Smart Roadside Initiative Macro Benefit Analysis

Project Report

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16. Abstract

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

This document has been prepared to present the benefit and cost method of the BCA tool.

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Executive Summary

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

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

Section 1 Introduction

Through the Smart Roadside Initiative (SRI), a Benefit-Cost Analysis (BCA) tool was developed for the evaluation of various new transportation technologies at a State level and to provide results that could support technology adoption by a State Department of Transportation (DOT). This report describes the techniques and procedures used to create the BCA tool.

1.1 Background

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

- Improved screening and automation of inspection/compliance checks
- Improved roadside commercial vehicle enforcement operations
  - Credential enforcement
  - Roadside inspections
  - Truck size and weight verification
- Extended geographic scope of enforcement data-sharing programs
- Improved safety through increased identification of unsafe trucks
- Improved, streamlined inspection process for compliant trucks
- Sharing of truck parking availability to support safer highway operations

1.2 Purpose of BCA Tool

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

1.3 Key Assumptions

Several analytical and procedural assumptions are required to apply BCA methods to the available data and unique conditions of transportation technologies. This section outlines these assumptions.

1.3.1 Real Discount Rate and Present Value

The benefits and costs are valued in constant dollars, which avoids forecasting future inflation and escalating future values for benefits and costs accordingly. The use of constant dollar values requires the use of a real discount rate for present value discounting. A real discount rate eliminates the effect of inflation and measures the risk-free interest rate that the market places on the time value of money. The time value of money concept represents a person's preference to consume a resource (such as money) sooner rather than later, meaning the value of the same resource in the future is less than the value of having the resource today (Pindyck and Rubinfeld, 1998).

Guidance provided by the U.S. Office of Management and Budget (OMB) in Circulars A-4, "Regulatory Analysis" (2003), and A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs" (1992), recommends using a 7 percent real discount rate and conducting an alternative analysis using a 3 percent real discount rate. The default discount rate in the tool is set at 3 percent, but the analyst can adjust the discount rate as desired. The higher the discount rate, the lower the present value of future cash flows. For investments with costs incurred in earlier periods and benefits following in later periods, a higher discount rate tends to reduce the economic feasibility of the project. The analyst can select the base year and adjust all monetary values using the Bureau of Labor Statistics' Consumer Price Index (CPI) to change the default values from 2014 dollars, if needed.

1.3.2 Period of Analysis

Benefits and costs are evaluated for a period that includes the installation of the transportation technology and the operations period, referred to as the period of analysis. The period of analysis should be commensurate with the expected life of the transportation technology. The period of analysis for typical infrastructure projects can range from 20 to 50 years. However, for some transportation technologies, a shorter period of analysis is considered more appropriate as technology continues to develop and the technologies being evaluated now become outmoded. The analyst can adjust the period of analysis to an appropriate time frame. End-of-year discounting is used, meaning all benefits and costs are assumed to occur at the end of each year.

1.3.3 Evaluation Date

The evaluation date is the nominal start of the technology implementation period, or Period 0, and spans the period of analysis. Period 0 is the base year for the project and is the period to which other costs and benefits are discounted or compounded. Any costs occurring during Period 0 are not discounted. The initial technology implementation and training cost is anticipated to occur in Period 0. Benefits begin to accrue at the beginning of Period 1. The recurring operating and maintenance costs of the technology and annual benefits are estimated over the remaining period of analysis. Estimated costs and benefits are discounted back to the base year to determine the present value (Pindyck and Rubinfeld, 1998).

1.4 Study Area

The analyst defines the geographic area being considered the study area for the BCA, such as a State, region, specific length of highway, or a single facility. The study area should be consistent with the nature of the technology being evaluated. For example, a weigh-in-motion technology may be appropriate to evaluate at the facility level, whereas a universal identification system may be appropriate to evaluate at the State level. Some benefits, such as a reduction in air emissions and safety impacts, may extend beyond the study area boundaries. However, the benefits are only included if they are generated/realized within the study area. It is important to ensure all data inputs pertain to the user-defined study area, specifically accident rates, total traffic volume and speed, facilities, and infrastructure.

Section 2 Overview of the BCA Tool

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

2.1 Structure of the Tool

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

2.1.1 Benefits Component

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

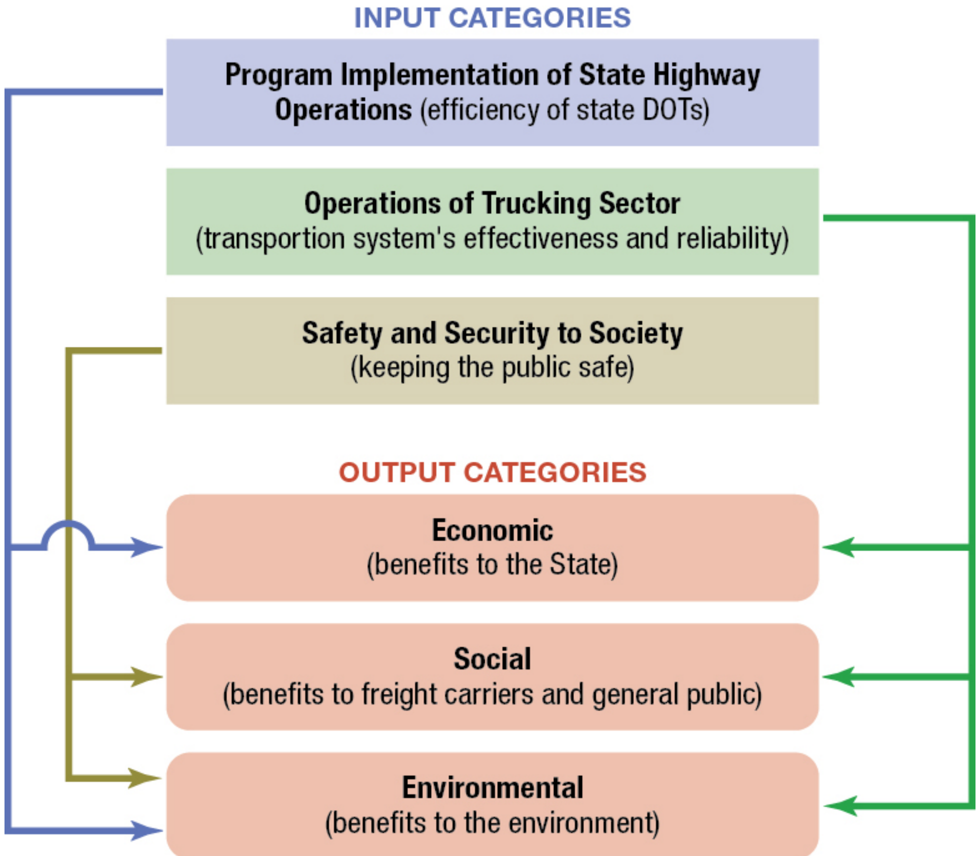
Analyst inputs for the benefits component consist of three categories:

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

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

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

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



Source: AECOM

Figure 2–1: Overview of Benefit Categories

2.1.2 Costs Component

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

Implementation and Startup: Deploying the technologies into the highway system; includes purchasing equipment, installing equipment, and training staff

Operations and Maintenance: Maintaining the technology over the period of performance; includes equipment operation and repair, utility and other ongoing support activities, and recurring staff training

2.2 Modeling Process

The BCA tool is intended to be widely applicable to a broad range of technologies, some of which have not yet been fully defined. Impacts from a technology are analyzed on a State basis. The impacts are a measure of the changes from the baseline compliance and travel conditions that result from implementing the technology. The baseline is defined as the existing and future conditions over the period of analysis without the technology (i.e., the "business as usual" conditions). The estimated impact of each technology is the incremental difference between the baseline conditions and the costs and benefits projected from implementing the technology.

Examples of impacts from transportation technologies include:

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

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

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

The results of the analysis are presented according to benefit and cost categories, with the total estimated benefits and project costs shown. Disaggregating the results allows the analyst to review the estimates and ensure they are appropriate. Each of the categories has an associated worksheet tab where the supporting calculations are performed (the "back end").

Section 3 Benefit Input Categories

There is a broad set of possible technology improvements that States can potentially measure to evaluate the value of a technology investment. Impacts from a technology are calculated from analyst inputs into the following three categories: (1) Program Implementation of State Highway Operations, (2) Operations of the Trucking Sector, and (3) Safety and Security to Society. Depending on the project, improvements may affect one or all of the analyst input categories.

The model performs various calculations based on analyst inputs and default values (standard default values used in the BCA tool are provided in Appendix B). The results of each of the analyst input categories are the quantities of selected variables that describe the impacts of the technology. For example, the outputs of the Safety and Security to Society category include the number of fatalities from accidents, the number of injuries from accidents, and the number of property damage only accidents.

3.1 Program Implementation of State Highway Operations

In the BCA tool, a series of questions ascertains which impacts are applicable to a particular technology. Table 3-1 provides examples of the questions and the impacts associated with the potential analyst inputs for the Program Implementation of State Highway Operations category. Results include changes in compliance labor hours, administrative labor hours, indirect operating costs, changes to planned/programmed infrastructure investments, changes in gallons of fuel used, number of noncompliant trucks identified, and number of accidents prevented. For any additional program implementation of State highway operations benefits not addressed, the analyst can input these values directly into the BCA tool as uncategorized benefits.

Table 3-1: Program Implementation of State Highway Operations

Questions	Analyst Inputs	Impacts (changes)
Will there be a change in full-time equivalents (FTEs) needed for compliance operations (e.g., field staff)?	• Number of employees that perform compliance functions • Average percent of time employees perform compliance functions • Percent of reduced compliance labor the technology would result in	• Compliance labor hours
Will there be a change in FTEs for admin (e.g., supervision, office activities)?	• Number of employees that perform administrative functions • Average percent of time employees perform administrative functions • Percent of reduced administrative labor the technology would result in	• Administrative labor hours
Will there be a change in current size of the vehicle fleet?	• Number of fewer vehicles needed for operations • Average number of miles driven annually by these vehicles • Frequency at which the vehicles are replaced • Annual maintenance cost per vehicle	• Gallons of fuel • Indirect operating costs
Will there be a change in the operations of current facilities (e.g., facility operates fewer hours)?	• Number of hours per year the facility currently operates • Number of hours per year the facility will operate with the technology • Hourly operating cost of facility (e.g., electricity, heating)	• Indirect operating costs
Will there be a change in future programmed infrastructure expenditures (e.g., delay in construction of weigh station)?	• Current programmed cost for infrastructure • Year the planned infrastructure would be constructed • Revised programmed cost for infrastructure • Revised year the planned infrastructure would be constructed • Annual operation and maintenance cost of the planned infrastructure • Annual operation and maintenance cost of the revised infrastructure	• Planned/programmed infrastructure costs
Will there be a change in the number of noncompliant vehicles identified (e.g., overweight or unsafe trucks)?	• Number of days the facility operates annually • Number of trucks processed per day (weight and inspection) • Average number of miles driven to destination by each truck • Current percentage of unsafe trucks • Current percentage of overweight trucks • Anticipated percentage of unsafe trucks • Anticipated percentage of overweight trucks	• Number of noncompliant trucks • Annual infrastructure maintenance costs • Number of accidents prevented

Source: AECOM

3.2 Operations of the Trucking Sector

Table 3-2 details the questions and the associated impacts that are expected to result from potential analyst inputs for the Operations of the Trucking Sector category. Results include changes in gallons of fuel used, truck driver labor hours, carrier administrative labor hours, and number of accidents prevented. For any additional operations of the trucking sector benefits not addressed, the analyst can input these values directly into the BCA tool as uncategorized benefits.

Table 3-2: Operations of the Trucking Sector

Questions	Analyst Inputs	Impacts (changes)
Will there be a change in delay to freight vehicles due to a change in speed?	• Pre-technology average truck speed • Post-technology average truck speed • Average number of trucks per mile annually (traffic count) • Pre-technology average auto speed • Post-technology average auto speed • Average number of autos per mile annually (traffic count) • Segment length	• Gallons of fuel • Truck driver labor hours
Will there be a change in delay to freight vehicles due to a change in queue time at weigh/inspection stations?	• Pre-technology average time spent at weigh/inspections stations • Post-technology average time spent at weigh/inspections stations • Average number of trucks processed per hour • Hours of operations per year • Average number of trucks that can bypass the weigh/inspections stations per hour • Average time savings from bypassing the weigh/inspections station	• Gallons of fuel • Truck driver labor hours
Will there be a change in transactional costs for carriers (e.g., scheduling)?	• Number of carrier employees that perform an administrative function • Average hours employees perform administrative functions per year • Percent reduction in administrative time expected from the technology	• Carrier administrative labor hours
Does the technology increase use of safer truck parking?	• Average annual number of truck accidents resulting in fatalities • Average annual number of truck accidents resulting in injuries • Expected reduction in fatal accidents involving unsafe truck parking • Expected reduction in injury accidents involving unsafe truck parking	• Gallons of fuel • Number of accidents prevented
Will there be an increase in truck electrification stations/idling reduction stations?	• Number of new parking facilities • Average number of truck electrification bays per facility • Expected average number of hours in use per day • Number of days in operation per year	• Gallons of fuel • Number of accidents prevented

Questions	Analyst Inputs	Impacts (changes)
	• Pre-technology average daily use level • Pre-technology average number of bays in use • Post-technology average daily use level • Post-technology average number of bays in use	

Source: AECOM

3.3 Safety and Security to Society

Table 3-3 details the questions and the associated impacts that are expected to result from potential analyst inputs for the Safety and Security to Society category. Results for this category include changes in number of accidents prevented, changes in gallons of fuel used, and accident-related delays. For any safety and security to society benefits not addressed, the analyst can input these values directly into the BCA tool as uncategorized benefits.

Table 3-3: Safety and Security to Society

Questions	Analyst Inputs	Impacts (changes)
Will the technology change the total number of accidents occurring (e.g., from reduction in merges)?	• Vehicle miles traveled for the study segment • Percentage of vehicles that are trucks • Percentage of highway that is urban • Accident rate information • Percent change in the accident rate	• Number of accidents prevented • Gallons of fuel • Delay hours
Does the technology result in fewer truck-related accidents involving highway workers?	• Number of truck accidents resulting in highway worker fatalities • Percent change in the number of highway worker fatalities • Number of truck accidents resulting in highway worker injuries • Percent change in the number of highway worker injuries	• Number of accidents prevented • Gallons of fuel • Delay hours

Source: AECOM

Section 4 Benefit Output Categories

The impacts of the technologies are allocated to three benefit categories, where calculations are performed to estimate a monetary value of the impact:

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

An impact may result in multiple benefits. For example, a reduction in fuel use would result in both lower operating costs for carriers (social benefit) and a reduction in air emissions (environmental benefit). Also, implementing new transportation technologies may result in a more efficient commercial freight industry (social benefit), while also increasing the efficiency of inspection and compliance activities (economic benefit).

4.1 Economic

Successful transportation technology implementation may change a State's labor costs, indirect operating costs, and/or indirect infrastructure costs. These types of increased, avoided, or reduced costs are classified as economic benefits (increased costs would be a negative economic benefit). A category for "other" economic benefits is also included to incorporate benefits that are not captured in the other categories.

4.1.1 Labor

While labor directly related to operating a technology would be a cost (see Section 5), indirect reductions to labor needs would be a benefit. Indirect savings to labor includes indirect changes to the number of hours worked by State employees as a result of a technology being implemented. The labor savings is calculated by multiplying the average wage by the number of hours reduced.

As an example, if a mobile weigh station requiring one compliance officer to operate replaces the need for two compliance officers at a fixed weigh station, the indirect labor savings (benefit) would be the two compliance officers at the fixed station, while the one compliance officer at the mobile station would be a direct cost attributed to the technology.

4.1.2 Operating Costs

Operating costs directly linked to operating and maintaining the technology are addressed in the Cost Category section (Section 5.2). Indirect operating costs are changes to existing State operating costs as an indirect result of the technology, such as a reduction in highway maintenance because fewer overweight vehicles are using the highway. To determine the effect of a transportation technology on States and users, the indirect State operating costs need to be calculated both without (meaning if the technology was not implemented) and with the technology. The difference between the two costs is the benefit attributable to the transportation technology, either as an operating cost savings or an operating cost increase (i.e., a negative benefit) if there would be additional indirect operating costs from future use of the technology.

4.1.3 Infrastructure

Some transportation technologies may result in savings on infrastructure for the State's current and/or planned infrastructure. For example, if fewer or smaller weigh stations are needed for future freight management, an infrastructure savings may occur. Infrastructure savings are measured as the difference between the infrastructure costs that would occur without the implementation of the transportation technology and the infrastructure costs with the transportation technology.

4.1.4 Other Economic Benefits

This category includes any economic benefits that are not captured in the categories above. For example, in the future, States may generate revenue by selling air emissions reductions or offsets that are the direct result of a new transportation technology. These benefits would need to be calculated outside the BCA tool and then entered into the tool by the analyst.

4.2 Social

Because the BCA is from the perspective of each State, social benefits are defined to include benefits that would accrue to the freight carriers, highway users, and the general public. If the BCA were conducted from the perspective of the freight carriers, then the benefits categorized as social benefits for the freight carriers would become economic benefits. Although freight carriers are included in the highway users category, direct benefits specific to the trucking sector (such as truck driver travel time and fuel savings from reduced queue time at a weigh station) are identified separately.

The highway users category includes indirect fuel and time savings for both freight carriers and other highway users resulting from traffic delays associated with a reduction in accidents. The life safety category is primarily the benefit of reducing accident-related personal injuries and property damage from accidents. The analysts using the BCA tool also have the option of including additional social benefits that are not currently defined. These benefits would need to be calculated outside the BCA tool and then entered into the tool by the analyst.

4.2.1 Freight Carriers

Some new transportation technologies are intended to create a more efficient commercial vehicle shipping industry, while also increasing the efficiency of inspection and compliance activities. These goals and objectives may reduce the number of vehicle hours traveled (VHT) for freight carriers. VHT changes (such as the queue time at weigh stations) would directly affect fuel and labor costs that the freight carriers may pass on in whole or in part to shippers via lower freight rates. Shippers may, in turn, pass on these savings in whole or in part to consumers.

4.2.2 Highway Users

The highway users benefit category includes indirect fuel and travel time savings (measured as VHT) that would benefit the user population of a highway (including passenger cars and freight carriers) resulting from either less congestion or avoided accidents from highway safety improvements. Other vehicle operating costs, such as tire wear, maintenance, oil, etc., are not included. The value of travel time savings depends on the characteristics of the traveling population, the mode, time, purpose of travel, and in some cases, the location and/or availability of alternative transportation modes. The value users assign to their travel time depends on their opportunity cost for that time. Travel time may be work travel time or personal time. The national average employer cost for employee compensation per hour (wage rate) is used as a default to value work travel time. Following standard USDOT guidance, work travel time is valued at 100 percent of the wage rate, while personal travel time (including commute time) is valued at 50 percent of the wage rate (USDOT FHWA, 2007). The reduced rate to value personal time is based on the assumption that individuals benefit from the travel or are willing to accept additional travel time in order to gain something.

Delays, property damage, and increased fuel consumption from accidents are calculated on a per-accident basis. In cases where the number of accidents is reduced, time delay, emissions, and excess fuel burn costs are also reduced. The average values for time delay, emissions, and excess fuel burn are available in Appendix B.

4.2.3 Life Safety

The life safety benefit category includes the value of avoided fatalities, injuries, property damage (to vehicles and structures), and the avoided cost of emergency services. A decline in the number or severity of accidents, or both, leads to lower accident-related costs. Accident costs can include fatalities, injuries, property damage (to vehicles and structures), and emergency services. Accident-related traffic delays and additional fuel use are recognized in the highway users category above.

The economic benefit of any safety improvement can be estimated by the avoided cost of the various types of expected injuries. Methodologies in USDOT guidance documents were followed to estimate the cost of accidents, including consideration of their severity and frequency. Changes in vehicle traffic patterns (e.g., reduced highway merging, braking) can be used to project future safety benefits.

Safety benefits can be estimated from the changes in accident incident rates, the type and severity of the resulting accidents, and the unit costs of accidents. In addition to these direct user costs, there are indirect costs of accidents that are borne by society. Indirect costs include the emergency response to accidents, which is generally paid with public funding.

Certain baseline conditions of the study area are required to calculate any safety and security to society benefits. These include the vehicle miles traveled (VMT) for the study segment (an annual estimate of the amount of vehicular travel on the study segment), the percentage of the study segment that is considered urban (the percentage that is not urban is assumed to be rural) and the percentage of vehicles that are freight carriers (the percentage that is not trucks is assumed to be passenger vehicles).

The accident types are separated into injury accidents, fatal accidents, and accidents resulting in property damage. Analyst inputs are used to estimate the change in the number of each of these types of accidents. Because States compile accident statistics in different formats, the model offers two approaches used to measure safety. If analysts have specific accident rate information for the study area, they can enter the accident rates for fatalities, injuries, and property damage only accidents or the KABCO accident rates. KABCO is used by law enforcement to classify injury severity using five categories: K = Killed, A = Severe Injury, B = Other Visible Injury, C = Complaint of Pain and O = Property Damage Only. These definitions vary slightly for different States. The analyst also has the option to enter the accident rate data separately for freight trucks and automobiles or for all vehicle types combined. If the technology is only expected to change truck-related accident rate information, the analyst should choose the option for separate auto and truck accident rates.

In the absence of specific accident rate information for the study area, the model uses national average accident rates. National average accident rates were obtained from the most recent accident rates published by Federal Motor Carrier Safety Administration (FMCSA, 2014). Default accident rates are provided for fatalities, injuries, and property damage only (FIPDO) accidents and the KABCO accident rates for both automobiles and truck combined or separated.

The accident incident rates and accident types (e.g., fatality rates, injury types) are used to estimate expected future accident costs in both the before transportation technology and after transportation technology scenarios. Delays, property damage, and increased fuel consumption from accidents are calculated on a per-accident basis. In cases where the number of accidents is reduced, time delay, emissions, and excess fuel burn costs are also reduced. The default values used to calculate benefits related to accidents are available in Appendix B.

4.2.4 Other Social Benefits

This category would include any social benefits that are not captured in the categories above. A new transportation technology may create other social benefits that can be measured and monetized. These benefits would need to be calculated outside the BCA tool and then entered into the tool by the analyst. Other social benefits may include the reliability benefit of a more efficient transportation system; however, this benefit is difficult to measure and would not commonly be included in the BCA.

4.3 Environmental

If a transportation technology reduces travel time or VMT, there would also be a reduction in fuel use. Burning fuel releases greenhouse gas (GHG) emissions and criteria air pollutant (CAP) emissions. These pollutants are regulated by the U.S. Environmental Protection Agency primarily because they harm human health and the environment and can cause property damage.

4.3.1 Greenhouse Gas Emissions

As fuel consumption and/or idling time decreases, GHG emissions would also decrease. The amount of GHG emissions generated by vehicle users varies depending on fuel use efficiency and the amount of fuel consumed. The default GHG emission values are based on the Social Cost of Carbon (SCC) developed by the Federal Interagency Working Group (2010). The SCC values include net agricultural productivity, human health, property damage from increased flood risk, and the value of ecosystem services. SCC values already inflated from the reference year (in 2007 nominal dollars) are available in Appendix B.

Federal SCC guidance recommends that GHG emissions be valued with a lower discount rate than other benefits because carbon dioxide emissions are long-lived and subsequent damages persist over many years (Interagency Working Group on the Social Cost of Carbon, 2010). A 3 percent discount rate was selected as a central value that reflects the after-tax riskless interest rate and is consistent with OMB's Circular A-4 guidance for the consumptive rate of interest.

The GHG emissions value is calculated by first converting the 2007 SCC values to the base year using the CPI, then multiplying the quantity in metric tons of carbon dioxide by the appropriate SCC value in that same year. The GHG benefits would be discounted to the base year at the same SCC discount rate of 3 percent, regardless of the discount rate selected for the BCA, to obtain the net present value.

4.3.2 Criteria Air Pollutant Emissions

Transportation technologies that reduce delays can lower CAP emissions given less idling and otherwise constant VMT. Similar to GHG emissions, the amount of CAP emissions emitted depends on the amount of fuel (diesel or gasoline) consumed, the emission profile, and the fuel efficiency of the vehicle. Any fuel use that is reduced translates into a reduction in CAP emissions. CAP emissions from vehicles include nitrogen oxides (NOx), particulate matter (PM), sulfur oxides (SOx), and volatile organic compounds (VOCs).

CAP emission values estimated by the USDOT National Highway Traffic Safety Administration (USDOT NHTSA, 2012) are available in Appendix B. CAP emissions are monetized by first converting the 2010 emission values to the base year using the CPI, then multiplying the quantity of each CAP in metric tons by the appropriate value.

4.3.3 Other Environmental Benefits

This category would include any environmental benefits that are not captured in the categories above. These benefits would need to be calculated outside the BCA tool and then entered into the tool by the analyst.

Section 5 Cost Category

The term “cost” is used to refer to the monetary costs of implementing, operating, and maintaining a transportation technology throughout the period of analysis. These are the direct costs of the technology that are anticipated to be incurred by State DOTs adopting the transportation technology. Indirect cost savings, such as not having to construct a new weigh station or reduction in labor, are considered benefits and are addressed in the benefit analysis.

The total costs are related to the amount of the investment necessary for the technology’s deployment; as more improvements are implemented, the associated implementation costs increase. Additionally, as the rate and size of the technology deployment increase across the system, the incremental per-unit costs may decrease through economies of scale.

The costs that each State would incur for the transportation technology implementation and operation will likely be estimated after the prototype is developed. As development continues and technologies are better defined and understood, the cost values can be adjusted to reflect improved cost estimates and incorporate more realistic/accurate system performance projections.

5.1 Implementation and Startup Costs

Implementation or startup costs are the expenditures that are initially incurred to deploy the technologies within the highway system. These expenditures include not only the cost to purchase the technology and necessary supporting equipment, but also the installation costs and cost of training agency staff to use the technology. The costs may occur throughout the period of analysis if the technology is deployed to additional areas within the State or expanded within the initial deployment area.

5.2 Operating and Maintenance Costs

Operating and maintenance costs are the expenditures necessary to run and maintain the technology after implementation. These costs include maintaining and operating the technology and recurring training. The costs may occur annually or periodically throughout the period of analysis. The tool calculates the present value of the total expected operating and maintenance costs, as well as the expected average annual cost.

Section 6 Benefit-Cost Analysis Results

Transportation technologies are intended to improve the transportation system. The primary purpose of the BCA tool is to determine whether the estimated benefits of implementing the transportation technologies are greater than the estimated costs. The impacts of the transportation technologies are compared with the baseline (business as usual) to determine the benefits and costs. Environmental and social impacts are monetized using economic valuation methods. The results of the benefit and cost analyses for each technology are calculated over the period of analysis based on end-of-year discounting. The BCA tool provides various metrics for evaluating the BCA results, namely the benefit-cost ratio (BCR), net present value (NPV), financial return-on-investment (ROI), and sustainable ROI (sROI). These metrics can be useful for determining whether or not to invest in a particular transportation technology.

For the specific technology being analyzed, the BCA tool divides its projected benefits by the respective costs to determine the technology's BCR. A BCR greater than 1.0 indicates that the benefits of the transportation technology exceed the costs and therefore, the technology would be a cost-effective use of resources. When comparing technologies, a technology with a higher BCR would be considered a more cost-effective use of resources; however, that would not necessarily guarantee greater total benefits.

The NPV is the difference between the present value (i.e., discounted value) of the technology's projected total benefits and costs over the period of analysis. If the NPV is positive (i.e., the discounted total benefit exceeds the total costs), then investing in the technology would typically be considered worthwhile. When comparing technologies, a technology estimated to have a higher NPV would indicate that the technology will result in greater net benefits overall than a technology with a lower NPV.

The financial ROI is a traditional financial metric used to describe the future cash flows in relation to the initial capital investment. The financial ROI includes only the economic benefits and the costs, whereas the sROI includes the economic, social, and environmental benefits and costs. Both the financial ROI and sROI ratios are used to evaluate the efficiency of an investment. The financial ROI is calculated by dividing the present value of the economic benefits by the cost of the new technology. The sROI is calculated by dividing the present value of the economic, social, and environmental benefits by the cost of the new technology. As the ROI increases, the value of the investment increases.

The analyst may select which benefit categories to include in the results analysis. For example, if State guidelines do not allow selected environmental benefits to be included in an analysis, that particular benefit can be removed. Allowing analysts to select which benefits and costs to include in the results provides the flexibility to meet many requirements.

Section 7 Using the BCA Tool

This section provides some basics for using the BCA tool. A more detailed process can be found in the accompanying "User's Guide for the BCA Tool."

7.1 Software Requirements

As mentioned previously, the BCA tool was built using Microsoft Excel as the base platform. Excel is a well-established software package that is currently available to most potential analysts, thus eliminating the need for special licensing. The BCA tool should be able to operate on Excel version 2007 and newer. Visual Basic was used to program the BCA tool, so VBA macros need to be enabled in order to run the tool.

Note: Near the end of the development of the BCA tool, Microsoft released a Microsoft Office update (December 2014). Unfortunately, the update caused many issues for programs designed using Visual Basic, including error messages and program crashes. If difficulties are experienced when running the BCA Tool, refer to Section 7.3 (Troubleshooting).

7.2 Process for Using the BCA Tool

When opening the BCA tool, the analyst is required to click the "Enable Content" button to run the software. Immediately, the BCA tool will open with a brief introduction to the tool. On clicking the "Begin Analysis" button, the analyst will be guided step-by-step through a series of questions to identify the impacts of the transportation technology being evaluated and input information. The analyst will have the option of using default values for some variables or inputting a value specific to the study area. For every question and input, the analyst can click "What's This?" to get further clarification (see Appendix C). The analyst has the option to skip to a particular section of the tool or go back to the previous screen.

The BCA tool contains different screens that are specific to the project assumptions and each input category. The first screen allows the analyst to verify the base year, period of analysis, and discount rate that would be used to calculate the BCA results. The analyst can also access and change other general default values from this screen.

The Program Impacts screen has seven main questions to identify impacts of the transportation technology and allow the analyst to input data related to program impacts. Additional details can be found in Section 3.1. The Operations Impacts screen has five main questions to identify impacts of the transportation technology and allow the analyst to input data related to operational impacts. Additional details can be found in Section 3.2. The Safety and Security to Society screen has seven main questions to identify impacts of the transportation technology and allow the analyst to input data related to safety impacts. Additional details can be found in Section 3.3. The Implementation and Startup Costs screen has five main questions to identify costs of the transportation technology and allow the analyst to input data related to initial costs. Additional details can be found in Section 5.1. The Operation and Maintenance Costs screen has four main questions to identify ongoing costs of the transportation technology and allow the analyst to input data related to recurring costs. Additional details can be found in Section 5.2.

Once the analyst has completed all the questions and input required information, the results screen is displayed. The results are categorized as economic, environmental and social benefits, and implementation/operational costs. Subcategories are also shown and the analyst has the option of selecting which subcategories to include in the overall result summary. A pie chart is displayed of the total economic, environmental, and social benefits.

In case adjustments are needed, the analyst has the option of jumping to a particular section or working backwards through the BCA tool. The results can be printed and saved. To start over, the analyst can click "New Scenario" and begin again.

7.3 Troubleshooting

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

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

Another Microsoft link explains how to fix the problem:

http://support.microsoft.com/kb/3025036/

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

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

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

Section 8 Bibliography

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Appendix A List of Acronyms

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

Appendix B Default Values and Formulas

B.1 Program Implementation of State Highway Operations

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

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

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

Source: AECOM

B.2 Operations of the Trucking Sector

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

Fuel Savings Values

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

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

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

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

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

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

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

Table B-2: Fuel Consumption by Average Operating Speed

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

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

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

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

Where:

C_{fuel} = user cost of fuel, in cents per vehicle-mile

E_{gpm} = fuel efficiency, in gallons per mile

E_{mpg} = fuel efficiency, in miles per gallon

P_{fuel} = fuel price, in dollars per gallon

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

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

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

Where:

$\Delta C(D)_{c,fuel}$ = change in fuel costs as a function of delay (cents)

$gal_{c,min}$ = gallons per minute for vehicles class c

D_0 = average delay before improvement (minutes)

D_1 = average delay after improvement (minutes)

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

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

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

mph = miles per hour

SUV = sport utility vehicle

SU = single unit

Source: AASHTO, 2010

B.3 Safety and Security to Society

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

Table B-4: FIPDO Default Accident Rates

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

Source: FMCSA, 2012

Table B-5: KABCO Default Accident Rates

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

Source: FMCSA, 2012

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

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

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

Source: FMCSA, 2013

Table B-7: Diesel and Gasoline Consumption Percentages

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

Source: FMCSA, 2013

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

Table B-8: Estimated Delay Time by Accident Classification

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

Source: FMCSA, 2013

B.4 Economic Benefits

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

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

Description	Value
Compliance staff hourly wage	$50
Administrative staff hourly wage	$40
Price of a gallon of gasoline	$3.50
Price of a gallon of diesel	$4.25
Cost per fleet vehicle	$30,000
Damage cost per mile from overweight trucks	$0.09

B.5 Social Benefits

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

Travel Time Value for Highway Users

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

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

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

Accident Cost Values

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

Table B-10: AIS Conversion Matrix

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

Source: NHTSA, 2011

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

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

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

Sources: USDOT, 2014 and 2012 & NHTSA, 2000

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

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

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

Where: ΔAC = change in accident costs

ΔI = change in expected number of injury accidents

ΔD = change in expected number of fatal accidents

ΔP = change in expected number of property damage accidents

ΔE = change in number of emergency responders

v_I = cost associated with an injury accident

v_D = cost associated with a fatal accident

v_P = cost associated with a property damage incident

v_E = cost associated with emergency response

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

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

Where: ΔAC_C = change in accident costs (cents per vehicle mile) for vehicle class c

ΔI = change in expected number of injury accidents (per vehicle mile)

ΔD = change in expected number of fatal accidents (per vehicle mile)

ΔP = change in number of property damage accidents (per vehicle mile)

ΔE = change in number of emergency responders (per vehicle mile)

v_I = perceived cost associated with an injury accident (cents)

v_D = perceived cost associated with a fatal accident (cents)

v_P = perceived cost associated with a property damage accident (cents)

v_E = cost associated with emergency response (cents)

B.6 Environmental Benefits

Greenhouse Gas Emission Values

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

Table B-12: Value of Greenhouse Gas Emissions

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

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

Criteria Air Pollutant Values

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

Table B-13: Value of Criteria Air Pollutants

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

Source: NHTSA, 2012

Appendix C BCA Tool “What’s This?” Feature

The text described in this appendix is incorporated into the BCA Tool for the “What’s This?” feature. “What’s This?” provides analysts with specific information on the type of data requested, how to develop the data, and sources.

C.1 Program Impacts

The Program Impacts category assesses the freight transportation system’s delivery of value and its efficiency. As such, the performance measures indicate the effectiveness of State departments of transportation, transportation projects, and existing infrastructure. When proposed technologies are evaluated, these performance measures can indicate the need for change and the likelihood of success within time and budget constraints.

1. **Will there be a change in FTEs needed for compliance operations?**

   This measure tracks the change in the number of full-time equivalencies (FTEs), a calculation of hours expended during current compliance operations, and compares it to the number of FTEs in the operations with the implemented improvements. Compliance operations are field activities conducted by employees such as weigh and inspection station operators.

   An FTE is the amount of regular hours worked plus paid leave of temporary and salaried employees, including overtime worked, divided by the number of expected hours per employee per year. The default value in the model is 2,080 (40 hours per week times 52 weeks), which can be adjusted in the default values menu.

   For the model to derive the FTE value, answer the following questions in the tool:

   a.) Input the total number of employees in the department who work on compliance issues, whether full time or part time.

   b.) Input an estimate of the percentage of the time that all employees identified in question 1a spend on specific compliance tasks (input percentage as whole number e.g., 5% = 5).

   c.) Input the estimated percent change of total labor required for the same duties after the targeted technology improvements are made (input percentage as a whole number e.g., 5% = 5). This change could affect the number of employees performing compliance functions or the percent of time performing compliance functions. If the number of FTEs is reduced 50%, enter 50. If the percent of time each employee spends performing compliance function is reduced 50%, enter 50

   The FTE hours are calculated by multiplying the number of employees (1a) by 2,080 hours and then by the percentage of time spent on the task (1b). The total impact is determined by reducing the amount of calculated FTEs by the percentage value provided in cell 1c.

   See the default values menu for the default inputs associated with benefits calculations for this section. The model calculates costs using a default value of $50 an hour for each FTE. This number should represent the average fully burdened wage including overtime per worker for all workers performing compliance activities.

   The inputs in this model are purposely arranged for ease of estimation in the absence of complete labor information. However, should the analyst have exact labor hours (regular, part time, overtime, and vacation) expended for compliance activities, divide those hours by the expected hours (default is 2,080) to determine the total number of employees (1a), and then enter 100 percent in the average percentage cell (1b).

Will there be a change in FTEs for administrative duties (e.g., supervision, office activities)?

This measure tracks the change in the number of FTEs, a calculation of hours involved in administrative duties for the targeted operation, and compares it to the number of FTEs in the operations with the implemented improvements.

An FTE is the amount of regular hours worked plus paid leave of temporary and salaried employees, including overtime worked, divided by the number of expected hours per employee per year. The default value in the model is 2,080 (40 hours per week times 52 weeks).

For the model to derive the FTE value, answer the following questions in the tool:

a.) Input the total number of employees in the department who perform administrative functions, whether full time or part time.

b.) Input an estimate of the percentage of the time that all employees identified in question 2a spend on administrative functions (input percentage as whole number e.g., 5 percent = 5).

c.) Input the estimated reduction of total labor required for the same administrative duties after the targeted technology improvements are made (input percentage as whole number e.g., 5 percent = 5).

The FTE hours are calculated by multiplying the number of employees (2a) by 2,080 hours and then by the percentage of time spent on the task (2b). The total impact is determined by reducing the amount of estimated FTEs calculated using 2a and 2b by the percentage value provided in cell 2c.

See the assumptions box for the default data associated with benefits calculations for this section. The model calculates labor benefits using a default value of $40 an hour for each administrative FTE. This number should represent the average fully burdened wage including overtime per worker for all workers performing administrative activities.

The information in this model is purposely arranged for ease of estimation in the absence of complete labor information. However, should the analyst have exact labor hours (regular, part time, overtime, and vacation) expended for administrative duties, divide those hours by the expected hours (default is 2,080) to determine the total number of employees (2a), and then enter 100 percent in the average percentage cell (2b).

2. Will there be a change in current size of the vehicle fleet?

This measure tracks the benefits resulting from improved efficiencies in the use of fleet vehicles required to maintain the highway system and its components. Fleet vehicles include dump trucks, box trucks, flatbeds, and other work vehicles, but do not include heavy construction equipment such as bucket loaders and cranes. It is assumed that these vehicles operate using gasoline.

To calculate the benefits, the first two questions focus on only those vehicles that can be removed from service, or would no longer be required, as a result of implementing a new technology:

a.) Input the number of vehicles that will be removed from regular fleet operations if the new technology is implemented.

b.) Input the average miles driven annually by those vehicles that will be removed from operation.

The average miles driven per vehicle should reflect the average of all vehicles in the subset indicated in question 3a. If multiple types of vehicles are included in the reduction, the average miles driven per vehicle should be the average of all types.

These inputs are then used to derive the total number of miles saved by implementing the technology improvement, which forms the basis for the remaining benefit calculations. For the model to compute the impact:

c.) Input the lengths of time that vehicles remain in service before replacement (in years).

d.) Input the average annual maintenance cost per vehicle for all vehicles identified in question 3a

Outputs derived in this section include changes in total annual miles driven, which is used to derive savings from fuel purchases, cost of recapitalization, and ongoing annual maintenance costs.

A technology improvement that keeps the same number of vehicles but reduces total miles driven or reduces the total maintenance costs per vehicle can also be assessed using this model. Set the number of vehicles reduced to 1, and input the total value of mileage reduction or total maintenance improvements for all vehicles in the respective input fields. If you do not wish to compute a cost for maintenance, enter zero for the cost amounts in question 3d.

3. Will there be a change in the operations of current facilities (e.g., facility operates fewer hours)?

This measure tracks the benefits from implementing any technology improvement that improves efficiencies in the use of highway facilities such as weigh stations, toll booths, and operational facilities such as storage hangars and mechanical shops.

If a technology will improve the operation of the facility itself, including more efficient use of labor, then complete the following questions. This question is about improvement in the facility itself, not to the trucks entering the facility or to other highway users.

a.) Input the total number of hours that targeted facilities currently operate annually without the new technology improvement.

b.) Input the total number of hours that targeted facilities are expected to operate annually after the new technology improvement.

c.) Input the average hourly operating cost of all targeted facilities (e.g., electricity, heating). If the technology results in a reduction of the hourly cost, input the current operating cost and make the adjustments to the baseline and projected operating hours.

These inputs will be used to calculate facilities benefits based on the change in the number of operating hours, which is multiplied by the hourly operating cost input in the default values tab for this section. Information on the hourly operating cost is found in the default values tab.

4. Will there be a change in future programmed infrastructure expenditures (e.g., delay in construction of weigh station or reduction of infrastructure costs)?

This section measures the projected benefits provided by a technology that can delay the construction of a future infrastructure project, improve the construction process, or reduce the time to completion. Populate the inputs in this section if the new technology will improve the operation or efficiency or extend the life of existing infrastructure, or if the new technology uses new and better methods for construction, enabling larger, more expensive projects to be postponed, completed in a reduced time frame, or completed at a lower cost.

If a new technology changes the construction process, enables greater efficiencies, or lowers the cost of construction, answer questions 5a through 5d:

a.) Input the current programmed construction cost for a planned infrastructure project without the use or implementation of the new technology.

b.) Input the current planned year of completion of the infrastructure project without the new technology.

c.) If a new technology changes the construction process, input the revised cost of construction for the infrastructure project utilizing this new technology.

d.) Input the new expected completion year for this project with the new technology.

If a new technology improves the efficiency or lowers the cost of annual maintenance on highway infrastructure, either for the new project or on existing infrastructure, answer questions 5e and 5f:

e.) Input the current or projected operations and maintenance costs of infrastructure not including new technology implementation.

f.) Input the new operations and maintenance cost with the new technology included.

The default discount rate used in the model is given in the previous introductory screen and should be updated if appropriate for the analysis. The analyst should input all values in current dollars, and the model will calculate net present value using the applied discount rate.

5. Will there be a change in the number of noncompliant vehicles identified (e.g., overweight, unsafe trucks)?

This measure tracks the benefits from implementing any technology that improves efficiency or the effectiveness of monitoring, inspecting, screening, and investigating the safety and compliance of trucks and trailers hauling freight. Populate this section if a targeted technology will reduce the days of safety and compliance operations, reduce the number of inspections, reduce the time required for inspection activities (efficiency), or increase the capture rate of compliance violations (effectiveness).

The model requires basic operational information for the inspection facility (or facilities) in the first three inputs. A facility in this capacity can be anything used to perform compliance and weight inspections, such as roadside inspection equipment:

a.) Input the total number of days the facility operates per year.

b.) Input the total number of trucks that the facility processes per day.

c.) Input the average number of miles each truck identified in 6b typically drives to its destination. For example, if a truck enters an inspection station, upon completion of that inspection, how far on average does it need to drive to reach its destination point?

The next inputs determine the current percentage of trucks passing through the facility determined to be out of compliance, unsafe, or overweight based on the inspection:

d.) Enter the percentage of trucks deemed unsafe as a result of the current inspection process (input percentage as whole number e.g., 5 percent = 5).

e.) Enter the percentage of trucks found to be overweight as a result of the current inspection process (input percentage as whole number e.g., 5 percent = 5).

Input for the remaining questions the anticipated percentage of trucks found to be unsafe or overweight based on improvements in technologies or methods employed during inspections.

This can also include technologies employed outside targeted inspection facilities that improve the inspection process such as weigh-in-motion systems:

f.) Enter the anticipated percentage of trucks that will be deemed unsafe as a result of the new inspection process (input percentage as whole number e.g., 5 percent = 5).

g.) Enter the anticipated percentage of trucks that will be found to be overweight as a result of the new inspection process (input percentage as whole number e.g., 5 percent = 5).

Outputs derived from the data in this section include the total reduction in miles driven by unsafe or overweight trucks based on the change in the number of violations captured, or a reduction in total operational cost to perform compliance and weight inspections.

6. Are there any additional program benefits that have not been accounted for in the questions?

Use this section to input an amount (in dollars) of any additional program benefits that have not been addressed by the questions in this section. The value input in this field will be added to the total amount in the economic benefits section.

C.2 Operations Impacts

The Operations Impacts category assesses the freight transportation system's effectiveness and reliability. The performance measures focus on the highway user's ability to arrive at destinations on time and without delay. The causes and impacts of system delays are captured in this category.

1. Will there be a change in delay for freight vehicles (e.g., queue at weigh station or processing time)?

This measure tracks the operational benefits derived from implementing a technology that improves the efficiency of the highway freight system. Populate this section if a technology will reduce the total vehicle hours traveled (VHT) on a highway segment by improving average highway speeds, or if the technology will reduce wait times at inspection facilities, truck parking facilities, or other facilities such that the overall throughput speed is increased for users of the highway system. Any technology analysis performed should factor in all highway users, even if the technology is for freight traffic only. A yes answer will display two follow-on questions, 1.1 and 1.2.

1.1 Will there be a change in delay for freight vehicles (e.g., queue at weigh station or processing time)?

These inputs are used to calculate a total change in fuel consumption resulting from a change in highway speed and flow of traffic. Populate the questions in this section if a technology is designed to increase traffic speed and flow.

The model requires transit time information for all highway users under current conditions and after implementation of the technology. The analyst should target one specific segment of highway being evaluated and enter those data. The average segment speed should be derived for both trucks and cars separately. For trucks, enter the following variables:

a.) Average truck speed on the target segment of highway before implementing the technology improvement. This should be the average speed of all trucks passing through the segment of highway during a fixed interval (or intervals) of time (in mph).

b.) Average truck speed after implementing the technology improvement on the same segment (in mph).

c.) Average number of trucks per mile annually on segment (truck traffic count).

Input the same values for automobile traffic on the same segment of highway:

d.) Pre-technology average automobile speed (in mph).

e.) Post-technology average automobile speed (in mph).

f.) Average annual number automobiles per mile on the segment the technology will impact (automobile traffic count).

g.) Input the length of the segment of highway the proposed technology will impact.

1.2 Will there be a change in queue time at weigh/inspection stations?

The next series of inputs relates to technologies that improve throughput time at weigh and inspection stations or other similar operational facilities. These inputs are used to quantify the benefits to the users of the highway system in terms of fuel savings produced through less idling time. To calculate the benefits, input the following:

a.) Average time spent waiting at a highway facility such as a weigh station before any improvements, including the wait time to enter and the time it takes for the inspection to be completed (in minutes).

b.) Average wait time waiting after technology improvements have been completed on the same facility/facilities. If the technology enables all truck traffic to bypass, enter 0 (in minutes).

c.) Average number of trucks processed through the facility per hour.

d.) The combined annual hours of operation at each targeted facility. If the technology results in a reduction in operating hours, input the current operating hours and make the adjustments to the baseline and projected throughput rates using a constant number of hours.

e.) Post-technology average number of trucks that bypass the facilities per hour. This value is important to derive the total net improvement for the entire segment of highway, not just those trucks moving through the facility. For example, if a virtual weigh station replaced an existing facility, the number of trucks by-passing the weigh station would be equal to the number of trucks in 1.2.c.

f.) Post-technology average time savings that will be gained from bypassing the facilities (in minutes) for trucks that would no longer be required to stop at the weigh/inspection station.

Using the information input in this section, the model will derive the total change in the amount of fuel used, based on a default gallons/hour value for truck idling, which can be updated in the default values tab.

2. Will there be a change in transactional costs for the carriers (e.g., scheduling)?

This measure tracks the benefits gained by the users of the freight highway system as a result of implementing a technology that improves administrative functions such as driver logs, and electronic scheduling tools at port facilities. Populate this section if the technology will reduce the total administrative burden on users of the freight highway system.

The model requires some aggregate statistics from the trucking companies that operate in the targeted improvement area:

a.) Input the current total number of employees at trucking companies that perform administrative functions, such as scheduling, managing hours of service, or tracking deliveries.

b.) Input the amount of time each of the employees (identified in question 2a) spends performing these administrative functions (in hours).

c.) Input the percent reduction in administrative time resulting from implementing the technology (input percentage as whole number e.g., 5 percent = 5).

3. Does the technology improve truck parking safety?

These numbers are used to measure the benefit of fewer accidents resulting from implementing safer truck parking technologies. While this question addresses a specific technology, any technology that has the same outcome can be substituted because the model calculates a reduction in accidents. Enter these values if the technology will reduce the total accidents in the area of heavy truck activity such as truck stops, off-highway parking, and rest stations.

To perform these calculations, the model will need some high-level accident information:

a.) Input the average annual number of truck accidents resulting in fatalities along the targeted segment of highway or in the truck parking area where the technology will be implemented.

b.) Input the average annual number of truck accidents resulting in injuries along the targeted segment of highway or in the truck parking area where the technology will be implemented.

c.) Input the expected reduction in fatal accidents that the technology will have on the existing accident rate (input percentage as whole number e.g., 5 percent = 5).

d.) Input the expected reduction in injury accidents that the technology will have on the existing accident rate (input percentage as whole number e.g., 5 percent = 5).

4. Will there be an increase in truck electrification stations or idling reduction stations?

This section measures the operational benefits of truck electrification stations from two types of improvements: adding new stations and increasing the use of existing stations. A yes answer will display two follow-on questions, 4.1 and 4.2, requesting inputs for each type of improvement. If a planned improvement both adds new stations and increases existing usage, answer the questions in both subsections. The primary impact the model will evaluate is decreased fuel use, as more trucks will be able to run heat, air conditioning, and other amenities without idling.

4.1 Will there be new facilities?

These values are used to calculate a total change in fuel consumption resulting from a change in the number of electrification or idle reduction stations. Populate the questions in this section if new stations are a planned infrastructure improvement.

The model requires three simple inputs about the new stations, specifically:

a.) Enter the number of new facilities.

b.) Input the average number of electrification bays/idling reduction stations per facility.

c.) Enter how long each facility will operate per day (in hours). It is assumed that the facility operates 365 days a year.

4.2 Will there be an increase in use of existing facilities?

If the investment will increase the use of existing electrification or idle reduction stations, populate the inputs in this section. The data required are similar to question 4.1 inputs, but additional information is required for the baseline utilization amount and the post-implementation change in station use. The model requires six inputs, specifically:

a.) Enter the number of electrification bays/idling reduction stations.

b.) Input the number of days in operation per year.

c.) Average daily use level before the technology.

d.) Average number of electrification bays/idling reduction stations in use before the technology.

e.) Average daily use level after the technology is implemented.

f.) Average number of electrification bays/idling reduction stations in use after the technology is implemented.

Using the input in this section, the model will derive the total change in the amount of fuel used based on a default gallons/hour value for truck idling.

5. Are there any additional operations benefits that have not been accounted for in the questions?

Use this section to input an amount (in dollars) of any additional operations benefits that have not been addressed by the questions in this section. The value input in this field will be added to the total amount in the economic benefits section.

C.3 Safety Impacts

The Safety Impacts category assesses the freight transportation system's impact on accident rates. The performance measures focus on changes in safety.

Note that the "Operations Impacts" module requests information about safer truck parking. Do not include these changes to the accident rates in the safety module to avoid double-counting safety impacts.

1. Would the technology change the accident rate of highway users?

Use this section to set the baseline conditions of the study area. If the technology is expected to change the accident rate of highway users, enter the following values to properly assess the safety impacts.

a.) Vehicle miles traveled (VMT) is measured in millions of VMT per year (e.g., 100 VMT = 100,000,000 VMT). VMT is calculated by multiplying the number of miles being analyzed by the number of vehicles traveling on that segment per year.

b.) Percent of highway that is urban – The percentage of the study segment that is in an urban area. The percentage that is not urban is assumed to be rural.

c.) Percent of vehicles that are trucks – The percentage of all vehicles traveling on the study segment that are freight carriers. The percentage that is not trucks is assumed to be automobiles.

2. Do you have specific accident rate information for the study area?

Answer "yes" to this question if the technology is expected to change the rate of accidents along the targeted segment of highway. Answer "no" to skip accident rate inputs, or use the default accident rate values.

3. How do you have accident rate information?

Because States can compile accident statistics in a couple different formats, the model offers two common methods used to compile accident statistics. These scales are used to provide indicators of accident severity so that accident investigators and State and Federal DOT administrators can categorize accident events for evaluation and tracking. The model will accommodate accident data with the following two formats:

- **KABCO severity scale** (National Safety Council, 1990) is used by law enforcement to classify injury severity using five categories: K = Killed, A = Severe Injury, B = Other Visible Injury, C = Complaint of Pain, and O = Property Damage Only. These definitions may vary slightly for different states.

- **Fatalities, Injuries, Property Damage Only (FIPDO)** accident categorization. Selecting this option allows analysts to input accident rate information for fatalities, injuries, and property damage only.

For more information on these accident formats, see FHWA Research Report: FHWA-RD-91-0155, The Costs of Highway Crashes, McLean, VA, October 1991

4. Is the accident rate information separate for trucks and autos?

This question is used to further define the accident rate data. Accident rate data can be reported for all vehicles types combined or accident rates for autos and trucks separately. The model allows the analyst to account for differences in the rate between autos and trucks. If the technology is only expected to change truck-related accident rate information, the analyst should choose the option for separate auto and truck accident rates. The default values are the national average accident rate values. In the absence of specific accident rate information for the study area, the model will use these default values.

Select the options that best fit the data available. Select "No" if the data available apply to both autos and trucks combined. Select "Yes" if the data are specific to trucks and autos. This selection will influence the number of inputs required in the remainder of the section. Separating autos and trucks requires two inputs, one for each, where combined data only requires one input.

5. Will the technology change the total number of accidents occurring?

A change in the accident rates resulting from a new technology is derived from percentage reductions input for each accident type. Input the percent reduction for each type of accident that will result from implementation of the new technology (input the percentage as whole number e.g., 5 percent = 5).

6. Does the technology result in fewer truck-related accidents involving highway workers?

This section quantifies the safety benefits specific to a reduction in truck-related fatality and injury accidents involving highway workers that result from implementing a new technology. Reduction in truck-related accidents can be achieved with safer technologies, processes, driving conditions, equipment, or infrastructure. Answer "Yes" to this question if the technology will result in a change in truck-related accident involving highway workers.

If the technology is expected to result in fewer truck-related accidents involving highway workers, several inputs will be required. To perform these calculations, the following high-level accident information is required:

a.) Input the average annual number of truck accidents resulting in highway worker fatalities along the targeted segment of highway where the technology will be implemented.

b.) Input the expected percent reduction in truck accidents resulting in highway worker fatalities from implementing the technology (input percentage as whole number, e.g., 5 percent = 5).

c.) Input the average annual number of truck accidents resulting in highway worker injuries along the targeted segment of highway where the technology will be implemented.

d.) Input the expected percent reduction in truck accidents resulting in highway worker injuries from implementing the technology (input percentage as whole number, e.g., 5 percent = 5).

7. Are there any additional safety benefits that have not been accounted for in the above questions?

Use this section to input (in dollars) any additional safety benefits that have not been addressed in the other sections. The values input in these fields will be included in the social benefit results.

C.4 Implementation and Startup Costs

The Implementation and Startup Costs section is where the analyst enters the costs associated with implementing a new technology within the highway system. Analyst inputs for this section should consist of the costs to field and deploy the new technologies and are considered one-time costs incurred at the start of the program. These costs are not intended to recur on a yearly basis and should be entered using present value dollars.

1. Is any special equipment required?

Populate this section if implementing the technology requires any specialized equipment to be purchased, leased, or rented in addition to the technology itself. This specialized equipment will be dedicated to the installation or maintenance of the new technology and will have limited other applications. The model uses this measure to perform a simple calculation based on the values provided for total units of the equipment (1a) multiplied by the cost per unit in present value dollars (1b).

2. Are infrastructure changes/improvements required?

Populate this section if infrastructure improvements not included in the cost of the technology are necessary to support the use or installation of the technology. Infrastructure improvements can include items such as new buildings, gantries, signs, and computer or network hardware and software integration costs. This model will not guide the analyst through estimating costs of infrastructure improvements, so these costs should be estimated independently of the model and input in this section. The model uses this measure to perform a simple calculation based on the values provided for the total number of facilities that require an improvement (2a) multiplied by the cost per facility in present value dollars (2b).

3. Does the technology require setup/installation?

Input values into this section for costs associated with the setup, installation, and testing of the new technology, whether performed internally or by contract. These are costs that are incurred in addition to the purchase price of the technology. If the particular technology price includes installation and the price of installation is not broken out, then do not populate the values in this section. Answering yes to this question will trigger four follow-on questions:

a.) Input the total installation cost per unit for any work that will be performed by a vendor or contractor. This input can be in addition to work performed by administration staff. Input in present value dollars.

b.) Alternately, input the total cost of vendor or contractor installation services. This value can replace the per-unit cost in 3a, or it can reflect a fixed amount in addition to the per-unit cost. The model will add the total cost values from 3a and 3b together, so leave one blank if necessary.

c.) Input the number of administration staff required to install the technology. These can include line workers or supervisors of contract workers.

d.) Input the number of hours for each administration staff worker identified above will work to install the technology. This value should reflect the total for all workers combined.

The model will calculate administrative labor costs using the workers and hours input in 3c and 3d and multiply them by the administrative hourly cost, which is input in the default values tab. These costs will be added to the contractor/vendor costs input in 3a and 3b.

4. Is initial training required to operate the technology?

Input values into this section for costs associated with training users, including administrative users, and training and public outreach for the general public and highway users. These are costs that are incurred during the initial implementation and ramp-up period and should not include any ongoing training, maintenance, or public outreach. Answering yes to this question will trigger five follow-on questions:

a.) Input the number of administration (office) staff who will require training on the operation or administration of the new technology.

b.) Input the total number of hours of training for each of the administrative staff members identified in question 4a. This value should reflect the total for all workers combined.

c.) Input the number of compliance staff (field workers at weigh/inspections stations) who will require training on the operation of the new technology.

d.) Input the total number of hours of training for each of the compliance staff members identified in question 4c. This value should reflect the total for all workers combined.

e.) Input any additional training costs not covered in questions 4a through d. Costs can include external training personnel, cost of advertising and publicity, and cost for travel to training sites, among others. Input the value as a total cost for these activities in present value dollars.

The model will calculate administrative and compliance personnel training costs using the workers and hours input in 4a through d and multiply them by the administrative and compliance hourly costs, which are input in the default values tab.

5. Are there any additional implementation and startup costs that have not been accounted for in the above questions?

Use this section to input any additional implementation and startup costs that have not been addressed in the other sections. The value input in this field will be added to the total amount in the costs section.

C.5 Operations and Maintenance Costs

The Operations and Maintenance Costs section calculates the costs associated with the technology over the period of performance. Analyst inputs for this section should consist of ongoing costs for operating and maintaining the new technology and should be planned yearly for the duration of the project. Ongoing costs include equipment operation and repair, utilities and other ongoing support, and recurring staff training.

1. Does the technology require staff to operate?

This section requires information on the annual labor cost to operate the new technology or to perform any new or ancillary processes or operate equipment as a result of implementing the new technology. These inputs represent new labor in addition to existing labor requirements. For the model to derive the FTE value:

a.) Input the total number of full-time administrative employees required to operate the new technology. Administrative employees perform office or clerical functions relating to the technology.

b.) Input the total number of full-time compliance staff employees required to operate the new technology. Compliance staff employees perform field work or technical duties (such as at an inspection station) relating to the technology.

The model will calculate FTE hours by multiplying the number of employees (1a and 1b) by the expected number of employee annual work hours. The default value in the model is 2,080 (40 hours per week times 52 weeks), which can be adjusted in the default values menu.

See the default values menu for the default inputs for calculations in this section. The model calculates costs using an input for labor wage per hour for both administrative and compliance staff employees. These numbers should represent the average fully burdened wage including overtime per worker for all workers performing compliance activities. They can be adjusted in the default settings tab.

2. Is annual training required?

This section requires information on the ongoing annual training required to operate the new technology or to perform any new or ancillary processes or operate equipment as a result of implementing the new technology. This training is in addition to the initial startup training input under the startup and implementation costs section. Recurring training costs can include regularly scheduled refresher training, new hire training specific to the technology, or advanced training as needed. The inputs are for annual training; for other training frequencies, convert the total into an annual number (e.g., by multiplying a monthly total by 12 or dividing a biannual number by 2).

a.) Input the number of administration (office) staff who will require training on the operation or administration of the new technology.

b.) Determine the number of hours of training per year for each administrative staff member identified in question 2a. Input the total hours for all administrative staff.

c.) Input the number of compliance staff (field workers at weigh/inspection stations) who will require training on the new technology.

d.) Determine the number of hours of training per year for each compliance staff member identified in question 2c. Input the total hours for all compliance staff.

The model will calculate administrative and compliance personnel training costs using the workers and hours input in 2a through d and multiply them by the applicable administrative and compliance hourly wages, which are input in the default values tab.

3. Does the technology require annual or periodic maintenance?

This section assesses the costs required to keep the new technology operating. Populate the inputs in this section if the technology will incur annual or scheduled maintenance and repair expenditures. Maintenance costs can include repairs and inspections, as well as hardware or software upgrades and license renewals. Answering yes to this question will trigger two options for entering maintenance costs.

a.) Enter an annual amount for maintenance, which will recur every year for the duration of the project (enter annual maintenance is present dollars).

b.) Enter any periodic maintenance costs in the period in which they will be incurred. This input is useful if the maintenance costs increase or decrease in the out years, or if they occur only during select years, such as a software upgrade. (Enter the periodic maintenance costs in current dollars; the model will calculate net present value on any future years’ expected costs based on the discount rate input on the first tab.)

The model will add the present value of the annual amount and the present amount inputs (3a and 3b) together to calculate the total maintenance costs. Ensure that costs in the periodic maintenance do not contain annual maintenance costs or that maintenance costs do not contain periodic costs.

4. Are there annual operations costs not included above (e.g., electricity usage)?

Use this section to input an amount (in dollars) of any additional costs that have not been addressed by the questions in this section. The value input in this field will be added to the total amount in the costs section.

C.6 Results

The “Results” section presents the outcomes of the benefit-cost analysis. The overall results of the analysis and the costs and benefits are presented according to category. Categories include economic benefits (direct economic benefits from the State perspective), social benefits (direct and indirect benefits to freight carriers and the general public), environmental benefits (primarily in the form of reduced air emissions), and implementation/operational costs.

Economic Benefits

Implementing a new transportation technology may change a State’s labor costs, operating costs, and/or infrastructure costs. These types of increased, avoided, or reduced costs are classified as economic benefits (increased costs would be a negative economic benefit). A category for “other” economic benefits is also included to incorporate benefits not captured in the first three categories.

The **labor** category includes any change in number of State employees or how many hours they work that is attributable to the technology being evaluated. Employee changes could be needed for compliance operations, administration, infrastructure, and other agency operations.

Operating costs directly linked to operating and maintaining the technology are addressed in the Cost section. Indirect operating costs are changes to existing State operating costs as an indirect result of the technology, such as a change in highway maintenance costs because fewer overweight vehicles are using the highway. To determine the effect of a transportation technology on State and user costs, the indirect State operating costs need to be calculated both without and with the improvement. The difference between the two cost calculations is the benefit attributable to the transportation technology, either as an operating cost savings or an operating cost increase (i.e., a negative benefit).

Some transportation technologies may result in a change of **infrastructure** costs for the State’s current or planned infrastructure. The changes in infrastructure costs are measured as the difference between the infrastructure costs that would occur without implementing the transportation technology and the infrastructure costs with the transportation technology.

The **other** program benefits are any benefits that are not captured in the categories above. These benefits are calculated outside the BCA tool and then entered into the tool by the analyst.

The annual value for each category is the average annual benefit amount, and the present value is the present discounted value of expected future benefits. Next to each category is a checked box. To exclude one of the categories from the results, click the box to remove the check mark.

Environmental Benefits

Burning fuel releases greenhouse gas (GHG) emissions and criteria air pollutant (CAP) emissions. When a transportation technology decreases fuel use, air emissions would also be reduced. Conversely, an increase in fuel use would increase air emissions. Tracking the reduction of GHG and CAP emissions is beneficial for States that are trying to meet the standard for certain areas of non-attainment.

As fuel consumption and/or idling time decreases, **GHG emissions** would also decrease. GHG emissions are measured in short tons of carbon dioxide (CO2). The monetized value includes net agricultural productivity, damage to human health, property damage from increased flood risk, and the value of ecosystem services.

Similar to GHG emissions, the amount of **CAP emissions** emitted depends on the amount of fuel (diesel or gasoline) consumed, the emission profile, and the fuel efficiency of the vehicle. Any reduction in fuel use translates into a reduction in CAP emissions. CAP emissions from vehicles include volatile organic compounds (VOCs), nitrogen oxides (NOx), sulfur dioxide (SO2), particulate matter (PM2.5), and carbon monoxide (CO). The monetized value includes damage to human health, materials, plants and animals, ecology, visibility, and aesthetics.

The annual value for each category is the average annual benefit amount, and the present value is the present discounted value of expected future benefits. The number of short tons for each type of pollutant is calculated by the model. Next to each category is a checked box. To exclude one of the categories from the results, click the box to remove the check mark.

Social Benefits

Because the BCA is from the perspective of each State, social benefits are defined as benefits that would accrue to the freight carriers, highway users, and general public. Two categories for “other” benefits, one for operations benefits (from the operating impact module) and one for other safety benefits (from the safety impact module), are also included to incorporate benefits not captured in the first three categories.

The **safety** category is primarily the benefit of reducing accident-related personal injuries and property damage from accidents. When the number or severity of accidents, or both, are reduced, the accident-related costs will also be reduced. Accident costs can include fatalities, injuries, property damage (to vehicles and structures), and emergency services. Accident-related traffic delays and additional fuel use are recognized in the "highway users" category.

The **freight carriers** category consists of operating costs such as a change in administrative labor, reduced travel time, and fuel savings. These changes in operating costs are a direct result of the transportation technology and do not include indirect fuel and time savings associated with a reduction in accidents.

The **highway users** category includes indirect fuel and time savings, for both freight carriers and other highway users, resulting from a reduction in accidents.

"Other" (operations or safety) includes any benefits not captured in the categories above. These benefits are calculated outside the BCA tool and then entered into the tool by the analyst.

The annual value for each category is the average annual benefit amount, and the present value is the present discounted value of expected future benefits. Next to each category is a checked box. To exclude one of the categories from the results, click the box to remove the check mark.

Implementation/Operational Costs

The **implementation and startup** costs are the first costs required to implement the transportation technology. These costs are incurred during the first year of the project. Costs associated with projects that are financed over several years (i.e., finance charges and interest) can be entered in the "other" category.

The **operation and maintenance** costs are those that recur annually and/or periodically during the analysis period. Operation and maintenance costs may include additional labor hours needed to operate the transportation technology, annual training for staff, and annual or periodic maintenance of the transportation technology.

Any implementation and startup or operation and maintenance costs not captured in the categories above can be input into the **"other"** category. These costs are calculated outside the BCA tool and then entered into the tool by the analyst.

The annual value for each category is the average annual benefit amount, and the present value is the present discounted value of expected future benefits. Next to each category is a checked box. To exclude one of the categories from the results, click the box to remove the check mark.

Project Assumptions

The **base year** should be the year that operational costs and benefits begin accruing for the project, also known as the first year of implementation. The evaluation date is the nominal start of the technology implementation period, or Period 0, and spans the period of analysis. Period 0 is the base year for the project. Any costs or benefits occurring in future years would be discounted to the base year. Any costs incurred during Period 0 will not be discounted. The initial technology implementation and training cost is anticipated to occur in Period 0. Benefits begin to accrue at the beginning of Period 1. The recurring operating and maintenance costs of the technology and annual benefits are estimated over the remaining period of analysis. Estimated costs and benefits are discounted back to the base year to determine the present value.

Benefits and costs are evaluated for a period that includes the installation of the transportation technology and the operations period, referred to as the **analysis period**. The analysis period should be commensurate with the expected life of the transportation technology (in years), beginning from the base year. The analyst can adjust the period of analysis to an appropriate time frame.

The **discount rate** is used to compare the value of a dollar received/spent in the future to a dollar received/spent today. The higher the discount rate, the lower the present value of future cash flows. For investments with costs incurred earlier and benefits following later, a higher discount rate tends to reduce the economic feasibility of the project. All benefits and costs are expressed in constant dollars, which avoids forecasting future inflation and escalating future values for benefits and costs accordingly. The use of constant dollar values requires the use of a "real discount rate." A "real discount rate" is one that has been adjusted to eliminate the effect of expected inflation and measures the risk-free interest rate that the market places on the time value of money. The time value of money concept represents a person's preference to consume a resource (such as money) sooner rather than later, meaning the value of the resource in the future is less than the value of the same resource today. The BCA tool uses end-of-year discounting, meaning all benefits and costs are assumed to occur at the end of each year.

Results

The **total benefits** and the **total costs** are calculated as the present value. Total benefits include all benefits from the economic, social, and environmental categories. Total costs include implementation and operational costs.

Net present value (NPV) is the difference between the present value (i.e., discounted value) of the technology's projected total benefits and costs over the period of analysis. If the NPV is positive (i.e., the discounted total benefits exceed the total costs), then investing in the technology would typically be considered worthwhile. When comparing technologies, a technology estimated to have a higher NPV would indicate that the technology will result in greater net benefits overall than a technology with a lower NPV.

The **benefit-cost ratio** (BCR) measures whether the benefits exceed the costs of an investment and is calculated as the net present value of benefits divided by the net present value of costs. A BCR greater than 1.0 indicates that the benefits of the transportation technology exceed the costs, and therefore, the technology would be a cost-effective use of resources. When comparing technologies, a technology with a higher BCR would be considered a more cost-effective use of resources; however, that would not necessarily guarantee greater total benefits.

The **financial return on investment** (ROI) is the ratio of the net value of an investment relative to the cost of the investment. The financial ROI only includes the economic benefits, whereas the **sROI** includes the economic, social, and environmental benefits relative to the cost of the investment.

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