Incorporating Data-Driven Analysis in Intersection Analyses Through the Use of Intersection Control Evaluations:

A How-To Guide

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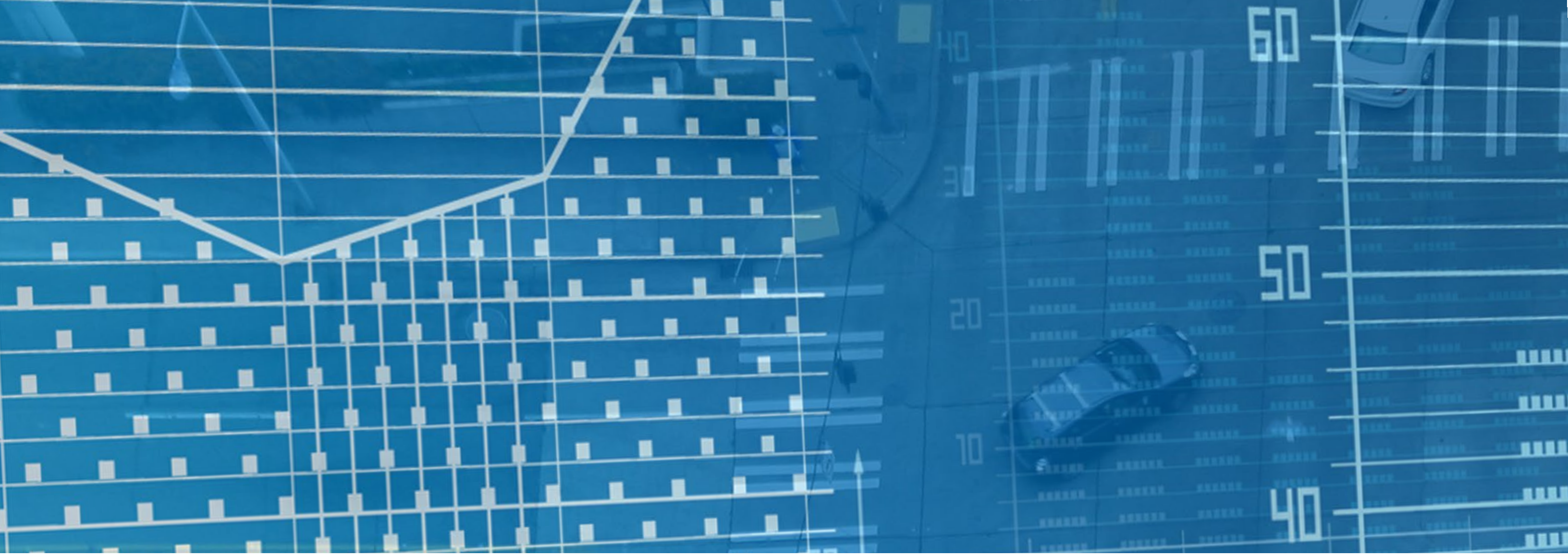
U.S. Department of Transportation
Federal Highway Administration



Introduction

Background

Traditionally, safety analysis to support roadway and intersection planning and design was largely based on qualitative or surrogate measures, or consisted only of a historical summary of crashes. Data-Driven Safety Analysis (DDSA) employs newer, evidence-based models that provide state and local agencies with the means to quantify safety impacts, similar to the way they do other impacts such as environmental effects, traffic operations, and pavement condition. DDSA provides reliable estimates of an existing or proposed roadway's current and future safety performance and helps agencies make more informed decisions, better target investments, and reduce crashes occurring on their roadways. This guide describes how DDSA is being incorporated into intersection projects.

When an intersection project is contemplated, studies are usually conducted to evaluate various alternatives. Typically, these studies involve intersection analyses that focus more on the capacity and operational aspects of the alternatives being considered, and less (if any) on analyzing the substantive safety performance of the proposed alternatives. To remedy this disconnect, a growing number of transportation agencies have begun implementing intersection control evaluation (ICE) policies and procedures. ICE is a data-driven, performance-based framework used to objectively screen alternatives and identify an optimal solution for an intersection. It involves quantitative and independent analyses of the safety, operations, right-of-way, cost, and other metrics important to transportation agencies. DDSA serves as the platform for comparing safety performance among intersection alternatives under the ICE process.

According to the Federal Highway Administration (FHWA) Primer on ICE, the ICE process is intended to occur as part of an established project development process, and apply to the construction of new intersections or when an agency is considering making any substantive changes to the traffic control or geometry of existing intersections. Substantive changes are usually considered for the following reasons:

- *To implement safety improvements,*
- *To relieve congestion,*
- *To enhance multimodal facilities,*
- *To change the access to an adjacent parcel of land or development, and*
- *To implement broader corridor improvements, such as widening.*

Credit: Fotosearch.com

Benefits of Using DDSA on Intersection Projects

Incorporating DDSA into ICE helps to elevate safety performance as a criterion for choosing a preferred alternative, thereby enabling the development of safer roadways with each intersection project. From the transportation agency's perspective, incorporating DDSA into the project development phases of every intersection project can foster steady progress toward achieving reductions in fatal and serious injury crashes, which form the basis of initiatives such as Vision Zero and Toward Zero Deaths.

This guide provides a high-level overview of how to conduct straightforward safety analyses using readily available tools and data as part of the ICE process. Information on the tools discussed in this guide and others can be found at Data-Driven Safety Analysis Resources - DDSA Toolbox. In addition, some state and local agencies have developed their own tools. Therefore, the analyst conducting the analysis should check with the agency about data availability and tool preferences.

Overview of the Intersection Control Evaluation Process

A typical ICE is conducted in two distinct stages. The first stage, scoping (or screening), is usually completed early in the project development process. During Stage 1, the analyst will inventory existing conditions by reviewing physical characteristics and geometrics, collecting traffic and safety data, characterizing the adjacent land uses, and assessing the site for walking and biking. Next, the analyst assesses the existing condition and an array of potential alternatives to determine if and to what extent each meets the project purpose and need, project goals, and site constraints. The purpose of Stage 1 is to establish a short list of viable design and control strategies for the intersection being evaluated. If there are multiple viable alternatives, these alternatives proceed to Stage 2 for further design development and in-depth analysis to determine the preferred alternative. The results from Stage 2 can be used to conduct a benefit-cost analysis to support the selection of the preferred alternative.

Figure 1 shows the integration of DDSA into the typical intersection analysis process by conducting an ICE, with the opportunities to integrate safety shown in **bold** lettering.

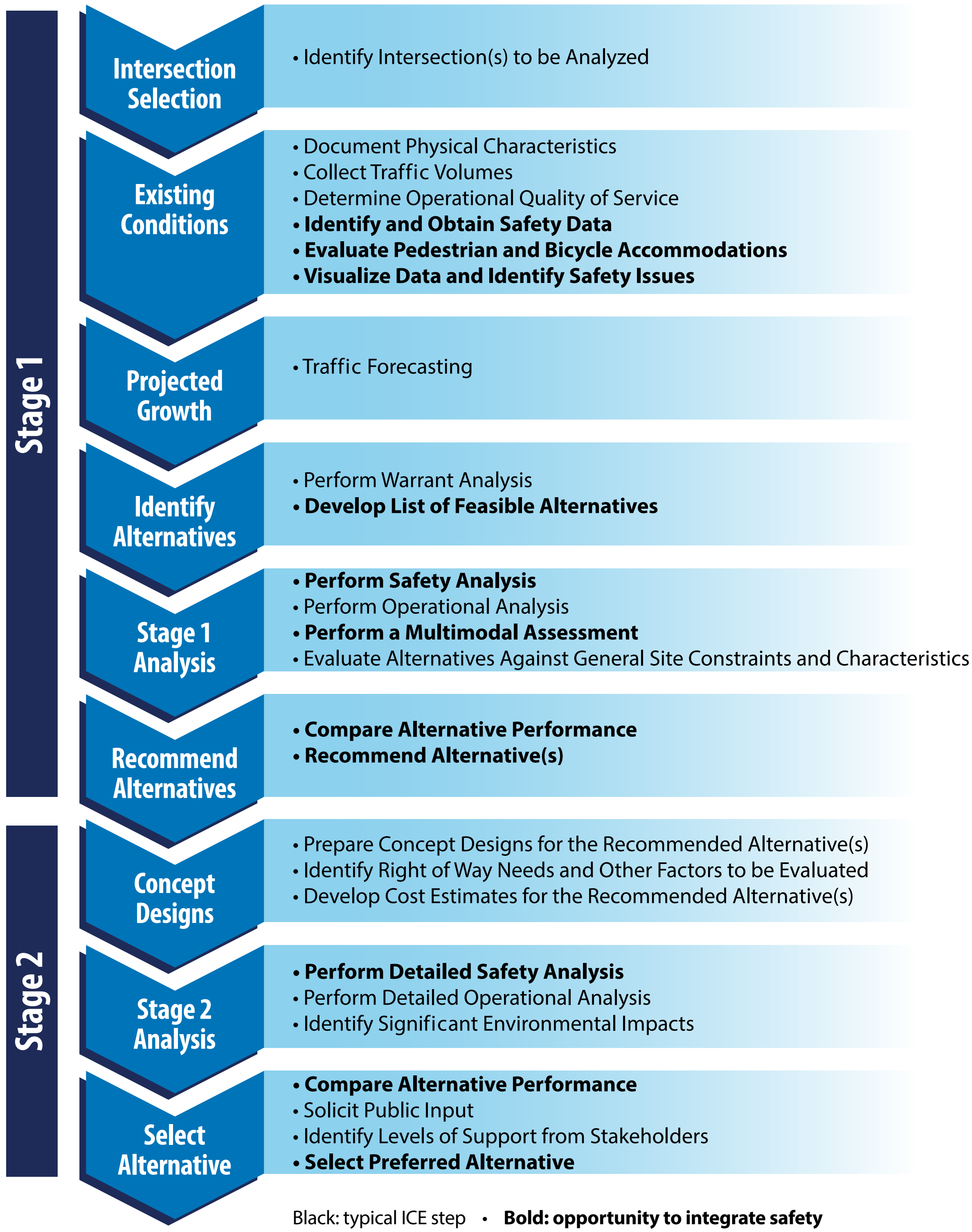


Figure 1: Opportunities to Integrate Safety in the Typical Intersection Analysis Process Using ICE

Application of DDSA into Intersection Analyses

There are several opportunities to apply DDSA approaches and concepts into intersection analyses. These opportunities include obtaining and visualizing safety data, evaluating pedestrian and bicyclist accommodations, and conducting safety analyses on potential alternatives. This and other information about overcoming potential challenges in applying DDSA can be found in the companion document *Incorporating Data-Driven Safety Analysis in Traffic Impact Analyses: A How-To-Guide*.

Example: Intersection Analysis with Data-Driven Safety Analysis Integration

The following section provides an example of how DDSA can be integrated into an ICE. This example was based on an investigation due to ongoing safety concerns at the intersection. The example describes the typical process for an ICE, but places an emphasis on the crash data and safety analyses.

Project Overview

The intersection of Main Street and Park Avenue currently experiences heavy congestion and delay during both the AM and PM peak periods. A local property owner has also raised concerns regarding the number of crashes that have occurred at the intersection and has inquired about possible improvements. As a result, the road agency has determined that the intersection of Main Street and Park Avenue should undergo an intersection control evaluation.

Credit: Fotosearch.com

Existing Conditions and Projected Growth

Main Street and Park Avenue are rural two-lane roadways located in the town of Springfield. The intersection currently operates as a two-way stop-controlled intersection, with Main Street operating under free-flow conditions. Park Avenue comprises the southern leg of the intersection, while an unpaved driveway acts as the northern leg of the intersection. Both the north and south approaches operate under stop-controlled conditions. Existing signage at the intersection includes:

- *"Combination Curve/Intersection" (W1-10) signage with 30 MPH advisory speed plates on both the eastbound and westbound approaches,*
- *"Watch for Turning Vehicles" (W11-V3) signage along the eastbound approach, and*
- *Double-facing Chevron (W1-8L/W1-8R) signs on the southwest quadrant for approaching eastbound and westbound vehicles.*

The existing intersection geometry is shown in **Figure 2.**

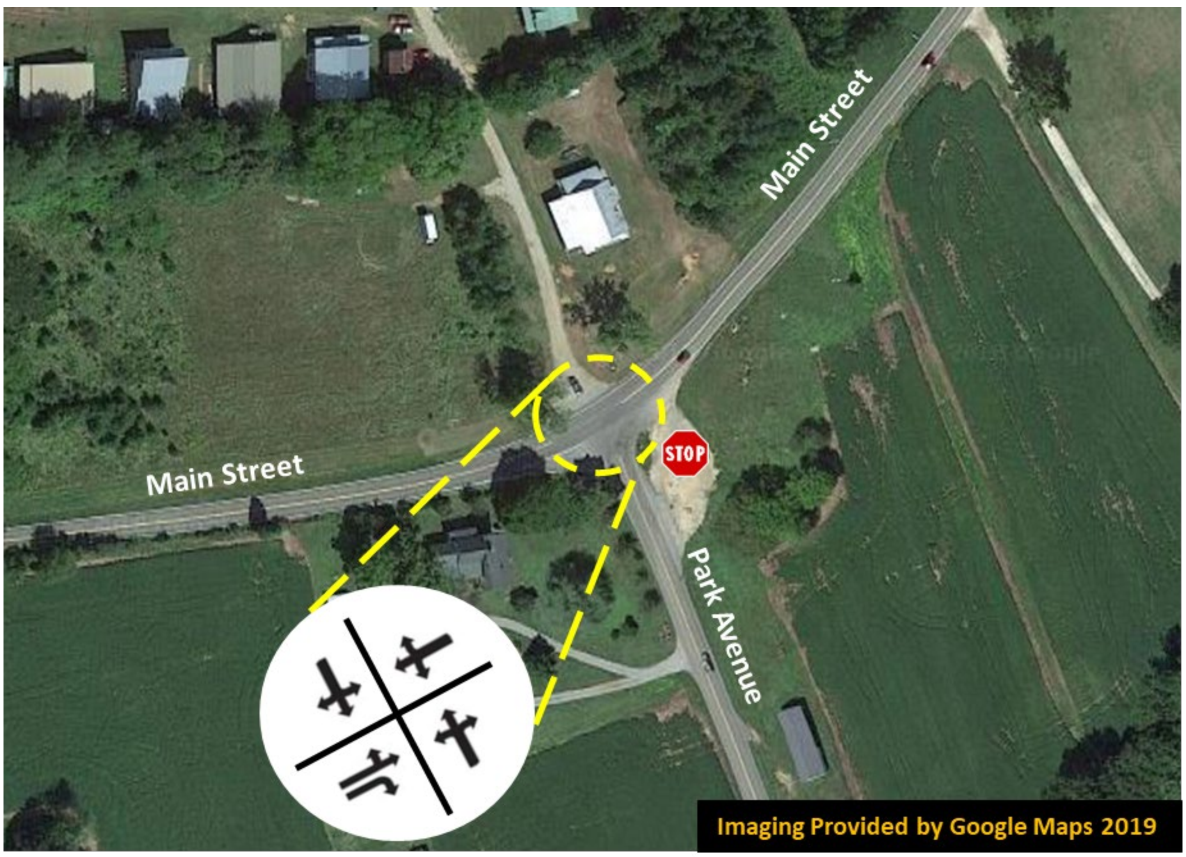


Figure 2: Existing Conditions

Existing (2018) Intersection Volumes

The analyst collected existing condition turning movement counts for the intersection on a typical weekday in 15-minute intervals. Turning movement counts were collected for both the AM (7:00 to 9:00 AM) and PM (4:00 to 6:00 PM) peak periods. The existing AM and PM peak hour turning movement volumes are shown in **Figure 3.**

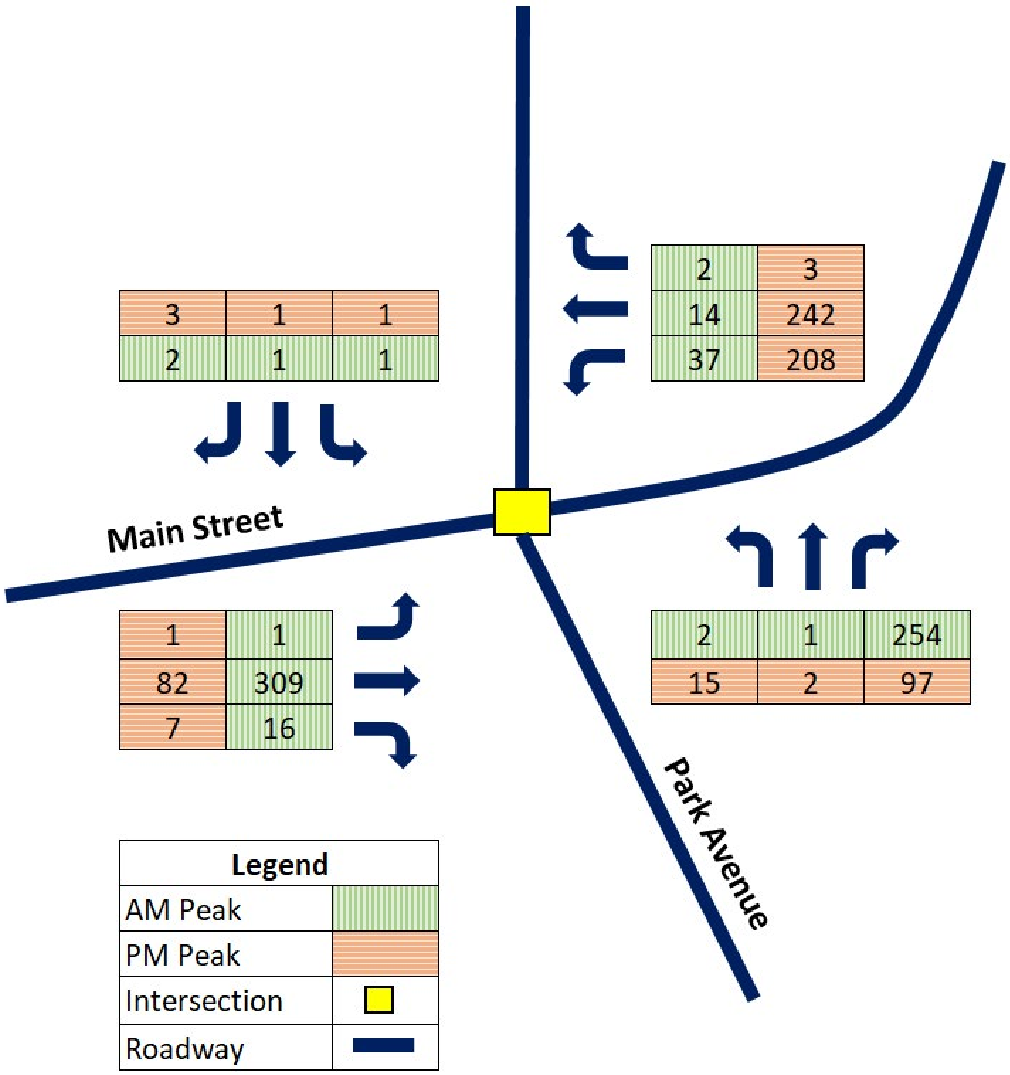


Figure 3: Existing Peak Hour Volumes

Pedestrian Volumes

Along with vehicular volumes, the analyst also collected pedestrian volumes for the intersection on a typical weekday in 15-minute intervals. The AM and PM peak period pedestrian counts are shown in **Table 1**.

Table 1: Peak Period Pedestrian Counts

Intersection Leg	AM Peak Period	PM Peak Period
North	0	2
South	0	0
East	1	0
West	0	1

Pedestrian and Bicycle Accommodations

While documenting the existing conditions, the analyst took an inventory of existing pedestrian and bicycle facilities during an on-site visit. The analyst documented the following observations:

- *There are no pedestrian facilities present within the study area. Neither Main Street nor Park Avenue is equipped with sidewalks. Crosswalks are not provided at any of the four intersection approaches.*
- *There were no ADA facilities, such as ramps and tactile domes, present at the intersection.*
- *A small number of cyclists were observed during the site visit. Due to the lack of separated bike facilities within the study area, all observed cyclists were seen sharing the road with motorists.*
- *There are no shared-use paths or trails present near the study intersection.*
- *No pedestrian generators are located immediately adjacent to the study intersection. However, the surrounding area is mostly residential.*

Crash Data

The most recent five years of crash data were obtained and analyzed to evaluate trends by time of day, type of crash, and roadway conditions, and to develop collision diagrams and crash summaries. The collision diagrams helped determine crash patterns in relation to the subject intersection. The findings of the crash data analyses, illustrated in **Figure 4** and **Figure 5**, included the following observations:

- *A total of 11 crashes occurred at the intersection in the 5-year study period (2013-2017), and 5 of these 11 crashes resulted in injuries.. There were no crashes in 2017.*
- *Angle and fixed object crashes are the most prominent crash types, both accounting for approximately 36% of the total number of crashes each. Rear-end crashes are the third most prominent crashes (18% of crashes).*
- *5 of the 11 crashes were a result of drivers "failing to maintain proper control." This could be a result of geometry and roadway conditions promoting higher speeds.*
- *3 of the 11 crashes occurred during dark lighting conditions. The lack of roadway lighting could be negatively impacting drivers' ability to see and react to the intersection.*
- *5 of the 11 crashes occurred under wet pavement conditions. The friction or pavement quality could be negatively impacting drivers' ability to navigate the intersection.*

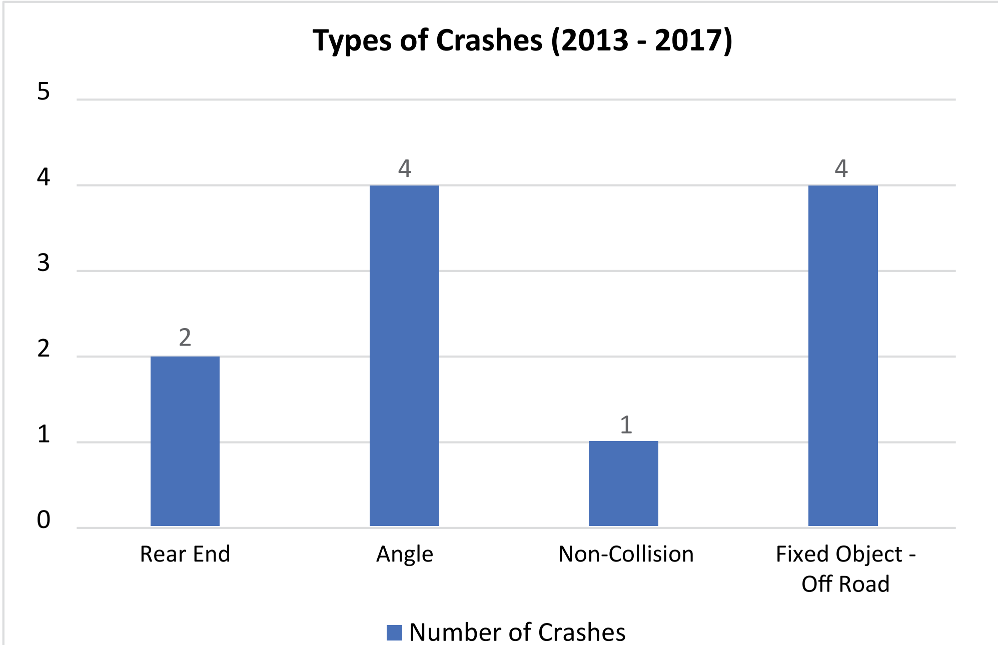


Figure 4: Crash Frequency by Type of Crash

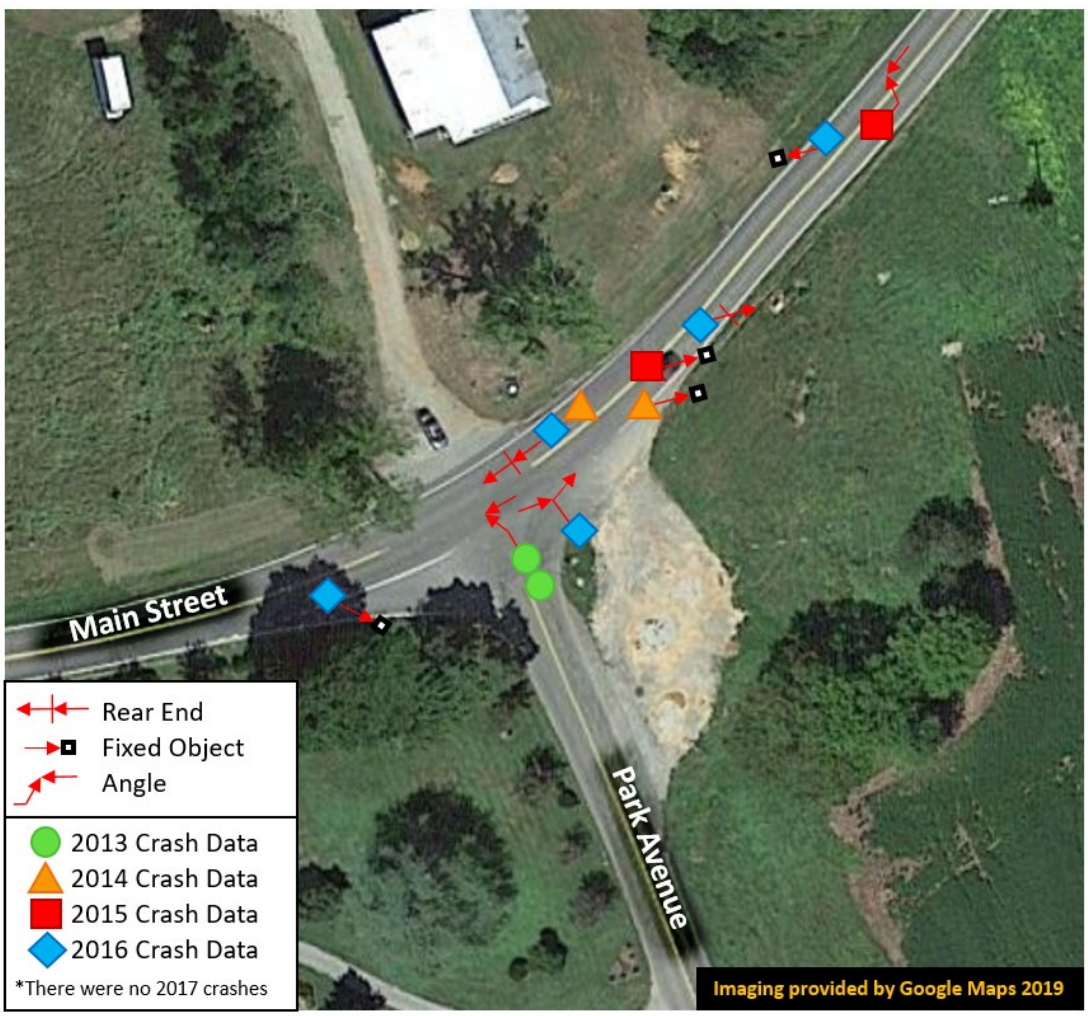


Figure 5: Collision Diagram (2013-2017)

Projected Growth

Volume Forecasting

The build-out date is projected to be 2020; however, the analyst projected traffic growth to 2040, the proposed horizon date, by applying a historic growth rate to existing 2018 traffic volumes. Historic AADT data was collected from the state department of transportation's (DOT) online database and used to determine historical growth trends along both Main Street and Park Avenue. **Table 2** outlines the expected growth rates along the corridor segments approaching the existing intersection. A growth rate was not provided for the unpaved driveway representing the north leg of the intersection; therefore, an average of the three growth rates was used (1.763%).

Table 2: Estimated Growth Rates

Approach	Growth Rate
Main Street from Second Street to Park Avenue	2.39%
Main Street from Park Avenue to Oak Lane	0.99%
Park Avenue from Maple Avenue to Main Street	1.91%

The projected future volumes for the AM and PM peak period are shown in **Figure 6.**

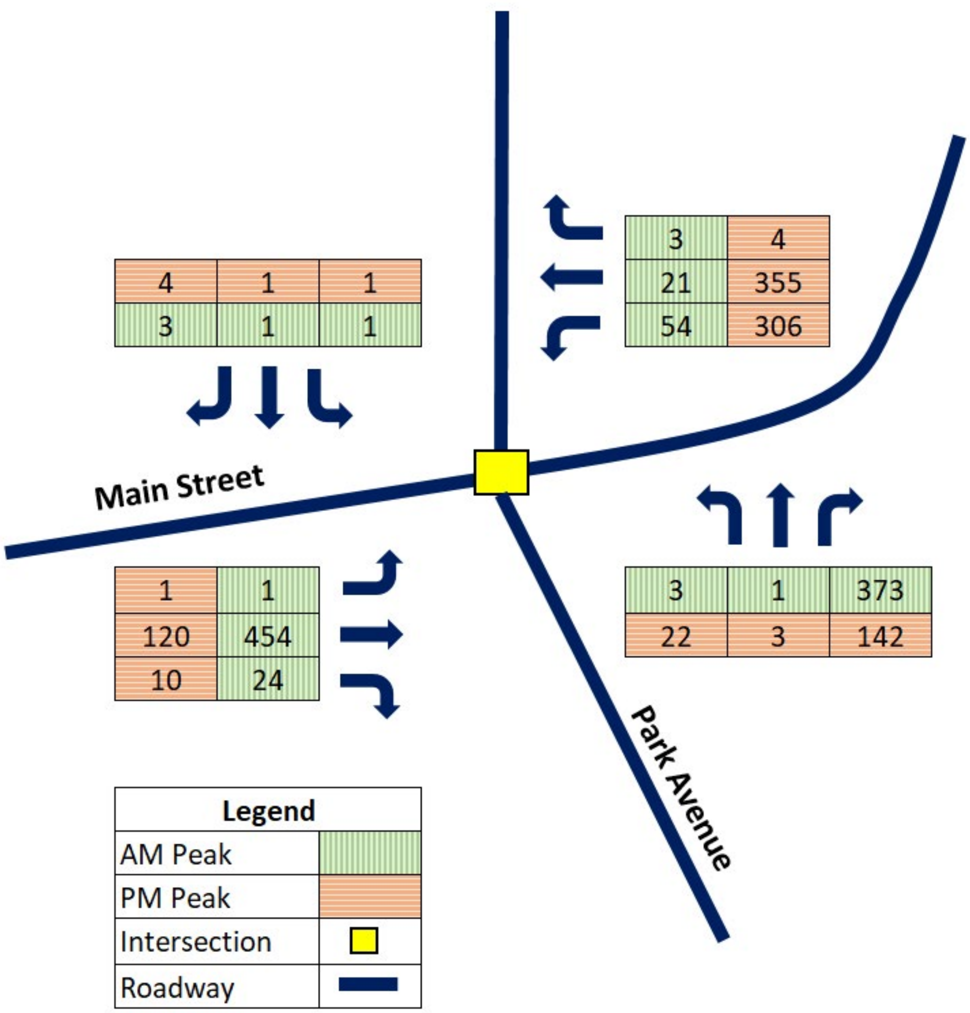


Figure 6: Future (2040) Peak Hour Volumes

Pedestrian Volumes

The analyst also projected pedestrian volumes to the design year (2040) to evaluate future pedestrian needs for the project alternatives. While pedestrian volumes are estimated to be low and there is not existing pedestrian connectivity along either corridor, the analyst considered installing low-cost pedestrian improvements to accommodate existing and future pedestrian demand.

Identify Alternatives

Preliminary Alternatives

Based on the results of the existing conditions evaluations, including the identification of safety issues, the analyst recommended the following alternatives:

- ***Alternative 1: Minor Road Stop with Turn Lane additions*** *This alternative proposes to straighten the existing curvature of Main Street and relocate the intersection to be northeast of its current location to eliminate any impacts to the private property on the southwest corner. This option maintains a two-way stop control at the study intersection but provides a modified lane geometry. Currently, three of the four approaches operate as shared lanes; however, the alternative proposes to modify two approaches to include separate turn lanes.*
- ***Alternative 2: Continuous T-Intersection*** *This alternative proposes to modify the existing intersection to accommodate a continuous T-intersection design to favor the major movements of westbound to southbound and northbound to eastbound. The southbound approach (unpaved driveway) will be relocated to the west of the intersection.*
- ***Alternative 3: Roundabout*** *This alternative proposes to modify the existing intersection to accommodate a roundabout design. As the intersection operates with low volumes, only one concept was proposed for evaluation purposes, which includes one circulating lane, with one lane entry and one lane exit points on all four approaches of the intersection.*

All three alternatives will include the addition of shoulders to provide pedestrians the ability to maintain separation from motor vehicles at the intersection.

Credit: Fotosearch.com

Stage 1 Scoping

Stage 1 analysis activities are designed to screen alternatives to determine if they are feasible as well as to calculate planning-level information on safety and operational performance.

Safety Analysis

The predictive analysis was conducted using the Safety Performance for Intersection Control Evaluation (SPICE) tool.[1] For purposes of comparing relative safety performance, crash frequencies and severities were calculated for each of the three alternatives described previously for both the opening year (2020) and the design year (2040). To conduct the analysis, the analyst filled the parameters within SPICE with the available intersection information, such as existing and future AADT, intersection configuration, and historical crash data.

The analyst established the basic analysis parameters and determined which control strategies to include in the SPICE analysis. The inputs selected for this analysis are shown in **Figure 7.** Opening year AADT's were obtained from the state DOT's traffic data database. The design year AADT's were calculated using historical growth rates for Main Street and Park Avenue. Since the northern leg of the study intersection functions as a driveway, only 3-legs were used for the analysis.

Control Strategy Selection and Inputs	
Specify the Facility Level Inputs and the Control Strategies to be included in the SPICE Analysis.	
Parameter	User Entry
Intersection Type	At-Grade Intersections
Analysis Year	Opening and Design Year
Opening Year	2020
Design Year	2040
Facility Type	On Rural Two Lane Highway
Number of Legs	3-leg
1-Way/2-Way	2-way Intersecting 2-way
# of Major Street Lanes (both directions)	5 or fewer
Major Street Approach Speed	Less than 55 mph
Opening Year - Major Road AADT	7,781
Opening Year - Minor Road AADT	3,363
Design Year - Major Road AADT	13,078
Design Year - Minor Road AADT	5,098

Figure 7: Control Strategy Selection Worksheet Inputs

1 *American Association of State Highway and Transportation Officials. (2019). Tools. Retrieved from the Highway Safety Manual website: http://www.highwaysafetymanual.org/Pages/Tools.aspx*

The control strategies selected for the analysis were "Minor Road Stop", "Continuous Green-T Intersection", and "1-Lane Roundabout", representing Alternatives 1, 2, and 3, respectively. The control strategy selections for this analysis are shown in **Figure 8.**

Control Strategy	Include	Base Intersection
Traffic Signal	No	--
Traffic Signal (Alternative Configuration)	No	--
Minor Road Stop	***Yes***	--
All Way Stop	No	--
1-Lane Roundabout	***Yes***	--
2-Lane Roundabout	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 Intersection	***Yes***	Traffic Signal
Jughandle	No	Traffic Signal
Other 1	No	Traffic Signal
Other 2	No	Minor Road Stop

Figure 8: Control Strategy Selections

The analyst used the At-Grade Inputs worksheet to enter pertinent information relating to the at-grade study intersection for the SPICE analysis. The top section of the page, shown in **Figure 9**, allows users to override AADT information taken from the Control Strategy Selection worksheet, as well as provide information regarding the number of turn lanes for the stop-controlled and signalized control strategies. Although they are associated with the Highway Safety Manual (HSM) Part C Crash Modification Factors (CMF), turn lane inputs are required for planning-level analysis because they have a relatively high impact on crash prediction values. The turning lane inputs were updated to reflect the accurate number of turning lanes included in the minor road stop with turn lane additions (Alternative 1).

Input	Input Type	Minor Road Stop	Control Strategy	
			1-lane Roundabout	Continuous Green-T Intersection
Opening Year Major Road AADT	Optional AADT Overrides	7781	7781	7781
Opening Year Minor Road AADT		3363	3363	3363
Design Year Major Road AADT		13078	13078	13078
Design Year Minor Road AADT		5098	5098	5098
Number of Approaches with Left-Turn Lanes	Additional Required Control Strategy Inputs			
Number of Approaches with Right-Turn Lanes				
Number of Uncontrolled Approaches with Left-Turn Lanes		2		
Number of Uncontrolled Approaches with Right-Turn Lanes		1		

Figure 9: At-Grade Intersection Inputs

The bottom section of the At-Grade Inputs worksheet allowed the analyst to override the default CMF-related inputs from Part C of the HSM. Since this is a planning-level analysis, the analyst left most of the inputs as the default value. The only inputs that were modified were the inscribed circle diameter and the volume entering the roundabout from the fourth leg, which represents the driveway on the northern end of the intersection. Once this step was completed, the analyst calculated the results of the analysis on the Results worksheet, shown in **Figure 10**

Results					
Summary of crash prediction results for each alternative					
Project Information					
Project Name:	Main Street Intersection Control Evaluation (ICE)		Intersection Type	At-Grade Intersections	
Intersection:	Main Street & Park Avenue		Opening Year	2020	
Agency:	State Department of Transportation		Design Year	2040	
Project Reference:	XX-####-XXXX		Facility Type	On Rural Two Lane Highway	
City:	Springfield		Number of Legs	3-leg	
State:	XXXX		1-Way/2-Way	2-way Intersecting 2-way	
Date:	12/1/2018		# of Major Street Lanes	5 or fewer	
Analyst:	John Smith		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	0.62	0.85	15.53	Yes
	Fatal & Injury	0.14	0.23	3.84	
Minor Road Stop	Total	1.24	2.28	36.75	No
	Fatal & Injury	0.51	0.95	15.25	
Continuous Green-T Intersection	Total	2.00	2.91	51.68	N/A
	Fatal & Injury	0.66	0.96	17.07	

Figure 10: Results Worksheet

The bottom section of the worksheet provides a crash prediction summary for each control strategy selected for this analysis. The summary includes the predicted total and fatal-injury crash frequencies for the opening year, design year, and the total project life cycle. For example, based on the results shown in **Figure 10**, the 1-lane roundabout is anticipated to have 0.62 total and 0.14 fatal-injury crashes during the opening year (2020), 0.85 total and 0.23 fatal-injury crashes during the design year (2040), and 15.53 total and 3.84 fatal-injury crashes over the project's lifecycle (2020-2040). The results are summarized in **Table 3.**

Table 3: Life Cycle Crash Frequency Results (SPICE)

Alternative	Total Project Life Cycle Crash Frequency
Future No-Build*	76.26 (44.61 – PDO; 31.65 – FI)
Minor Road Stop with Turn Lane additions (Alternative 1)	36.75 (21.50 – PDO; 15.25 – FI)
Continuous T-Intersection (Alternative 2)	51.68 (34.61 – PDO; 17.07 – FI)
Roundabout (Alternative 3)	15.53 (11.69 – PDO; 3.84 – FI)

**The crash frequency for the Future No-Build scenario was generated using the Minor Road Stop road strategy, similar to Alternative 1, but the at-grade intersection inputs were modified to reflect the existing number of lanes.*

Each of the proposed alternatives was compared to the Future No-Build scenario to determine total crash reductions. The equation below illustrates the calculation for determining total crash reduction percentages for each alternative and the results are shown in **Table 4.**

$$\textit{Total Crash Reduction Percentage} = \left(\frac{\textit{Alternative Crash Frequency - No Build Crash Frequency}}{\textit{No Build Crash Frequency}} \right)$$

$$\textbf{Alternative 1}\ \textit{Total Crash Reduction Percentage} = \left(\frac{36.75 - 76.26}{76.26} \right) \text{x } 100\%$$

Table 4: Crash Reduction Results from SPICE

Alternative	Total Project Life Cycle Crash Frequency	Total Crash Reduction	Total Crash Reduction (Percentage)
Future No-Build	76.26 (44.61 – PDO; 31.65 – FI)	N/A	0%
Minor Road Stop with Turn Lane additions (Alternative 1)	36.75 (21.50 – PDO; 15.25 – FI)	39.51 (23.11 – PDO; 16.40 – FI)	51.8%
Continuous T-Intersection (Alternative 2)	51.68 (34.61 – PDO; 17.07 – FI)	24.58 (10.00 – PDO; 14.58 – FI)	32.2%
Roundabout (Alternative 3)	15.53 (11.69 – PDO; 3.84 – FI)	60.73 (32.92 – PDO; 27.81 – FI)	79.6%

Based on the safety analysis, **51.8%, 32.2%,** and **79.6%** total crash reduction percentages are expected for Alternatives 1, 2, and 3, respectively.

Operational Analysis

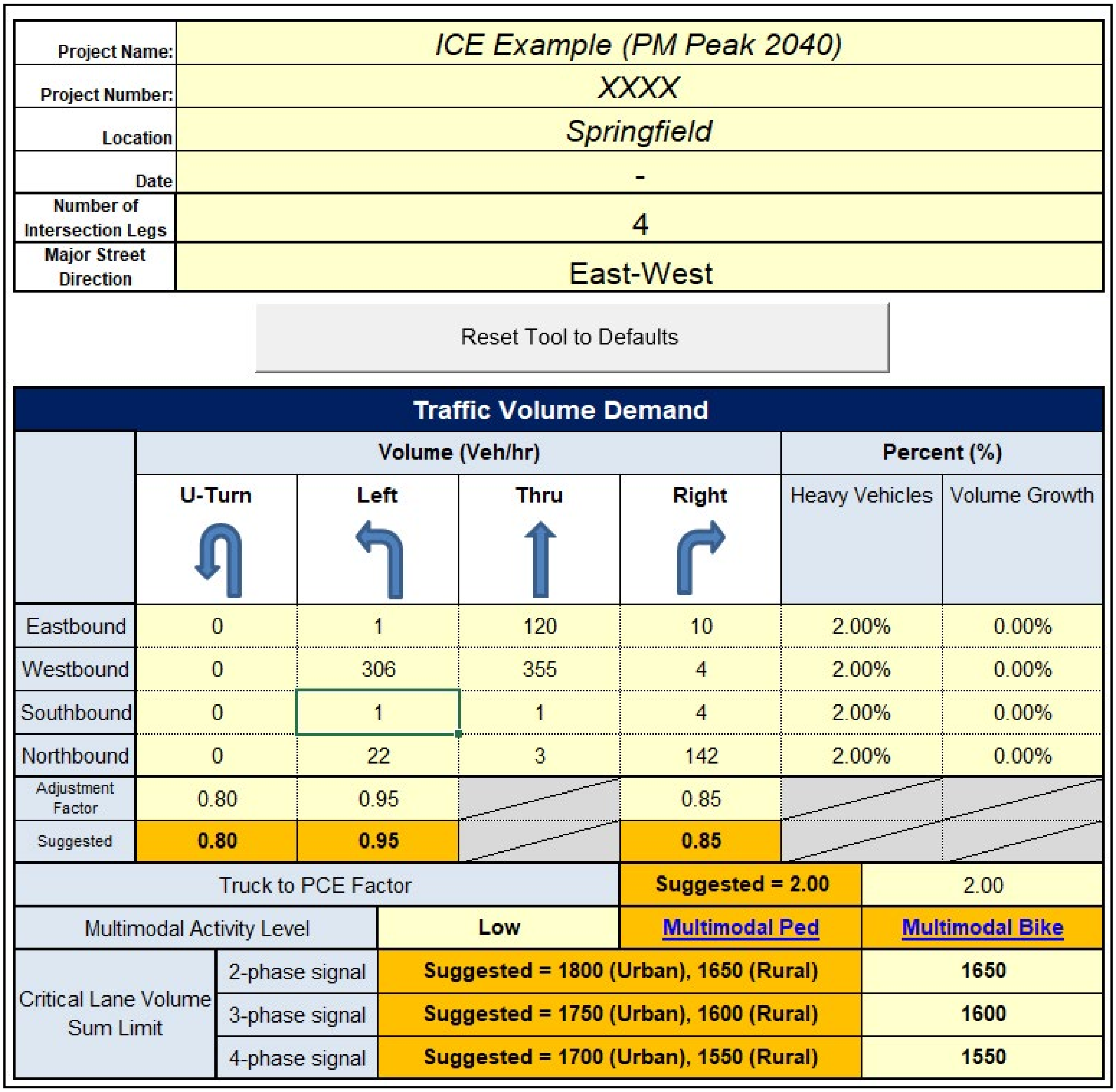
The analyst conducted a capacity analysis for the three alternatives using the Capacity Analysis for Planning of Junctions (CAP-X) tool,[2] as shown in **Figure 11**. The analyst used peak traffic volumes as well as details on lane configuration, pedestrian facilities, and bicyclist facilities to estimate the volume-to-capacity (V/C) ratio for each alternative.

The first step of the CAP-X analysis involves entering the traffic volume information. In order to account for the different analysis periods (AM and PM peak) and geometric arrangements (4-legged for Alternatives 1 and 3 and 3-legged for Alternative 2), four separate runs of CAP-X are required. The volumes are consistent across the different analysis scenarios, except for the very low volumes related to the north leg, which would not exist if 3-legged, effectively eliminating those volumes for analysis purposes. **Table 5** reflects the volumes used for the 2040 PM peak period for the 4-legged scenarios. Note that in addition to hourly flows for each movement by approach in vehicles per hour, CAP-X prompts for the percentage of heavy vehicles and percentage of volume growth. For these analyses, truck percentage was set at 2 percent, and since future traffic demand was accounted for separately, volume growth was set to zero. Additional parameters required for CAP-X input includes the factor to use for Truck to Passenger Car Equivalent (PCE), Multimodal Activity Level (pedestrians/bicycles from low to high), and Critical Lane Volume Sum Limit based on number of basic signal phases. For all these additional parameters, default suggested values were used.

2 *American Association of State Highway and Transportation Officials. (2019). Tools. Retrieved from the Highway Safety Manual website: http://www.highwaysafetymanual.org/Pages/Tools.aspx*

Table 5: CAP-X Analysis Traffic Volume Demand Inputs for the 4-Legged Intersection Alternatives.

Approach Direction	U-Turn Volume (veh/hr)	Left Turn Volume (veh/hr)	Thru Volume (veh/hr)	Right Turn Volume (veh/hr)	Heavy Vehicles (percent)	Volume Growth (percent)
Eastbound	0	1	120	10	2.00	0.00
Westbound	0	306	355	4	2.00	0.00
Southbound	0	1	1	4	2.00	0.00
Northbound	0	22	3	142	2.00	0.00



Project Name:	ICE Example (PM Peak 2040)
Project Number:	XXXX
Location	Springfield
Date	-
Number of Intersection Legs	4
Major Street Direction	East-West

Reset Tool to Defaults

Traffic Volume Demand

	Volume (Veh/hr)				Percent (%)	
	U-Turn	Left	Thru	Right	Heavy Vehicles	Volume Growth
Eastbound	0	1	120	10	2.00%	0.00%
Westbound	0	306	355	4	2.00%	0.00%
Southbound	0	1	1	4	2.00%	0.00%
Northbound	0	22	3	142	2.00%	0.00%
Adjustment Factor	0.80	0.95		0.85		
Suggested	0.80	0.95		0.85		

Truck to PCE Factor		Suggested = 2.00	2.00
Multimodal Activity Level	Low	Multimodal Ped	Multimodal Bike
Critical Lane Volume Sum Limit	2-phase signal	Suggested = 1800 (Urban), 1650 (Rural)	1650
	3-phase signal	Suggested = 1750 (Urban), 1600 (Rural)	1600
	4-phase signal	Suggested = 1700 (Urban), 1550 (Rural)	1550

Figure 11: CAP-X Volume Input for the 4-Legged Intersection Alternatives as depicted in the accessible version of the sample data is available in Table 5.

The analyst next accessed the Base and Alt Sel worksheet to enter the existing intersection configuration and select the alternatives to analyze. The analyst selected "Two Way Stop Control" and "1x1 Roundabout" in the 4-legged instance of the tool, and "Continues Green T" in the 3-legged instance of the tool. In both cases, the two-way stop-controlled intersection was selected as the existing intersection configuration. **Figure 12** and **Figure 13** show the inputs for the 4-legged alternatives being analyzed by instance of the tool.

Capacity Analysis for Planning of Junctions

Step 2A: Base Conditions Analysis

Project Name:	*ICE Example (PM Peak 2040)*
Project Number:	*XXXX*
Location:	*Springfield*
Date:	-
Major Street Direction	East-West

Existing Intersection Configuration	*Two-Way Stop Control*

Number of Lanes for Existing Configuration
(Can be edited in "3- Alt Num Lanes Input" as needed)

TYPE OF INTERSECTION	Sheet	Northbound				Southbound				Eastbound				Westbound			
		U	L	T	R	U	L	T	R	U	L	T	R	U	L	T	R
Two-Way Stop Control	E-W		0	1	1		0	1	0		1	1	0		1	1	0

Results for Existing Configuration

TYPE OF INTERSECTION	Sheet	Zone 1 (North)		Zone 2 (South)		Zone 3 (East)		Zone 4 (West)		Zone 5 (Center)			
		CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C		
Two-Way Stop Control	E-W	--	--	--	--	--	--	--	--	--	*0.21*	--	--

Existing Configuration Results

Overall v/c Ratio	0.21	Pedestrian Accommodation	Fair	Bicycle Accommodation	Fair

Figure 12: CAP-X Base Conditions Analysis for the 4-Legged Intersection Alternatives

Rankings Inclusion		Yes/No	Comment
At-Grade Non-Roundabout Intersections?		Yes	
Traffic Signal		No	
Two-Way Stop Control		Yes	
All-Way Stop Control		No	
Continuous Green T		No	
Quadrant Roadway	S-W	No	
	N-E	No	
	S-E	No	
	N-W	No	
Partial Displaced Left Turn		No	
Displaced Left Turn		No	
Signalized Restricted Crossing U-Turn		No	
Unsignalized Restricted Crossing U-Turn		No	
Median U-Turn		No	
Partial Median U-Turn		No	
Bowtie		No	
Split Intersection		No	
Grade Separated Intersections?		No	
Echelon			
Center Turn Overpass			
Roundabouts?		Yes	
50 ICD Miniroundabout		No	
75 ICD Miniroundaobut		No	
1x1		Yes	
1x2		No	
2x1		No	
2x2		No	
3x3		No	
Grade Separated Interchanges?		No	
Diamond			
Partial Cloverleaf A			
Partial Cloverleaf B			
Displaced Left Turn Interchange			
Contraflow Left Interchange			
Diverging Diamond Interchange			
Single Point			
Single Point with Roundabout			

Figure 13: CAP-X Alternative Selection for the 4-Legged Intersection Alternatives

Next, the analyst reviewed the Alt Num Lanes worksheet to enter the number of lanes for each alternative. CAP-X provides default values for each alternative, and the analyst adjusted these values to represent the lane configuration for each of the three alternatives. **Figure 14** shows the completed worksheet for the 4-legged intersection (Alternatives 1 and 3).

Capacity Analysis for Planning of Junctions

Step 3

Project Name:	*ICE Example (PM Peak 2040)*
Project Number:	*XXXX*
Location:	*Springfield*
Date:	-
Analysis Type:	Intersections and Interchanges

Number of Lanes for Non-roundabout Intersections

TYPE OF INTERSECTION	Sheet	Northbound				Southbound				Eastbound				Westbound			
		U	L	T	R	U	L	T	R	U	L	T	R	U	L	T	R
Two-Way Stop Control	E-W		0	1	1		0	1	0		1	1	0		1	1	0

For shared lanes, enter "0" in L or R

For AWSC enter number of approach lanes (1 or 2) for each approach.

Capacity Analysis for Planning of Junctions

Step 3 (Cont.)

Number of Lanes for Grade Separated Intersections

TYPE OF INTERSECTION	Sheet	Northbound				Southbound				Eastbound				Westbound			
		U	L	T	R	U	L	T	R	U	L	T	R	U	L	T	R

Number of Lanes for Interchanges

TYPE OF INTERCHANGE	Sheet	Northbound				Southbound				Eastbound				Westbound			
		U	L	T	R	U	L	T	R	U	L	T	R	U	L	T	R

Figure 13: CAP-X Alternative Selection for the 4-Legged Intersection Alternatives

Next, the analyst reviewed the Alt Num Lanes worksheet to enter the number of lanes for each alternative. CAP-X provides default values for each alternative, and the analyst adjusted these values to represent the lane configuration for each of the three alternatives. **Figure 14** shows the completed worksheet for the 4-legged intersection (Alternatives 1 and 3).

Figure 14: CAP-X Alt Number of Lanes Input for the 4-Legged Intersection Alternatives

While the analyst does not expect high pedestrian or bicyclist demand in the future, understanding the safety effects of the different alternative designs is important when selecting the preferred alternative. CAP-X allowed the analyst to enter basic details about the lane crossings (**Figure 15**) and bicycle facilities (**Figure 16**). The tool uses these basic inputs to provide qualitative assessments of the pedestrian and bicyclist accommodations.

Pedestrian Crossing Configurations for Non-roundabout Intersections										
TYPE OF INTERSECTION	Sheet	# Of X-ings	Crossing #1		Crossing #2		Crossing #3		Crossing #4	
			# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed
Two-Way Stop Control	E-W	4	3+ Lanes	>30mph	3+ Lanes	Stop / Signal	3+ Lanes	>30mph	1 Lane	Stop / Signal

Pedestrian Crossing Configurations for Separated Intersections										
TYPE OF INTERSECTION	Sheet	# Of X-ings	Crossing #1		Crossing #2		Crossing #3		Crossing #4	
			# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed

Pedestrian Crossing Configurations for Roundabouts										
TYPE OF ROUNDABOUT	Sheet	# Of X-ings	Crossing #1		Crossing #2		Crossing #3		Crossing #4	
			# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed
Single Lane Roundabout	1 X 1	4	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph

Figure 15: CAP-X Inputs for the Multimodal Intersection Configuration for Pedestrian Crossing for the 4-Legged Intersection Alternatives

Bicycle Segment Configurations for Non-roundabout Intersections										
TYPE OF INTERSECTION	Sheet	# Of Seg.	Segment #1		Segment #2		Segment #3		Segment #4	
			Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed
Two-Way Stop Control	E-W	4	Shared with Vehicles	>30mph	Shared with Vehicles	>30mph	Shared with Vehicles	>30mph	Shared with Vehicles	<20mph

Bicycle Segment Configurations for Separated Intersections										
TYPE OF INTERSECTION	Sheet	# Of Seg.	Segment #1		Segment #2		Segment #3		Segment #4	
			Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed

Bicycle Segment Configurations for Roundabouts										
TYPE OF ROUNDABOUT	Sheet	# Of Seg.	Segment #1		Segment #2		Segment #3		Segment #4	
			Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed
Single Lane Roundabout	1 X 1	4	Shared with Vehicles	<20mph	Shared with Vehicles	<20mph	Shared with Vehicles	<20mph	Shared with Vehicles	<20mph

Figure 16: CAP-X Inputs for the Multimodal Intersection Configuration for Bicycle Segments for the 4-Legged Intersection Alternatives

At this point, the analyst had entered all of the details needed to use the tool. The Summary Results worksheet provides an overview of the analysis results. The alternatives are ranked by their V/C ratio, and an assessment of both pedestrian and bicycle accommodations is presented. **Figure 17** shows the output from CAP-X for the 4-legged intersection alternatives, and **Table 6** shows the combined results for all three alternatives.

Capacity Analysis for Planning of Junctions

Dynamic Results Summary

TYPE OF INTERSECTION	Overall V/C Ratio	V/C Ranking	Pedestrian Accommodations	Bicycle Accommodations
Two-Way Stop Control E-W	0.21	1	Fair	Fair
1 X 1 Roundabout	0.51	2	Good	Good
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--

Use the "yes/no" drop-down menus in Step 2 (Base and Alt Selection) to exclude intersection types from summary rankings, if they are not applicable.

Figure 17: CAP-X Summary Results for the 4-Legged Intersection Alternatives (PM Peak)

Table 6: Summary of CAP-X Results

Alternative	Period	V/C Ratio	Pedestrian Accommodations	Bicycle Accommodations
Future No-Build	2040 AM Peak	0.48	Fair	Fair
Future No-Build	2040 PM Peak	0.21	Fair	Fair
Curve Realignment (Alt 1)	2040 AM Peak	0.48	Fair	Fair
Curve Realignment (Alt 1)	2040 PM Peak	0.21	Fair	Fair
Continuous T-Intersection (Alt 2)	2040 AM Peak	0.34	Poor	Fair
Continuous T-Intersection (Alt 2)	2040 PM Peak	0.29	Poor	Fair
Roundabout (Alt 3)	2040 AM Peak	0.45	Good	Good
Roundabout (Alt 3)	2040 PM Peak	0.51	Good	Good

Results of the CAP-X analysis show that all three alternatives have a V/C ratio of less than 0.85 in both of the peak periods. A V/C ratio of less than 0.85 indicates that the intersection typically has sufficient capacity to support the expected traffic demand. The V/C ratios range from 0.21 (Future No-Build and Alternative 1 during the 2040 AM peak) to 0.51 (Alternative 3 during the 2040 PM peak).

Stage 2 Alternative Selection

Results of the CAP-X analysis (**Table 6**) show that all three of the alternatives will provide sufficient capacity for the expected demand. As such, the analyst decided that selecting the preferred alternative should be based on the expected safety benefits estimated by the SPICE tool (**Table 5**), and recommended that the roundabout (Alternative 3) should be the preferred alternative. Given this recommendation, a more detailed Stage 2 analysis to compare the other alternatives may not be necessary. To further confirm the recommendation, the analyst conducted a benefit-cost analysis to determine if the safety benefits of the preferred alternative are expected to outweigh the alternative's cost.

Benefit-Cost Analysis

To begin the benefit-cost analysis, the analyst developed a severity-weighted crash cost for fatal and injury crashes using three years of crash data and the costs shown in **Table 7**.[3] The severity-weighted crash cost was calculated to be $446,212 (2016 dollars). The crash cost used for property damage only crashes was $11,900 (2016 dollars).

Table 7: Comprehensive Crash-Level Costs

Severity	Comprehensive Crash-Level Cost (2016 dollars)
K	$11,295,400
A	$655,000
B	$198,500
C	$125,600
O	$11,900

The analyst estimated the present value of the cost savings due to the reduction in crashes for the roundabout (Alternative 3) to be $7,454,973. With an estimated cost of $3,467,500, this project is expected to have a benefit-cost ratio of 2:1.

3 *Harmon, T., Bahar, G., & Gross, F. (2018). Crash Costs for Highway Safety Analysis (Final Report No. FHWA-SA-17-071). Washington, DC. Retrieved from https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf*

Preferred Alternative

Given the results of the benefit-cost analysis, the analyst recommended moving forward with implementing the roundabout (Alternative 3). The roundabout is superior to the other alternatives based on the reduction in fatalities and serious injuries. All three alternatives are comparable from an operational perspective. Selecting the alternative with the greatest safety improvement allows the analyst to be consistent with FHWA's vision of zero deaths and serious injuries on the Nation's roadways.

Key Findings

This analysis addressed the traffic-related impacts associated with the reconfiguration of the intersection between Main Street and Park Avenue. The following conclusions are based on the conducted typical capacity and safety analyses:

- *The existing intersection has had 11 crashes over the most recent five years (2013 – 2017), with angle and fixed object crashes (36%) being the most common crash types. Nearly half of the crashes are a result of drivers "failing to maintain proper control." The preferred solution, the roundabout, requires drivers to decrease their speed during the approach to the intersection. This decrease in speed is anticipated to reduce crashes related to drivers failing to maintain proper control and reduce the number of crashes at the intersection.*
- *Further, roundabouts greatly reduce the possibility of angle and head-on crashes. Both of these crash types are often severe, and angle crashes were observed frequently at this location.*
- *While estimates show little pedestrian demand in future years, all alternatives would include shoulder accommodations as a low-cost approach to improve pedestrian safety. The roundabout alternative is described as a more favorable option for pedestrians and bicycles in terms of vehicle speeds and crossing or segment characteristics.*
- *The roundabout (Alternative 3) is expected to make the greatest safety improvement, and the benefits are also expected to outweigh the costs. As such, this alternative has been selected as the preferred alternative. The design includes one circulating lane with one lane entry and one lane exit point on all four approaches of the intersection.*

Conclusion

An analyst can integrate DDSA into an ICE with a few basic steps. This guide presented an overview of ICE and an example to compare intersection designs and address safety concerns. In this example, a roundabout was recommended as the preferred alternative. The analysis shows that the roundabout will provide a greater reduction in fatal and injury crashes while having similar operational characteristics as the other alternatives. The benefit-cost analysis found that the benefits exceed the costs for the recommended alternative, demonstrating that it is a sound safety investment that is one step closer to realizing the goal of zero deaths and serious injuries on the Nation's roadways.

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