPF calibration factors and CMFs to their default values, select the grey *Reset to Default Values* button in the top right corner of the *Calibration* tab.

RESULTS TAB/RESULTS-RTI TAB

The *Results* tab provides a one-page summary of the results of the analysis. For ease of printing and including in an ICE report, key project information entered on previous tabs is displayed at the top of the tab. **Table 15** provides an example print out of the *Results* tab.

Table 15. Example Print-Out of the Results Tab.

Results			
Summary of crash prediction results for each alternative			
Project Information			
Project Name:	E. Passyunk Ave./9th Ave. Intersection Improvements	**Intersection Type**	At-Grade Intersections
Intersection:	E. Passyunk Ave./9th Ave.	**Opening Year**	2017
Agency:	State Department of Transportation	**Design Year**	2037
Project Reference:	XX-####-XXXX	**Facility Type**	On Urban and Suburban Arterial
City:	Franklin	**Number of Legs**	4-leg
State:	XXXX	**1-Way/2-Way**	2-way Intersecting 2-way
Date:	11/1/2017	**# of Major Street Lanes**	5 or fewer
Analyst:	AJB	**Major Street Approach Speed**	Less than 55 mph

Crash Prediction Summary					
Control Strategy	**Crash Type**	**Opening Year**	**Design Year**	**Total Project Life Cycle**	**AADT Within Prediction Range?**
1-lane Roundabout	Total	3.20	4.25	78.17	N/A
	Fatal & Injury	0.66	0.89	16.18	
2-lane Roundabout	Total	3.69	4.90	90.07	N/A
	Fatal & Injury	0.45	0.60	10.98	
Minor Road Stop	Total	1.85	2.33	43.87	No
	Fatal & Injury	0.79	1.02	18.93	
All-Way Stop	Total	No SPF	No SPF	No SPF	N/A
	Fatal & Injury	No SPF	No SPF	No SPF	
Traffic Signal	Total	4.55	6.05	111.20	Yes
	Fatal & Injury	1.54	2.07	37.85	
Traffic Signal (Alt)	Total	4.55	6.05	111.2	Yes
	Fatal & Injury	1.54	2.07	37.85	
Displaced Left-Turn (DLT)	Total	4.01	5.33	97.85	N/A
	Fatal & Injury	1.23	1.66	30.28	
Median U-Turn (MUT)	Total	3.87	5.14	94.52	N/A
	Fatal & Injury	1.08	1.45	26.50	
Signalized RCUT	Total	3.87	5.14	94.52	N/A
	Fatal & Injury	1.20	1.62	29.53	
Unsignalized RCUT	Total	1.20	1.51	28.52	N/A
	Fatal & Injury	0.36	0.47	8.71	
Jughandle	Total	3.37	4.48	82.29	N/A
	Fatal & Injury	1.14	1.54	28.01	

The bottom section of the tab provides a crash prediction summary for each control strategy selected on the *Control Strategy Selection* tab. Depending on the analysis selected, the predicted total- and fatal-injury crash frequencies are displayed for the opening year, design year, and total project life cycle. For example, in **Table 15**, Median U-turn control strategy is anticipated to have 3.87 total and 1.08 fatal-injury crashes during the opening year (2017), 5.14 total and 1.45 fatal-injury crashes during the design year (2037), and 94.52 total and 26.50 fatal-injury crashes over the project's lifecycle (2017−2037).

The final column (*AADT Within Prediction Range*) indicates if the intersection's projected AADT is within the range used to develop the SPFs for the respective control strategy. For example, in **Table 15**, the *No* in the Minor Road Stop-Control strategy indicates the AADT of the project exceeds the AADT range used to develop the minor road stop control SPF in the HSM, and therefore, the crash frequency predictions should be used with caution.

The *Results RTI* tab provides a summary of the results of the analysis for the case of a grade-separated intersection junction. For ease of printing and including in an ICE report, key project information entered on previous tabs is displayed at the top of the tab. **Table 16** provides an example print-out of the *Results RTI* tab.

Table 16. Example Print-Out of the Results RTI Tab.

Results			
Summary of crash prediction results for each alternative			
Project Information			
Project Name:	Ramp Terminal Example	**Intersection Type**	Ramp Terminal Intersections
Intersection:	I-XX/SR YY	**Opening Year**	2017
Agency:	State Department of Transportation	**Design Year**	2037
Project Reference:	XX-####-XXXX	**Area Type**	Urban
City:	City		
State:	XXXX		
Date:	11/1/2017		
Analyst:	AJB		

Crash Prediction Summary					
Control Strategy	**Crash Type**	**Opening Year**	**Design Year**	**Total Project Life Cycle**	**AADT Within Prediction Range?**
Conventional Traffic Signal	Total	14.88	18.43	349.36	Yes
	Fatal & Injury	6.96	8.75	164.86	
Conventional Traffic Signal (Alt)	Total	14.88	18.43	349.36	Yes
	Fatal & Injury	6.96	8.75	164.86	
Minor Road (ramp) Stop	Total	7.51	9.16	174.82	No
	Fatal & Injury	2.58	3.22	60.88	

The top portion of the page includes project information entered on previous tabs. The bottom section of the tab provides a crash-prediction summary for each of the selected control strategies. As with the Results tab from the at-grade scenario, the predicted total- and fatal-injury crash frequencies are displayed for opening year, design year, and total project life cycle. For example, in **Table 16**, the conventional traffic signal control strategy is anticipated to have 14.88 total and 6.96 fatal-injury crashes during the opening year (2017), 18.43 total and 8.75 fatal-injury crashes during the design year (2037), and 349.36 total and 164.86 fatal-injury crashes over the project's lifecycle (2017−2037).

Similar to the *Results* tab, the final column (*AADT Within Prediction Range*) again indicates if the intersection's projected AADT is within the range used to develop the SPFs for the respective control strategy. For example, in **Table 16**, the *No* in the Minor Road (ramp) Stop-Control strategy indicates the AADT of the project exceeds the AADT range used to develop the minor road (ramp) Stop-Control SPF, and therefore, use the crash frequency predictions with caution.

DATA SOURCES

SAFETY PERFORMANCE FUNCTIONS

Table 17 provides the sources for each at-grade intersection SPF contained in the SPICE tool. **Table 18** provides the sources for each ramp-terminal intersection SPFs.

Table 17. Sources of At-Grade Intersection SPFs Contained in the SPICE Tool.

Control Type	Safety Performance Function	# of Legs	Source
Traffic Signal	On Rural Two-Lane Highway	4	HSM (Chapter 10)
		4	HSM (Chapter 11)
	On Urban and Suburban Arterial	3	HSM (Chapter 12)
		4	
Two-Way Stop-Control	On Rural Two-Lane Highway	3	HSM (Chapter 10)
		4	
	On Rural Multilane Highway	3	HSM (Chapter 11)
		4	
	On Urban and Suburban Arterial	3	HSM (Chapter 12)
		4	

Table 18. Sources of Ramp Terminal SPFs Contained in the SPICE Tool.

Control Type	Safety Performance Function	Source
Conventional Traffic Signal	Four-leg terminals with diagonal ramps	HSM Supplement
Two-Way Stop--Controlled	Four-leg terminals with diagonal ramps	

PART D CRASH MODIFICATION FACTORS

Table 19 provides the source of each of the CMFs contained in the SPICE Tool.

Table 19. Source of Alternative Intersection Crash Modification Factors Contained in SPICE Tool.

Crash Modification Factor	Geometry	Crash Type(s)	Source	Link
Traffic Signal on Rural Two-Lane Highway	3-Legs	Total Crashes	CMF Clearinghouse	http://www.cmfclearinghouse.org/detail.cfm?facid=325
All-Way Stop on Rural Two-Lane Highway	4-Legs	Total Crashes	CMF Clearinghouse	http://www.cmfclearinghouse.org/detail.cfm?facid=315
Roundabout	3- and 4-Legs	Total Crashes Injury Crashes	HSM and Safety Effectiveness of Converting Signalized Intersections to Roundabouts (TRB Paper) (2012)	Printed Documents
Displaced Left-Turn (DLT)/Continuous Flow Intersection (CFI)	4-Legs	Total Crashes	Development of Performance Matrices for Innovative Intersections and Interchanges (UDOT)	https://www.udot.utah.gov/main/uconowner.gf?n=25601022404950131
Median U-Turn (MUT)/Michigan Left	4-Legs	Total Crashes Injury Crashes	NCHRP Report 420	http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_420.pdf
Signalized Restricted Crossing U-Turn (RCUT)/Superstreet	4-6 Lanes	Total Crashes Injury Crashes	Safety Evaluation of Restricted Crossing U-Turn Intersections (FHWA-HRT-17-082)	https://www.fhwa.dot.gov/publications/research/safety/17082/17082.pdf
Unsignalized Restricted Crossing U-Turn (RCUT)/J-Turn	3- and 4- Legs	Total Crashes Injury Crashes	CMF Clearinghouse	http://www.cmfclearinghouse.org/detail.cfm?facid=5556 http://www.cmfclearinghouse.org/detail.cfm?facid=5555
Continuous Green-T Intersection/Florida T	3- and 4- Legs	Total Crashes Fatal and Injury Crashes	FHWA Safety Evaluation of Continuous Intersections (2016)	https://www.fhwa.dot.gov/publications/research/safety/16036/16036.pdf
Jughandles	4-Legs	Fatal and Injury Crashes	FHWA Traffic Performance of Three Typical Designs of New Jersey Jughandle Intersections	http://www.fhwa.dot.gov/publications/research/safety/07032/
Diverging Diamond Interchange (DDI)	-	Total Crashes Injury Crashes	Safety Evaluation of Seven of the Earliest DDIs installed in the US (TRB paper) (2015)	http://docs.trb.org/prp/16-5481.pdf

CASE STUDIES

CASE STUDY #1. NEW PRIVATE ACCESS DRIVEWAY

Private Development Company A proposes a new residential development on a currently vacant plot of land adjacent to Route 500 in Concordville. The development plan, which includes 75 single-family homes, proposes access to Route 500 by a single, new intersection. The proposed development would open in 2018 and is being evaluated at a design year of 2024. **Figure 2** illustrates the location of the proposed site.

Original Photo: © 2014 Google® (modified by Kittelson & Associates, Inc.)

Figure 2. Case Study #1, Site Location.

Best described as a suburban area, the surrounding land uses include private residential developments, vacant plots, and an 18-hole golf course a half-mile to the east. This section of Route 500 is a two-lane, undivided arterial featuring curb-and-gutter, a shared-use path running along its north side, and a 35 mile-per-hour posted speed limit. It primarily serves as a means of accessing the adjacent private residential developments and experiences little through traffic. As the land directly opposite the proposed development on Route 500 is currently undeveloped, no intersections or site access points lie along the frontage of the proposed development. Consequently, a new access point to Route 500 is proposed, and analysts undertook an Intersection Control Evaluation (ICE) was undertaken.

While a proposed new intersection could conceivably consider any or all intersection types and control options, in this case the list of viable alternatives were vetted prior to a SPICE analysis. Through prior coordination, the State and the developer agreed to the following list of intersection-control strategies to asses further:

- Two-way Stop-Control

- Traffic Signal
- Roundabout
- Continuous Green Tee

The SPICE tool was applied to help evaluate the three identified control strategies based on anticipated safety performance the SPICE tool was applied. The following steps were applied:

1. Review information provided on the *Introduction* tab.
2. Enter basic project information on the *Project Information* tab.
3. Select an evaluation type and enter information on *Control Strategy Selection* tab.
4. Enter data required to apply Part C CMFs on *At-Grade Inputs* tab.
5. Determine whether locally-developed SPF calibration factors or CMFs are available.
6. Review the crash frequencies predicted on the *Results* tab.

Each of these steps is then outlined.

Step #1: Review the information provided on the *Introduction* tab.

Prior to applying the SPICE tool, the information on the *Introduction* tab was reviewed.

Step #2: Enter basic project information on the *Project Information* tab.

As **Table 20** shows, the basic project information was entered on the *Project Information* tab to document which project was being analyzed.

Table 20. Case Study #1, Project Information Tab.

Project Information	
Project Name:	Concordville Residential Development
Intersection:	Route 500 (Perry Road)/Site Driveway A
Agency:	State Department of Transportation
Project Reference:	XX-####-XXXX
City:	Concordville
State:	XXXX
Date:	11/1/2017
Analyst:	AJB

Step #3: Select evaluation type and enter information on *Control Strategy Selection* tab.

After entering the basic project information, the at-grade intersection type was selected on the *Control Strategy Selection* tab. This selection determined the inputs required for the remainder of the analysis. **Table 21** illustrates the facility-level inputs entered into the tool. **Table 22** illustrates selection of control strategies to be included in the SPICE analysis. As determined in the preliminary stages of the ICE, only three control strategies are proposed for evaluation. All other control strategies were excluded from the evaluation by selecting *No* under the *Include* column at the bottom of the tab.

Table 21. Case Study #1, Facility-Level Inputs.

Intersection Type	At-Grade Intersections
Analysis Year	Opening and Design Year
Opening Year	2018
Design Year	2024
Facility Type	On Urban and Suburban Arterial
Facility Secondary Type (For Roundabouts Only)	Suburban
Number of Legs	3-leg
Opening Year - Major Road AADT	16,000
Opening Year - Minor Road AADT	1,000
Design Year - Major Road AADT	20,000
Design Year - Minor Road AADT	1,200

Table 22. Case Study #1, Select Control Strategy.

Control Strategy	Include	Base Intersection
Traffic Signal	Yes	--
Traffic Signal (Alternative Configuration)	No	--
Minor Road Stop	Yes	--
All-Way Stop (No SPF/CMF Available)	No	--
1-Lane Roundabout	Yes	Traffic Signal
2-Lane Roundabout	Yes	Traffic Signal
Displaced Left-Turn (DLT)	No	Traffic Signal
Median U-Turn (MUT)	No	Traffic Signal
Signalized Restricted Crossing U-Turn (RCUT)	No	Traffic Signal
Unsignalized Restricted Crossing U-Turn (RCUT)	No	Minor Road Stop
Continuous Green-T (CGT) Intersection	No	Traffic Signal
Jughandle	No	Traffic Signal
Other 1	No	Traffic Signal
Other 2	No	Minor Road Stop

Step #4: Enter data required to apply Part C CMFs on *At-Grade Inputs* tab.

As **Table 23** shows, the number of anticipated turn lanes for each strategy evaluated was entered on the *At-Grade Inputs* tab to determine the appropriate Part C CMF to apply for each control strategy. As the AADT on each approach is anticipated to remain the same, regardless of the control strategy employed, the optional overrides for opening year and design year AADTs were left unaltered.

Table 23. Case Study #1, Part C CMF Inputs.

Input		Control Strategy			
		Traffic Signal	**Minor Road Stop**	**1-lane Roundabout**	**2-lane Roundabout**
Number of Approaches with Left-Turn Lanes	Additional Required Control Strategy Inputs	1			
Number of Approaches with Right-Turn Lanes		1			
Number of Uncontrolled Approaches with Left-Turn Lanes			1		
Number of Uncontrolled Approaches with Left-Turn Lanes			0		

As this is a planning level-analysis, none of the default values at the bottom of the *At-Grade Inputs* tab were modified.

Step #5: Determine availability of locally developed SPF calibration factors or CMFs.

At the time of the project, no locally developed SPF calibration factors have been developed for the identified control strategies. As a result, no changes were made on the *Calibration* tab.

Step #6: Review the crash frequencies predicted on the *Results* tab.

Table 24 illustrates the outputs on the *Results* tab.

Table 24. Case Study #1, Results.

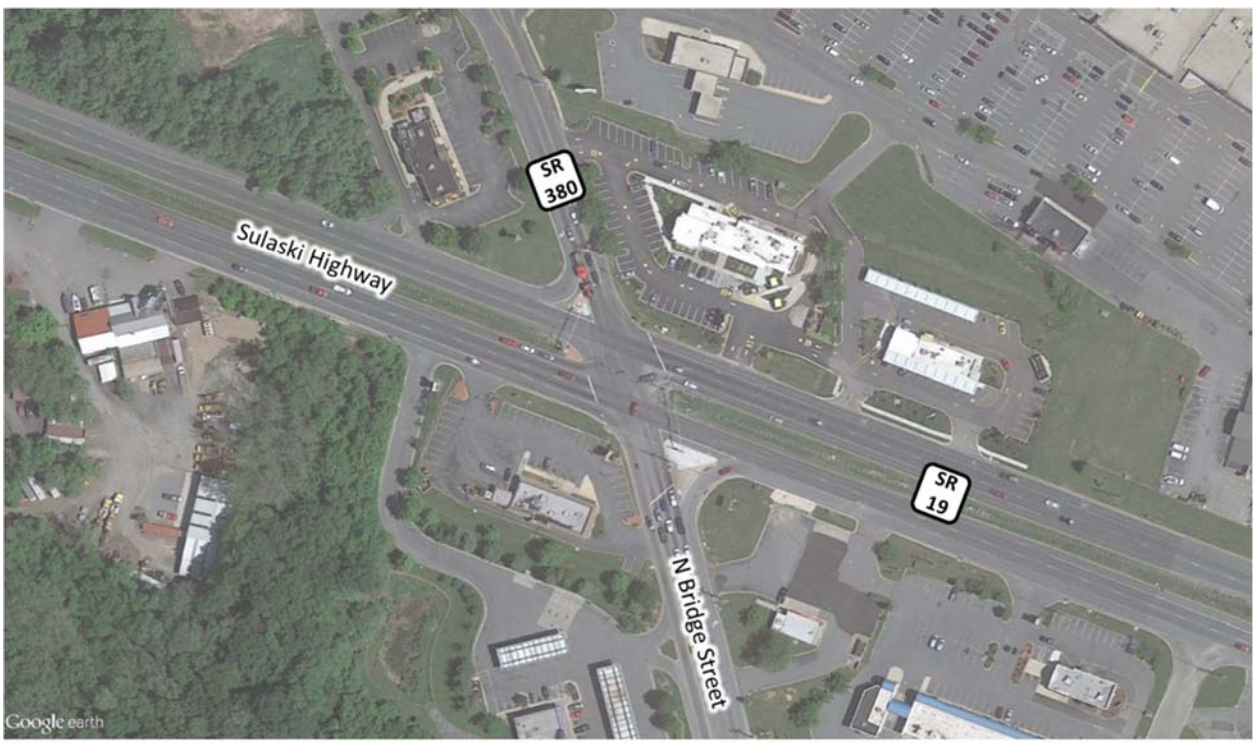
<table>
<tr><th colspan="6">Results</th></tr>
<tr><td colspan="6">Summary of crash prediction results for each alternative</td></tr>
<tr><th colspan="6">Project Information</th></tr>
<tr><td>Project Name:</td><td colspan="2">Concordville Residential Development</td><td colspan="2">Intersection Type</td><td>At-Grade Intersections</td></tr>
<tr><td>Intersection:</td><td colspan="2">Route 500 (Perry Road)/Site Driveway A</td><td colspan="2">Opening Year</td><td>2018</td></tr>
<tr><td>Agency:</td><td colspan="2">State Department of Transportation</td><td colspan="2">Design Year</td><td>2024</td></tr>
<tr><td>Project Reference:</td><td colspan="2">XX-####-XXXX</td><td colspan="2">Facility Type</td><td>On Urban and Suburban Arterial</td></tr>
<tr><td>City:</td><td colspan="2">Concordville</td><td colspan="2">Number of Legs</td><td>3-leg</td></tr>
<tr><td>State:</td><td colspan="2">XXXX</td><td colspan="2">1-Way/2-Way</td><td>2-way Intersecting 2-way</td></tr>
<tr><td>Date:</td><td colspan="2">11/1/2017</td><td colspan="2"># of Major Street Lanes</td><td>5 or fewer</td></tr>
<tr><td>Analyst:</td><td colspan="2">AJB</td><td colspan="2">Major Street Approach Speed</td><td>Less than 55 mph</td></tr>
<tr><th colspan="6">Crash Prediction Summary</th></tr>
<tr><th>Control Strategy</th><th>Crash Type</th><th>Opening Year</th><th>Design Year</th><th>Total Project Life Cycle</th><th>AADT Within Prediction Range?</th></tr>
<tr><td rowspan="2">1-lane Roundabout</td><td>Total</td><td>0.99</td><td>1.32</td><td>8.07</td><td rowspan="2">No</td></tr>
<tr><td>Fatal & Injury</td><td>0.24</td><td>0.31</td><td>1.93</td></tr>
<tr><td rowspan="2">2-lane Roundabout</td><td>Total</td><td>1.08</td><td>1.44</td><td>8.83</td><td rowspan="2">Yes</td></tr>
<tr><td>Fatal & Injury</td><td>0.16</td><td>0.20</td><td>1.24</td></tr>
<tr><td rowspan="2">Minor Road Stop</td><td>Total</td><td>0.90</td><td>1.21</td><td>7.36</td><td rowspan="2">Yes</td></tr>
<tr><td>Fatal & Injury</td><td>0.36</td><td>0.47</td><td>2.90</td></tr>
<tr><td rowspan="2">Traffic Signal</td><td>Total</td><td>1.34</td><td>1.78</td><td>10.90</td><td rowspan="2">Yes</td></tr>
<tr><td>Fatal & Injury</td><td>0.53</td><td>0.69</td><td>4.29</td></tr>
</table>

The application of SPFs show a minor road Stop-controlled intersection is anticipated to result in the fewest total crashes over the lifecycle of the project and a two-lane roundabout is anticipated to have the fewest fatal and injury crashes over the lifecycle of the project relative to the other control strategies evaluated. Comparing the other control strategies, both roundabouts and the minor road Stop controlled intersection are expected to result in fewer crashes than a traffic signal.

CASE STUDY #2. INTERSECTION IMPROVEMENT

The intersection of Route 19 (Sulaski Highway) and Route 380 (N Bridge Street) near Charleston is routinely identified as a high-crash location. A substantial number of crashes were reported at the intersection during the 3-year period of 2011-2013 – a total of 17 property damage only (PDO) crashes and 22 injury crashes. The number and proportion of rear-end crashes (56 percent) at the intersection indicates that one or multiple factors are causing this location to be high risk for rear-end crashes. There were also 5 left-turn crashes, despite protected left-turn signal phasing on all approaches. The fundamental safety issues at this intersection are related to the skew of the roadways and the poor operational performance resulting in long queues.

A recently conducted operational analysis determined the intersection currently operates at capacity with a level-of-service (LOS) *E* during the weekday p.m. peak period. Each through movement has volume that exceeds capacity. The long queues, in conjunction with the prevalence of “failure to give full attention” crash causes could indicate that unexpectedly slowed or stopped vehicles far in advance of this intersection are contributing to rear-end crashes. The purpose of the overall ICE is to enhance safety performance and reduce vehicular delays and queues. **Figure 3** illustrates the study intersection.



Original Photo: © 2013 Google® (modified by Kittelson & Associates, Inc.)

Figure 3. Case Study #2, Site Location.

Adjacent development makes many of the control strategies unfeasible. Considering right-of-way constraints and crash history at the intersection, the viable control strategies include:

- Traffic Signal (*existing*)
- Median U-Turn
- Signalized Restricted Crossing U-Turn (RCUT)
- Displaced Left-Turn (DLT)

Currently, channelized right-turn lanes are provided on northbound and southbound approaches; both of the turning lanes have a sufficiently large radius to allow relatively high-speed, yield-controlled turning movements.

To help evaluate the four identified control strategies based on anticipated safety performance the SPICE tool was applied. The following steps were applied:

1. Review information provided on the *Introduction* tab.
2. Enter basic project information on the *Project Information* tab.
3. Select an evaluation type and enter information on *Control Strategy Selection* tab.
4. Enter data required to apply Part C CMFs on *At-Grade Inputs* tab.
5. Determine availability of locally developed SPF calibration factors or CMFs.
6. Review crash frequencies predicted on the *Results* tab.

Each of these steps is outlined subsequently.

Step #1: Review the information provided on the *Introduction* tab.

Prior to applying the SPICE tool, the information on the *Introduction* tab was reviewed.

Step #2: Enter basic project information on the Project *Information* tab.

As **Table 25** shows, the basic project information was entered on the *Project Information* tab to document which project was being analyzed.

Table 25. Case Study #2, Project Information Tab.

Project Information	
Project Name:	SR 19/SR 380 Improvements
Intersection:	SR 19 (Sulaski Hwy)/SR 380 (N Bridge Street)
Agency:	State Department of Transportation
Project Reference:	XX-####-XXXX
City:	Charleston
State:	XXXX
Date:	11/1/2017
Analyst:	AJB

Step #3: Select evaluation type and enter information on *Control Strategy Selection* tab.

After entering the basic project information, the at-grade intersection type was selected on the *Control Strategy Selection* tab. This selection determined the inputs required for the remainder of the analysis. **Table 26** illustrates the facility level inputs entered into the tool. **Table 27** illustrates the selection of control strategies to be included in the SPICE analysis. As determined in the preliminary stages of the ICE, only four control strategies are proposed for evaluation. All other control strategies were excluded from the evaluation by selecting *No* under the *Include* column at the bottom of the tab.

Table 26. Case Study #2, Facility Level Inputs.

Intersection Type	At-Grade Intersections
Analysis Year	Opening and Design Year
Opening Year	2020
Design Year	2025
Facility Type	On Urban and Suburban Arterial
Facility Secondary Type (For Roundabouts Only)	Suburban
Number of Legs	4-leg
Opening Year - Major Road AADT	40,000
Opening Year - Minor Road AADT	24,000
Design Year - Major Road AADT	43,000
Design Year - Minor Road AADT	29,000

Table 27. Case Study #2, Control Strategy Selection.

Control Strategy	Include	Base Intersection
Traffic Signal	Yes	--
Traffic Signal (Alternative Configuration)	No	--
Minor Road Stop	No	--
All-Way Stop	No	--
1-Lane Roundabout	No	Traffic Signal
2-Lane Roundabout	No	Traffic Signal
Displaced Left-Turn (DLT)	Yes	Traffic Signal
Median U-Turn (MUT)	Yes	Traffic Signal
Signalized Restricted Crossing U-Turn (RCUT)	Yes	Traffic Signal
Unsignalized Restricted Crossing U-Turn (RCUT)	No	Minor Road Stop
Continuous Green-T (CGT) Intersection	No	Traffic Signal
Jughandle	No	Traffic Signal
Other 1	No	Traffic Signal
Other 2	No	Minor Road Stop

Step #4: Enter data required to apply Part C CMFs on *At-Grade Inputs* tab.

As **Table 28** shows, engineers entered the number of anticipated turn lanes for each strategy evaluated on the *At-Grade Inputs* tab to determine the appropriate Part C CMF to apply for each control strategy. As the AADT on each approach is anticipated to remain the same between control strategies, the optional overrides for opening year and design year AADTs of a traffic signal were left unaltered.

Table 28. Case Study #2, Part C CMF Inputs.

Input		Control Strategy			
		Traffic Signal	Displaced Left-Turn (DLT)	Median U-Turn (MUT)	Signalized RCUT
Number of Approaches with Left-Turn Lanes	Additional Required Control Strategy Inputs	4			
Number of Approaches with Right-Turn Lanes		4			
Number of Uncontrolled Approaches with Left-Turn Lanes					
Number of Uncontrolled Approaches with Left-Turn Lanes					

As this is a planning-level analysis, none of the default values at the bottom of the *At-Grade Inputs* tab were modified.

Step #5: Determine availability of locally developed SPF calibration factors or CMFs.

A recent research study evaluated the safety performance of Median U-Turn intersections in this State, which led to the development of State-specific CMF values for overall (0.83) and fatal-injury crashes

(0.75). As these values differed from those derived for MUT intersections in NCHRP Report 420 (and used in the SPICE Tool), the CMF values for MUTs were overridden in the *Calibration* tab. **Table 29** shows this.

Table 29. Case Study #2, Overriding CMF Values with Locally Developed CMFs.

Local CMFs				
Optional - Override default CMFs with locally-developed or new CMFs				
Control	**Type of Crashes**	**Default CMF**	**Optional User Override**	**Use Value**
Displaced Left-Turn (DLT)	Total	0.88		0.88
	Fatal-Injury	0.88		0.88
Median U-Turn (MUT)	Total	0.85	0.83	0.83
	Fatal-Injury	0.70	0.75	0.75
Signalized Restricted Crossing U-Turn (RCUT), also known Superstreet	Total	0.85		0.85
	Fatal-Injury	0.78		0.78

Step #6: Review the crash frequencies predicted on the *Results* tab.

Table 30 illustrates the outputs on the *Results* tab.

Table 30. Case Study #2, Results.

Results					
Summary of crash prediction results for each alternative					
Project Information					
Project Name:	SR 19/SR 380 Improvements			**Intersection Type**	At-Grade Intersections
Intersection:	SR 19 (Sulaski Hwy)/SR 380 (N Bridge Street)			**Opening Year**	2020
Agency:	State Department of Transportation			**Design Year**	2025
Project Reference:	XX-####-XXXX			**Facility Type**	On Urban and Suburban Arterial
City:	Charleston			**Number of Legs**	4-legs
State:	XXXX			**1-Way/2-Way**	2-way Intersecting 2-way
Date:	11/1/2017			**# of Major Street Lanes**	5 or fewer
Analyst:	AJB			**Major Street Approach Speed**	Less than 55 mph
Crash Prediction Summary					
Control Strategy	**Crash Type**	**Opening Year**	**Design Year**	**Total Project Life Cycle**	**AADT Within Prediction Range?**
Traffic Signal	Total	7.90	8.91	50.43	Yes
	Fatal & Injury	2.81	3.18	17.95	
Displaced Left-Turn (DLT)	Total	6.95	7.84	44.38	N/A
	Fatal & Injury	2.47	2.80	15.80	
Median U-Turn (MUT)	Total	6.56	7.39	41.86	N/A
	Fatal & Injury	2.11	2.38	13.47	
Signalized RCUT	Total	6.72	7.57	42.87	N/A
	Fatal & Injury	2.19	2.48	14.00	

Despite using a locally calibrated fatal-injury crash CMF for MUT intersections that was higher than derived in NCHRP Report 420, the MUT intersection was still anticipated to have the lowest overall and fatal-injury crash frequencies relative to the other three alternatives analyzed. However, both the Signalized RCUT and Displaced Left-Turn are anticipated to have a similar number of crashes over the life of the project. Given their relative similarities in predicted safety performance, other differentiating factors within the ICE (e.g., traffic operations, environmental impacts) will likely play a large role in determining the most appropriate control strategy.

CASE STUDY #3. NEW INTERCHANGE

Burgeoning traffic demands along the outskirts of Pueblo have lead to oversaturation of several of interchanges along I-7. To help alleviate congestion, a new interchange between I-7 and Route 535 (Zermatt Road) is being proposed to reroute local trips within the network. **Figure 4** illustrates the site location, which currently features agriculutral land uses in all four quadrants. Engineers used regional traffic models for the opening year (2020) and the design year (2035) to develop traffic forecasts for the ramp terminals.

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Figure 4. Case Study #3, Site Location.

Currently, the two-lane overpass (Zermatt Road) over the eight-lane highway (I-7) is scheduled for a complete replacement. A diamond form has been chosen because there are no unique impediments to acquiring right-of-way in any of the quadrants. The only control strategy exluded from the evaluation is Stop control on the ramp terminals based on the high volume forecasts on Zermatt Road. Each of the other ramp terminal control strategies contained with the SPICE Tool were evaluated to determine their expected relative safety performnace:

- Conventional Traffic Signal
- Crossover Traffic Signal (of DDI)
- 1-Lane Roundabout
- 2-Lane Roundabout

The following steps were applied within the SPICE Tool:

1. Review information provided on *Introduction* tab.
2. Enter basic project information on *Project Information* tab.
3. Select an evaluation type and enter information on *Control Strategy Selection* tab.
4. Enter data required to apply Part C CMFs on *Ramp Terminal Inputs* tab.
5. Determine availability of locally developed SPF calibration factors or CMFs.
6. Review crash frequencies predicted on the *Results* tab.

Each of these steps is outlined subsequently.

Step #1: Review the information provided on *Introduction* tab.

Prior to applying the SPICE tool, the information on the *Introduction* tab was reviewed.

Step #2: Enter basic project information on *Project Information* tab.

As **Table 31** shows, the basic project information was entered on the *Project Information* tab to document which project was being analyzed.

Table 31. Case Study #3, Project Information Tab.

Project Information	
Project Name:	Zermatt Road Interchange
Intersection:	I-7/Route 535 (Zermatt Road)
Agency:	State Department of Transportation
Project Reference:	XX-####-XXXX
City:	Pueblo
State:	XXXX
Date:	11/1/2017
Analyst:	AJB

Step #3: Select evaluation type and enter information on *Control Strategy Selection* tab.

After entering the basic project information, the ramp terminal intersection type was selected on the *Control Strategy Selection* tab. This selection determined the inputs required for the remainder of the analysis. **Table 32** illustrates the facility level inputs entered into the tool. **Table 33** illustrates the selection of control strategies to be included in the SPICE analysis.

Table 32. Case Study #3. Facility-Level Inputs.

Intersection Type	Ramp Terminal Intersections	
Analysis Year	Opening and Design Year	
Opening Year	2020	
Design Year	2035	
Freeway Orientation	North-South	
Area Type	Rural	
Opening Year AADT	**NB Ramp Terminal**	**SB Ramp Terminal**
Crossroad - Inside Leg	21500	21000
Crossroad - Outside Leg	19700	19500
Exit Ramp	4500	4000
Entrance Ramp	3000	3000
Design Year AADT	**NB Ramp Terminal**	**SB Ramp Terminal**
Crossroad - Inside Leg	25000	24500
Crossroad - Outside Leg	23400	23300
Exit Ramp	5000	5000
Entrance Ramp	3300	3350

Table 33. Case Study #3, Control Strategy Selection.

Traffic Control (both intersections)	Include	Base Intersection
Conventional Traffic Signal	Yes	--
Conventional Traffic Signal (Alt)	No	--
Crossover Traffic Signal (of DDI)	Yes	--
Single-Point Diamond Traffic Signal	No	--
Minor Road (ramp) Stop	No	--
1-lane Roundabout	No	Minor Road (ramp) Stop
2-lane Roundabout	No	Minor Road (ramp) Stop
Other 1	No	Conventional Traffic Signal
Other 2	No	Minor Road (ramp) Stop

Step #4: Enter data required to apply Part C CMFs on *Ramp Terminal Inputs* tab.

As **Table 34** shows, the number of anticipated crossroad lanes for the signalized control strategy was entered on the *Ramp Terminal Inputs* tab to determine the appropriate Part C CMF to apply. As the AADT on each approach is anticipated to remain the same between control strategies, the optional overrides for opening year and design year AADTs of a traffic signal were left unaltered.

Table 34. Case Study #3, Part C CMF Inputs.

Alternative	Traffic Signal	
	4-Leg Terminal w/ Diagonal Ramps (D4)	
Ramp Terminal	NB Ramp Terminal	SB Ramp Terminal
Number of Crossroad Lanes	2	2
Number of through traffic lanes that oppose the left-turn movement on inside crossroad leg	2	2
Number of through traffic lanes that oppose the left-turn movement on outside crossroad leg	0	0

As this is a planning level-analysis, none of the default values at the bottom of the *Ramp Terminal Inputs* tab were modified.

Step #5: Determine availability of locally developed SPF calibration factors or CMFs.

At the time of the project, no locally developed SPF calibration factors have been developed for the identified control strategies. As a result, no changes were made on the *Calibration* tab.

Step #6: Review the crash frequencies predicted on the *ResultsRTI* tab.

Table 35 illustrates the outputs on the *ResultsRTI* tab.

Table 35. Case Study #3, Results.

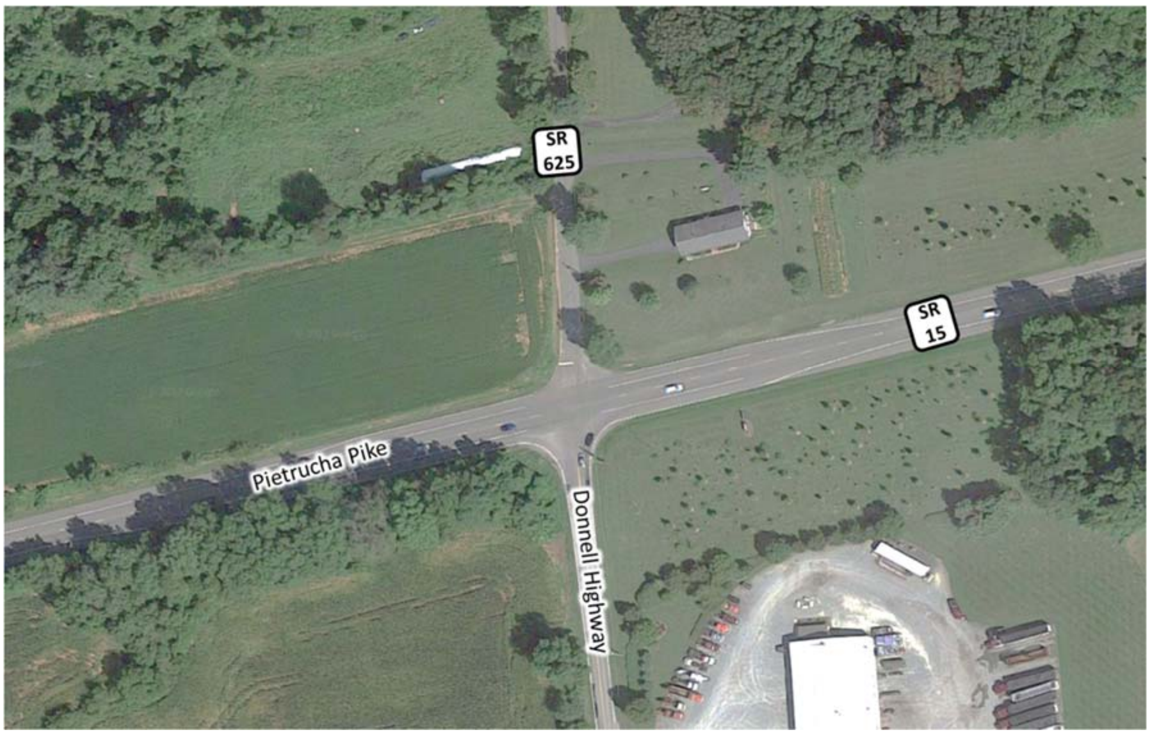
Results					
Summary of crash prediction results for each alternative					
Project Information					
Project Name:	Zermatt Road Interchange			**Intersection Type**	Ramp Terminal Intersections
Intersection:	I-7/Route 535 (Zermatt Road)			**Opening Year**	2020
Agency:	State Department of Transportation			**Design Year**	2035
Project Reference:	XX-####-XXXX			**Area Type**	Rural
City:	Pueblo				
State:	XXXX				
Date:	11/1/2017				
Analyst:	AJB				
Crash Prediction Summary					
Control Strategy	**Crash Type**	**Opening Year**	**Design Year**	**Total Project Life Cycle**	**AADT Within range?**
Conventional Traffic Signal	Total	8.74	10.92	157.02	Yes
	Fatal & Injury	3.28	4.11	59.03	
Crossover Traffic Signal (of DDI)	Total	5.85	7.31	105.21	N/A
	Fatal & Injury	1.93	2.43	34.83	
1-Lane Roundabout	Total	1.84	2.30	33.12	N/A
	Fatal & Injury	0.32	0.41	5.76	
2-Lane Roundabout	Total	No SPF	No SPF	No SPF	N/A
	Fatal & Injury	No SPF	No SPF	No SPF	

Application of the SPFs and CMFs show that a 1-Lane roundabout ramp terminal is predicted to have fewer total and fatal and injury crashes than a conventional traffic signal or crossover traffic signal (of

DDI). The 2-Lane roundabout alternative cannot be evaluated in this scenario because of the lack of an available CMF or SPF for this location.

CASE STUDY #4. EXISTING TWO-WAY STOP WITH SAFETY AND CAPACITY ISSUES

A corridor study of State Route 625 in Rickman evidenced the four-legged, Stop-controlled intersection of Route25/Route 625 currently operates at level-of-service (LOS) *F* during the weekday a.m. and weekday p.m. peak hours. A review of the historical crash data also showed a pattern of angle crashes between minor and major approach movements. The study intersection lies just east of Cookeville, and aside from the small residential community to the east, the surrounding area primarily consists of farmland. Land uses directly adjacent to the study intersection include low-density farmlands. The purpose of the overall ICE is to determine if a different control strategy would help alleviate these existing issues, as well as accommodate anticipated future growth in the region. **Figure 5** illustrates the study intersection.



Original Photo: © 2014 Google® (modified by Kittelson & Associates, Inc.)

Figure 5. Case Study #4, Site Location.

The preliminary analyses evidenced that many intersection-control types would not be suitable given the two-lane, rural nature of Route 15 and Route 525 in the region. The turning movement counts and crash history at the intersection lent themselves to three intersection-control strategies:

- Two-way Stop-control (*existing*)
- Traffic Signal
- Roundabout

The existing two-way Stop-control strategy was included in the analyses in the event neither of the two proposed control strategies offered improvements to existing conditions or further vetting evidenced they were not viable.

The SPICE Tool was applied to help evaluate the three identified control strategies based on anticipated safety performance. The following steps were applied:

1. Review information provided on the *Introduction* tab.
2. Enter basic project information on the *Project Information* tab.
3. Select an evaluation type and enter information on *Control Strategy Selection* tab.
4. Enter data required to apply Part C CMFs on *At-Grade Inputs* tab.
5. Determine whether locally developed SPF calibration factors or CMFs are available.
6. Review the crash frequencies predicted on the *Results* tab.

The following outlines each of these steps.

Step #1: Review information provided on the *Introduction* tab.

Prior to applying the SPICE Tool, the information on the *Introduction* tab was reviewed.

Step #2: Enter basic project information on the *Project Information* tab.

As **Table 36** shows, the basic project information was entered on the *Project Information* tab to document which project was being analyzed.

Table 36. Case Study #4, Project Information Tab.

Project Information	
Project Name:	SR 15/SR 525 Improvements
Intersection:	SR 15 (Pietrucha Pike)/SR 525 (Donnell Hwy)
Agency:	State Department of Transportation
Project Reference:	XX-####-XXXX
City:	Rickman
State:	XXXX
Date:	11/1/2017
Analyst:	AJB

Step #3: Select evaluation type and enter information on *Control Strategy Selection* tab.

After entering the basic project information, the intersection type was selected on the *Control Strategy Selection* tab. This selection determined the inputs required for the remainder of the analysis. **Table 37** illustrates the facility level inputs entered into the tool. **Table 38** illustrates the selection of control strategies to be included in the SPICE analysis. As determined in the preliminary stages of the ICE, only three control strategies are being proposed for evaluation. All other control strategies were excluded from the evaluation by selecting *No* under the *Include* column at the bottom of the tab.

Table 37. Case Study #4, Facility Level Inputs.

Intersection Type	At-Grade Intersections
Analysis Year	Opening and Design Year
Opening Year	2018
Design Year	2020
Facility Type	On Rural Two Lane Highway
Number of Legs	4-leg
Opening Year - Major Road AADT	10,000
Opening Year - Minor Road AADT	2,200
Design Year - Major Road AADT	10,500
Design Year - Minor Road AADT	2,400

Table 38. Case Study #4, Control Strategy Selection.

Control Strategy	Include	Base Intersection
Traffic Signal	Yes	--
Traffic Signal (Alternative Configuration)	No	--
Minor Road Stop	Yes	--
All-Way Stop	No	--
1-Lane Roundabout	Yes	Minor Road Stop
2-Lane Roundabout (No SPF/CMF Available)	No	
Displaced Left-Turn (DLT)	No	Traffic Signal
Median U-Turn (MUT)	No	Traffic Signal
Signalized Restricted Crossing U-Turn (RCUT)	No	Traffic Signal
Unsignalized Restricted Crossing U-Turn (RCUT)	No	Minor Road Stop
Continuous Green-T (CGT) Intersection	No	Traffic Signal
Jughandle	No	Traffic Signal
Other 1	No	Traffic Signal
Other 2	No	Minor Road Stop

Step #4: Enter data required to apply Part C CMFs on *At-Grade Inputs* tab.

As **Table 39** shows**,** the number of anticipated turn lanes for each strategy evaluated was entered on the *At-Grade Inputs* tab to determine the appropriate Part C CMF to apply for each control strategy. As the AADT on each approach is anticipated to remain the same between control strategies, the optional overrides for opening year and design year AADTs of a traffic signal were left unaltered.

Table 39. Case Study #4, Part C CMF Inputs.

Input		Control Strategy		
		Traffic Signal	**Minor Road Stop**	**1-lane Roundabout**
Number of Approaches with Left-Turn Lanes	Additional Required Control Strategy Inputs	2		
Number of Approaches with Right-Turn Lanes		2		
Number of Uncontrolled Approaches with Left-Turn Lanes			2	
Number of Uncontrolled Approaches with Left-Turn Lanes			2	

Given the rural nature of the study intersection, the intersection would likely remain without roadway lighting under the current two-way Stop-control. As such, the planning-level Part C CMF input for intersection lighting was overridden at the bottom of the tab. **Table 40** shows the Part C CMF input in the *At-Grade Inputs* tab.

Table 40. Case Study #4, Overriding Default Part C CMF Inputs.

Input	Control Strategy			
		Traffic Signal	Minor Road Stop	1-lane Roundabout
	Highway Safety Manual Part C CMF Inputs			
Skew Angle	A yellow cell indicates the value may be used in the SPF computation	N/A	0	N/A
Lighting Present		Yes	No	
# of Approaches Permissive LT Signal Phasing		0		
# of Approaches Perm/Protected LT Signal Phasing		0		
# of Approaches Protected LT Signal Phasing		0		
Number of Approaches with Right-Turn-on-Red Prohibited		0		
Red Light Cameras Present		No		
Number of Major Street Through Lanes		0		
Number of Minor Street Lanes		0		
Pedestrian Volume by Activity Level		Low (50)		
User-Specified Sum of all daily pedestrian crossing volumes		50		
Max # of Lanes Crossed by Pedestrians		5		
Number of Bus Stops within 1,000 ft of Intersection		0		
Schools within 1,000 ft of intersection		No		
Number of Alcohol Sales Establishments within 1,000 ft of Intersection		0		

Step #5: Determine availability of locally developed SPF calibration factors or CMFs.

At the time of the project, no locally developed SPF calibration factors have been developed for the identified control strategies. As a result, no changes were made on the *Calibration* tab.

Step #6: Review the crash frequencies predicted on the *Results* tab.

Table 41 illustrates the outputs on the *Results* tab.

Table 41. Case Study #4, Results.

Results			
Summary of crash prediction results for each alternative			
Project Information			
Project Name:	SR 15/SR 525 Improvements	**Intersection Type**	At-Grade Intersections
Intersection:	SR 15 (Pietrucha Pike)/SR 525 (Donnell Hwy)	**Opening Year**	2018
Agency:	State Department of Transportation	**Design Year**	2020
Project Reference:	XX-####-XXXX	**Facility Type**	On Rural Two Lane Highway
City:	Rickman	**Number of Legs**	4-leg
State:	XXXX	**1-Way/2-Way**	2-way Intersecting 2-way
Date:	11/1/2017	**# of Major Street Lanes**	5 or fewer
Analyst:	AJB	**Major Street Approach Speed**	Less than 55 mph

Crash Prediction Summary					
Control Strategy	**Crash Type**	**Opening Year**	**Design Year**	**Total Project Life Cycle**	**AADT Within Prediction Range?**
1-lane Roundabout	Total	0.59	0.64	1.84	N/A
	Fatal & Injury	0.11	0.12	0.36	
Minor Road Stop	Total	2.03	2.20	6.34	Yes
	Fatal & Injury	0.87	0.95	2.73	
Traffic Signal	Total	3.81	3.99	11.69	Yes
	Fatal & Injury	1.29	1.36	3.97	

The crash predictions show a single-lane roundabout is anticipated to result in approximately 29 percent and 16 percent of the total crashes predicted for the minor road stop control and traffic signal control strategies, respectively, over the lifecycle of the project. It is also forecast to have approximately 87 percent fewer fatal and injury crashes over the lifecycle of the project relative to the minor road Stop-control and 91 percent fewer fatal and injury crashes relative to the traffic signal.

For More Information:

Visit [https://safety.fhwa.dot.gov/intersection/ice/]

FHWA, Office of Safety

Jeffrey Shaw
jeffrey.shaw@dot.gov
708-283-3524

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