Bridge Investment Program Benefit-Cost Analysis Tool

User Manual **v1.0.0**

September 2023

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16. Abstract This user manual is a companion to the USDOT FHWA Bridge Investment Program Benefit-Cost Analysis Tool. The tool was developed to assist project sponsors who apply for a Bridge Investment Program grant that requires a project benefit-cost analysis. This user manual provides instructions on how to use the tool and provides background on the tool's functionality, calculation procedures, and inputs and outputs.		
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Version Notes

This manual reflects the BIP BCA Tool version 1.0.0.

- In the 2023 NBI data there are two sets of bridges with the same structure number. The structure number for those have been distinguished using the following adjustments:
  - The Massachusetts N100108PDDOTNBI bridge owned and maintained by MassDOT has the structure number N100108PDDOTNBI_A, and Massachusetts N100108PDDOTNBI bridge owned and maintained by U.S. Fish and Wildlife has the structure number N100108PDDOTNBI_B.
  - The Virginia 000000000001826 bridge owned and maintained by VDOT has the structure number 000000000001826_A, and the Virginia 000000000001826 bridge owned and maintained by U.S. Army Corps of Engineers (USACE) has the structure number 000000000001826_B.

List of Abbreviations

Abbreviation	Term
AADT	Average Annual Daily Traffic
BCA	Benefit-Cost Analysis
BIP	Bridge Investment Program
CMF	Crash Modification Factor
CRF	Crash Reduction Factor
C&P	FHWA's Conditions and Performance Report
EPA	Environmental Protection Agency
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
IIJA	Infrastructure Investment and Jobs Act
MOVES	Motor Vehicle Emission Simulator
MPH	Miles per Hour
MVMT	Million Vehicle Miles Traveled
NBI	National Bridge Inventory
NBIAS	National Bridge Investment Analysis System
NOFO	Notice of Funding Opportunity
O&M	Operation and Maintenance
USDOT	United States Department of Transportation
VOC	Vehicle Operating Costs
VMT	Vehicle Miles Traveled

Introduction

Purpose

The United States Department of Transportation (USDOT) and its modal administrations provide discretionary grants to help build up and maintain a fast, safe, efficient, accessible and convenient transportation system for the American people, today and into the future. There is a myriad of programs available to help States, local governments, Tribes, and other eligible entities plan for and deliver transformative infrastructure projects and services to meet the transportation infrastructure needs for all transportation users.

The Bridge Investment Program (BIP) is a discretionary grant program administered by the Federal Highway Administration (FHWA) and provides grants on a competitive basis to improve bridge condition and the safety, efficiency, and reliability of the movement of people and freight over bridges. Section 11118 of the Bipartisan Infrastructure Law (Pub. L. No. 117-58, Nov. 15, 2021), established the BIP, codified at 23 U.S.C. 124 [1]. BIP provides funding for replacement, rehabilitation, preservation, and protection of bridges to reduce the overall number of bridges in poor condition, or in fair condition at risk of falling into poor condition. For Bridge Projects under 23 U.S.C. 124, the USDOT FHWA is statutorily required to evaluate specific benefits including whether the benefits of a project outweigh the total project costs [2]. There is a statutory requirement under 23 U.S.C. 124 that the USDOT FHWA evaluate whether a Large Bridge project is cost effective. [3] The USDOT FHWA is also required under 23 U.S.C. 124(f)(1)(B) to develop a template for applicants to use to summarize these project needs and benefits and to enable BIP Bridge grant applicants to use data from the National Bridge Inventory under 23 U.S.C. 114(b) to populate the template.

This Bridge Investment Program Benefit-Cost Analysis Tool (BIP BCA Tool) will allow applicants for either BIP Bridge or Large Bridge grants to summarize project costs and benefits, and obtain data from the NBI in preparation of the economic analysis required for both Bridge and Large Bridge applications.

User Manual Contents

This user manual is intended to provide clarification on the proper setup and application of the tool. It assumes familiarity with BCA, the USDOT BCA guidance [4], and the challenges of applying a BCA to bridge

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[1] https://uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title23-section124&num=0&edition=prelim
[2] The USDOT FHWA must evaluate whether the extent to which the benefits, including those described in 23 U.S.C. 124(f)(3)(B)(i), are more likely than not to outweigh the total project costs (23 U.S.C. 124(f)(3)(B)(ii)).
[3] The USDOT FHWA must evaluate whether a Large Bridge project is cost effective based on an analysis of whether the benefits and avoided costs, described in 23 U.S.C. 124(g)(B), are expected to outweigh the project costs (23 U.S.C. 124(g)(4)(C)).
[4] USDOT OST. January 2023. "Benefit-Cost Analysis Guidance for Discretionary Grant Programs." Accessed from: https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance/

investments. In addition, the user manual assumes knowledge of Microsoft® Excel®.

The User Manual is divided into the following sections:

- Getting Started
  - Provides an overview of the BIP BCA Tool, describes the process for downloading and initiating an analysis, provides a basic description of the tool navigation, and discusses the default National Bridge Inventory (NBI) data provided within the tool.
- Benefit-Cost Analysis
  - Describes the benefit and cost sections of the tool with detailed explanations of the information the user will need to provide to calculate benefits and costs for each bridge in the project.
- Appendix A: Frequently Asked Questions
  - Provides a quick guide for addressing common questions about the tool and the required data inputs and outputs.
- Appendix B: Data Sources
  - Describes the main data sources used in the BIP BCA Tool and the data processing used to generate and format the data.
- Appendix C: BCA Tool Benefit and Cost Calculation Methodology
  - Describes the calculations and methodologies in the tool.

Unless otherwise noted, "table" refers to the table in the BIP BCA Tool. Tables from other worksheets will begin with the worksheet name, then the table number; for example, Table 3 on the Results spreadsheet is called "Results Table 3."

Key Benefit Cost Analysis Concepts

BIP BCA Tool users should first familiarize themselves with the USDOT BCA guidance. [5] The tool calculations follow the guidance with options for user inputs.

Key Concepts from the USDOT BCA guidance include:

- **Build Scenario**: This represents what would happen in the world <u>with</u> the proposed project.
- **No-build Scenario**: Also referred to as the "baseline," this represents what would happen in the world <u>without</u> the proposed project.
- **Analysis Period**: This is the years of analysis in the BCA. It includes both the years for initial planning and construction, as well as the period of benefits that is being used for BCA analysis.
- **Benefits Period**: This is the subset within the overall period of analysis that is specifically for operations bounded by the project opening and the end of the period of analysis. Projects aimed primarily at capacity expansion or to address other operating deficiencies should use a service life of 20 years. Projects involving the initial construction or full reconstruction of highways or similar facilities should use an expected service life of 30 years.
- **Expected Service Life**: This is the expected life of the asset which reflects the number of years until the same type of action would need to be taken (e.g., a bridge service life may be 75 years at which point the bridge would need to be replaced).
- **Residual Value**: This is the value of the asset at the end of the period of benefits if the project's useful life would extend beyond the period of analysis.

Data Sources

The BIP BCA Tool uses several data sources.

- **USDOT BCA Guidance**: Monetary and key parameter values from the most recent USDOT BCA guidance are used where appropriate.
- **National Bridge Inventory (NBI)**: Bridge-specific information about the bridge including annual average daily traffic (AADT) and detour length.
- **National Bridge Investment Analysis System (NBIAS):** The NBIAS deterioration model was used to estimate the future year of condition rating for condition ratings 3 and 2. These estimates are used to forecast year of closure and load posting. See the Bridge Conditions and Closures section below for more information about how to use these estimates.
- **Motor Vehicle Emission Simulator (MOVES):** The U.S. Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) was used to estimate emission rates per mile for passenger vehicles and trucks based on functional class and speed.

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[5] USDOT OST. January 2023. "Benefit-Cost Analysis Guidance for Discretionary Grant Programs." Accessed from: https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance/

For more detail on how these data sources were processed and included in the tool, see Appendix B: Data Sources.

Getting Started

This section provides information about how to get started using the BIP BCA Tool, including describing what it is, how to download and use it, and basic controls.

Before You Start: Downloading and Opening the Tool

The tool is distributed as a Microsoft® Office Excel® Macro-Enabled workbook (file extension ".xlsb"). The file name indicates the version number, which is also displayed in the first tab of the worksheet within the tool itself. Users should download the tool from the BIP website and save it to their computer's hard drive. Users should rename the file in accordance with their file keeping structure; renaming the file will not impact the tool's functionality.

Macros must be enabled to use the tool. Excel® will typically have a banner to alert that the tool is macro-enabled and will provide a link to turn on macros. Otherwise, users can enable macros under Options -> Trust Center -> Trust Center Settings in the Excel® file menu.

Navigate the Tool

The tool can be navigated by selecting the desired tab within the workbook. Shortcut navigation is provided at the bottom of each tab.

The tool begins by requesting basic data on the bridge, its use, detours, and bridge AADT followed by sections for capital and operating and maintenance (O&M) costs. The remaining portion of the tool provides sections for each of the benefit categories.

- Construction Disbenefits
- Bridge Condition and Closures (which includes the NBIAS closure forecast)
- Resilience to Weather, Seismic, or other Extreme Events
- Safety Baseline, Detour Safety Benefits, and Safety Countermeasures
- Travel Time and Mobility-Related Benefits
- Mobility-Related Emissions and Other Environmental Benefits
- Other Quantitative Benefits Not Captured Elsewhere
- Manual Entry for AADT by Mode and Year

Each of these benefit category sections begins with a **YES** – **NO** drop-down menu that the user will select to activate the corresponding tables. When the user selects **YES** in the benefit section the tool will also turn-on the appropriate column in

Bridge Tab Table 57a: BCA Annual Calculations. If the user keeps the default value, **NO**, the user can select the hyperlink under the table "If NO, please skip down to next section" or simply scroll down to the next section.

The tool automatically computes the AADT by Mode and Year (Bridge Tab Table 54: Calculated AADT) based on the user's inputs in Bridge Tab Table 3: Annual Average Daily Traffic (AADT) or Bridge Tab Table 53: Manual Entry of AADT, depending on how the user chose to input AADT into the tool. Then the model uses the AADT to compute the Detour Emissions Dollar per Mile (Bridge Tab Table 55: Calculated Emissions Inputs and Bridge Tab Table 56: Calculated Emissions Outputs) using defaults generated in MOVES.

The final table on a bridge spreadsheet is the BCA Annual Calculations (Bridge Tab Table 57). This table computes the discounted benefits and costs and links those values to the Results spreadsheet.

WARNING: Users should NOT cut and paste the bridge spreadsheet into another workbook. Each bridge spreadsheet is linked to workbook data in the Defaults and NBI Data spreadsheets.

Initial Tabs

The tool tabs include:

- **Overview**: This tab provides a brief overview of the tool and navigation.
  - This tab also provides additional formatting to aid in understanding which cells require user input and which cells do not. The color-coding is as follows:
    - Green, bold, and underlined cells represent mandatory user input cells. These cells require numeric input and cannot be left blank, or have "-" or "N/A." The most important cells have 'Required' in the input field for user awareness.
    - Blue, italic, and underlined cells represent optional user input cells.
    - Gray cells and plain text cells represent a cell that does not require user input and should not be edited.
- **Select State NBI Data**: This tab allows the user to select NBI data for the State(s) used in the analysis. As the NBI data set is large, this selection is required to reduce the workbook file size. The remaining tabs will only be visible once the user has selected the relevant State(s) and has run the macro. [6]
- **Example Bridge**: This tab is an example bridge analysis that can be used for reference to understand the bridge tab functionality and explore how the tool works overall. This tab is the basic format for how all bridge tabs work. New bridge tabs can be generated by clicking the "Add New Bridge Tab" button or by entering Ctrl + Shift + I on the keyboard (see the following section for more about adding and deleting bridge tabs). Users should not delete this tab.

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[6] This step is provided to address the file size issue of the NBI data. Users who are not able to download and open the Excel® workbook should contact BridgeInvestmentProgram@dot.gov and someone will prepare a version of the tool with the requested NBI data.

- **Results**: This tab presents the summary results of the analysis using a dynamic table that adds and removes columns for each new bridge tab added or deleted. Users can also describe any unquantified benefits of the project on this tab.
- **Defaults**: This tab contains default values from the USDOT BCA guidance. The tab is viewable for reference but is locked for editing.
- **NBI Data**: This tab contains the 2023 NBI data. The tab is viewable for reference but is locked for editing. The data in this tab is filtered to States that are selected in the "Select the State NBI Data" workbook.

Selecting State NBI Data

Open the "Select State NBI Data" tab and select up to three States using the table shown below (Select State NBI Data Tab Table 1).

Select State NBI Data Tab Table 1: State NBI Data Selection

State Number	State	NBI State ID
State 1	mystate	0
State 2	-	0
State 3	-	0

Then click the "Select State NBI Data" button at the top of the State NBI Selection sheet or press Ctrl + Shift + I on your keyboard (Figure 1).

Figure 1: "Select State NBI Data" Button

WARNING: The selection processing may take up to 5 minutes.

Adding and Deleting Bridge Tabs

To add additional bridge tabs, click the "Add New Bridge" button at the top of the Example Bridge tab (or any bridge tab) or press Ctrl + Shift + B on your keyboard (Figure 2). The tool will prompt the user to name the new bridge spreadsheet and will create a new bridge tab with the user-supplied bridge name. On the Results tab the BCA Results table (table 1) will add a column for the new bridge.

Figure 2: "Add New Bridge" button

To delete a bridge tab, use either the "Delete Bridge" button at the top of the bridge tab or press Ctrl + Shift + D on your keyboard (note: this button is not on the Example Bridge Tab) (Figure 3). The tool will confirm deletion with a "Yes/No" dialog box. If yes, the current bridge tab will be deleted and its entry on the Results tab BCA Results table will also be deleted. Sensitivity analysis tabs can be deleted this way as well.

Figure 3: "Delete this Bridge" button

To change the name of a bridge tab, use either the "Change Bridge Name" button at the top of the bridge tab or press Ctrl + Shift + D on your keyboard (note: this button is not on the Example Bridge Tab) (Figure 4).

Figure 4: "Change Bridge Name" button

If the application includes multiple bridges, be careful not to double-count benefits on different bridge tabs. [7] Each bridge tab can only represent the benefits for a single bridge. For example, capital costs from a bridge tab are summed in the Summary Results table on the Results tab, so the capital costs on each bridge tab should reflect only those capital costs for that bridge.

WARNING: Adding or Deleting a bridge must use the buttons described above. Do not attempt to add a bridge by using Excel's® function to copy a worksheet. Do not attempt to delete a bridge by using the Excel® function to delete the worksheet. Do not change a spreadsheet name by using the Excel® function for renaming a spreadsheet.

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[7] The BIP BCA Tool cannot be used if the construction costs for a bundle of bridges cannot be separated.

Benefit-Cost Analysis Tool

This section provides directions on how to use the tool to compute a BCA for a single bridge as well as a description of the methodology and calculations used. Each benefit and cost category presented in the tool is separated into the sections as ordered in the bridge tab. This section also covers other items related to the analysis process, including how to analyze multiple bridges, how to interpret the results, and sensitivity testing.

Analysis for an Individual Bridge

This section describes the process for analyzing a single bridge. The information is organized vertically so that users do not need to scroll left and right to find information or provide input.

Gather Data Before Starting the BCA

To complete a BCA for a single bridge using the tool the following information will be required:

- Bridge information, including State, County, and Structure Number.
- Detailed project description for build and no-build scenarios including:
    - Project construction costs
    - O&M costs in the build and no build scenarios
    - Construction time-period
    - AADT for passenger vehicles, trucks, buses, and, if available, pedestrian and cyclists.
    - Information specific to the benefits being claimed, such as annual average crashes or the annual probability of weather/seismic events.
- Alternatives to the NBI values for each bridge (such as AADT, detour length), if the user does not want to use the NBI default data.
- Information specific to the benefits being claimed; some benefits may need information like annual average crashes, the annual probability of weather/seismic events, or pedestrian and cyclists AADT.

Example Bridge

The Example Bridge tab (also referred to as the Bridge Tab) is used to demonstrate the functionality of the tool using an example project. Each of the tables in this tab contain the inputs and values that are used in the tool. The walkthrough provides additional description of the example project where necessary in the following sections.

The example project is the reconstruction of a bridge to avoid future load posting and closure and to improve safety by adding a crossing turn lane on an approach to the bridge, improve travel time by adding a shoulder, improve pedestrian and cycling facilities on the roadway, improve rainwater runoff,

and protect the bridge from damage from seismic events. Construction will take place from 2024 to 2027 and require closing one half of the bridge for 150 days annually resulting in delays for vehicle users. As the project is a reconstruction, the benefits period is 30 years, from 2028 to 2057. Without the project, the bridge would be load posted in 2035 for 50 percent of all trucks and buses, load posted in 2042 for all trucks and buses, and finally closed to all traffic in 2050.

Enter Bridge Information

The Bridge and Project Overview section provides identifying information about the bridge using the State, County, and Structure Number dropdowns to pull forward NBI data for the particular bridge (Bridge Tab Table 1). The first dropdown identifies the State, the second identifies the county, and the third uniquely identifies the bridge with the structure number. The user can use these dropdowns to find the appropriate structure number. The State and structure number are required to uniquely identify the bridge, while the county dropdown is used to filter down to a smaller list of bridges within the State. After selecting the State, County, and Structure Number, the gray cells of Bridge Tab Table 1 will show the NBI data.

Bridge Tab Table 1: Bridge Variable

Bridge Variables	Bridge Values
State	**mystate**
County	**mycounty**
Structure Number	**001**
Inventory Route	00000
Feature Intersected	Example Roadway'
Facility Carried	Example Route'
Latitude	00° 00' 00.00"
Longitude	-00° 00' 00.0"
Bridge Length (mi)	0.16
Bypass, Detour Length (mi)	2.50
Owner	mystate
Functional Class, Rural/Urban	11
Bridge Road Type	Urban - Principal Arterial - Interstate
Year Built	1970
Year Reconstructed	1985
Lanes on the Structure	2

The Project Timeline table (Bridge Tab Table 2) has required inputs for the current year, the first year in which future construction costs occur, the last year in which construction costs occur, the first year in

which the project is open to the public, [8] and the years of benefits. The first and last year of analysis are computed by the tool, the discount year is set by the USDOT BCA guidance, and the base year of the NBI is set by the latest NBI year.

Bridge Tab Table 2: Project Timeline

Timeline Variables	Timeline Values
Current Year	**2023**
First Year of Construction Costs	**2024**
Last Year of Construction Costs	**2027**
Project Opens (Start of Benefits)	**2028**
Years of Benefits for Analysis	**30**
First Year of Period of Analysis	2028
Last Year of Period of Analysis	2057
Discount Year	2021
Base Year of NBI	2023

The AADT table (Bridge Tab Table 3) requires AADT for passenger vehicles, trucks, and buses for both the build and no-build scenarios. NBI values are provided for reference, including forecasts of AADT for the period of benefits based on the implied growth rate from NBI current year AADT and future AADT (Bridge Tab Table 5). [9]

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[8] At this time, the tool is unable to estimate partial year benefits, and accordingly the user should use the first full year when the project is open. For example, if construction ends in September 2027 and the project opens in October 2027, the user should enter 2028 as the first full year of project opening.

[9] See the Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridge for how it treats Average Daily Traffic (ADT), Item 29, which is the total AADT for the roadway, which includes trucks and may also include buses. Users will need to distinguish between bus and passenger AADT.
https://www.fhwa.dot.gov/bridge/mtguide.cfm

Bridge Tab Table 3: Annual Average Daily Traffic (AADT)

Scenario and Mode	NBI Year of AADT	NBI Year of Future AADT	Forecast using NBI Growth Rate	Forecast using NBI Growth Rate2	Project Opens	Last Year	Explanation and Source
Year	2019	2029	2028	2057	2028	2057	N/A
No Build - Passenger AADT	5400	7020	6838	14635	**6838**	**14245**	Use growth rate of comparing 2020 and 2010 decennial census growth rate
No Build - Truck AADT	600	780	760	1626	**760**	**1626**	-
No Build - Bus AADT	N/A	N/A	N/A	N/A	**300**	**390**	Transit service from MPO study (provided as BCA appendix)
Build Passenger AADT	5400	7020	6838	14635	**6838**	**14245**	Use growth rate of comparing 2020 and 2010 decennial census growth rate
Build - Truck AADT	600	780	760	1626	**760**	**1626**	-
Build - Bus AADT	N/A	N/A	N/A	N/A	**300**	**390**	Transit service from MPO study (provided as BCA appendix)

The NBI AADT implied growth rate on Bridge Tab Table 4 will not impact the user inputs AADT inputs in either Bridge Tab Table 54 or Bridge Tab Table 3. Users simply record their AADT estimates in Bridge Tab Table 3, along with the explanation and source, without entering a growth rate. As an alternative, use Bridge Tab Table 53 to manually enter AADT for each mode in the build and no build scenarios (described below).

Bridge Tab Table 4: NBI's Calculated Average Annual Daily Traffic (AADT) Growth Rate

The NBI Calculated Annual Growth Rate 2019-2029 (NBI)	2.66%

The Detour Road Type table (Bridge Tab Table 5) has a drop down to select the detour road type from the list of road types.

Bridge Tab Table 5: Detour Road Type

Detour Road Type	Rural - Principal Arterial - Interstate
Detour Road Type - Simple	Rural

The Detour and Bridge Information table (Bridge Tab Table 6) requires input on the detour route including the net length and average speed of the detour for vehicles and the net detour length for

pedestrians and cyclists, and it requires bridge length information. The detour average speed is a default value generated by the detour route road type based on FHWA vehicle hours traveled modeling. Bridge length in the NBI does not include the approach length so users should enter a value for bridge length that includes the approach length when appropriate. The bridge length is used to calculate noise, congestion, and emissions disbenefits for induced vehicle AADT, and the vehicle operating cost benefits for induced vehicle AADT. These are the external costs that drivers induced to use the bridge impose on others that are not internalized.

WARNING: Detour length should represent the net detour, which is detour length minus the original route length.

Bridge Tab Table 6: Detour and Bridge Length Information

Detour Details	Reference	User Value	Explanation and Source
Net Detour Length, For Vehicles (mi) (NBI)	2.5	**2.5**	-
Detour Average Speed, for Vehicles (mph) (FHWA VHT)	66.0	**60.0**	**Average speeds lower than FHWA proposed average for bridge road type.**
Net Detour Length, For Cycling/Pedestrian (mi) (NBI)	2.5	**0.5**	**Pedestrian and bicycle accessible crossing near bridge.**
Detour Average Travel Time (min)	2.3	2.5	N/A
Bridge Length (mi)	0.16	**0.16**	-

The Reference table (Bridge Tab Table 7) is included as a reference point for calculations throughout the workbook. It is visible to avoid accidental deletion.

Bridge Tab Table 7: Reference Table

Reference Cells	mystatemycounty	mystate001

WARNING: Do not delete or manually adjust the reference table.

The Travel Assumptions (Bridge Tab Table 8) table provides default values of speed (based on roadway classification), occupancy, shares of intercity commuting and business travel and value of time for roadway users. If using different values than the USDOT BCA guidance, please provide justification.

Bridge Tab Table 8: Travel Assumptions

Parameters	Reference	User Value	Explanation and Source
Bridge Average Speed (FHWA)	60	**60**	-
Average Car Occupancy	1.67	**1.67**	-
Share of Long-Distance Personal Travel	0.0%	**0%**	-
Value of Time - Long-Distance Personal Travel	$23.80	**$23.80**	-
Share of Business Travel	11.8%	**11.8%**	-
Value of Travel Time - Business	$31.90	**$31.90**	-
Value of Travel Time - Personal	$17.00	**$17.00**	-
Value of Travel Time - All Purposes	$18.80	$18.80	-
Walking, Cycling, Waiting, Standing, and Transfer Time	$34.00	**$34.00**	-
Truck Driver	$32.40	**$32.40**	-
Bus Driver	$35.00	**$35.00**	-
Average Bus Occupancy	0	**10**	**Data from MyCounty Transportation Authority**

Capital Costs and Residual Values

The capital cost and residual values section has four tables that require user input.

The Expenditure Dollars Option table (Bridge Tab Table 9) provides a drop-down button to select whether the costs entered are in nominal (*year of expenditure)* or in constant dollars (inflation adjusted), and a place to enter the future inflation rate if one applies. If the user selects nominal dollars, the tool will automatically convert nominal costs into constant dollars using the inflation rate for capital costs entered into this table. [10]

Bridge Tab Table 9: Expenditure Dollars Option

Are costs entered in year of expenditure dollars (not adjusted for inflation)?	**NO**
Enter future inflation rate for capital costs.	**0%**

[10] See USDOT BCA guidance sections 3.3 and 3.4 on inflation and discounting adjustments.
USDOT OST. January 2023. "Benefit-Cost Analysis Guidance for Discretionary Grant Programs." Accessed from:
https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance/

Enter the year of the costs and the nominal value of the costs in the Already Incurred Costs table (Bridge Tab Table 10). The tool will automatically apply the appropriate discounting.

Bridge Tab Table 10: Already Incurred Costs

Year	Costs	Real Costs	Discounted Costs
2022	*$100,000*	$100,000	$93,458
2023	*$100,000*	$100,000	$87,344
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

Enter the future capital costs in the correct year of dollar (as specified in Bridge Tab Table 9) in the Capital Costs table (Bridge Tab Table 11). Capital costs generally include the cost of land, labor, material and equipment rentals used in the project's construction. In addition to direct construction costs, capital costs may include costs for project planning and design, environmental reviews, land acquisition, utility relocation, or transaction costs for securing financing. The year of construction is automatically generated based on the project timeline information. The tool will compute the real discounted capital costs for each year, by applying the discount rate and the inflation factor. If the year is 2021, then no inflation adjustment is made. If the year is before 2021, then the inflation factor comes from the USDOT BCA guidance. If a user selects a future inflation factor (a value greater than 0) in Bridge Tab Table 9, the tool automatically applies it to capital costs for years after 2021.

Bridge Tab Table 11: Capital Costs

Year	Costs	Real Costs	Discounted Costs
2024	*$5,000,000*	$5,000,000	$4,081,489
2025	*$5,000,000*	$5,000,000	$3,814,476
2026	*$10,000,000*	$10,000,000	$7,129,862
2027	*$10,000,000*	$10,000,000	$6,663,422
N/A	-	-	-
N/A	-	-	-
N/A	-	-	-
N/A	-	-	-
N/A	-	-	-
N/A	-	-	-
N/A	-	-	-

The Capital Cost Summary table provides the total capital costs, the real capital costs, and the total discounted capital costs for the project based on input entered in Bridge Tab Table 10, Bridge Tab Table 11, and Bridge Tab Table 12.

Bridge Tab Table 12: Capital Cost Summary

Total Capital Costs:	$30,200,000
Total Real Capital Costs:	$30,200,000
Total Discounted Capital Costs:	$21,870,051

The Residual Value table requires input for calculating the residual value of the project components (Bridge Tab Table 13). Enter the share of the capital costs and the asset life for each separate component of the project where appropriate. The share of capital costs column should sum to 100 percent. The tool will automatically calculate the residual value at the end of the period of benefits using linear depreciation and applying discounting as required by the USDOT BCA guidance.

Bridge Tab Table 13: Residual Value

Share of Capital Costs	Asset Life (Years)	Explanation; including asset component
100%	40	*The improvement has an expected life of 40 years at which point it would need to be redeployed, or a new bridge constructed*
0%	0	-
0%	0	-
0%	0	-
100%	Summation	N/A

Operating and Maintenance (O&M) Costs

In the "Operating and Maintenance Costs" table (Bridge Tab Table 14) all O&M costs should be entered in *real* terms, with the user noting the appropriate year of dollars. Select whether you will enter the O&M costs using the Manual Frequency Calculations (Bridge Tab Tables 16a-d) or using the manual entry (Bridge Tab Table 17). The frequency calculations can be used to define recurring O&M costs, while the manual entry allows the user to enter the costs for each calendar year.

Bridge Tab Table 14: O&M Cost Year

Which method would you like to use to enter O&M costs?	Manual Entry
Year of O&M Cost Dollars	2021

If you have annual O&M, enter the annual O&M cost information in the Annual Maintenance Calculation Input table by specifying the annual O&M costs in the no build and build scenarios, and the annual real growth rate of those costs with and without the project (Bridge Tab Table 15). The growth rate should

not include inflation, but solely reflect any increase in O&M costs in real terms.

Bridge Tab Table 15: Annual O&M Calculation Input

Category	Value
Annual O&M Costs in the No Build Scenario	*-*
Annual O&M Costs Real Growth Rate in the No Build Scenario	*0%*
Annual O&M Costs in the Build Scenario	*-*
Annual O&M Costs Real Growth Rate in the Build Scenario	*0%*

For recurring non-annual costs, Bridge Tab Tables 16a-d can be used to enter the initial year, the last year the cost occurs, the recurrence (set to 30 if the cost only occurs once), and the O&M cost in the build and no-build scenarios.

Bridge Tab Tables 16a-d: Intermittent O&M Calculation Input

Category	Value
Initial year	*-*
Last Year	*-*
Occurs every _____ Years; set to 30 if occurs only once	*1*
Annual O&M Costs in the No Build Scenario	*-*
Annual O&M Costs Real Growth Rate in the Build Scenario	*-*

Use the Manual Maintenance Cost Entry table (Bridge Tab Table 17) to enter the annual costs for each calendar year of the project for the no-build and build scenarios. These costs should be entered as the year of dollar entered in Bridge Tab Table 14. The tool will automatically adjust these values to the appropriate year of dollar and apply discounting. O&M costs between current year and end of construction year can be entered as well.

In the example, the project is expected to be closed in the no build scenario in 2050 and will not require additional O&M thereafter, and additionally the no build scenario will see O&M costs in the no build scenario. However, in the build scenario the project will require additional O&M costs through 2057.

Bridge Tab Table 17: Manual O&M Cost Entry

Calendar Year	Analysis Year	No Build Annual Cost	Build Annual Cost	Discounted O&M Costs
2023	-4	$10,000.00	$1,000.00	$7,860.95
2024	-3	$-	$-	$-
2025	-2	$-	$-	$-
2026	-1	$-	$-	$-
2027	0	$10,000.00	$1,000.00	$5,997.08
2028	1	$-	$-	$-
2029	2	$-	$-	$-
2030	3	$-	$-	$-
2031	4	$10,000.00	$1,000.00	$4,575.14
2032	5	$-	$-	$-
2033	6	$-	$-	$-
2034	7	$-	$-	$-
2035	8	$10,000.00	$1,000.00	$3,490.36
2036	9	$-	$-	$-
2037	10	$-	$-	$-
2038	11	$-	$-	$-
2039	12	$10,000.00	$1,000.00	$2,662.78
2040	13	$-	$-	$-
2041	14	$-	$-	$-
2042	15	$-	$-	$-
2043	16	$10,000.00	$1,000.00	$2,031.42
2044	17	$-	$-	$-
2045	18	$-	$-	$-
2046	19	$-	$-	$-
2047	20	$10,000.00	$1,000.00	$1,549.76
2048	21	$-	$-	$-
2049	22	$-	$-	$-
2050	23	$-	$-	$-
2051	24	$-	$1,000.00	$(131.37)
2052	25	$-	$-	$-
2053	26	$-	$-	$-
2054	27	$-	$-	$-
2055	28	$-	$1,000.00	$(100.22)
2056	29	$-	$-	$-
2057	30	$-	$-	$-
N/A	N/A	-	-	$-
N/A	N/A	-	-	$-
N/A	N/A	-	-	$-
N/A	N/A	-	-	$-
N/A	N/A	-	-	$-

WARNING: Users should be careful not to enter O&M costs beyond the life of the bridge if the no-build

scenario assumes bridge closure.

Construction Disbenefits

The "Construction Disbenefits" section is for the travel impacts during construction that include direct impacts to travelers on the bridge such as increased travel time and increased crash risk, as well as costs associated with circuitry due to delays or bridge closure.

In the Disbenefits Option table (Bridge Tab Table 18), select whether the project will have construction disbenefits, and provide an explanation and the methodology for disbenefits. If no construction disbenefits are calculated, explain why.

Bridge Tab Table 18: Disbenefits Option

Will project construction cause delays or increase crashes in the work zone, or cause other construction disbenefits?	**YES**
Explanation/Methodology for disbenefits. If no construction disbenefits are calculated, explain why.	**Construction will close one lane of traffic on the bridge alternating directions at 75 days. Pedestrians and cyclists will continue to be able to use the roadway during construction with no expected delay. Crash risk is expected to increase marginally given the construction zone.**

For travel time disbenefits, enter the AADT by mode, minutes of delay by mode, and days of impact annually by year to calculate the total discounted travel time costs (Bridge Tab Table 19). Enter the percent increase in crashes to calculate the total discounted crash costs (Bridge Tab Table 19). These crash costs are estimated as a percent increase in the baseline crashes for the roadway on the theory that work zones may increase the inherent crash risk on the roadway. If no crash increases are expected due to the construction enter "0" percent for each year. See the section "Safety Baseline, Detour Safety Benefits, and Safety Countermeasures" below for how to enter the baseline crash rate on the bridge.

Bridge Tab Table 19: Travel Time and Safety Construction Disbenefits

Year	Passenger AADT	Truck AADT	Bus AADT	Pedestrian AADT	Cyclist AADT	Vehicle Delay (minutes)	Pedestrian Delay (minutes)	Cyclist Delay (minutes)	Days of Impact Annually	Total Discounted Travel Time Disbenefits	Percent Increase in Crashes due to Work Zone	Total Discounted Safety Disbenefits
2024	6200	680	260	-	-	1	-	-	150	$(560,526)	5%	$(4,708)
2025	6400	700	270	-	-	1	-	-	150	$(541,321)	5%	$(4,400)
2026	6600	720	280	-	-	1	-	-	150	$(522,230)	5%	$(4,113)
2027	6800	740	290	-	-	1	-	-	150	$(503,320)	5%	$(3,843)
N/A	-	-	-	-	-	-	-	-	-	$-	-	$-
N/A	-	-	-	-	-	-	-	-	-	$-	-	$-
N/A	-	-	-	-	-	-	-	-	-	$-	-	$-
N/A	-	-	-	-	-	-	-	-	-	$-	-	$-
N/A	-	-	-	-	-	-	-	-	-	$-	-	$-
N/A	-	-	-	-	-	-	-	-	-	$-	-	$-
N/A	-	-	-	-	-	-	-	-	-	$-	-	$-
Total Discounted Disbenefits	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$(2,127,395)	N/A	$(17,065)

For other construction disbenefits besides travel time and safety, enter the total category, discounted disbenefits, and an explanation of the disbenefit in question (Bridge Tab Table 20). The tool will treat any entry as a negative value to represent that it is a cost.

Bridge Tab Table 20: Other Construction Disbenefits

Disbenefit Category	Total Discounted Disbenefits (-)	Explanation of Disbenefits
Police Detail	$(300,000)	**Additional Police detail required for construction period (one time cost)**
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-

Bridge Condition and Closures

The Bridge Condition and Closures section provides the posting and closure estimates from the NBIAS model with the ability for the user to provide alternative values with information supporting deviations from the NBIAS model closure estimate. This is distinct from bridge closures due to extreme events, which is the Resilience to Weather, Seismic, or other Extreme Events section. The tool automatically calculates the travel time, vehicle operating and safety benefits from avoided detouring.

Select YES if there will be bridge load posting or closure benefits in the Condition Impact Option table (Bridge Tab Table 21).

Bridge Tab Table 21: Condition Impact Option

Will the project improve or preserve the bridge's condition in a way that reduces the risk of closure and/or load posting?	YES

The Bridge Condition and Closures section will automatically populate with data from the NBI on the current bridge status. The tool provides the NBIAS deterioration model estimate of the year when the bridge is expected to have an overall condition rating of 3 and 2, the year estimated to reach superstructure condition rating 4 and 3, and the current superstructure condition rating and the current operating rating (Bridge Tab Table 22 and Bridge Tab Table 23). The tool calculates the expected year of load posting and closure based on these values (see Appendix B for more details on how those estimates are calculated).

Bridge Tab Table 22: Bridge Details

Variable	Value
Bridge Currently Closed or Load Posted? (NBI)	A
NBI Coding Translation	Open, no restriction
Current Superstructure Condition Rating	5
Current Operating Rating (metric tons)	40.0

Bridge Tab Table 23: Forecasted Condition Rating

Bridge Component and Rating	Condition Rating Reference Value	NBIAS Forecast Year
Overall Condition Rating 3	3	2038
Overall Condition Rating 2	2	2048
Superstructure Condition Rating 4	4	2038
Superstructure Condition Rating 3	3	2043

Enter load posting of up to three levels of expected future load posting in the Anticipated Load Postings table (Bridge Tab Table 24). If the bridge is currently load posted, enter the current year and load posting level for trucks and buses. After entering the estimated year of posting, the user should enter the expected percentage reduction in truck traffic and in bus traffic for the load postings.

Bridge Tab Table 24: Anticipated Load Postings

Load Posting Level	Forecast Year	Year	% Reduction in Truck Traffic	% Reduction in Bus Traffic	Explanation for year if not reference; for % reduction
Load Posted, level 1	2038; 50% for Truck and Bus	**2035**	**50%**	**50%**	**Bridge anticipated to be load posted for half of trucks and buses in 2035 ahead of NBIAS forecast based on engineering study.**
Load Posted, level 2	2043; 100% for Truck and Bus	**2042**	**100%**	**100%**	**Bridge anticipated to be closed to 100 percent of trucks and buses in 2042 ahead of NBIAS forecast based on engineering study.**
Load Posted, level 3	N/A	**2070**	**0%**	**0%**	-

For indefinite closures, enter the year the closure will begin and the percent reduction in all traffic (e.g., 100 percent in the case of full closure, or 25 percent closure in the case of one closed lane of a four-lane bridge) (Bridge Tab Table 25). The NBIAS estimated year of closure is presented for reference. Without supporting information from the applicant, FHWA assumes bridge closure will match the NBIAS bridge closure year.

Bridge Tab Table 25: Anticipated Closure

Closure Level	Forecast Year	Year	% Reduction in All Traffic	Explanation for year if not reference; for % reduction
Closure	2052; Based on when year Overall Condition Rating 2 is reached plus average time to closure of 3.68 years	**2050**	**100%**	**Bridge anticipated to be close ahead of NBIAS forecast based on engineering study.**

If the bridge closure will be partial in duration rather than indefinite, use the short-term closure fields to enter the initial year of closure, the last year of closure, the recurrence (enter 30 if it only occurs once), the number of days of closure, and the percent reduction in all traffic on the bridge due to the closure (Bridge Tab Table 26a-d).

Bridge Tab Table 26a-d: Short-term or Intermittent Closures

Category	Value
Initial Year	*-*
Last Year	*-*
Occurs every _____ Years; set to 30 if occurs only once	*1*
Days of closure	*0*
% Reduction in All Traffic	*0%*

Resilience to Weather, Seismic, or Other Extreme Events

The Resilience to Weather, Seismic, or other Extreme Event section covers two approaches to enter the benefits of resilience. The first uses a probability-consequence framework, which calculates the impact of the resilience investment using three different levels of weather, seismic, or other extreme events that are specified by the user while the second is a free-form alternative approach that allows the user to calculate benefits based on any other approach and provide an explanation of that approach.

Select **YES** in Bridge Tab Table 27 to activate the resilience benefit section of the spreadsheet.

Bridge Tab Table 27: Resiliency Option

Will the project improve the bridge's resiliency to weather, seismic, or other extreme events, reducing damage and/or closures, or other service interruptions?	**YES**

Select **YES** in Bridge Tab Table 28 to activate the probability-consequence approach.

Bridge Tab Table 28: Probability Resilience Option

Are you providing a probability-consequence analysis of the resilience impacts?	**YES**

Weather, seismic, or other extreme events can be entered in three consequence severity types:

- **Closure, Traffic Restriction, or Load Restriction Only**: This consequence level refers to closure of the asset reducing some amount of capacity for at least one day a year but will not cause any structural damage to the asset requiring repair. Traffic restriction may occur when a lane or speed reduction is imposed on the bridge or results from an onsite temporary detour. A load restriction will occur when a load posting is imposed (ex. no trucks allowed). An example event that could cause this consequence would be a recurring flooding event that overtops the bridge or inundates roadways on approach to the bridge.
- **Lesser Structural Damage (Level one)**: This consequence level can be any level of damage as long as it is correctly correlated with the event and its probability as supported in the

application narrative or BCA memo. The user inputs the days of closure, travel reduction, and repair costs for both the build and no-build scenarios.

- **Larger Structural Damage (Level two)**: This is a higher consequence level of damage to the bridge, which might cause fatalities or injuries on the structure itself. Alternatively, the number of fatalities or injuries could be left at zero to model a higher impact but less frequent event. Repair costs should restore the bridge to its condition and service life before the hazardous event. Per USDOT BCA guidance, the no build scenario cannot include rebuilding the bridge so any maintenance, repair, or operational costs under the larger structural damage consequence cannot amount to bridge reconstruction.

Note that the tool is hazard-agnostic; the calculations can handle any type of weather or seismic event. However, the user must provide supporting documentation in supplementary materials or BCA memo.

A user will enter the annual probability of the event occurring in the project opening year and the final year for any event type. While the impacting event probability is the same for the build and no-build scenarios, the event impacts will be different in the build and no-build scenarios. The tool allows users to assume the probability of the impacting event can change over time. If the user is assuming an increasing probability linked to climate change, then the user needs to define the exact climate change estimate being used in the BCA memo. The Annual Probability Calculator (Bridge Tab Table 29) calculates the growth rate over the benefit period using the compound annual growth rate function, and the growth rate is used to define the annual probability of event occurrence in the calculation of the benefits elsewhere in the tool. Recurring closures that occur more than once in a given year can be entered by entering an annual probability of event occurrence greater than 100 percent in Bridge Tab Table 29, e.g., enter 200 percent if the event is expected to occur twice a year.

In the example project, the hazard event levels have a probability of event occurrence of 1 percent, 0.1 percent, and 0.01 percent, which were determined by an engineering study. The engineering study also demonstrates how the bridge would be damaged with and without the project and the expected consequences of that damage in terms of the expected maintenance/repair/operating costs, the expected injuries and fatalities given an event, the repair duration and how much traffic will be detouring during repair.

Bridge Tab Table 29: Annual Probability of Event occurrence

Consequence Level	Project Open Year	Final Year	Growth Rate	Explanation and source
Volume Capacity Reduction Only	*1.00%*	*1.00%*	0.000%	**MyCounty seismic report – included with application**
Structural Damage	*0.10%*	*0.10%*	0.000%	**Same as above**
Failure	*0.01%*	*0.01%*	0.000%	**Same as above**

Next, the user can enter the requested variables for the relevant event types (Bridge Tab Table 30,

Bridge Tab Table 31, and Bridge Tab Table 32). Each of the events requires the user to provide the duration of the closure/service interruption, the capacity reduction for passenger vehicles, the capacity reduction for truck traffic, and the maintenance/repair/operations costs. The user can enter these estimates for both the no build and build scenarios. Note that the reduced traffic is using the detour route. Make sure that the days of closure or service interruption is apportioned to the frequency of the event rather than the total number of days a year, e.g., an event that is expected to occur twice annually with a duration of impact of five days in the no build and 2 days in the build scenario should be entered as 5 and 2 days respectively in the Days of Closure of Service Interruption row.

Bridge Tab Table 30: Volume Capacity Reduction Impacts

Impact	No Build	Build
Days of Closure or Service Interruption	2	1
Passenger Volume Capacity Reduction (%)	25%	25%
Truck Volume Capacity Reduction (%)	25%	25%
Bus Volume Capacity Reduction (%)	25%	25%
Bike/Ped Volume Capacity Reduction (%)	25%	25%
Maintenance/Repair/Operation Costs ($)	$20,000	$10,000

Bridge Tab Table 31: Lesser Structural Damage (Level one) Impacts

Impact	No Build	Build
Days of Closure or Service Interruption	10	5
Passenger Volume Capacity Reduction (%)	50%	50%
Truck Volume Capacity Reduction (%)	50%	50%
Bus Volume Capacity Reduction (%)	50%	50%
Bike/Ped Volume Capacity Reduction (%)	50%	50%
Maintenance/Repair/Operation Costs ($)	$200,000	$50,000

The Larger Structural Damage (Level two) category also asks for the expected number of fatalities and injuries (Bridge Tab Table 32). The user can enter these estimates for both the no build and build scenarios. Note again, that per USDOT BCA guidance, the no build scenario cannot include rebuilding the bridge so any maintenance, repair, or operational costs under the failure consequence cannot amount to bridge reconstruction.

Bridge Tab Table 32: Larger Structural Damage (Level two) Impacts

Impact	No Build	Build
Days of Closure or Service Interruption	_25_	_5_
Passenger Volume Capacity Reduction (%)	_100%_	_100%_
Truck Volume Capacity Reduction (%)	_100%_	_100%_
Bus Volume Capacity Reduction (%)	_100%_	_100%_
Bike/Ped Volume Capacity Reduction (%)	_100%_	_100%_
Maintenance/Repair/Operation Costs ($)	_$2,000,000_	_$100,000_
Number of Fatalities in Year 1	_1_	_0_
Number of Injuries in Year 1	_10_	_0_

The alternative weather, seismic, and extreme weather event benefits calculation approach is available if the user is using an alternative method for assessing the impact of the resilience project or for calculating the benefits. Other calculation methods may include calculations that yield a benefit value but do not precisely follow the tool's approach or could include an engineering evaluation that determines if the bridge design is sufficient to withstand a given level of extreme event. If a benefit value is calculated, it may be included in Bridge Tab Table 51: Additional Quantified Benefits. If a benefit value is not calculated the results of the calculation method or the results of a qualitative assessment may be explained in the Results sheet section designated for unquantified benefits.

If providing an explanation of the other calculation methods used select YES on Bridge Tab Table 33.

Bridge Tab Table 33: Other Resilience Method Option

Are you providing an explanation of the other calculation method used?	**NO**

Enter your explanation in Bridge Tab Table 34 for this method. A reference to the materials in your application that cover this information is acceptable. If your application materials include documentation of this alternative approach simply note which document(s) provides this information.

Bridge Tab Table 34: Other Resilience Method Explanation

Explanation	-

WARNING: In accordance with the USDOT BCA guidance, a user should not include replacing the structure in a no-build scenario. The applicant should assume that the facility/structure remains closed, and the tool will compute the detour costs.

Safety Baseline, Detour Safety Benefits, and Safety Countermeasures

The Safety Baseline, Detour Safety Benefits, and Safety Countermeasures section contains three subsections. The first subsection is for entering the historical crash rates. The second subsection is for entering the impact of safety countermeasures deployed on the bridge itself. The third subsection is for

entering safety benefits from avoided detouring – which occur due to avoiding increased crash risk on the detour route.

Select whether you will be using KABCO or General crash costs, per the USDOT BCA Guidance, in Bridge Tab Table 36.

Bridge Tab Table 35: Crash Cost Estimate Option

Are you using KABCO or General crash cost estimates?	KABCO

Bridge Tab Table 37 Historical Crash Data provides the data used for computing construction disbenefits, resilience mitigation and safety countermeasure benefits. Enter historical crash data for the bridge (including approach if appropriate given the safety countermeasure or construction zone) by entering the years of data that the crashes represent and the number of crashes for each crash type, and provide a source for the crash cost including the calendar years of the data in Bridge Tab Table 36. [11] Per USDOT BCA guidance, either KABCO [12] or general injury and fatality costs can be used, but not both. Please see USDOT BCA guidance "Valuing Injuries and Fatalities" section and Appendix A Table A-1 for more information on the difference between the KABCO scale and the injury and fatal crash cost approaches. The tool calculates the annual average crashes for the bridge.

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[11] The FHWA Fatality Analysis Reporting System (FARS) dataset may be a good resource for those agencies that do not have access to high-quality crash data for their area. Accessed from: https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars

[12] The KABCO scale follows: K = fatal injury; A = severe injury; B = other visible injury; C = possible injury; O = property damage only.

Bridge Tab Table 36: Historical Crash Data

Crash Type	Years of Data	Number of Crashes	Average Annual Crashes	Average Annual Crash Cost Historical	Source for Crash; Calendar Years of Data
Property Damage Only	_10_	_20_	2.00	$9,600	**Data are from 2013 to 2022; provided by MyCounty law enforcement; details in BCA narrative.**
No Injury	_10_	_5_	0.50	$2,000	**Same as above**
Possible Injury	_10_	_2_	0.20	$15,700	**Same as above**
Non-incapacitating	_10_	_1_	0.10	$15,370	**Same as above**
Incapacitating	_10_	_1_	0.10	$56,430	**Same as above**
Killed	_10_	_0_	-	$-	**Same as above**
Injured (severity unknown)	_10_	_1_	0.10	$16,260	**Same as above**
Injury	_-_	_-_	N/A	N/A	_-_
Fatal	_-_	_-_	N/A	N/A	_-_
Total Annual Crash Cost	N/A	N/A	N/A	$115,360	N/A

If the project will deploy a safety countermeasure on the bridge itself, select **YES** in Bridge Tab Table 37, enter the years of benefit in Bridge Tab Table 38, and enter the appropriate crash modification factor (CMF) for each crash type, the CMF number from the CMF Clearinghouse if used, and a source for the CMF in Bridge Tab Table 39. Be certain to use the CMF and not the crash reduction factor (CRF). Convert the CRF to a CMF by taking [1 – CRF]. Link to the specific CMF that applies on the FHWA's Crash Modification Clearing House website and specify the study and conditions for the CMF used. [13] See the USDOT BCA guidance for how to select appropriate CMFs and for how to compute the CMF when multiple safety countermeasures are being deployed. [14] Additional guidance for multiple CMFs can be found on FHWA's CMF Clearinghouse. [15] The tool will calculate the average annual crash cost reduction based on the historical crash rate and the CMF.

Bridge Tab Table 37: CMF Option

Does the project improve safety on the bridge via a Crash Modification Factor (CMF)?	**YES**

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[13] FHWA. CMF Clearinghouse." Accessed from: https://www.cmfclearinghouse.org/

[14] USDOT OST. January 2023. "Benefit-Cost Analysis Guidance for Discretionary Grant Programs". Accessed from: https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance/

[15] FHWA's CMF Clearinghouse has several resources available including instructional videos and pre-recorded webinars that provide information about when and how to calculate combined CMFs. FHWA. "Using CMFs." Accessed from: http://cmfclearinghouse.org/using_cmfs.cfm

Bridge Tab Table 38: CMF Time Frame

Category	Benefit Period	Year
Initial Year of CMF-related Safety Benefits	2028	**2028**
Last Year of CMF-related Safety Benefits	2057	**2057**

In the example project, the CMF is for a positive offset left-turn lane for one of the bridge approaches, and has the CMF ID of 276 in FHWA's CMF Clearinghouse.

Bridge Tab Table 39: Safety Countermeasures – Crash Costs Avoided

Crash Type	CMF	Average Annual Crashes Reduced	Average Annual Crash Costs Avoided	CMF Reference Number, if CMF Clearinghouse value is used (https://www.cmfclearinghouse.org/)	Explanation and Source for CMF
Property Damage Only	_0.74_	0.52	$2,496	**CMF ID: 276**	**Introducing a positive offset left-turn lane for the bridge approach. http://www.cmfclearinghouse.org/detail.cfm?facid=276**
No Injury	_0.74_	0.13	$520	**CMF ID: 276**	**Same as above**
Possible Injury	_0.74_	0.05	$4,082	**CMF ID: 276**	**Same as above**
Non-incapacitating	_0.74_	0.03	$3,996	**CMF ID: 276**	**Same as above**
Incapacitating	_0.74_	0.03	$14,672	**CMF ID: 276**	**Same as above**
Killed	_0.74_	0.00	$-	**CMF ID: 276**	**Same as above**
Injured (severity unknown)	_0.74_	0.03	$8,003	**CMF ID: 276**	**Same as above**
Injury	-	0.00	$-	-	-
Fatal	-	0.00	$-	-	-
Total Annual Crash Cost	N/A	N/A	$33,769	N/A	N/A

If closure or resilience mitigations, or safety countermeasures are selected, the Safety Benefits due to Avoided Detouring section will become active. These are increased safety risks to users who are detoured due to the fact that they drive additional miles. For safety crash risk on the detour route, enter the crash rate per million vehicle miles (MVMT) in Bridge Tab Table 41, and the tool will calculate the crash cost per mile automatically. As with the previous categories, the user should enter injury and fatal crashes either on the KABCO scale or as the general types, but not both.

In the example, the crash rate for the detour route was determined using crash data from law enforcement.

Bridge Tab Table 40: Safety Benefits Due to Avoided Detouring

Crash Type	Crash Rate per Million VMT on Detour	Crash Cost Per Mile	Explanation and Source
Property Damage Only	*20*	$0.0960	**Data are from 2013 to 2022; provided by MyCounty law enforcement; details in BCA narrative.**
No Injury	*4*	$0.0160	**Same as above**
Possible Injury	*2*	$0.1570	**Same as above**
Non-incapacitating	*1*	$0.1537	**Same as above**
Incapacitating	*0.01*	$0.0056	**Same as above**
Killed	*0.001*	$0.0118	**Same as above**
Injured (severity unknown)	*0.5*	$0.0813	**Same as above**
Injury	-	N/A	-
Fatal	-	N/A	-
Total	N/A	$0.52	N/A

Travel Time and Mobility-Related Improvements

The Travel Time and Mobility-Related Improvements section captures travel time related benefits due to investments made to improve mobility on the bridge itself. These are travel time savings *separate* from travel time savings from avoided detouring. For example, if the new bridge replaces an at-grade intersection with ramps.

Select **YES** on Bridge Tab Table 41 to select whether these benefits apply.

Bridge Tab Table 41: Travel Time Option

Does the project improve travel time/mobility, <u>separate from reducing bridge closures or load posting?</u>	**YES**

Enter the time saved *in minutes* per vehicle in the project opening year and the final year in Bridge Tab Table 42.

Bridge Tab Table 42: Travel Time Savings

Initial or Last Year	Benefits Period	Year	Minutes Saved Per Vehicle
Initial Year	2028	*2028*	*0.04*
Last Year	2057	*2057*	*0.04*

If you have not already calculated the minutes saved per vehicle, you can use the optional Bridge Tab Table 43 to calculate the minutes saved using distance of the bridge and the speed in the build and no-build scenario. Enter the speed with and without the project for both the project opening year and the final year, and then enter the distance traveled in miles. The tool calculates minutes saved which you can enter in Bridge Tab Table 42. Enter these calculated values (cells E472 and E473) into Bridge Tab Table 43 for Minutes Per Vehicle Saved (cells D466 and D467). Note: Bridge Tab Table 43 is not referenced in the benefits calculation formulas. To enter travel time savings, you much enter minutes saved values in Bridge Tab Table 42.

In the example, the travel time benefits for existing users are limited because the distance of the bridge and its approach as shown in Bridge Tab Table 43.

Bridge Tab Table 43: Optional Travel Time Savings Calculator

Year	Speed (mph) - No Build	Speed (mph) - Build	Distance Traveled (Miles)	Minutes Saved Per Vehicle
Initial Year	_60_	_70_	_0.25_	0.04
Final Year	_60_	_70_	_0.25_	0.04

Mobility-Related Emissions and Other Environmental Benefits

Select **YES** in Bridge Tab Table 44 if the project has wildlife connectivity, noise, and/or water runoff benefits.

Bridge Tab Table 44: Other Environmental Benefits Option

Does the project have benefits related to improved wildlife connectivity, reduced noise, or improved water runoff?	**YES**

Use Bridge Tab Table 45 to enter benefit values for wildlife connectivity, noise, and/or water runoff. Enter the annual benefit in dollars in the first year of project opening and the annual expected growth rate for the benefit value. Be sure to include the explanation of the benefit and a link to the source documentation of the benefit for the reviewers to verify.

Noise in this section is the noise benefit that accrues from noise countermeasures deployed on the bridge itself. The noise-related benefits from avoiding the detour, as specified in the USDOT BCA guidance Appendix Table A-14, are included in Bridge Tab Table 58 under Vehicle Operating Cost (VOC). [16]

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[16] Similarly, the congestion externality is included in the Vehicle Operating Cost (VOC) in Table 58.

Bridge Tab Table 45: Other Environmental Benefits

Environmental Benefit Category	Annual Benefit ($) in Initial Year	Annual Growth Rate (%)	Initial Year	Last Year	Explanation and Source
Wildlife Connectivity	*-*	*0%*	*-*	*-*	*-*
Noise	*-*	*0%*	*-*	*-*	*-*
Water Runoff	*$100,000.00*	*1%*	*2028*	*2057*	*Additional treatments on the bridge will allow water runoff to flow less disruptively; full description in BCA narrative*

Pedestrian and Bicyclist Benefits

Enter **YES** in Bridge Tab Table 47 if pedestrians or cyclists will be impacted by the project, including due to detouring or through pedestrian and cyclist facility improvements.

Bridge Tab Table 46: Improved Pedestrian/Bicycling Option

Does the project improve pedestrian/bicycling facilities or detour pedestrians or bicyclists?	**YES**

Enter the total volume of pedestrians and cyclists for the build and no build scenarios for the project opening year and the last year of the project for pedestrians and cyclists in the project opening year and the final year in Bridge Tab Table 47.

In the example project, the bridge currently has limited pedestrian and cyclist use, but is expected to see increases in use over the benefits period due to the improvements of adding 6 feet of pedestrian sidewalk and installing a marked crosswalk.

Bridge Tab Table 47: Pedestrian and Cyclist AADT

Scenario and Mode	First Year of Benefit Period	Last Year of Project Benefits	Explanation and Source
No Build - Pedestrian AADT	**10**	**10**	**Based on trip analysis described in BCA narrative.**
No Build -Cyclist AADT	**5**	**5**	**Same as above**
Build - Pedestrian AADT	**10**	**15**	**Same as above**
Build - Cyclist AADT	**5**	**10**	**Same as above**

Bridge Tab Table 48 has YES/NO dropdowns to select which pedestrian and cyclist improvements are

included in the project, and it has several input cells to select the specific degree of impact of that improvement, including sidewalk width, upslope, MPH reduced, vehicles reduced, and the average number of crossings.

Bridge Tab Table 48: Pedestrian and Cyclist Improvement Information

Improvement	Input
Extend Pedestrian Sidewalk Width?	*YES*
If the sidewalk is widened, by how many additional feet?	*6*
Reduce upslope by 1%?	*NO*
How many upslope percents reduced?	*-*
Reduces traffic speed by 1 mph (for speeds ≤45 mph)?	*NO*
How many mph reduced?	*-*
Reducing Traffic Volume by 1 Vehicle per Hour (for ADT ≤55,000)?	*NO*
How many vehicles reduced?	*-*
Install a Marked Crosswalk?	*YES*
Average number of crossings on new marked crosswalks per trip?	*0.5*
Install a Signal for a Pedestrian Crossing?	*NO*
Average number of crossings on new signaled crosswalks per trip?	*0*
Add a Cycling Path with At-Grade Crossings?	*NO*
Add a Cycling Path with no At-Grade Crossings?	*NO*
Add a Dedicated Cycling Lane?	*NO*
Create a Cycling Boulevard/"Sharrow"?	*NO*
Add a Separated Cycle Track?	*NO*

Use Bridge Tab Table 49 to enter the percent of trips induced from non-active modes, which are the share of new users of the pedestrian and cycling facility that are predicted to switch from non-active modes such as motor vehicles, as well as the length of the new or improved facility in miles. The USDOT BCA guidance notes that applicants should ensure the benefits of induced pedestrian and cycling trips are only applied to trips induced from non-active transportation modes within the relevant age ranges for each mode. Absent more localized data on the proportion of induced trips coming from non-active transportation modes, applicants may apply a general assumption of 89% of induced trips falling into that category, assuming a distribution matching the national average travel pattern.

Bridge Tab Table 49: Pedestrian and Cyclist Inputs

Parameter	Reference	User Value
Trips Induced from non-active modes (%)	89%	**89%**
Length of the new or improved pedestrian/cycling facility (mi)	N/A	*1*

Other Quantified Benefits Not Captured Elsewhere

Select **YES** in Bridge Tab Table 50 if there are any other quantified benefits not captured above.

Bridge Tab Table 50: Additional Quantified Benefits Option

Does the project have other quantified benefits not captured above?	YES

Use Bridge Tab Table 51 to specify additional benefits by providing the following:

- The name of the additional benefit category;
- The annual total benefit in the first year that the project is open;
- The annual growth rate; and
- A written explanation of how the user calculated the benefit.

Bridge Tab Table 51: Additional Quantified Benefits

Additional Benefit Category	Annual Benefit ($) in First Year	Annual Growth Rate (%)	First Year of Benefit	Last Year of Benefit	Explanation/ Methodology/ Source for Benefit Value
Reductions in temporary loss of emergency services	*$50,000*	*1%*	*2028*	*2057*	*Study included in application materials*
-	-	*0%*	-	-	-
-	-	*0%*	-	-	-
-	-	*0%*	-	-	-
-	-	*0%*	-	-	-
-	-	*0%*	-	-	-
-	-	*0%*	-	-	-
-	-	*0%*	-	-	-
-	-	*0%*	-	-	-

Manual Entry for AADT by Mode and Year

If you are entering AADT manually, select **YES** in Bridge Tab Table 52, and the tool will override any existing AADT entries from Bridge Tab Table 3: Annual Average Daily Traffic (AADT) and Bridge Tab Table 47: Pedestrian and Cyclist AADT.

In the project example, the AADT is entered using Bridge Tab Table 3: Annual Average Daily Traffic (AADT) and Bridge Tab Table 47 rather than being entered manually.

Bridge Tab Table 52: Manual Entry of AADT Option

Will you manually enter AADT data for this project?	**No**
Explain the source of the manually entered AADT data.	-

Enter AADT in Bridge Tab Table 53 for each mode and year for the build and no build scenarios. The table is shown as if YES had been selected in Bridge Tab Table 52 so that input cells are shown as required cells (green, bold, and underlined).

Bridge Tab Table 53: Manual Entry of AADT

Calendar Year	Analysis Year	Passenger - No Build	Trucks - No Build	Bus - No Build	Pedestrian - No Build	Cyclist - No Build	Passenger - Build	Trucks - Build	Bus - Build	Pedestrian - Build	Cyclist - Build
2028	1	-	-	-	-	-	-	-	-	-	-
2029	2	-	-	-	-	-	-	-	-	-	-
2030	3	-	-	-	-	-	-	-	-	-	-
2031	4	-	-	-	-	-	-	-	-	-	-

Reviewing Calculations

Summary calculation tables are provided on each Bridge Tab to allow review of the calculations and results. These include the AADT by Mode and Year (Bridge Tab Table 54), Detour Emissions Cost per Mile (Bridge Tab Table 55 and Bridge Tab Table 56), and BCA Annual Calculations (shown in two separate tables here because of the number of columns in Bridge Tab Table 57a: BCA Annual Calculations and Bridge Tab Table 57b (58): BCA Annual Calculations Cont.). These tables do not require any input from the user.

Bridge Tab Table 54: Calculated AADT

Calendar Year	Analysis Year	Passenger - No Build	Trucks - No Build	Bus - No Build	Pedestrian - No Build	Cyclist - No Build	Passenger - Build	Trucks - Build	Bus - Build	Pedestrian - Build	Cyclist - Build
2028	1	6838	760	300	10	5	6838	760	300	10	5
2029	2	7093	790	303	10	5	7093	790	303	10	5
2030	3	7349	820	306	10	5	7349	820	306	10	5
2031	4	7604	850	309	10	5	7604	850	309	11	6

Bridge Tab Table 55: Calculated Emissions Inputs

Variable	Value
Detour MOVES Functional Class	Rural Unrestricted
Detour Average Speed, Rounded	60

Bridge Tab Table 56: Calculated Emissions Outputs

Calendar Year	Analysis Year	NOX - Passenger	SOX - Passenger	PM2.5 - Passenger	CO2 - Passenger	NOX - Trucks	SOX - Trucks	PM2.5 - Trucks	CO2 - Trucks	Passenger - Non-CO2 Emissions Total	Trucks - Non-CO2 Emissions Total
2028	1	$0.0074	$0.0001	$0.0061	$0.0203	$0.0980	$0.0002	$0.1631	$0.0745	$0.01	$0.26
2029	2	$0.0075	$0.0001	$0.0062	$0.0207	$0.1001	$0.0002	$0.1657	$0.0757	$0.01	$0.27
2030	3	$0.0015	$0.0001	$0.0034	$0.0173	$0.0367	$0.0002	$0.0494	$0.0694	$0.01	$0.09
2031	4	$0.0015	$0.0001	$0.0034	$0.0176	$0.0367	$0.0002	$0.0494	$0.0705	$0.01	$0.09

Bridge Tab Table 57a: BCA Annual Calculations

Calendar Year	Analysis Year	Discounted Safety	Discounted Travel Time	Discounted VOC	Discounted Resilience	Discounted Health and Amenity	Discounted CO2 Emissions	Discounted Non-CO2 Emissions
Pre-Benefits Period	0	$(17,065)	$(2,127,395)	N/A	N/A	N/A	N/A	N/A
2028	1	$21,030	$46,402	$-	$1,267	$1,705	$-	$-
2029	2	$20,371	$44,737	$-	$1,218	$1,890	$-	$-
2030	3	$19,709	$43,091	$-	$1,167	$2,044	$-	$-

Bridge Tab Table 57b (58): BCA Annual Calculations Cont.

Discounted Other Environmental	Discounted Maintenance Cost Savings	Residual Value	Discounted Other Benefits	Total Discounted Benefits	Total Discounted Costs	Net Present Value	7 Percent Discount Rate	3 Percent Discount Rate
N/A	$13,858	N/A	$(300,000)	$(2,430,602)	$21,870,051	$(24,300,654)	#N/A	#N/A
$62,275	$-	$-	$31,137	$163,815	$-	$163,815	0.62	0.81
$58,783	$-	$-	$29,391	$156,390	$-	$156,390	0.58	0.79
$55,487	$-	$-	$27,743	$149,241	$-	$149,241	0.54	0.77

Multiple Bridges and Bundling

Some applications may include investments on multiple bridges. The BCA tool is designed to allow users to calculate benefits and costs for each bridge independently. Bridges can be added as described above in the "Adding and Deleting Bridge Tabs" section. The tool can accommodate up to 250 bridges in a single project file (the limitation is on the number of tabs that a workbook can generate).

The tool can be used to calculate BCAs on each bridge included in the project, and importantly will also calculate an overall BCA for the entire project by summing all benefits and costs across all of the bridges in the project.

In some cases, projects with multiple bridges may benefit from bundling where costs are reduced through pooling administrative and procurement costs across multiple bridge investments within a project. Those bundling savings are not properly part of the benefit cost analysis because they are already included in the build scenario. To account for bundling cost savings in the build scenario, ensure that the capital costs entered for each bridge reflects the capital costs inclusive of the bundling savings.

The BIP does require applicants to note where bundling has reduced the cost of the projects overall. To include these savings in the tool, describe the bundling savings in the text box on the results tab (see next section for more details on where to describe any bundling cost savings).

Results

The BCA summary information is available on the Results Tab Table 1. This table includes all bridges added to the workbook including any added using the New Bridges or Sensitivity Analyses buttons as discussed above. The "Include in Analysis?" row provides a dropdown to select whether to include the bridge in the total BCR and Net Present Value.

WARNING: Users must select "Not Include" in the drop-down menu for the Example Bridge, otherwise it will be included in the total BCR calculation.

Results Tab Table 1: BCA Results

Category	Example Bridge	Total	Percent of Total Benefits [17]
Include in Analysis?	**INCLUDE**	N/A	N/A
Safety	$8,763,420	$8,763,420	25%
Travel Time	$11,523,648	$11,523,648	33%
VOC	$10,296,803	$10,296,803	30%
Resilience	$21,456	$21,456	0%
Health and Amenity	$63,743	$63,743	0%
CO2 Emissions	$1,829,701	$1,829,701	5%
Non-CO2 Emissions	$255,475	$255,475	1%
Other Environmental	$933,937	$933,937	3%
Maintenance	$27,936	$27,936	0%
Residual Value	$660,893	$660,893	2%
Other Benefits	$156,965	$156,965	0%
Total	$34,533,976	$34,533,976	100%
Total Discounted Costs	$21,870,051	$21,870,051	N/A
BCR	1.58	1.58	N/A
Net Present Value (NPV)	$12,663,924	$12,663,924	N/A

Enter the qualitative benefits, including the bundling cost savings, alternative design cost savings, and any other unquantified benefits in Results Tab Table 2. The other unquantified benefits can include national or regional economic growth.

In the example, the overall BCR is 1.58 with benefits primarily coming from safety, travel time reducing detouring due to load posting and closure.

Results Tab Table 2: Unquantified Benefits

Unquantified Benefits	Qualitative Description of Benefits
Bundling Cost Savings	-
Alternative Design Cost Savings	-
Other Benefits	-

Use the dropdowns in Results Tab Table 3 to select whether to include benefit categories in the analysis. Note: This functionality is for BIP BCA reviewers.

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[17] Benefit categories may not sum 100 percent due to rounding.

Results Tab Table 3: Benefit Categories Option

Category	Include in Analysis?
Safety	INCLUDE
Travel Time	INCLUDE
VOC	INCLUDE
Resilience	INCLUDE
Health & Amenity	INCLUDE
CO2 Emissions	INCLUDE
Non-CO2 Emissions	INCLUDE
Other Environmental	INCLUDE
Maintenance	INCLUDE
Residual Value	INCLUDE
Other Benefits	INCLUDE
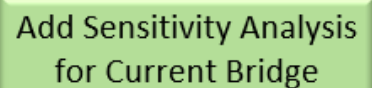
Sensitivity Testing

The tool provides a simple method for conducting sensitivity testing. Users can create a duplicate tab in the tool workbook using the "Add a Sensitivity Analysis for Current Bridge" button located at the top of each bridge tab that is created (not on the Example Bridge Tab) (Figure 5).

WARNING: Do not create a sensitivity analysis for a bridge by manually copying a bridge tab. The results table will not recognize bridge tabs created manually by the user.

When clicked, the tool makes a copy of the currently active bridge tab, copying all of the same user-supplied values, and names the tab "[current bridge name] + '_sns" and adds the sensitivity to Table 1 in the Results tab.

Add Sensitivity Analysis for Current Bridge (press Ctrl + Shift + S)

Figure 5: "Add Sensitivity Analysis for Current Bridge" button

Use the sensitivity tabs to test the impact of alternative inputs and assumptions. Review the impact of those adjustments side-by-side with the original analysis on the Summary Review table on the Results tab. Results Tab Table 1 (4) below shows the results table with an example of the sensitivity analysis as it contains a column for "New Bridge" and the sensitivity analysis of that bridge called "*New Bridge_sns*".

Results Tab Table 1 (4): BCA Results with Sensitivity Analysis

Category	Example Bridge	*New Bridge_sns*	New Bridge	Total	Percent of Total Benefits [18]
Include in Analysis?	**INCLUDE**	*INCLUDE*	**INCLUDE**	N/A	N/A
Safety	$8,763,420	$-	$-	$8,763,420	25%
Travel Time	$11,523,648	$-	$-	$11,523,648	33%
VOC	$10,296,803	$-	$-	$10,296,803	30%
Resilience	$21,456	$-	$-	$21,456	0%
Health & Amenity	$63,743	$-	$-	$63,743	0%
CO2 Emissions	$1,829,701	$-	$-	$1,829,701	5%
Non-CO2 Emissions	$255,475	$-	$-	$255,475	1%
Other Environmental	$933,937	$-	$-	$933,937	3%
Maintenance	$27,936	$-	$-	$27,936	0%
Residual Value	$660,893	$-	$-	$660,893	2%
Other Benefits	$156,965	$-	$-	$156,965	0%
Total	$34,533,976	$-	$-	$34,533,976	100%
Total Discounted Costs	$21,870,051	$-	$-	$21,870,051	N/A
BCR	1.58	$-	$-	1.58	N/A
Net Present Value (NPV)	$12,663,924	$-	$-	$12,663,924	N/A

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[18] Benefit categories may not sum 100 percent due to rounding.

Appendix A: Frequently Asked Questions

The following questions represent frequently asked questions regarding the tool. This FAQ section is meant to provide a quick guide for users, however much of this information is also provided either earlier in the user guide or within the tool itself.

Question: How do I enter future AADT values in the baseline if the bridge is expected to close?

    Answer: Enter the expected future AADT assuming the bridge does not close. The closure costs are calculated under the Bridge Condition and Closure section, and those calculations are based on the expected level of travel absent the closure.

Question: The file is too large for me to use on my machine. How can I get a smaller version with just the state NBI data I need?

    Answer: Contact the FHWA support team (BridgeInvestmentProgram@dot.gov) with the State(s) for which you want data. A BIP BCA Tool with the specified State(s) records will be emailed to you.

Question: What's the difference between a CMF and a CRF?

    Answer: A CMF is a Crash Modification Factor whereas a CRF is a Crash Reduction Factor. A CMF describes the percent of crashes that remain after the treatment, whereas the CRF describes the percent of crashes that are reduced. If a treatment is anticipated to reduce crashes by 20%, the CMF is 80% and the CRF is 20%. The BIP BCA Tool uses the CMF.

Question: Why aren't vehicle operating costs included? How do I add fuel cost savings?

    Answer: Vehicle operating costs, including fuel savings, are calculated within the tool as benefits of avoided detours based on the USDOT BCA guidance monetary values for vehicle operating costs.

Question: How do I enter the hours of travel time for the detour route?

    Answer: The detour route travel time is calculated for each vehicle type (passenger, truck, bus, cyclist, and ped) based on the detour distance and average speed along the route. For cyclists and pedestrians, the USDOT BCA guidance provides values for average speed.

Question: Can I enter in partial years of construction and period of benefits?

    Answer: The tool doesn't allow for partial years of construction or benefits at the present time.

Question: How do I apply discounting?

    Answer: Discounting is automatically applied based on the USDOT BCA guidance.

Question: One or more of my benefit categories are not computing. How do I fix this?

    Answer: The tool requires numerical inputs for any green, bold, and underlined cells, and the most critical cells have the word "Required" to alert the user. Search CTRL+F for any instances of required and replace with an appropriate numerical value (may be "0"), and otherwise check each green, bold, and underlined cell.

Question: What do I do if I need to delete a bridge tab?

    Answer: The Example bridge tab should not be deleted. To delete any bridge tabs that the user has created, use the "Delete Bridge" at the top of each bridge sheet which will remove the tab and remove the bridge from the Results Tab Table 1.

Appendix B: Data Sources

USDOT BCA Guidance – BCA Default Values

USDOT BCA guidance tables of monetary values and key parameters, tables A-1 through A-13 are used as default values where appropriate. The default values can be found in the Defaults tab of the workbook and in the USDOT BCA guidance document online. [19] The workbook uses the January 2023 guidance. If the guidance is updated then FHWA will either issue a new BIP BCA Tool or provide directions to users on how to update the current model.

National Bridge Inventory (NBI) – Identifying Information and Bridge Defaults

The National Bridge Inventory (NBI) is a database of information on all bridges and culverts in the United States, which is compiled and managed by FHWA. Data are collected by the States and submitted to FHWA annually. The BCA Tool and the NOFO tool are populated with NBI 2023 data and are not filtered or processed in any way. The NBI fields used include the following:

- STATE_CODE_001
- COUNTY_CODE_003
- RECORD_TYPE_005A
- ROUTE_NUMBER_005D
- FEATURES_DESC_006A
- FACILITY_CARRIED_007
- LOCATION_009
- LAT_016
- LONG_017
- DETOUR_KILOS_019
- MAINTENANCE_021
- OWNER_022
- FUNCTIONAL_CLASS_026

- YEAR_BUILT_027
- TRAFFIC_LANES_ON_028A
- ADT_029
- YEAR_ADT_030
- OPEN_CLOSED_POSTED_041
- SERVICE_ON_042A
- SUPERSTRUCTURE_COND_059
- OPR_RATING_METH_063
- OPERATING_RATING_064
- YEAR_RECONSTRUCTED_106
- PERCENT_ADT_TRUCK_109
- FUTURE_ADT_114
- YEAR_OF_FUTURE_ADT_115

For more information about the NBI please see https://www.fhwa.dot.gov/bridge/mtguide.cfm.

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[19] USDOT OST. January 2023. "Benefit-Cost Analysis Guidance for Discretionary Grant Programs". Accessed from: https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance/

National Bridge Investment Analysis System (NBIAS) Condition Rating Forecasts

The NBIAS deterioration model data used for the USDOT Conditions and Performance report (C&P) was used to forecast the year each bridge will reach condition ratings of 3 and 2 for the overall bridge condition rating (or for the culvert rating in the case of culverts), and to estimate the year each bridge will reach superstructure condition rating 4. These forecasts of condition ratings are the expected condition ratings for the bridge in the no-build scenario in which no capital investments are made to improve the bridge's condition, which is consistent with the USDOT guidance for how baseline scenarios are to be constructed: "Baselines should not assume that the same (or similar) proposed improvement will be implemented later." [20] The NBIAS model used the most recent configuration from the Conditions and Performance (C&P) report using 2023 NBI data. The NBIAS model assumed a capital investment budget of $0 and assumed no maintenance spending to simulate the effects of deterioration of the bridges absent investment (to reflect the no-build scenario). Bridges were filtered from the analysis using C&P screening rules and if they were not otherwise economical to maintain over the analysis period. See the C&P methodology section for more detail on the NBIAS model. [21]

The NBIAS deterioration model estimates expected year of condition rating using NBI variables and historical data on condition rating changes. The model uses 5-year increments, and the forecasts were made over 10 periods resulting in a 50-year forecast of the bridge condition ratings. Forecasts were made for each individual element condition rating (for deck, substructure, superstructure, and culvert in the case of culverts), which was then used to determine the overall condition rating using the minimum value among the three elements (or the culvert rating in the case of culverts).

Important modeling considerations to note:

- One deterioration model was specified for each of the nine climate zones, and the climate zone was specified by county.
- Bridges that were not economical to maintain were filtered out of the analysis.
- A number of bridges were filtered out of the model based on the C&P screening rules so not all bridges may be represented in the data set.
- The assumption of no maintenance may be overly pessimistic, particularly for decks.

Additional steps were required to estimate the year of closure and the year of load posting based on the expected year of condition ratings 3 and 2.

For closures, the average number of years bridges remain at condition rating 2 before changing directly

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[20] See section 3.2 Baselines and Alternatives. USDOT OST. January 2023. "Benefit-Cost Analysis Guidance for Discretionary Grant Programs". Accessed from: https://www.transportation.gov/mission/office-secretary/office-policy/transportation-policy/benefit-cost-analysis-guidance/

[21] USDOT. November 22, 2019. "Appendix B: Bridge Investment Analysis Methodology." Accessed from: https://www.fhwa.dot.gov/policy/23cpr/appendixb.cfm

to a 1 or 0 was estimated using NBI data from 1992 to 2023 (Figure 6). This estimate is meant to represent the rate of natural deterioration of bridges at condition rating 2, but because the maintenance spending cannot be observed it may not be an unbiased reflection of deterioration. Bridges that moved from condition rating 2 to a higher condition rating, reflecting a capital investment of some kind, were excluded. The mean time to 1 or 0 from condition rating of 2 is 3.68 years using a little more than 7,000 observations of bridges from 1992 through 2023. [22]
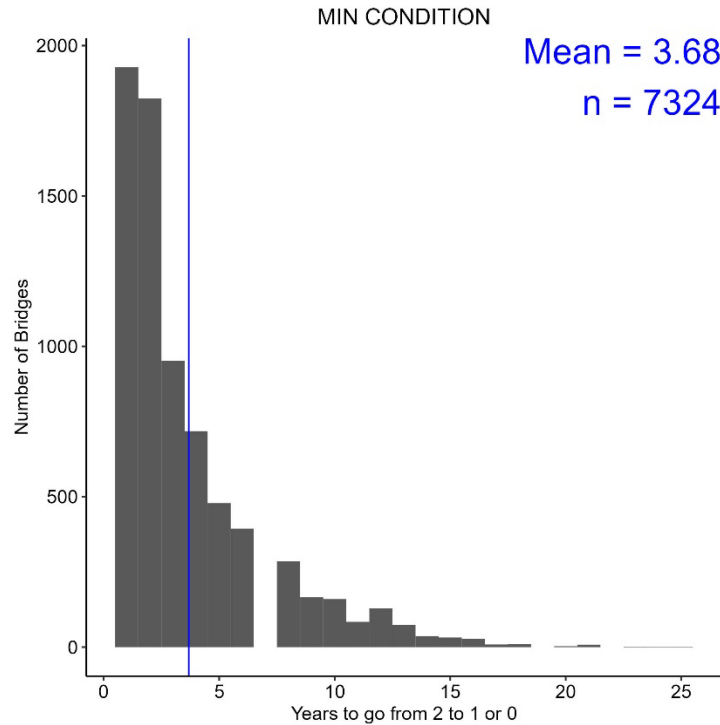
Figure 6: Histogram of Years Bridges Remain at Condition Rating 2 Before Condition Rating 1 or 0

To estimate the year of load posting, the following rules were applied based on the 2023 NBI data elements OPEN_CLOSED_POSTED_041, SUPERSTRUCTURE_COND_059, OPERATING_RATING_064, and the NBIAS forecast of superstructure condition: [23]

- If SUPERSTRUCTURE_COND_059 > 4, OPERATING_RATING_064 > 40.0, and OPEN_CLOSED_POSTED_041 = A or G, then "No Load Posting Forecasted".
- If SUPERSTRUCTURE_COND_059 > 4, OPERATING_RATING_064 <= 40.0, and OPEN_CLOSED_POSTED_041 = A or G, and NBIAS forecast of superstructure condition is 4 in a given year, then bridge is posted with 50% reduction in capacity for trucks and buses starting in that year.

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[22] Note these results were not clustered by the 9 zones as with the NBIAS model.
[23] The Operating Rating Item 64 in the NBI dataset is coded as operating rating as a 3-digit number to represent the total mass in metric tons of the entire vehicle measured to the nearest tenth of a metric ton (with an assumed decimal point). It is represented as a 2-digit number with a decimal in the tool, e.g., for example a "400" value is "40.0" in the tool.

- If SUPERSTRUCTURE_COND_059 > 4, OPERATING_RATING_064 <= 40.0, and OPEN_CLOSED_POSTED_041 = A or G, and NBIAS forecast of superstructure condition is 3 in a given year, then bridge is posted with 100% reduction in capacity for trucks and buses starting in that year.
- If SUPERSTRUCTURE_COND_059 = 4, OPERATING_RATING_064 <= 40.0, and OPEN_CLOSED_POSTED_041 = A or G, and NBIAS forecast of superstructure condition is 3 in a given year, then bridge is posted with 50% reduction in capacity for trucks and buses starting in that year.
- If OPEN_CLOSED_POSTED_041 = B, P, or R, OPERATING_RATING_064 => 36.3, SUPERSTRUCTURE_COND_059 > 4 (then assume a present 0% reduction in capacity for trucks and buses) and NBIAS forecast of superstructure condition is 4 in a given year, then bridge is posted with 50% reduction in capacity for trucks and buses starting that year; 3 in a given year then bridge is posted with 100% reduction starting in that year.
- If OPEN_CLOSED_POSTED_041 = B, P, or R, OPERATING_RATING_064 => 36.3, SUPERSTRUCTURE_COND_059 = 4 (then assume a present 50% reduction in capacity for trucks and buses) and NBIAS forecast of superstructure condition is 3 in a given year, then bridge is posted with 100% reduction in capacity for trucks and buses starting in that year.
- If OPEN_CLOSED_POSTED_041 = B, P, or R, OPERATING_RATING_064 => 36.3, SUPERSTRUCTURE_COND_059 < 4 (then assume a present 100% reduction in capacity for trucks and buses)
- If OPEN_CLOSED_POSTED_041 = B, P, or R, OPERATING_RATING_064 < 36.3, SUPERSTRUCTURE_COND_059 > 4 (then assume a present 50% reduction in capacity for trucks and buses) and NBIAS forecast of superstructure condition is 4 in a given year, then bridge is posted with 100% reduction in capacity for trucks and buses starting that year.
- If OPEN_CLOSED_POSTED_041 = B, P, or R, OPERATING_RATING_064 < 36.3, SUPERSTRUCTURE_COND_059 <= 4 (then assume a present 100% reduction in capacity for trucks and buses)

Motor Vehicle Emission Simulator (MOVES) – Vehicle Emissions

- The U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator (MOVES) model was used to estimate per mile emissions rates (kg/mi) for NOx, SOX, CO_2, PM2.5 based on the following variables: [24]
    - Vehicle type: Passenger vehicles (light-duty vehicles), and trucks (including combination and single-unit trucks).
    - Year: Model runs include years 2020, 2030, 2040, and 2050.
    - Functional class: MOVES uses four functional class categories defined in the table below.
    - Speed: Emissions rates were calculated based on speeds at 10 mph increments from 10 mph to 70 mph.

---

[24] EPA. June 13, 2022. "MOVES and Other Mobile Source Emissions Models." Accessed from: https://www.epa.gov/moves

Table 1: FHWA to MOVES Functional Class Crosstab

NBI Code	Roadway Types	MOVES Roadway Type
01	Rural - Principal Arterial - Interstate	Rural Restricted
02	Rural - Principal Arterial - Other	Rural Restricted
06	Rural - Minor Arterial	Rural Unrestricted
07	Rural - Major Collector	Rural Unrestricted
08	Rural - Minor Collector	Rural Unrestricted
09	Rural - Local	Rural Unrestricted
11	Urban - Principal Arterial - Interstate	Urban Restricted
12	Urban - Principal Arterial - Other Freeways or Expressways	Urban Restricted
14	Urban - Other Principal Arterial	Urban Unrestricted
16	Urban - Minor Arterial	Urban Unrestricted
17	Urban - Collector	Urban Unrestricted
19	Urban - Local	Urban Unrestricted

Appendix C: BCA Tool Benefit and Cost Calculation Methodology

This appendix describes the benefit and cost calculation methodology used in the tool. The sections are organized by the order in which the benefits appear Bridge Tab Table 57a: BCA Annual Calculations, where these calculations take place with noted exceptions.

Safety Benefits

Safety benefits are calculated for two separate types of impact.

Avoided Crashes using a Crash Modification Factor accrue when a safety improvement on the bridge reduces crashes on the bridge for existing and induced vehicle AADT. The formulas for Avoided Crashes using the Crash Modification Factor are:

For each year and vehicle mode – passenger, truck, and bus:

$$= [(a + c + e + f)] * 7\ percent\ discount\ rate$$

Figure 7: Total Safety Benefits Formula

- Compute avoided crash costs for induced travel (AADT in the build scenario that is greater than that in the no build scenario for any given year) by taking the percent difference between AADT in the build and no build relative to the base period times 0.5, multiplied by the average annual crash costs.

$$a = \frac{\left(Build\ AADT_{by\ vehicle\ mode} - No\ Build\ AADT_{by\ vehicle\ mode}\right)}{\left(No\ Build\ AADT_{by\ vehicle\ mode}\right)} * 0.5 \\ * (Annual\ Crash\ Cost)$$

Figure 8: Avoided Crash Costs for Induced Travelers

The average crash cost by crash type comes from the USDOT BCA guidance and are calculated as follows (these are calculated in Bridge Tab Table 39).

$$b = \frac{Number\ of\ Crashes_{by\ vehicle\ mode}}{Years\ of\ Data_{by\ crash\ type}} * Average\ Crash\ Cost_{by\ crash\ type}$$

Figure 9: Average Crash Costs by Crash Type for Induced Travelers

- Compute avoided crash cost for existing travel by taking the percent difference between AADT in the build and no build relative to the base period multiplied by the average annual crash costs.

$$c = \left(\frac{(Build\ AADT_{by\ mode})}{(No\ Build\ AADT_{by\ mode})} - 1\right) * (Annual\ Crash\ Cost)$$

Figure 10: Avoided Crash Costs for Existing Travelers

The average crash cost by crash type comes from the USDOT BCA guidance and are

calculated as follows (these are calculated in Bridge Tab Table 39).

$$b = \frac{Number\ of\ Crashes_{by\ vehicle\ mode}}{Years\ of\ Data_{by\ crash\ type}} * Average\ Crash\ Cost_{by\ crash\ type}$$

Figure 11: Average Crash Costs for Existing Travelers

Avoided Detour Crash benefits accrue when the bridge is load posted or closed to vehicle traffic and vehicles take the detour route resulting in additional VMT and more crash risk exposure. For each vehicle mode – passenger, truck, and bus:

- Compute avoided crash cost for travel by taking the percent difference between AADT in the build and no build relative to the base period times 0.5, multiplied by the average annual crash costs.

$$e = (No\ Build\ AADT_{by\ vehicle\ mode}) * (Vehicle\ Detour\ Length)$$
$$* (Detour\ Route\ Crash\ Cost\ per\ Mile)$$

Figure 12: Avoided Detour Crash Costs

The average detour crash costs by crash type comes from the USDOT BCA guidance and are calculated as follows (these are calculated in Bridge Tab Table 40).

$$f = Number\ of\ Crashes\ per\ Million_{by\ vehicle\ mode}$$
$$* Average\ Crash\ Cost_{by\ crash\ type}$$

Figure 13: Average Crash Costs for Detour Crashes

Travel Time

As with safety benefits, the project can impact travel times by either improving the travel time on the bridge itself or by avoiding detours.

Improved Travel Time on Bridge benefits accrue when an improvement to the bridge or approach reduces travel time for existing and induced users of the roadway. The formulas are:

Improved travel time on bridge: For each year and mode – automobile, truck, and bus:

$$= [(a + b + c + d)] * 7\ percent\ discount\ rate$$

Figure 14: Travel Time Benefits

- Compute avoided delay for induced travel by multiplying the difference of build and no build AADT by 0.5, the vehicle occupancy by mode, the value of travel time by mode, the minutes of delay avoided, and the annualization factor (365).

$$a = (Build\ AADT_{by\ mode} - No\ Build\ AADT_{by\ mode}) * 0.5 * (Occupancy_{by\ mode})$$
$$* (Value\ of\ Time_{by\ mode}) * (Delay\ Minutes/60) * 365$$

Figure 15: Avoided Delay for Induced Travelers

- Compute avoided delay for existing travel by multiplying the no build AADT by the vehicle occupancy, the value of travel time, the minutes of delay avoided, and the annualization factor (365).

$$b = \left(No\ Build\ AADT_{by\ mode}\right) * \left(Occupancy_{by\ mode}\right) * \left(Value\ of\ Time_{by\ mode}\right) * \left(Delay\ Minutes/60\right) * 365$$

Figure 16: Avoided Delay for Existing Travelers

Avoided detour travel time benefits accrue when the project avoids load postings or closures to vehicle traffic. For each vehicle mode – passenger, truck, bus, pedestrian, and bicyclist:

- Compute avoided travel time by multiplying the no build AADT by the occupancy multiplied by the value of time by mode and the minutes of delay avoided plus the detour length times the congestion cost per mile, and multiplied by the 7 percent discount factor.

$$c = \left(No\ Build\ AADT_{by\ vehicle\ mode}\right) * \left(\frac{Detour\ Length}{Detour\ Average\ Speed}\right) * \left(\left(Occupancy_{by\ mode}\right) * \left(Value\ of\ Time_{by\ mode}\right) + \left(Detour\ Length * Congestion\ Cost\ per\ Mile\right)\right)$$

Figure 17: Avoided Detour Travel Time Costs

Congestion disbenefits accrue when additional vehicle AADT uses the bridge in the build scenario which produces additional congestion. For each vehicle mode – passenger, truck, and bus:

- Compute additional congestion disbenefits by subtracting the no build AADT from the build AADT and multiplying by bridge length and the congestion cost per mile by vehicle type and the bridge's road type, and the 7 percent discount factor.

$$d = \left(Build\ AADT_{by\ vehicle\ mode} - No\ Build\ AADT_{by\ vehicle\ mode}\right) * \left(Congestion\ Cost\ per\ Mile_{by\ vehicle\ mode,\ bridge\ road\ type}\right)$$

Figure 18: Avoided Congestion Disbenefits from Induced Travel

Note, here and elsewhere when travel time is calculated: for bus travel time, the occupancy and value of time for bus includes both the driver and the passengers, and occupancy for trucks, pedestrians, and bicyclists is equal to 1.

Vehicle Operating Costs (VOC)

Operating cost savings are the avoided congestion, noise, and vehicle operating costs that accrue from additional VMT due to load postings or closure.

The formula for Vehicle Operating Costs savings is:

$$= [(a + b)] * 7\ percent\ discount\ rate$$

Figure 19: Operating Cost Savings

For each year and vehicle mode – passenger, truck, and bus:

- Compute the operating costs by multiplying no build AADT by vehicle mode by detour length, operating costs per vehicle mode (USDOT BCA guidance values), and 7 percent discount rate.

$$a = \left(No\ Build\ AADT_{by\ vehicle\ mode}\right) * (Detour\ Length) \\ * \left(Operating\ Costs_{\ by\ vehicle\ mode}\right)$$

Figure 20: Operating Cost Savings for Existing Vehicles

- Compute the induced operating costs by subtracting the no build AADT from the build AADT and multiplying by detour length, 0.5, operating costs per vehicle mode (USDOT BCA guidance values), and 7 percent discount rate.

$$b = \left(Build\ AADT_{by\ vehicle\ mode} - No\ Build\ AADT_{by\ vehicle\ mode}\right) * 0.5 \\ * (Detour\ Length) * \left(Operating\ Costs_{\ by\ vehicle\ mode}\right)$$

Figure 21: Operating Cost Savings for Induced Vehicles

Resilience

Resilience benefits accrue from three benefit categories that all accrue from avoiding disruption and damage to the bridge through resilience and mitigation of weather, seismic, or other extreme events. These impacts include reduced or avoided infrastructure maintenance, repair, and operations cost savings due to avoided damage; avoided detouring including travel time, vehicle operating costs, emissions, and safety costs; and avoided injury and fatal costs in the event of bridge failure.

Resilience benefits are calculated based on reduction in capacity for each mode for avoided detour for safety, travel time, and operating cost savings multiplied by the annual probability of the hazard event:

For each year and category of hazard event:

$$= [(a + b + c)] * 7\ percent\ discount\ rate * Probability\ of\ Hazard\ Event$$

Figure 22: Resilience Benefits

- For each mode — passenger, truck, bus, pedestrian, and bicyclist — compute avoided *detour* costs for travel time, safety, operating costs, and emissions as demonstrated in each relevant section multiplied by the percent capacity reduced by mode and the build days of disruption minus the no build days of disruption. The resilience calculation is separate from the travel time, safety, operating costs, and emissions calculated in other sections:

$$a = \left(Avoided\ Detour\ Travel\ Time + Avoided\ Detour\ Safety + \\ Avoided\ Detour\ Operating\ Costs + Emissions\ Costs_{by\ mode}\right) * \\ \left(\%\ Capacity\ Reduced_{by\ mode}\right) * (No\ build\ days - Build\ days)$$

Figure 23: Avoided Resilience Detour Costs

- Compute maintenance or repair cost savings by subtracting the build maintenance and repair costs from the no build maintenance or reconstruction costs.

$$b = (No\ Build\ Maintenance\ or\ Repair\ Costs -$$
$$Build\ Maintenance\ or\ Repair\ Costs) \cdot$$

Figure 24: Avoided Resilience Maintenance Costs

- Compute avoided fatality or injury costs by taking the difference in injury and fatality cost in the build and no build scenario multiplied by the ratio of no build AADT in the current year over the first year (to reflect increased risk of injury due to increased traffic volume).

$$c = (((No\ Build\ Injuries - Build\ Injuries) * General\ Injury\ Cost) +$$
$$((No\ Build\ Fatalities - Build\ Fatalities) * General\ Fatality\ Cost))$$
$$* \frac{All\ Vehicle\ No\ Build\ AADT_{year\ of\ benefit}}{All\ Vehicle\ No\ Build\ AADT_{first\ year\ of\ benefits}}$$

Figure 25: Avoided Resilience Fatality and Injury Costs

Health and Amenity

Health and Amenity benefits accrue when the facilities for pedestrians and bicyclists are improved.

For each year and active mode – pedestrians and cyclists:

$$= [(a + b + c)] * 7\ percent\ discount\ rate$$

Figure 26: Health and Amenity Benefits

- Compute the health benefits for induced active trips by taking the difference between the build and no build AADT and multiplying by the percent of induced trips that are coming from non-active modes, the modal age adjustment (68 percent for pedestrians and 59 percent for cyclists), the monetized trip benefit value provided by the USDOT BCA guidance, and the annualization factor (365).

$$a = (Build\ AADT_{by\ mode} - No\ Build\ AADT_{by\ mode}) * (\%\ From\ Non - Active\ Modes)$$
$$* (Age\ Adjustment) * (Value\ of\ Trip_{by\ mode}) * 365$$

Figure 27: Health Benefits for Induced Users of Active Modes

- Compute the amenity benefits to existing users by multiplying the no build AADT, by the length of the improved facility (miles), the monetization factor for each facility improvement (per mile), and the annualization factor (365).

$$b = (No\ Build\ AADT_{by\ mode}) * (Length\ of\ Improved\ Facility)$$
$$* (Value\ of\ Facility\ Improvements_{by\ mode,\ improvement\ type})$$
$$* (Facility\ Improvement\ Factor_{by\ mode,\ improvement\ type}) * 365$$

Figure 28: Amenity Benefits for Existing Users of Active Modes

- Compute the amenity benefits for induced pedestrian and cyclists by taking the difference between the build and no build AADT and multiplying by one half, the length of the improved facility (miles), the days per year AADT is anticipated to be observed, the monetization factor for each facility improvement (per mile), and the annualization factor (365). "Length of Improved Facility" does not apply for pedestrian crossings. "Facility Improvement Factor" refers to sidewalk width, upslope, MPH reduced, vehicles reduced, and the average number of crossings.

$$
\begin{aligned}
c = \big(Build\ AADT_{by\ mode} &- No\ Build\ AADT_{by\ mode}\big) * 0.5 \\
&* (Length\ of\ Improved\ Facility) \\
&* \left(Value\ of\ Facility\ Improvement_{by\ mode,\ improvement\ type}\right) \\
&* \left(Facility\ Improvement\ Factor_{by\ mode,\ improvement\ type}\right) * 365
\end{aligned}
$$

Figure 29: Amenity Benefits for Induced Users of Active Modes

Emissions

As discussed in **Appendix B,** EPA MOVES was used to generate default emission factors (grams per mile) for CO_2, NO_X, $PM_{2.5}$, and SO_X for both passenger vehicles and trucks (the truck value is applied to buses as well). The appropriate emission factors are chosen by the tool based on the detour route's functional class, average speed, and the year (which accounts for changes in the fleet composition and other factors). Once the appropriate emission factors have been chosen, they are multiplied by the VMT estimates from reduced closures and load postings. These emissions are then monetized using USDOT BCA guidelines. The formulas for emission benefits are:

For each vehicle mode – passenger, truck, and bus:

$$
= [(a + b + c)] * 7\ percent\ discount\ rate\ (3\ percent\ discount\ rate\ for\ CO_2)
$$

Figure 30: Emissions Benefits and Disbenefits

- Compute the emissions produced by detouring during load postings and closures by multiplying AADT, by the percentage of AADT detoured, the detour length, the monetized emission rates per mile, and the annualization factor (365). This is repeated for load posting levels 1 through 3 and closure (only applying them to the relevant year).

$$
\begin{aligned}
a = \big(No\ Build\ Vehicle\ AADT_{by\ mode}\big) &* \big(\%\ of\ No\ Build\ AADT\ Detoured_{by\ mode}\big) \\
&* (Vehicle\ Detour\ Length) \\
&* \left(Emissions\ per\ Mile\ in\ kg_{by\ emission\ type,mode,speed,and\ roadway\ type}\right) \\
&* \frac{1\ metric\ ton}{1000\ kg} * \left(Emissions\ Cost\ per\ Metric\ Ton_{by\ emission\ type}\right) * 365
\end{aligned}
$$

Figure 31: Emissions Benefits due to Avoided Detouring

- Compute the emissions produced by short-term and intermittent closure by multiplying AADT by the percent of AADT detoured, by the detour length, the monetized emission rates per mile, and the days of closure per year. This is repeated for each short-term and intermittent closure

table and only applies to the years specified by the applicant.

$$b = (No\ Build\ Vehicle\ AADT_{by\ mode}) * (\%\ of\ No\ Build\ AADT\ Detoured_{by\ mode})$$
$$* (Vehicle\ Detour\ Length)$$
$$* (Emissions\ per\ Mile\ in\ kg_{by\ emission\ type,mode,speed,and\ roadway\ type})$$
$$* \frac{1\ metric\ ton}{1000\ kg} * (Emissions\ Cost\ per\ Metric\ Ton_{by\ emission\ type})$$
$$* Days\ of\ Closure$$

-
Figure 32: Emissions Benefits for Short-term and Intermittent Closures

Emissions disbenefits accrue when additional induced vehicles use the bridge in the build scenario and produce additional emissions.

For each year and vehicle mode – passenger, truck, and bus:

- Compute additional congestion disbenefits by subtracting the no build AADT from the build AADT and multiplying by bridge length, the emissions cost per mile by emissions type, vehicle mode, and bridge road type, and the congestion cost per mile by vehicle type and for the bridge's road type.

$$c = (Build\ AADT_{by\ vehicle\ mode} - No\ Build\ AADT_{by\ vehicle\ mode}) * (Bridge\ Length)$$
$$* \frac{1\ metric\ ton}{1000\ kg}$$
$$* (Emissions\ per\ Mile\ in\ kg_{by\ emission\ type,vehicle\ mode,bridge\ road\ type}) *$$
$$* (Emissions\ Cost\ per\ Metric\ Ton_{by\ emission\ type})$$

Figure 33: Emissions Disbenefits

Other Environmental Benefits and Other Benefits Not Quantified Elsewhere

This category includes additional benefits like wildlife connectivity, noise, and water runoff as well as the miscellaneous benefit section. The calculation for these categories simply multiplies the average annual benefit by its appropriate growth rate factor for each year in which the benefit occurs.

For each benefit (either Other Environmental Benefits or Other Benefit Not Quantified Elsewhere): Compute the annual benefit adjusted by the annual growth rate given each calendar year benefits are estimated to occur using the following formula:

$$a = (Annual\ Benefit) * (1 + Annual\ Growth\ Rate)^{(Analysis\ Year - 1)}$$
$$* 7\ percent\ discount\ rate$$

Figure 34: Other Environmental Benefits and Other Benefits Not Quantified Elsewhere

Analysis year is the count of the year from the first year of the opening (i.e., 1-30 for a 30-year period of

operations).

Noise disbenefits accrue when additional vehicle AADT uses the bridge in the build scenario introducing additional noise on the bridge and approach.

For each year and vehicle mode – passenger, truck, and bus:

- Compute additional noise disbenefits by subtracting the no build AADT from the build AADT and multiplying by bridge length and the noise cost per mile by vehicle type for the bridge's road type.

$$b = \left(Build\ AADT_{by\ vehicle\ mode} - No\ Build\ AADT_{by\ vehicle\ mode}\right)$$
$$* \left(Noise\ Cost\ per\ Mile_{by\ vehicle\ mode,\ bridge\ road\ type}\right)$$
$$* (7\ percent\ discounting)$$

Figure 35: Noise Disbenefits for Induced Vehicles

Operating and Maintenance (O&M) Cost Savings

O&M costs are calculated as the difference in the O&M costs in the build and no-build scenario. The tool applies this difference for any year specified by the user. A real growth rate is applied if selected by the user for the main O&M cost benefits.

For each O&M cost table:

$$= [(a + b + c)] * 7\ percent\ discount\ rate$$

Figure 36: O&M Costs

- Compute the O&M costs by taking the annual cost in the build scenario multiplied by the growth rate in the build scenario minus the annual cost in the no build scenario multiplied by the growth rate in the no build scenario, for each year in the period of benefits:

$$a = (Build\ Annual\ O\&M\ Cost)$$
$$* (1 + Build\ Annual\ O\&M\ Cost\ Growth\ Rate)^{(Analysis\ Year\ -\ 1)}$$
$$- (No\ Build\ Annual\ O\&M\ Cost)$$
$$* (1 + No\ Build\ Annual\ O\&M\ Cost\ Growth\ Rate)^{(Analysis\ Year\ -\ 1)})$$

Figure 37: O&M Costs using Bridge Tab Table 15

- Compute the intermittent O&M costs in the build scenario by taking the build O&M costs minus the no build O&M costs. For each year specified:

$$b = (Build\ Annual\ O\&M\ Cost) - (No\ Build\ Annual\ O\&M\ Cost)$$

Figure 38**: O&M Costs using Bridge Tab Table 16a-d**

- Compute the manually entered O&M costs in the build scenario by taking the build O&M costs minus the no build O&M costs. For each year specified:

$$c = (Build\ Annual\ O\&MCost) - (No\ Build\ Annual\ O\&M\ Cost)$$

Figure 39: O&M Costs using Bridge Tab Table 17

Analysis year is the count of the year from the first year of the opening (i.e., 1-30 for a 30-year period of operations).

Residual Value

The residual value is calculated using the USDOT BCA guidance methodology by subtracting benefit years from the useful life, dividing by the useful life, and multiplying by the project costs.

$$Residual\ Value = \left(\frac{Useful\ Life - Benefit\ Years}{Useful\ Life}\right) * Total\ Capital\ Cost$$

Figure 40: Residual Value

Construction Disbenefit

Construction disbenefits are the negative impacts to safety and travel time during the project construction period. The formulas for Construction Disbenefits are:

1. For each year of construction and vehicle mode:

$$[(a + b)] * 7\ percent\ discount\ rate$$

Figure 41:Construction Disbenefits - Vehicles

- Compute travel time delays caused by construction by multiplying the construction no build AADT, estimated delay (in hours), and the travel time monetization value.

$$a = \left(Construction\ AADT_{by\ vehicle\ mode}\right) * \left(\frac{Vehicle\ Delay_{by\ vehicle\ mode}}{60}\right)$$
$$* \left(Occupancy_{by\ vehicle\ mode}\right) * \left(Value\ of\ Time_{by\ vehicle\ mode}\right)$$
$$* Days$$

Figure 42:Travel Time Disbenefits Vehicles

- Compute increased crash cost by multiplying the calculated average annual crash cost using historical data provided by the applicant by the estimated increase in crashes due to the work zone.

$$b = (Average\ Annual\ Crash\ Cost)$$
$$* (Percent\ Increase\ in\ Crashes\ due\ to\ Work\ zone)$$

Figure 43: Construction Safety Disbenefits

2. For each year of construction and active mode – pedestrians and cyclists:
    - Compute travel time delays caused by construction by multiplying the construction

AADT, estimated active mode delay (in hours), the travel time monetization value, and the days of construction.

$$a = \left(Construction\ AADT_{by\ active\ mode}\right) * \left(Delay_{by\ active\ mode}\right) *$$
$$* \left(Value\ of\ Time_{by\ active\ mode}\right) * (7\ percent\ discount\ rate) * Days$$

Figure 44: Construction Travel Time Disbenefits – Pedestrians and Cyclists

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