HSAM Volume 2:

INTERSECTION & INTERCHANGE EVALUATION

Introduction, IIE Form Guidance, Methodology

Tennessee Department of Transportation | January 29, 2021

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Intersection & Interchange Evaluation Introduction

Intersection and Interchange Evaluation (IIE) Purpose

The Tennessee Department of Transportation (TDOT)'s Intersection and Interchange Evaluation (IIE) process helps practitioners select the best intersection or interchange design at a given location. TDOT's IIE utilizes the Federal Highway Administration (FHWA)'s Intersection Control Evaluation (ICE) guidance as its foundation. As with ICE, TDOT's IIE is a data-driven, performance-based approach to objectively screen intersection and interchange options. In lay terms, IIE is a documented approach to "good traffic engineering." It is not intended to be a rigid selector of intersection or interchange control; it is a process to ensure practitioners consider all reasonable improvement options. It helps eliminate individual practitioner's bias and provides an institutionalized approach to intersection and interchange option selection. It allows innovative intersection and interchange options to be more broadly considered, placing them on equal footing with standard intersection or interchange control options such as signalized intersections.

There are dozens of conventional and innovative intersection and interchange options proven to work in the United States. These options are described in FHWA's *Alternative Intersections/Interchanges: Informational Report* (AIIR), which is available for free download at https://www.fhwa.dot.gov/publications/research/safety/09060/ (see Figure 2-1). With so many choices, it is important to use a consistent process to assess what options best meet project need and purpose. Utilizing IIE procedures to evaluate and select the geometry and control for an intersection or interchange offers many potential benefits to TDOT and the traveling public, including:

- Implementation of safer, more balanced, and more cost-effective options.
- Consistent documentation that improves the transparency of transportation decisions.
- Increased awareness of innovative intersection solutions and emphasis on objective performance metrics for consistent comparisons.
- The opportunity to consolidate and streamline existing intersection-related policies and procedures, including access or encroachment approvals, new traffic signal requests, and impact studies for development.

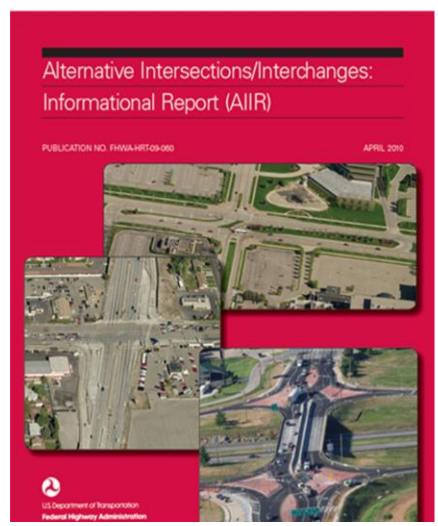


Figure 2-1: FHWA AIIR

TDOT's IIE process is implemented in two stages:

1. A "Stage I – Scoping" step to determine the short list of all possible options that merit further consideration and analysis because they meet project needs and are practical to pursue.
2. A "Stage II – Preferred Option Selection" step to determine the preferred option based on more detailed evaluations conducted during typical preliminary engineering activities.

Benefits of IIE

Transportation projects should be sustainable and improve the mobility and safety of all users. At-grade intersections and interchanges provide one of the greatest opportunities for improving mobility and safety. These junctions inherently have crossing traffic patterns that place users of various modes in conflict and create delay. Intersections make up a small part of total road system mileage, but they account for a high percentage of all crashes, especially severe crashes producing injuries and fatalities. The quantitative methods outlined in TDOT's IIE process include predictive safety analysis, auto-focused performance metrics, multimodal travel assessments, and initial and life-cycle cost guidance. TDOT's IIE process will improve mobility and safety for all users with an efficient use of the public's funds.

Traditionally, the performance metrics used to select between intersection or interchange control types focused on the movement of vehicles and initial construction cost. In recent years, several new or innovative intersection and interchange designs have been introduced across the United States. These "alternative" control types (including roundabouts, cross-over-based designs, and U-turn-based designs) are enhancing safety and improving operations, often at lower cost than traditional control types such as signalized intersections. TDOT's IIE process ensures these alternative control types are considered in project development.

Data Needs

To complete TDOT's IIE process, the practitioner will need the data listed in Table 2-1. The data needs are discussed in detail in the *Intersection & Interchange Evaluation Form Guidance*.

Table 2-1: IIE Data Needs

Data Inputs

- **Project and Location Data**
  - General Project Location Data
  - Intersection / Interchange Orientation (North, South, East, West)
  - Number of Intersection / Interchange Legs
  - Opening and Design Years
  - Functional Classifications of Roadways
  - Land Use Context
  - Project Type
- **Traffic Data**
  - Opening and Design Year Mainline AADTs
  - Opening and Design Year Hourly Turning Movement Volumes
  - Truck Percentages
  - Pedestrian Counts
- **Multimodal Activity**
  - Knowledge of Multimodal Trip Generators within 0.5 Mile of the Project Location
  - Estimate of Existing and Future Multimodal Activity (Low, Medium or High)
- **Crash History and Intersection Crash Rate**
  - Crash Data (Typically 3 Years of Data)
  - Existing Approach AADTs
  - Statewide Average Crash Rate of Similar Locations

Stage I – Scoping

- Data Listed in "Data Inputs"
- CAP-X Traffic Analysis

State II – Preferred Option Selection

- Data Listed in "Data Inputs"
- TDOT STID's Cost Estimate Tool (Or Other Similar Tool)
- Traffic Analysis Tool (HCS, Synchro, VISSIM, SIDRA, or Other)
- Knowledge of Stakeholder Support
- *Optional - Life-Cycle Cost Tool (LCCET or Other Similar Tool)*
- *Optional - Predictive Crash Analysis Tool (SPICE or Other)*

Multimodal Considerations

Pedestrian and bicyclist demand should be considered by the practitioner early in the planning process. Intersections and interchanges can pose both opportunities and challenges for pedestrians and bicyclists. Concerning opportunities, these areas typically provide interruptions in free-flow traffic for bicyclists and pedestrians to cross roadways. Concerning challenges, many intersections and interchanges have free-flow movements incorporated into their designs. The best intersection and interchange configurations for pedestrians and bicyclists are those where the roadways intersect at 90-degree angles and where a stop sign or signal controls all movements at the intersection and no free-flow right turns (or other movements) are permitted. The characteristics of the best intersection cause motorists to slow down before turning, increasing the likelihood that they will see and yield to non-motorists. If an impact occurs, severity is lessened because of slower vehicular speeds.

Concerning selecting the “best” intersection or interchange design for pedestrians and bicyclists, it often depends more on the details of the intersection or interchange design than the junction type, i.e. the presence of free-flow movements. When the practitioner is selecting an intersection or interchange they should consider, on a case-by-case basis, if the proposed design will improve or maintain multimodal access. The practitioner should also consider the context of the location to determine the level of emphasis to place on multimodal design compared to motor-vehicle movements. Multimodal access is not a concern on facilities that prohibit pedestrian or bicyclist activity, a lesser concern in areas with land uses that do not support walking and biking, and higher concern in areas with commercial and residential uses. TDOT’s IIE forms have many prompts built into them concerning multimodal needs. There are few “hard and fast” rules concerning which alternatives are “best”, but guidance is provided below to assist the practitioner.

Alternative Intersections

FHWA’s AIIR notes pedestrian and bicyclist mobility needs can be met by all alternative intersections, albeit to differing degrees. For example, Median U-Turn (MUT) and Quadrant Roadway intersections have been judged to be more favorable to accommodating pedestrians and bicyclists crossing all legs than the other alternative intersections. In the case of the MUT intersection, the removal of left-turn maneuvers and associated left-turn phases from a conventional intersection result in fewer conflict points for pedestrians and bicyclists. In addition, the removal of the left-turn signal phases also allows for a reduction in the cycle length, which reduces pedestrian and bicyclist delays. While the conflicting right-turning volume is expected to be higher at an MUT intersection compared to a conventional intersection, the reduction in the number of expected conflicts between left-turning vehicles and pedestrians and bicyclists on all four legs has a positive safety effect for pedestrians and bicyclists. This benefit may offset the increase in the right-turning volume. Similarly, the Quadrant Roadway intersection also enhances pedestrian and bicyclists safety at the main intersection by removing all left turns. Depending on their origins, destinations, and directions of travel, some pedestrians and bicyclists may need to cross an additional intersecting leg at a Quadrant Roadway intersection.

If the pedestrian activity in the immediate vicinity of the subject intersection is low or nonexistent, then all at-grade alternative intersections and roundabout designs are practical. However, if pedestrian or bicyclist activity is high on all four legs, then there are limitations with respect to accommodating them at the Continuous Green-T, roundabout and the Restricted Crossing U-Turn (J-Turn / RCUT) intersections. The Continuous Green-T intersection has free-flow traffic in one direction, creating an obvious hazard for pedestrians or bicyclists wishing to cross. Because there are no traffic signals to stop traffic at roundabouts, some pedestrian advocates have expressed concerns about the ability of pedestrians, notably pedestrians with disabilities, to safely cross approaches to the roundabouts. Bicyclists must either travel in the circulating roadway or use a side path and face the same crossing concerns as pedestrians. The J-Turn / RCUT intersection design restricts left turns at an intersection but allows the same movement downstream via a U-turn. In standard terminology, a J-Turn is an unsignalized RCUT. The J-Turn / RCUT intersection allows pedestrians and bicyclists to cross diagonally but not directly across the major roadway leg at the main intersection. Pedestrians and bicyclists can be afforded a direct crossing of the major road at a signal-controlled midblock crossing located beyond the main intersection. However, the J-Turn / RCUT intersection's inability to allow direct crossings of all legs at the main intersection may be sufficient to drop this alternative from further consideration if the subject intersection has very high levels of pedestrian and bicyclist activity.

Interchanges

One of the more challenging areas to design multimodal facilities is in interchange areas. Interchanges often provide the only pedestrian and bicycle access across a freeway but are not always designed to provide comfortable pedestrian and bicycle access. When feasible, the intersection of freeway ramps and local streets should be designed like other multimodal-friendly intersections in terms of slow vehicle approach speeds, narrow crossing distances, and appropriate signs, signals, and markings. Traffic and pedestrian signals are often appropriate at the intersection of ramps with the surface streets, and these can be timed to facilitate safer pedestrian travel. When free-flow right-turn lanes are necessary, they should be designed to be as pedestrian and bicyclist friendly as possible in terms of roadway approach angle, marked crosswalks, and narrow turn lanes. Raised medians or islands that can serve as refuge areas are recommended to allow crossing the roadway in phases.

Ideally, free-flow turn lanes would not be constructed where pedestrian and bicyclist activity exist. However, if a traffic analysis shows that free-flow lanes are required to prevent vehicular queues from reaching the mainline of the highway they should be considered. The project team's design recommendations should balance the safety of motorists with that of pedestrians and bicyclists. For new construction projects, the design team should consider an interchange configuration that is more accommodating to pedestrians and bicyclists. These types include diamond interchanges and partial cloverleaf interchanges that do not have free-flow turn lanes on the arterial. Examples are shown in Figure 2-2. If a diverging diamond interchange configuration is selected, current guidance recommends placing pedestrians and bicyclists in the median between the ramps. Examples of interchange configurations that are more difficult to accommodate pedestrians and bicyclists include trumpet interchanges, partial and full cloverleaf interchanges with free-flow turn lanes, and single point interchanges. Examples are shown in Figure 2-3.

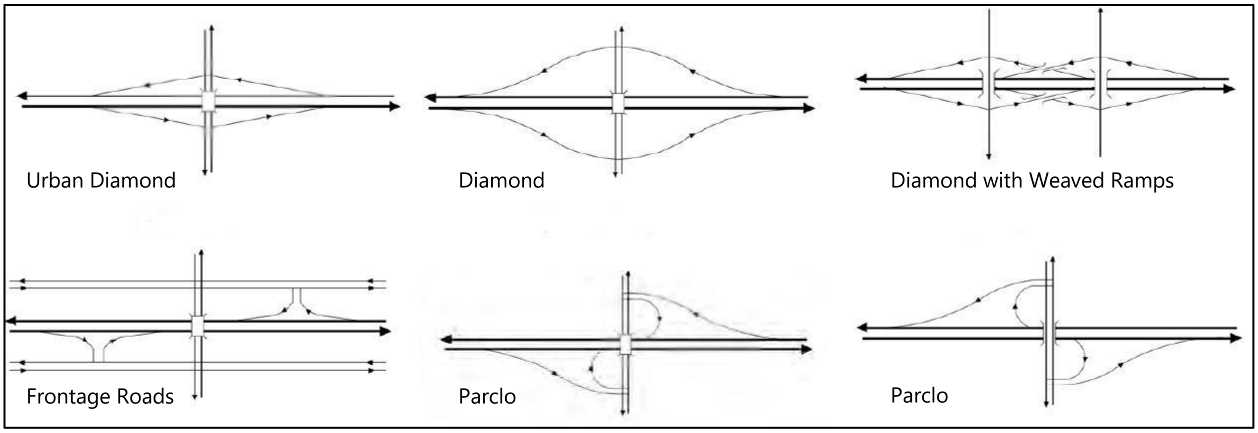


Figure 2-2: Pedestrian and Bicyclist Accessible Interchange Configurations

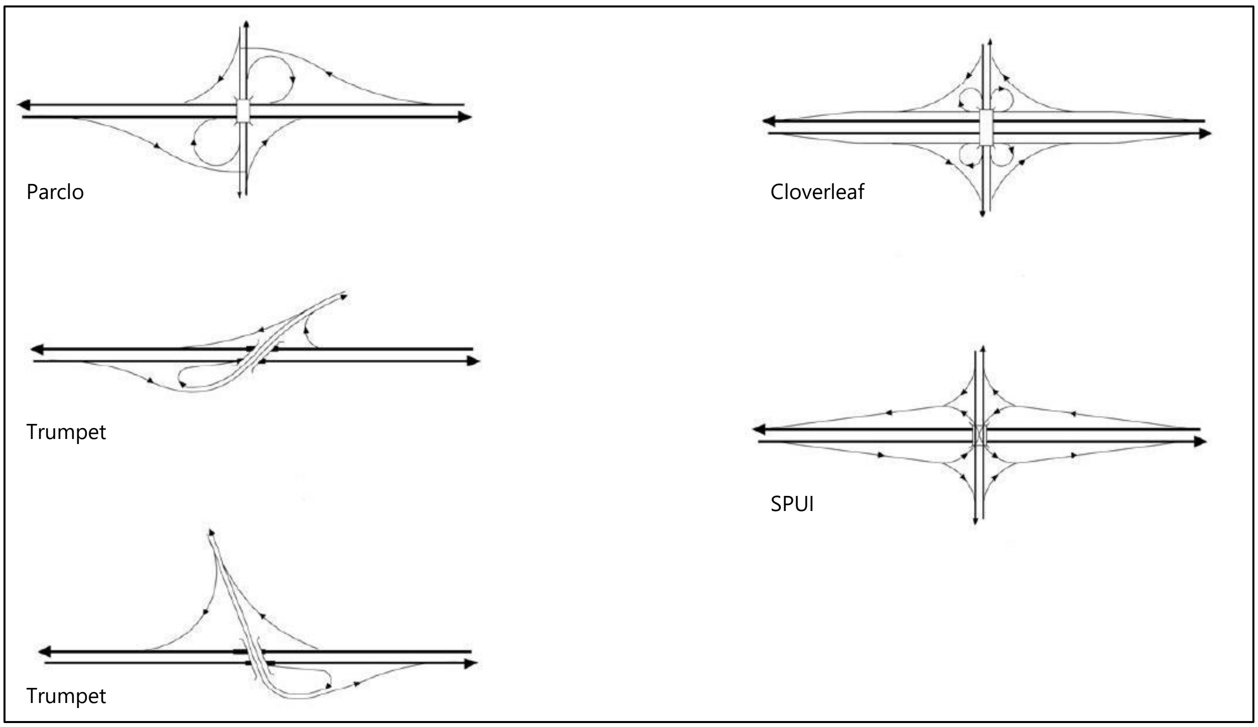


Figure 2-3: Pedestrian and Bicyclist Challenging Interchange Configurations

Predictive Crash Analysis Overview

The Highway Safety Manual (HSM) predictive methods assume similar roadways and intersections with similar roadway and traffic characteristics are likely to experience similar crash frequencies, severities, and crash types. The HSM predictive methods provide procedures to analyze safety performance in terms of crash severity, crash types, and number of vehicles involved in the crashes. Predictive crash analysis uses equations known as Safety Performance Functions (SPFs) to estimate the predicted average crash frequency as a function of traffic volume and roadway and intersection characteristics.

The SPFs developed in Part C of the HSM provide relatively straightforward means of predicting crashes. However, the HSM is fairly limited concerning SPFs for the potential intersection-control strategies in TDOT's IIE. 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 statistical method.

Several tools have been developed and are available for free download to conduct a predictive crash analysis. One of the simplest and most straight-forward to use is the Safety Performance for Intersection Control Evaluation (SPICE) tool. SPICE was developed by FHWA 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 National Cooperative Highway Research Program [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. The SPICE Tool can be downloaded from the following address: http://www.cmfclearinghouse.org/resources_selection.cfm .

When conducting a planning-level analysis of alternatives, the SPICE Tool allows practitioners to quickly apply the HSM SPFs and CMFs with minimal data input [e.g., Annual Average Daily Traffic (AADT), 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. The SPICE Tool only provides predicted crash frequencies and severities for intersections, which can be input into life-cycle cost 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). However, many of these tools have a steeper learning curve than SPICE (although they can perhaps provide more accurate predictions). In general, SPICE is TDOT's preferred IIE predictive crash analysis tool due to its intersection-focus, ease of use, and consistent approach. However, it may not provide the full range of intersection control options needed and it is limited in its use for interchange options. Therefore, the practitioner may need to utilize the other tools listed above or apply HSM methodology directly. Crash modification factors from the Crash Modification Factors Clearinghouse (http://www.cmfclearinghouse.org/) may need to be investigated.

To be effective, TDOT's IIE process needs a high-level traffic analysis tool that can be used in its Stage I – Scoping stage with minimal data and by practitioners with minimal traffic analysis experience. TDOT has selected The Capacity Analysis for Planning of Junctions (CAP-X) tool to serve this purpose. Table 2-2 and Table 2-3 provide a comparison of intersection / interchange control options in CAP-X compared to those in SPICE.

The primary goal of predictive crash analysis in TDOT's IIE process is to apply a method consistently to all options considered. With a consistent approach, the relative safety benefits of each option are considered equitably. Predictive crash analysis is recommended but optional in TDOT's IIE process. The TDOT project manager will determine if it is required on a case-by-case basis. *Predictive Crash Analysis – SPICE Tool* provides guidance for the practitioner concerning how to use the SPICE Tool in TDOT's IIE process.

Predictive crash analysis is recommended but optional in TDOT's IIE process.

Table 2-2: Intersection / Interchange Control Options in CAP-X vs. SPICE

Intersection / Interchange Control	In SPICE?
At Grade Intersections	
Traffic Signal	●
Two-Way Stop Control	●
All-Way Stop Control	○
Continuous Green T	●
Quadrant Roadway	◑
Partial Displaced Left Turn	●
Displaced Left Turn	●
Signalized Restricted Crossing U-Turn (RCUT)	●
Unsignalized Restricted Crossing U-Turn (J-Turn)	●
Median U-Turn	●
Partial Median U-Turn	◑
Bowtie	◑
Split Intersection	◑
Roundabouts	
Mini	●
Single-Lane	●
Multilane	●

Legend:
● = Direct calculation in SPICE
◑ = Can be calculated with SPICE
○ = Not in SPICE

Table 2-3: Intersection / Interchange Control Options in CAP-X vs. SPICE (Continued)

Grade Separated Intersections	In SPICE?
Echelon	○
Center Turn Overpass	○
Grade Separated Interchanges	
Diamond	●
Partial Cloverleaf	○
Displaced Left Turn Interchange	○
Contraflow Left Interchange	○
Diverging Diamond Interchange	●
Single Point	○
Single Point with Roundabout	◑

Legend:
● = Direct calculation in SPICE
◑ = Can be calculated with SPICE
○ = Not in SPICE

Life-Cycle Cost Overview

The FHWA promotes life-cycle cost analysis to quantify the costs of different transportation options. By considering all costs—agency and user—incurred during the design life of a project, life-cycle cost analysis provides transportation officials with a total cost of transportation options instead of focusing solely on initial construction and engineering cost.

In TDOT's IIE process, life-cycle cost analysis is recommended but optional. The TDOT project manager will determine if it is required on a case-by-case basis. In its standard and most streamlined approach for TDOT's IIE process, life-cycle cost analysis requires the following three (3) elements:

Life-cycle cost analysis is recommended but optional in TDOT's IIE process.

1. Agency's initial engineering, construction, right-of-way, and utility relocation costs (calculated in IIE Stage II);
2. Roadway users' operations or delay cost (calculated with inputs from the IIE Stage II Traffic Analysis); and
3. Roadway users' safety cost (calculated with inputs from the IIE Stage II Predictive Crash Analysis; it should be noted that if a life-cycle cost analysis is required then a predictive crash analysis must also be developed).

TDOT's standard cost analysis includes only calculating the initial construction and engineering costs. TDOT considers the user costs of operations and safety when evaluating options, though these are reported as informative values in separate traffic analysis and safety assessments, and not incorporated into a life-cycle cost.

Several tools or methods could be used for life-cycle cost analysis. For a consistent approach, TDOT selected the Life-Cycle Cost Estimating Tool (LCCET). LCCET was developed as part of NCHRP Project 03-110. The objective of this project was to develop a spreadsheet-based tool that can be used to compare the life-cycle costs of alternative designs for new and existing intersections. It is a companion to NCHRP 220 "Estimating the Life-Cycle Cost of Intersection Designs". Both the LCCET spreadsheet tool and NCHRP 220 can be downloaded for free from the following address: http://www.trb.org/Main/Blurbs/173928.aspx .

The LCCET spreadsheet tool provides life-cycle cost comparisons between different intersection or influence area treatments. The tool incorporates the following costs: safety, vehicular delay, multimodal delay, operations, maintenance, initial capital costs and emissions. Any of these elements can be excluded from the analysis by unselecting them in the "Outputs" worksheet.

As mentioned previously, TDOT's standard and most streamlined life-cycle cost analysis approach utilizes initial capital costs, safety, and vehicular delay. However, the LCCET tool provides the flexibility for more advanced analysis when conditions merit (and when the input data are available). Conditions where more advanced analysis may be requested by the TDOT project manager could include emissions costs on projects funded through the Congestion Mitigation and Air Quality Improvement (CMAQ) program or multimodal analysis on transit or bicycle and pedestrian grant projects. In these situations, data input needs should be evaluated at project scoping.

Intersection & Interchange Evaluation Form Guidance

The Tennessee Department of Transportation (TDOT) has developed Microsoft Excel based forms to document a consistent and transparent intersection / interchange selection approach. The Excel file has three primary elements; *Data Inputs Form*, *IIE Stage I – Scoping Form*, and *IIE Stage II – Preferred Option Selection Form*.

Limitations of the IIE Forms

These three forms should be used to the maximum extent possible. In general, the forms are proper for all three- and four-legged intersections. However, TDOT recognizes that unique configurations, such as five-legged intersections and interchanges, will require the practitioner to develop custom documentation to supplement the forms. All intersection and interchange configurations will need, at a minimum, a summary memo noting the intersection or interchange control selected and an appendix of relevant calculations to supplement the forms. When a unique intersection configuration or interchange does not comply with the forms, the information requested in the forms should be documented in a technical study format.

CAP-X Integration

To be effective, TDOT's Intersection and Interchange Evaluation (IIE) process needs a high-level traffic analysis tool that can be used in concert with the forms with minimal data and by practitioners with minimal traffic analysis experience. TDOT has selected *The Capacity Analysis for Planning of Junctions* (CAP-X) tool to serve this purpose. It is a free, publicly available, spreadsheet tool. Guidance concerning usage of CAP-X is provided in *CAP-X Workflow Guidance* beginning on page 2-40. Many of the drop-down menu options in TDOT's IIE forms are derived from options available in CAP-X.

Data Inputs Form

Figure 2-4 provides an image of TDOT's IIE Data Inputs form. Once completed, the form will summarize the data needed to complete the IIE process. It also prompts the practitioner to consider multimodal and safety needs of the location. The form is color-coded. Fields with required practitioner inputs are colored yellow. Cells not requiring practitioner inputs or that host calculations are locked and typically colored white. The cells are locked to prevent erroneous inputs, overriding of cell calculations, or overriding of descriptions. However, the practitioner may unlock the spreadsheet if needed. The password to unlock the spreadsheet is "tdot".

TN TDOT Department of Transportation

Intersection and Interchange Evaluation (IIE) Forms

TDOT IIE Form - Data Inputs

Version: 09042020

Project Information

Project and Location Data

Project Name:			
Major Road Name:		Minor Road Name:	
PIN:		County:	
Date:		Analyst/Firm:	
Existing Control Type:	None	No. of Legs:	-
Major Road Direction:	-	Opening Year:	Design Year:
Funct. Class of Major Road:	-	Land Use Context:	-
Project Type of Work:	-		

Traffic Data

Opening Year	0000	Major Road AADT:	
Design Year	0000	Major Road AADT:	
Major Road T % (AADT):	0%	Minor Road T % (AADT):	0%
Major Road T % (DHV):	0%	Minor Road T % (DHV):	0%

Multimodal Activity

Within a 1/2 mile of the projecct location are there:

Bus stop:	-	School:	-	Library:	-
Retail Center:	-	Other Civic Institution:	-	Context to Support Multimodal Activity:	-

Existing or Future Estimated Multimodal Activity Level: -

Crash History and Intersection Crash Rate

Crash Data Year(s):		No. of Years:	
		No. of Crashes:	
Leg	**Current AADT**		
North:		SW Avg. Rate:	
East:		Crash Rate (A):	######
South:		Critical Rate (C):	######
West:		A/SW:	######
Entering AADT:	0	A/C:	####

Turning Movement Volumes (TMV)

0000 =Opening Year Design Hourly Volumes (DHV)

				-				
		0	0	0	0			
		(0)	(0)	(0)	(0)	SB		
	EB	PEDS ↕	←	↓	→	PEDS ↔	(0)	0
0	(0)	↑		Entering Hourly Volumes		↑	(0)	0
0	(0)	→				←	(0)	0
0	(0)	↓				↓	(0)	0
0	(0)	PEDS ↔	←	↑	→	PEDS ↕	WB	
		NB	(0)	(0)	(0)	(0)		
			0	0	0	0		

(AM) = AM Peak Hour Approach

PM = PM Peak Hour Approach

Blue = Pedestrian Volumes

N, E, S, W

0000 = Design Year Design Hourly Volumes (DHV)

				-				
		0	0	0	0			
		(0)	(0)	(0)	(0)	SB		
	EB	PEDS ↕	←	↓	→	PEDS ↔	(0)	0
0	(0)	↑		Entering Hourly Volumes		↑	(0)	0
0	(0)	→				←	(0)	0
0	(0)	↓				↓	(0)	0
0	(0)	PEDS ↔	←	↑	→	PEDS ↕	WB	
		NB	(0)	(0)	(0)	(0)		
			0	0	0	0		

Figure 2-4: IIE Data Inputs Form (No Inputs)

Project and Location Data

The Project and Location Data inputs summarize the project location, intersection configuration, Opening and Design Years, land use context of the area, and the type of work being proposed.

Project Name

The practitioner inputs a short description of the project in the provided cell.

Major Road Name

The practitioner inputs the higher functionally classified road at the intersection / interchange in the provided cell. The location description should include the interstate or State Route designation of the intersecting roadway(s), if applicable.

Minor Road Name

The practitioner inputs the lower functionally classified road at the intersection / interchange in the provided cell. The location description should include the interstate or State Route designation of the intersecting roadway(s), if applicable.

PIN

The practitioner inputs the TDOT Project Identification Number (PIN), if it has been assigned.

County

The practitioner inputs the county where the project is located.

Date

The practitioner inputs the date the form is completed.

Analyst / Firm

The practitioner inputs their name and TDOT Division or consulting firm name.

Existing Control Type

The practitioner selects the existing control type from a drop-down menu of all available control types in CAP-X. If the project is on new location, the practitioner may select "None."

Number of Intersection Legs

Typically, the practitioner selects "3" or "4" intersection legs from the drop-down menu. The selection should be for the proposed number of intersection legs if different than the existing number, i.e. if a fourth leg is to be added to a three-legged intersection, "4" should be selected. The number of intersection legs selected is automatically updated on the *IIE Stage I – Scoping Form* and used to calculate the *Conflict Point Score.*

Note, intersections with more than four legs are not standard and due to their uniqueness often require the practitioner to proceed directly to Stage II – Preferred Option Selection processes. When intersections have five or more legs the practitioner should select "Other." Additionally, interchanges will require the practitioner to develop custom documentation to supplement the forms. When analyzing an interchange location the practitioner should leave the input as "-".

Major Road Direction

The practitioner selects the direction of the higher functionally classified road at the intersection / interchange from the drop-down menu in the provided cell. The selection will auto-populate the road name labels in the *Turning Movement Volumes (TMV)* diagrams.

Opening Year

The practitioner inputs the Opening Year of the project. This is typically provided by TDOT. The selection will auto-populate the labels in the *Turning Movement Volumes (TMV)*.

Design Year

The practitioner inputs the Design Year of the project. This is typically provided by TDOT and equal to 20 years after the Opening Year. The selection will auto-populate the labels in the *Turning Movement Volumes (TMV)*.

Functional Class of Major Road

The practitioner selects the functional class of the major road from the drop-down menu.

Land Use Context

The practitioner selects the location's land use context from the drop-down menu. The practitioner should select the likely land use context in the Design Year of the project, and not the existing land use context. The context options are based on the American Association of State Highway Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets 7th Edition* (also known as "The Green Book") and includes Rural, Rural Town, Suburban, Urban, and Urban Core. TDOT's current classification system only lists Rural or Urban. Therefore, the practitioner should use judgement concerning which selection best applies.

Project Type of Work

The practitioner selects the project's type of work from the drop-down menu. The options mirror those utilized by TDOT's Strategic Transportation Investments Division.

Traffic Data

The Traffic Data inputs summarize the Opening Year and Design Year Average Annual Daily Traffic (AADT) and truck percentage.

Opening Year AADT

The practitioner inputs the Opening Year AADT of the major road. Note, the Opening Year is auto-populated in the description based upon the year the practitioner inputs in the *Project and Location Data* section.

Design Year AADT

The practitioner inputs the Design Year AADT of the major road. Note, the Design Year is auto-populated in the description based upon the year the practitioner inputs in the *Project and Location Data* section.

Major Road Truck Percentage

The practitioner inputs the major road truck percentage (AADT). This is typically provided by TDOT or obtained from TDOT's Enhanced Tennessee Roadway Information Management System (eTRIMS). The form will auto-populate the major road truck percentage of the Design Hourly Volume (DHV) in the field below. As standard TDOT practice, the DHV Truck Percentage is calculated as two-thirds of the AADT Truck Percentage.

Minor Road Truck Percentage

The practitioner inputs the minor road truck percentage (AADT). This is typically provided by TDOT or obtained from eTRIMS. The form will auto-populate the minor road truck percentage of the Design Hourly volume (DHV) in the field below. As standard TDOT practice, the DHV Truck Percentage is calculated as two-thirds of the AADT Truck Percentage.

Multimodal Activity

The Multimodal Activity section prompts the practitioner to select "Yes" or "No" from the drop-down menus related to facilities located within 0.5 mile of the project location that will generate multimodal activity. The intent of these prompts is to promote consideration of multimodal needs in the project area. The practitioner should consider not only the existing conditions, but those anticipated by the Design Year of the project. This is especially relevant to the selections related to "Context to Support

Multimodal Activity" and "Existing or Future Estimated Multimodal Activity" prompts. Likely development patterns should be considered by the practitioner. The response to "Existing or Future Estimated Multimodal Activity" should be included in the CAP-X analysis.

Crash History and Intersection Crash Rate

The Crash History and Intersection Crash Rate summarizes past safety conditions at the project location. It only applies to intersection locations and not interchanges. The inputs and calculations are a condensed version of those found in TDOT Strategic Transportation Investments Division (STID)'s "Yellow Sheet" crash summary report. The purpose of this section is to alert the practitioner if there is a safety concern which should promote enhanced concern for safety-related improvements compared to capacity improvements.

Typically, the practitioner obtains the most recent three-year period of crashes at the intersection from eTRIMS or the Tennessee Integrated Traffic Analysis Network (TITAN). If the practitioner does not have access to either source, crash data should be requested from the TDOT STID.

Crash Data Year(s)

The practitioner inputs the date range of crash data in the provided cell. Note, this should be a date range such as 5/1/17 to 4/30/20, and not simply 2017 to 2020.

Number of Years

The practitioner inputs the number of years of crash data, consistent with the date range provided in *Crash Data Year(s)*. This is typically "3", as per standard TDOT practice to analyze the most recent three-year period. This number is used in subsequent crash rate calculations.

Number of Crashes

The practitioner inputs the number of crashes at the intersection in the time-period reported.

Current AADT (by intersection leg)

The practitioner inputs the current AADT for each intersection leg. If available, the AADT of the middle year of crash data would be reported for each intersection leg. This is current, and not the Opening or Design year AADT, as the purpose of these values is to calculate the existing crash rate. Also, if any of the legs are one-way, then the practitioner should double the AADT reported for that one-way leg. This is because the calculations assume two-way travel for each leg and halve the AADT of each leg to obtain the entering AADT to the intersection.

Entering AADT

The form auto-populates this value. It is calculated as the sum of half of each leg's AADT.

Statewide (SW) Average Rate

The practitioner should obtain and input the most recent statewide (SW) average crash rate for similar intersections from TDOT's STID. The crash rate calculated for the intersection will be compared to this SW average rate.

Crash Rate (A)

The form auto-populates the crash rate. It is the crash rate per million entering vehicles to the intersection.

Critical Rate (C)

The form auto-populates the critical rate. To be reasonably certain that an observed crash rate differs significantly from the average rate, a statistical technique is used. Upper and lower control limits can be established for the average crash rate in such a way that the probability of a crash rate being outside these limits by chance alone is very small. The upper control limit is often referred to as the "critical" crash rate because any rate larger than that value is most likely not due to chance but to some unfavorable characteristic of the local conditions. TDOT uses a confidence level of ninety-nine percent.

A/SW

The form auto-populates the Actual to Statewide (A/SW) crash ratio.

A/C

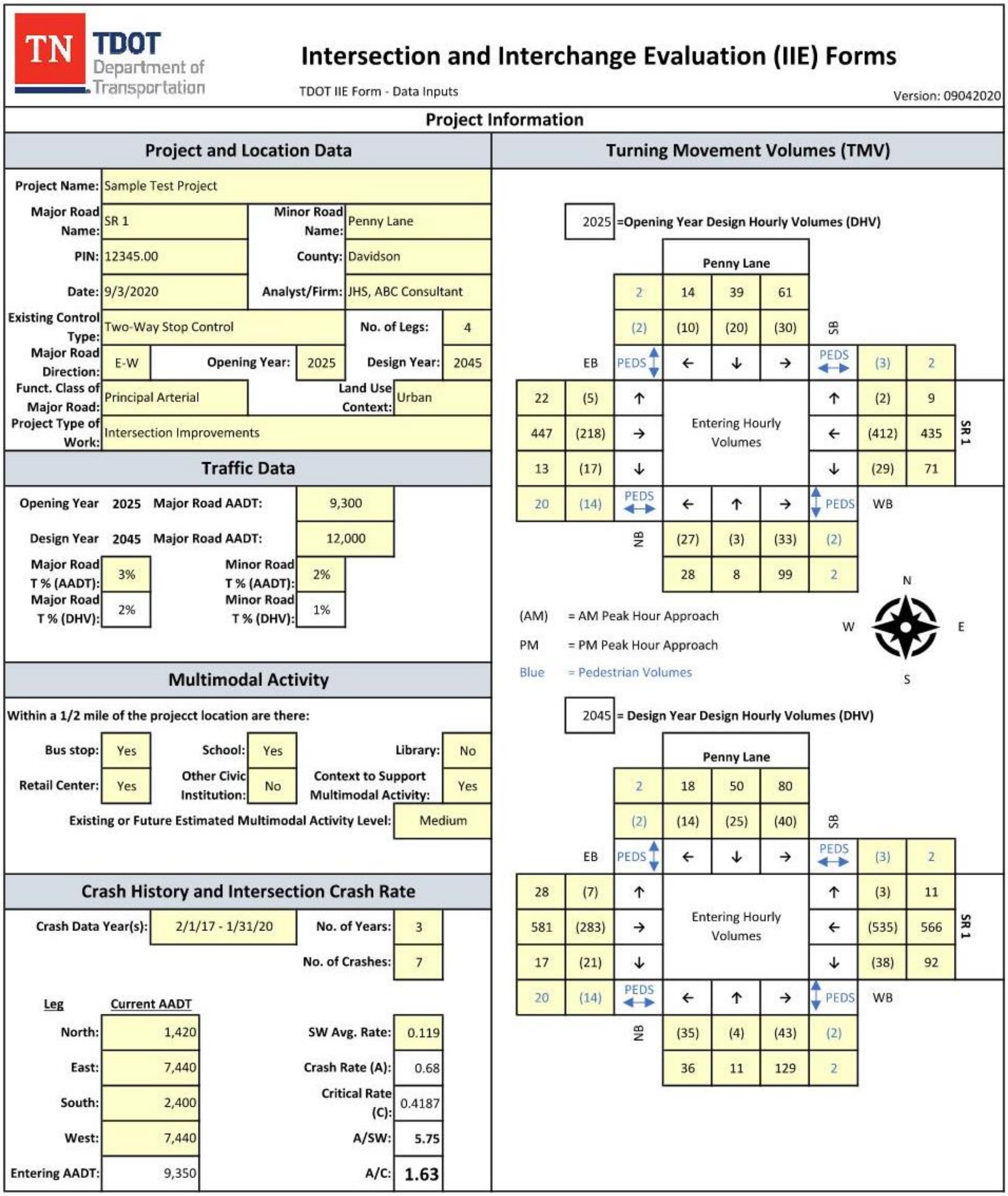
The form auto-populates the Actual to Critical (A/C) crash ratio. A/C ratios greater than 1.0 indicate that the higher than average number of crashes are not likely due to random occurrence, and that there may be some unfavorable characteristics of the roadway that contribute to a higher crash rate than the statewide average of similar intersections.

Turning Movement Volumes (TMV)

The Turning Movement Volumes (TMV) summarizes the Opening Year and Design Year AM and PM Peak Hour turning movement volumes at the project location. It only applies to three- or four-legged intersection locations and not interchanges or intersections with more than four legs. In these circumstances the practitioner should provide the turning movement volumes in separate sketches.

In the TMV diagram, the road names and Opening and Design Years are auto-populated based upon inputs previously provided by the practitioner. The practitioner inputs motor-vehicle and pedestrian hourly volumes for each movement. Pedestrian volumes should typically be requested with field-collected traffic counts. Pedestrian volumes are typically not projected for the Opening and Design Years by TDOT. In these circumstances the practitioner should input the existing field-collected pedestrian volumes, if available.

A sample completed Data Inputs form is provided in Figure 2-5.



TN TDOT Department of Transportation

Intersection and Interchange Evaluation (IIE) Forms

TDOT IIE Form - Data Inputs

Version: 09042020

Project Information

Project and Location Data

Project Name:	Sample Test Project		
Major Road Name:	SR 1	Minor Road Name:	Penny Lane
PIN:	12345.00	County:	Davidson
Date:	9/3/2020	Analyst/Firm:	JHS, ABC Consultant
Existing Control Type:	Two-Way Stop Control	No. of Legs:	4
Major Road Direction:	E-W	Opening Year: 2025	Design Year: 2045
Funct. Class of Major Road:	Principal Arterial	Land Use Context:	Urban
Project Type of Work:	Intersection Improvements		

Traffic Data

Opening Year 2025 Major Road AADT:	9,300		
Design Year 2045 Major Road AADT:	12,000		
Major Road T % (AADT):	3%	Minor Road T % (AADT):	2%
Major Road T % (DHV):	2%	Minor Road T % (DHV):	1%

Multimodal Activity

Within a 1/2 mile of the projecct location are there:

Bus stop:	Yes	School:	Yes	Library:	No
Retail Center:	Yes	Other Civic Institution:	No	Context to Support Multimodal Activity:	Yes

Existing or Future Estimated Multimodal Activity Level: Medium

Crash History and Intersection Crash Rate

Crash Data Year(s):	2/1/17 - 1/31/20	No. of Years:	3
		No. of Crashes:	7

Leg	Current AADT		
North:	1,420	SW Avg. Rate:	0.119
East:	7,440	Crash Rate (A):	0.68
South:	2,400	Critical Rate (C):	0.4187
West:	7,440	A/SW:	5.75
Entering AADT:	9,350	A/C:	1.63

Turning Movement Volumes (TMV)

2025 =Opening Year Design Hourly Volumes (DHV)

				Penny Lane					
		2	14	39	61				
		(2)	(10)	(20)	(30)	SB			
	EB	PEDS	←	↓	→	PEDS	(3)	2	
22	(5)	↑	Entering Hourly Volumes			↑	(2)	9	
447	(218)	→				←	(412)	435	SR 1
13	(17)	↓				↓	(29)	71	
20	(14)	PEDS	←	↑	→	PEDS	WB		
		NB	(27)	(3)	(33)	(2)			
			28	8	99	2			

(AM) = AM Peak Hour Approach

PM = PM Peak Hour Approach

Blue = Pedestrian Volumes

N W E S

2045 = Design Year Design Hourly Volumes (DHV)

				Penny Lane					
		2	18	50	80				
		(2)	(14)	(25)	(40)	SB			
	EB	PEDS	←	↓	→	PEDS	(3)	2	
28	(7)	↑	Entering Hourly Volumes			↑	(3)	11	
581	(283)	→				←	(535)	566	SR 1
17	(21)	↓				↓	(38)	92	
20	(14)	PEDS	←	↑	→	PEDS	WB		
		NB	(35)	(4)	(43)	(2)			
			36	11	129	2			

Figure 2-5: IIE Data Inputs Form (Sample Data)

IIE Stage I – Scoping Form

Figure 2-6 provides an image of TDOT's IIE Stage I - Scoping form to be used by practitioners in the Stage I – Scoping step. To be effective, the Stage I – Scoping step needs a high-level traffic analysis tool that can be used in concert with the Scoping form with minimal data and by practitioners with minimal traffic analysis experience. TDOT has selected the CAP-X tool to serve this purpose. It is a free, publicly available, spreadsheet tool. Guidance concerning usage of CAP-X is provided in *CAP-X Workflow Guidance* beginning on page 2-40.

TDOT has selected CAP-X as its IIE Stage I – Scoping traffic analysis tool.

TDOT's IIE Stage I - Scoping form lists all available CAP-X intersection and interchange control options. The form is color-coded consistent with CAP-X's format. Fields with either optional or required practitioner inputs are colored yellow. In the case of optional inputs, suggested values are provided in orange cells. Cells not requiring practitioner inputs are locked and typically colored white. The cells are locked to prevent erroneous inputs, overriding of cell calculations, or overriding of descriptions. However, the practitioner may unlock the spreadsheet if needed. The password to unlock the sheet is "tdot".

Typically, most control options available in the IIE Stage I Scoping form need only a cursory consideration whether or not to proceed to TDOT's Stage II – Preferred Option Selection step. Typically, the practitioner would know if at-grade options vs. interchange options should be considered, if right-of-way is available for a Quadrant Intersection, if a median is available for a Median U-Turn intersection, etc. Factors that should be considered include projected traffic volumes, the context of the surrounding land use, a high-level knowledge of available funding, and the number of approach lanes on the intersecting roadways. For an extreme example, a mini-roundabout would never be included in an analysis that also considers a single-point interchange. Analyzing more than a few intersection / interchange control options creates additional and often unnecessary work finalizing the CAP-X inputs. For additional guidance concerning screening control type options please refer to *Screening Selection* on page 2-25.

Intersection Location:	at in County				
Number of Intersection Legs:	-	**PIN:**	0.00	**Date:**	1/0/00
Existing Control Type:	None	**Analyst:**	0	Version: 09142020	

TDOT Department of Transportation

TDOT IIE Stage I Form - Scoping

Control Type	Conflict Point Score (lower # is better)	Is the option feasible and reasonable?	Is the option likely to improve or maintain safety?	Is the option likely to improve operations?	Is the Optoin likely to improve or maintain multimodal access?	AM V/C Ratio (CAP X)	PM V/C Ratio (CAP X)	Should the Option proceed to Stage II?	
At-Grade Intersection	Safety	Q1	Q2	Q3	Q4	Capacity		Decision	Screening Decision Justification
Traffic Signal	-	-	-	-	-			-	
Two-Way Stop Control	-	-	-	-	-			-	
All-Way Stop Control	-	-	-	-	-			-	
Continuous Green T	-	-	-	-	-			-	
Quadrant Roadway	-	-	-	-	-			-	
Partial Displaced Left Turn	-	-	-	-	-			-	
Displaced Left Turn	-	-	-	-	-			-	
Signalized RCUT	-	-	-	-	-			-	
J-Turn (Unsignalized RCUT)	-	-	-	-	-			-	
Median U-Turn	-	-	-	-	-			-	
Partial Median U -Turn	-	-	-	-	-			-	
Bowtie	-	-	-	-	-			-	
Split Intersection	-	-	-	-	-			-	
Roundabout	-	-	-	-	-			-	
Other (provide description)		-	-	-	-			-	
Grade-Separated Intersection	Safety	Q1	Q2	Q3	Q4	CAP-X		Decision	Screening Decision Justification
Echelon	-	-	-	-	-			-	
Center Turn Overpass	-	-	-	-	-			-	
Interchange	Safety	Q1	Q2	Q3	Q4	CAP-X		Decision	Screening Decision Justification
Diamond	-	-	-	-	-			-	
Partial Cloverleaf	-	-	-	-	-			-	
Displaced Left Turn Interchange	-	-	-	-	-			-	
Contraflow Left Interchange	-	-	-	-	-			-	
DDI	-	-	-	-	-			-	
Single Point	-	-	-	-	-			-	
Single Point with Roundabout	-	-	-	-	-			-	
Other (provide description)		-	-	-	-			-	

Figure 2-6: IIE Stage I – Scoping Form (No Inputs)

Guidance concerning inputs for the Stage I - Scoping form follow.

Project Information

The top three rows of the Stage I - Scoping form are reserved for project information inputs. These inputs are automatically updated from practitioner-provided inputs in the *Data Inputs Form*.

Intersection Location

Based upon practitioner inputs in the *Data Inputs Form,* the location description is auto-populated and should include the State Route designation of the intersecting roadway(s) and county of the intersection / interchange.

Number of Intersection Legs

Based upon practitioner inputs in the *Data Inputs Form*, the number of intersection legs is auto-populated. The selection should be consistent with the selection chosen in the CAP-X tool for the proposed number of legs at the location. When an option is selected, the Conflict Point Score is auto-populated in the designated column. Refer to *Conflict Point Score* on page 2-25 for additional information concerning these values. Note, intersections with more than four legs are not standard and due to their uniqueness often require the practitioner to proceed directly to Stage II – Preferred Option Selection processes.

Existing Control Type

Based upon practitioner inputs in the *Data Inputs Form,* the existing control type is auto-populated. The options are based upon all available control types in CAP-X. If the project is on new location, the practitioner may select "None." Once a control type is selected it is highlighted in the Control Type list. This serves as a visual reminder that all improvement options should be compared to the existing condition.

PIN

The TDOT PIN is auto-populated based upon practitioner inputs in the *Data Inputs Form*.

Analyst

The analyst is auto-populated based upon practitioner inputs in the *Data Inputs Form*.

Date

The date is auto-populated based upon practitioner inputs in the *Data Inputs Form*.

Scoping Form Version

The version of the scoping form is listed in the bottom right block. The version is named by the date it is updated.

Screening Selection

The remainder of the Stage I – Scoping form is for the practitioner to answer questions to determine which control options should proceed to Stage II – Preferred Option Selection.

Control Type

The Control Type column lists all available CAP-X intersection and interchange control options. If an *Existing Control Type* is selected in the Project Information area, then that control type is highlighted. If an intersection / interchange type is not listed in the Stage I - Scoping form and is desired for consideration, the practitioner should simply describe it in the "Other" row. Potential options not listed on the form include jug handle intersections and fully directional interchanges.

Conflict Point Score

The number of conflict points (locations where vehicle travel paths intersect) provides a planning-level metric that can be used to evaluate the safety of an intersection or interchange. There are three categories: crossing, merging, or diverging. In general, merging and diverging conflict points — where vehicles are moving in the same direction — are associated with less severe crash types than crossing conflict points, where vehicles move in opposite directions. Safety research suggests that intersection crash rates are related to the number of conflicts at an intersection.

There are 32 conflict points associated with a four-legged conventional intersection – eight merging (or joining), eight diverging (or separating), and 16 crossing. In contrast, there are only eight total conflict points at an equivalent roundabout – four merging and four diverging. Not only are conflict points halved with the roundabout, the type of conflicts that remain are the same-direction variety, which result in substantially less severity, and as a result, less likelihood of injury. The reduction of both the total number of conflict points and their severity is also true for pedestrians. All other intersection control options have between 32 and eight conflict points.

To provide the practitioner with a high-level planning safety assessment, the Stage I – Scoping form provides a Conflict Point Score based upon conflict points. The lower the score the "safer" a control type is. The Conflict Point Score is automatically adjusted based upon the number of legs to an intersection (3 or 4 selected in the *Number of Intersection Legs* drop-down menu. The scores are color-coded on a gradient from green ("safer") to yellow ("less safe").

The Conflict Point Score is based upon the conflict points of each intersection or interchange type. To account for crossing conflicts being more hazardous than merging or diverging conflicts, crossing conflicts are weighted by two (2) by default. The Conflict Point Score tab provides the calculations behind the Conflict Point Count and Conflict Point Weighted Score. The practitioner can adjust the weightings for each conflict type in the orange colored cells located on the Conflict Point Score tab, if desired. However, it is recommended to always weight crossing conflicts higher than merging or diverging conflicts.

Is the option feasible and reasonable?

"Is the option feasible and reasonable" is the first of four screening questions the practitioner should consider. For each option, the practitioner should select "Yes" or "No" from the drop-down menu. The practitioner should consider if each option is feasible and reasonable given site and geometric characteristics; notably right-of-way constraints, sheer nature of the junction (three vs. four legs), access control limitations, adjacent land-use context, and the presence or absence of median potential. The practitioner should always consider if the control type option is in balance with the scale of the problem. Additional considerations include:

- Initial capital and recurring costs. Note, no cost values are necessary in the Stage I Scoping step, just an educated assumption of project cost compared to available funding.
- Stakeholder and public support.
- Project development time.
- Continuity / uniformity with the remaining corridor.
- Environmental impacts.
- Utility impacts.

Any specific information should be documented in the *Screening Decision Justification cells*.

Is the option likely to improve or maintain safety?

"Is the option likely to improve or maintain safety" is the second of four screening questions. The practitioner should consider if there is a realistic expectation the control type option will improve or maintain safety. The Conflict Point Score can help guide this selection but should not be used as the sole determiner. The Conflict Point Score provides a planning-level metric that can be used to evaluate the safety of an intersection or interchange, but should not take the place of engineering judgment, especially when considering restricted movement options or bicyclist and pedestrian safety.

If an *Existing Control Type* is selected from the drop-down menu then that control type is highlighted in the list. This serves as a visual cue to compare the conflict point score to other options considered.

A more detailed safety assessment is recommended in Stage II – Preferred Option Selection for those chosen to proceed to Stage II.

As noted, the Conflict Point Score unfortunately does not always fully inform the practitioner concerning the "safer" intersection or interchange option. The practitioner should use engineering judgement as well as their knowledge of the Highway Capacity Manual and Crash Modification Factors when determining if an option is likely to improve or maintain safety.

Is the option likely to improve operations?

"Is the option likely to improve operations" is the third of the four screening questions. The practitioner should consider if there is a realistic expectation the control type option will improve traffic operations. If the practitioner selected "Yes" for the first two screening questions, then it is a candidate for CAP-X analysis. The results of the CAP-X analysis should guide this "Yes" or "No" answer concerning if the option is likely to improve operations.

Is the option likely to improve or maintain multimodal access?

"Is the option likely to improve or maintain multimodal access?" is the last of the four screening questions. The practitioner should consider the option's effect on multimodal transportation, especially when multimodal activity is anticipated to be medium to high; the land use context supports multimodal transportation; or facilities such as bus stops, schools, or other institutions nearby are likely to generate multimodal activity. Additional considerations are noted in *Multimodal Considerations*.

AM and PM V/C Ratio (CAP X)

The AM and PM design year peak hour analyses volume to capacity (v/c) ratio results from CAP-X should be input in the appropriate columns for those options that the practitioner selected "Yes" for the first two screening questions. CAP-X analysis does not need to be completed for options that are not feasible and reasonable or expected to improve or maintain safety. The Stage I Scoping form automatically assigns color coding for each input. Those with v/c ratios of 0 to 0.74 are color-coded green, 0.75 to 0.90 are color-coded yellow, 0.91 to 0.99 are color-coded orange, and those with a v/c ratio of 1.0 or above are color-coded red. This provides a visual cue for those options expected to operate adequately through the design year. The v/c ratios should also be compared to those of the existing control type to determine if the option may have improved operations.

Should the Option proceed to Stage II?

Based on the inputs of the Stage I Scoping form, the Practitioner should decide if an intersection / interchange control type should proceed to the Stage II – Preferred Option Selection stage. Only a few options should be selected. Analyzing more than a few intersection / interchange control options would typically create additional and unnecessary work finalizing the CAP-X inputs and more effort summarizing the recommendations for options to carry forward into IIE Stage II - Preferred Option Selection. The additional analysis required in Stage II – Preferred Option Selection includes more detailed capacity, safety, and cost assessments. Typically, it is not necessary to include more than three options that address the project need and that are in context with the surrounding land use.

Note, it is not necessary for an option to have all "Yes" answers to the four screening questions or "passing" v/c ratios to recommend an option to proceed to Stage II. However, those answers should inform the practitioner's recommendation and help support the decision. The cells are color-coded green for those that "Yes" is selected.

Screening Decision Justification

The practitioner is strongly encouraged to provide brief notes concerning why each option was or was not selected to proceed to Stage II – Preferred Option Selection. This is important for documentation purposes. A sample completed Stage I Scoping form is provided in Figure 2-7.

Conflict Point Score

The Conflict Point Score tab provides the calculations behind the *Conflict Point Score.* The practitioner can adjust the weightings for each conflict type in the orange colored cells if desired. The Conflict Point Score is based upon the conflict points of each intersection type. To account for crossing conflicts being more hazardous than merging or diverging conflicts, crossing conflicts are weighted by two (2) by default.

Intersection Location:	SR 1 at Penny Lane in Davidson County				
Number of Intersection Legs:	4	**PIN:**	12345.00	**Date:**	9/3/20
Existing Control Type:	Two-Way Stop Control	**Analyst:**	JHS, ABC Consultant	Version: 09142020	

TDOT Department of Transportation

TDOT IIE Stage I Form - Scoping

Control Type	Conflict Point Score (lower # is better)	Is the option feasible and reasonable?	Is the option likely to improve or maintain safety?	Is the option likely to improve operations?	Is the Optoin likely to improve or maintain multimodal access?	AM V/C Ratio (CAP X)	PM V/C Ratio (CAP X)	Should the Option proceed to Stage II?	
At-Grade Intersection	Safety	Q1	Q2	Q3	Q4	Capacity		Decision	Screening Decision Justification
Traffic Signal	48	Yes	Yes	Yes	Yes	0.22	0.34	**Yes**	Should proceed to Stage II
Two-Way Stop Control	48	Yes	Yes	No	Yes	0.19	1.17	No	Over capacity
All-Way Stop Control	48	Yes	Yes	No	Yes	0.73	1.04	No	Over capacity, Do not want multilane stop control
Continuous Green T	n/a	-	-	-	-			No	Not applicable
Quadrant Roadway	40	No	-	-	-			No	No ROW for connecting road
Partial Displaced Left Turn	44	No	-	-	-			No	Not necessary for volumes
Displaced Left Turn	40	No	-	-	-			No	Not necessary for volumes
Signalized RCUT	20	Yes	Yes	Yes	No	0.22	0.31	No	Pedestrian crossing is important, no U-turn option
J-Turn (Unsignalized RCUT)	20	Yes	Yes	Yes	No	0.18	0.47	No	Pedestrian crossing is important, no U-turn option
Median U-Turn	20	No	-	-	-			No	Median not wide enough
Partial Median U -Turn	28	No	-	-	-			No	Median not wide enough
Bowtie	24	No	-	-	-			No	Not necessary for volumes
Split Intersection	36	No	-	-	-			No	Not necessary for volumes
Roundabout	8	Yes	Yes	Yes	Yes	0.25	0.30	**Yes**	Should proceed to Stage II
Other (provide description)		-	-	-	-			-	
Grade-Separated Intersection	Safety	Q1	Q2	Q3	Q4	CAP-X		Decision	Screening Decision Justification
Echelon	28	No	-	-	-			No	Not necessary for volumes
Center Turn Overpass	32	No	-	-	-			No	Not necessary for volumes
Interchange	Safety	Q1	Q2	Q3	Q4	CAP-X		Decision	Screening Decision Justification
Diamond	28	No	-	-	-			No	Not necessary for volumes
Partial Cloverleaf	20	No	-	-	-			No	Not necessary for volumes
Displaced Left Turn Interchange	28	No	-	-	-			No	Not necessary for volumes
Contraflow Left Interchange	32	No	-	-	-			No	Not necessary for volumes
DDI	20	No	-	-	-			No	Not necessary for volumes
Single Point	32	No	-	-	-			No	Not necessary for volumes
Single Point with Roundabout	12	No	-	-	-			No	Not necessary for volumes
Other (provide description)		-	-	-	-			No	Not necessary for volumes

Figure 2-7: IIE Stage I – Scoping Form (Sample Data)

IIE Stage II – Preferred Option Selection Form

Figure 2-8 provides an image of TDOT's IIE Stage II – Selection form to be used by practitioners in the Stage II – Selection step. The IIE Stage II – Selection form summarizes key analysis results and qualitative information used by decision makers to select a Preferred Option on one sheet. The form is color-coded consistent with the IIE Stage I – Scoping form. Fields with either optional or required practitioner inputs are colored yellow. Cells not requiring practitioner inputs are locked and colored white. The cells are locked to prevent erroneous inputs, overriding of cell calculations, or overriding of descriptions. However, the practitioner may unlock the spreadsheet if needed. The password to unlock the sheet is "tdot".

The IIE Stage II – Selection form provides inputs for the existing condition (if applicable) and up to four (4) proposed options. Only options that the practitioner selected "Yes" to the question "Should the Option proceed to Stage II" in the Stage I – Scoping form will be summarized. The intent of the form is to provide a single summary form to document the intersection / interchange control selection process. All supporting calculations and analysis shall be documented in an appendix.

The IIE Stage II – Selection form summarizes the items listed below in one form. The form automatically color-codes the input values to provide the practitioner a visual representation of suitability.

- Project Cost
- Life-cycle Cost (Optional)
- Traffic Operations
    - Level of Service
    - Delay
    - Volume to Capacity (v/c) Ratio
    - Queue Results
- Predictive Crash Analysis (Optional)
- Multimodal Qualitative Assessment
- Stakeholder Posture
- TDOT Approval

TN TDOT Department of Transportation	Intersection Location:			at in County						
	Number of Intersection Legs:			-	PIN:	0.00			Date:	1/0/00
	TDOT IIE Stage II Form - Selection				Analyst:	0			Version: 09042020	
	Existing Control		Option 1		Option 2		Option 3		Option 4	
TDOT IIE Stage II Form - Selection	None		None		None		None		None	
Project Cost										
Tool Used	Not Applicable		-		-		-		-	
Total Project Cost	Not Applicable		-		-		-		-	
Life Cycle Cost										
Tool Used	-		-		-		-		-	
Analysis Period	to		to		to		to		to	
Total Life Cycle NPV Cost	-		-		-		-		-	
Traffic Operations										
Traffic Analysis Software Used	-		-		-		-		-	
0 Opening Year	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
LOS	-	-	-	-	-	-	-	-	-	-
Delay (s/veh)										
v/c										
Queues Accommodated?	-	-	-	-	-	-	-	-	-	-
0 Design Year	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
LOS	-	-	-	-	-	-	-	-	-	-
Delay (s/veh)										
v/c										
Queues Accommodated?	-	-	-	-	-	-	-	-	-	-
Predictive Crash Analysis										
Tool Used	-		-		-		-		-	
Analysis Period	to		to		to		to		to	
Total Crashes										
Fatal & Injury Crashes										
Multimodal										
Are peds, bicyclists, and transit riders accommodated?	-		-		-		-		-	
Stakeholder Posture										
Local Community Support	Not Applicable		-		-		-		-	
TDOT Support	Not Applicable		-		-		-		-	
TDOT Approval										
Preferred Option?	Not Applicable		-		-		-		-	
Comments										
TDOT Reviewer Name and Title				Signature					Date	

Figure 2-8: IIE Stage II – Selection (No Inputs)

Project Data Information

The top three rows of the Stage II - Selection form are reserved for project information inputs. These inputs are automatically updated from practitioner-provided inputs in the *Data Inputs Form*.

Control Type (for each Option)

The Existing Control type is automatically updated from practitioner-provided inputs in the *Data Inputs Form - Existing Control Type*. The practitioner selects the control type of Options 1 through 4 from a drop-down menu of all available control types in CAP-X. If an intersection / interchange type is not listed in the drop-down menu and is desired for consideration, the practitioner should select "Other". The "Other" configuration should be the same as described in the IIE Stage I – Scoping form under *Control Type*. If fewer than four (4) options are under consideration the practitioner should select "None" for the columns not used.

Project Cost

The practitioner summarizes project development costs consisting of engineering, construction, right-of-way, and utility relocations in the Project Cost section.

Tool Used

Project costs should be calculated with the TDOT STID's Cost Estimate Tool. The tool is maintained by STID with current average unit prices of construction. When a project's cost is developed, the practitioner should request that their TDOT project manager supply them with the most up-to-date version of the TDOT STID Tool.

The practitioner can select either the "TDOT STID Tool" or "Other" from the drop-down menu. If a unique situation exists where the TDOT STID Tool is not efficient or applicable, the practitioner should seek approval from their TDOT project manager to develop costs in some other manner.

Total Project Cost

The practitioner summarizes project development costs consisting of engineering, construction, right-of-way, and utility relocations in the Total Project Cost cells. Whether the project costs are calculated with the TDOT STID Tool or another way, all calculations should be clearly documented in an appendix.

Life-cycle Cost

In TDOT's IIE process, life-cycle cost analysis is recommended but optional. The TDOT project manager will determine if it is required on a case-by-case basis. In its standard and most streamlined approach for TDOT's IIE process, life-cycle cost analysis requires the following three (3) elements:

1. Agency's initial engineering, construction, right-of-way, and utility relocation costs, as described in *Project Cost*.
2. Roadway users' operations or delay cost, as described in *Traffic Operations*.
3. Predictive Crash Analysis (see *Predictive Crash Analysis Overview*). It should be noted that if a life-cycle cost analysis is required then a predictive crash analysis must also be developed.

The Life-Cycle Cost Estimating Tool (LCCET) tool provides the flexibility for more advanced analysis when conditions merit (and when the input data are available). Conditions where more advanced analysis may be requested by the TDOT project manager could include emissions costs on projects funded through the Congestion Mitigation and Air Quality Improvement (CMAQ) program or multimodal analysis on transit or bicycle and pedestrian grant projects. In these situations, data input needs should be evaluated at project scoping.

Tool Used

Several tools or methods could be used for life-cycle cost analysis. For a consistent approach, TDOT selected the LCCET. For more information on life-cycle cost analysis and the LCCET too, refer to *Life-Cycle Cost Overview* on page 2-11 and *Life-Cycle Cost Analysis – LCCET Tool* on page 2-73.

A drop-down menu allows the practitioner to select the tool used in the life-cycle cost analysis. "None" should be selected if a life-cycle cost analysis is not required. "LCCET [National Cooperative Highway Research Program (NCHRP) 220]" should be selected if the LCCET tool is used. "Other" should be selected if another life-cycle cost analysis tool or methodology is used. Whether the life-cycle project costs are calculated with the LCCET or another method, all calculations should be clearly documented in an appendix.

Analysis Period

The Analysis Period cells are automatically updated from practitioner-provided inputs for the Opening Year and Design Year on the *Data Inputs Form*.

Total Life-Cycle NPV Cost

The practitioner inputs the results of the life-cycle net present value (NPV) cost analysis in the "Total Life-cycle NPV Cost" cells for each option. Note that the Existing Control condition has a life-cycle cost even though it has no initial project cost. This is the cost of no improvements associated with roadway users' operations / delay and safety costs. The life-cycle costs are color-coded on a gradient from dark green (less expensive) to white (most expensive).

Traffic Operations

Final decisions for intersection / interchange control types should be based, in part, on the results of detailed traffic analysis tools such as the Highway Capacity Software (HCS), Synchro, VISSIM, SIDRA, etc. The practitioner inputs the results of their detailed traffic analysis in the Traffic Operations section.

Traffic Analysis Software Used

TDOT allows many different software packages to be used for traffic analysis. The more common ones include the HCS, Synchro, VISSIM and SIDRA. The practitioner selects the traffic analysis software used for the Existing Control and Options 1 through 4 from a drop-down menu of these common types. If the practitioner uses another software package they should select "Other" from the drop-down menu. The same software package does not need to be used for every option. For instance, the practitioner may elect to use Synchro for signalized intersection analysis and SIDRA for roundabout analysis. It is recommended for the practitioner to coordinate with their TDOT project manager concerning acceptable software for each option prior to starting analysis. Regardless of the software used, all calculations should be clearly documented in an appendix.

Opening Year Level of Service

The practitioner inputs the intersection control's level of service (LOS) for the Opening Year AM and PM time periods in the cells. The LOS inputs are color-coded based on the inputs: A = Dark Green, B = Light Green, C = Yellow, D = Dark Yellow, E = Orange, and F = Red.

Opening Year Delay

The practitioner inputs the intersection control's delay in seconds per vehicle for the Opening Year AM and PM time periods in the cells. Note that this is the overall intersection's delay. The delay inputs are color-coded on a gradient from dark green (least delay) to white (most delay). The color gradient compares the AM times to AM times and PM times to PM times.

Opening Year Volume to Capacity Ratio

The practitioner inputs the intersection control's v/c ratio for the Opening Year AM and PM time periods in the cells. Note that this is typically reported as the worst v/c ratio of an approach to the intersection since this is the controlling v/c ratio. The v/c ratio inputs are color-coded on a gradient from dark green (lower v/c ratio) to white (highest v/c ratio). The color gradient compares the AM times to AM times and PM times to PM times.

Opening Year Queues Accommodated?

The practitioner answers if all queues are accommodated with selection of "Yes" or "No" from the drop-down menu. The results of queue analysis and reporting will vary by traffic analysis software tool.

The practitioner should review the analysis to ensure queues do not create safety or operational concerns. The results are color-coded: "Yes" = Green, "No" = Red.

Design Year Level of Service

The practitioner inputs the intersection control's LOS for the Design Year AM and PM time periods in the cells. The LOS inputs are color-coded based on the inputs: A = Dark Green, B = Light Green, C = Yellow, D = Dark Yellow, E = Orange, and F = Red.

Design Year Delay

The practitioner inputs the intersection control's delay in seconds per vehicle for the Design Year AM and PM time periods in the cells. Note that this is the overall intersection's delay. The delay inputs are color-coded on a gradient from dark green (least delay) to white (most delay). The color gradient compares the AM times to AM times and PM times to PM times.

Design Year Volume to Capacity Ratio

The practitioner inputs the intersection control's v/c ratio for the Design Year AM and PM time periods in the cells. Note that this is typically reported as the worst v/c ratio of an approach to the intersection since this is the controlling v/c ratio. The v/c ratio inputs are color-coded on a gradient from dark green (lower v/c ratio) to white (highest v/c ratio). The color gradient compares the AM times to AM times and PM times to PM times.

Design Year Queues Accommodated?

The practitioner answers if all queues are accommodated with selection of "Yes" or "No" from the drop-down menu. The results of queue analysis and reporting will vary by traffic analysis software tool. The practitioner should review the analysis to ensure queues do not create safety or operational concerns. The results are color-coded: "Yes" = Green, "No" = Red.

Predictive Crash Analysis

TDOT strives to make data-driven decisions to improve the safety of the state's roadway network. The Highway Safety Manual (HSM) predictive methods assume similar roadways and intersections with similar roadway and traffic characteristics are likely to experience similar crash frequencies, severities, and crash types. The HSM predictive methods provide procedures to analyze safety performance in terms of crash severity, crash types, and number of vehicles involved in the crashes. TDOT's Predictive Crash Analysis leverages the HSM predictive methods along with its associated tools to inform the selection of a preferred intersection / interchange control option. The practitioner inputs the results of their predictive analysis in the Traffic Operations section.

Tool Used

Several tools have been developed and are available for free download to conduct predictive crash analysis. One of the simplest and most straight-forward to use is the Safety Performance for Intersection Control Evaluation (SPICE) tool. SPICE was developed by FHWA to provide practitioners with a means of evaluating the anticipated safety performance of control strategies within a single tool. 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 NCHRP 17-38 spreadsheets, Enhanced Interchange Safety Analysis Tool (ISATe), or the Interactive Highway Safety Design Module (IHSDM). However, many of these tools have a steeper learning curve than SPICE (although perhaps can provide more accurate predictions). In general, SPICE is TDOT's preferred IIE predictive crash analysis tool due to its intersection-focus, ease of use, and consistent approach. *Predictive Crash Analysis Overview* on page 8 provides additional information on this subject. *Predictive Crash Analysis – SPICE Tool* on page 63 provides guidance for using SPICE. Other tools may be used for predictive crash analysis.

TDOT allows many different predictive crash analysis tools to be used. The more common ones include SPICE, ISATe, IHSDM, HSM Spreadsheet Tools, and HSM Calculations (by hand). The practitioner selects the tool used for the Existing Control and Options 1 through 4 from a drop-down menu of these common types. If the practitioner uses another software package they should select "Other" from the drop-down menu. If a predictive crash analysis is not required, the practitioner selects "Not Applicable". The same tool does not need to be used for every option. For instance, the practitioner may elect to use SPICE for one option and IHSDM for another. However, this is strongly discouraged as it may not result in consistent predictions across all options. So, when possible the practitioner should use the same tool for every option. It is recommended for the practitioner to coordinate with their TDOT project manager concerning acceptable tool(s) to use prior to starting analysis. Regardless of the tool used, all calculations should be clearly documented in an appendix.

Analysis Period

The Analysis Period cells are automatically updated from practitioner-provided inputs for the Opening Year and Design Year on the *Data Inputs Form*.

Total Crashes

The practitioner inputs the total crashes over the analysis period in the "Total Crashes" cells. The total crashes inputs are color-coded on a gradient from dark green (least crashes) to white (most crashes).

Fatal and Injury Crashes

The practitioner inputs the sum of the fatal and injury crashes over the analysis period in the “Fatal and Injury Crashes” cells. The fatal and injury crashes inputs are color-coded on a gradient from dark green (least crashes) to white (most crashes). The fatal and injury crashes results are combined consistent with SPICE’s output, which combines these crash types. If other analysis methods are used and they provide separate values for fatal and injury crashes the practitioner should simply add them together.

Multimodal

The practitioner selects a qualitative assessment of how well each option addresses pedestrian, bicyclist, and transit riders from a drop-down menu. The options include: “Well”, “Adequately”, “Poorly”, “Not Accommodated”, and “Not Applicable”. The practitioner should refer to guidance in *Multimodal Considerations* on page 2-4 to assist in their assessment. The option that accommodates multimodal users “Well” may be the best of the options in Stage II – Selection. For an intersection or interchange to score “Well,” it should provide safe multimodal access via pedestrian signal heads or stop condition for motor-vehicles across all legs / crossings. Those that score “Adequately” may accommodate multimodal users, but not as well as others. “Adequately” scored intersections / interchanges could include signalized intersections that have yield-condition channelized right turns. Those that accommodate multimodal users “Poorly” may not accommodate multimodal users in all four quadrants of an intersection but still provide access or have free-flow ramp turning movements. “Not Accommodated” would be for locations that have multimodal activity but do not provide access. “Not Applicable” would be selected for intersections / interchanges on controlled access facilities such as freeways that do not allow multimodal users. The Multimodal inputs are color-coded based on the inputs: “Well” = Dark Green, “Adequately” = Light Green, “Poorly” = Pink, “Not Accommodated” = Red, and “Not Applicable” = Yellow (original cell color).

Stakeholder Posture

It is important for the practitioner to consider stakeholder posture or preference in the IIE process. The form provides input for both local community support and TDOT support. The practitioner should strive to obtain the posture of these stakeholders during project development.

Local Community Support

The practitioner selects a qualitative assessment of how well each option is supported by the local community or agency from a drop-down menu. The options include: “Supportive”, “Neutral”, “Negative”, “Opposed”, and “Unknown”. If the local community has a Preferred Option(s), it should be marked “Supportive”. If the local community would neither support nor oppose the option, it should be marked “Neutral”. If the local community does not prefer an option but does not outright oppose it, it should be marked "Negative". If the local community is outright opposed to an option and would prefer to keep the Existing Control, it should be marked "Opposed". If the local community's support is not known, it should be marked "Unknown." The Local Community Support inputs are color-coded based on the inputs: "Supportive" = Dark Green, "Neutral" = Yellow, "Negative" = Pink, "Opposed" = Red, and "Unknown" = Yellow (original cell color).

TDOT Support

The practitioner selects a qualitative assessment of how well each option is supported by TDOT from a drop-down menu. Refer to *Local Community Support* for guidance concerning the drop-down menu options.

TDOT Approval

The TDOT Approval section documents TDOT's Preferred Option selection.

Preferred Option?

The practitioner selects "Yes" or "No" from a drop-down menu concerning if the option is the Preferred Option. Only one Preferred Option should be selected. The responses are color-coded: "Yes" = Green, "No" = Red.

Comments

The practitioner should include brief comments summarizing why the Preferred Option was selected. Significant criteria used in the determination should be documented. The comment box allows for up to four lines of text.

TDOT Reviewer Approval

The appropriate TDOT reviewer should sign and date their approval of the Preferred Option. A sample completed Stage II – Selection form is provided in Figure 2-9.

TN TDOT Department of Transportation	**Intersection Location:**			SR 1 at Penny Lane in Davidson County						
	Number of Intersection Legs:			4	**PIN:**	12345.00			**Date:**	9/3/20
	TDOT IIE Stage II Form - Selection				**Analyst:**	JHS, ABC Consultant			Version: 09042020	
	Existing Control		**Option 1**		**Option 2**		**Option 3**		**Option 4**	
TDOT IIE Stage II Form - Selection	Two-Way Stop Control		Traffic Signal		Roundabout		None		None	
Project Cost										
Tool Used	Not Applicable		TDOT STID Tool		TDOT STID Tool		-		-	
Total Project Cost	Not Applicable		$1,000,000		$3,000,000		-		-	
Life Cycle Cost										
Tool Used	LCCET (NCHRP 220)		LCCET (NCHRP 220)		LCCET (NCHRP 220)		-		-	
Analysis Period	2025 to 2045		2025 to 2045		2025 to 2045		2025 to 2045		2025 to 2045	
Total Life Cycle NPV Cost	$13,835,701		$16,359,474		$3,626,270		-		-	
Traffic Operations										
Traffic Analysis Software Used	Synchro		Synchro		Synchro		-		-	
2025 Opening Year	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
LOS	C	F	B	B	A	A	-	-	-	-
Delay (s/veh)	20	290	12	10	4	8				
v/c	0.28	1.25	0.55	0.4	0.2	0.5				
Queues Accommodated?	Yes	No	Yes	Yes	Yes	Yes	-	-	-	-
2045 Design Year	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
LOS	D	F	B	B	A	A	-	-	-	-
Delay (s/veh)	25.3	354	14.4	11.8	4.6	9.7				
v/c	0.328	1.53	0.65	0.52	0.249	0.595				
Queues Accommodated?	Yes	No	Yes	Yes	Yes	Yes	-	-	-	-
Predictive Crash Analysis										
Tool Used	SPICE		SPICE		SPICE		-		-	
Analysis Period	2025 to 2045		2025 to 2045		2025 to 2045		2025 to 2045		2025 to 2045	
Total Crashes	17.36		28.37		15.28					
Fatal & Injury Crashes	6.77		11.62		1					
Multimodal										
Are peds, bicyclists, and transit riders accommodated?	Poorly		Well		Adequately		-		-	
Stakeholder Posture										
Local Community Support	Not Applicable		Supportive		Neutral		-		-	
TDOT Support	Not Applicable		Supportive		Neutral		-		-	
TDOT Approval										
Preferred Option?	Not Applicable		**Yes**		**No**		-		-	
Comments	Evening is controlling time. Two-Way Stop Control has LOS F on stop-controlled approaches (reported values). Roundabout shows improved LOS compared to signal, but concern with pedestrians and bicyclists crossing multilane roundabout. Budget constraints are a concern with Roundabout - initial costs more of a concern than life-cycle. Local Governement is not as supportive of a roundabout due to ROW impacts.									
TDOT Reviewer Name and Title	John Doe, STID Supervisor			Signature					Date	9/4/20

Figure 2-9: IIE Stage II – Selection (Sample Data)

CAP-X Workflow Guidance

CAP-X Description

CAP-X Overview

The Capacity Analysis for Planning of Junctions (CAP-X) tool was developed by Federal Highway Administration (FHWA) to provide practitioners with a means of evaluating the anticipated operational performance of both conventional and innovative intersection and interchange control options. The CAP-X tool is now maintained by the Crash Modification Factors Clearinghouse (CMF), which is funded by FHWA and maintained by the University of North Carolina Highway Safety Research Center. The CAP-X Tool uses a critical lane volume analysis to determine the volume to capacity (v/c) ratio for a variety of intersection control strategies and provides an assessment of the pedestrian and bicycle accommodations for the selected intersection types. The intersection and interchange control strategies included in CAP-X mirror those found in FHWA's AIIR. Based on the input parameters, CAP-X will generate a list of intersection or interchange types, ranked by v/c ratio, and provide a high-level multimodal score based on pedestrian and bicycle accommodations.

> *CAP-X will generate a list of intersection or interchange types, ranked by v/c ratio, and provide a high-level multimodal score based on pedestrian and bicycle accommodations.*

How do I Obtain and Run CAP-X?

The CAP-X Tool is an Excel-based macro workbook available for download on CMF Clearinghouse. For functionality of the tool, the practitioner must enable macros (use the prompt dialog at the top of the workbook) upon opening the spreadsheet.

> *The CAP-X Tool is available for free download from the CMF Clearinghouse: http://www.cmfclearinghouse.org/resources_selection.cfm.*

What Data Inputs are Needed for CAP-X?

The following data inputs are required to conduct a CAP-X analysis:

- Turning Movement Counts with truck percentages;
- Knowledge or estimate of number of approach lanes (both thru and turning lanes); and
- Knowledge or estimate of channelized islands, approach speeds, and presence of bicycle lanes (if a pedestrian / bicyclist multimodal assessment is needed).

> *For a TDOT IIE Stage I - Scoping analysis, both AM and PM Peak Hour turning movement counts (TMCs) must be run in two separate CAP-X Excel files.*

CAP-X can only be run for one time period per Excel file. For a Tennessee Department of Transportation (TDOT) Intersection and Interchange Evaluation (IIE) Stage I - Scoping analysis, both AM and PM Peak Hour turning movement counts (TMCs) must be run in two separate CAP-X Excel files. Unless the practitioner has received approval from their TDOT project manager, they should use volumes projected to the design year and approved by the Strategic Transportation Investments Division's (STID) Special Projects Office. If projected volumes are not available, CAP-X does allow for the input of a factor to "grow" the existing counts to a future value. TDOT's historical traffic count data may be used to estimate a percent increase based upon past volume trends. However, this approach may not be acceptable in an official IIE analysis. TDOT's traffic history data are available for download at:

https://www.arcgis.com/apps/webappviewer/index.html?id=075987cdae37474b88fa400d65681354.

What are the Range of Intersection / Interchange Control Options Evaluated?

CAP-X can assess the intersection or interchange control types listed below. For design information concerning each intersection / interchange control type please refer to FHWA's Alternative Intersections/Interchanges: Informational Report (AIIR) at the link below: (https://www.fhwa.dot.gov/publications/research/safety/09060/).

At-Grade Intersections

- Traffic Signal
- Two-Way Stop Control
- All-Way Stop Control
- Continuous Green T
- Quadrant Roadway
- Partial Displaced Left Turn
- Displaced Left Turn
- Signalized Restricted Crossing U-Turn (RCUT)
- Unsignalized Restricted Crossing U-Turn (J-Turn)
- Median U-Turn (MUT)
- Partial Median U-Turn
- Bowtie
- Split Intersection
- Roundabouts

Grade Separated Intersections

- Echelon
- Center Turn Overpass

Grade Separated Interchanges

- Diamond
- Partial Cloverleaf
- Displaced Left Turn Interchange
- Contraflow Left Interchange
- Diverging Diamond Interchange
- Single Point
- Single Point with Roundabout

Should All Possible Control Options be Evaluated?

CAP-X allows the number of options included in its summary report to be limited to only those determined by the practitioner to be applicable at the location under study. Options are eliminated from analysis and reporting through drop-down options in the *Base and Alt Sel Tab*. Typically, all control options should not be included in the IIE Stage I - Scoping analysis. Typically, the practitioner would know if at-grade options vs. interchange options should be considered, if right-of-way is available for a Quadrant Intersection, if a median is available for a Median U-Turn intersection, etc. Factors that should be considered include projected traffic volumes, the context of the surrounding land use, a high-level knowledge of available funding, and the number of approach lanes on the intersecting roadways. For an extreme example, a mini-roundabout would never be included in an analysis that also considers a single-point interchange. In summary, just because a practitioner *can* analyze all 33 potential intersection / interchange configurations in CAP-X does not mean they *should*. It would create additional and unnecessary work finalizing the CAP-X inputs and more effort summarizing the recommendations for options to carry forward into IIE Stage II - Preferred Option Selection.

What are CAP-X's Limitations Compared to Other Tools?

CAP-X is a screening tool to evaluate a wide range of control strategies in a consistent and reproducible manner. That is why it is applicable for use in TDOT's IIE Stage I – Scoping step. It provides guidance for control strategies that *may* be feasible. The CAP-X Tool is not intended to replace the functionality of more detailed traffic analysis tools. Final decisions for intersection / interchange control types should not be based solely on CAP-X; it is not a replacement for analysis tools such as the Highway Capacity Software (HCS), Synchro, VISSIM, SIDRA, etc. that would typically be used in TDOT's IIE Stage II – Preferred Option Selection.

CAP-X Instructions

Guidance concerning tabs within the CAP-X Tool follow. In CAP-X, fields with either optional or required practitioner inputs are colored yellow. In the case of optional inputs, suggested values are provided in the orange cells. To prevent erroneous inputs, overriding of cell calculations, overriding of descriptions, or breaking of macro functionality, cells not requiring/permitting practitioner inputs are locked. These are typically light blue.

Fields with either optional or required inputs are colored yellow. Suggested or default values are provided in orange cells.

Introduction Tab

The *Introduction Tab* provides an overview of the purpose, intent, and functionality of the CAP-X Tool.

Abbreviations & Assumptions Tab

The *Abbreviations & Assumptions Tab* provides an overview of all abbreviations used throughout the CAP-X Tool, general assumptions, intersection-specific assumptions, and instructions for how to input the number of lanes for approaches with shared lane configurations.

Changelog Tab

The *Changelog Tab* provides software update notes.

Volume Input Tab

The *Volume Input Tab* (see Figure 2-10) is the first step in the CAP-X analysis. The practitioner should input all relevant project description information in the top table, including:

- Project Name: The input will typically include the State Route designation of the major route and a sideroad.
- Project Number: The input will typically include the TDOT Project Identification Number (PIN).
- Location: The location should include the county. Also include the name of the city if it is within one.
- Date: The date should include the Analysis Year and AM or PM. It should not be the date the analysis was developed. For instance, if the traffic analysis is for 2045 AM projected volumes, this is what should be placed in the Date field.
- Number of Intersection Legs: Select three or four legs from the drop-down menu.
- Major Street Direction. Select North-South or East-West from the drop-down menu. This selection affects calculations in the CAP-X Tool.

It is recommended to download a new CAP-X Tool file from the CMF Clearinghouse for each analysis (see *How do I Obtain and Run CAP-X*?). However, if the practitioner is using a CAP-X file stored on their computer or server, CAP-X has a "Reset Tool to Defaults" button on the *Volume Input Tab*. This should be selected if using a file that could have had the defaults modified.

Capacity Analysis for Planning of Junctions

Step 1

Project Name:	*SR 1 at Penny Lane*
Project Number:	*12345*
Location	*Davidson County, TN*
Date	2045 AM
Number of Intersection Legs	4
Major Street Direction	East-West

Traffic Volume Demand

	Volume (Veh/hr)				Percent (%)	
	U-Turn	**Left**	**Thru**	**Right**	Heavy Vehicles	Volume Growth
Eastbound	0	7	283	21	2.00%	0.00%
Westbound	0	38	535	38	2.00%	0.00%
Southbound	0	40	25	14	1.00%	0.00%
Northbound	0	35	4	43	1.00%	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	**Medium**	**Multimodal Ped**	**Multimodal Bike**
Critical Lane Volume Sum Limit	2-phase signal	**Suggested = 1800 (Urban), 1650 (Rural)**	**1800**
	3-phase signal	**Suggested = 1750 (Urban), 1600 (Rural)**	**1750**
	4-phase signal	**Suggested = 1700 (Urban), 1550 (Rural)**	**1700**

Equivalent Passenger Car Volume

	Volume (Veh/hr)			
	U-Turn	**Left**	**Thru**	**Right**
Eastbound	0	7	289	21
Westbound	0	39	546	39
Southbound	0	40	25	14
Northbound	0	35	4	43

Notes:

Left-Turn Adjustment Factor	*Conversion of left-turning vehicles to equivalent through vehicles*
Right-turn Adjustment Factor	*Conversion of right-turning vehicles to equivalent through vehicles*
U-turn Adjustment Factor	*Conversion of U-turning vehicles to equivalent through vehicles*
Truck to PCE Factor	*1 truck = X Passenger Car Equivalents*
Critical Lane Volume Sum Limit	*Saturation Value for Critical Lane Volume Sum at an intersection*

Figure 2-10: Volume Input Tab

The *Traffic Volume Demand* section requires the practitioner to enter vehicle turning volumes, in vehicles per hour, heavy vehicle percentage (for each approach), growth percentage (for each approach), volume adjustment factors, truck to passenger car equivalent (PCE) factor, multimodal activity level, and critical lane volume sum limits. The *Volume Growth* percentage is an optional input to grow volumes to a future analysis year based on a practitioner supplied growth percentage, if design year traffic projections are not available (see *What Data Inputs are Needed for CAP-X?*). The *Volume Growth* value defaults to zero percent (no growth) and should be maintained when projected volumes are available.

The *Adjustment Factor* converts turning vehicles to equivalent through vehicles for analysis; default values are provided in the CAP-X Tool and should typically not be adjusted. The *Truck to PCE* factor converts trucks to passenger car equivalent values, the factor value defaults to the suggested value of 2.00 and should typically not be adjusted. The *Multimodal Activity Level* can be set to low, medium, or high. There are also links that will take the practitioner to the Multimodal Scoring Tabs; more information about these tabs are provided in the Multimodal Ped Tab and Multimodal Bike Tab sections. The *Critical Lane Volume Sum Limits* allow the practitioner to modify the saturation value for critical lane volumes at an intersection. Practitioner changes to this value are optional but the default values are provided in the CAP-X Tool and recommended for use for Urban or Rural contexts.

Following the *Traffic Volume Demand* section, there is a table displaying the equivalent passenger car volumes for each turning movement. This table is an output provided for informational purposes based on the practitioner provided traffic volume demand values and does not contain any cells that can be modified by the practitioner. These equivalent passenger car values are used in the calculations of the critical lane volumes for each intersection type.

Base and Alt Sel Tab

The *Base and Alt Sel Tab* includes inputs for the existing intersection configuration (see Figure 2-11 "Step 2A") and allows the practitioner to select which proposed intersection types are to be included in the analysis and ranking (see Figure 2-12 "Step 2B").

Step 2A: Base Conditions Analysis includes a drop-down menu to select the intersection control of the existing intersection / interchange. The number of lanes for the existing configuration is displayed on this tab; however, to edit the existing number of lanes, the practitioner is referred to the Alt Num Lanes Input Tab. Based on the practitioner-selected existing intersection configuration, the v/c ratio, pedestrian accommodation, and bicycle accommodation results for the existing configuration are displayed on this tab. If the location is on new alignment "none" may be selected from the drop-down menu.

Step 2B: Alternative Selection allows the practitioner to turn on or off individual intersection or interchange types (shown in yellow) or entire intersection or interchange groups, such as grade separated intersections, roundabouts, or interchanges (shown in orange). When the options are turned off, the control type is not reported in the summary output and the detailed analysis tabs are hidden by the CAP-X Tool's macros. Typically, all control options <u>should not be included</u> in the IIE Stage I - Scoping analysis. The practitioner would know if at-grade options vs. interchange options should be considered. Practitioners should simply include a concise reason in the comment field why the option was not included such as the option is not applicable due to the projected traffic volumes, cost, access control limitations, or context of the study area. "No" should then be selected in the drop-down menu. Leaving all options available would create additional and unnecessary work finalizing the CAP-X inputs on the following tabs and more effort summarizing the recommendations for options to carry forward into IIE Stage II - Preferred Option Selection.

Capacity Analysis for Planning of Junctions

Step 2A: Base Conditions Analysis

Project Name:	*SR 1 at Penny Lane*
Project Number:	*12345*
Location:	*Davidson County, TN*
Date:	2045 AM
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	0		0	1	0		1	2	0		1	2	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**	--	--	--	--	--	--	--	--	--	***0.19***	--	--

Existing Configuration Results

Overall v/c Ratio	0.19	**Pedestrian Accommodation**	Fair	**Bicycle Accommodation**	Good

Figure 2-11: Base and Alt Sel Tab (1 of 2)

Step 2B: Alternative Selection

Rankings Inclusion		Yes/No	Comment
At-Grade Non-Roundabout Intersections?		Yes	
Traffic Signal		Yes	
Two-Way Stop Control		Yes	
All-Way Stop Control		Yes	
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		Yes	
Unsignalized Restricted Crossing U-Turn		Yes	
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		No	
1NS x 2EW		Yes	
2NS x 1EW		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 2-12: Base and Alt Sel Tab (2 of 2) – With At-Grade Intersections Active

Alt Num Lanes Input Tab

The *Alt Num Lanes Input Tab* allows practitioners to customize the number of lanes for each turning movement for both the existing configuration and the selected proposed options. The number of lanes is used in conjunction with the practitioner supplied turning volumes to determine the critical lane volume for each junction. Lanes with shared movements are input by entering "0" in either the left or right column for the given movement. Example lane configurations and their associated inputs are shown in Figure 2-13.

Example Lane Configuration				
User Input (L,C,R)	0,1,0	0,2,0	0,1,1	1,1,0

Figure 2-13: Lane Coding Format

The "Analysis Type" drop-down menu allows the practitioner to choose to display analysis for intersections only or intersections and interchanges. This option toggles whether or not the table for modifying the number of lanes at interchanges is shown. The *Alt Num Lanes Input Tab* (see Figure 2-14) includes inputs to select the number of lanes for non-roundabout intersections, grade separated intersections, and interchanges. It is also noteworthy that when options are turned off via the drop-down menus in the *Base and Alt Sel Tab* they are hidden on the *Alt Num Lanes Input Tab*. This is a primary benefit to the practitioner; they do not need to code the number of approach lanes for options not under consideration.

Each intersection type includes a link in the Sheet column that, when clicked, takes the practitioner to the analysis tab for the selected intersection type (see *Detailed Options Tabs (53 Tabs)*). The number of lanes coded in the *Alt Num Lanes Input Tab* are automatically populated in the respective *Detailed Options Tabs*. The *Detailed Options Tabs* provide graphics to help the practitioner ensure the lane configurations are coded properly. There are three intersection types which utilize their respective intersection specific tab for the number of lanes inputs rather than the *Alt Num Lanes Input Tab*. These three intersection types are the quadrant roadway, split intersection, and single point interchange with roundabout.

Capacity Analysis for Planning of Junctions

Step 3

Project Name:	*SR 1 at Penny Lane*
Project Number:	*12345*
Location:	*Davidson County, TN*
Date:	2045 AM
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
Traffic Signal	FULL		0	1	0		0	1	0		1	2	0		1	2	0
Two-Way Stop Control	E-W		0	1	0		0	1	0		1	2	0		1	2	0
All-Way Stop Control	FULL		0	1	0		0	1	0		1	2	0		1	2	0
Signalized Restricted Crossing U-Turn	E-W				1				1	1	1	2	0	1	1	2	0
Unsignalized Restricted Crossing U-Turn	E-W				1				1	1	1	2	0	1	1	2	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

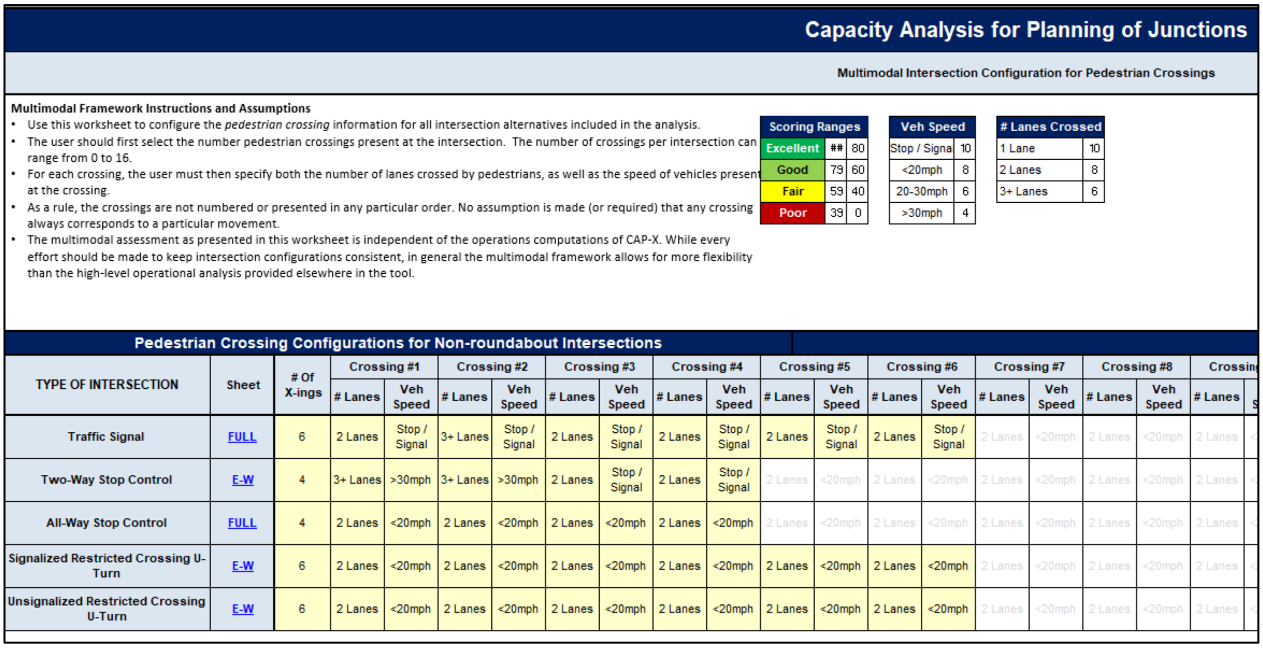
Number of Lanes for Interchanges

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 2-14: Alt Num Lanes Input Tab

Multimodal Ped Tab

The *Multimodal Ped Tab* contains optional inputs used in conducting the assessment of pedestrian accommodations. Default values are available and populated for all inputs in the tab, and the pedestrian analysis will still be carried out if the practitioner does not make any modifications to this tab. For each row, the practitioner uses drop-down menus to select the number of crossings, as well as the number of lanes and vehicle speed category for each crossing. Each intersection type includes a link in the Sheet column that, when clicked, takes the practitioner to the analysis tab for the selected intersection type (see *Detailed Options Tabs (53 Tabs)*). When options are turned off via the drop-down menus in the *Base and Alt Sel Tab* they are hidden on the *Multimodal Ped Tab*. This is a primary benefit to the practitioner; they do not need to code the pedestrian crossing data for options not under consideration. Figure 2-15 shows a portion of the *Multimodal Ped Tab*.



Capacity Analysis for Planning of Junctions

Multimodal Intersection Configuration for Pedestrian Crossings

Multimodal Framework Instructions and Assumptions

- Use this worksheet to configure the *pedestrian crossing* information for all intersection alternatives included in the analysis.
- The user should first select the number pedestrian crossings present at the intersection. The number of crossings per intersection can range from 0 to 16.
- For each crossing, the user must then specify both the number of lanes crossed by pedestrians, as well as the speed of vehicles present at the crossing.
- As a rule, the crossings are not numbered or presented in any particular order. No assumption is made (or required) that any crossing always corresponds to a particular movement.
- The multimodal assessment as presented in this worksheet is independent of the operations computations of CAP-X. While every effort should be made to keep intersection configurations consistent, in general the multimodal framework allows for more flexibility than the high-level operational analysis provided elsewhere in the tool.

Scoring Ranges		
Excellent	##	80
Good	79	60
Fair	59	40
Poor	39	0

Veh Speed	
Stop / Signa	10
<20mph	8
20-30mph	6
>30mph	4

# Lanes Crossed	
1 Lane	10
2 Lanes	8
3+ Lanes	6

Pedestrian Crossing Configurations for Non-roundabout Intersections

TYPE OF INTERSECTION	Sheet	# Of X-ings	Crossing #1		Crossing #2		Crossing #3		Crossing #4		Crossing #5		Crossing #6		Crossing #7		Crossing #8		Crossin
			# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes	Veh Speed	# Lanes
Traffic Signal	FULL	6	2 Lanes	Stop / Signal	3+ Lanes	Stop / Signal	2 Lanes	Stop / Signal	2 Lanes	Stop / Signal	2 Lanes	Stop / Signal	2 Lanes	Stop / Signal	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes
Two-Way Stop Control	E-W	4	3+ Lanes	>30mph	3+ Lanes	>30mph	2 Lanes	Stop / Signal	2 Lanes	Stop / Signal	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes
All-Way Stop Control	FULL	4	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes
Signalized Restricted Crossing U-Turn	E-W	6	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes
Unsignalized Restricted Crossing U-Turn	E-W	6	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes	<20mph	2 Lanes

Figure 2-15: Multimodal Ped Tab

It does not matter in which order pedestrian crossings are evaluated, as long as all crossings are included in the analysis. For consistency, it is recommended to begin the evaluation in the north-east quadrant of the intersection, and then number crossings sequentially in a clockwise direction. The goal of the multimodal methodology is to provide a process that can be used to conduct a high-level assessment of multimodal accommodations at various intersection types. These assessments can then be used as an additional reference point when comparing intersection options under differing conditions.

The number of lanes of each pedestrian crossing is evaluated to account for the level of exposure pedestrians have to vehicular traffic during the crossing. Each crossing is categorized into one of three conditions:

- One-Lane Crossing – pedestrians have to cross a single lane at a time.
- Two-Lane Crossing – pedestrians have to cross two lanes at a time, introducing the risk of a "multiple threat" situation with a vehicle stopped/yielding in the near lane blocking the view (and audible information) between the pedestrians and vehicles in the far lane.
- Three-Lane Crossing or greater – pedestrians have to cross three or more lanes at a time, increasing the level of exposure of pedestrians significantly.

An intersection may have anywhere from four crossings (two major and two minor street crossings at a standard intersection) to sixteen crossings (four right turns, four left turns, and two-stage mainline and side-street crossings at all four approaches of a Displaced Left Turn Intersection).

The assessment of vehicular speed and number of lanes is based on general design assumptions. For example, it can be assumed that single-lane roundabouts and channelized turn lanes can be designed at a low design speed, and that intersections either have signalized (stopped condition) or unsignalized crosswalks. For complex intersection designs, each crosswalk should be considered individually. An intersection may have anywhere from four crossings (two major and two minor street crossings at a standard intersection) to 16 crossings (four right turns, four left turns, and two-stage mainline and side-street crossings at all four approaches of a Displaced Left Turn Intersection). For intersections with channelization islands (e.g. roundabouts) or medians [e.g. Restricted Crossing U-Turn Intersections (J-Turns / RCUTs) and Median U-Turn Intersections (MUTs)], each crossing component should be evaluated separately.

Multimodal Bike Tab

The *Multimodal Bike Tab* contains optional inputs used in conducting the assessment of bicyclist accommodations. Default values are available and populated for all inputs in the tab, and the bicycle analysis will be carried out even if the practitioner does not make any modifications to this tab. For each row, the practitioner uses drop-down menus to select the number of segments, as well as the type of bicycle facility (Separate Path, On-Street Lane, or Shared with *Motor* Vehicle) and motor vehicle speed category for each crossing.

- Separate Path – Bicycles are physically separated from vehicles on a separate path. Separation is provided through either a physical barrier or curb. A bike facility separated by only paint falls into the next category.
- On-Street Bike Lane – Bicycles travel in a dedicated on-street bike lane with a width of at least five (5) feet, but no physical separation to motorized traffic is provided.
- Shared Lane with Vehicles – Bicycles travel in a lane shared with vehicular traffic.

Concerning the number of segments, a traditional four-legged intersection will have four segments (one bicycle facility per approach). More complex intersection / interchange configurations will have more. For complex intersection designs, each approach to the intersection should be considered as an individual segment, as well as each unique maneuver that cyclists have to complete. To summarize, an intersection will typically have four segments (two major and two minor street crossings at standard intersection) and up to 12 segments (four right turns, four left turns, and all four mainline approaches of a Displaced Left Turn Intersection). In general, channelized lanes and U-turn movements should be considered as separate segments. If in doubt, the practitioner should utilize the default number of segments pre-filled by the CAP-X Tool.

An intersection will typically have four segments but up to twelve segments at complex intersections

Each intersection type includes a link in the Sheet column that, when clicked, takes the practitioner to the analysis tab for the selected intersection type (see Detailed Options Tabs (53 Tabs)). When options are turned off via the drop-down menus in the Base and Alt Sel Tab they are hidden on the *Multimodal Bike Tab*. This is a primary benefit to the practitioner; they do not need to code the bicycle crossing data for options not under consideration. Figure 2-16 shows a portion of the *Multimodal Bike Tab*.

Capacity Analysis for Planning of Junctions

Multimodal Intersection Configuration for Bicycle Segments

Multimodal Framework Instructions and Assumptions

- Use this worksheet to configure the *bicycle segment* information for all intersection alternatives included in the analysis.
- The user should first select the number bicycle crossing segments present at the intersection. The number of segments per intersection can range from 0 to 12.
- For each seg,emt, the user must then specify both the type of bike lane present, as well as the speed of vehicles present at the segment.
- As a rule, the segments are not numbered or presented in any particular order. No assumption is made (or required) that any segment always corresponds to a particular movement.
- The multimodal assessment as presented in this worksheet is independent of the operations computations of CAP-X. While every effort should be made to keep intersection configurations consistent, in general the multimodal framework allows for more flexibility than the high-level operational analysis provided elsewhere in the tool.

Scoring Ranges		
Excellent	##	80
Good	79	60
Fair	59	40
Poor	39	0

Veh Speed	
<20mph	10
20-30mph	8
>30mph	6

Bike Lane Type	
Separate Path	10
On-Street Lane	8
Shared with Vehicles	6

Bicycle Segment Configurations for Non-roundabout Intersections

TYPE OF INTERSECTION	Sheet	# Of Seg.	Segment #1		Segment #2		Segment #3		Segment #4		Segment #5		Segment #6		Segment #7		Segment #8	
			Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed	Bike Lane	Veh Speed
Traffic Signal	FULL	6	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mp
Two-Way Stop Control	E-W	4	On-Street Lane	>30mph	On-Street Lane	>30mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	>30mph	On-Street Lane	>30mph	On-Street Lane	Stop Signa
All-Way Stop Control	FULL	4	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mp
Signalized Restricted Crossing U-Turn	E-W	6	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mp
Unsignalized Restricted Crossing U-Turn	E-W	6	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mph	On-Street Lane	<20mp

Figure 2-16: Multimodal Bike Tab

Summary Results Tab

The *Summary Results Tab* provides an overview of the results for the top ten selected intersection / interchange types, ranked by overall v/c ratio. When options are turned off via the drop-down menus in the *Base and Alt Sel Tab* they are hidden on the *Summary Results Tab*. This is a primary benefit to the practitioner; options that are not applicable do not clutter the summary results. In addition to the v/c ratio, the multimodal score, pedestrian accommodation, and bicycle accommodation results of potential options are provided in this summary tab. Figure 2-17 provides an example of the *Summary Results Tab* for non-interchanges.

Capacity Analysis for Planning of Junctions

Dynamic Results Summary

TYPE OF INTERSECTION	Overall V/C Ratio	V/C Ranking	Pedestrian Accommodations	Bicycle Accommodations
Unsignalized Restricted Crossing U-Turn E-W	0.18	1	Good	Excellent
Two-Way Stop Control E-W	0.19	2	Fair	Good
Traffic Signal	0.22	3	Good	Excellent
Signalized Restricted Crossing U-Turn E-W	0.22	3	Good	Excellent
1NS X 2EW Roundabout	0.25	5	Good	Excellent
All-Way Stop Control	0.73	6	Good	Excellent
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--

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 2-17: Summary Results Tab

Detailed Results Tab

The *Detailed Results Tab* provides complete v/c ratios and critical lane volumes for each relevant zone of each selected type of intersection, as well as the overall v/c ratio. Results are color-coded based on the overall v/c ratio, with green depicting v/c ratios less than 0.750, yellow from 0.750 to 0.875, orange from 0.875 to 1.00, and red greater than 1.00. A summary of the results that fall within these ranges is provided in the table in the top section of this tab. Results are separated into a different table for each of the intersection type categories: non-roundabout intersections, grade separated intersections, roundabouts, and interchanges. Pedestrian accommodation results and bicycle accommodation results are also provided for each of the selected intersection / interchange options. Each intersection type includes a link in the Sheet column that, when clicked, takes the practitioner to the analysis tab for the selected intersection type (see *Detailed Options Tabs (53 Tabs)*). When options are turned off via the drop-down menus in the *Base and Alt Sel Tab* they are hidden on the *Detailed Results Tab*. This is a primary benefit to the practitioner; options that are not applicable do not clutter the summary results. An example of the *Detailed Results Tab* for non-roundabout intersections is provided in Figure 2-18.

Capacity Analysis for Planning of Junctions

Detailed Results Worksheet

Project Name:	SR 1 at Penny Lane
Project Number:	12345
Location	Davidson County, TN
Date	2045 AM

Estimated Volume-to-Capacity Ratio			
Number of Configurations			
< 0.750	0.750 - 0.875	0.875 - 1.00	≥ 1.00
4	0	0	1

Results for Non-roundabout Intersections

TYPE OF INTERSECTION	Sheet	Zone 1 (North)		Zone 2 (South)		Zone 3 (East)		Zone 4 (West)		Zone 5 (Center)		Overall v/c Ratio	Pedestrian Accommodations	Bicycle Accommodations
		CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C			
Traffic Signal	FULL									382	0.22	0.22	Good	Excellent
Conventional Shared RT LN	CSRL									395	0.23	0.23	Excellent	Excellent
Two-Way Stop Control	E-W									--	0.19	0.19	Fair	Good
All-Way Stop Control	FULL									1094	0.73	0.73	Good	Excellent
Signalized Restricted Crossing U-Turn	E-W	403	0.22	271	0.15	361	0.20	240	0.13			0.22	Good	Excellent
Unsignalized Restricted Crossing U-Turn	E-W	603	0.18	352	0.13	624	0.05	317	0.06			0.18	Good	Excellent

Results for Grade Separated Intersections

TYPE OF INTERSECTION	Sheet	Zone 1 (North)		Zone 2 (South)		Zone 3 (East)		Zone 4 (West)		Zone 5 (Center)		Zone 6 (Raised)		Overall v/c Ratio	Ped	Bike
		CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C			

Capacity Analysis for Planning of Junctions

Detailed Results Worksheet

Results for Roundabouts

TYPE OF ROUNDABOUT	Zone 1 (North)			Zone 3 (East)			Zone 2 (South)			Zone 4 (West)			Overall v/c Ratio	Pedestrian Accommodations	Bicycle Accommodations
	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3	Lane 1	Lane 2	Lane 3			
1NS X 2EW	0.10			0.13	0.14		0.08			0.24	0.25		0.25	Good	Excellent

Results for Interchanges

TYPE OF INTERCHANGE	Sheet	Zone 1 (Rt Mrg)		Zone 2 (Lt Mrg)		Zone 3 (Ctr. 1)		Zone 4 (Ctr. 2)		Zone 5 (Lt Mrg)		Zone 6 (Rt Mrg)		Overall v/c Ratio	Pedestrian Accommodations	Bicycle Accommodations
		CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C			

Figure 2-18: Detailed Results Tab

Summary Report Tab

The *Summary Report Tab* replicates and combines information shown on previous tabs into a single location for documentation purposes. There are no inputs on this tab. *The Summary Report Tab* includes output from the *Volume Input Tab* and *Summary Results Tab*. Output from the *Summary Report Tab* for both AM and PM Peak Hours will typically be included with the TDOT IIE Stage I – Scoping form to document those options to be carried forward into the Stage II – Preferred Option Selection step. Figure 2-19 provides an example of the *Summary Report Tab* for non-roundabout intersections.

Output from the Summary Report Tab for both AM and PM Peak Hours will typically be included with the TDOT IIE Stage I – Scoping form to document those options to be carried forward into the Stage II – Preferred Option Selection step.

Capacity Analysis for Planning of Junctions

Summary Report

Project Name:	SR 1 at Penny Lane
Project Number:	12345
Location:	Davidson County, TN
Date:	2045 AM
Number of Intersection Legs:	4
Major Street Direction	East-West

Traffic Volume Demand

	Volume (Veh/hr)				Percent (%)	
	U-Turn	Left	Thru	Right	Heavy Vehicles	Volume Growth
Eastbound	0	7	283	21	2.00%	0.00%
Westbound	0	38	535	38	2.00%	0.00%
Southbound	0	40	25	14	1.00%	0.00%
Northbound	0	35	4	43	1.00%	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	**Medium**	

Critical Lane Volume Threshold		
2-phase signal	**Suggested = 1800 (Urban), 1650 (Rural)**	**1800**
3-phase signal	**Suggested = 1750 (Urban), 1600 (Rural)**	**1750**
4-phase signal	**Suggested = 1700 (Urban), 1550 (Rural)**	**1700**

Capacity Analysis for Planning of Junctions

Summary Report

#############

TYPE OF INTERSECTION	Overall v/c Ratio	V/C Ranking	Pedestrian Accommodations	Bicycle Accommodations
Unsignalized Restricted Crossing U-Turn E-W	0.18	1	Good	Excellent
Two-Way Stop Control E-W	0.19	2	Fair	Good
Traffic Signal	0.22	3	Good	Excellent
Signalized Restricted Crossing U-Turn E-W	0.22	3	Good	Excellent
1NS X 2EW Roundabout	0.25	5	Good	Excellent
All-Way Stop Control	0.73	6	Good	Excellent
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--
--	--	--	--	--

Figure 2-19: Summary Report Tab

Detailed Report Tab

The *Detailed Report Tab* replicates and combines information shown on previous tabs into a single location for documentation purposes. There are no inputs on this tab. *The Detailed Report Tab* includes output from the *Volume Input Tab*, *Alt Num Lanes Input Tab*, and *Detailed Results Tab*.

Detailed Options Tabs (53 Tabs)

The *Detailed Options Tabs* include sketches of each intersection / interchange type. Included in the figures are schematics of each option's v/c ratio "zone." The lane configuration inputs from the *Alt Num Lanes Input Tab* are summarized in figures. This serves as a good source for the practitioner to check their lane assignment inputs. The lane assignment inputs can also be modified in the *Detailed Option Tab* and it will be updated in the *Alt Num Lanes Input Tab*. These *Detailed Options Tabs* (up to 53 tabs) are accessible either by scrolling through the Excel File or by selecting the "Sheet" column in the *Alt Num Lanes Input Tab*, *Multimodal Bike Tab*, *Detailed Results Tab*, or *Detailed Report Tab*. When options are turned off via the drop-down menus in the *Base and Alt Sel Tab* their corresponding *Detailed Options Tab* is hidden. This is a primary benefit to the practitioner; options that are not applicable do not clutter the Excel file and lead to confusion as to whether the practitioner should quality check the option's inputs. Figure 2-20 and Figure 2-21 provide an example of the Roundabout Intersection with one north-south approach lane and two east-west approach lanes Detailed Option Tab – *1 NS x 2EW Lane Roundabout*.

1 NS x 2 EW Lane Roundabout

Design and Results

Project Name:	*SR 1 at Penny Lane*
Project Number:	*12345*
Location	*Davidson County, TN*
Date	2045 AM

Volume-to-Capacity Ratio				
< 0.750	0.750 - 0.875	0.875 - 1.00	≥ 1.00	
VOLUME / CAPACITY RATIO:	Zone 1	0.10	Zone3	0.25
	Zone 4	0.14	Zone 2	0.08

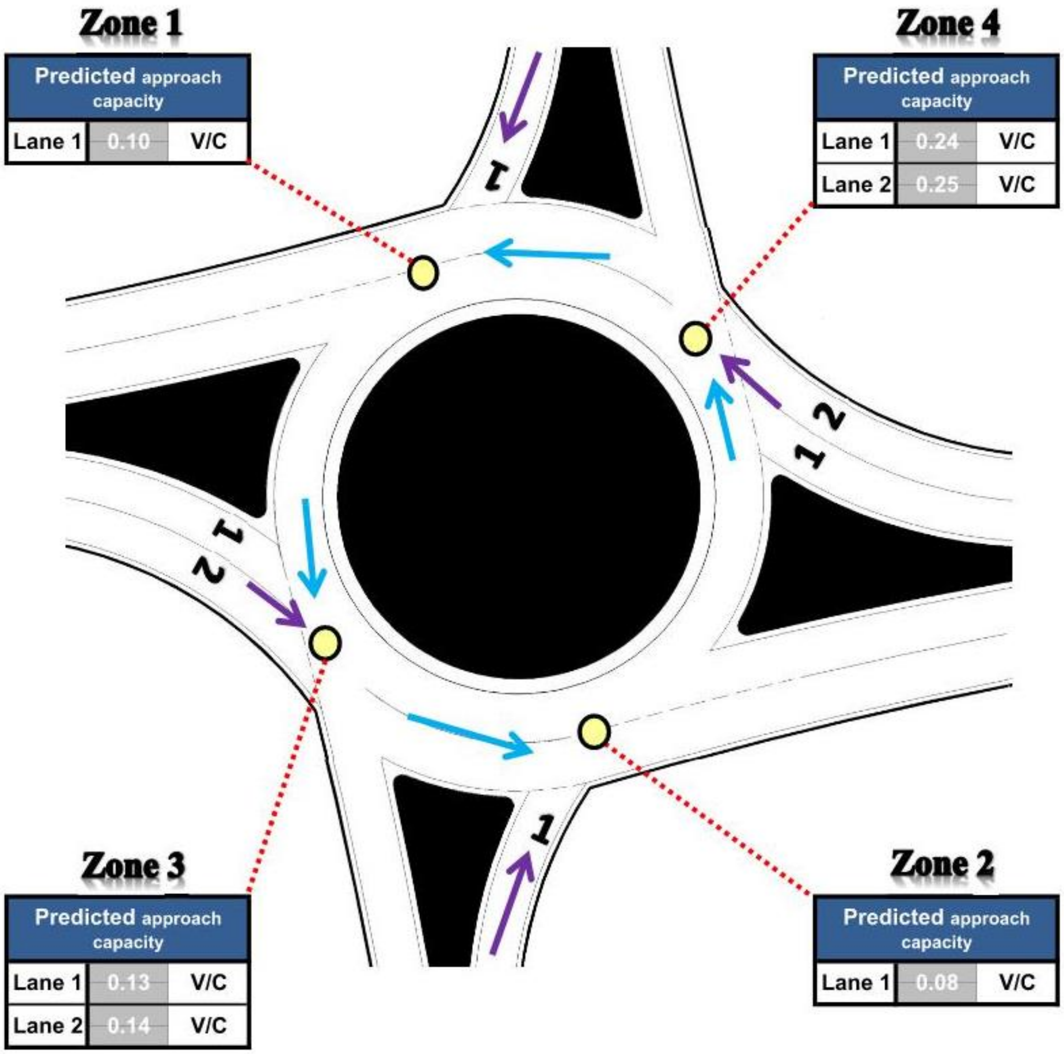


Figure 2-20: Roundabout Intersection Detailed Option Tab (1 of 2)

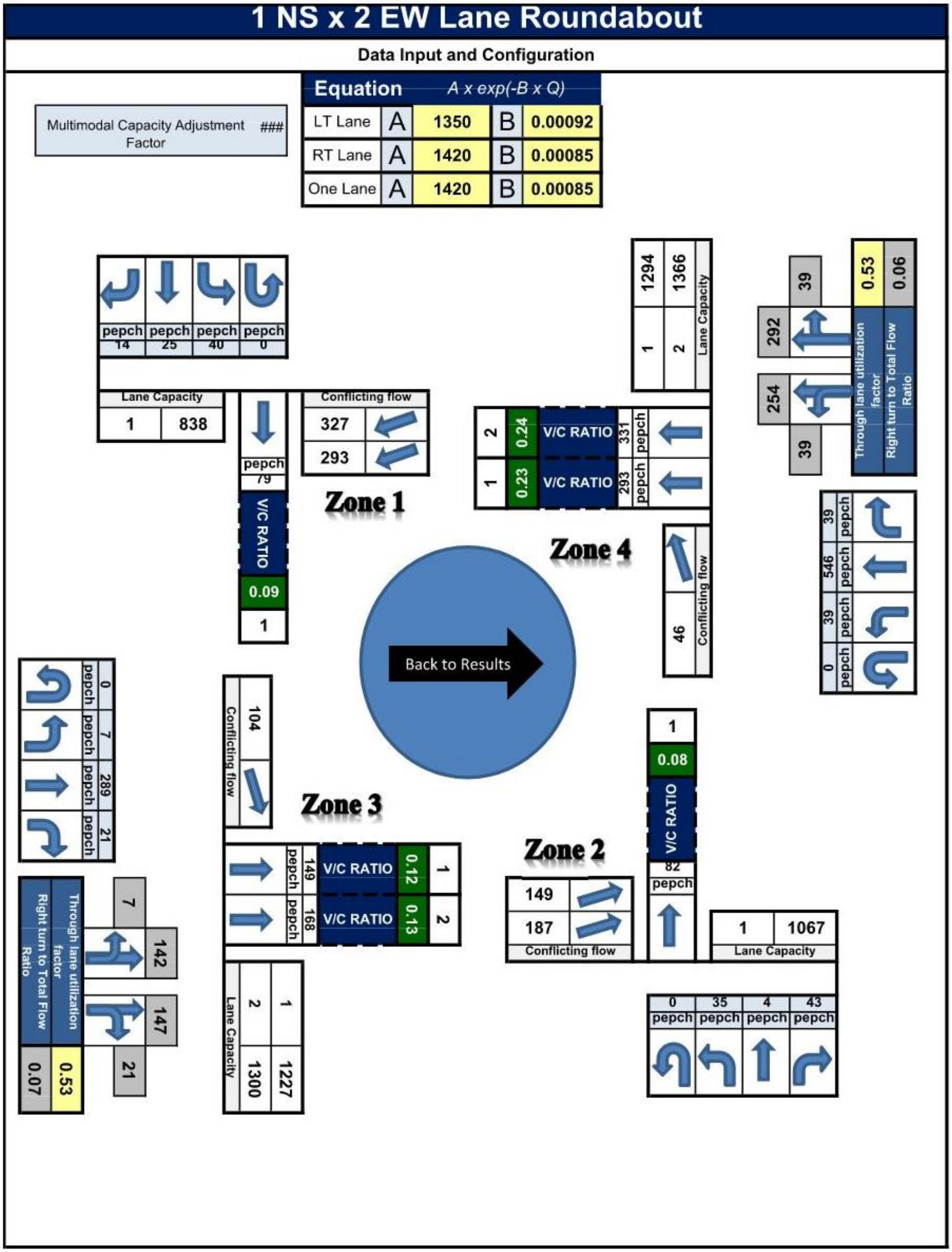


Figure 2-21: Roundabout Intersection Detailed Option Tab (2 of 2)

References

"Intersection Control Evaluation (ICE) - Safety: Federal Highway Administration." Safety, safety.fhwa.dot.gov/intersection/ice/.

Jenior, P. H. (2018). *Capacity Analysis for Planning of Junctions (CAP-X) Tool User Manual*. Washington, DC: Federal Highway Administration. Retrieved from http://www.cmfclearinghouse.org/collateral/FHWA-SA-18-067%20CAP-X%202018%20Tool%20User%20Guide%20(Final).pdf

Predictive Crash Analysis – SPICE Tool

SPICE Description

The Safety Performance for Intersection Control Evaluation (SPICE) tool was developed to assist practitioners with conducting intersection safety analysis during the scoping and screening stages of project development. This tool allows practitioners preparing Intersection & Interchange Evaluations (IIE) to consider predictive safety performance. The SPICE Tool utilizes Safety Performance Functions (SPFs) and crash modification factors (CMFs) primarily from the American Association of State Highway Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets 7th Edition* (also known as "The Green Book") HSM and the Federal Highway Administration (FHWA) Crash Modification Factors (CMF) Clearinghouse.

How do I Obtain and Run SPICE?

The SPICE Tool is an Excel-based macro workbook available for download on CMF Clearinghouse. For functionality of the tool, the practitioner must enable macros (use the prompt dialog at the top of the workbook) upon opening the spreadsheet.

> *The SPICE Tool is available for free download from the CMF Clearinghouse:*
> *http://www.cmfclearinghouse.org/resources_selection.cfm.*

What Data Inputs are Needed for SPICE?

The following data inputs are required to conduct a SPICE analysis:

- Opening Year
- Design Year (typically Opening Year + 20)
- Functional Classification of the intersecting roadways
- Land Use Classification of the Study Area
- Number of Intersecting Legs
- Opening Year Annual Average Daily Traffic (AADT) of the intersecting roadways
- Design Year AADTs of the intersecting roadways
- Left turn signal phasing treatment (for signal options)
- Right-turn-on-red phasing treatment (for signal options)
- Red light camera presence
- Pedestrian volume by activity level estimate (low to high) or Pedestrian volume counts
- Maximum number of lanes crossed by pedestrians
- Number of bus stops within 1,000 feet

- Number of alcohol sales establishments within 1,000 feet
- Interchange geometric characteristics (if analyzing interchange ramps)

What are the Range of Intersection / Interchange Control Options?

The SPICE Tool performs predictive safety analysis of at-grade intersection options and ramp-terminal intersections of basic service interchanges. The SPICE Tool assumes that certain attributes of the intersection – AADT, facility type, and number of legs – are the same for all alternatives. If they are not, practitioners will be required to use the tool twice to get results. The tool will not allow simultaneous evaluation of at-grade intersections and ramp-terminal intersections. For projects where analysis of both intersections and interchanges is needed, practitioners are required to use the tool twice to get results. For a listing of the intersection / interchange control options available for analysis in the SPICE Tool, please refer to Table 2-2 and Table 2-3 beginning on page 2-10.

SPICE Instructions

In general, SPICE is TDOT's preferred IIE predictive crash analysis tool due to its intersection-focus, ease of use, and consistent approach. SPICE relies on data inputs that are normally available to the analyst during project scoping and screening stages of project development. In Tennessee Department of Transportation's (TDOT) IIE Process, SPICE is typically run with default values for data inputs. This creates a simple and streamlined approach to predictive crash analysis. When conducting a planning-level analysis of alternatives, the SPICE Tool allows practitioners to quickly apply the Highway Safety Manual (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. When complex conditions necessitate, and more detailed data inputs are available, the SPICE Tool can be updated with practitioner-supplied calibration factors.

Introduction Tab

The *Introduction Tab* provides an overview of the purpose, intent, and functionality of the SPICE Tool.

Disclaimer Tab

The *Disclaimer Tab* provides terms of use and liability limitation information.

Project Information Tab

The practitioner inputs identifying information in the *Project Information Tab*. The practitioner should typically input the PIN in the "Project Reference" cell, county that the project is located in the "City" cell, and their name and firm or agency name in the "Analyst" cell. It is recommended to download a new SPICE workbook from the CMF Clearinghouse for each use (see *How do I Obtain and Run SPICE?*How do I Obtain and Run CAP-X?). However, if the practitioner cannot access the internet, they may copy an existing workbook and select the "Reset Spice" button to restore it to initial defaults. Figure 2-22 provides an example of the practitioner inputs on the tab.

Project Name:	Sample Test Project	
Intersection:	SR 1 at Penny Lane in Davidson County	
Agency:	TDOT	
Project Reference:	12345	
City:	Davidson County	
State:	TN	
Date:	9/4/2020	
Analyst:	JHS, ABC Consultant	
Use this button to clear all inputs/outputs and reset the tool to its initial defaults	Load Cap-X	Reset SPICE Tool

Figure 2-22: Project Information Tab

Definitions Tab

The *Definitions Tab* provides definitions for some of the more complex terms and inputs used within the SPICE Tool. No practitioner inputs are required; the tab is for informational purposes only. Many useful figures and definitions are provided in the comments fields of cells. These may be particularly useful when analyzing interchange ramps, which have more complex inputs than intersections. The comment boxes can be expanded to full view by unlocking the sheet with the password "kai123." To unlock the *Definitions Tab* sheet, go to Excel's "Review" ribbon and select "Unprotect Sheet," then expand the size of the comment box.

Control Strategy Selection Tab

The *Control Strategy Selection Tab* allows practitioners to determine which control strategies to include in the predictive crash analysis. Practitioners 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.

Practitioners 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 the AADT for years between the Opening Year and Design Year and predicts crashes for each intermediate year. For TDOT projects, the practitioner should select the "Opening and Design Year" option. The life-cycle crashes are what are reported on TDOT's *IIE Stage II – Preferred Option Selection Form*. The life-cycle crashes are also required if a life-cycle cost analysis is conducted.

The remaining practitioner input fields displayed on the *Control Strategy Tab* are self-explanatory. A useful feature in the SPICE Tool is it reports if either the Opening Year or Design Year AADTs exceed the range of data used to develop the SPFs for each control strategy. When this occurs, a note will appear in red next to the respective intersection control strategy. The SPICE Tool will still analyze the control strategy. However, the practitioner should use the results with caution. This is also indicated on the *Results Tab*. Figure 2-23 provides an example of the *Control Strategy Selection Tab* inputs.

Safety Performance for Intersection Control Evaluation

Control Strategy Selection

Intersection Type	At-Grade Intersections	(Select from Dropdown)
Analysis Year	Opening and Design Year	(Select from Dropdown)
Opening Year	2025	
Design Year	2045	
Facility Type	On Urban and Suburban Arterial	(Select from Dropdown)
Facility Secondary Type (For Roundabouts Only)	Urban	(Select from Dropdown)
Number of Legs	4-leg	(Select from Dropdown)
Opening Year – Major Road AADT	9,300	
Opening Year – Minor Road AADT	2,200	
Design Year – Major Road AADT	12,000	
Design Year – Minor Road AADT	3,000	

Note: The CMFs associated with roundabouts differentiate between urban and suburban areas, while the SPFs and CMFs for all othe

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	No	
2-Lane Roundabout	Yes	Minor Road Stop
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 (RCU	No	Minor Road Stop
Continuous Green-T (CGT) Intersection	No	Traffic Signal
Jughandle	No	Traffic Signal
Other 1	No	Traffic Signal
Other 2	No	Traffic Signal

Figure 2-23: Control Strategy Tab

At-Grade Inputs Tab

The *At-Grade Inputs Tab* will only be visible when the practitioner selects "At-Grade Intersections" for the "Intersection Type" on the *Control Strategy Selection Tab*. The *At-Grade Inputs Tab* allows the practitioner to enter pertinent information relating to the at-grade study intersection for the SPICE analysis. Figure 2-23 provides an example of the *At-Grade Inputs Tab* inputs.

The top section includes required inputs regarding the number of turn lanes for the stop-controlled and signalized control strategies. The required input cells are pale yellow. Although they are associated with the HSM Part C CMFs, turn lane inputs were placed in the required portion of the spreadsheet 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.

The bottom section of the *At-Grade Inputs Tab* allows the practitioner to override the default CMF-related inputs from Part C of the HSM. These optional input cells are orange. If conducting a planning-level analysis or the information is not known, 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. To reset the default CMF inputs, select the "Reset Planning Input Defaults" button at the top left of the section.

Safety Performance for Intersection Control Evaluation					
At-Grade Intersection Inputs					
Control Strategy					
Input		Traffic Signal	Minor Road Stop	2-lane Roundabout	
Number of Approaches with Left-Turn Lanes	Additional Required Control Strategy Inputs	4			Do not include stop controlled approaches for minor stop
Number of Approaches with Right-Turn Lanes		0			
Number of Uncontrolled Approaches with Left-Turn Lanes			2		
Number of Uncontrolled Approaches with Right-Turn Lanes			2		
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				
Skew Angle	A yellow cell indicates the value may be used in the SPF computation	N/A		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		
# of Approaches Permissive LT Signal Phasing		2			
Phasing		4			
# of Approaches Protected LT Signal Phasing		2			
Number of Approaches with Right-Turn-on-Red Prohibited		0			
Red Light Cameras Present		No			
Pedestrian Volume by Activity Level		Medium (700)			
User-Specified Sum of all daily pedestrian crossing volumes					
Max # of Lanes Crossed by Pedestrians		7			
Number of Bus Stops within 1000 ft of Intersection		2			
Schools within 1000 ft of intersection		No			
Number of Alcohol Sales Establishments within 1000 ft of Intersection		1			

Figure 2-24: At-Grade Intersection Inputs

Ramp Terminal Inputs Tab

The *Ramp Terminal Inputs Tab* will only be visible if the practitioner selects "Ramp Terminal Intersections" for the "Intersection Type" on the *Control Strategy Selection Tab*. The *Ramp Terminal Inputs Tab* allows the practitioner to enter pertinent information relating to the ramp terminal study intersection for the SPICE analysis. The top section allows the practitioner to override AADT information for the ramp and crossroad approaches (optional), as well as information regarding the number of lanes on the crossroad. The bottom section of the *Ramp Terminal Inputs Tab* allows the practitioner 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, practitioners should modify these inputs to match the anticipated conditions under each applicable control strategy.

Calibration Tab

The *Calibration Tab* allows the practitioner 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 proper data field (blue cells). SPICE's crash prediction computations will automatically use the "Optional User Override" calibration factors or local CMFs entered on this sheet. Figure 2-25 provides an example of the *Calibration Tab*.

To override CMF values with locally derived values, enter the desired value into the proper data field (blue cells). For example, if state- or location-specific research illustrated Displaced Left-Turn intersections were more effective at reducing fatal-injury crashes than the CMFs in SPICE, enter the local CMF value. To return all SPF calibration factors and CMFs to their default values, select the "Reset to Default Values" button in the top right corner of the Calibration tab.

In general, the practitioner may leave the "Optional User Override" inputs blank. However, TDOT is developing state-specific calibration factors (CFs). If CFs are available for ALL intersection control options investigated, then the practitioner may use the TDOT CFs. However, if CFs are not available for all intersection control options studied, then they should not be used as this could lead to unintentional weighting of control types that have been studied vs. those that have not. The practitioner should check with their TDOT project manager if state-specific CFs are available and should be used for the control types under study. Table 2-4 provides available TDOT CFs as of October 2020.

Safety Performance for Intersection Control Evaluation

Calibration
(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 (For more information on determining signal type, refer to the "Definitions" worksheet)	On Rural 2-Lane Highway	3-leg	-	-	1.00		1.00
		4-leg	-	-	1.00		1.00
	On Rural Multilane Highway	3-leg	-	-	1.00		1.00
		4-leg	-	-	1.00		1.00
	On Urban and Suburban Arterial	3-leg	2x2	5 or fewer	1.00		1.00
		4-leg	2x2	5 or fewer	1.00		1.00
Minor Road Stop	On Rural 2-Lane Highway	3-leg	-	-	1.00		1.00
		4-leg	-	-	1.00		1.00
	On Rural Multilane Highway	3-leg	-	-	1.00		1.00
		4-leg	-	-	1.00		1.00
	On Urban and Suburban Arterial	3-leg	2x2	5 or fewer	1.00		1.00
		4-leg	2x2	5 or fewer	1.00		1.00

Figure 2-25: Calibration Tab

Table 2-4: TDOT Intersection CFs

	Calibration Factors (CFs)			
	Rural Two-lane Two Way	Rural Multilane	Urban Intersection Single Vehicle Collisions	Urban Intersection Multiple Vehicle Collisions
Unsignalized three-leg (stop control on minor-road approaches) (3ST)	0.633	2.201	1.805	2.505
Unsignalized four-leg (stop control on minor-road approaches) (4ST)	0.980	1.959*	1.652	2.622
Signalized three leg (3SG)	NA	NA	0.819	2.000
Signalized four-leg (4SG)	0.730	0.526*	0.982	1.834

*Without applying CMF

Source: *Final Report, Highway Safety Manual Safety Performance Functions & Roadway Calibration Factors: Intersections Phase 2, Part 2*, Dao Chimba, Ph.D., for TDOT, December 2, 2019.

Results Tab

The *Results Tab* provides a one-page summary of the results of the SPICE Tool analysis. For ease of printing and including in an IIE report, key project information entered on previous tabs is displayed at the top of the tab. To calculate the results the practitioner must select the “Compute / Update Results” button. Anytime inputs are changed elsewhere in the tool this button must be re-selected to update the results.

The bottom section of the tab provides a crash prediction summary for each intersection 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 Figure 2-26, the “Traffic Signal” control strategy is anticipated to have 1.15 total and 0.48 fatal-injury crashes during the opening year (2025), 1.56 total and 0.63 fatal-injury crashes during the design year (2045), and 28.37 total and 11.62 fatal-injury crashes over the project’s life-cycle (2025–2045).

As noted above, the SPICE Tool combines the fatal and injury crashes into one total. Often, the practitioner is interested in the number of fatal and the number of injury crashes reported individually. Reporting the fatal and injury crashes individually is necessary for most life-cycle cost analysis. To obtain an estimate of the number of fatal crashes the practitioner should multiply the “Fatal & Injury” results by 0.02. To obtain the number of injury crashes the practitioner should multiply the "Fatal & Injury" results by 0.98. These ratios are derived from statewide crash data provided in the Tennessee Integrated Traffic Analysis Network (TITAN) for 2019. In 2019 in Tennessee there were 49,881 crashes with an injury and 1,080 crashes with a fatality. This is equivalent to ratios of two percent of fatal + injury crashes were fatal crashes and 98 percent of fatal + injury were injury crashes.

Fatal Crashes = 0.02 x Fatal & Injury

Injury Crashes = 0.98 x Fatal & Injury

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. This is duplicated from the *Control Strategy Selection Tab*. If a red "No" is present in the final column the practitioner should use the results with caution.

Safety Performance for Intersection Control Evaluation Tool

Results

Summary of crash prediction results for each alternative

Project Information

Project Name:	Sample Test Project	**Intersection Type**	At-Grade Intersections
Intersection:	SR 1 at Penny Lane in Davidson County	**Opening Year**	2025
Agency:	TDOT	**Design Year**	2045
Project Reference:	12345	**Facility Type**	On Urban and Suburban Arterial
City:	Davidson County	**Number of Legs**	4-leg
State:	TN		
Date:	9/4/2020		
Analyst:	JHS, ABC Consultant		

Crash Prediction Summary

Control Strategy	Crash Type	Opening Year	Design Year	Total Project Life Cycle	AADT Within Prediction Range?
2-lane Roundabout	Total	0.63	0.82	15.28	N/A
	Fatal & Injury	No SPF	No SPF	No SPF	
Minor Road Stop	Total	0.72	0.94	17.36	Yes
	Fatal & Injury	0.28	0.37	6.77	
Traffic Signal	Total	1.15	1.56	28.37	Yes
	Fatal & Injury	0.48	0.63	11.62	

Figure 2-26: Results Tab

References

"Intersection Control Evaluation (ICE) - Safety: Federal Highway Administration." Safety, safety.fhwa.dot.gov/intersection/ice/.

Jenior, P. H. (2018). *Capacity Analysis for Planning of Junctions (CAP-X) Tool User Manual*. Washington, DC: Federal Highway Administration. Retrieved from http://www.cmfclearinghouse.org/collateral/FHWA-SA-18-067%20CAP-X%202018%20Tool%20User%20Guide%20(Final).pdf

Life-Cycle Cost Analysis – LCCET Tool

The Federal Highway Administration (FHWA) promotes life-cycle cost analysis to quantify the costs of different transportation options. By considering all costs—agency and user—incurred during the design life of a project, life-cycle cost analysis provides transportation officials with a total cost of transportation options instead of focusing solely on initial construction and engineering cost.

In Tennessee Department of Transportation's (TDOT) Intersection and Interchange Evaluation (IIE) process, life-cycle cost analysis is recommended but optional. The TDOT project manager will determine if it is required on a case-by-case basis. In its standard and most streamlined approach for TDOT's IIE process, life-cycle cost analysis requires the following three elements:

Life-cycle cost analysis is recommended but optional in TDOT's IIE process.

1. Agency's initial engineering, construction, right-of-way, and utility relocation costs (calculated in IIE Stage II)
2. Roadway users' operations or delay cost (calculated with inputs from the IIE Stage II Traffic Analysis)
3. Roadway users' safety cost (calculated with inputs from the IIE Stage II Predictive Crash Analysis; it should be noted that if a life-cycle cost analysis is required then a predictive crash analysis must also be developed).

Several tools or methods could be used for life-cycle cost analysis. For a consistent approach, TDOT selected the Life-Cycle Cost Estimating Tool (LCCET). Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP) Web-Only Document 220: *Estimating the Life-Cycle Cost of Intersection Designs describes the Life-Cycle Cost Estimation Tool (LCCET)*. The LCCET spreadsheet allows practitioners to compare alternative intersection designs based on initial construction costs, ongoing maintenance and operations costs, operational efficiencies for a variety of modes, safety effects, and emissions. Alternative designs include roundabouts and traditional intersections using stop signs and traffic signals. Use of the tool is designed to help provide a consistent approach to these comparisons based on benefits and costs.

It should be noted that the LCCET tool has the capability to include greenhouse gas (GHG) emissions in the calculations. In base TDOT analysis this is not recommended due to the additional emphasis on operations in the results and the general lack of data for the calculations. However, these and other options may be applicable on some projects, especially Congestion Mitigation and Air Quality (CMAQ) funded or transit projects. The practitioner should coordinate with their TDOT project manager concerning alternative life-cycle cost tools and methodologies.

LCCET Tool Guidance

The report (NCHRP Web-Only Document 220) and the tool may be downloaded at http://www.trb.org/Publications/Blurbs/173928.aspx. The practitioner should download the NCHRP report and LCCET tool for detailed instructions. Guidance and tips for its basic application on TDOT projects is provided in following text.

Introduction Tab

General tool information is provided in the *Introduction Tab*.

Organization Information Tab

The practitioner should input all relevant project description information in the *Organization Information Tab*'s table, including:

- Agency (facility owner, typically TDOT).
- Project Name: The input will typically include the State Route designation of the major route and a sideroad and county.
- Project Reference: The input will typically include the TDOT Project Identification Number (PIN).
- Location: Duplicate the information in the Project Name cell.
- City: Input the city (if applicable) and county of the project location.
- State: Input "TN".
- Performing Department or Organization: Input the Division within TDOT if the analysis is developed by TDOT staff. If a consultant project, the firm's name should be input.
- Date: The date of the analysis.
- Analyst: The name of the practitioner developing the analysis.

Cost Parameters Tab

The Cost Parameters Tab provides the unit cost data that are used to calculate costs for each option. The practitioner should input the current year in the green "Base year for discounting" cell. Other unit cost data may be overridden in the blue "Override value" cells. In general, this is not necessary. Concerning crash costs, the "Fatality, injury, PDO" option should be selected for use in TDOT's IIE process. These crash categories are most in line with TDOT's crash categories and allow for the most seamless transition of SPICE's predictive crash analysis results into the LCCET tool.

GHG Cost Tab

The GHG Cost Tab is typically not utilized in TDOT's IIE process.

Demand Parameters Tab

The *Demand Parameters Tab* provides for the input of total traffic demand entering the study area. LCCET will take peak hour data and transform it into daily demand curves. Refer to Figure 2-27 for the following discussion. The discussion is for a streamlined approach when limited data are available. The practitioner may use more site-specific data if they wish or if conditions dictate.

- Enter the times of the AM and PM Peak Hours. If this is not known estimate 7 AM to 8 AM and 4 PM to 5 PM.
- Select "Average Annual Volume" from the drop-down menu for the analysis basis.
- Select the facility type from the drop-down menu of the higher classified roadway of the intersection / interchange.
- Keep the default values for the volume adjustment factors.
- Input the Opening Year AM and PM Peak Hour Volumes entering the intersection / interchange for all approaches. Input the Opening Year AADT entering the intersection / interchange for all approaches. The Opening Year will be "Year 1" in the Quantity Table.
- Select "No" from the drop-down menu for the "Adjust hourly volume profile to input peak hour volumes?" question.
- In the Year 1 cell input the Opening Year. In the Year 2 cell input the Design Year.
- Input the Opening Year and Design Year AADT and directional design hour volume (DDHV) volumes entering the intersection / interchange in the table. It is not required to input weekend data.
- If the average annual auto occupancy is known for "passengers per vehicle" in the study area, insert it. If it is not known, input "1.7"[1].
- The average annual truck percentage should be available from Enhanced Tennessee Roadway Information Management System (eTRIMS) or the TDOT-supplied traffic projections.
- All other cells may remain blank.

Once the practitioner has completed all inputs they should select the "Create Demand Profile" button to create the daily and yearly demand profiles from the data provided.

[1] From nationwide data from 2018 https://www.fhwa.dot.gov/tpm/guidance/avo_factors.pdf

Demand Volume Profile

This sheet creates demand profiles for specified years based on the major facili
provide your own. These profiles are applied to all alternatives to convert peak

Peak Hours and Facility Profile

Enter peak period begin and end times:

Peak Weekday Time Period	From	To
AM peak	7:00 AM	8:00 AM
PM peak	4:00 PM	5:00 PM
Weekend peak		

Select Analysis Basis: Average Annual Volume

Select facility type: Urban Principal Arterial — At intersections of varying facilities sele

Volume Adjustment Factor:	Automated Adj. Factor	Override Value	Value Applied	
Weekday Adjustment:	1.000		100.0%	This adjustment factor is used to align tl
Weekend Adjustment:	1.000		100.0%	This adjustment factor is used to align tl

	Base Analysis Volumes	Adjusted Average Annual Volume	Override Value	Year 1 Value Applied	
AM peak hour:	800	800		800	
PM peak hour:	1,200	1,200		1,200	Volume entries are
Weekend peak hour:					develop demand pr
Average Annual Daily Traffic (AADT):	11,500	11,500		11,500	table. If data is not a delay equation, not

Adjust hourly volume profile to input peak hour volumes (Yes/No)?

If 'Yes' is selected the default hourly volume profiles will be adjusted to mat
Review plots of demand profiles to the right of Column "R" to assess the ap|

Quantity (sum over all cordon approaches)	Units	Year 1	Year 2	Year 3	Year 4
		2025	2045		
Average annual daily traffic (AADT)	Avg veh/day	11,500	15,000		
AM peak hour volume	veh/hr	800	1,768		
PM peak hour volume	veh/hr	1,200	2,277		
Weekend peak hour volume:	veh/hr				
Average annual auto occupancy	Passengers per vehicle	1.7	1.7		
Average annual % trucks	Average %	2.0%	2.0%		
Annual transit passengers	Transit passengers per year				
Annual cyclists	Cyclists per year				
Annual pedestrians	Pedestrians per year				

Click button when years are entered to set up calculations tables: — This button should be pressed any time

Figure 2-27: LCCET Demand Parameters Tool

Alternatives Master List Tab

The *Alternatives Master List Tab* maintains a list of options to be analyzed.

Base Case Tab

The Base Case Tab is where the practitioner inputs data related to the Existing Control condition, or No Build Option.

- The current year is input in the "Begin planning & construction" cell.
- The Opening Year is input in the referenced cell.
- The Design Year is input in the "End year" cell.
- Then select the "Setup Worksheet" button.
- For the spreadsheet to work there must be a Planning & Construction cost value input. For the base case assume some minimal amount of signing and pavement markings would be installed with a minimal cost, such as $5,000. This amount is input so the tool will work.
- Input the Opening Year and Design Year AM and PM Peak Hour intersection / interchange delay (in seconds / vehicle) from the traffic analysis.
- Input the Opening Year and Design Year estimated crashes from the predictive crash analysis.

Alternative Tab(s)

The Alternative Tab(s) is where the practitioner inputs data related to the intersection / interchange control options. The same inputs as the *Base Case Tab* are input. For cost, the cost estimate for each option is input. It is acceptable to simply place the sum of all engineering, design, right-of-way, construction, and utility relocations in the "Construction" cell.

Outputs Tab

The results of the life-cycle cost computations are provided on the Outputs Tab. The practitioner selects the "Compile Analysis Summary" button to calculate the total life-cycle cost for each option.