

# Intersection Life Cycle Cost Comparison Tool User Guide

## *Version 1.0*



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## 1. Introduction

The Intersection Life Cycle Cost Comparison Tool User Guide was developed as part of North Carolina Department of Transportation Research Project No. 2014-11: Evaluation of Life Cycle Impacts of Intersection Control Type Selection.

This spreadsheet-based computational engine is designed to analyze the long-term costs and benefits of NCDOT conversions of two-way stop controlled intersections to other intersection types. It is designed to be used during the planning phase of potential intersection conversion projects to help stakeholders identify the most cost-effective conversion configuration option.

This user-friendly tool combines enhanced 2010 Highway Capacity Manual methodologies and standard cost benefit analysis methodologies to calculate the long-term net benefits of converting a two-way stop controlled intersections to three different alternatives: 1) all-way stop controlled, 2) signalized, and 3) roundabout types. For the purpose of tool, a two-way stop controlled (TWSC) intersection is defined as a four-way intersection with no control mechanism for the main approach and stop signs positioned at the minor approach.

Based on user inputs and standard state and national data, site-specific construction and maintenance, user delay, and safety costs and benefits are calculated for each of the three conversion types. These costs and benefits are projected into the future using a methodology that considers the changing value of money over time. The resulting dollar figures can be compared to identify the intersection type that offers the greatest return on investment to North Carolina citizens over a user-specified time period.

Much of the material in this manual is in the accompanying instructional video at [http://go.ncsu.edu/lcca\\_video](http://go.ncsu.edu/lcca_video).

## 2. Overview of Tool

The future costs and benefits of conversion alternatives are projected using a method called Life Cycle Cost Analysis (LCCA). Using LCCA, variables that may not have clear financial value, such as reduced pollution, are given a monetary value so that they can be calculated and then compared using common units. The LCCA method is used because many of the costs and benefits associated with intersection reconfigurations may not be realized until years, sometimes decades, after an initial conversion. Analyzing each intersection project with a LCCA can help ensure that state funds are allocated as effectively as possible.

“Monetizing,” or applying a monetary value to non-monetary variables such as improved roadway safety, helps planners and policymakers account for both the social and fiscal costs and benefits of a project. Consequently, the final outputs of this tool are the monetized costs

and benefits of installing each alternative intersection type. The difference between the outcomes that would be expected if the TWSC intersection was not converted are subtracted from the monetized outcomes projected for alternatives to produce an estimation of the long-term costs and benefits of implementing each option. These final values are referred to as the “Net Present Value”, or NPV for each intersection option.

Each monetized figure is projected into the future using an LCCA method called discounting. Similar to the idea of inflation, discounting adjusts monetized costs and benefits to reflect how their value will typically decline over time. The discount rate applied in this tool is 3% per year. As with inflation, this rate is assumed to compound each year until the end of the period of analysis.

Three categories of variables are used to calculate the costs and benefits of each option: 1) Construction & Maintenance, 2) User Delay, and 3) Safety. Monetizing each of these involves a combination of unique user inputs and standardized, or “default,” values which are applied throughout the tool. Using default values helps limit user input time and ensures that intersection LCCAs are being uniformly conducted across NCDOT divisions. Extensive research was conducted to identify the most appropriate default values for monetizing the costs and benefits calculated by this tool.

These three larger variable types are monetized into the future using the following sub-variables:

**1) Construction & Maintenance**

- *Construction Costs*: The up-front funds needed to convert the TWSC intersection including pre-construction (right-of-way purchases and preliminary engineering) and physical construction (utility moves/additions, infrastructure changes/additions, etc.)
- *Annual Maintenance Costs*: Annual and incremental operations and upkeep costs for a facility option, such as landscaping and signal timing

**2) User Delay**

- *Fuel Burned during Idling*: Based on North Carolina fuel costs for the day of analysis and delay projections for each alternative
- *Value of User Travel Time*: Estimation of the monetary value of an hour of time for roadway users

**3) Safety**

- *Crash Costs*: Broken down by crash type, based on the NCDOT’s annual KABCO cost estimations, projected for each alternative option using historic crash numbers for the site and applying well-researched crash reduction factors

The steps of this tool are broken into eight steps organized by input and variable type. These include:

- 1) **Global Inputs:** Site-specific data and user details
- 2) **Traffic Demand:** Demand data for current TWSC site
- 3) **Crash Data:** Crash data for current TWSC site
- 4) **Roundabout Configuration:** Projections for roundabout construction costs and configurations at site of interest
- 5) **All-Way Stop Configuration:** Projections for AWSC construction costs and configurations at site of interest
- 6) **Signal Configuration:** Projections for signal construction costs and configurations at site of interest
- 7) **Results:** Tool outputs including informational tables comparing different intersection options
- 8) **Printable Report:** Automatically generated report including details of the tool analysis that can be easily printed and shared with decision-makers

**IMPORTANT NOTES:**

- 1) **Color Codes:** Throughout the tool, different colors indicate different types of inputs:
  - o Yellow cells indicate required data entry fields
  - o Green cells indicate required data entry fields with pre-determined default values
  - o Light blue cells are used for descriptions of the input/output cells
- 2) **Units:** All the units (if applicable) are shown in the parenthesis next to each input/output field.
- 3) **Process Order:** All steps should be completed by the user in the order that they occur. The user must click the appropriate button to move to the next step in the tool. A failure to follow steps in order could result in miscalculations or data loss.
- 4) **Data Collection:** Users are strongly encouraged to collect/calculate the site-specific data needed for the inputs before beginning the analysis process to reduce the risk of error. In this user guide, the data required for the steps of this tool is listed at the beginning of the instructions for each step.
- 5) **File Saving:** Users are advised to save the file with the analysis data and site name immediately upon beginning an analysis to prevent calculation errors. Files should be re-saved after performing any additional analyses or revising inputs.

### 3. Step 1: Global Inputs

Several site-specific details are required in *Step 1: Global Inputs* of the tool. To begin the intersection option comparison process, input basic information about the intersection in first tab.

→ **What you need for Step 1:**

- 1) **Major and Minor Approach Name:** Names of the intersecting roadways of interest.
- 2) **County:** Name of county where intersection is located.
- 3) **Analyst Name:** Name of the person using the tool.
- 4) **Major Approach Orientation:** Ordinal direction of the minor approach roadway, either “North-South” or “East-West.”
- 5) **Analysis Date:** Analysis date in the form MM/DD/YYYY.
- 6) **NCDOT Division:** Number of the NCDOT division responsible for the location.
- 7) **Does the TWSC intersection have a median with a width of 20+ feet?:**  
Select Configuration type, either “Yes” or “No,” based on the configuration of the TWSC intersection.
- 8) **Operation Analysis Period (Years):** Number of years desired into the future that the tool will consider when calculating Life Cycle Costs. The methodology is designed to analyze periods of time only between 10 and 25 years. Note: The analysis period begins on the data the model is applied, the *Analysis Date*.
- 9) **Volume Growth Factor Per Year (Anticipated):** Percent of traffic volume growth that the intersection is expected to experience annually (NCDOT recommends 2-3%).
- 10) **Current Percent Heavy Vehicle (%):** Percentage of the vehicles as the intersection which are considered heavy vehicles.
- 11) **Peak Hour Factor (PHF):** Input the ratio of the total hourly traffic volume against the busiest 15-minute interval.
- 12) **Area Type:** Type of location (Rural, Urban, or Suburban) at which the intersection is located.
- 13) **Current Unleaded Fuel Costs:** Current unleaded fuel price for North Carolina, which can be obtained via the American Automobile Association’s website:  
<http://fuelgaugereport.aaa.com/states/north%20carolina/>.
- 14) **Current Diesel Fuel Costs:** Current diesel fuel price for North Carolina, which can be obtained via the American Automobile Association’s website:  
<http://fuelgaugereport.aaa.com/states/north%20carolina/>.

Exhibit 1 below shows what the input entry table within the spreadsheet tool looks like.

**Exhibit 1.** Global Inputs Table Example

<b>Major and Minor Approach Name:</b>	<b>Road A and Road B</b>
<b>County:</b>	<b>Wake</b>
<b>Analyst Name:</b>	<b>John Doe</b>
<b>Major Approach Orientation:</b>	<b>East-West</b>
<b>Analysis Date (MM/DD/YYYY):</b>	<b>3/21/2016</b>
<b>NCDOT Division:</b>	<b>5</b>
<b>Does the TWSC intersection have a median with a width of 20+ feet?:</b>	<b>Yes</b>
<b>Operation Analysis Period (Years, min=10,max=25):</b>	<b>21</b>
<b>Volume Growth Factor Per Year (recommended 2% to 3%):</b>	<b>3.0%</b>
<b>Current Percent Heavy Vehicle (%):</b>	<b>2%</b>
<b>Peak Hour Factor (PHF):</b>	<b>0.90</b>
<b>Area Type:</b>	<b>Suburban</b>
<b>Current Unleaded Fuel Cost (\$/gal):</b>	<b>\$2.00</b>
<b>Current Diesel Fuel Cost (\$/gal):</b>	<b>\$2.00</b>

After completing the inputs, the user can either choose to move forward with the next steps by clicking “Proceed to Step 2” or can choose to view the default values used in calculations by clicking “See Default Values,” which will take them to a separate tab.

**NOTE:** Values in the “Default Values” tab can only be adjusted by those with the permission of the NCDOT who have the password needed to change them.

Changes should not be made to these defaults unless absolutely necessary because doing so will make it more difficult for the NCDOT to compare project outcomes over time. The defaults in the tool are based on federal and state standards as well as state transportation data and findings from peer-reviewed research. All default monetary variables used have been converted to 2016 dollars for consistency. Explanations of each default value and its source are outlined in Appendices 1 and 2 of the project’s final report.



#### 4. Step 2: Traffic Demand

For *Step 2: Traffic Demand*, the user will enter the demand data for the TWSC intersection being analyzed. In this step, the user will input information about the traffic demand that is currently observed at the intersection, which will be used in the underlying methodologies used to evaluate delay.


→ **What you need for Step 2:**

**Demand Data:** Demand/volume information for the current intersection in **ONE** of these three forms, including these specific sets of data:

- 1) Hourly counts
  - 13 or more hours of turning movement counts for each approach
- 2) Peak hour counts
  - 12 hours or less of turning movement count data for each approach
  - An idea of the hourly demand distribution of traffic at the TWSC site OR actual hourly demand distribution percentages for the TWSC site
- 3) AADT
  - Two-directional average annual daily traffic (AADT) data for each approach
  - Percent distributions of left, through, and right movements for each approach
  - An idea of the hourly demand distribution of traffic at the TWSC site OR actual hourly demand distribution percentages for the TWSC site

The model allows the flexibility to provide one of following three methods for characterizing traffic demand: 1) Hourly Counts 2) Peak Hour Count, or 3) AADT. The user only needs to provide data using one of these options. Each of these three methods is explained below. To select the most appropriate demand data option based on the details below, the user will click the aerial button beside their selection, as shown in Exhibit 2.

**Exhibit 2.** Demand Method Selection Example



**Step 2: Enter Traffic Flow Demand Data**

Enter the specific demand information that is currently observed at the intersection of interest. This information includes traffic demand (counts or AADT) and also expected distribution for different movements.

Please select the method that you prefer to enter demand data:

Hourly Counts

Peak Hour Count

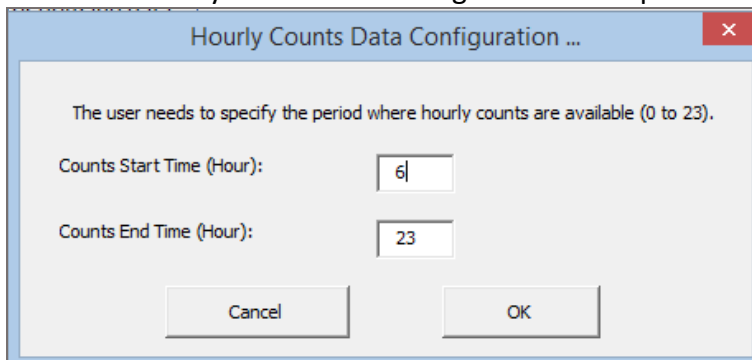
AADT

**Hourly Counts - 13 or More Hours of Turning Movement Counts**

To ensure the accuracy of delay calculations, users are advised to use the hourly count method only when 13 or more hours of turning movement count data is available. This correlates with the recommended practice in the MUTCD for considering signal timing devices and is the standard that the NCDOT uses internally.

To begin entering data using this option, users should fill in the popup box that appears when the aerial button “Hourly Counts” is selected. As shown in Exhibit 3, the user is required to enter the beginning and end of the time period for the turning movement counts available. For example, a user may have 13 hours of turning movement counts from hour turning movement counts starting at hour 6 and ending at hour 18.

**Exhibit 3.** Hourly Count Data Configuration Example



**Exhibit 4.** Detailed Volume Counts Example

Detailed Volume Counts												
Approach	Eastbound (West Leg)			Eastbound (West Leg)			Eastbound (West Leg)			Eastbound (West Leg)		
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
Flow (veh/h) at Hour 6	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 7	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 8	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 9	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 10	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 11	15	60	17	24	85	34	67	55	29	8	30	6
Flow (veh/h) at Hour 12	15	60	17	24	85	34	67	55	29	10	32	11
Flow (veh/h) at Hour 13	10	40	12	15	60	19	23	56	29	13	35	12
Flow (veh/h) at Hour 14	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 15	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 16	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 17	10	40	12	15	60	19	23	55	29	8	30	6
Flow (veh/h) at Hour 18	6	10	6	6	10	6	6	10	6	6	10	6

The number of rows in the “Detailed Volume Counts” table, shown in Exhibit 4 above, will adjust to accommodate the number of hours in the time period selected by the user. Once the table has adjusted appropriately, the user must provide turning movement counts for vehicles per hour for left, through, and right at each of the four approaches. The tool will apply a value of zero for each count in each hour for which the user does not provide data because the delay incurred outside those time periods is assumed to be minimal compared to that incurred during the count. For example, if only 13 hours of turning movement counts are provided it will be assumed that all of the counts for the remaining 11 hours of the 24 hour period are zero.

After entering turning movement count data, the user has finished Step 2 and can choose to move forward to the next step by clicking “Proceed to Step 3” or clicking “Return to Step 1” to modify previous entries.

**Peak Hour Count - 12 or Less Hours of Turning Movement Counts**

In some cases, sufficient turning movement count data for the peak periods of the day may not be available. In this case, the “Peak Hour Count” option can be selected for demand data entry. It is recommended that this option be chosen when 12 hours or less of turning movement count data is available.

To begin entering data using this option, the user must first select one hour of turning movement count data to enter into the tool for analysis, most likely a peak hour. This single hour of count data will be used to model a traffic distribution for a full day within the tool’s calculations. After the radial button beside “Peak Hour Count” has been selected, the user can enter the hour for which the turning movement count data will be provided into the “Specified Analysis Period” table, shown in

Exhibit 5. For example, if counts for the hour starting at 5PM will be used, then the user can choose the “5PM” option from the dropdown box in the table.

**Exhibit 5.** Specified Analysis Period Table Example

Specified Analysis Period	
Hour	5PM

Next, the user can begin entering the turning movement counts for vehicles per hour for left, through, and right turn lanes for each approach in to the “Demand Flow Rate Data” table, shown in

Exhibit 6. Again, these counts should be for the specific hour of analysis selected in the “Specified Analysis Period” table.

**Exhibit 6.** Demand Flow Rate Data Table for 12 Hour Count Example

<b>Demand Flow Rate Data</b>												
Approach	Eastbound (West Leg)			Eastbound (West Leg)			Eastbound (West Leg)			Eastbound (West Leg)		
	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
Flow (veh/h)	25	800	25	25	800	25	10	400	10	10	400	10

Finally, the user must populate the “Hourly Demand Distribution” table with percent of traffic at the current TWSC intersection each hour compared to the total for an entire day, as shown in Exhibit 7.

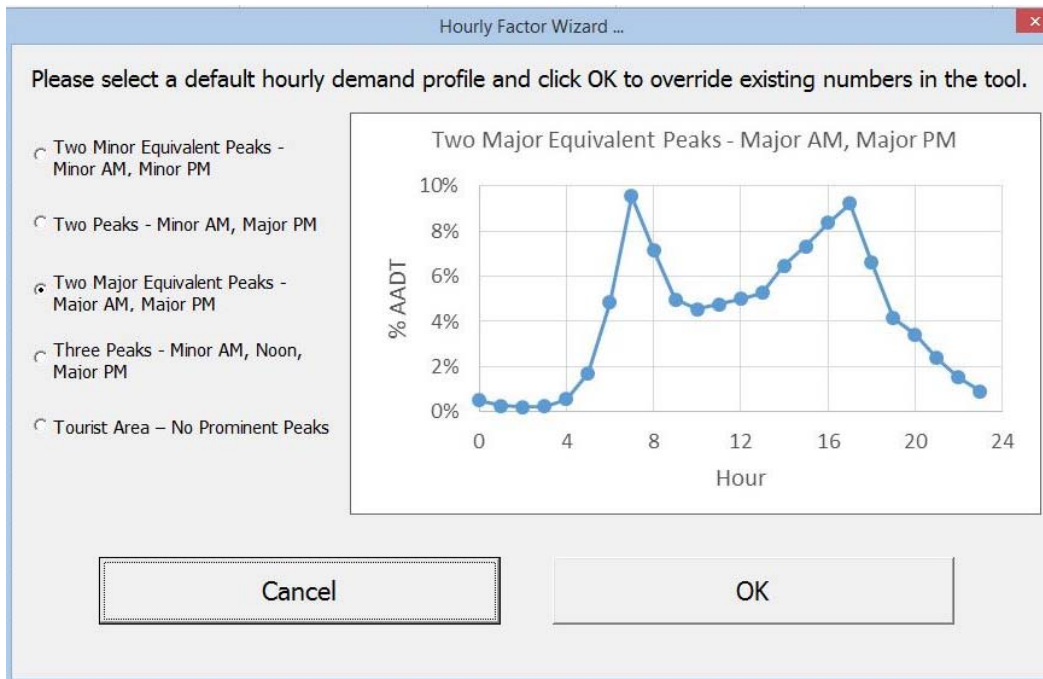
**Exhibit 7.** Hourly Demand Distribution Input Table Example

<b>Hourly Demand Distribution (For Default Hourly Factors Press "Insert Default Hourly Factors" button on the top left side of this spreadsheet)</b>		
Hour		% AADT
From	To	
12 AM	1 AM	0.53%
1 AM	2 AM	0.28%
2 AM	3 AM	0.21%
3 AM	4 AM	0.26%
4 AM	5 AM	0.56%
5 AM	6 AM	1.71%
6 AM	7 AM	4.84%
7 AM	8 AM	9.55%
8 AM	9 AM	7.17%
9 AM	10 AM	4.96%
10 AM	11 AM	4.54%
11 AM	12 PM	4.76%
12 PM	1 PM	5.01%
1 PM	2 PM	5.26%
2 PM	3 PM	6.46%
3 PM	4 PM	7.33%
4 PM	5 PM	8.37%
5 PM	6 PM	9.21%
6 PM	7 PM	6.60%
7 PM	8 PM	4.14%
8 PM	9 PM	3.42%
9 PM	10 PM	2.39%
10 PM	11 PM	1.52%
11 PM	12 AM	0.92%
<i>sum=</i>		<b>100.00%</b>

Although these percentages can be manually entered, the user has the option to auto-populate this table by clicking the “Insert Default Hourly Factor” button in the upper left section of the tab and choosing the default distribution profile which best aligns with the site of interest. As shown below in Exhibit 8, five default options for hourly demand distribution are provided. These distributions, listed below, are based on NCDOT continuous count data at intersections across the state:

- 1) Two Minor Equivalent Peaks - Minor AM, Minor PM
- 2) Two Major Equivalent Peaks - Major AM, Major PM
- 3) Two Peaks - Minor AM, Major PM
- 4) Three Peaks - Minor AM, Noon, Major PM
- 5) Tourist Area - No Prominent Peaks

**Exhibit 8.** Demand Distribution Profile Selection



Users can auto-populate the distribution table by clicking the corresponding radial button and clicking the “OK” button. To change the distribution, click the “Insert Default Hourly Factor” button again and either hit “Cancel” or select a different distribution and click “OK” again. Percentages can be entered manually by typing directly into the cells for each hour in the column labeled “% AADT.” Regardless of entry type, the final distribution in the table should add up to a total sum of 100%.

Once turning movement count data for the specified analysis period and the hourly demand distribution have been entered, the user has finished Step 2 and can either choose to move forward with the next steps by clicking “Proceed to Step 3” or clicking “Return to Step 1” to modify previous entries.

**AADT - No or Few Turning Movement Counts Available**

The final entry option “AADT” is based on planning level data using average annual daily traffic (AADT) data. This method can be useful during the early planning stages of a project, especially if the user does not have access to turning movement counts. Using this method, the user is required to enter the two-directional AADT for each approach of the intersection. Two-directional AADTs are the total traffic recorded in both directions along the roadway that intersects at or near the TWSC intersection of interest. This is the most common form of AADT data provided by NCDOT.

To begin entering data using the “AADT” option, enter the AADT value for each approach into the “Demand Flow Rate Data” table as shown in Exhibit 9 below.

**Exhibit 9.** AADT Demand Flow Rate Input Table Example

<b>Demand Flow Rate Data</b>				
<b>Approach</b>	<b>Eastbound (West Leg)</b>	<b>Westbound (East Leg)</b>	<b>Northbound (South Leg)</b>	<b>Southbound (North Leg)</b>
<b>Two-Directional AADT</b>	4,000	4,000	9,000	8,500

Next, the distribution of turning traffic for each approach must be entered in the “Current Traffic Distribution” table, as shown in Exhibit 10. The user is required to enter the percentages of turns for left, through, and right lanes on each approach leg. For each leg, the sum for the total percentage of traffic should be 100%.

**Exhibit 10.** Distribution of Turning Traffic Table Example

<b>Current Traffic Turning Distribution</b>				
<b>Approach</b>	<b>Left Turn</b>	<b>Through</b>	<b>Right</b>	<b>Sum</b>
<b>EB % Movement:</b>	10%	70%	20%	<b>100%</b>
<b>WB % Movement:</b>	20%	70%	10%	<b>100%</b>
<b>NB % Movement:</b>	25%	65%	10%	<b>100%</b>
<b>SB % Movement:</b>	10%	70%	20%	<b>100%</b>

Finally, similar to the “Peak Hour Count” entry method, the hourly demand distribution is required to populate traffic demand over the entire day. The most likely entry method for this will be using one of the defaults provided in the tool by using the “Insert Default Hourly Factor” button. For more details on how to populate the distribution table, see Exhibit 7 and the “Peak Hour Count” section above.

Once AADT, turning movement distribution, and the hourly demand distribution data have been entered, the user has finished Step 2 and can either choose to move forward with the next steps by clicking “Proceed to Step 3” or clicking “Return to Step 1” to modify previous entries.

### 5. Step 3: Crash Data

Step 3: Crash Data focuses on past crash data for the intersection being analyzed.

→ **What you need for Step 3:**

**Crash Data** - the most recent 3 to 5 years for the current TWSC intersection broken down by the standard KABCO types used by the NCDOT, as described in the Exhibit 11 below.

**Exhibit 11.** NCDOT Crash Severity Type Categories

Crash Severity Types	
Category	Description
<b>K (fatal)</b>	Death occurred within twelve months of the crash
<b>A (disabling)</b>	Injuries serious enough to prevent normal activity for at least one day such as massive loss of blood, broken bones, etc.
<b>B (evident)</b>	Non-fatal or A injuries are evident at the scene such as bruises, swelling, limping, etc.
<b>C (possible)</b>	No visible injury but there are complaints of pain or momentary unconsciousness
<b>O (property damage only)</b>	Pain or momentary unconsciousness

Source: NCDOT, 2013

Before entering data, the user will select the number of years of data they will be entering, as shown below in Exhibit 12.

**Exhibit 12.** Number of Years of Crash Data Input Table

<b>Number of Years of Crash Data? (At Least 3 Years):</b>	<b>3</b>
---	----------

To choose the appropriate number of years, click the number field and then type in the number of years for which data is available. At least 3 years of crash data, preferably more, should be used. Then enter the total number of crashes experienced per year at the intersection of interest, broken down by 1) Fatal, 2) Type A, 3) Type B, 4) Type C, and 5) PDO collisions, as described above in Exhibit 11. Note that the number input into the cells should be a whole number; however, the calculated “average number of crashes per year” values may include decimals.

**Note:** If data is missing for a crash type in a given year, leave the corresponding cell empty, as shown for Type A in Year 1 in Exhibit 7. Adding a “0” into a cell will result in miscalculations. Alternatively, if crash data indicated there were no crashes of a particular type in a given year, enter a “0” into the appropriate cell, as shown for Type K in Exhibit 7.



**Exhibit 13.** Crash Data Inputs Table Example

Crashes at Intersection					
Severity	K	A	B	C	O
<b>Total Number of Crashes for All Years:</b>	1.0	3.0	5.0	7.0	10.0
<b>Average Number of Crashes Per Year:</b>	0.3	1.0	1.7	2.3	3.3

After entering all crash data, either choose to move forward with the next steps by clicking “Proceed to Step 4” or click “Return to Step 2” to modify previous entries.

**6. Steps 4, 5, and 6: Conversion-Specific Configurations**

Steps 4, 5, and 6 are broken down by alternative type. In the tab for each step, the user will enter two key sets of inputs specific to each alternative type: construction costs and geometric configuration. Users are advised to enter all inputs for each step before moving on to the next one.

→ **What you need for Steps 4, 5, and 6:**


- 1) **Construction Costs:** Estimates for the cost of constructing each alternative facility at the specific intersection of interest, considering related costs such as:
  - Preliminary design
  - Utility moves/additions
  - Right-of-way purchases
  - Infrastructure changes (island removal, driveway realignment, connection to city signal system, etc.)
- 2) **Configurations:** Plans for the geometric configurations for each of the alternative facilities that would be installed at the intersection of interest, including:
  - Roundabout - Right-turn bypass configuration (none, yield, or add lane) planned for each approach
  - AWSC - Number of lanes planned for each approach
  - Signal - Number of lanes for each movement (left, through, and right) planned for each approach

Before entering the configurations for each facility option in the tabs of Steps 4, 5, and 6, the user should select the appropriate construction cost for each alternative. Construction costs for the purposes of this tool are the capital funds needed to convert an intersection from a two-way stop to another intersection type, including pre-construction (right-of-way purchases and preliminary engineering) and physical construction (utility moves/additions, infrastructure changes/additions, etc.).

When entering the anticipated initial design and construction costs for each conversion type, the user can either enter one of the default cost estimates provided in the tool or enter their own estimation. At a minimum, the default cost estimates should be used to check any estimates entered manually, as initial estimates are often lower than the actual costs provided by this tool are based on actual project costs.

The dollar amount of each of these design plus construction cost options in the tool varies by conversion type. The tool provides three default cost levels (low, average, and high) for each alternative type, shown in Exhibit 14. These defaults are based on data from years of North Carolina conversion projects. These estimates are broken into the three levels based site-specific factors that can influence cost, such as utility moves, ROW purchase cost, etc.

**Exhibit 14. Construction Cost Data Entry Example**



**Step 4: Enter RBT Configuration and Data**

Note that this tool only accounts for single lane roundabouts.  
 Enter 1) the anticipated construction costs for converting the intersection of interest to a roundabout and  
 2) the lane configure that would be expected if a roundabout was installed at this location.

Design + Construction Cost	
Initial Cost Estimation*:	\$ 750,000.00

*\* Type in either an estimate you already have or use one of the following default options, based on years of NCDOT data:*

1. Low Option = \$500,000 (basic roundabout installation with minimal ROW purchase)
2. Average Option = \$750,000 (significant ROW purchase OR significant utility move)
3. High Option = \$1,000,000 (significant ROW purchase AND one or more of these: significant utility move, realignment, raising of intersection, or other additional features costing more that \$10K)

The characteristics associated with each estimated cost are described for the user in the space below the “Design + Construction Cost” table, as shown in Exhibit 14. The user should enter the estimated construction cost that best fits the nature of the conversion at the specific site of interest. For example, a conversion at an intersection that would require a realignment may be significantly more costly than one that does not and as a result a user may chose a funding option higher than the lowest option.

**NOTE:** There is not a pull down menu for the “Design + Construction Cost” table; the user must manually enter the construction cost into the table.

For each configuration step, the user is required to input configuration data for all three facility options once estimated construction costs have been selected, as described below. The configuration data entered by the user in each of these alternative-specific steps should be based on what the tool user and/or decision makers have determined to be the most appropriate facility configuration for the site. These geometric configuration inputs will be used with 2010 HCM methodologies to project future delays for each facility alternative.

**Step 4: Roundabout Configuration**

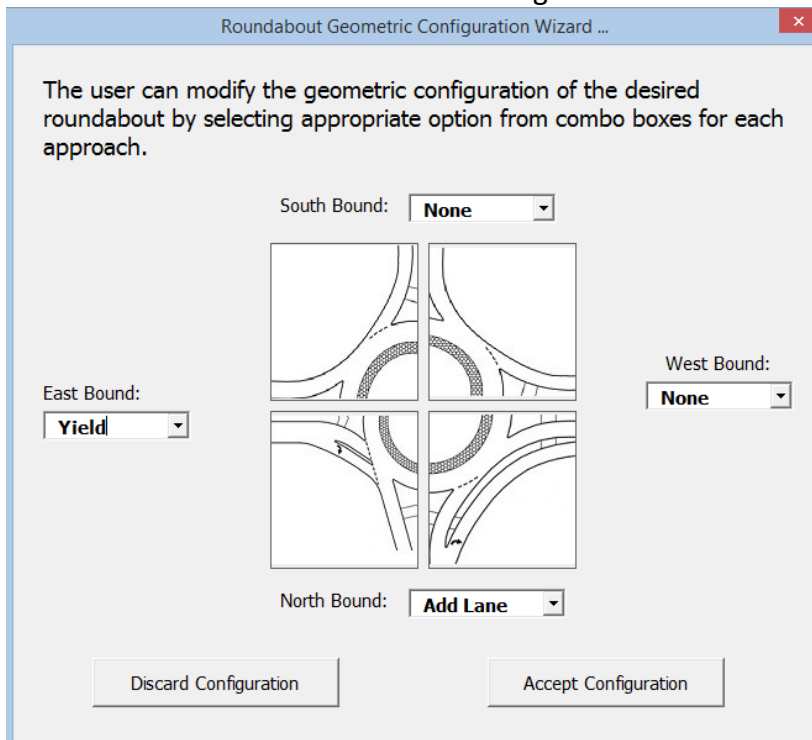
Once roundabout construction costs have been entered, the user can enter the desired geometric characteristics for the associated roundabout. Exhibit 15 below shows the data the user must provide in the “Roundabout Lane Configuration” table, including the entry lane and right turn bypass configurations for each approach.

**Exhibit 15.** Roundabout Lane Configuration Data Entry Table

Roundabout Lane Configuration				
Approach	Eastbound (West Leg)	Westbound (East Leg)	Northbound (South Leg)	Southbound (North Leg)
Right-Turn bypass configuration	Add Lane	Add Lane	Yield	Yield

The user can either manually select configurations by clicking in the yellow cells for each approach and selecting the best option from the pull down menu that appears, or can auto-populated the configuration table using the tool’s Geometry Designer Wizard. To use the wizard, click the “Launch Geometry Designer Wizard for Roundabout” button. A pop-up screen with configurations for each approach should appear, as shown in Exhibit 16.

**Exhibit 16.** Roundabout Geometric Configuration Wizard



To adjust the configuration using the wizard, select the appropriate chosen configuration using the pull down menu for each of the four approaches. A new image should appear with each new configuration selection; examine these pictures to ensure they align with your planned configuration. Because this tool is only designed for one lane roundabouts, the user has the option of selecting one of the three following approaches for each leg of the intersection:

- 1) None - standard single lane with yield control
- 2) Yield - a dedicated right turn lane that has to yield
- 3) Add Lane - a dedicated right turn lane that does not have to yield

At any point in the process, the user can click “Discard Configuration” to develop a new configuration, or to manually enter inputs into the table. Once a configuration is finalized using the wizard, the user can confirm the configuration by clicking the “Accept Configuration” button. Both the “Design + Construction Cost” and the “Roundabout Lane Configuration” tables should be inspected to ensure the correct inputs have been selected before clicking the “Proceed to Step 5” button to move to the next step, or click “Return to Step 3” to modify previous entries.

**Step 5: AWSC Configuration**

After entering AWSC construction costs, the user can enter the desired geometric characteristics for the planned AWSC. As seen in Exhibit 17, users will provide data for the number of lanes for each approach in the “AWSC Lane Configuration” table.

**Exhibit 17. AWSC Lane Configuration Data Entry Table**

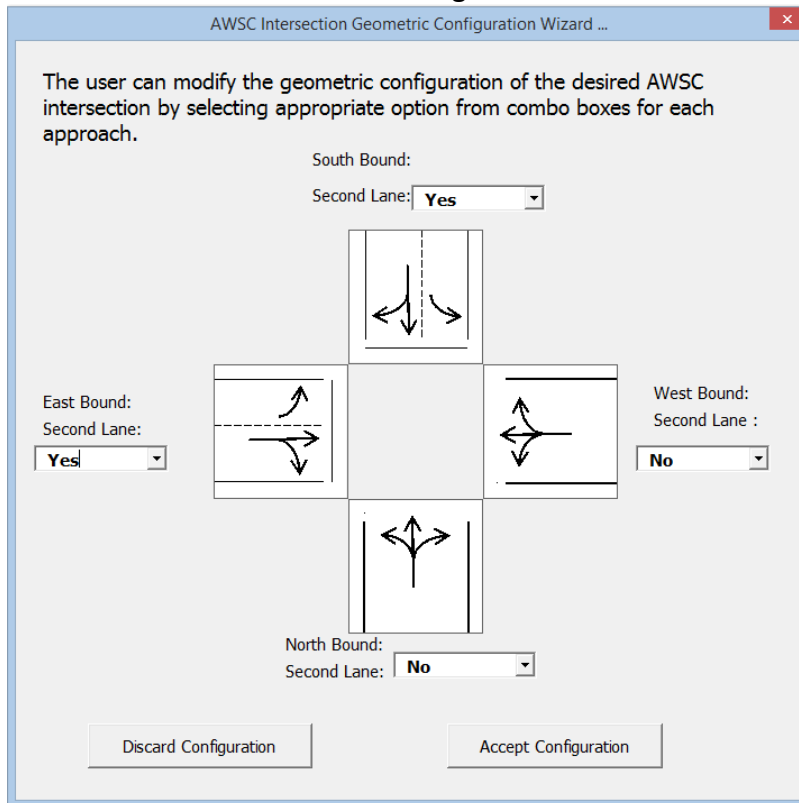
AWSC Lane Configuration								
Approach	Eastbound (West Leg)		Westbound (East Leg)		Northbound (South Leg)		Southbound (North Leg)	
Lane #	Lane #1	Lane #2	Lane #1	Lane #2	Lane #1	Lane #2	Lane #1	Lane #2
Lane Exists?	Yes	Yes	Yes	Yes	Yes	No	Yes	No

The user can either manually select configurations by clicking in the yellow cells for each approach and selecting either “Yes” or “No” from the dropdown box that appears, or can auto-populated the configuration table using the tool’s Geometry Designer Wizard. To use the wizard, click the “Launch Geometry Designer Wizard for AWSC Intersection” button. A pop-up screen with configurations for each approach should appear, as shown in Exhibit 18.

To adjust the configuration using the wizard, select the appropriate chosen configuration using the drop down boxes for each of the four approaches. A new image should appear with each new configuration selection; examine these pictures to ensure they align with your planned configuration. Any entry of “Yes” in Lane 1 and “No” in Lane 2 means the approach has a shared

left-through-right lane configuration. If Lane 2 entry is also “Yes” then there is a left turn bay present for the left turn and the through-right are shared. “Yes” is the default entry for all Lane 1 cells for each approach; this default cannot be altered by the user.

**Exhibit 18.** AWSC Geometric Configuration Wizard



At any point in the process, the user can click “Discard Configuration” to develop a new configuration, or to manually enter inputs into the table. Once a configuration is finalized using the wizard, the user can confirm the configuration by clicking the “Accept Configuration” button. Both the “Design + Construction Cost” and the “AWSC Lane Configuration” tables should be inspected to ensure the correct inputs have been selected before clicking the “Proceed to Step 6” button to move to the next step, or click “Return to Step 4” to modify previous entries.

**Step 6: Signal Configuration**

Once construction costs for the proposed signalized intersection have been entered, the user can input the signal geometric characteristics. The expected minimum and maximum cycle lengths for signal timing, shown in the “Signal Timing Configuration” table in Exhibit 19, are default values which the user can only alter if provided with the password needed to edit the default values. According to an NCDOT panel of experts, the default cycle lengths provided represent a reasonable minimum and maximum cycle length during all hours of operation.

**NOTE:** Because most isolated intersections in North Carolina are running under fully actuated mode, signal inputs for this step are used to calculate delay with the assumption full actuation.

**Exhibit 19.** Signal Min and Max Cycle Length Table Example

Signal Timing Configuration	
Minimum Cycle Length, Cmin (second)	45
Maximum Cycle Length, Cmax (second)	120

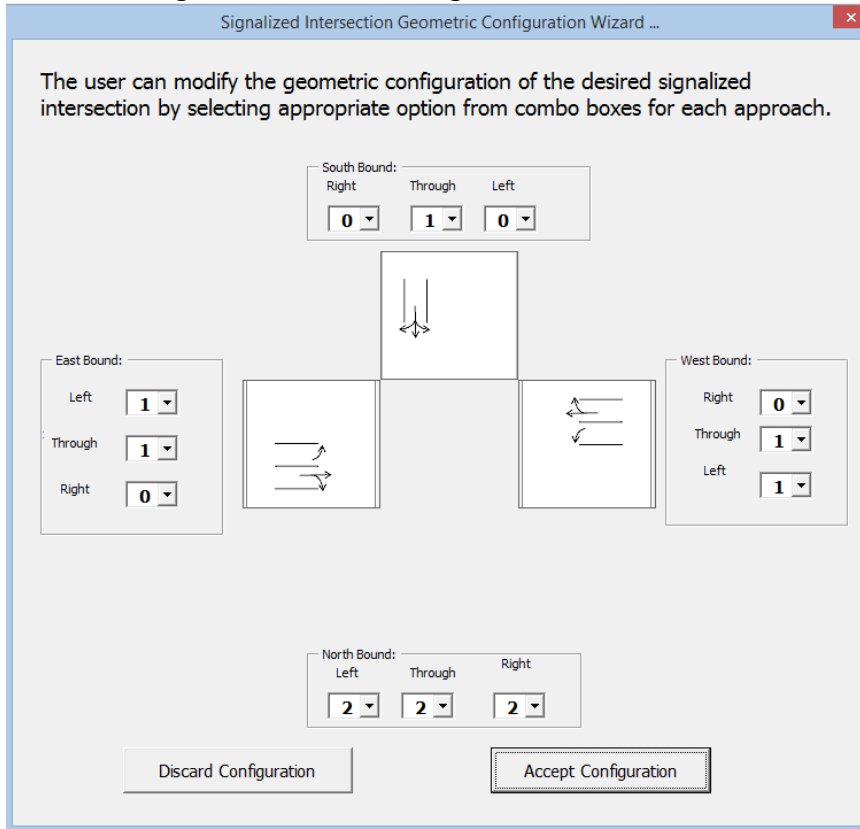
Next, enter the proposed configurations in the “Signal Lane Configuration” table, shown in Exhibit 20.

**Exhibit 20.** Signal Lane Configuration Table Example

Signal Lane Configuration												
Approach	East Bound			West Bound			North Bound			South Bound		
Movement	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
Number of Lanes	1	2	0	1	2	0	1	2	1	1	2	1

The user can either manually select configurations by clicking in the yellow cells for each approach and selecting the best option from the dropdown box that appears, or can auto-populated the configuration table using the tool’s Geometry Designer Wizard. To use the wizard, click the “Launch Geometry Designer Wizard for Signalized Intersection” button. A pop-up screen with configurations for each approach should appear, as shown in Exhibit 21.

**Exhibit 21. Signal Geometric Configuration Wizard**



To adjust the configuration of lanes using the wizard, select the appropriate chosen configuration using the drop down boxes for each of the four approaches. A new image should appear with each new configuration selection; examine these pictures to ensure they align with your planned configuration. The user should enter the lane configuration as it appears at the stop bar by selecting either a 0, 1, or 2 for each turning movement for each approach, with these numerical options indicating:

- 1) "0" for Left or Right - no dedicated lane for the turn movement
- 2) "1" for Left or Right - a dedicated turning lane for the turn movement
- 3) "1" or "2" for through - either one or two dedicated through lanes, respectively

For example, an entry of 0-1-0 for left-through-right, such as that shown for the north and southbound directions above, would mean the approach has a shared left-through-right lane. An entry of 1-1-1 for left-through-right, such as that for the east and westbound directions above, would mean the approach has a through lane with left and right turn lanes (or turn pockets). Volumes per movement and lost time per phase are calculated internally in the model.

At any point in the process, the user can click “Discard Configuration” to develop a new configuration, or to manually enter data into the table. Once a configuration is finalized using the wizard, the user can confirm the configuration by clicking the “Accept Configuration” button. All three of the input tables for this step should be inspected to ensure the correct inputs have been selected before proceeding.

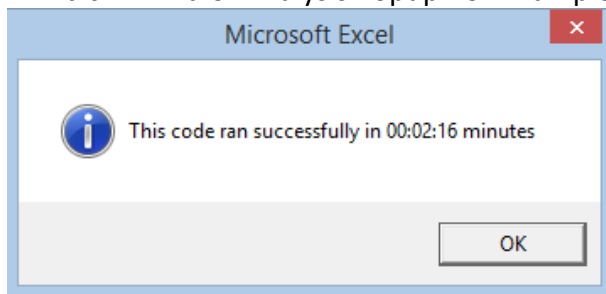
Step 6 is different from previous steps because the user cannot immediately proceed to the next step once the configurations are finalized. Instead, after finalizing all signal construction cost and configuration inputs, the user must click the “Run Analysis & Go to Step 7” button in the upper left section of the page instead of proceeding to another step. This action is necessary to process the final outputs of the tool, including the projected value of the costs and benefits of each alternative. The user should click the “Proceed to Step 5” button if they changes need to be made to inputs before the final analysis is run.

**NOTE:** The analysis process may take several minutes and may cause other computer programs to temporarily freeze during processing due to the amount of data analyzed.

While the analysis is running, a pop-up box may appear notifying the user that a Level of Service of F (LOS F) is projected to occur for one or more of the conversion alternatives at some point during the timeframe of analysis. The user must click “OK” in the popup to acknowledge this message and to continue with the analysis. If an LOS F is projected, the user can return to the previous steps make adjustments to the period of analysis, geometric configuration(s), or other inputs to address the LOS F as appropriate. For some intersections, high levels of demand may lead to an LOS F regardless of the geometric configurations of facilities. In such cases, users can use the comment sections of the tool’s printable report to explain related recommendations.

Once the analysis process is complete, the user will be notified by a popup box like the one shown in Exhibit 22. At that time, the user must click the “OK” button in the popup to proceed to the Results page, which will show the final outputs of the tool.

**Exhibit 22.** End of Analysis Popup Box Example



**IMPORTANT NOTE:** Anytime changes are made to inputs on any page, the user must return to Step 6 and click the “Run Analysis & Go to Step 7” button again. A failure to do this can result in inaccurate outputs which defeats the purpose of using this tool.



## 7. Step 7: Results

Once the six previous steps have been completed, user inputs are used to monetize the costs and benefits of each intersection option.

### → What to pay attention to in Step 7:

- 1) **Net Present Value:** The total long term benefits minus the costs projected for each intersection alternative; the option with the highest Net Present Value is the one recommended by the tool.
- 2) **Errors:** Look for table values that are unexpectedly large or small; if something looks erroneous check user inputs to ensure they are accurate and appropriate.

Information in the *Results* tab data includes a table that brake down the first full year of each facility alternative after construction compared to projections for the same year of the current TWSC intersection, as shown in Exhibit 23.

**Exhibit 23.** Snapshot of Intersection Options in First Year Example

<b>Snapshot of Intersection Options in 1st Year of Analysis*</b>				
<b>Benefit/Cost</b>	<b>TWSC</b>	<b>Roundabout</b>	<b>AWSC</b>	<b>Signal</b>
<b>% Reduction in Fatal &amp; Type A Crashes:</b>	0%	78%	71%	44%
<b>% Reduction in B &amp; C Crashes:</b>	0%	78%	71%	44%
<b>% Reduction in PDO Crashes:</b>	0%	78%	61%	44%
<b>Annual Number of Fatal &amp; A Injury Crashes:</b>	2.0	0.4	0.6	1.1
<b>Annual Number of B &amp; C Injury Crashes:</b>	7.0	0.4	0.6	1.1
<b>Annual Number of PDO Crashes:</b>	19.2	4.2	7.5	10.8
<b>Annual Crash Cost:</b>	\$9,951,500	\$2,189,300	\$2,898,600	\$5,572,900
<b>Daily User Delay (hours per day):</b>	25	18	35	26
<b>Annual User Delay Cost:</b>	\$214,700	\$158,000	\$303,100	\$231,700
<b>Annual User Fuel Cost:</b>	\$7,100	\$5,200	\$10,000	\$7,600
<b>Construction Cost:</b>	\$0	\$750,000	\$25,000	\$90,000
<b>Annual Maintenance Cost:</b>	\$0	\$2,500	\$0	\$2,500

**NOTE:** The monetized values in this table are not discounted. This table provides a simple snapshot of how applying a given alternative may change outcomes at the existing intersection. However, the data in this table are not the final outputs of the analysis and should not be used to compare the long-term costs of alternatives.

The final outputs of the analysis are presented in another table labeled the “Long-Term Difference between TWSC and Conversion Alternatives,” shown in Exhibit 24. This table breaks down the long-term, discounted costs and benefits of each alternative based on variable type,

and most importantly, provides the ultimate deliverable of the analysis: the Net Present Values for each option.

**Exhibit 24.** Difference between TWSC and Alternatives Example

<b>Long-Term Difference between TWSC and Conversion Alternatives**</b>			
<b>Benefits/Costs Relative to TWSC</b>	<b>Roundabout</b>	<b>AWSC</b>	<b>Signal</b>
<b>Crash Reduction Benefit:</b>	\$108,433,000	\$107,335,000	\$65,355,000
<b>User Delay Decrease Benefit:</b>	\$792,000	(\$1,345,000)	(\$254,000)
<b>User Fuel Cost Savings:</b>	\$27,000	(\$44,000)	(\$7,000)
<b>Conversion Construction Cost:</b>	\$750,000	\$25,000	\$90,000
<b>Regular Maintenance Cost:</b>	\$35,000	\$0	\$37,000
<b>Service Life Replacement Cost:</b>	\$0	\$21,000	\$44,000
<b>Total Long-Term Benefits (Net Present Value)***:</b>	<b>\$108,467,000</b>	<b>\$105,900,000</b>	<b>\$64,923,000</b>

Pay special attention to the Total Long-Term Benefits (Net Present Value) row of the outputs table because it outlines the total benefits minus the costs expected for each alternative over the course of the analysis period. These outputs are the Net Present Values (NPVs) of each intersection option being considered. These are the values that should be compared in order to identify the best intersection option based on life cycle costs. The NPVs represent the benefits that the State of North Carolina can expect to gain from an intersection option. Therefore, the intersection type with the highest NPV is considered the best option because it will provide the greatest value in the long-run.

It should be noted that, for some conversions, user delay and the costs associated with them may actually increase due to a projected level of service failure or other factors. This can vary on a case-by-case basis. In cases where user delay is increased due to a conversion, the “benefit” of decreased delay will be a negative value, which is indicated as red text encased by parentheses. These values will in turn be treated as costs instead of benefits. In such cases, these costs will be subtracted from the value of total net benefits as opposed to being added to it.

Additionally, users and decision-makers should be aware that the highest costs and benefits of a conversion are usually associated with User Delay and Safety. This is because the NCDOT’s KABCO estimates can be in the millions and significant delay can result in very high costs to roadway users. For example, tool tests showed that high volume inputs typically result in high delay costs due to excessive facility congestion and high crash data numbers typically result in significant safety benefits, and vice versa.



Once the final outputs have been calculated in the *Results* tab, users can proceed with editing and printing the tool’s report on the analysis, as explained in the “Printable Report” section below, or can click “Return to Step 6” to edit previous inputs and re-run the analysis.

The user should review these tables carefully before proceeding to printing the summary report. Also, the user should examine the tables for data that does not seem to match inputs for the intersection. These could be signs of input errors. In addition, the Net Present Values for alternatives could be in the billions. If this occurs, the user should double-check all inputs to ensure that the projects are as accurate as possible. If a problem is identified, return to the related step, fix the problem, and click the “Run Analysis” button in the Step 6 again.

### 8. Step 8: Printable Report

After the analysis has run and the outputs have been reviewed, the user can develop and print a formal report of the results in *Step 8: Printable Report*. The report is automatically generated using a stylized template designed to share with decision makers, including government leaders. This step requires minimal user time because vital inputs and outputs, such as site location and the NPV table, will be automatically fed to the report. To create the report, the user will click on the “Printable Report” tab, fill in the areas of the template highlighted in yellow. An example of the report entry page is shown below in Exhibit 25.

**Exhibit 25.** Report Comment Entry Example

		<p><b>NCDOT Intersection Life Cycle Cost Analysis (LCCA) of Road A and Road B</b></p>		<p>Print This Report</p> <p>Return to Step 7</p>
Date of Analysis:	3/21/2016	DOT Division:	1	
Analyst Name:	John Doe	County of Intersection:	Wake	
Period of Time Analyzed (years) :	21	Annual Volume Growth:	3%	
Area Type:	Suburban	Peak Hour Factor:	0.90	
<p>Configuration Proposed by Analyst: Roundabout</p>		<p>Analyst Comments:</p>		
<p>Configuration Proposed by Tool: Roundabout</p>		<p>Other alternatives are expected to reach an LOS F within the 21 year period</p>		
<p>Level of Service F Reached for Proposed Configuration(s)? No</p>		<p>Analyst Comments:</p>		
<p>Details: Reached for other configurations but not roundabout</p>				
<p>NCDOT Defaults Changed? No</p>		<p>Analyst Comments:</p>		
<p>Details:</p>				
 <p>This analysis was conducted using Version 1.0 of the NCDOT Intersection Life Cycle Cost Analysis Tool.</p>				

The yellow sections of the report allow the user to explain or clarify the outputs for a given section. For example, users can explain their reasoning for suggesting a particular alternative even if it is projected to reach an LOS of F in the future, or to explain certain data that may be

confusing to readers, etc. All of the colored areas and lines in the entry section will disappear when the report is printed. Users should review the report for errors or potentially confusing data prior to hitting the “Print This Report” button in the top left corner of the sheet. Note that the tool does not offer a print preview option; instead the generated document will print directly to the default printer of the user’s computer once “Print This Report” is clicked. To generate a file instead of printing, the user can set their computer’s default printer to print to PDF.

Once the analysis has been completed and the resulting report has been printed, the tool file should be immediately saved a final time. As previously mentioned, users are advised to include the analysis data and site name in the file name.

For further information on this tool, including source references, view the *NCDOT 2014-11 Final Project Report*, available through the NCDOT website, or contact Chris Cunningham with North Carolina State University at [cmcunnin@ncsu.edu](mailto:cmcunnin@ncsu.edu) or 919.515.8562.