Smart Roadside Initiative Macro Benefit Analysis

User's Guide for the Benefit-Cost Analysis Tool

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Final Report — March 2015
FHWA-JPO-14-198

Prepared for

U.S. Department of Transportation
Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

Produced by AECOM
U.S. Department of Transportation
Federal Highway Administration

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-14-198		

4. Title and Subtitle	5. Report Date
Smart Roadside Initiative Macro Benefit Analysis User's Guide for the Benefit-Cost Analysis Tool	3/31/2015
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Andrea Bohmholdt and Jason Weiss	

9. Performing Organization Name And Address	10. Work Unit No. (TRAIS)
AECOM 12420 Milestone Center Drive, Suite 150 Germantown, MD 20876 LMI 2000 Corporate Ridge McLean, VA 22102	11. Contract or Grant No. DTFH61-11-D-00016-T-13002

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Federal Highway Administration 1200 New Jersey Ave., SE Washington, DC 20590	User's Guide for the Benefit-Cost Analysis Tool
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Through the Smart Roadside Initiative (SRI), a Benefit-Cost Analysis (BCA) tool was developed for the evaluation of various new transportation technologies at a State level and to provide results that could support technology adoption by a State Department of Transportation (DOT). The BCA tool provides general guidance on the cost-effectiveness of implementing a freight-related transportation technology and the use of State resources. The BCA tool can be used to evaluate a transportation-related technology after development and prototype testing have been completed. The BCA tool is designed to evaluate the new technology's economic (to the agency), social (to road users), and environmental impacts.

This document has been prepared to as a user's guide to provide analysts with an understanding of how to use the BCA tool.

17. Key Words	18. Distribution Statement
Smart roadside initiative, benefit-cost analysis, transportation technology	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	54	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Executive Summary

Through the Smart Roadside Initiative (SRI), a Benefit-Cost Analysis (BCA) tool was developed for the evaluation of various new transportation technologies at a State level and to provide results that could support technology adoption by a State Department of Transportation (DOT). The BCA tool provides general guidance on the cost-effectiveness of implementing a freight-related transportation technology and the use of State resources. It can be used to evaluate a transportation-related technology after development and prototype testing have been completed. The BCA tool is designed to evaluate the new technology's economic (to the agency), social (to road users), and environmental impacts.

The BCA tool is built using Microsoft Excel (version 7 or newer) as the base platform. Excel is a well-established software package that is currently available to most potential analysts, thus eliminating the need for special licensing. The tool has a basic "front end" where an analyst enters information related to the categories being evaluated. Data are entered by first selecting entries on drop-down lists and then entering specific inputs (e.g., reduction in processing time). The tool uses national data as default values and/or analyst-entered values to generate results. The analyst may replace the national values with more specific State or local values. While the model will offer default values, the data inherently reside with the user's organization and a more thorough analysis is encouraged outside the model to derive useful inputs. Once the analyst has completed all the questions and input required information, the results are categorized as economic, environmental and social benefits, and implementation/operational costs.

This document has been prepared to as a user's guide to provide analysts with an understanding of how to use the BCA tool.

Section 1 Introduction

This document is a user's guide to accompany the benefit-cost analysis software (BCA tool) developed under the Smart Roadside Initiative (SRI). The BCA tool was designed to analyze various new transportation technologies at a State level and provide results to support technology adoption by State Department of Transportation (DOT) agencies.

1.1 Background

Under the SRI, the U.S. Department of Transportation (USDOT) is supporting research and development of wireless communication to facilitate the advancement and deployment of a fully connected transportation system. These transportation technologies would use multi-modal, transformational applications to improve safety and mobility on the Nation's roadways, while also decreasing the environmental impacts of freight trucking. SRI is an effort by the USDOT that focuses on truck safety applications. Key goals and objectives of the collaboration include:

- Improving screening and automating inspection/compliance checks
- Improving roadside commercial vehicle enforcement operations, including:
  - Credential enforcement
  - Roadside inspections
  - Truck size and weight verification
- Extending the geographic scope of enforcement data-sharing programs
- Enhancing safety by improving identification of unsafe trucks
- Improving and streamlining the inspection process for compliant trucks
- Sharing information on available truck parking to support safer highways

1.2 Purpose of the BCA Tool

The BCA tool was designed to support State DOT agencies' preliminary decision-making on the cost-effectiveness of implementing freight-related transportation technologies. The BCA tool provides general guidance on the cost-effectiveness of implementing a transportation technology and the use of State resources. The BCA tool can be used to evaluate a transportation-related technology after development and prototype testing have been completed. It is designed to evaluate the new technology's economic (to the agency), social (to road users), and environmental impacts. While useful as an initial screening tool, it is not meant to be a complete substitute for a detailed technology-specific BCA.

1.3 Intended Audience

State DOT agencies are the intended users of the BCA tool. The tool results can be used to determine whether implementing a specific technology would be a cost-effective use of State resources. Analysts should have a basic understanding of the freight transportation system. A model run can be completed

with relatively little experience and technological information. More advanced analysts can refine the assumptions to better suit the technology and/or area being evaluated.

1.4 Software Requirements

The BCA tool operates on Excel version 2007 and newer. Visual Basic was used to program the BCA tool, so VBA macros need to be enabled in order to run the tool. Excel is a well-established software package that is currently available to most potential analysts, thus eliminating the need for special licensing.

Note: Near the end of the development of the BCA tool, Microsoft released a Microsoft Office update (December 2014). Unfortunately, the update caused many issues for programs designed using Visual Basic, including error messages and program crashes. If difficulties are experienced when running the BCA Tool, refer to Section 3.6 (Troubleshooting).

Section 2 Overview of the BCA Tool

The overall structure of the tool and the modeling process are presented below.

2.1 Structure of the Tool

The structure of the tool is presented in two major components: benefits and costs. The term "benefit" refers to the changes (positive or negative) that result from implementing the technology (e.g., reduced labor costs, reduced fuel expenditures, postponed/avoided infrastructure expenditures). The term "cost" refers to the monetary outlay of implementing and maintaining the analyzed transportation technology throughout the period of analysis (e.g., purchasing equipment, training personnel, annual operations and maintenance costs).

2.1.1 Benefits Component

The analysis of benefits consists of inputs and outputs. Various calculations are performed to quantify the impacts of a proposed technology based on analyst inputs and default model values (standard default values used in the BCA tool are provided in Appendix B). The outputs are the estimated dollar value of the impacts.

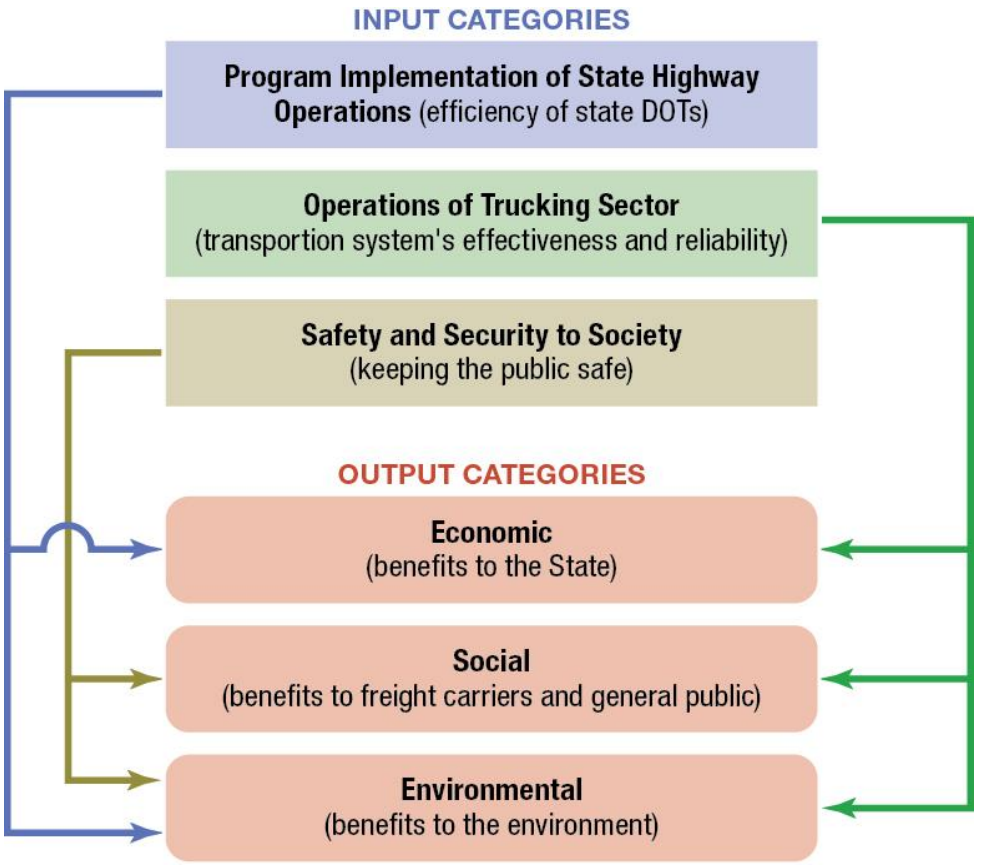
Analyst inputs for the benefits component consist of three categories:

- **Program Implementation of State Highway Operations**: Assesses the State DOT's delivery of value and its efficiency. This input category focuses on the effectiveness of State DOTs, transportation projects, and existing infrastructure.
- **Operations of the Trucking Sector:** Assesses the freight transportation system's effectiveness and reliability. This input category focuses on the highway user's ability to arrive at destinations on time and without delay.
- **Safety and Security to Society:** Assesses the effect on safety of the transportation system. This input category focuses on a technology's ability to keep highway users, State DOT employees, and the general public safe by decreasing injuries and fatalities.

Various calculations are performed for each input category based on analyst input and default model values. Once quantified and monetized, the results of the benefits component are presented as estimated dollar values in three output categories:

- **Economic:** Direct economic benefits from the State perspective
- **Social:** Direct and indirect benefits to freight carriers and the general public
- **Environmental:** Indirect benefits to the environment, primarily in the form of reduced air emissions

Figure 2-1 presents an overview of the input and output categories.



Source: AECOM

Figure 2–1: Overview of the Benefits Component

2.1.2 Costs Component

The BCA tool evaluates the costs anticipated to be incurred by a State DOT implementing the transportation technology. The term "cost" is used to refer to the monetary costs of implementing and maintaining a transportation technology throughout the period of analysis. Avoided infrastructure costs, such as not having to construct a new weigh station because a technology performs that same function, are considered a benefit and should be entered as a benefit component, as described in Subsection 2.1.1. Analyst input for the costs component consists of two categories:

- **Implementation and Startup:** Deploying the technologies into the highway system; includes purchasing equipment, installing equipment, and training staff
- **Operations and Maintenance:** Maintaining the technology over the period of performance; includes equipment operation and repair, utility and other ongoing support activities, and recurring staff training

2.2 Modeling Process

The BCA tool is intended to be widely applicable to a broad range of technologies, some of which have not yet been fully defined. Impacts from a technology are analyzed on a State basis. The impacts are a measure of the changes from the baseline compliance and travel conditions that result from implementing the technology. The baseline is defined as the existing and future conditions over

the period of analysis without the technology (i.e., the "business as usual" conditions). The estimated impact of each technology is the incremental difference between the baseline conditions and the costs and benefits projected from implementing the technology.

Examples of impacts from transportation technologies include:

- Change in time required for commercial vehicle enforcement and compliance activities
- Change in planned operating and infrastructure costs
- Change in safety
- Change in the amount of fuel used

The BCA tool begins with questions that the analyst responds to with yes or no to determine which impacts are applicable. The questions guide the analyst through the BCA tool and require data inputs when necessary. The primary inputs are used throughout the tool to estimate the benefits and costs. The analyst will need to consider the nature of effects on and extent that the technology would affect each input category. If a category is not affected, no analysis is performed. If the analyst thinks the technology would influence the category, then the analyst enters data related to the baseline conditions and anticipated effects.

The BCA tool is built using Microsoft Excel as the base platform. Excel is a well-established software package that is currently available to most potential analysts, thus eliminating the need for special licensing. The tool has a basic "front end" where an analyst enters information related to the categories being evaluated. Data are entered by first selecting entries on drop-down lists and then entering specific inputs (e.g., reduction in processing time). The tool uses national data as default values and/or analyst-entered values to generate results. The analyst may replace the national values to more specific State or local values. While the model will offer default values, the data inherently reside with the analyst's organization and a more thorough analysis is encouraged outside the model to derive useful inputs.

The results of the analysis are presented according to benefit and cost categories, with the total estimated benefits and project costs shown. Disaggregating the results allows the analyst to review the estimates and ensure they are appropriate.

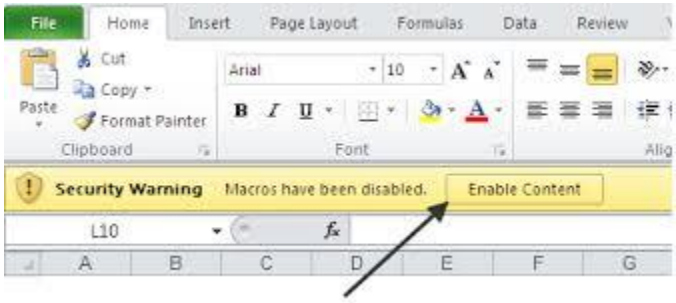
Section 3 Using the Tool

This section describes how to use the BCA tool for evaluating a technology.

3.1 Tool Basics and Navigation

3.1.1 Opening File

The first step is to open the Excel file for this program. Once the file is open, the analyst may need to click the yellow “Enable Editing” button in the yellow bar near the top of the screen, if visible. Then click the yellow “Enable Content” button near the top of the screen to use the program.

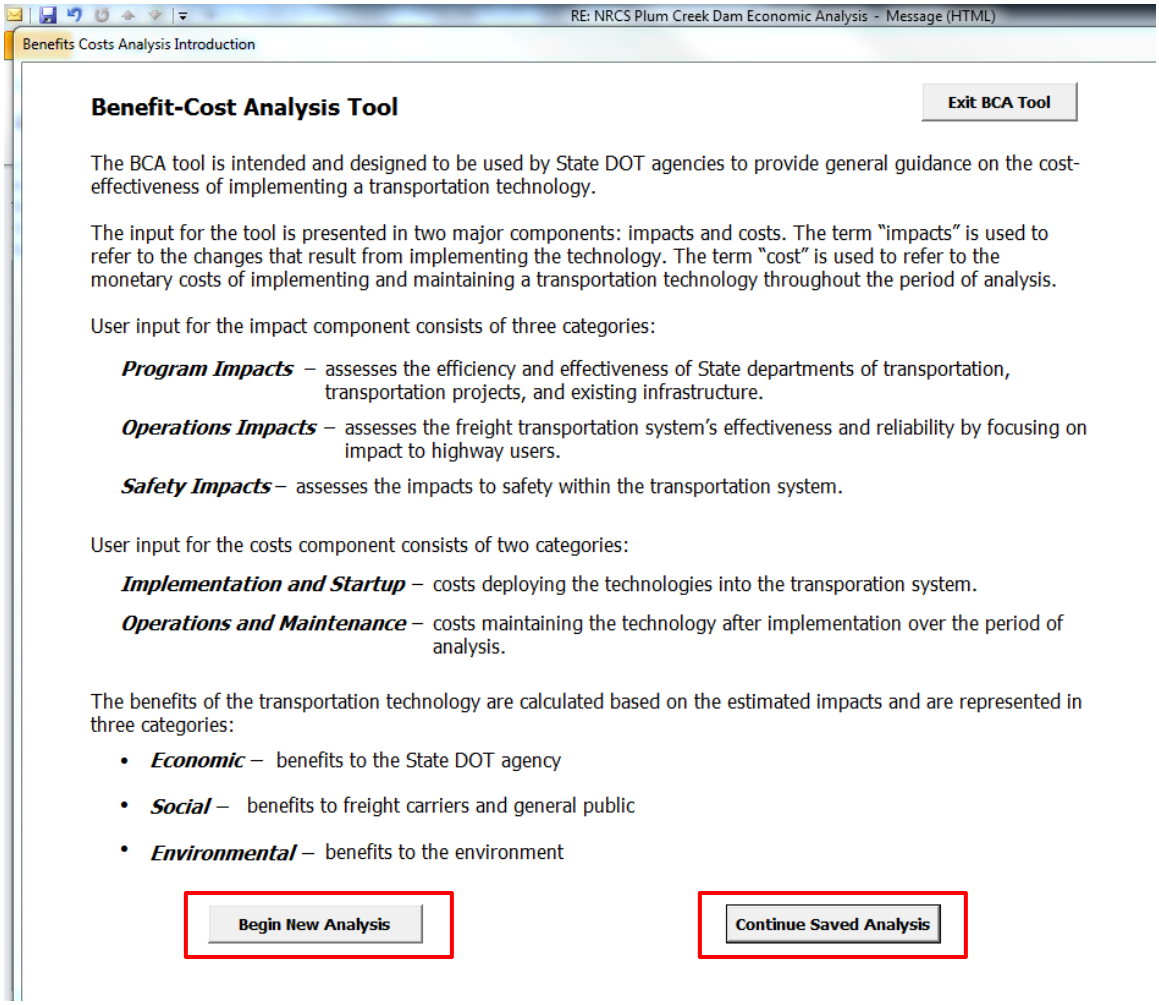


Source: AECOM

Due to recent Microsoft updates, an error may appear on the first use of the tool. If an error appears, please refer to Section 3.5 for the solution.

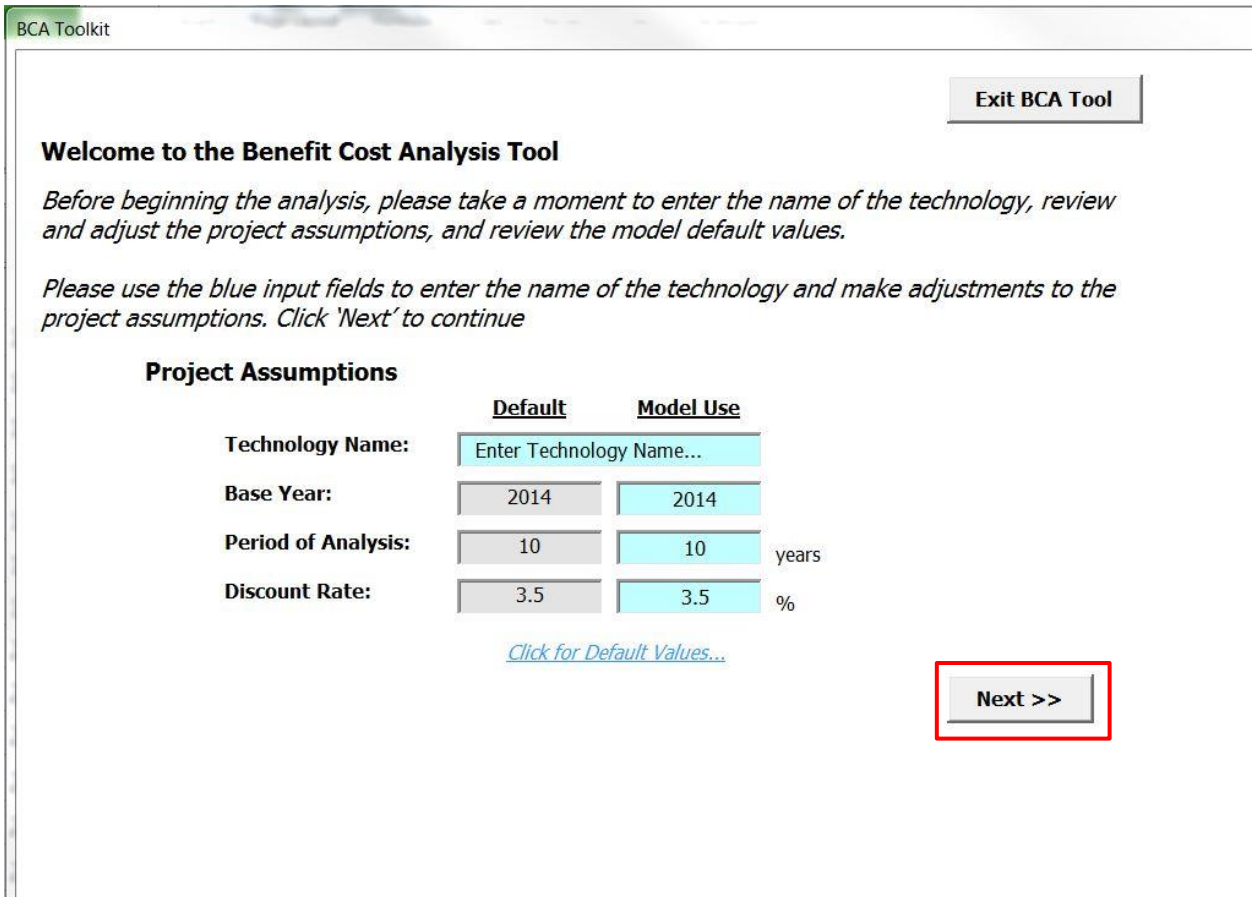
3.1.2 Basic Information and Default Values

Select “Continue Saved Analysis” to continue the evaluation of a proposed technology. Select “Begin New Analysis” to start a new analysis.



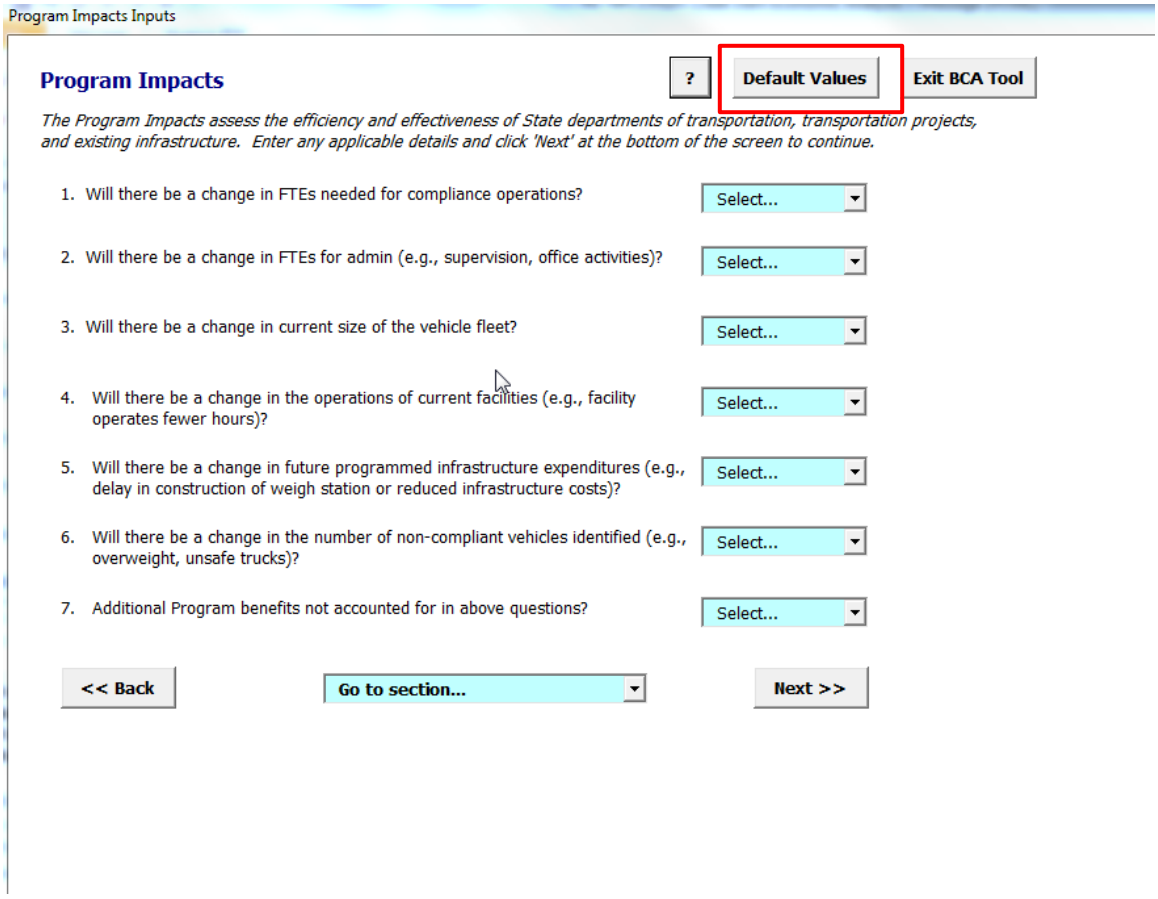
Source: AECOM

This will open the tool's welcome page where analysts can enter the name of the technology. Analysts can keep the defaults for Base Year, Period of Analysis, and Discount Rate or enter their own values. Once the values have been entered and the technology assigned a name, click "Next" to open the Program Impacts screen.



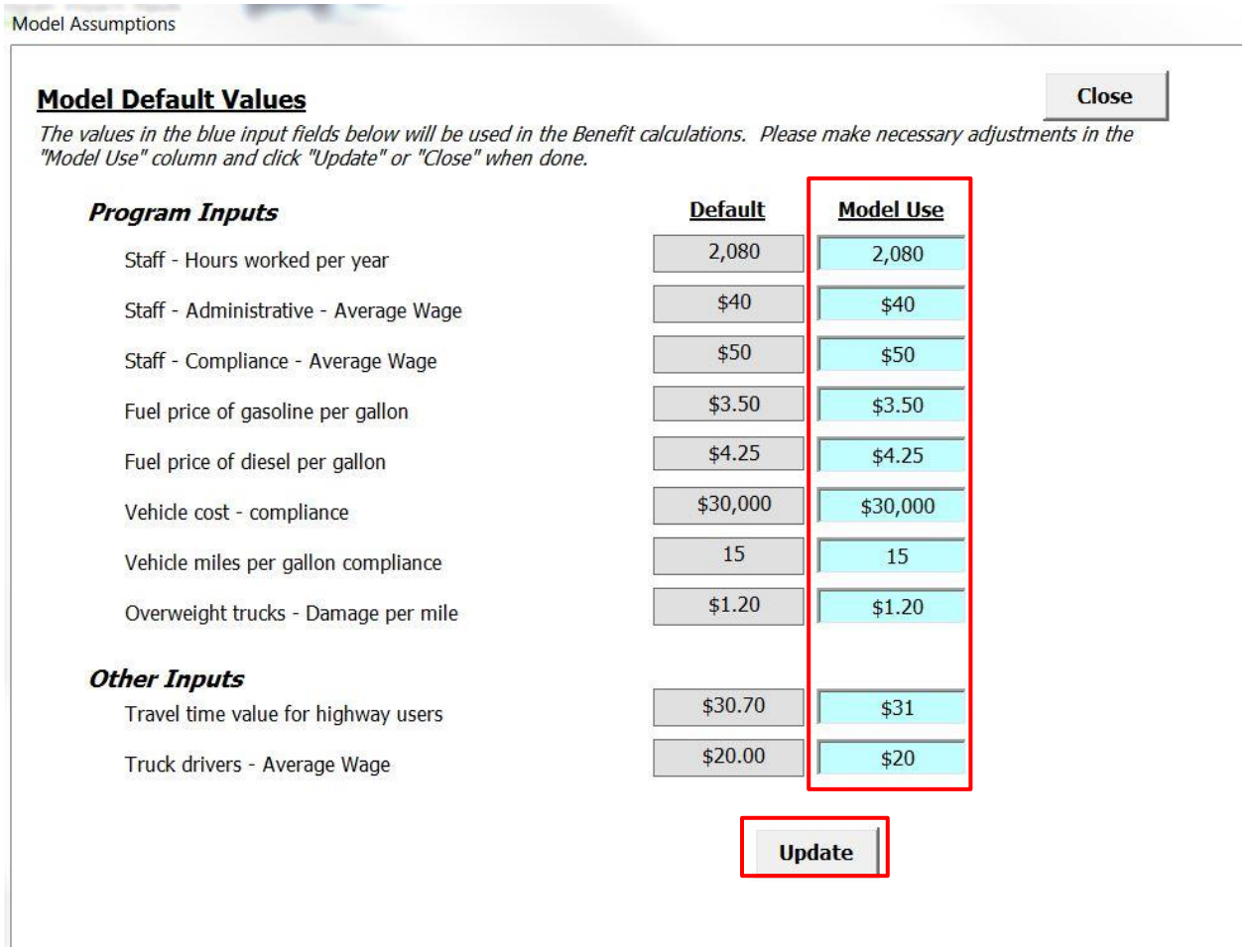
Source: AECOM

The BCA tool uses a number of default values to calculate benefits, and at the top of each page is a button called “Default Values”; click the button to review and adjust the values.



Source: AECOM

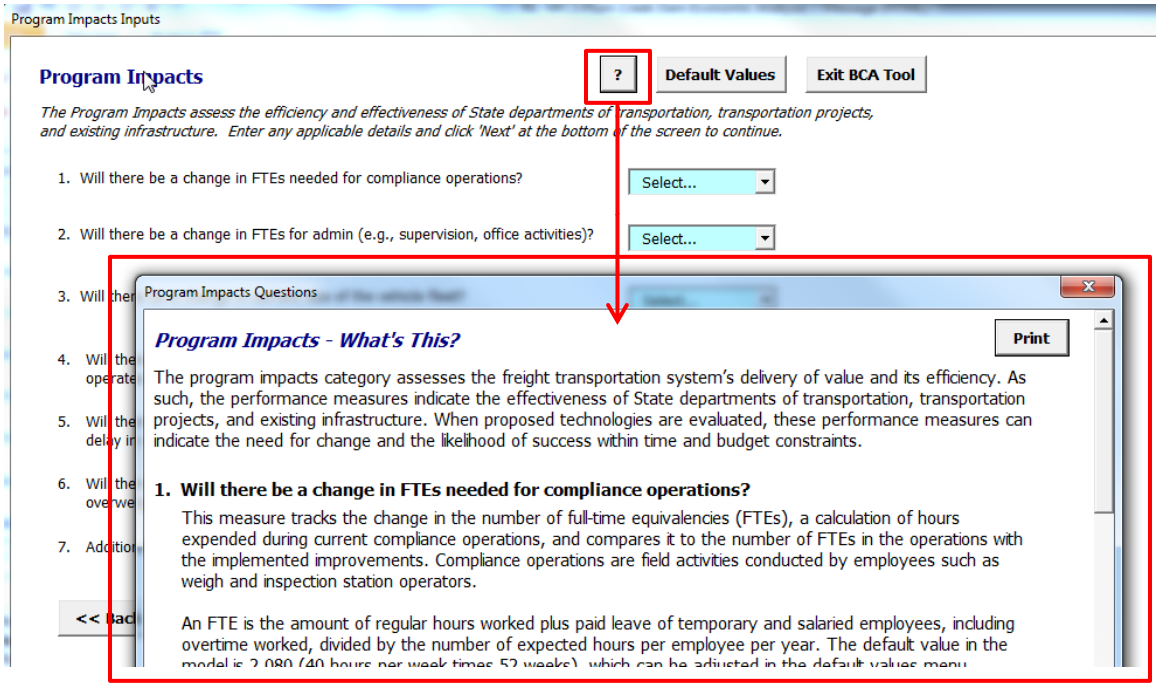
Default values are in the gray shaded cells. Values can be revised by entering the information into the adjacent blue shaded cell under the “Model Use” column. Once the desired values have been entered, click “Update.” Additional information on the default values used for the evaluation can be found in Appendix A.



Source: AECOM

3.1.3 Help

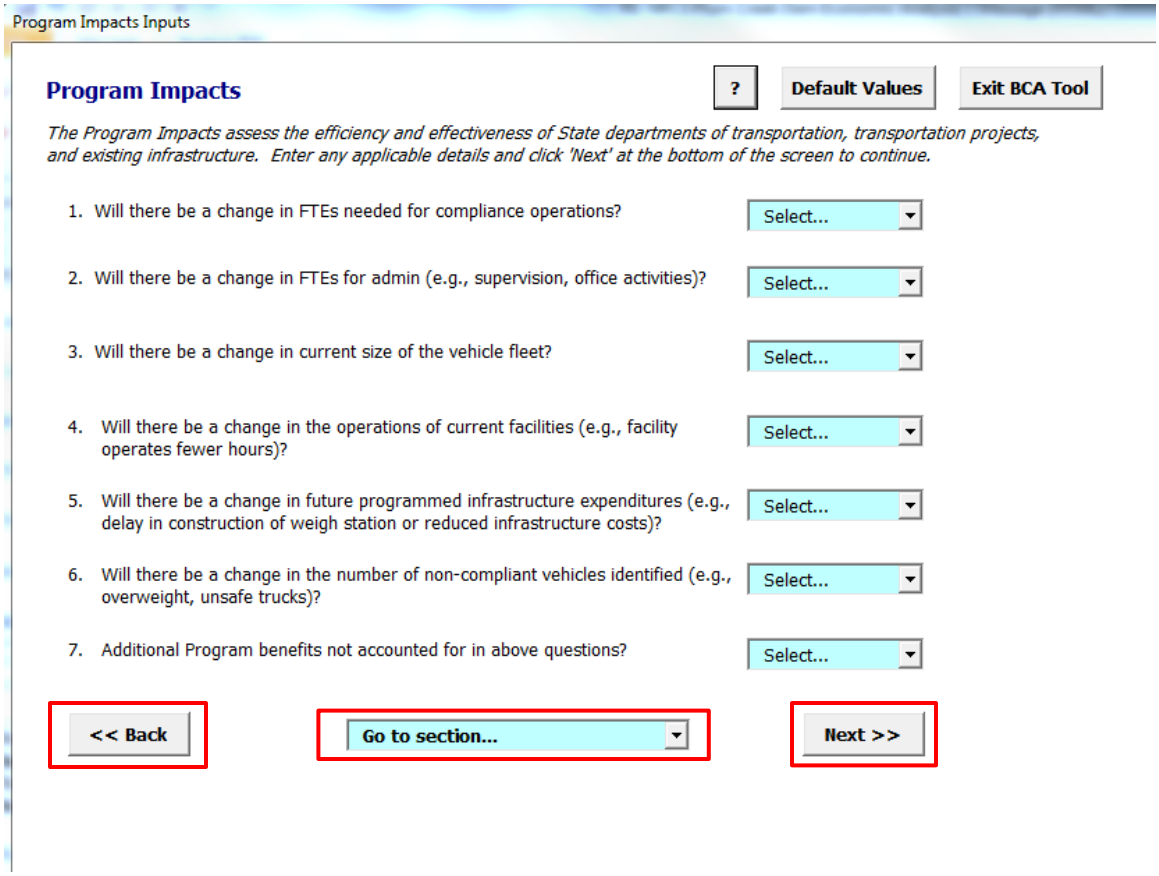
Selecting “What’s This?” will activate pop-up support with additional information pertaining to the question and how to develop required values. If unsure of how to answer a question or provide an input, click “?” for help.



Source: AECOM

3.1.4 Navigation

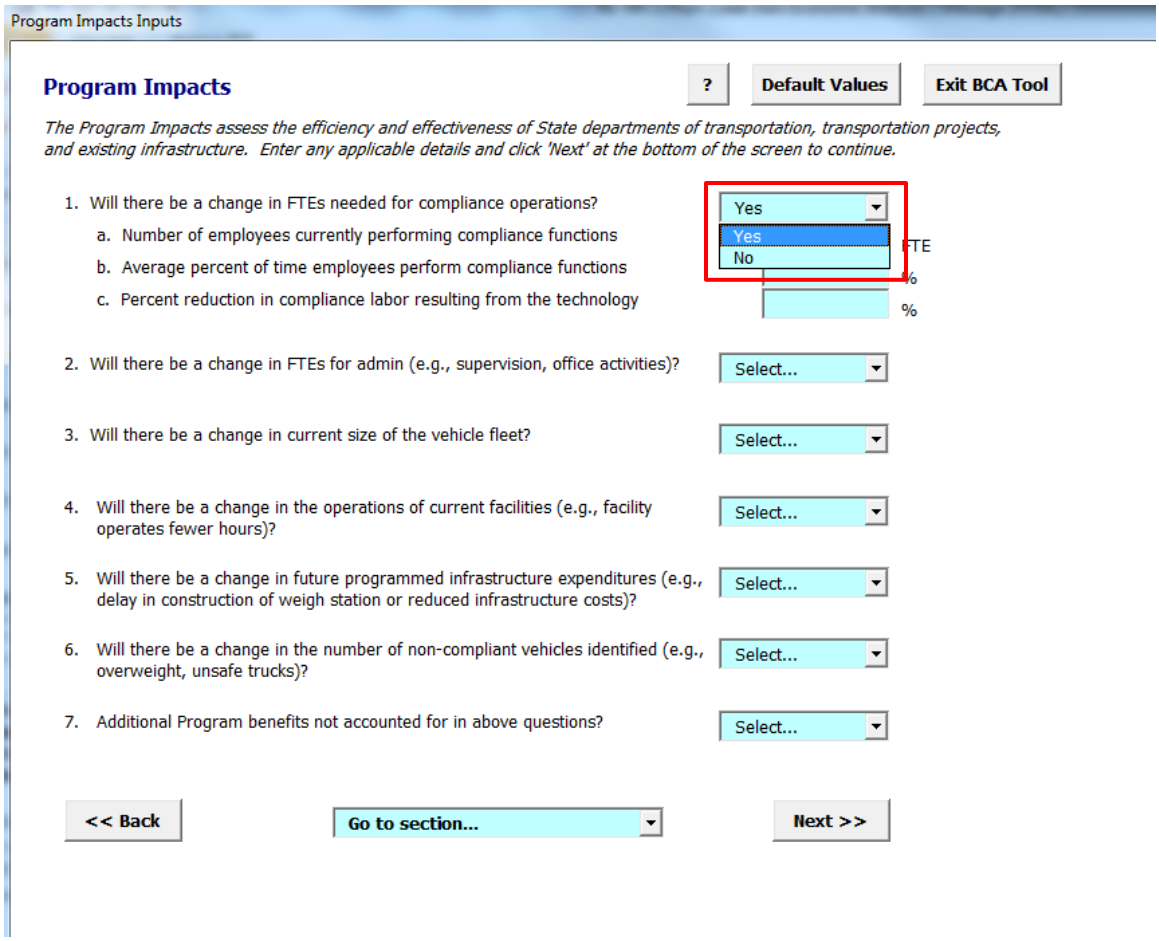
The BCA tool is set up to enter information sequentially, starting with Program Impacts and ending with the Results page. Analysts navigate the impact categories by clicking the “Next” or “Back” button or go to a particular section using the drop-down box (“Go to section…”).



Source: AECOM

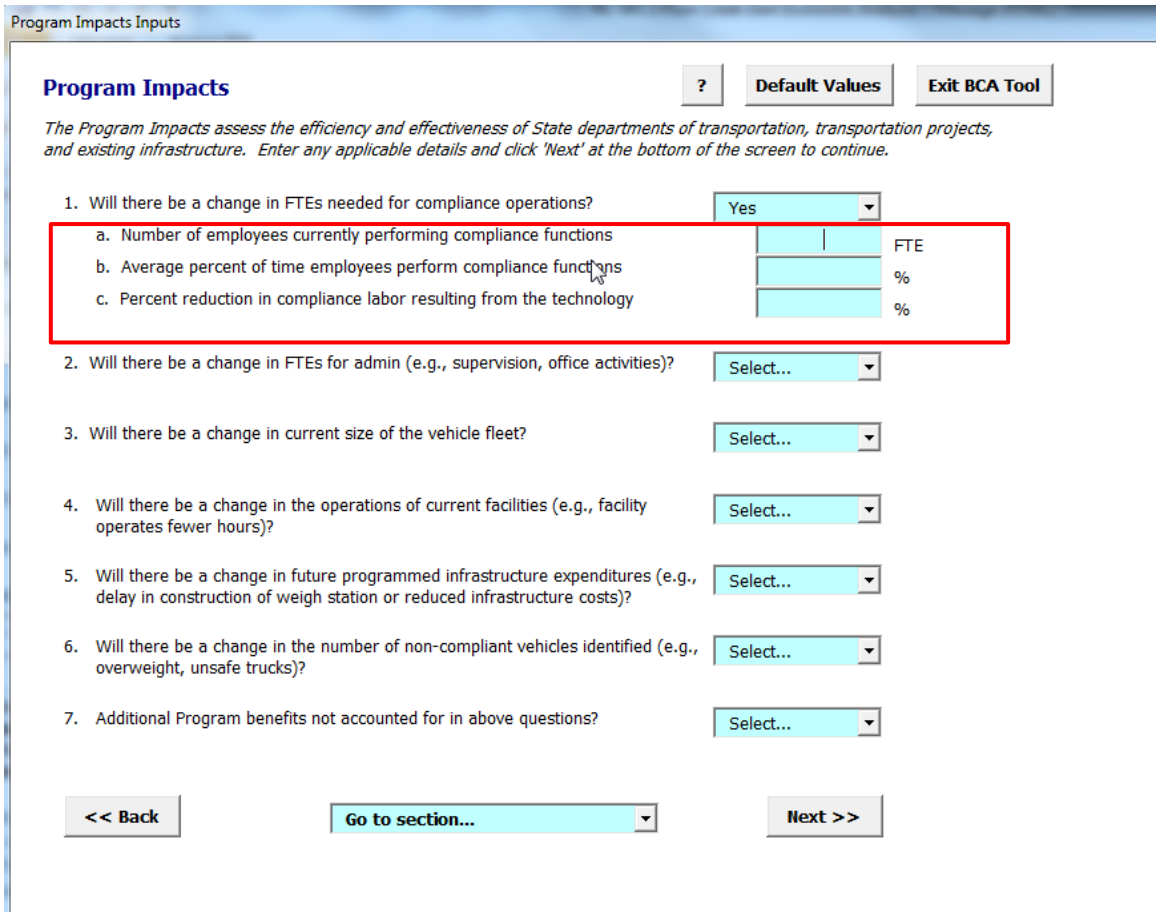
3.2 Entering Impacts

For each of the input categories, analysts answer questions on how the technology will impact the category. Most primary questions throughout the tool are in Yes/No format. If unsure of how to answer a question, click “What’s This?” for help and additional information.



Source: AECOM

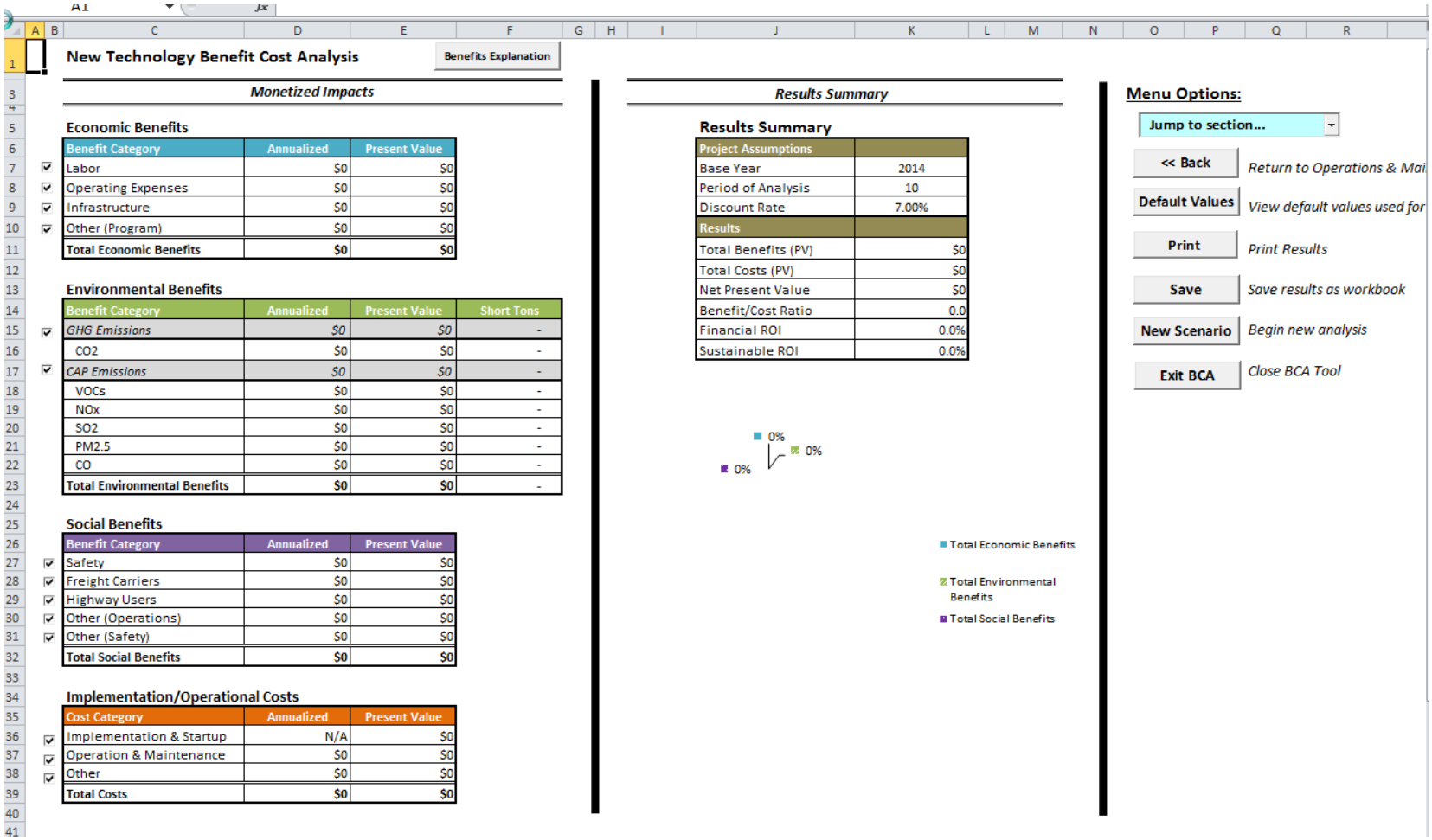
If the analyst selects "Yes," follow-up questions may appear asking for specific information.



Source: AECOM

3.3 Results

After clicking through all of the benefit and cost input categories, the results page will be displayed. The results are displayed according to output category.



New Technology Benefit Cost Analysis

Benefits Explanation

Monetized Impacts

Economic Benefits

Benefit Category	Annualized	Present Value
Labor	$0	$0
Operating Expenses	$0	$0
Infrastructure	$0	$0
Other (Program)	$0	$0
Total Economic Benefits	**$0**	**$0**

Environmental Benefits

Benefit Category	Annualized	Present Value	Short Tons
GHG Emissions	*$0*	*$0*	-
CO2	$0	$0	-
CAP Emissions	*$0*	*$0*	-
VOCs	$0	$0	-
NOx	$0	$0	-
SO2	$0	$0	-
PM2.5	$0	$0	-
CO	$0	$0	-
Total Environmental Benefits	**$0**	**$0**	-

Social Benefits

Benefit Category	Annualized	Present Value
Safety	$0	$0
Freight Carriers	$0	$0
Highway Users	$0	$0
Other (Operations)	$0	$0
Other (Safety)	$0	$0
Total Social Benefits	**$0**	**$0**

Implementation/Operational Costs

Cost Category	Annualized	Present Value
Implementation & Startup	N/A	$0
Operation & Maintenance	$0	$0
Other	$0	$0
Total Costs	**$0**	**$0**

Results Summary

Results Summary

Project Assumptions	
Base Year	2014
Period of Analysis	10
Discount Rate	7.00%
Results	
Total Benefits (PV)	$0
Total Costs (PV)	$0
Net Present Value	$0
Benefit/Cost Ratio	0.0
Financial ROI	0.0%
Sustainable ROI	0.0%

Menu Options:

Jump to section...

<< Back — *Return to Operations & Mai*

Default Values — *View default values used for*

Print — *Print Results*

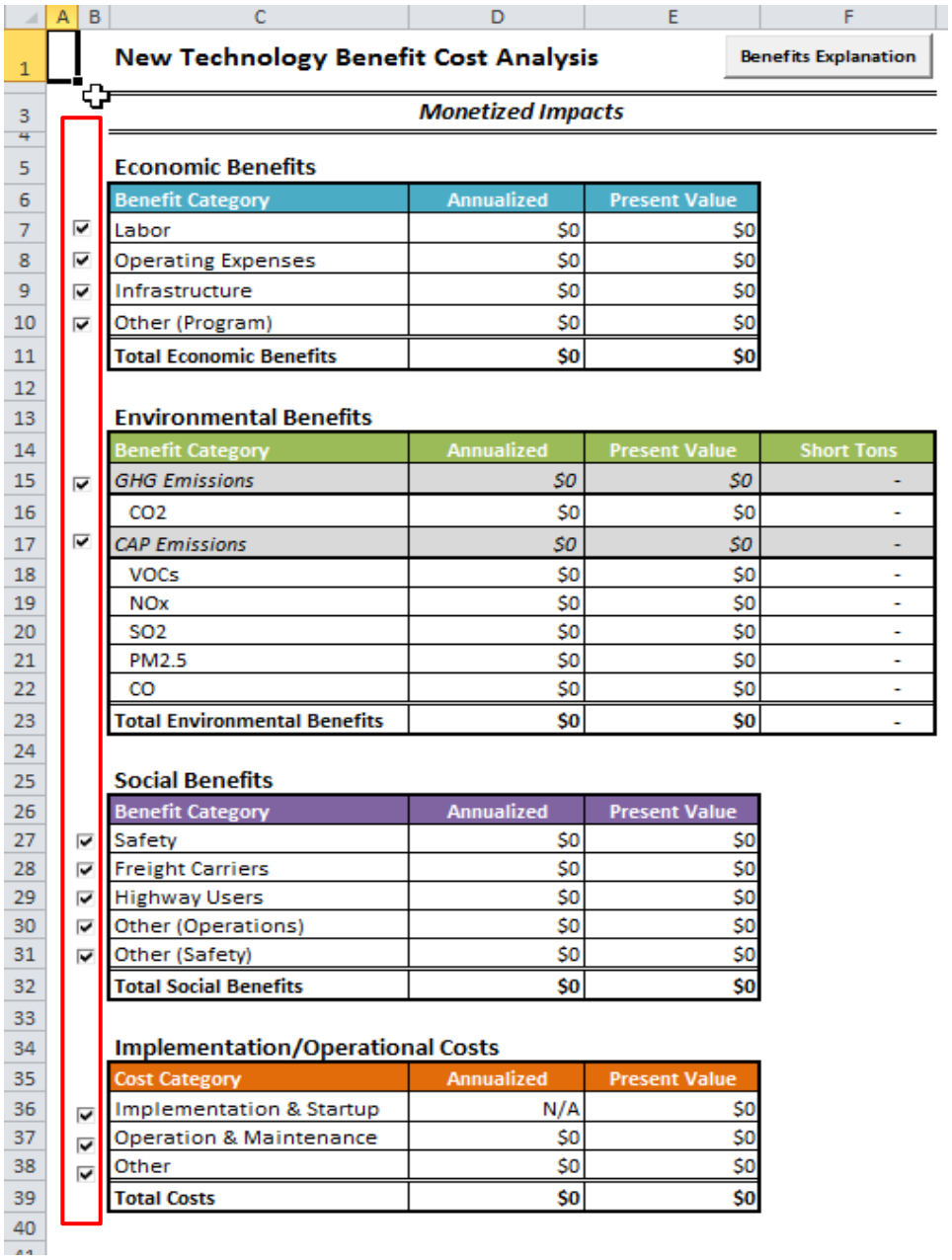
Save — *Save results as workbook*

New Scenario — *Begin new analysis*

Exit BCA — *Close BCA Tool*

Source: AECOM

If certain aspects of the output are not needed or wanted for the analysis, they can be unchecked to be excluded from the calculations.



New Technology Benefit Cost Analysis — Benefits Explanation

Monetized Impacts

Economic Benefits

	Benefit Category	Annualized	Present Value
☑	Labor	$0	$0
☑	Operating Expenses	$0	$0
☑	Infrastructure	$0	$0
☑	Other (Program)	$0	$0
	Total Economic Benefits	**$0**	**$0**

Environmental Benefits

	Benefit Category	Annualized	Present Value	Short Tons
☑	*GHG Emissions*	*$0*	*$0*	-
	CO2	$0	$0	-
☑	*CAP Emissions*	*$0*	*$0*	-
	VOCs	$0	$0	-
	NOx	$0	$0	-
	SO2	$0	$0	-
	PM2.5	$0	$0	-
	CO	$0	$0	-
	Total Environmental Benefits	**$0**	**$0**	-

Social Benefits

	Benefit Category	Annualized	Present Value
☑	Safety	$0	$0
☑	Freight Carriers	$0	$0
☑	Highway Users	$0	$0
☑	Other (Operations)	$0	$0
☑	Other (Safety)	$0	$0
	Total Social Benefits	**$0**	**$0**

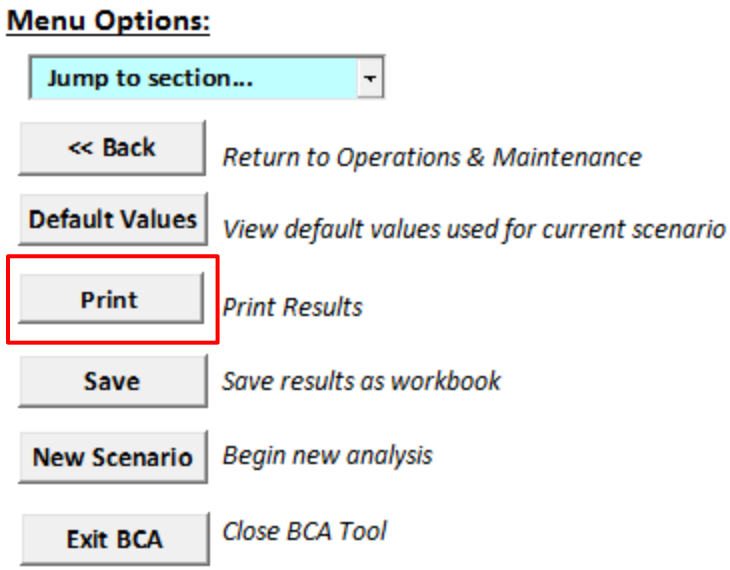
Implementation/Operational Costs

	Cost Category	Annualized	Present Value
☑	Implementation & Startup	N/A	$0
☑	Operation & Maintenance	$0	$0
☑	Other	$0	$0
	Total Costs	**$0**	**$0**

Source: AECOM

3.3.1 Printing Results

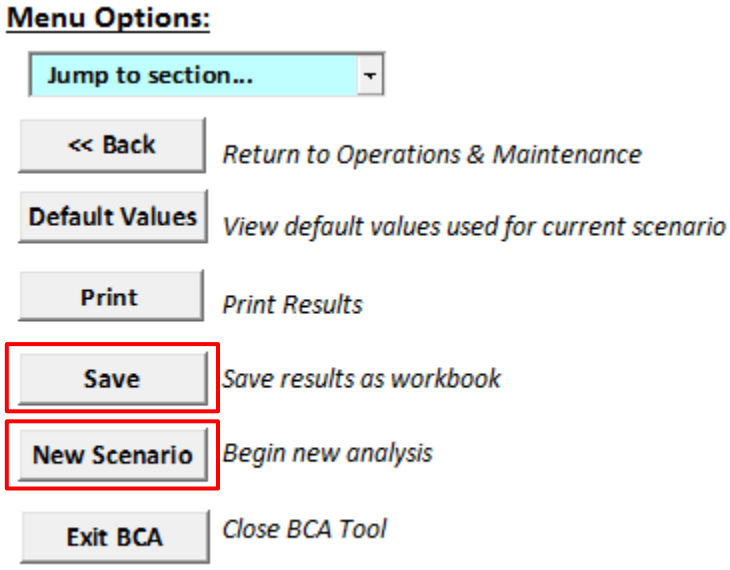
On the results screen, the analyst has the option to print the results. After clicking the “Print” button, a print preview of the results will be displayed. Then the analyst can print the page, edit the page setup, or close the print preview.



Source: AECOM

3.3.2 Saving Files

There are two ways the analyst can save the results. On the results screen, the analyst can click the "Save" button and then select the location to save the results. Also, by clicking "New Scenario," the analyst will be given the option to save the results before continuing.



Source: AECOM

3.4 Benefit-Cost Analysis Tool Example

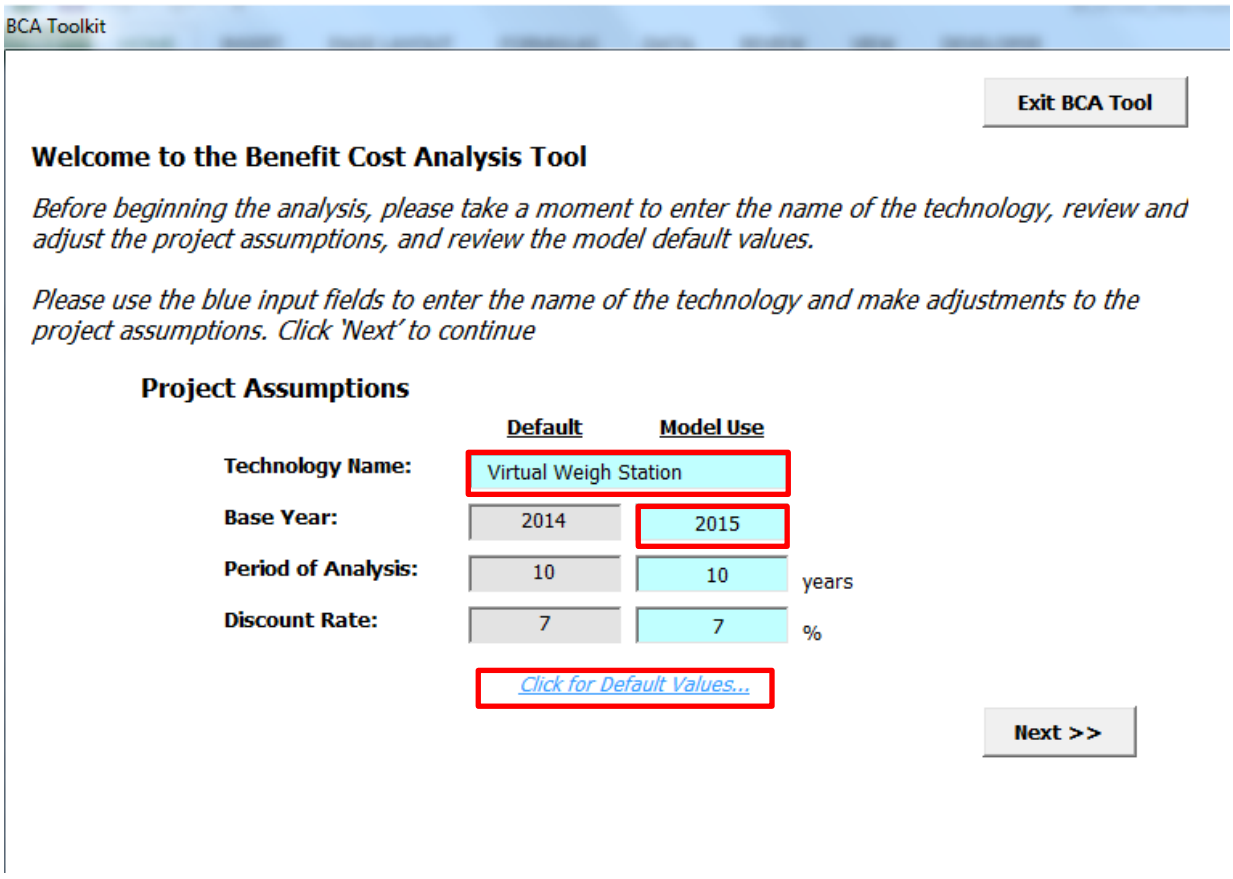
This scenario estimates the cost-effectiveness of implementing a virtual weigh station in a given location to replace an existing weigh station. This virtual weigh station will send data to a local traffic management center, State data center, and Federal Motor Carrier Safety Administration (FMCSA) data center for analysis and enforcement actions. This example will walk through the appropriate inputs to the tool for the given data.

The average administrative wage at the existing weigh station is $38/hour and the average compliance staff wage is $52/hour in the area of interest. The current fuel price per gallon is $2.75 and the diesel fuel price per gallon is $3.00.

The virtual weigh stations will reduce the number of compliance staff needed and will reduce the amount of time facilities need to remain open. The technology is also expected to increase the number of noncompliant trucks identified because it will allow fewer trucks to bypass.

3.4.1 Welcome to the Benefit-Cost Analysis Tool

On this screen, the analyst enters the basic introductory information, including the technology name, base year, period of analysis, and discount rate into the blue boxes as appropriate. Any values the analyst does not change will remain at the default.



Source: AECOM

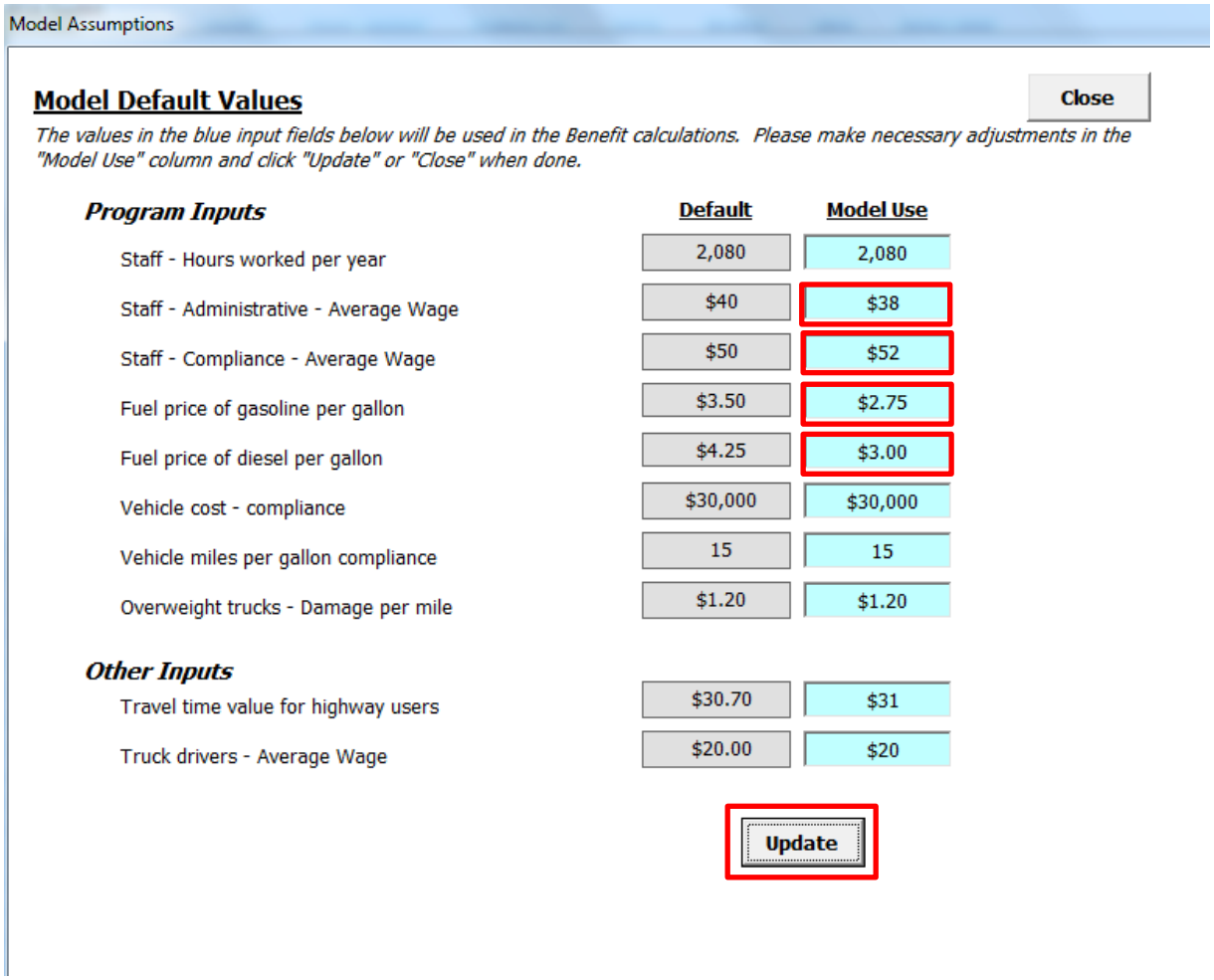
The analyst will:

- Enter “Virtual Weigh Station” as the name
- Enter the appropriate base year

The analyst should click default values below the blue input fields to view and edit default values, including wages and fuel costs. The analyst should leave any fields where information is not known or where data should remain unchanged at the default value.

For this scenario, change four fields for which more specific information is available. All other fields will remain at the default values.

When the analyst is finished updating the values, he/she clicks “Update” at the bottom of the screen.



Source: AECOM

Once the analyst clicks “Update,” he/she will be returned to the welcome page. Click “Next” to reach the Program Impacts section.

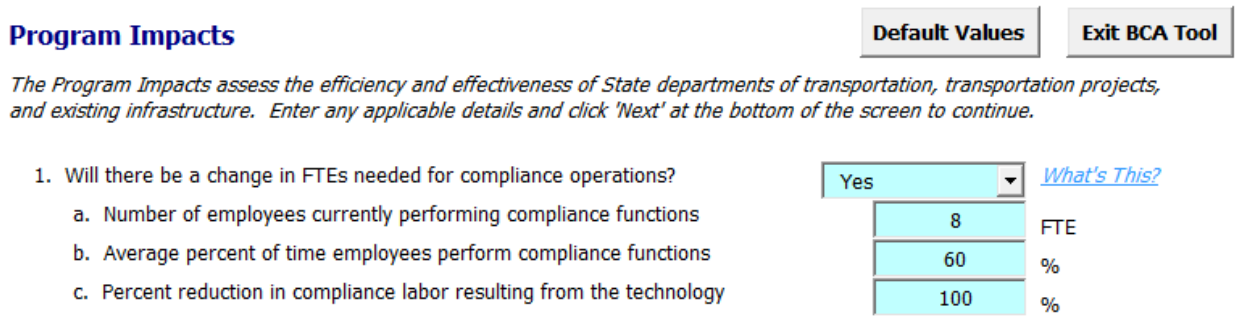
3.4.2 Program Impacts

This section assesses the effects of the technology on State agencies and existing infrastructure.

The number of full-time equivalents (FTEs) will change because the weigh station will be virtual with traffic management center, local enforcement, and back-end analysis support. The benefit is the

reduced FTEs at the weigh station. This scenario includes FTEs that will provide support at the traffic management center, but the cost is included in the costs section since it is associated with the technology. The analyst should click the drop-down arrow next to question 1 and select "Yes."

In this scenario, the number of compliance staff at the weigh station will be reduced from 8 to 0. If the scenario were applied to multiple locations, the total number of reductions across all sites should be included. The percentage of time compliance employees spend performing compliance functions is 60%, so enter 60 in block 1a. The technology would result in reduction of compliance labor of 100% by eliminating 100% of existing staff from 8 to 0, so enter 100 into block 1c.

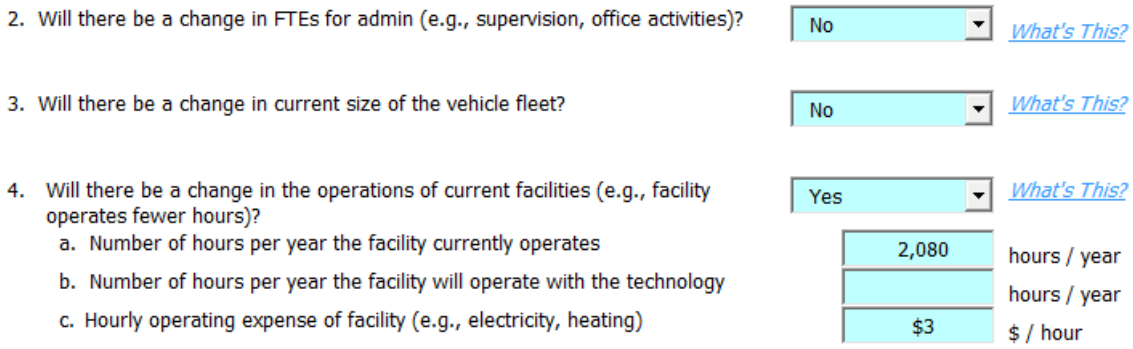


Source: AECOM

No FTE changes will occur for admin, so the analyst should answer "No" for block 2.

No change in the current vehicle fleet size is expected to occur, so the analyst should answer "No" for block 3.

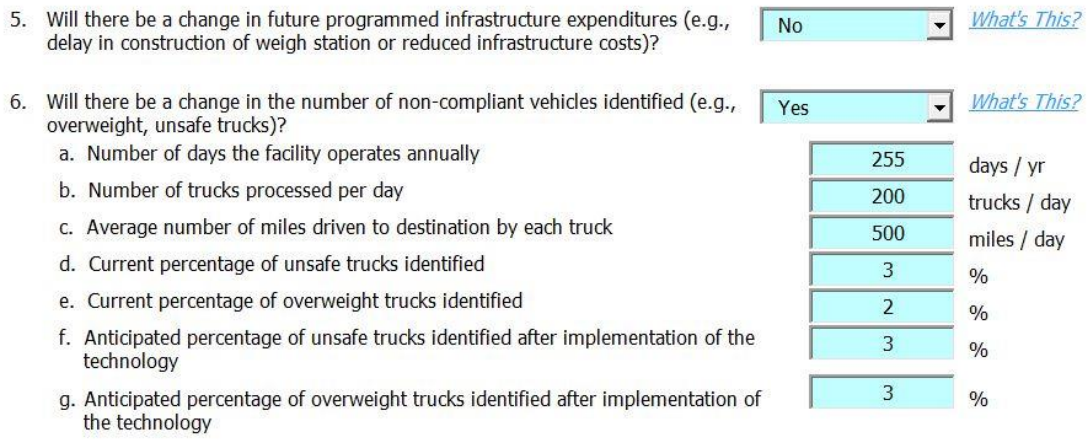
The number of operating hours of the existing weigh station will change by replacing it with a virtual weigh station. The analyst should answer "Yes" for block 4. The weigh station hours will be reduced from 2,080 to 0 with an hourly operating cost of $3.



Source: AECOM

No infrastructure changes are planned for the existing weigh station, so the analyst should answer "No" in block 5.

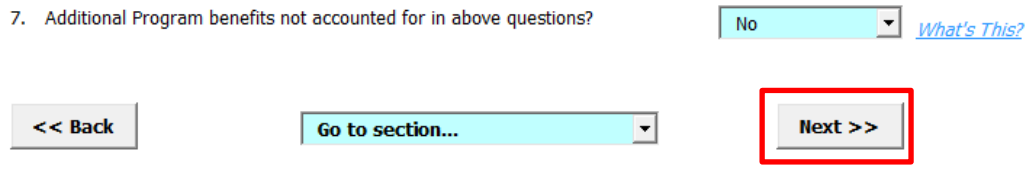
The virtual weigh station is expected to increase the number of overweight vehicles identified because fewer trucks can bypass weigh in motion technology and it will operate at all times with no closures for maintenance, unlike the existing weigh station. Answer "Yes" for block 6.



Source: AECOM

The current facility operates 255 days per year and processes 200 trucks per day, each of which drives an average of 500 miles a day. Currently, 3% of trucks are found to be unsafe and 2% of trucks are found to be overweight. The expected actual percentage of unsafe trucks would remain at 3%, while the anticipated percentage of overweight trucks identified would increase to 3% based on a more efficient system of identifying overweight vehicles.

No other program benefits are expected, so the analyst should enter "No" in block 7 and click "Next" to go to the Operations Impacts section.



Source: AECOM

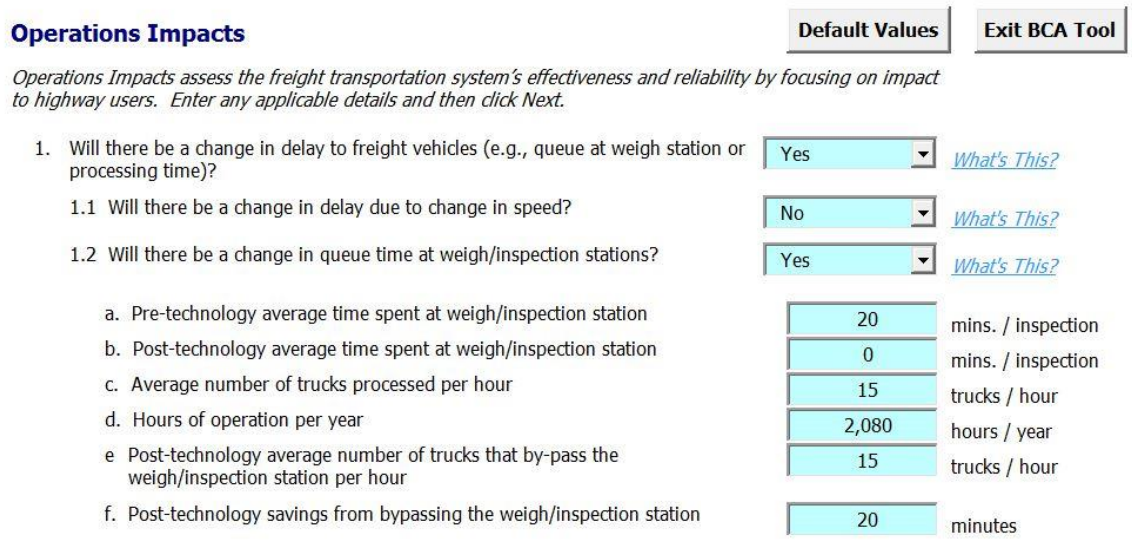
3.4.3 Operations Impacts

This section assesses the impact of the technology on highway users.

There will be a change in delay to freight vehicles because they will not need to wait in a queue at the virtual weigh station. Processing time will be faster. The analyst should select "Yes" for block 1.

The change in delay will not be due to speed, so the analyst should select "No" for block 1.1.

The change in delay will be in queue time, so the analyst should select "Yes" for block 1.2. The average time spent at a weigh station will be reduced from 20 minutes to 0 minutes. The average number of trucks processed per hour is 15. The average number of trucks that bypass the station is 15 for a per-truck time savings of 20 minutes.



Source: AECOM

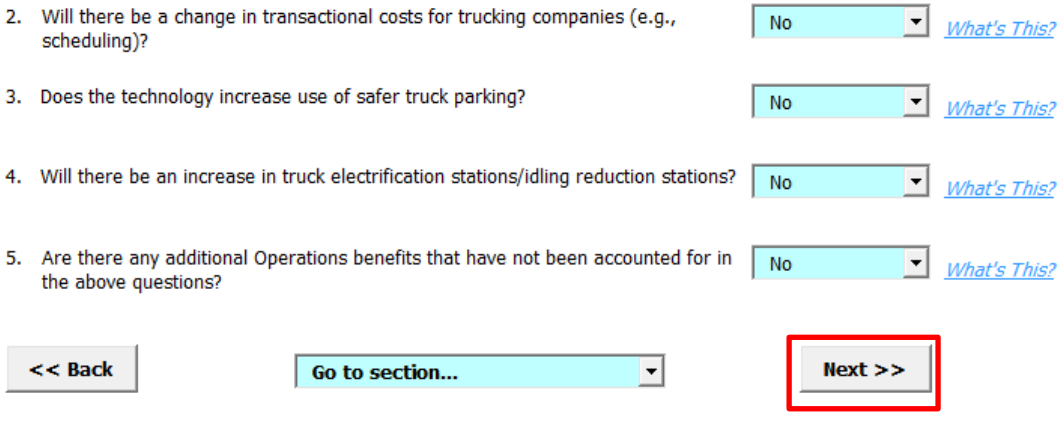
The technology will not cause transactional cost changes, so the analyst should answer "No" for block 2.

The technology does not affect truck parking, so the analyst should answer "No" for block 3.

The technology does not affect truck electrification stations, so the analyst should answer "No" for block 4.

No additional operational benefits are expected, so the analyst should answer "No" for block 5.

The analyst should click "Next" to proceed to the Safety Impacts section.



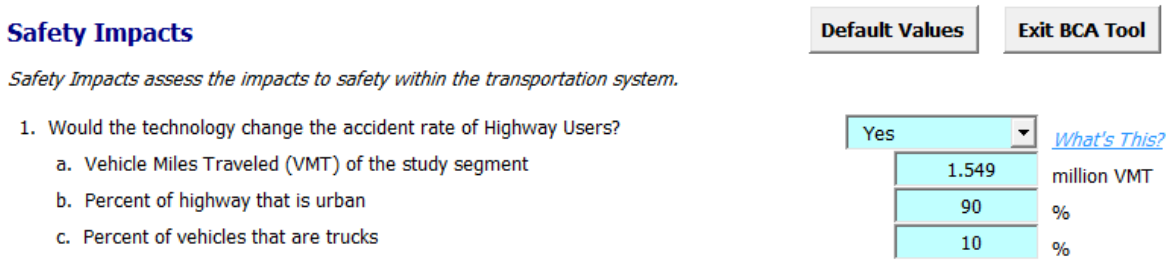
Source: AECOM

3.4.4 Safety Impacts

This section assesses the impact that the technology will have on the safety of the transportation system.

The virtual weigh station may change the accident rate of highway users by reducing unsafe queues, minimizing freight vehicle merge points, and reducing the number of unsafe trucks on the road, so the

analyst should select “Yes” for block 1. The average annual vehicle miles traveled on the interstate within the area of interest is 1,549,457 for all vehicles, of which 10% are trucks. 90% of the area of interest is considered urban.



Source: AECOM

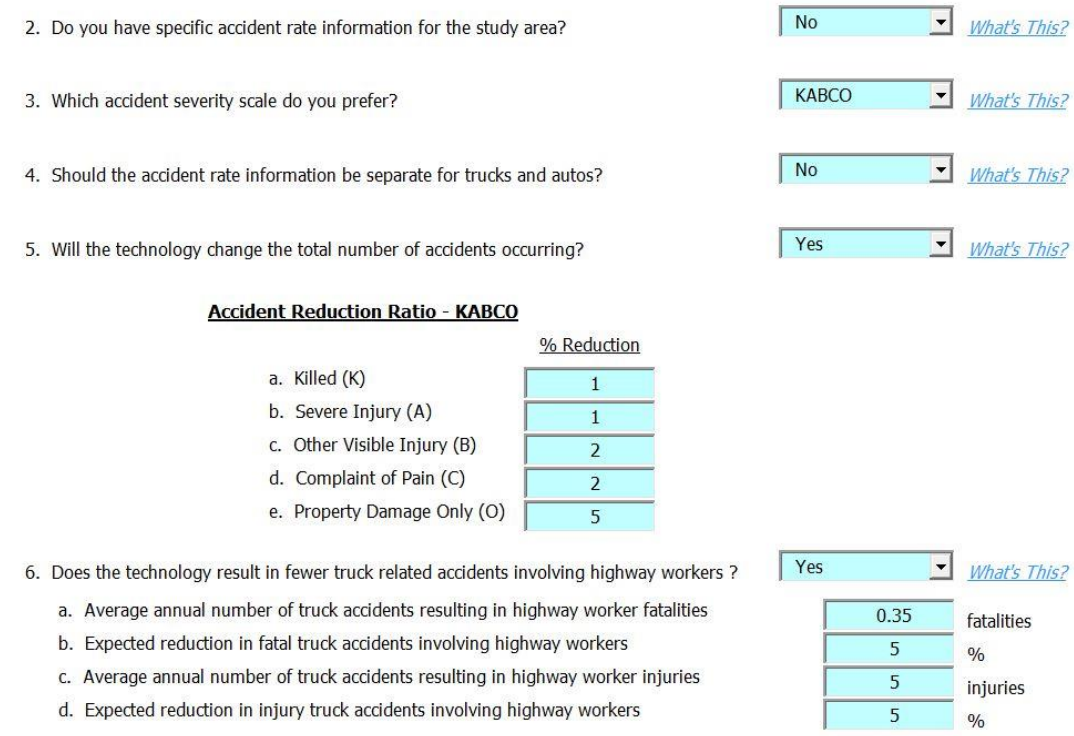
No specific accident information is available for the area, so the analyst should enter “No” in block 2. The model will use default values.

The analyst should select a preferred severity scale in question 3. This scenario will use the KABCO model, where K = Killed, A = Severe Injury, B = Other Visible Injury, C = Complaint of Pain and O = Property Damage Only.

The analyst should decide if the information should be separate for tracks and autos. This scenario will use combined accident rate information, so the analyst should select “No” in question 4.

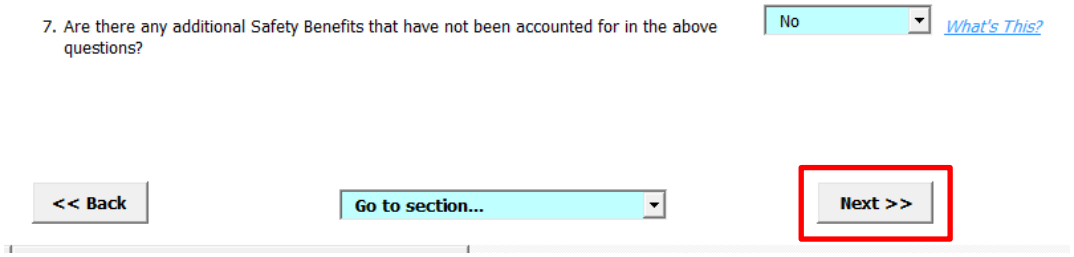
The technology will change the total number of accidents that occur, so the analyst should answer “Yes” in block 5. The technology will result in a 1% reduction in deaths, 1% reduction in injuries, 2% reduction in other visible injuries, 2% reduction in complaint of pain, and 5% reduction in property damage only.

The technology will result in fewer accidents involving highway workers because increased compliance will result in safer equipment and reduced infrastructure damage, so answer “Yes” in block 6. Annually, 5 truck-related accidents with injuries and 0.35 truck-related accidents with fatalities occur within the area of study. The technology is expected to reduce each by 5%.



Source: AECOM

No further safety benefits are expected, so the analyst should select "No" for block 7. The analyst should click "Next" to proceed to the Implementation and Startup Costs section.

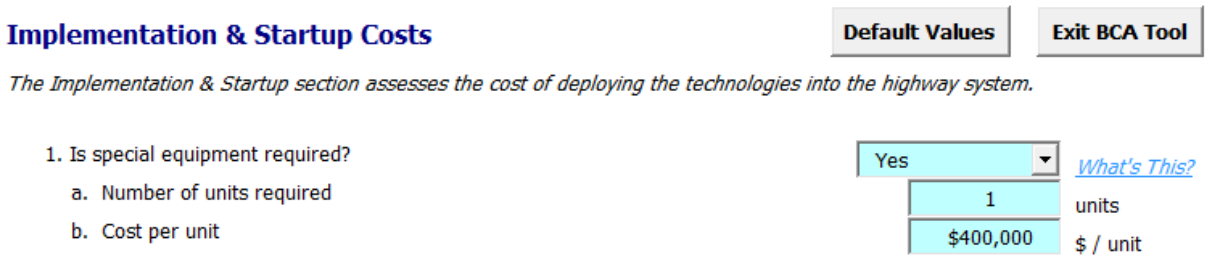


Source: AECOM

3.4.5 Implementation and Startup Costs

This section assesses the costs of implementing the technology.

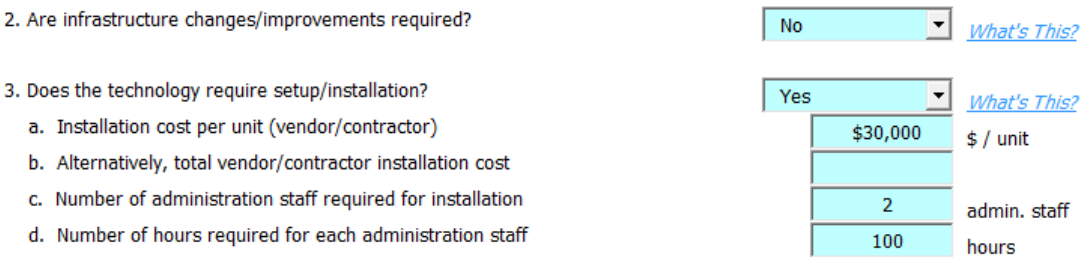
The special equipment required is weigh in motion technology, so the analyst should answer "Yes" in block 1. This example is for one virtual weigh station at $400,000 per unit.



Source: AECOM

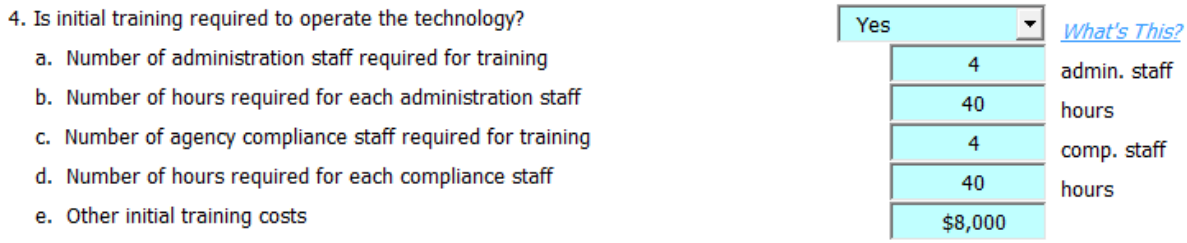
No changes to existing infrastructure are required, so the analyst should answer "No" in block 2.

The technology requires installation by a contractor, so the analyst should answer "Yes' in block 3. The installation cost is $30,000 to the contractor and 2 administration staff working 100 hours each.



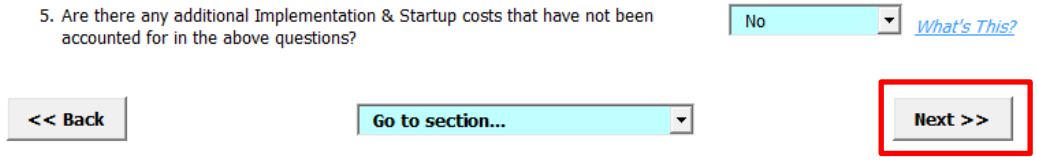
Source: AECOM

Initial training of compliance staff and freight operators will be required, so the analyst should select "Yes" in block 4. Training of 4 administrative and 4 compliance staff with 40 hours each will be required. An additional $8,000 in training costs will be used to publicize the new technology to highway users.



Source: AECOM

No additional implementation or startup costs apply, so select "No" in block 5. Click "Next" to proceed to the Operation and Maintenance Costs section.

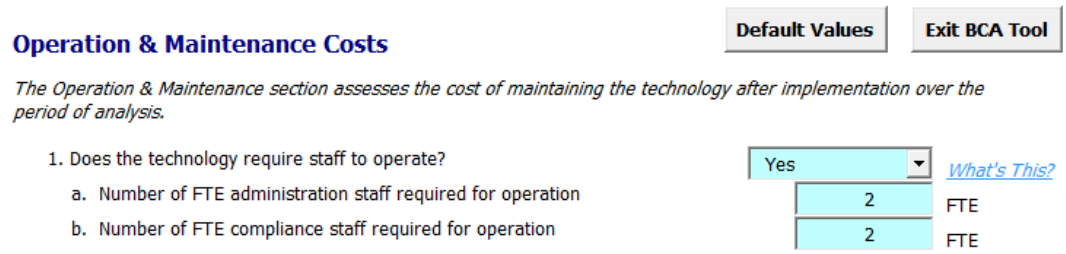


Source: AECOM

3.4.6 Operation and Maintenance Costs

This section assesses the operating cost associated with the technology.

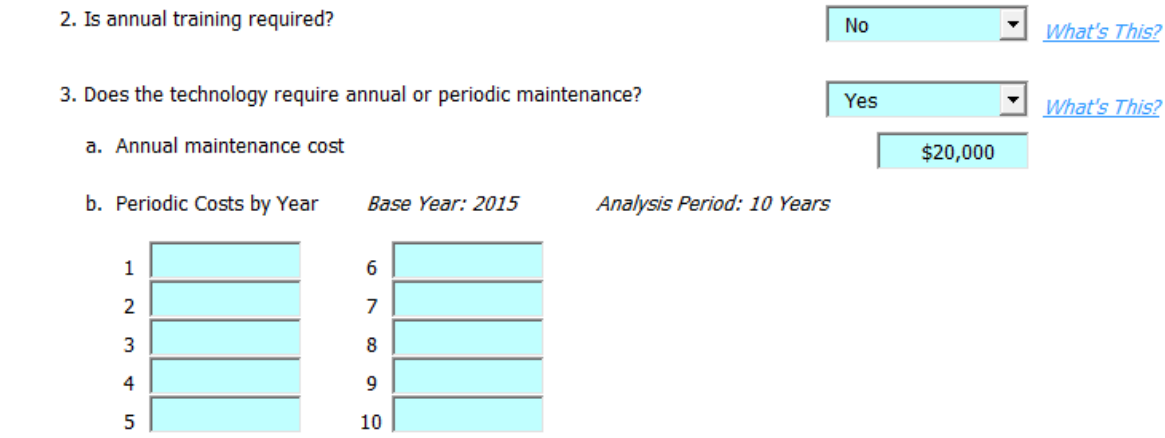
The technology does not require staff to operate the virtual weigh station, but it does require local compliance staff to respond when enforcement action is needed and back-office staff for support so the analyst should answer "Yes" in block 1. Two additional compliance staff and two additional administration staff are required.



Source: AECOM

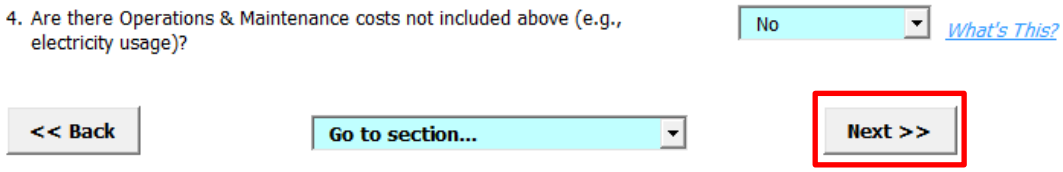
No annual training will be required, so the analyst should answer "No" in block 2.

The technology will require $20,000 of maintenance and operating costs annually, so the analyst should answer "Yes" in block 3.



Source: AECOM

No additional operations and maintenance costs are expected, so the analyst should answer "No" in block 4.



Source: AECOM

3.4.7 Results

The results section will display monetized impacts and a results summary. The analyst will also have the option to jump to a section in the current analysis, view default values, print or save results, begin a new scenario, exit the tool, or unlock the workbook.

Virtual Weigh Station Benefit Cost Analysis

Monetized Impacts

Economic Benefits — Details... — What's This?

Benefit Category	Annualized	Present Value
Labor	$519,200	$3,646,400
Operating Expenses	$6,200	$43,800
Infrastructure	$23,000	$161,200
Other (Program)	$0	$0
Total Economic Benefits	**$548,400**	**$3,851,400**

Environmental Benefits — Details... — What's This?

Benefit Category	Annualized	Present Value	Short Tons
GHG Emissions	*$17,400*	*$122,500*	*3,175*
CO2	$17,400	$122,500	3,175
CAP Emissions	*$6,900*	*$48,300*	*21*
VOCs	$500	$3,300	1
NOx	$6,100	$42,700	11
SO2	$0	$200	0
PM2.5	$200	$1,200	0
CO	$100	$900	9
Total Environmental Benefi	**$24,300**	**$170,800**	**3,197**

Social Benefits — Details... — What's This?

Benefit Category	Annualized	Present Value
Safety	$206,500	$1,450,400
Freight Carriers	$486,700	$3,418,400
Highway Users	$323,500	$2,272,100
Other (Operations)	$0	$0
Other (Safety)	$0	$0
Total Social Benefits	**$1,016,700**	**$7,140,900**

Implementation/Operational Costs — Details... — What's This?

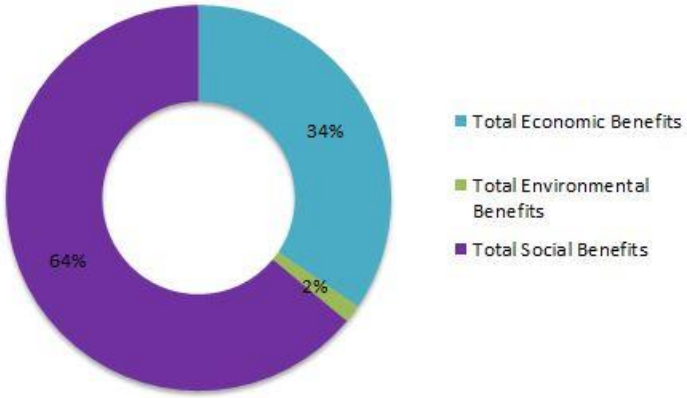
Cost Category	Annualized	Present Value
Implementation & Startup	N/A	$460,000
Operation & Maintenance	$394,400	$2,770,100
Other	$0	$0
Total Costs	**$394,400**	**$3,230,100**

Source: AECOM

Results Summary

Results Summary *What's This?*

Project Assumptions	
Base Year	2015
Period of Analysis	10
Discount Rate	7.00%
Results	
Total Benefits (PV)	$11,163,100
Total Costs (PV)	$3,230,100
Net Present Value	$7,933,000
Benefit/Cost Ratio	3.5
Financial ROI	119.2%
Sustainable ROI	345.6%



Source: AECOM

3.5 Troubleshooting

Near the end of the development of the BCA tool, Microsoft released a Microsoft Office update (December 2014). Unfortunately, the update caused many issues for programs designed using Visual Basic, including error messages and program crashes. The issue has to do with a file that has ".exd" as the extension. Microsoft explains the purpose of the .exd file at:

http://support.microsoft.com/kb/290537/EN-US

Another Microsoft link explains how to fix the problem:
http://support.microsoft.com/kb/3025036/

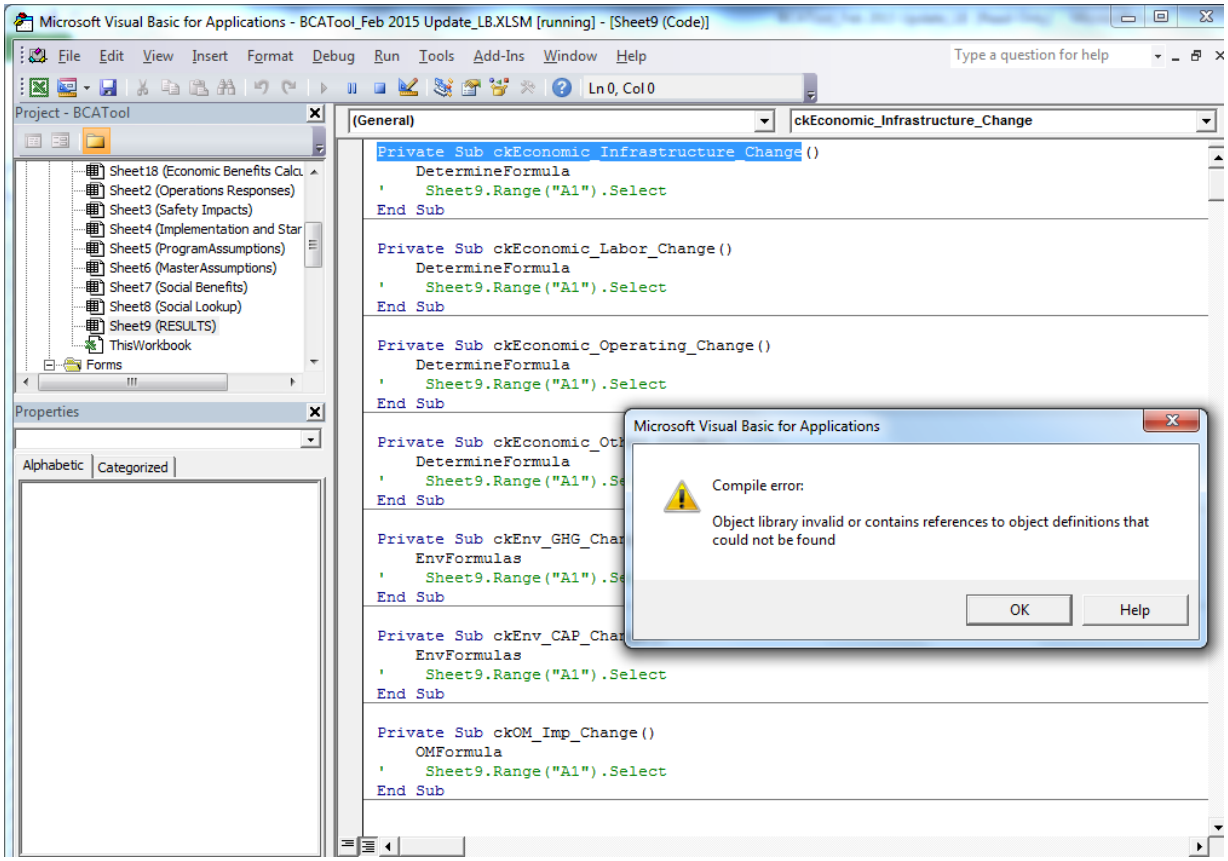
This process to delete the .exd file and fix the problem is also explained below:

1. Close all Office applications.

2. Open an Explorer window and in the search bar type "*.exd". Look specifically for MSForms.exd files, NOT .EXE. The path should be similar to the following: C:\users\username\AppData\Local\Temp\Excel8.0\MSForms.exd
3. Delete the .exd file related to Excel.
4. Reboot the computer (this is not always necessary, but is a good precaution).
5. Reopen Excel and use the BCA tool.

Since the BCA tool is locked for analysts, the exact error message may be different than provided in the link. Since the BCA tool only relies on Excel, only the .exd related to Excel needs to be deleted.

An example of an error message is as follows:



Source: AECOM

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Appendix A List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AIS	Abbreviated Injury Scale
BCA	Benefit-Cost Analysis
BCR	benefit-cost ratio
CAP	criteria air pollutant
CO	carbon monoxide
CPI	Consumer Price Index
DOT	Department of Transportation
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIPDO	fatalities, injuries, and property damage only
FMCSA	Federal Motor Carrier Safety Administration
FTE	full-time equivalent
GHG	greenhouse gas
KABCO	K = Killed, A = Severe Injury, B = Other Visible Injury, C = Complaint of Pain and O = Property Damage Only
mph	miles per hour
NHTSA	National Highway Traffic Safety Administration
NOx	nitrogen oxides
NPV	net present value
OMB	U.S. Office of Management and Budget
PDO	property damage only
PM	particulate matter
ROI	return on investment
SCC	Social Cost of Carbon
SOx	sulfur oxides
SRI	Smart Roadside Initiative
sROI	sustainable return on investment
SU	single unit
SUV	sport utility vehicle
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
VHT	vehicle hours traveled
VMT	vehicle miles traveled
VSL	value of statistical life
VOC	volatile organic compound

Appendix B Default Values and Formulas

B.1 Program Implementation of State Highway Operations

For this category, the model uses default values and allows the analyst to update these defaults with values specific to the study area. Default values for this category are listed in Table B-1.

Table B-1: Default Values for Program Implementation of State Highway Operations

Description	Value
Hours worked per year	2,080
Compliance vehicle miles per gallon	15

Source: AECOM

B.2 Operations of the Trucking Sector

For this category, the model uses default values based on guidance from the American Association of State Highway and Transportation Officials (AASHTO, 2010). The analyst may update these defaults with revised estimates if necessary.

Fuel Savings Values

The change in fuel and labor costs is straightforward. For carriers, vehicle operating costs are generally a function of speed. Speed-related changes in fuel costs can be calculated using the following equation (AASHTO, 2010):

$$\Delta C(S)_{fuel} = \left(gal_{c,speed0} - gal_{c,speed\ 1}\right)P_c$$

Where: $\Delta C(S)_{fuel}$ = change in fuel costs as a function of speed for vehicle class c (cents)

$gal_{c,speed0}$ = gallons per mile for vehicle class c, pre-improvement speed

$gal_{c,speed\ 1}$ = gallons per mile for vehicle class c, post-improvement speed

P_c = fuel price per gallon for vehicle class c (cents)

Table B-2 provides fuel consumption for autos and trucks by average operating speed (Cohn, et al., 1992).

Table B-2: Fuel Consumption by Average Operating Speed

Speed (mph)	Fuel Consumption (gallons per mile)	
	Autos	Trucks
5	0.117	0.503
10	0.075	0.316
15	0.061	0.254
20	0.054	0.222
25	0.050	0.204
30	0.047	0.191
35	0.045	0.182
40	0.044	0.176
45	0.042	0.170
50	0.041	0.166
55	0.041	0.163
60	0.040	0.160
65	0.039	0.158

mph = miles per hour
Source: Cohn, et. al., 1992

Fuel costs can be calculated directly from fuel consumption information. Fuel costs can be calculated as the number of gallons multiplied by the cost of fuel or, if the fuel efficiency of the vehicle is known, fuel costs per vehicle mile can be calculated using the following equation (AASHTO, 2010):

$$C_{fuel} = 100E_{gpm}P_{fuel} = 100P_{fuel}/E_{mpg}$$

Where:
C_{fuel} = user cost of fuel, in cents per vehicle-mile
E_{gpm} = fuel efficiency, in gallons per mile
E_{mpg} = fuel efficiency, in miles per gallon
P_{fuel} = fuel price, in dollars per gallon

Fuel costs can also be expressed as a function of time rather than as a function of travel speed. Table B-3 provides the costs of fuel consumption per minute as a result of delays (AASHTO, 2010). The fuel consumption is primarily due to acceleration of vehicles after being delayed, rather than fuel consumed in idling during delay periods.

Fuel costs are calculated as a function of time using the following equation (AASHTO, 2010):

$$\Delta C(D)_{c,fuel} = (gal_{c,min})(D_0 - D_1)P_c$$

Where:
$\Delta C(D)_{c,fuel}$ = change in fuel costs as a function of delay (cents)
$gal_{c,min}$ = gallons per minute for vehicles class c
D_0 = average delay before improvement (minutes)
D_1 = average delay after improvement (minutes)
P_c = fuel price per gallon for vehicle class c (cents)

Table B-3: Fuel Consumption (Gallons per Minute) of Delay by Vehicle Type

Free Flow Speed (mph)	Vehicle Type					
	Small Car	Big Car	SUV	2-Axle SU	3-Axle SU	Combo
20	0.011	0.022	0.023	0.074	0.102	0.198
25	0.013	0.026	0.027	0.097	0.133	0.242
30	0.015	0.030	0.032	0.122	0.167	0.284
35	0.018	0.034	0.037	0.149	0.203	0.327
40	0.021	0.038	0.043	0.177	0.241	0.369
45	0.025	0.043	0.049	0.206	0.280	0.411
50	0.028	0.048	0.057	0.235	0.321	0.453
55	0.032	0.054	0.065	0.266	0.362	0.495
60	0.037	0.060	0.073	0.297	0.404	0.537
65	0.042	0.066	0.083	0.328	0.447	0.578
70	0.047	0.073	0.094	0.360	0.490	0.620
75	0.053	0.080	0.105	0.392	0.534	0.661

mph = miles per hour
SUV = sport utility vehicle
SU = single unit
Source: AASHTO, 2010

B.3 Safety and Security to Society

For this category, the model uses national accident rates from the U.S. Department of Transportation Federal Motor Carrier Safety Administration (FMCSA, 2012). The analyst may use accident rates specific to the study area in place of these defaults. The default accident rates for fatalities, injuries, and property damage only (PDO) accidents (FIPDO) are presented in Table B-4. The default KABCO accident rates are presented in Table B-5.

Table B-4: FIPDO Default Accident Rates

FIPDO	Combined Values	Auto Only Values	Truck Only Values
Fatalities	0.010	0.010	0.013
Injuries	0.550	0.589	0.272
PDO	1.330	1.453	0.899
Total	1.890	2.052	1.244

Source: FMCSA, 2012

Table B-5: KABCO Default Accident Rates

KABCO	Combined Values	Auto Only Values	Truck Only Values
Killed (K)	0.010	0.010	0.013
Severe Injury (A)	0.026	0.028	0.013
Other Visible Injury (B)	0.145	0.155	0.071
Complaint of Pain (C)	0.380	0.407	0.188
Property Damage Only (O)	1.330	1.453	0.899
Total	1.890	2.052	1.184

Source: FMCSA, 2012

Tables B-6 and B-7 are used to calculate the amount of diesel and gasoline consumed due to an accident. This information was obtained from the FMCSA.

Table B-6: Estimated Excess Fuel Burn by Roadway Type and Severity

Roadway Type	Accident Type			Average for Road Type
	Fatal	Injury Only	Property Damage Only	
Urban Interstate/Expressway	2,655.95	995.54	846.03	893.81
Rural Interstate/Principal Arterial	483.72	165.18	139.43	148.01

Source: FMCSA, 2013

Table B-7: Diesel and Gasoline Consumption Percentages

Roadway Type	Diesel Factor	Gas Factor
Urban Interstate/Expressway	44%	56%
Rural Interstate/Principal Arterial	32%	68%

Source: FMCSA, 2013

Tables B-8 is used to calculate the number of delay hours per accident according to the type of roadway. This information was obtained from the FMCSA.

Table B-8: Estimated Delay Time by Accident Classification

Roadway Type	Accident Classification		
	Fatal	Injury Only	Property Damage Only
Urban Interstate/Expressway	6,729	2,522	2,144
Rural Interstate/Principal Arterial	464	159	134

Source: FMCSA, 2013

B.4 Economic Benefits

For this category, the model uses default values and allows the analyst to update these defaults with values specific to the study area. Default values for this category are listed in Table B-9.

Table B-9: Default Values for Program Implementation of State Highway Operations

Description	Value
Compliance staff hourly wage	$50
Administrative staff hourly wage	$40
Price of a gallon of gasoline	$3.50
Price of a gallon of diesel	$4.25
Cost per fleet vehicle	$30,000
Damage cost per mile from overweight trucks	$1.20

B.5 Social Benefits

Social benefits include indirect fuel and time savings for both freight carriers and other highway users resulting from traffic delays associated with a reduction in accidents and the benefit of reducing accident-related personal injuries and property damage from accidents. The travel time value for all highway users is described below. The average truck driver wage of $20 per hour is used to calculate travel time savings specific to truck drivers. These values may be updated by the analyst.

Travel Time Value for Highway Users

According to the National Household Travel Survey (USDOT, 2006), 82 percent of vehicles on the road are personal passenger vehicles and the remaining 18 percent are commercial vehicles. The average number of persons per vehicle is 1.67 (USDOT, 2011). Using the national average employer cost for employee compensation per hour of $31.16, average number of persons per vehicle of 1.67 and USDOT's methodology for per-hour-value of time, the equation below (FEMA, 2011) was used to determine the hourly value of time per vehicle.

((%PPV*(W*0.5)) + (%COM*W))*PPV = ((0.82*(31.16*0.5)) + (0.18*31.16))*1.67 = **$30.70**

Where: PPV = personal passenger vehicles
COM = commercial vehicles
W = wage rate
PPV = persons per vehicle

Accident Cost Values

The Abbreviated Injury Scale (AIS) conversion matrix is used to convert FIPDO and KABCO to AIS. Table B-10 provides the KABCO/Unknown to AIS conversion matrix.

Table B-10: AIS Conversion Matrix

AIS	K	A	B	C	O	U
	Killed	Incapacitating	Non-Incapacitating	Possible Injury	Property Damage Only	Injured - Severity Unknown
0	0.00000	0.03437	0.08347	0.23437	0.92534	0.21538
1	0.00000	0.55449	0.76843	0.68946	0.07257	0.62728
2	0.00000	0.20908	0.10898	0.06391	0.00198	0.10400
3	0.00000	0.14437	0.03191	0.01071	0.00008	0.03858
4	0.00000	0.03986	0.00620	0.00142	0.00000	0.00442
5	0.00000	0.01783	0.00101	0.00013	0.00003	0.01034
Fatality	1.00000	-0.00000	0.00000	0.00000	0.00000	0.00000
Probability	1	1	1	1	1	1

Source: NHTSA, 2011

Based on the USDOT guidance (USDOT, 2014), the value of statistical life (VSL) is $9,200,000 per fatality in 2014 dollars. The value of accidents and emergency service is defined in Table B-11 according to the AIS and as a fraction of the VSL (USDOT, 2012).

Table B-11: Value of Injuries According to AIS Level

AIS Level	Severity	Fraction of VSL	Benefit of Each Reduced Accident	Emergency Service Benefit
AIS 1	Minor	0.003	$27,600	$65
AIS 2	Moderate	0.047	$432,400	$293
AIS 3	Serious	0.105	$966,000	$509
AIS 4	Severe	0.266	$2,447,200	$1,147
AIS 5	Critical	0.593	$5,455,600	$1,178
AIS 6	Unsurvivable	1.000	$9,200,000	$1,151

Sources: USDOT, 2014 and 2012 & NHTSA, 2000

In addition to injuries, the property damage to the vehicle is estimated to be $3,566 per vehicle in 2014 dollars based on USDOT guidance (USDOT, 2002) and the emergency service benefit is $37.

The following equation is used to calculate the value of accident cost savings (AASHTO, 2010):

$$\Delta AC = v_I \Delta I + v_D \Delta D + v_P \Delta P + v_E \Delta E$$

Where:
- ΔAC = change in accident costs
- ΔI = change in expected number of injury accidents
- ΔD = change in expected number of fatal accidents
- ΔP = change in expected number of property damage accidents
- ΔE = change in number of emergency responders
- v_I = cost associated with an injury accident
- v_D = cost associated with a fatal accident
- v_P = cost associated with a property damage incident
- v_E = cost associated with emergency response

The change in accident unit costs is a combination of the change in accident rates and costs of each component (AASHTO, 2010):

$$\Delta AC_C = v_I \Delta I + v_D \Delta D + v_P \Delta P + v_E \Delta E$$

Where:
- ΔAC_C = change in accident costs (cents per vehicle mile) for vehicle class c
- ΔI = change in expected number of injury accidents (per vehicle mile)
- ΔD = change in expected number of fatal accidents (per vehicle mile)
- ΔP = change in number of property damage accidents (per vehicle mile)
- ΔE = change in number of emergency responders (per vehicle mile)
- v_I = perceived cost associated with an injury accident (cents)
- v_D = perceived cost associated with a fatal accident (cents)
- v_P = perceived cost associated with a property damage accident (cents)
- v_E = cost associated with emergency response (cents)

B.6 Environmental Benefits

Greenhouse Gas Emission Values

Table B-12 provides the social cost of carbon dioxide emissions for years 2014 through 2023.

Table B-12: Value of Greenhouse Gas Emissions

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
2007$	$23.30	$23.80	$24.30	$24.80	$25.30	$25.80	$26.30	$27.00	$27.60	$28.30
2014$	$32.19	$32.88	$33.57	$34.26	$34.95	$35.64	$36.33	$37.30	$38.13	$39.10

Source: Interagency Working Group on the Social Cost of Carbon, 2010

Criteria Air Pollutant Values

Table B-13 provides criteria air pollutant emission values per short ton and per metric ton.

Table B-13: Value of Criteria Air Pollutants

Emissions Type	$ / Short Ton (2014$)	$ / Metric Ton (2014$)
Volatile Organic Compounds (VOCs)	$2,349	$2,589
Nitrogen Oxides (NOx)	$9,256	$10,203
Particulate Matter (PM)	$423,440	$466,762
Sulfur Oxides (SOx)	$54,709	$60,305

Source: NHTSA, 2012

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