Development of a Toolkit for Cost-Benefit Analysis of Specific Winter Maintenance Practices, Equipment and Operations:

User Manual

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DISCLAIMER

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EXECUTIVE SUMMARY

To achieve the benefits that various winter maintenance practices, equipment and operations present, agencies must first determine which of these offer the most significant benefits given their costs. The process required in order to make such a determination is cost-benefit analysis. . In a winter maintenance context, where the various costs and benefits of practices, equipment and operations vary greatly and are only sporadically reported (particularly quantified benefits), cost-benefit analysis may present a significant challenge to winter maintenance managers. These personnel are already charged with a range of managerial tasks and often lack the time to track down the requisite information to complete a thorough cost-benefit analysis to assess the addition of a new practice, equipment and operations to their existing toolbox for snow and ice control.

In light of this, the Clear Roads pooled fund identified the need for a research project to develop a toolkit which would facilitate cost-benefit analysis for a series of winter maintenance practices, equipment and operations. The purpose of this toolkit is to streamline the cost-benefit process and assist maintenance managers in meeting the demand of maximizing the benefits accrued versus the costs incurred when adopting a new practice, equipment or operation in a more efficient manner and justify the expenditures they propose.

To date, work quantifying the costs and benefits of various aspects of winter maintenance has been completed to various degrees. The result is that it is now feasible to develop a toolkit that brings such information together in one place and provide maintenance managers with a platform on which to quantify the expected benefit-cost ratio of selected practices, equipment, and operations. This document serves as the User Manual and training guide for the toolkit that has been developed. The intention of this document is to provide the user with a step-by-step process on how to use each of the items incorporated in the toolkit. Through its use, a practitioner will be able to walk through the process of completing a cost-benefit analysis for any toolkit item they select. The calculations involved in that analysis are completed automatically; the user is only required to provide input data for use in completing those calculations.

The toolkit facilitates benefit-cost analysis for the following winter maintenance items:

- Anti-icing
- Deicing
- Carbide blades
- Front plows
- Underbody plows
- Zero velocity spreader
- Maintenance Decision Support Systems (MDSS)
- Automatic Vehicle Location and Geographic Positioning Systems (AVL/GPS)
- Road Weather Information Systems (RWIS)
- Mobile pavement or air/pavement temperature sensors

This toolkit should allow winter maintenance managers to evaluate and justify expenditures on a variety of practices, equipment, and operations. The simplified nature of such a toolkit will also allow for a reevaluation of materials and procedures to be made on a frequent basis, as well as provide for the inclusion of additional information to account for new and emerging practices, equipment and operations in the future.

1. INTRODUCTION

The operators and maintainers of highway networks are facing increasing demands and customer expectations regarding mobility and transportation safety, especially during inclement weather, while also confronting unprecedented budget and staffing constraints and growing environmental concerns related to materials usage. Maintenance agencies are also continually challenged to provide a high level of service (LOS) and improve safety and mobility in a cost-effective manner. These objectives of winter road service may conflict or complement one another. In this context, it is desirable to use the most recent advances in the application of anti-icing and deicing materials, winter maintenance equipment and vehicle-based sensor technologies, and road weather information systems (RWIS) as well as other decision support systems. Such best practices are expected to improve the effectiveness and efficiency of winter road operations, to optimize materials usage, and to reduce associated annual spending and corrosion and environmental impacts.

Despite dwindling or flat budgets, significant expenditures are still made with respect to winter maintenance activities. The U.S. spends $2.3 billion annually to keep roads clear of snow and ice (1); in Canada, more than $1 billion is spent annually on winter maintenance (2). In addition to labor costs, these funds are expended on a variety of materials and equipment, each featuring its own unique set of costs and benefits. Just as the conflicting objectives faced by agencies make the task of cost-benefit analysis difficult, so do the multiple alternatives of practices, equipment, and operations employed in winter maintenance activities. For instance, some products for snow and ice control may cost less in materials, equipment and labor, but cost more in the long run as a result of their corrosion and environmental impacts.

To achieve the benefits that various winter maintenance practices, equipment and operations present, agencies must first determine which of these offer the most significant benefits given their costs. The process required to make such a determination is cost-benefit analysis. In a winter maintenance context, where the various costs and benefits of practices, equipment and operations vary greatly and are only sporadically reported (particularly quantified benefits), cost-benefit analysis may present a significant challenge to winter maintenance managers. These personnel are already charged with a range of managerial tasks and often lack the time to track down the requisite information to complete a thorough cost-benefit analysis to assess the addition of a new practice, equipment and operations to their existing toolbox for snow and ice control.

In light of this, the Clear Roads pooled fund identified the need for a research project to develop a toolkit which would facilitate cost-benefit analysis for a series of winter maintenance practices, equipment and operations. The purpose of this toolkit is to streamline the cost-benefit process and assist maintenance managers in meeting the demand of maximizing the benefits accrued versus the costs incurred when adopting a new practice, equipment or operation in a more efficient manner and justify the expenditures they propose.

This toolkit should allow winter maintenance managers to evaluate and justify expenditures on a variety of practices, equipment, and operations. The simplified nature of such a toolkit will also allow for a reevaluation of materials and procedures to be made on a frequent basis, as well as provide for the inclusion of additional information to account for new and emerging practices, equipment and operations in the future.

To date, work quantifying the costs and benefits of various aspects of winter maintenance has been completed to various degrees. The result is that it is now feasible to develop a toolkit that brings such information together in one place and provide maintenance managers with a platform on which to quantify the expected benefit-cost[1] ratio of selected practices, equipment, and operations. This document serves as the User Manual and training guide for the toolkit that has been developed. The intention of this document is to provide the user with a step-by-step process on how to use each of the items incorporated in the toolkit. Through its use, a practitioner will be able to walk through the process of completing a cost-benefit analysis for any toolkit item they select. The calculations involved in that analysis are completed automatically; the user is only required to provide input data for use in completing those calculations.

1.1. Cost-Benefit Analysis

In order to determine whether a practice, equipment, and operation should be implemented, the value of the costs associated with it, as well as the value of the resulting benefits must be considered. This consideration includes both tangible and intangible costs and benefits. Intangible costs and benefits are those for which a monetary value cannot be assigned. In the case of a winter maintenance practice, equipment, and operation, it is more common to observe benefits for which a monetary value cannot be readily assigned.

After researching the methodologies developed elsewhere, a standard methodology was designed in which costs and benefits were grouped by whether they applied to the government agency, the user (motorist), or society in general. As is typical in cost-benefit analysis, it was found that costs were easily identified and accounted for, but monetary values were hard to establish for many of benefits associated with winter maintenance items. Benefits were defined as tangible if a monetary value could easily be assigned and intangible if it could not; all benefits, tangible and intangible, are presented to the user in the toolkit. This approach employed by the toolkit in treating benefits is not complete, but it sets a starting point for the winter maintenance community to quantitatively assess choices.

When a financial value can be assigned to most of the costs and benefits, it becomes possible to compute a benefit-cost ratio. This approach is termed Benefit-Cost Analysis. Such procedures are traditionally employed to show the extent to which an investment will result in a benefit to the investor. Benefit-cost ratios greater than 1.0 are generally desired. Given that many of the items under consideration for winter maintenance possess long lives that incorporate present (e.g., initial capital expenditure) and future (e.g., annual maintenance) costs and benefits, there is a need to bring the values of all future costs and benefits accrued to a present value. A discount rate is employed to accomplish this. The discount rate is an opportunity cost value or the time value of the money. Simply stated, it helps to determine how much could the money to be potentially invested in a practice, equipment or operation make if it was invested in another way.

In conducting the cost-benefit analysis within this toolkit, a series of steps are undertaken. These are typically transparent to the user, aside from the provision of inputs (a discount rate, the cost of an item, maintenance, etc. and key assumptions for calculating benefits). However, the

[1] Note that in this text, the terms benefit-cost and cost-benefit are used interchangeably. Each refers to the same analysis, in which the ratio of present-value benefits are compared to present-value costs for an item.

overall process is summarized in the following to provide a better idea of the overall approach employed by the toolkit.

One key step (aside from providing the inputs for cost calculations) is to convert costs into annual and present value forms. Using the project life and discount rate supplied in the project parameters, these values are converted to both a present value and an annual value (or annual equivalent costs) by the following:

Present value = initial costs + the present value of the annualized cost PV(A), where

$$PV(A) = \frac{A}{i} * \left[1 - \frac{1}{(1+i)^n}\right], \text{ where}$$

A = present value of annualized cost

i = the discount rate, and

n = number of years

If the discount rate is zero, then the annualized cost is simply PV(A) = A*n. The toolkit also determines annualized value, which employs the same equations, but instead solves for A as opposed to PV(A).

Although users can only input annual benefits, these values are also converted into both annual and present value form. This is because although they are accrued annually, many benefits will materialize over an extended time period. The process and equations employed match those discussed for determining cost values. The present value is the total cost of the choice in today's dollars; the annualized value allows for better comparison between choices with different life spans.

Once present and annual values are available for costs and benefits, it is possible to calculate the benefit-cost ratio. This is calculated by dividing present value benefits by present value costs, or annual equivalent benefits by annual equivalent costs. The benefit-cost ratio is calculated agency-specific costs and benefits, as well as total costs and benefits. Total costs and benefits include both those accrued by the agency, as well as from other sources, such as road users and the overall society (via crash reduction, travel time savings, etc.).

1.2. Web Site Development Environment

The Cost Benefit Analysis toolkit was developed with open source tools to minimize the cost of development while maximizing functionality and providing a mean for easier expansion. Open source provides for freely distributable, tested software created by a community of developers which share a common problem. The toolkit uses the Joomla Content Management System (CMS), which was chosen because it is easy to use, has existed for a few years so it is relatively stable, and is free open source software. Joomla runs on the common LAMP (Linux, Apache, MySql, PHP) configuration which is comprised of all open source components. Joomla also allows for relatively easy updates to the content by non technical personnel and possesses a built in user management system which will ease in the expansion of the toolkit in the future.

Fabrik is an open source module that runs inside Joomla which was used to build the data entry forms. Fabrik has existed for a number of years and is well supported. It provides the tool necessary for saving the form fields to the database without having to write special database access tools. A downside to Fabrik is that it does not employ a very well structured change management system, which was not readily apparent at the beginning of the programming involved in this toolkit. Instead, Fabrik takes an ad hoc approach to making changes to the core software and does not employ much regression testing, which may cause other parts of the system to fail after a change is made to the software. Despite this shortcoming, the open source components used to build the toolkit provide for future expansion and can accommodate other winter maintenance technologies should they be of interest.

1.3. Cost-Benefit Toolkit Overview

The toolkit that has been developed by this project is the result of input from the Clear Roads Technical Advisory Committee (TAC) and winter maintenance practitioners. This input was solicited primarily through an online user survey, as well as through direct communication with the TAC. As the result of this input, the preference indicated by all parties was that the toolkit should take the form of a website (in place of other alternatives such as an Excel spreadsheet application and a stand-alone desktop program). When the remainder of this document refers to the toolkit, it is in reference to this website.

Based on feedback from practitioners and the TAC, an initial series of ten items were selected for inclusion in the current version of this toolkit, including:

- Anti-icing
- Deicing
- Carbide blades
- Front plows
- Underbody plows
- Zero velocity spreader
- Maintenance Decision Support Systems (MDSS)
- Automatic Vehicle Location and Geographic Positioning Systems (AVL/GPS)
- Road Weather Information Systems (RWIS)
- Mobile pavement or air/pavement temperature sensors

Based on their selection, information was gathered from research results and vendors in order to quantify[2] the various costs and benefits associated with each item.

The website itself has been developed and tested to function across multiple browsers (i.e. Internet Explorer, Firefox, etc.). ***Users should note that depending on the browser, the ability to input data may be slightly affected. For example, in Internet Explorer version 8.0, the user will need to verify they are not running in "Compatibility Mode" in order to enter data immediately in various calculators. If this mode is not disabled, the user will need to iteratively open and close each calculator one to two times before the data input function operates in its intended manner.*** In general, this issue may occur regardless of mode, and the user should be aware that entering and exiting a calculator has resolved the problem during testing. The user is encouraged to verify that the values they have entered are being taken into

[2] "Quantify" as used in this document refers to the assignment of a monetary value to a cost or benefit associated with a toolkit item.

account during the subsequent calculations performed; if they are not, the value should be reentered.

Data elements are input via a series of text boxes. In some cases, conservative default values are already entered; the user is free to change these to whatever value is warranted in their particular case. Information buttons and calculators are present throughout the toolkit to assist the user in determining when particular elements might be included, as well as what the financial implications might be.

The initial step in the toolkit seeks project parameter information, or the basic information required to complete the analysis (analyst name, number of vehicles in fleet, etc.). Next, cost information is entered, with the user selecting specific costs that will be employed (in some cases, different elements of a practice, equipment, and operation are not required, so their costs can be excluded). This is followed by the selection and entry of specific anticipated benefits, functioning in a similar manner to the cost component of the toolkit. Based on the benefits selected, the next step is the quantification of those benefits. The toolkit concludes with a presentation of cost and benefit results, including the benefit-cost ratio. For users that wish to have more information for reference or presentation, a brief white paper is also provided summarizing the results of existing research related to the particular item, such as previous case studies.

1.4. Data Requirements

As one might expect, the varied items included in the toolkit have different data requirements. These range from minimal data needs for an item like mobile temperature sensors to more extensive inputs for an item like AVL. The specific data requirements for each toolkit item are presented in the respective chapter covering that particular item. To inform the reader, a general overview of the various data needs for the toolkit is as follows:

- Number of trucks to equip
- Number of garages or sheds (may only be one, unless level of detail is larger)
- Loaded labor rate per hour (e.g., the typical cost of shop labor per hour, including benefits)
- Average labor hours per storm per vehicle (e.g., the average time a plow is out operating)
- Annual material costs (anti-icer, deicer, abrasives, etc.)
- Annual number of storm events (average or estimate)
- Lane miles covered per storm by all maintenance vehicles
- Total storm-related crashes (estimate if actual figures are unavailable)
- Total number of winter maintenance vehicles in fleet
- Type of deicer to be used (granular or liquid)
- Measure used in recording the lifespan of blades (miles, storms or hours)
- Routes covered by plows (Interstate or secondary)
- Miles covered by a plow over the course of a winter season
- Average time to change blade inserts (current time spent per plow)
- Average plowing duration (hours) per storm event
- Blade insert lifespan (average number of storms between replacement)
- Annual storm-related crashes and crash values
- Estimated hours to install and maintain spreader equipment

- Number of computers that MDSS software would be installed on
- Number of vehicles equipped with Mobile Data Collection
- Number of computers that AVL software would be installed on
- Number of vehicles equipped with AVL
- Operating cost per mile (if known)
- Hours per vehicle per storm spent on paperwork/reporting
- Current weather information costs (if any, e.g., for weather forecasts)
- Number of planned/existing RWIS stations
- Expected or existing number of RWIS users
- Annual hours of RWIS training required (expected or current) per user

These points are listed to prepare the potential user and illustrate the type of data that may be required for the various toolkit items. Note that not all of the points in this list are required inputs for each toolkit item. It is understood that different agencies collect different data and maintain different records. As such, the user may find that a piece of information required as an input for a specific toolkit item may not be available. In such a case, an estimate made by the user may be acceptable. In other cases, e.g., dealing with crashes, the user would be advised to not enter any data (e.g. enter a zero value), as this is more conservative than entering an estimated number of crashes.

1.5. Cost Information

Information provided in the toolkit related to the cost of specific practices, equipment and operations is presented by various information buttons/icons. The information presented came from a variety of manufacturers either through direct contact (telephone call) or information presented on the internet (manufacturer website). In some cases, limited cost information was provided by practitioners via the internet surveys conducted during this project. The information provided in this toolkit is for user reference and guidance only. ***The user is strongly encouraged to obtain individual cost quotes specific to the application they plan to evaluate/analyze using this toolkit***.

1.6. Known Gaps and Issues

As one might expect, some items have less information (particularly related to quantified benefits) than others. The more widely adopted or employed an item is, the more likely good quantified cost and benefit values are to exist (e.g., RWIS). This disparity of quantified values is one of the toolkit's shortcomings and is expected to be addressed by future research. While every attempt has been made to achieve a quantified value for costs and benefits associated with an item, the fact is that some significant potential values associated with benefits have not been developed. For example, the use of AVL is likely to reduce storm-related crashes and produce a cost avoidance or savings (through reduced injuries, property damage, etc.). However, no existing research has quantified the contribution by AVL to reduced crashes when used in conjunction with other winter maintenance practices (plowing, deicing, etc.). As such, a benefit-cost ratio less than 1.0 in some cases does not necessarily disapproves the investment in a certain practice, equipment, or operations, if there are significant intangible benefits to be achieved.

During the course of toolkit testing and validation, some issues have been identified which may potentially impact the user. For example, while developed to function in all of the most up-to-date web browsers, in Internet Explorer the toolkit may not automatically populate all necessary fields when a data input calculator is opened the first time. In such an instance, the user will need to exit and reenter the calculator a couple of times before the field is populated. This issue stems from the content management system running the overall program behind the scenes. The issue does not impact the calculations eventually conducted once the fields are populated.

Some minor formatting issues also exist that vary from browser to browser. These primarily consist of the alignment of certain data items on the screen. While every attempt has been made to address this issue, it may still exist depending on the browser version employed by the user. A future version of the toolkit may address such issues, along with implementing critical improvements suggested by users.

1.7. Manual Overview

At a high level, this user manual is intended to provide a step-by-step walk-through of each toolkit item. It has been developed using real-world data inputs from three states: Indiana, Iowa and Washington. This data came from a finer level – typically the garage or shed – with the intention of avoiding the complexities and overwhelming nature of statewide data.

The manual is divided into 10 chapters covering use of each toolkit item, followed by 2 additional chapters covering conclusions and implementation recommendations.

2. TOOLKIT OVERVIEW AND HOME PAGE

This chapter presents a high-level overview of the toolkit for reader familiarization. It also discusses the initial toolkit homepage the user will see when initially entering the website.

2.1. Toolkit Overview

The toolkit has been built in a manner that walks the user through a benefit-cost analysis in a series of steps. Based on the practice, equipment or operation selected by the user, they will be presented with a series of web pages that represent the steps of benefit-cost analysis and require various item parameter, cost and benefit values to be entered. These steps are as follows:

- Step 1 of 5: Define Project Parameters – On this page, the user will provide specific parameters related to the application of the item they plan to analyze at their agency. Depending on the toolkit item being examined, this will likely include information such as the number of vehicles the item will be applied to, the total size of the vehicle fleet, annual material expenditures, and so forth.
- Step 2 of 5: Enter Costs – On this page, the user will enter initial and annual costs specific to the agency. Such costs include the purchase price of the item of interest, installation, and so forth. Annual costs pertain to recurring costs such as yearly maintenance, communications, and so forth. In addition, while the developers of the toolkit did not identify any quantified values for them, the user may also enter costs to the user (ex. increased motorist delay) and society (ex. increased environmental harm) on this page.
- Step 3 of 5: Benefits – This page does not require input from the user. Rather, it presents the user with a list of quantified and nonquantified benefits that may be achieved by the agency, user and society through the use of the item being examined. The intention of this page is to make the user aware of all benefits that may be achieved, although many of these have no dollar value associated with them (i.e. nonquantified).
- Step 4 of 5: Benefit Quantification – On this page, the user will enter values related to the determination of benefits that use of an item will produce for the agency, user and society. In most cases, only the agency benefits can be quantified. For example, the item may produce an expected percent reduction in material use, resulting in a benefit to the agency. In some cases, the user may also receive a quantified benefit, such as a reduction in crashes occurring over a season. In no case did the toolkit developers encounter any information related to quantified benefit values for society. However, if the user has such values to enter, the toolkit provides a mechanism to do so.
- Step 5 of 5: Results – The final page the user will see presents the results of their analysis. This report includes an overview of the item being examined, related items that it may be used with, a summary of all the parameter, cost and benefit values they have entered, as well as the benefit-cost ratios that the toolkit has calculated.

2.2. Terminology

The toolkit employs several terms that may not be familiar to the user. These are presented with definitions in the glossary in Appendix A.

2.3. Toolkit Home Page

When initially visiting the toolkit, the user will be presented with the home page. This page provides general information about the toolkit itself. A screen capture of the toolkit home page is presented in Figure 2-1.

Figure 2-1: Toolkit home page

As the user will see, the left side of the screen will present a menu containing links to various toolkit options. The "Home" link brings the user to the displayed page. The "Cost Benefit Analysis" link brings the user to the page with the listing of equipment, tools, and practices. This menu link functions in the same manner as the button titled, "Begin Cost Benefit Analysis" in the middle of the page. The Resources link provides a listing of relevant links and documents pertaining to Benefit-Cost analysis. Finally, the "Contact Us" offers a contact point for this web page.

2.4. Key Toolkit Points

The user is encouraged to keep a few specific points related to this toolkit as they progress through it. These include the following:

- Benefit-cost ratios much greater than 1.0 are generally desired. A ratio exceeding 1.0 indicates that for each one dollar an agency spends on a particular item (cost), a benefit of greater than one dollar is accrued by the agency (and/or users and society).
- An agency-specific benefit-cost ratio has been included, recognizing sometimes agencies sometimes must make purchasing decisions based on their internal benefit-cost ratio. A total benefit-cost ratio is also included, as this reflects a comprehensive analysis that takes into account user and societal costs and benefits in addition to those of the agency.
- When entering numbers the user should not enter commas and dollar signs, as the software supporting the toolkit calculations does not function properly when these are used.
- The user is strongly encouraged to obtain individual cost quotes specific to the application they plan to evaluate/analyze using this toolkit
- Results show cost-benefit ratios for tangible values; sometimes intangible, non-quantified benefits can be significant and justify a choice where the quantified benefit-cost ratio is below 1.0.

3. ANTI-ICING

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of anti-icing.

3.1. Sample Data

For this example, data provided by the Indiana Department of Transportation will be employed. This data, along with that of Iowa and Washington are presented in Table 3-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 3-1: Anti-icing sample data

Anti-icing	Iowa	Indiana	Washington
Project Parameters			
Number of vehicles to equip	160	*4*	36
Number of sheds	110	1	17
Labor rate	*$21*	*$14*	*$31*
Average labor hours/storm/vehicle	*12*	*12*	16
Annual material costs	*$17,291,152*	$320,673	*$1,800,000*
Annual number of storm events	20	*12*	19
Lane miles covered per storm	24,867	679	2,531
Total storm crashes	8,346	0	383

Italics denote an assumed value for demonstration purposes

Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed are for one subdistrict in the state of Indiana. To begin, the user will select the "Anti-icing" link under the Operations heading on the Technology Selection page. This is displayed in Figure 3-1.

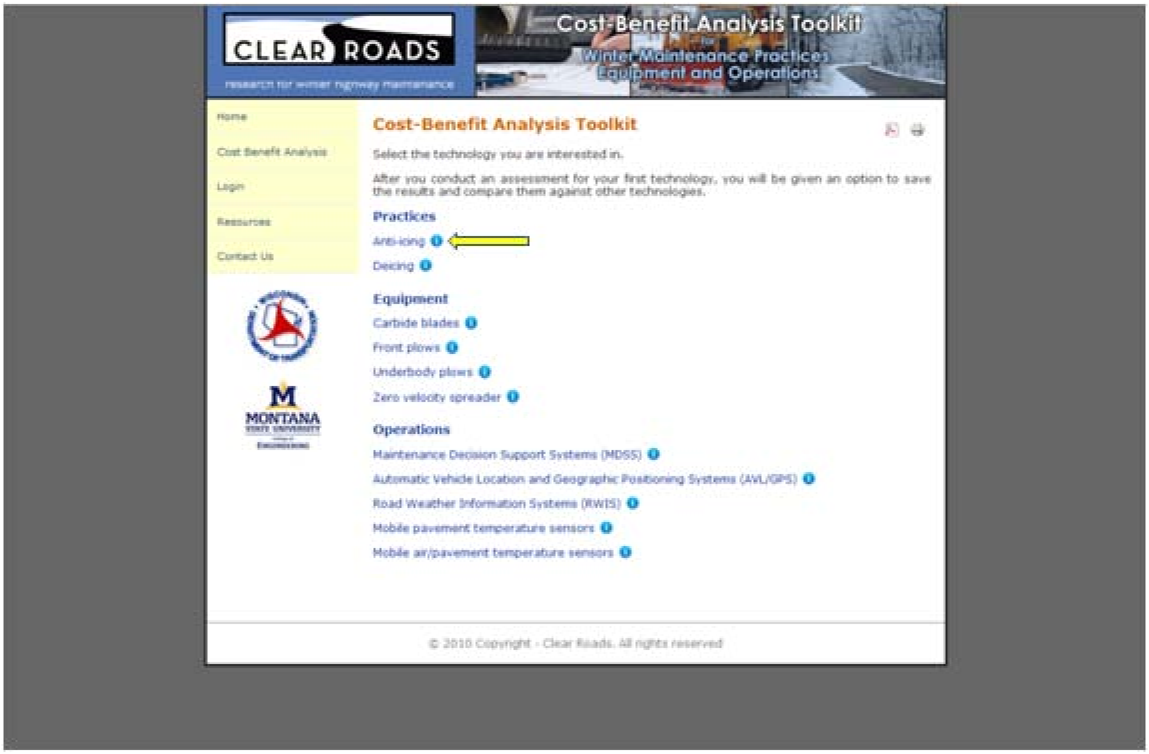


Figure 3-1: Anti-icing selection

3.2. Project Parameters

Once anti-icing has been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (5 years in this example, although the toolkit defaults to a life cycle of 12 years). However, ***the user is encouraged to employ the values presently of their respective agency***. For this example, the 7% rate and 5 year life cycle will be employed, as they are reasonable for demonstration purposes.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Number of equipped trucks. In this example, four trucks will be equipped for anti-icing.
- Total number of trucks. For this example, there is a total fleet of 23 trucks.
- Number of brine-making facilities. For this example, there will be one facility.
- Loaded labor cost. For this example, the loaded labor cost is $14.42.
- Average labor hours per storm. For this example, an assumed labor hours per storm figure of 12 hours is employed.

- Current annual material cost (deicing activities only). For this example, the current cost of materials is $320,673.
- Hours to produce brine material. For this example, an average of 2 hours per brine batch is used.
- Hours spent annual maintaining anti-icing equipment per vehicle. For this example, a figure of 25 hours is used, based on practitioner feedback.
- Annual number of storm events. For this example, an assumed value of 12 events is employed.
- Anticipated anti-icer application rate (gallons per mile). For this example, an assumed value of 50 gallons per mile is used.
- Lane miles covered by jurisdiction. For this example, the total lane miles covered by this subdistrict is 679.
- Annual number of storm related crashes. For this example, a total of 0 crashes is employed.
- Average crash cost. For this example, the cost of $33,700 employed by Ye. et.al. (**Error! Bookmark not defined.**) is employed.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, a material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 3-2.

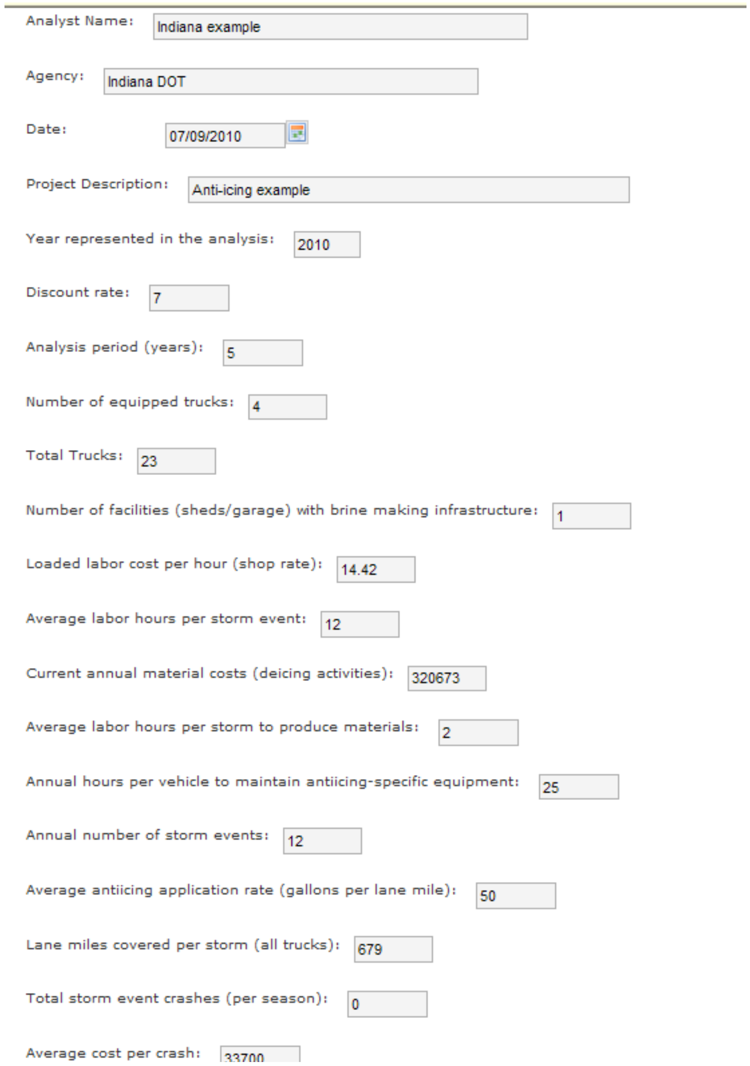

Analyst Name: Indiana example
Agency: Indiana DOT
Date: 07/09/2010
Project Description: Anti-icing example
Year represented in the analysis: 2010
Discount rate: 7
Analysis period (years): 5
Number of equipped trucks: 4
Total Trucks: 23
Number of facilities (sheds/garage) with brine making infrastructure: 1
Loaded labor cost per hour (shop rate): 14.42
Average labor hours per storm event: 12
Current annual material costs (deicing activities): 320673
Average labor hours per storm to produce materials: 2
Annual hours per vehicle to maintain antiicing-specific equipment: 25
Annual number of storm events: 12
Average antiicing application rate (gallons per lane mile): 50
Lane miles covered per storm (all trucks): 679
Total storm event crashes (per season): 0
Average cost per crash: 33700

Figure 3-2: Project parameters data entry

3.3. Cost Entry

Following the entry of initial project parameters, the user is required to enter costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For anti-icing, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the costs associated with the anti-icing equipment, its controller, and brine-making infrastructure. The spreadsheet is designed to automatically populate using the data entered by the user, as shown in Figure 3-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the cost per vehicle for anti-icing equipment is $8,000, its controller $2,389, and brine-making infrastructure $20,000. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.

Initial Costs Worksheet - Anti-icing

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
Tanks and sprayers	8000	4	vehicles	32000	
Flow controller	2389	4	vehicles	9556	
Infrastructure (brine making equipment)	20000	1	buildings	20000	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total initial expenditure				61556	

Figure 3-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet automatically populated with the project parameters. In this case the user will need to enter the annual cost of brine materials, brine plant maintenance and corrosion/environmental costs. The calculator automatically populates the spreadsheet with the costs associated with brine production and annual vehicle maintenance. For this example, the annual brine material cost is estimated to be $0.07 per gallon, brine plant maintenance $2,000, and corrosion/environmental costs $0 per ton of material used. Note that for this example, no environmental/corrosion costs were employed because such costs would greatly outweigh any benefits achieved given the small expenditures on materials and labor at the subdistrict level, as well as in the absence of expected crash savings, producing a benefit-cost ratio of much less than 1.0 (in reality, 0.0). Additionally, the user may enter the annual cost of sanding/grit materials used, as these would be reduced or eliminated by anti-icing. In this example, it is assumed that no such costs exist. Once the user has examined the spreadsheet, they should select the green check mark to return to the main cost page, which will be updated automatically.

Annual Costs Worksheet - Anti-icing

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Material costs	0	407400	gallons	28518	
Production costs	29	12	storms	346	
Equipment maintenance	361	4	vehicles	1442	
Brine plant maintenance	2000	1	buildings	2000	
Corrosion/environmental cost per ton	0	391	tons	0	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Cost of Alternative					
Minus cost of sanding and gritting	0	1	year	0	
Total Annual O&M Costs				32306	

Figure 3-4: Annual costs spreadsheet, manually populated

In the case of anti-icing, no tangible societal costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

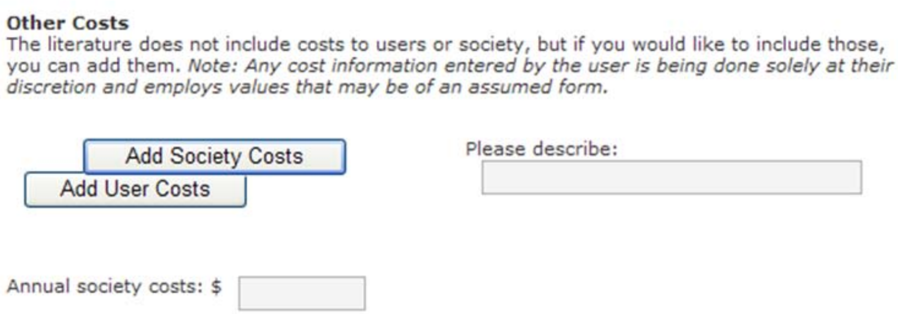


Figure 3-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the anti-icing (in this case over a life of 5 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 3-6.

Figure 3-6: Completed cost page

3.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 3-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".

Cost Benefit Analysis Toolkit - Anti-icing

Anti-icing Supporting Information

Step 3 of 5: Benefits

Research has identified the following potential benefits for Anti-icing. Those in **bold** are included as tangible benefits, while those in regular typeface are included as intangible.

Agency

Reduced material use
Reduced negative impacts to transportation infrastructure due to road salts
Reduced material costs
Reduced labor costs

User (Motorists)

Improved safety
Reduced traffic delay

Societal

Reduced impact on the environment (e.g., water, vegetation, and wildlife)

Figure 3-7: Benefits page

The "Benefit Quantification" screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In this example, the primary quantified benefits are material and labor savings. A conservative value of 15 percent material cost savings has been employed, while a labor savings of 50 percent has been employed based on past reported savings by agencies.

Notice
- We were unable to find the record (id = {AgencyCostBenefitsWorksheet_AI___fabrik_internal_id}) in the database

Agency Benefits Worksheet - Anti-icing

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Material savings	55769.217	15	material	8365	
Driver labor	3009.3913	50	labor	1505	
Other 1 (define)					
Other 2 (define)					
Total Annualized Benefit				9870	

Figure 3-8: Agency benefit calculator

In the case of anti-icing, user benefits, specifically crash reductions, have also been quantified. To include this benefit, the user will select the user benefits calculator by clicking inside the user benefits textbox. For anti-icing, a conservative crash reduction of 10 percent has been employed, although no crashes were reported for this example. The completed user benefits calculator is shown in Figure 3-9.

No known tangible societal benefits have been quantified for anti-icing. Of course, if any societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 3-10. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

User Benefits Worksheet - Anti-icing

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Improved safety	0	10	crashes	0	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				0	

Figure 3-9: User benefit calculator

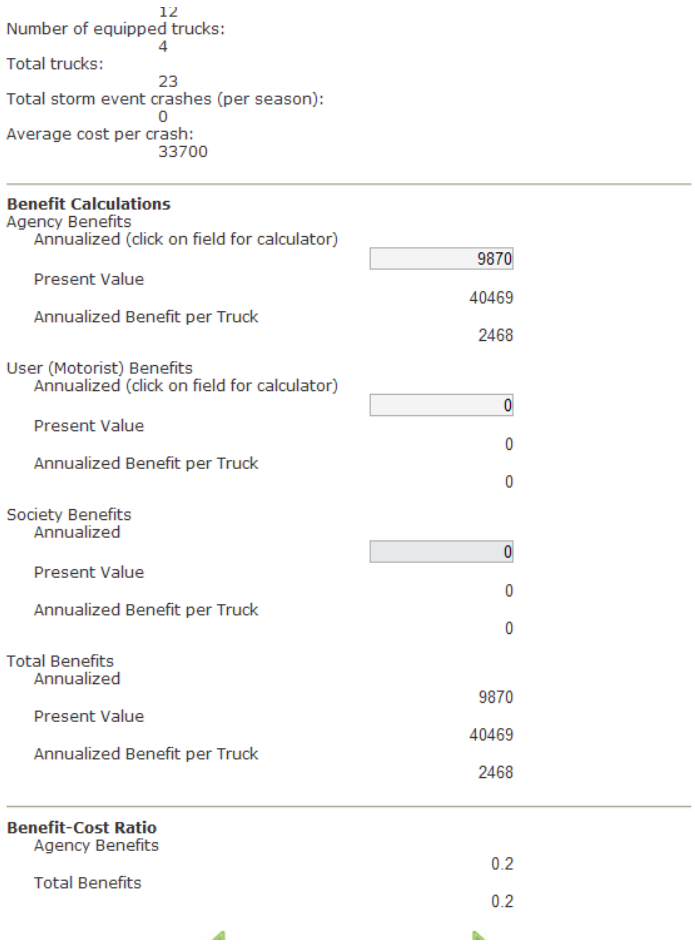


Figure 3-10: Completed benefit quantification screen

As Figure 3-10 indicates, both the agency and total benefit-cost ratios for anti-icing are 0.2. Note that both the agency and total benefit-cost ratios are identical in this case as no user (i.e. crash savings) or societal costs or benefits were available to include in this analysis. The computed ratios suggest that for each one dollar spent by the agency, a benefit of $0.20 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. In the case of anti-icing, it appears that the potential quantified benefits of the system are likely to grow when crash data are available. Additionally, as the scope of the system expands, so too may its benefits in material and labor savings. This example looked at a fairly small case, rather than a larger example.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the “Results” page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

3.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 3-2.

Table 3-2: Anti-icing results

Agency Costs - Initial	Iowa	Indiana	Washington
Tanks and sprayers ($8000)	$1,280,000	$32,000	$288,000
Flow controller ($2389)	$382,240	$9,556	$86,004
Brine plant ($20000)	$2,200,000	$20,000	$340,000
Agency Costs - Annual			
Material costs ($0.07)	$1,740,690	$28,518	$168,311
Production Costs ($14.42)	$94,270	$346	$19,935
Vehicle maintenance ($14.42)	$85,680	$1,442	$27,774
Brine infrastructure maintenance ($2000)	$220,000	$2,000	$24,000
Corrosion/environmental cost ton ($0)	$0	$0	
Total Costs - Summary			
Annualized cost	$2,690,514	$47,319	$424,160
Present value	$18,897,045	$194,017	$1,739,139
Annualized cost/truck	$16,816	$11,830	$11,782
Agency Benefits			
Material savings	416097	$8,365	$135,000
Labor savings	$91,392	$1,505	$111,096
User Benefits			
Crash savings	$5,000,181	$0	$645,355
Total Benefits - Summary			
Annualized benefit	$552,489	$9,870	$891,451
Present value	$3,880,454	$40,469	$3,655,125
Annualized benefit/truck	$3,453	$2,469	$24,763
Cost-Benefit Ratios			
Agency	0.2	0.2	0.6
Total	2.1	0.2	2.1

As the results indicate, depending on the specific agency parameters entered, similar benefit-cost ratios were generated between each state. In the case of anti-icing, quantified benefits are greatly enhanced when those accrued by society are taken into account. When solely agency costs and benefits are accounted for, benefit-cost ratios do not exceed 1.0. This is primarily the cost of the extensive infrastructure requirements and added material costs associated with anti-icing, which outweigh the agency benefits (specifically reduced deicing material use/cost). When societal benefits are accounted for, specifically crash savings, benefit-cost ratios greater than 1.0 are achieved.

3.6. Report Conversion

While step 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 3-11. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

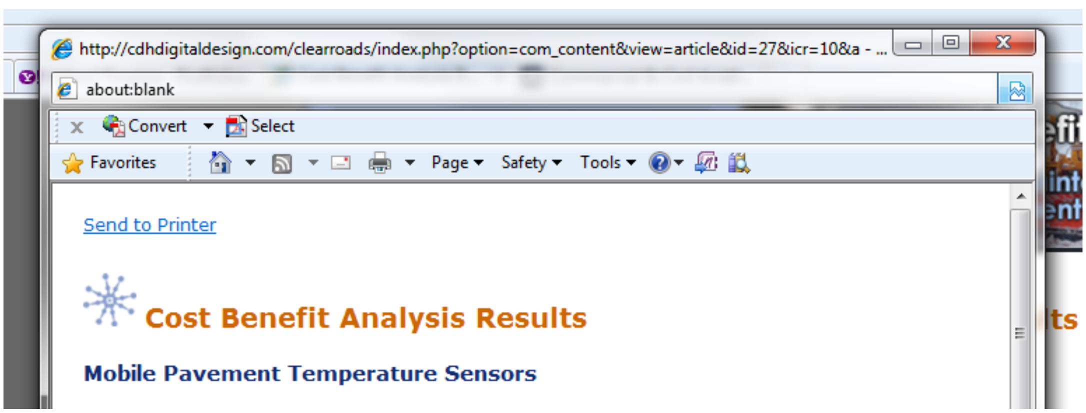


Figure 3-11: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [3]) or installed on their machine (if available).

3.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate anti-icing. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for anti-icing. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[3] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

4. DEICING

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of deicing.

4.1. Sample Data

For this example, data provided by the Iowa Department of Transportation will be employed. This data, along with that of Indiana and Washington are presented in Table 4-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 4-1: Deicing sample data

Deicing	Iowa	Indiana	Washington
Project Parameters			
Number of vehicles to equip	900	*23*	*72*
Total number of fleet vehicles	900	23	72
Number of sheds	*110*	*1*	17
Labor rate	*$21.42*	*$14.42*	*$30.86*
Average labor hours/storm/vehicle	*12*	12	16
Annual number of storm events	20	12	19
Type of deicer used	Salt and Brine	Salt and Brine	Salt and Brine
Lane miles covered per storm	24,867	*4,071*	*8,100*

Italics denote an assumed value for demonstration purposes
Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed are for the entire state of Iowa. To begin, the user will select the "Deicing" link under the Operations heading on the Technology Selection page. This is displayed in Figure 4-1.

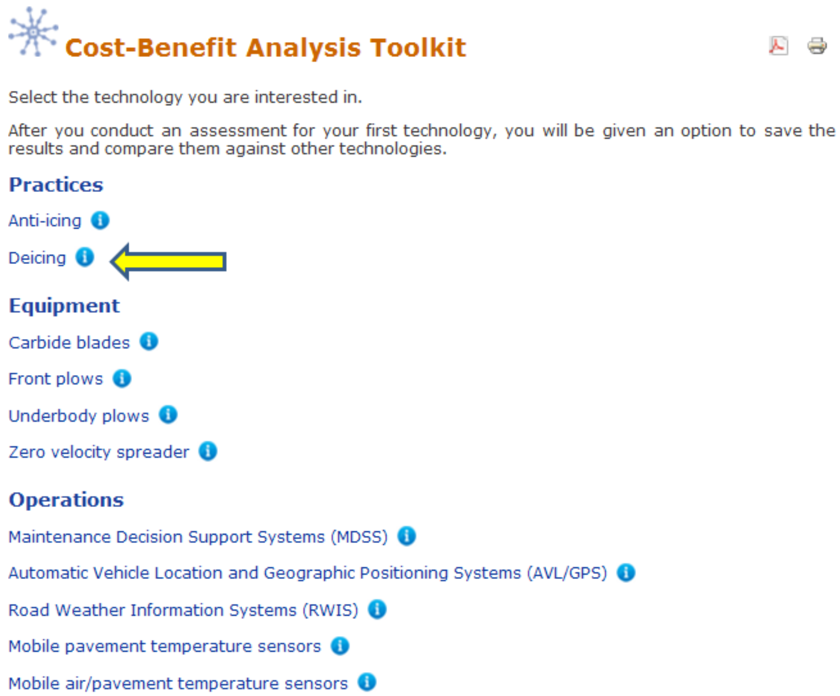


Figure 4-1: Deicing selection

4.2. Project Parameters

Once deicing has been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (10 years in this example, although the toolkit defaults to a life cycle of 12 years). However, ***the user is encouraged to employ the values presently employed by their respective agency.*** For this example, the 7% rate and 10 year life cycle will be employed, as they are reasonable for the purposes of demonstration.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Number of equipped trucks. In this example, 900 trucks will be equipped for deicing.
- Total number of trucks. For this example, there is a total fleet of 900 trucks.
- Number of facilitates with brine-making infrastructure (zero if only granular deicer is used). In this example, 0 brine-making plants are used as only a granular strategy is being examined.
- Loaded labor cost. For this example, the loaded labor cost is $21.42.

- Average labor hours per storm per vehicle. For this example, an assumed labor hour per storm per vehicle figure of 12 hours is employed.
- Average hours spent making liquid materials per facility. For this example, an assumed value of 0 hours is employed, as a granular strategy is being evaluated.
- Hours spent annually maintaining deicing equipment per vehicle. For this example, an assumed figure of 10 hours is used.
- Annual number of storm events. For this example, a value of 20 events is employed.
- Average deicer application rate. For this example, an assumed value of 0.05 tons per mile is employed.
- Lane miles covered per storm by all vehicles. For this example, the total lane miles covered is 24,867.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included.*** For example, a material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 4-2.

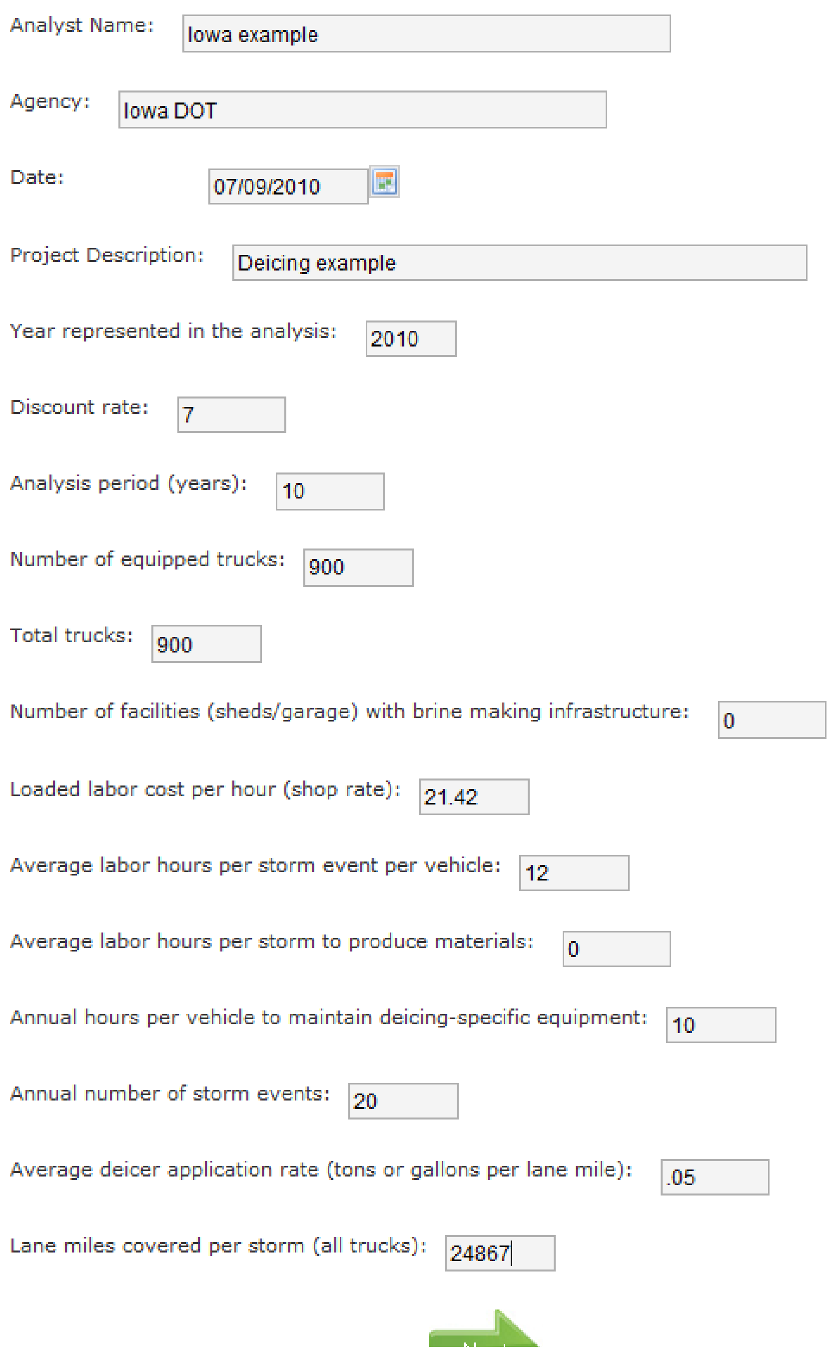

Analyst Name: Iowa example
Agency: Iowa DOT
Date: 07/09/2010
Project Description: Deicing example
Year represented in the analysis: 2010
Discount rate: 7
Analysis period (years): 10
Number of equipped trucks: 900
Total trucks: 900
Number of facilities (sheds/garage) with brine making infrastructure: 0
Loaded labor cost per hour (shop rate): 21.42
Average labor hours per storm event per vehicle: 12
Average labor hours per storm to produce materials: 0
Annual hours per vehicle to maintain deicing-specific equipment: 10
Annual number of storm events: 20
Average deicer application rate (tons or gallons per lane mile): .05
Lane miles covered per storm (all trucks): 24867

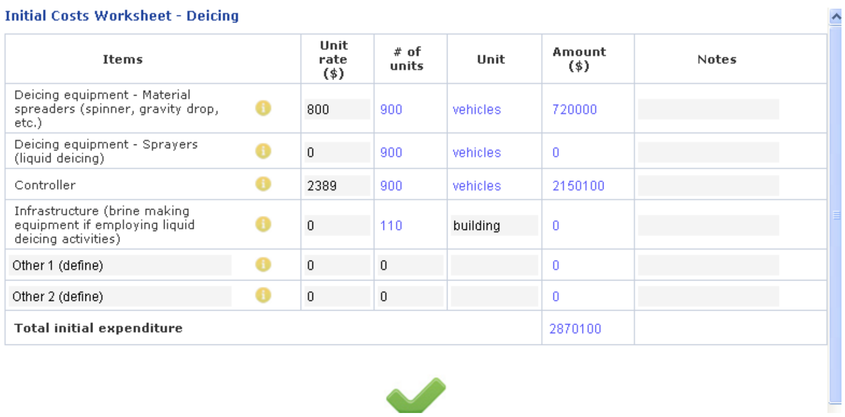
Figure 4-2: Project parameters data entry

4.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with all of society, such as environmental degradation (i.e. the impacts of salt on the environment).

For deicing, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the costs associated with the deicing material spreaders and its controller, as in this case, a granular strategy is being considered. If a liquid strategy was being considered, the user would input the appropriate data related to sprayer equipment, controllers and brine-making infrastructure. Note that at the present time the toolkit is not set up to determine a cost benefit ratio for a combined granular and liquid strategy. Instead, the user will need to perform two separate analyses for each of these approaches.

The spreadsheet is designed to automatically populate using the data entered by the user, as shown in Figure 4-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the cost per vehicle for material spreaders is $800 and controllers $2,389. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.


Initial Costs Worksheet - Deicing

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
Deicing equipment - Material spreaders (spinner, gravity drop, etc.)	800	900	vehicles	720000	
Deicing equipment - Sprayers (liquid deicing)	0	900	vehicles	0	
Controller	2389	900	vehicles	2150100	
Infrastructure (brine making equipment if employing liquid deicing activities)	0	110	building	0	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total initial expenditure				2870100	

Figure 4-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet automatically populated with the project parameters. In this case the user will need to enter the annual cost of deicing materials (depending on the strategy employed, granular or liquid), brine plant maintenance (if liquid is being evaluated) and corrosion/environmental costs. Additionally, the user may enter the annual cost of sanding/grit materials used, as these would be reduced or eliminated by anti-icing. In this example, it is assumed that no such costs exist.

The calculator automatically populates the spreadsheet with the costs associated with brine production and annual vehicle maintenance. For this example, the annual material cost is estimated to be $30 per ton, brine plant maintenance $0, and corrosion/environmental costs $0 per ton of material used. Note that for this example, no environmental/corrosion costs were employed because such costs might outweigh any benefits achieved by deicing and make the explanation of the overall toolkit item less clear. Once the user has examined the spreadsheet, they should select the green check mark to return to the main cost page, which will be updated automatically.

Annual Costs Worksheet - Deicing

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Material costs (year)	30	24867	tons	746010	
Production costs (liquid deicers)	0	20	storms	0	
Equipment maintenance	214.20000	900	vehicles	192780.00	
Brine plant maintenance		0	years		
Corrosion/environmental cost per ton		24867	tons		
Other 1 (define)					
Other 2 (define)					
Cost of Alternative					
Minus cost of sanding and gritting		1	years		
Total Annual O&M Costs				938790	

Figure 4-4: Annual costs spreadsheet, manually populated

In the case of deicing, no tangible societal costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

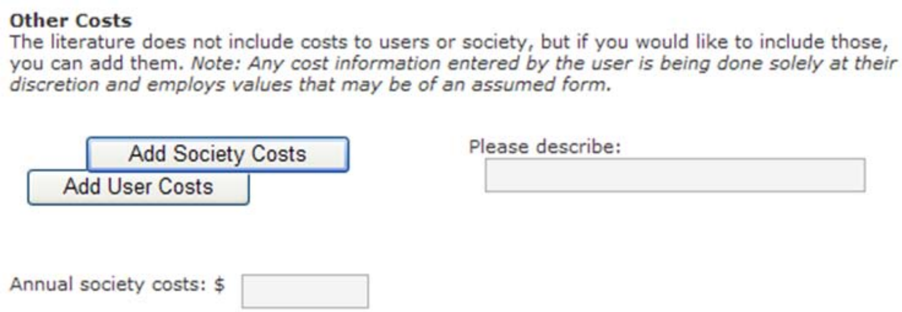


Figure 4-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the anti-icing (in this case over a life of 10 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 4-6.

Figure 4-6: Completed cost page

4.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 4-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".

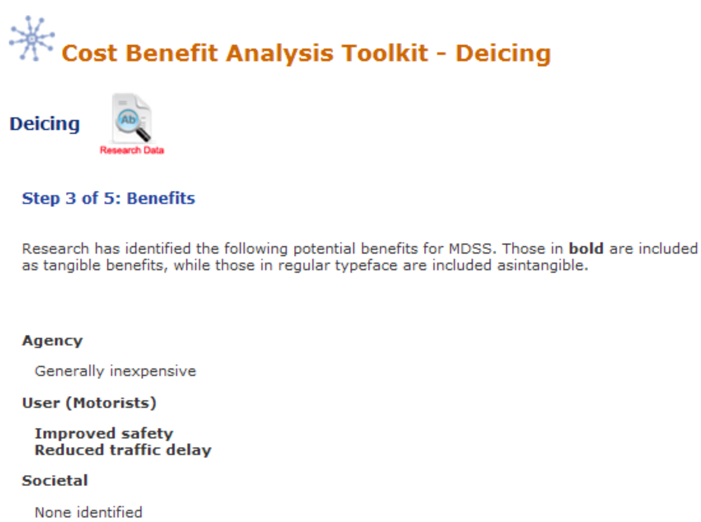


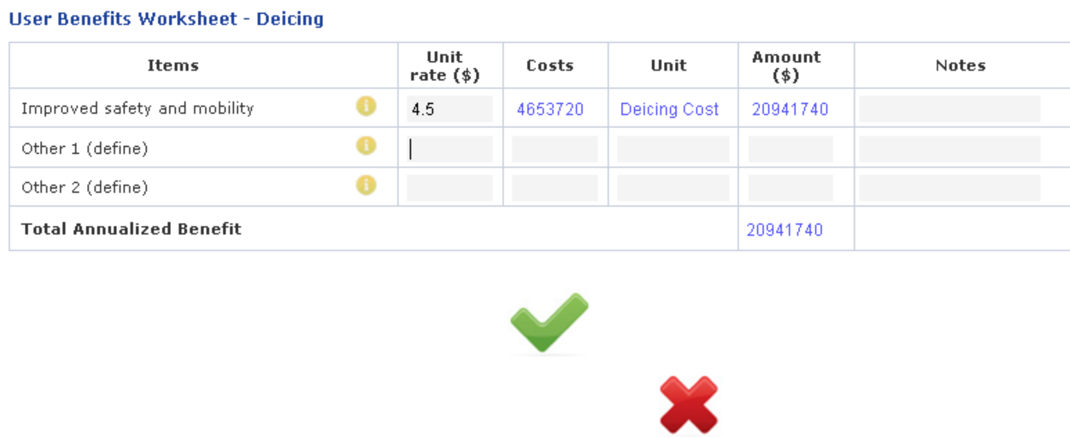
Figure 4-7: Benefits page

The "Benefit Quantification" screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item.

User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

Deicing is unique among the toolkit items in that it has no quantified agency benefits available. If the user is aware of any such values, they will be able to determine the total cost savings achieved by the agency through deicing and enter that figure into the appropriate text box on the benefit quantification page.

For deicing, the primary benefits that have been quantified are attributed to the user. The approach to applying these benefits is made through the user benefits calculator. For this example, an average crash and travel time savings of $4.50 for every $1.00 spent on deicing is employed. This is a conservative figure based on the savings range indicated by previous research.



User Benefits Worksheet - Deicing

Items	Unit rate ($)	Costs	Unit	Amount ($)	Notes
Improved safety and mobility	4.5	4653720	Deicing Cost	20941740	
Other 1 (define)					
Other 2 (define)					
Total Annualized Benefit				20941740	

Figure 4-8: User benefit calculator

No known tangible societal benefits have been quantified for deicing. Of course, if any societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 4-9. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

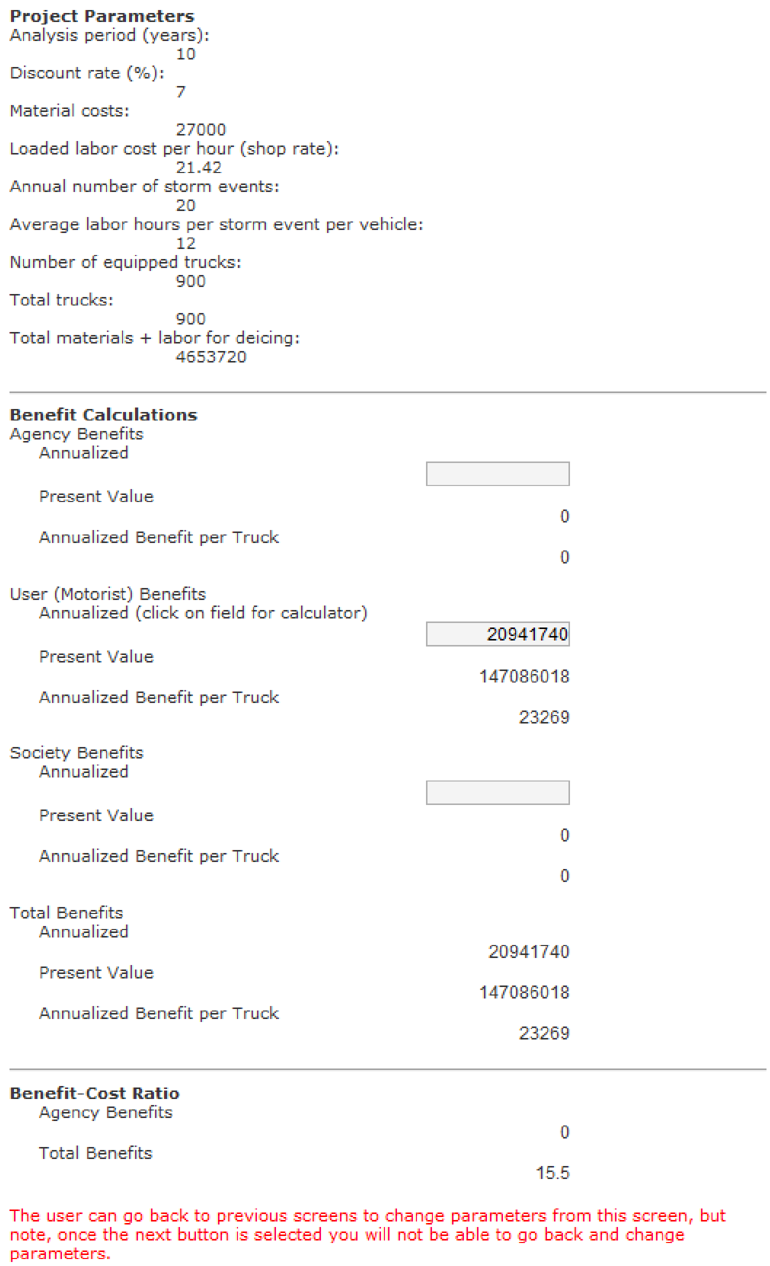


Figure 4-9: Completed benefit quantification screen

As Figure 4-9 indicates, an agency benefit-cost ratio of 0.0 is expected for deicing, due to the lack of quantified agency benefits associated with this procedure. The user benefit-cost ratio for deicing is 15.5, indicating that for each one dollar spent by the agency, a benefit of $15.50 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. In the case of deicing, it appears that the increased safety and improved travel time reliability offered by better pavement surface conditions offer a significant benefit.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the "Results" page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

4.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 4-2.

Table 4-2: Deicing results

Agency Costs - Initial	Iowa	Indiana	Washington
Material spreader ($800)	$720,000	$18,400	$57,600
Flow controller ($2389)	$2,150,100	$54,947	$172,008
Agency Costs - Annual			
Material costs ($30/ton)	$746,010	$73,278	$230,850
Production Costs ($14.42)	$0	$0	$0
Equiment maintenance ($14.42)	$192,780	$3,317	$22,219
Corrosion/environmental cost ton ($0)	$0	$0	$0
Total Costs - Summary			
Annualized cost	$1,347,428	$87,038	$285,760
Present value	$9,463,768	$611,315	$2,007,059
Present value	$1,497	$3,784	$3,969
User Benefits			
General savings	$0	$0	$0
User Benefits			
Crash and travel time savings	$20,941,740	$544,667	$3,161,087
Total Benefits - Summary			
Annualized benefit	$20,941,740	$544,667	$3,161,087
Present value	$147,086,018	$3,825,511	$22,202,152
Annualized benefit/truck	$23,269	$23,681	$43,904
Cost-Benefit Ratios			
Agency	0.0	0.0	0.0
Total	15.5	6.3	11.1

As the results indicate, there is no benefit-cost ratio generated for the agency-only case. This is because of the lack of quantified benefits (i.e. savings) accrued by the agency itself. Rather, as the result indicate, the primary recipients of deicing activities is society, primarily through reduced crashes and improved travel conditions. This indicates that in the example scenario presented in this chapter, based on the agency-specific parameters entered into the toolkit, deicing would be a technology that should be pursued.

4.6. Report Conversion

While step 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 4-10. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

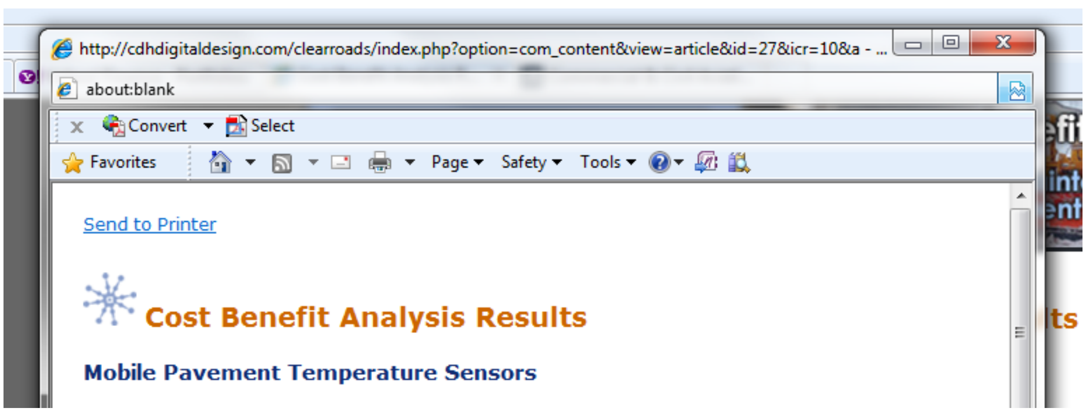


Figure 4-10: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [4]) or installed on their machine (if available).

4.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate deicing. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended practice for deicing. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[4] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

5. CARBIDE BLADES

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of carbide blade inserts.

5.1. Sample Data

For this example, data provided by the Indiana Department of Transportation will be employed. This data, along with that of Iowa and Washington are presented in Table 5-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Indiana at the conclusion of the chapter.

Table 5-1: Carbide blade sample data

Carbide Blade Inserts	Iowa	Indiana	Washington
Project Parameters			
Blade measure	miles	storms	storms
Interstate or secondary	secondary	secondary	secondary
Miles covered/vehicle/season	*3,315*	6,452	2,138
Number of vehicles to equip	900	23	72
Time to change inserts (hours)	2	2	1
Labor rate	$21.42	$14.42	$30.86

Italics denote an assumed value for demonstration purposes

Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed come from one maintenance subdistrict in Indiana. To begin, the user will select the “Carbide blades” link under the Operations heading on the Technology Selection page. This is displayed in Figure 5-1.

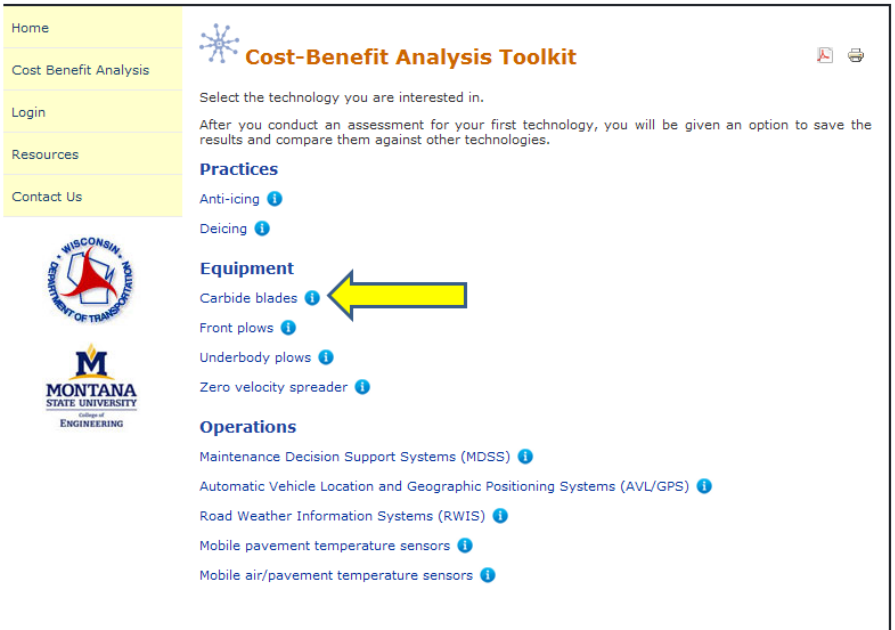


Figure 5-1: Carbide blades selection

5.2. Project Parameters

Once carbide blades have been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (1 year). These represent conservative values, and in the case of blades, representative life spans. However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 1 year life cycle will be employed, as they are reasonable in the context of carbide blades.

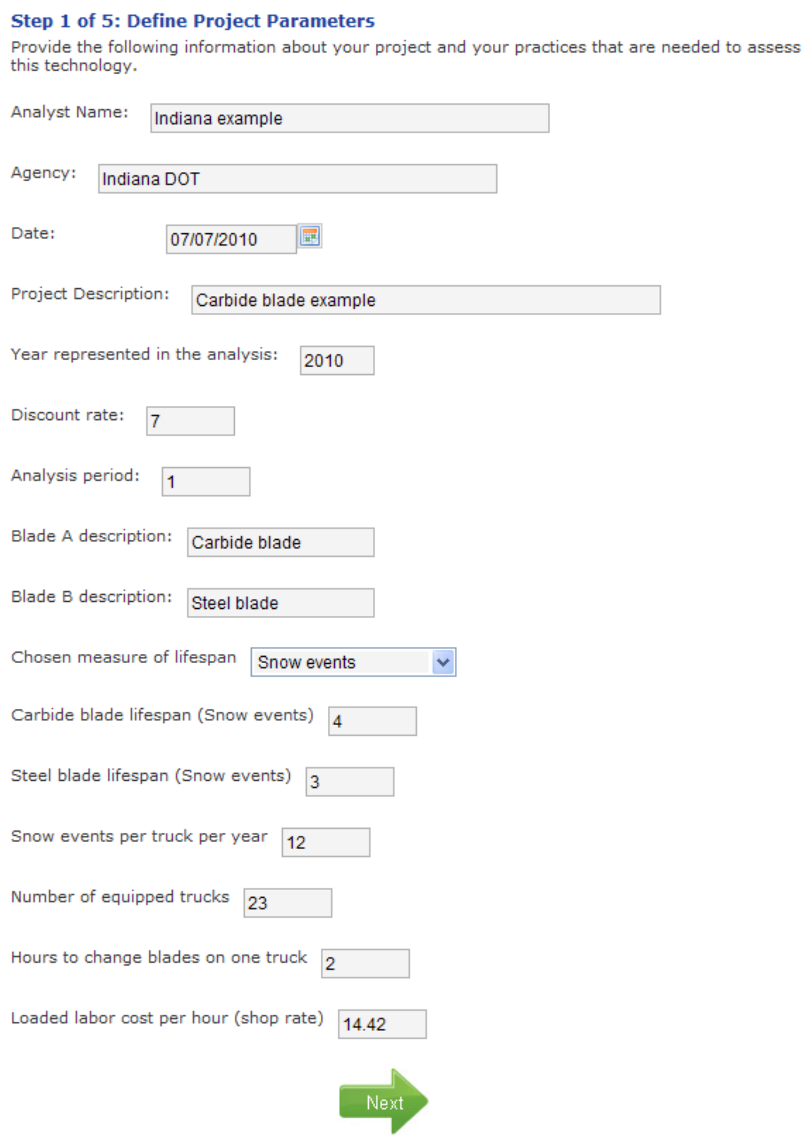
Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Chosen measure of lifespan. In this example, the measure is snow events. However, in other example, this measure may be in miles, fraction of a season (ex, life is ½ of a season, or 0.5) or hours, depending on the measure presently used by an agency.
- Carbide blade lifespan. In this example, the measure is in storm events, for which a carbide blade can be expected to have a service life of 4 storms, based on existing research results and the route type being plowed (secondary).

- Steel blade lifespan. In this example, the measure is in storm events, for which a steel blade can be expected to have a service life of 3 storms, based on existing research results and the route type being plowed (secondary).
- Snow events per year. For this example, a figure of 12 snow events per year (estimated) has been employed.
- Number of equipped trucks. In this example, there are 23 trucks equipped with carbide blades.
- Hours to change blade. For this example, a figure of 2 hours has been employed (1 labor-hour times 2 personnel).
- Hourly labor rate. In this example, hourly labor rate is $14.42.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, the maintenance material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 5-2.



Step 1 of 5: Define Project Parameters

Provide the following information about your project and your practices that are needed to assess this technology.

Analyst Name: Indiana example

Agency: Indiana DOT

Date: 07/07/2010

Project Description: Carbide blade example

Year represented in the analysis: 2010

Discount rate: 7

Analysis period: 1

Blade A description: Carbide blade

Blade B description: Steel blade

Chosen measure of lifespan: Snow events

Carbide blade lifespan (Snow events) 4

Steel blade lifespan (Snow events) 3

Snow events per truck per year 12

Number of equipped trucks 23

Hours to change blades on one truck 2

Loaded labor cost per hour (shop rate) 14.42

Next

Figure 5-2: Project parameters data entry

5.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For carbide blades, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In the case of carbide blades, their lifespan is such that they do not last for an entire year/storm season. As a result, there are no initial costs associated with them, and the user can disregard the Initial costs calculator.

Clicking on the Annual costs calculator icon, the user will be presented with a spreadsheet which determines the costs associated with the use of carbide blades. The spreadsheet is designed to automatically populate using the data entered by the user previously. The user is required to enter a cost for blades in the respective grey box. Note that the user must determine the entire cost of blades for the size of plow being examined. In other words, if carbide blade inserts of 4 feet in length are being used on a 12 foot plow, the user must select a cost for the blade insert being used and multiply it by the appropriate number of inserts required for the plow. In this example, a four foot blade insert costing $136 is being employed on 12 foot plows, resulting in a cost of 3* $136 = $408, which is entered into the appropriate box. This total cost figure is then multiplied across the entire fleet to produce a cost figure for carbide blade use over an entire storm season. A completed Annual cost spreadsheet for the present example is shown in Figure 5-3. The user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. Note that in this example, the spreadsheet has automatically updated the labor cost associated with an installation time of two hours. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the Annual costs will appear on the page.

Annual Costs Worksheet - Carbide Blades

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Carbide blade	408	69	blades	28152	
Installation cost	28.84	69	blades	1989.96	
Other 1 (define)					
Other 2 (define)					
Total Annual O&M Costs				30142	

Figure 5-3: Initial costs spreadsheet, automatically populated

In the case of carbide blades, no tangible societal or user costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

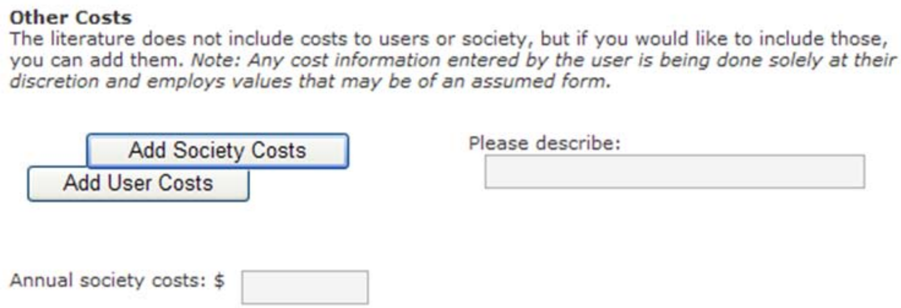


Figure 5-4: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the system (in this case over a life of 1 year), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 4-5.Figure 5-5: Completed cost page.

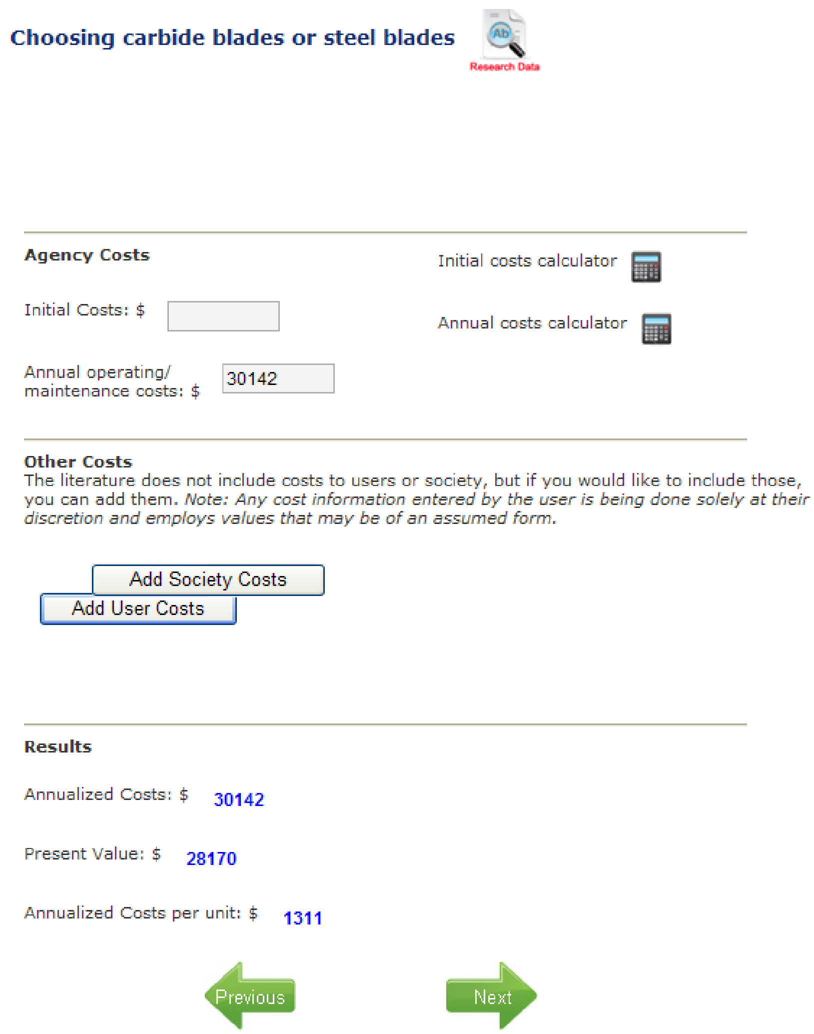


Figure 5-5: Completed cost page

5.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 5-6. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".

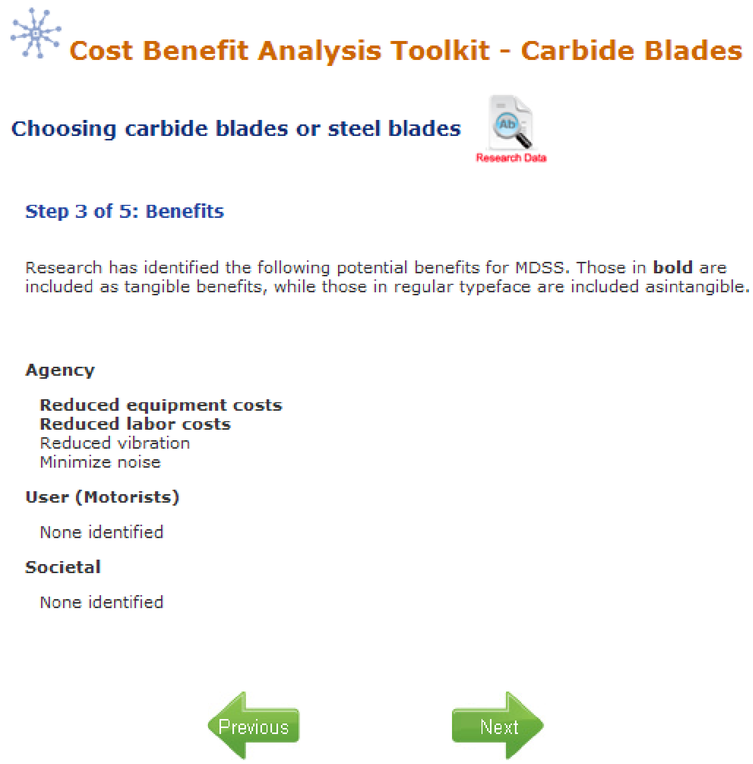


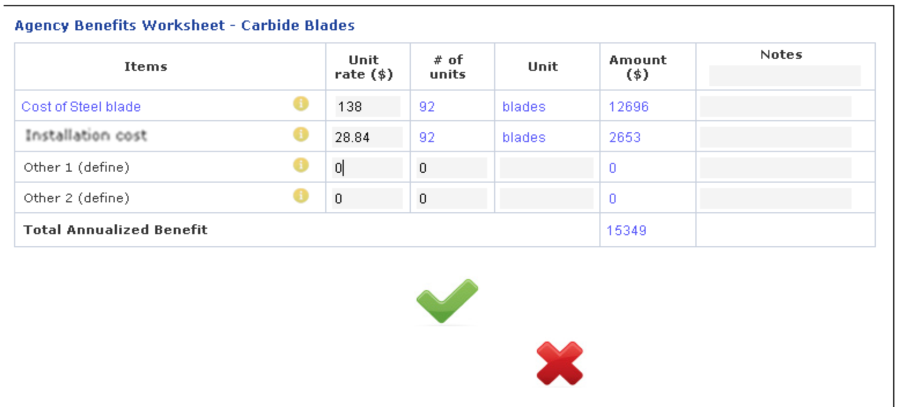
Figure 5-6: Benefits page

The "Benefit Quantification" screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In determining agency benefits, the user will be required to enter the expected cost of standard steel blade inserts for the length of plow that is being evaluated (in this case, an average of 12 foot was employed). Guidance is provided on the cost of steel blade inserts, but the user should employ their own existing cost or estimates obtained from manufacturers for their evaluation. For this demonstration, a cost of $69 for a 6 foot blade was employed. This totals $138 for a 12 foot plow. Note that the total cost for the plow must be entered. This figure is then multiplied by the total number of blade changes that would be required across the plow fleet. The entry of this information is made through a calculator accessed through the agency benefits text box is displayed in Figure 5-7.

As agency benefits are the only benefits which have been quantified for carbide blades, the user will have completed benefits quantification at this point. Of course, if any additional user or societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text boxes on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 5-8. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

Note that the Agency Benefits calculator requires the user to enter costs. This is not an error. In establishing the benefits of carbide blades, it is necessary to compare their cost to that of a standard steel blade. In theory, a carbide blade will exhibit a longer life than a standard steel blade, requiring less material purchases and installation time. In such a case, the cost difference between carbide blades and steel blades would represent the agency benefit, as determined by the information entered in this calculator.



Agency Benefits Worksheet - Carbide Blades

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
Cost of Steel blade	138	92	blades	12696	
Installation cost	28.84	92	blades	2653	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				15349	

Figure 5-7: Agency benefit calculator

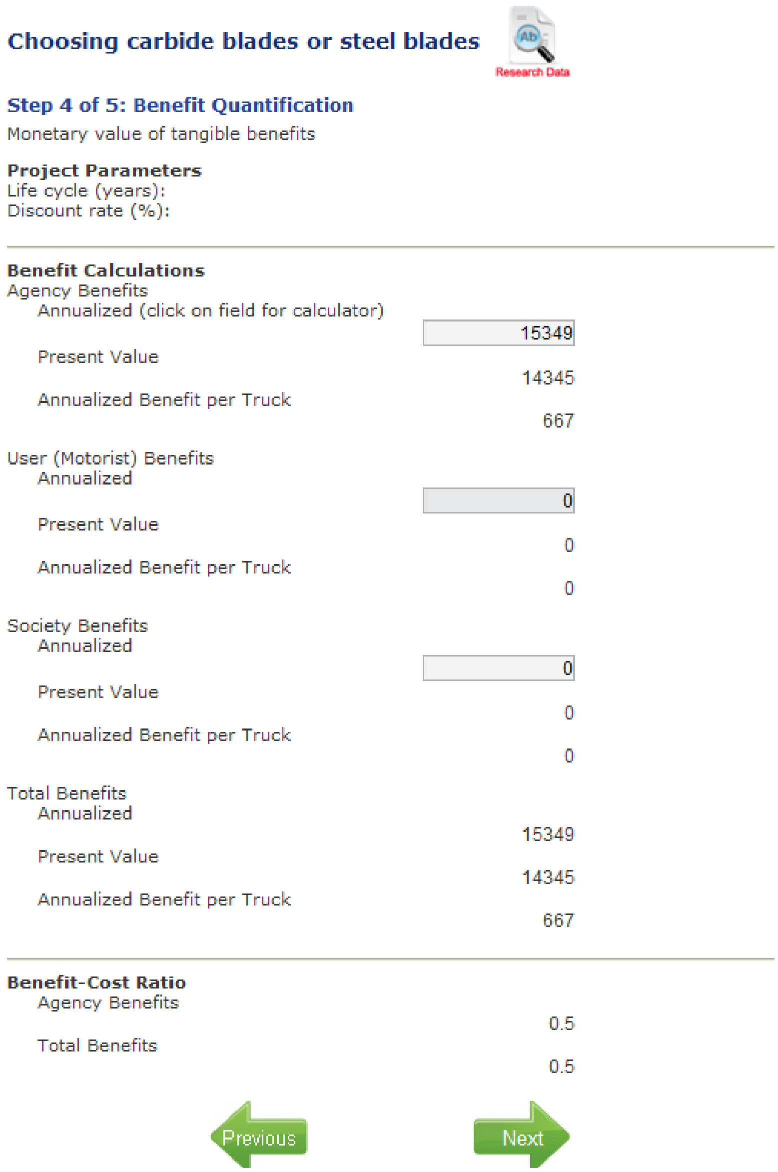


Figure 5-8: Completed benefit quantification screen

As Figure 5-8 indicates, both the agency and total benefit-cost ratios are 0.5. Note that this is because no user or societal costs or benefits were available to include in this analysis. This indicates that for each one dollar spent by the agency, a benefit of only $0.50 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. In the case of carbide blades, it appears that their use does not offer a significant advantage over that of standard steel blades. In other words, their use will need to be justified for reasons other than financial savings, as these do not accrue in this example evaluation.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the "Results" page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

5.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 5-2.

Table 5-2: Carbide blade results

Agency Costs - Annual	Iowa	Indiana	Washington
Blades ($408)	$573,240	$30,412	$39,984
Installation cost	$60,190	$1,900	$3,024
Total Costs - Summary			
Annualized cost	$633,430	$30,142	$43,008
Present value	$591,991	$28,170	$40,194
Annualized cost/truck	$704	$1,310	$597
Total Benefits - Summary			
Annualized benefit	$539,536	$15,349	$33,000
Present value	$504,239	$14,345	$30,841
Annualized benefit/truck	$599	$667	$458
Cost-Benefit Ratios			
Agency	0.9	0.5	0.8
Total	0.9	0.5	0.8

As the results indicate, depending on the specific agency parameters entered, similar benefit-cost ratios were generated between each state. In the case of carbide blades, the benefit-cost ratios do not exceed 1.0. While carbide blades represent an incremental cost over standard steel blades and last somewhat longer between changes, it would appear that this benefit is not entirely justified. In essence, the agency will need to determine whether carbide blades hold any intangible benefits that are not factored in to the cost benefit analysis should their use be desired.

5.6. Report Conversion

While step 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 5-9. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

Figure 5-9: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [5]) or installed on their machine (if available).

5.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate carbide blades. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as

[5] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for carbide blades. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

6. FRONT PLOWS

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of a wider (12+ feet) front plow.

6.1. Sample Data

For this example, data provided by the Indiana Department of Transportation will be employed. This data, along with that of Iowa and Washington are presented in Table 6-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 6-1: Front plow sample data

Front plows	Iowa	Indiana	Washington
Project Parameters			
Annual number of storm events	20	*12*	19
Annual material costs	$17,291,152	$373,186	$2,224,114
Avg plowing duration (hours/storm)	*8*	*8*	*7.5*
Lane miles plowed per storm	*151,200*	*4,071*	*8,100*
Blade insert lifespan	*11 storms*	6 storms	6 storms
Number of vehicles to equip	900	23	72
Total number of fleet vehicles	900	23	72
Labor rate	$21.42	$14.42	$30.86

Italics denote an assumed value for demonstration purposes
Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed come from one maintenance subdistrict in Indiana. To begin, the user will select the “Front plows” link under the Operations heading on the Technology Selection page. This is displayed in Figure 6-1.

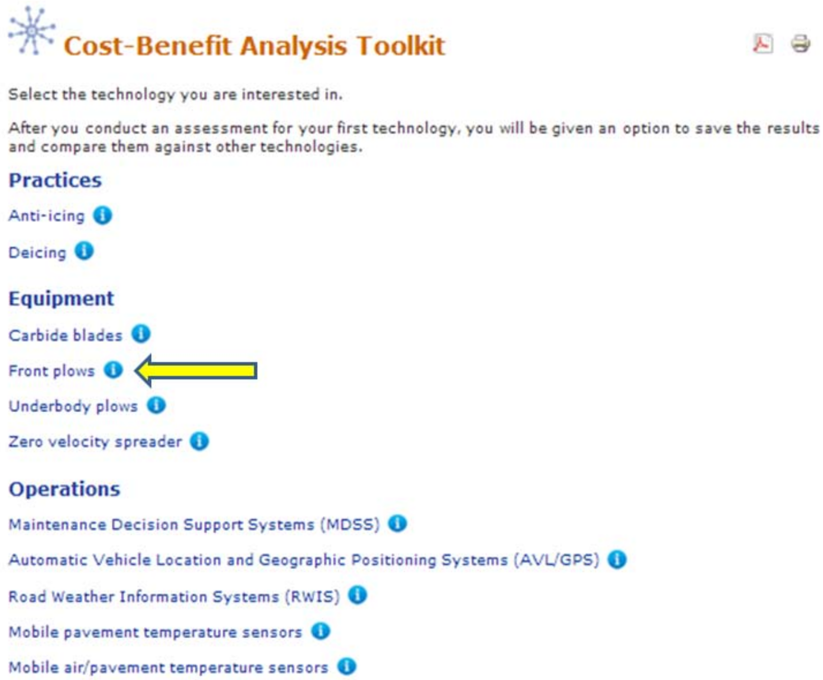


Figure 6-1: Front plows selection

6.2. Project Parameters

Once front plows have been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (10 years). However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 5 year life cycle will be employed, as they are reasonable in the context of front plows.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Annual material costs. For this example, the annual material cost is $373,186.
- Annual number of storm events. For this example, an estimated value of 12 is employed.
- Average duration of plowing (i.e. plow blade is down, do not include patrolling). For this example, the plow is in use for an assumed time of 8 hours.
- Lane miles plowed per storm. For this example, an assumed value of 4,071 miles is employed.
- Blade insert lifespan (in number of storms). For this example, a blade is expected to last for 6 storms.

- Number of vehicles installed with AVL. In this example, 23 vehicles will receive wider front plows.
- Total number of trucks. For this example, there is a total fleet of 23 trucks.
- Loaded labor cost. For this example, the loaded labor cost is $14.42.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, a material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 6-2.

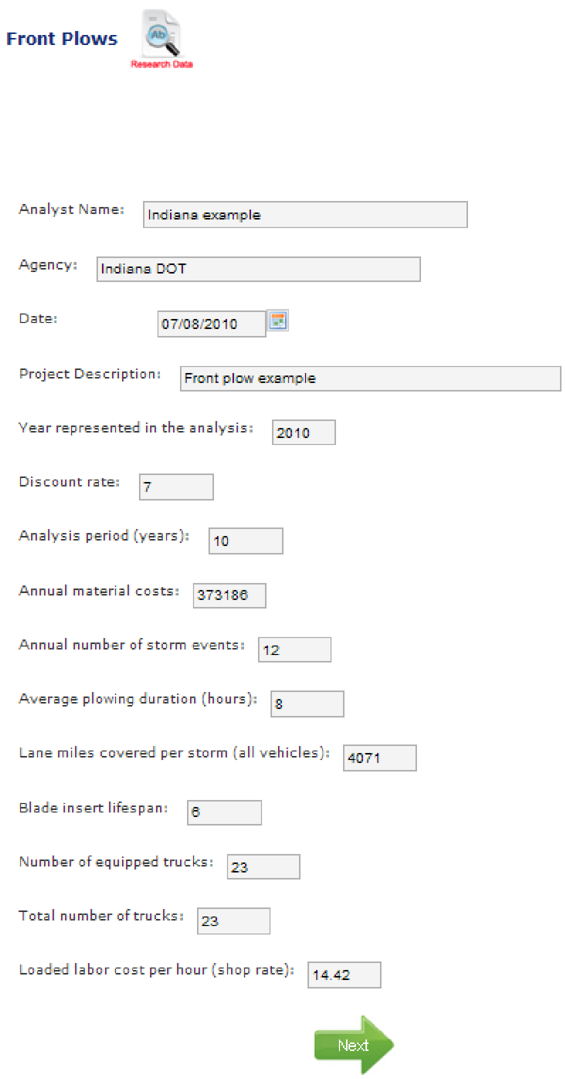


Figure 6-2: Project parameters data entry

6.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For front plows, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the in-vehicle, communication system and office equipment costs. The spreadsheet is designed to automatically populate using the data entered by the user previously, as shown in Figure 6-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the initial cost per wider front plow is assumed to be $3,678 per vehicle. Additionally, the user may account for the cost of a standard width plow that may have been installed instead of a wider plow. In this example, a cost of $3,482 is attributed to a standard plow. The premise is that the money for a baseline plow would have been spent in any case, and so the true cost of the wider front plow is that above and beyond the baseline (in this example, $3,482). Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.

Initial Costs Worksheet - Front Plows

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
Wider Plow	3678	23	vehicles	84594	
Other 1 (define)	0	0		0	
Other 1 (define)	0	0		0	
Cost of Alternative					
Minus cost for baseline 10-12 ft plow	-3482	23	vehicles	-80086	
Total initial expenditure				4508	

Figure 6-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet automatically populated with the project parameters. In this case the user will need to enter the value of replacement blades for both a wider plow and a standard plow. For this example, the cost of one entire blade change for a single 14 foot plow is $184. Similarly, the user will enter the cost of replacement blades per plow for a standard plow (12 foot). For this example, the cost of standard blades is $158. Once the user has examined the spreadsheet, they should select the green check mark to return to the main cost page, which will be updated automatically.

Annual Costs Worksheet - Front Plows

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Wider blades	184	46	blades	8464	
Other 1 (define)	0	0		0	
Other 1 (define)	0	0		0	
Cost of Alternative					
Minus cost for baseline 10-12 ft plow	-158	46	blades	-7268	
Total Annual O&M Costs				1196	

Figure 6-4: Annual costs spreadsheet, manually populated

In the case of front plows, no tangible societal costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

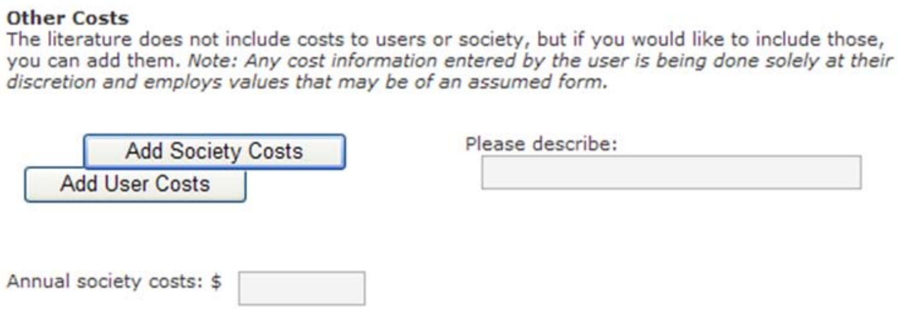


Figure 6-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the front plow (in this case over a life of 10 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 6-6.

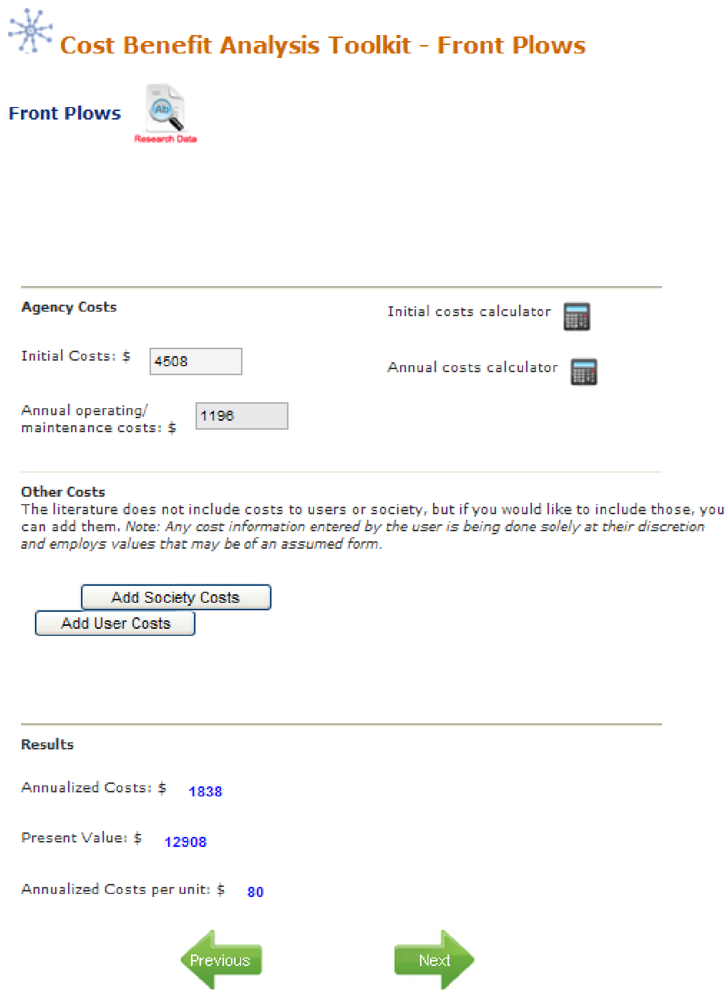


Figure 6-6: Completed cost page

6.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 6-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".

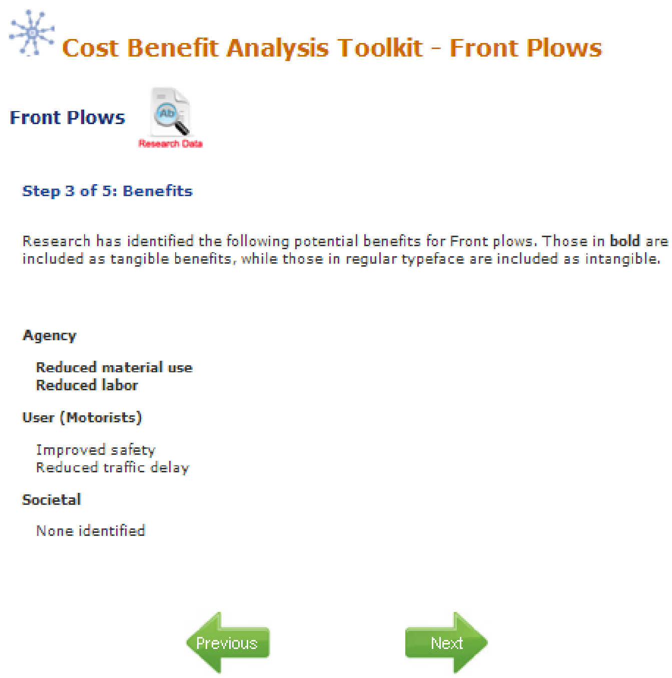
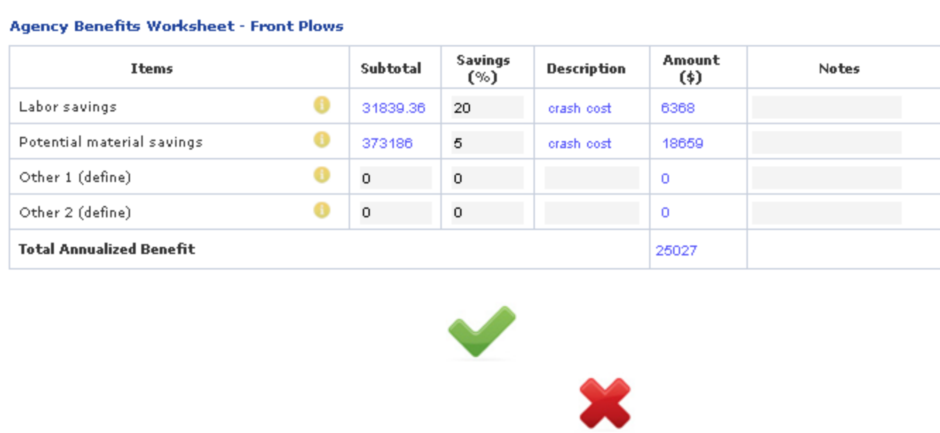


Figure 6-7: Benefits page

The “Benefit Quantification” screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In the case front plows, the primary quantified benefits are reduced labor costs and material savings. In this example, conservative values of 20 percent labor savings and 5 percent material cost savings have been employed. The reduction in labor is the result of less passes being required on a given roadway, allowing for personnel to cover routes in less time. Similarly, material savings are derived from a reduction in plowing passes resulting in an opportunity for less materials to be used.


Agency Benefits Worksheet - Front Plows

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Labor savings	31839.36	20	crash cost	6368	
Potential material savings	373186	5	crash cost	18659	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				25027	

Figure 6-8: Agency benefit calculator

In the case of front plows, no user or societal benefits have been quantified, so the user will have completed benefits quantification at this point. Of course, if any additional user or societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 6-9. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

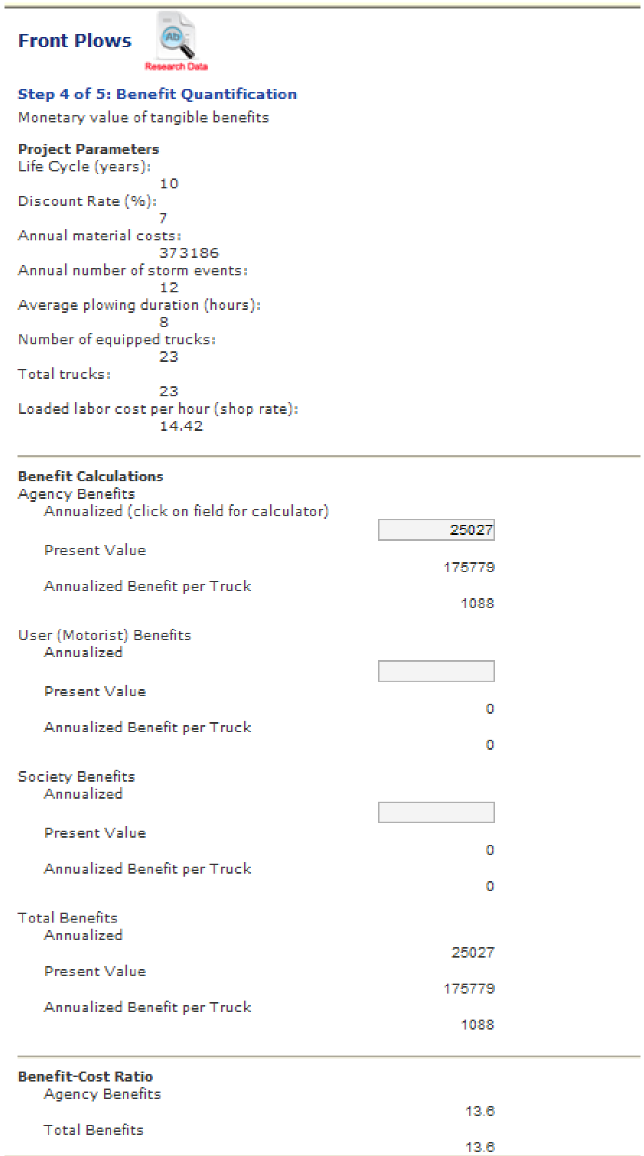


Figure 6-9: Completed benefit quantification screen

As Figure 6-9 indicates, both the agency and total benefit-cost ratios are 13.6. Note that both the agency and total benefit-cost ratios are identical in this case, as no user or societal costs or benefits were available to include in this analysis. This indicates that for each one dollar spent by the agency, a benefit of $13.60 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. In the case of front plows, it appears that their incremental additional cost over standard width plows holds the potential to produce significant benefits. Of course, if a higher priced from plow model was employed, a different result is likely to be produced.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the "Results" page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

6.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 6-2.

Table 6-2: Front plow results

Agency Costs - Initial	Iowa	Indiana	Washington
Plow ($3678)	$176,400	$84,594	$264,816
Agency Costs - Annual			
Replacement blades ($184)	$301,091	$8,464	$41,952
Total Costs - Summary			
Annualized cost	$67,661	$1,838	$7,937
Present value	$475,221	$12,908	$55,748
Annualized cost/truck	$75	$80	$110
Agency Benefits			
Labor savings	$616,896	$6,368	$135,093
Material savings	$864,558	$18,659	$111,206
Total Benefits - Summary			
Annualized benefit	$1,481,454	$25,027	$246,299
Present value	$10,405,110	$175,780	$1,729,901
Annualized benefit/truck	$1,646	$1,088	$3,421
Cost-Benefit Ratios			
Agency	21.7	13.6	31.0
Total	21.7	13.6	31.0

As the results indicate, depending on the specific agency parameters entered, different benefit-cost ratios were generated between each state. In the case of wider front plows, the benefit-cost ratios greatly exceed 1.0. This is the result of the alternative narrow (10-12 foot) plow costs being deducted from the overall cost of wider front plows. In other words, because an agency was going to purchase a plow anyway, only the added cost above and beyond the cost of the baseline plow should be attributed to the wider front plow. As a result, the costs of acquiring a wider front plow are incremental, while the benefits are potentially greater by a significant margin.

6.6. Report Conversion

While step 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 6-10. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

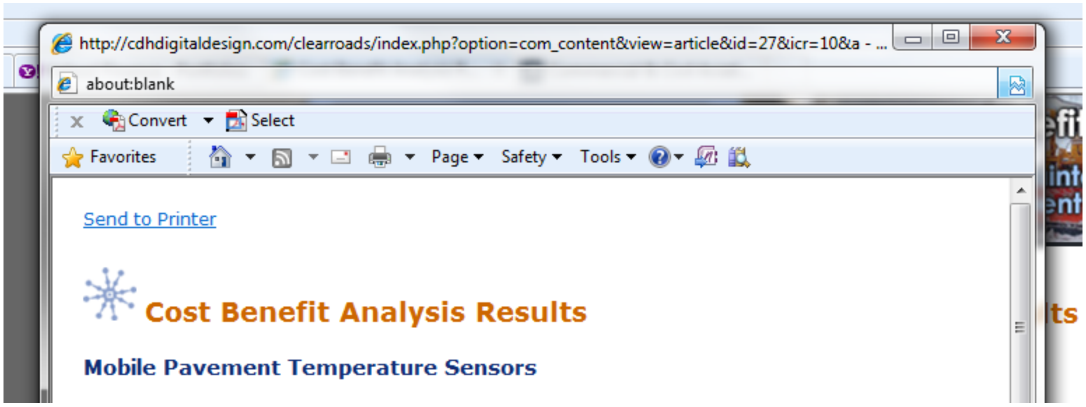


Figure 6-10: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [6]) or installed on their machine (if available).

6.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate wider front plows. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for wider front plows. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[6] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

7. UNDERBODY PLOWS

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of underbody plows.

7.1. Sample Data

For this example, data provided by the Iowa Department of Transportation will be employed. This data, along with that of Indiana and Washington are presented in Table 7-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 7-1: Underbody plow sample data

Underbody Plows	Iowa	Indiana	Washington
Project Parameters			
Number of vehicles to equip	142	3	*18*
Total number of fleet vehicles	900	23	72
Annual number of storm events	20	12	19
Blade insert lifespan	3000 miles	replace 2x yr	replace 3x yr
Annual material costs	$17,291,152	$373,186	$2,224,114
Labor rate	$21.42	$14.42	$30.86
Time to change inserts (hours)	2	2	1
Annual Injury crashes	2,583	0	130
Annual property damage crashes	5,720	0	224

Italics denote an assumed value for demonstration purposes
Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed come from the entire state of Iowa. To begin, the user will select the “Underbody plow” link under the Operations heading on the Technology Selection page. This is displayed in Figure 7-1.

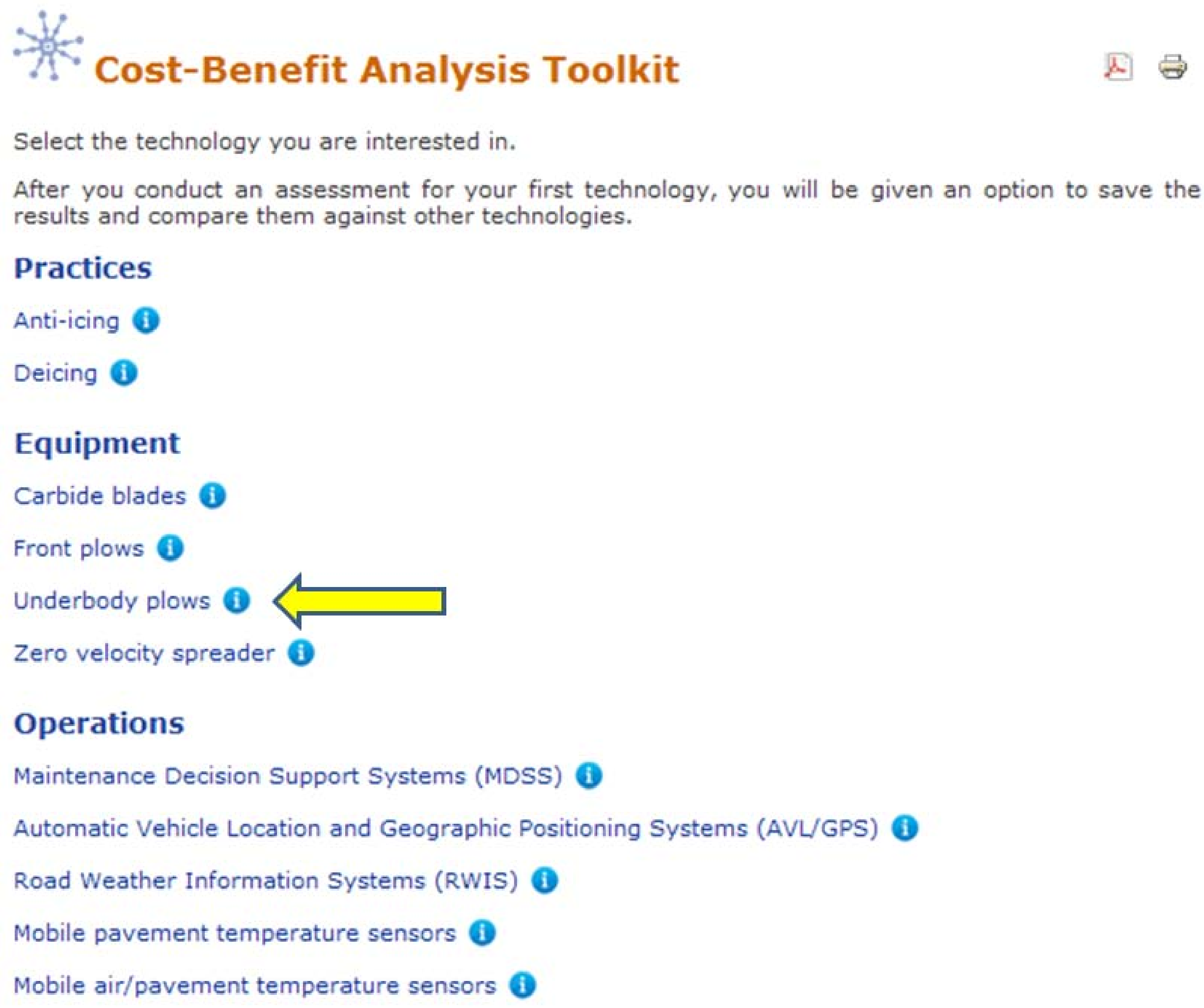


Figure 7-1: Carbide blades selection

7.2. Project Parameters

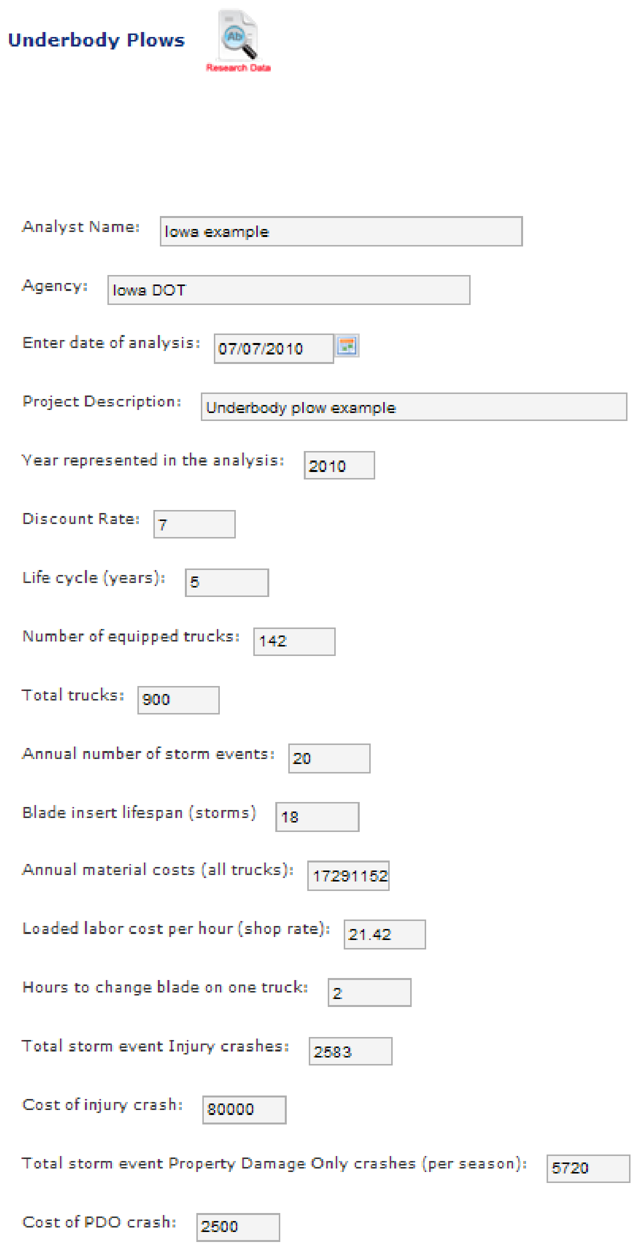
Once the underbody plow has been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (5 years). However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 5 year life cycle will be employed, as they are reasonable in the context of underbody plows.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Chosen measure of lifespan. In this example, the measure is snow events. However, in other example, this measure may be in miles, fraction of a season (ex, life is ½ of a season, or 0.5) or hours, depending on the measure presently used by an agency.
- Number of equipped trucks. For this example, 142 trucks are equipped with underbody plows.
- Total number of trucks. For this example, the total plow fleet is 900 trucks.
- Annual number of storm events. For this example, the average number of storms per year is 20.
- Blade insert lifespan, in storms. In this example, the DOT indicated that blades were changed out every 3,000 miles. Based on an average of 165 miles covered by a vehicle per storm, this equates to roughly 18 storms between changes.
- Annual material costs. For this example, the total material cost is $17,291,152.
- Hourly labor rate. In this example, hourly labor rate is $21.42.
- Hours to install an underbody plow blade. For this example, a figure of 2 hours has been employed (1 labor-hour times 2 personnel).
- Storm event injury crashes, per year. For this example, this value was 2,583.
- Injury crash value. For this example, a value of $80,000 is employed, as this is the average of Iowa's values for major and minor injury crashes.
- Storm event property damage crashes. For this example, this value was 5,720.
- Property damage crash value. For this example, a value of $2,500 is employed, as this is the average of Iowa's values for major and minor injury crashes.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, the maintenance material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 7-2.


Underbody Plows

Analyst Name: Iowa example

Agency: Iowa DOT

Enter date of analysis: 07/07/2010

Project Description: Underbody plow example

Year represented in the analysis: 2010

Discount Rate: 7

Life cycle (years): 5

Number of equipped trucks: 142

Total trucks: 900

Annual number of storm events: 20

Blade insert lifespan (storms) 18

Annual material costs (all trucks): 17291152

Loaded labor cost per hour (shop rate): 21.42

Hours to change blade on one truck: 2

Total storm event Injury crashes: 2583

Cost of injury crash: 80000

Total storm event Property Damage Only crashes (per season): 5720

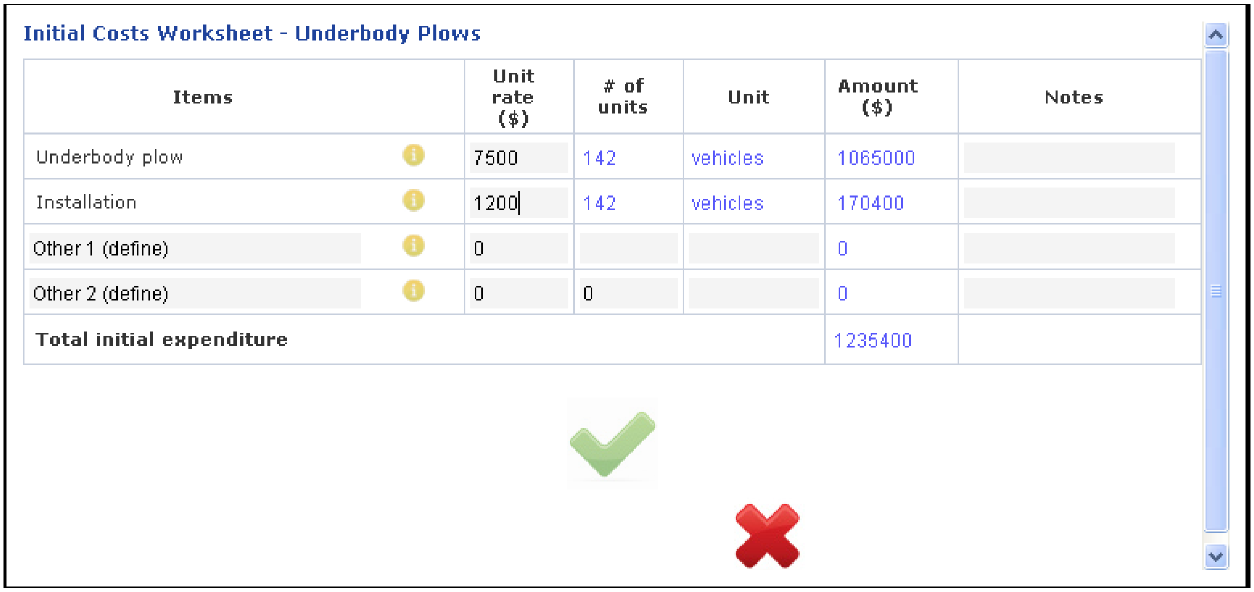
Cost of PDO crash: 2500

Figure 7-2: Project parameters data entry

7.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For Underbody plows, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the in-vehicle equipment costs. The spreadsheet is designed to automatically populate using the data entered by the user previously, as shown in Figure 7-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the initial cost per underbody plow is assumed to be $7,500 per vehicle. The assumed installation cost per underbody plow is $1,200. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.


Initial Costs Worksheet - Underbody Plows

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
Underbody plow	7500	142	vehicles	1065000	
Installation	1200	142	vehicles	170400	
Other 1 (define)	0			0	
Other 2 (define)	0	0		0	
Total initial expenditure				1235400	

Figure 7-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet partially populated with the project parameters. In this case however, the user will need to specify the cost of replacement blades (carbide) for the plow, based on the need to change these blades after approximately 18 storms. For this example, a cost per 8 foot blade was assumed to be $105. However, the user should employ known figures or estimates based on their particular case. The maintenance costs associated with changing the blades are automatically computed based on the project parameters previously entered.

Note that as the specific values are entered, the spreadsheet will update to display total costs. The user should enter only individual costs for each item, as these costs will then be multiplied by the number of units specified previously. Again, once completed, the user should select the green check mark to return to the main cost page, which will be updated automatically.

Annual Costs Worksheet - Underbody Plows

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Equipment maintenance	42.84	157.77777	blades	6759.2	
Replacement blades	105	157.77777	blades	16566.666	
Other 1 (define)				0	
Other 2 (define)					
Total Annual O&M Costs				23326	

Figure 7-4: Annual costs spreadsheet, manually populated

In the cast of underbody plows, no tangible societal costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

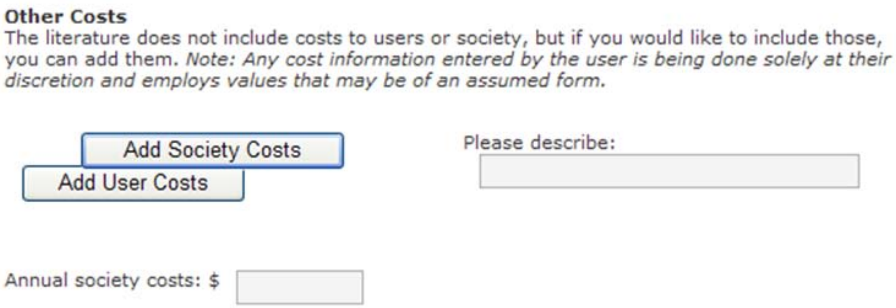


Figure 7-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the underbody plow (in this case over a life of 5 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 7-6.

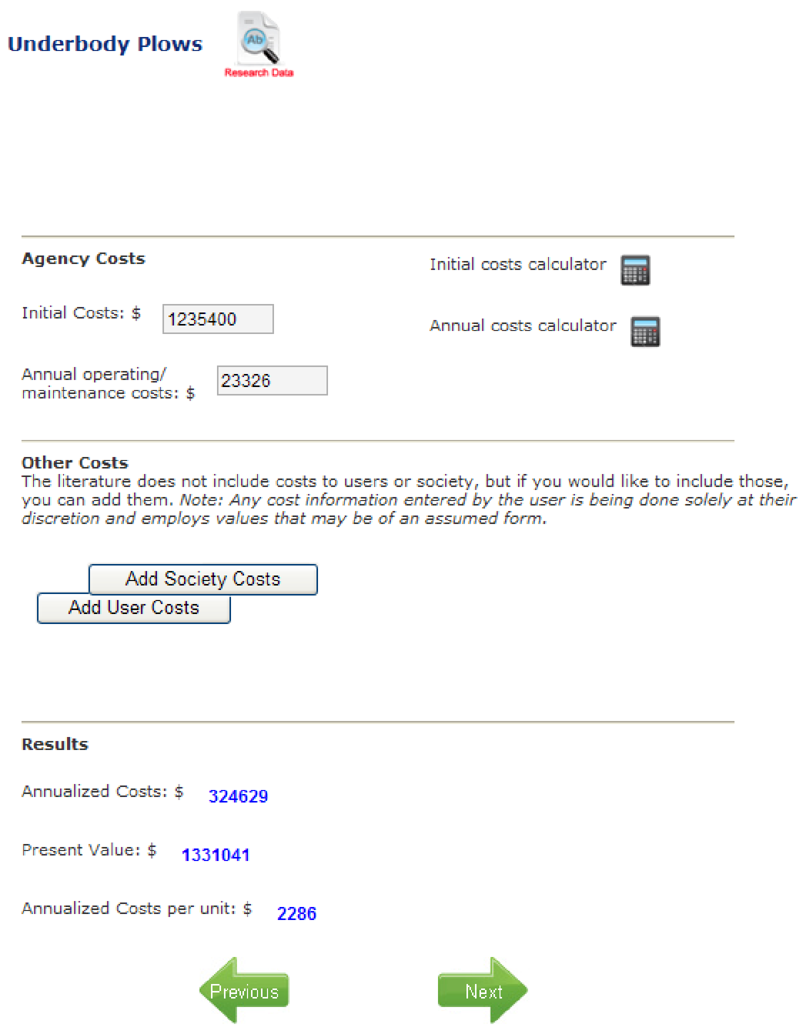
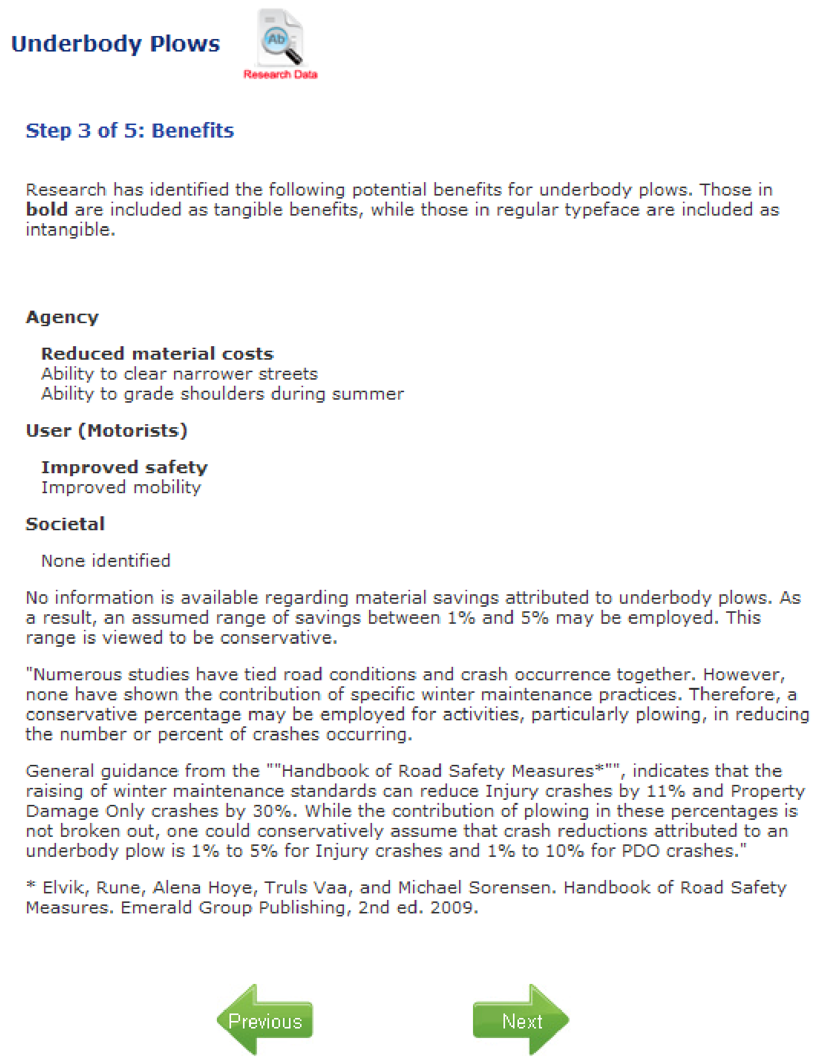


Figure 7-6: Completed cost page

7.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 7-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".



Underbody Plows Research Data

Step 3 of 5: Benefits

Research has identified the following potential benefits for underbody plows. Those in **bold** are included as tangible benefits, while those in regular typeface are included as intangible.

Agency

Reduced material costs
Ability to clear narrower streets
Ability to grade shoulders during summer

User (Motorists)

Improved safety
Improved mobility

Societal

None identified

No information is available regarding material savings attributed to underbody plows. As a result, an assumed range of savings between 1% and 5% may be employed. This range is viewed to be conservative.

"Numerous studies have tied road conditions and crash occurrence together. However, none have shown the contribution of specific winter maintenance practices. Therefore, a conservative percentage may be employed for activities, particularly plowing, in reducing the number or percent of crashes occurring.

General guidance from the ""Handbook of Road Safety Measures*"", indicates that the raising of winter maintenance standards can reduce Injury crashes by 11% and Property Damage Only crashes by 30%. While the contribution of plowing in these percentages is not broken out, one could conservatively assume that crash reductions attributed to an underbody plow is 1% to 5% for Injury crashes and 1% to 10% for PDO crashes."

* Elvik, Rune, Alena Hoye, Truls Vaa, and Michael Sorensen. Handbook of Road Safety Measures. Emerald Group Publishing, 2nd ed. 2009.

Previous   Next

Figure 7-7: Benefits page

The "Benefit Quantification" screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In determining agency benefits, the user will be required to enter the expected cost of standard steel blade inserts for the length of plow that is being evaluated (in this case, an average of 12 foot was employed). Guidance is provided on the cost of steel blade inserts, but the user should employ their own existing cost or estimates obtained from manufacturers for their evaluation. For this demonstration, a cost of $69 for a 6 foot blade was employed. This totals $138 for a 12 foot plow. Note that the total cost for the plow must be entered. This figure is then multiplied by the total number of blade changes that would be required across the plow fleet. The entry of this information is made through a calculator accessed through the agency benefits text box is displayed in Figure 7-8.

Agency Benefits Worksheet - Underbody Plows

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Potential material savings	2728159.5	2	material cost	54563	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				54563	

Figure 7-8: Agency benefit calculator

In the case of underbody plows, some general information is also available that provides a rough estimate of an expected reduction in crashes. This information allows the user, if they choose to do so, to estimate the potential reduction in injury and property damage crashes that may accrue through the use of underbody plows. Recommended guidance suggest that a reduction of between 1 percent and 5 percent in injury crash costs and between 1 percent and 10 percent property damage crash costs can be expected through the use of improved winter maintenance equipment, such as underbody plows. For this example, a conservative figure of 2 percent savings for injury crashes was specified in the user benefits worksheet, while a value of 5 percent was entered for property damage crashes.

User Benefits Worksheet - Underbody Plows

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Potential Crash Reduction (Injury)	32603199.	2	crash cost	652064	
Potential Crash Reduction (Property Damage Only)	2256222.2	5	crash cost	112811	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				764875	

Figure 7-9: User benefit calculator

As no tangible societal benefits have been quantified for underbody plows, the user will have completed benefits quantification at this point. Of course, if any additional societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 7-10. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

Step 4 of 5: Benefit Quantification

Monetary value of tangible benefits

Project Parameters

Life Cycle (years): 5

Discount Rate (%): 7

Annual material costs: 17291152

Number of equipped trucks: 142

Total trucks: 900

Total storm event Injury crashes (per season): 2583

Cost of injury crash: 80000

Total storm event Property Damage Only crashes (per season): 5720

Cost of PDO crash: 2500

Benefit Calculations

Agency Benefits	
Annualized (click on field for calculator)	54563
Present Value	223719
Annualized Benefit per Truck	384
User (Motorist) Benefits	
Annualized (click on field for calculator)	764875
Present Value	3136139
Annualized Benefit per Truck	5386
Society Benefits	
Annualized	
Present Value	0
Annualized Benefit per Truck	0
Total Benefits	
Annualized	819438
Present Value	3359858
Annualized Benefit per Truck	5771

Benefit-Cost Ratio

Agency Benefits	0.2
Total Benefits	2.5

Figure 7-10: Completed benefit quantification screen

As Figure 7-10 indicates, the agency benefit-cost ratio are 0.2, while the total benefit-cost ratio is 2.5. This difference is due to the inclusion of user benefits, name the expected reduction in crash costs associated with the use of underbody plows. Of course, if a more aggressive expected percent reduction in material use was employed, the agency benefit-cost ratio would rise. The user is cautioned to employ realistic and/or conservative expected percentages in all cases, based on experience or research findings.

In this example, from an agency perspective, for each one dollar spent by the agency, a benefit of only $0.20 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. When user benefits are factored in, the cost benefit ratio changes such that for each dollar spent on an underbody plow, a benefit of $2.5 is accrued, namely though the savings produced by reduced crashes and costs.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the "Results" page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

7.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 7-2.

Table 7-2: Underbody plow results

Agency Costs - Initial	Iowa	Indiana	Washington
Underbody plows ($7500)	$1,065,000	$22,500	$135,000
Installation cost ($1200)	$170,400	$3,600	$21,600
Agency Costs - Annual			
Replacement blades ($105)	$16,567	$630	$1,759
Equipment maintenance	$6,759	$173	$5,985
Total Costs - Summary			
Annualized cost	$324,629	$7,169	$45,937
Present value	$1,331,041	$29,392	$188,352
Annualized cost/truck	$2,286	$2,390	$2,552
Agency Benefits - Initial			
Material savings	$54,563	$974	$11,121
User Benefits			
Crash savings	$764,875	$0	$29,000
Total Benefits - Summary			
Annualized benefit	$819,438	$974	$40,121
Present value	$3,359,858	$3,994	$164,504
Annualized benefit/truck	$5,771	$325	$2,229
Cost-Benefit Ratios			
Agency	0.2	0.1	0.2
Total	2.5	0.1	0.9

As the results indicate, depending on the specific agency parameters entered, different benefit-cost ratios were generated between each state. In the case of underbody plows, no agency-only cost benefit ratios exceeded 1.0. However, when the benefits accrued by society were factored in, Iowa did generate a benefit-cost ratio exceeding 1.0. In the case of Indiana, no crash data was available, so the potential benefits to safety could not be accounted for in that state. For Washington, crash data were available, but the societal benefits accrued from underbody plows were not great enough under the assumed example to generate a benefit-cost ratio of 1.0 or greater. Depending on their particular instances, a state may have to consider the intangible benefits offered by an underbody plow in addition to the cost–benefit ratio if a purchase is still desired.

7.6. Report Conversion

While step 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 7-11. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

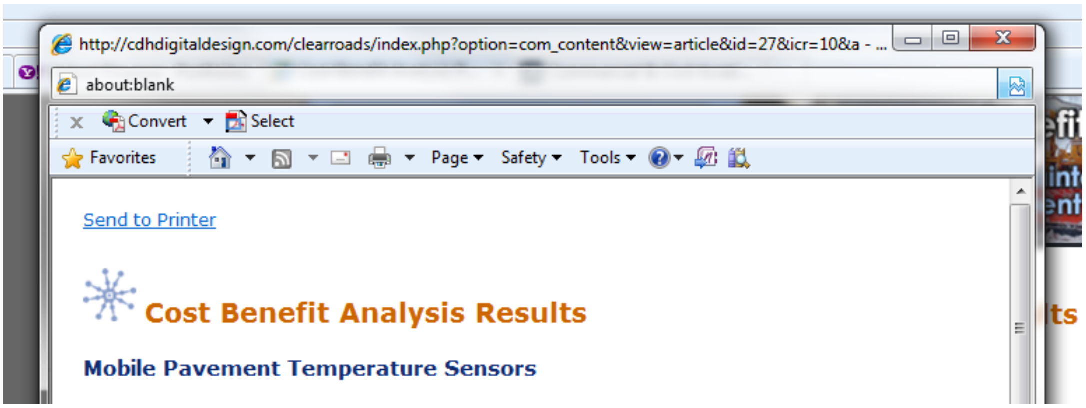


Figure 7-11: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [7]) or installed on their machine (if available).

7.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate underbody plows. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for underbody plows. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[7] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

8. ZERO VELOCITY SPREADERS

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of zero velocity spreaders.

8.1. Sample Data

For this example, data provided by the Iowa Department of Transportation will be employed. This data, along with that of Indiana and Washington are presented in Table 8-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 8-1: Underbody plow sample data

Zero Velocity Spreaders	Iowa	Indiana	Washington
Project Parameters			
Number of vehicles to equip	73	*3*	*18*
Total number of fleet vehicles	900	23	72
Labor rate	$21.42	$14.42	$30.86
Hours to install spreader	1	1	*1*
Hours to maintain spreader/year	10	10	*10*
Annual material costs	$15,598,288	$320,673	*$433,085*

Italics denote an assumed value for demonstration purposes
Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed are for the entire state of Iowa. To begin, the user will select the "Underbody plow" link under the Operations heading on the Technology Selection page. This is displayed in Figure 8-1.

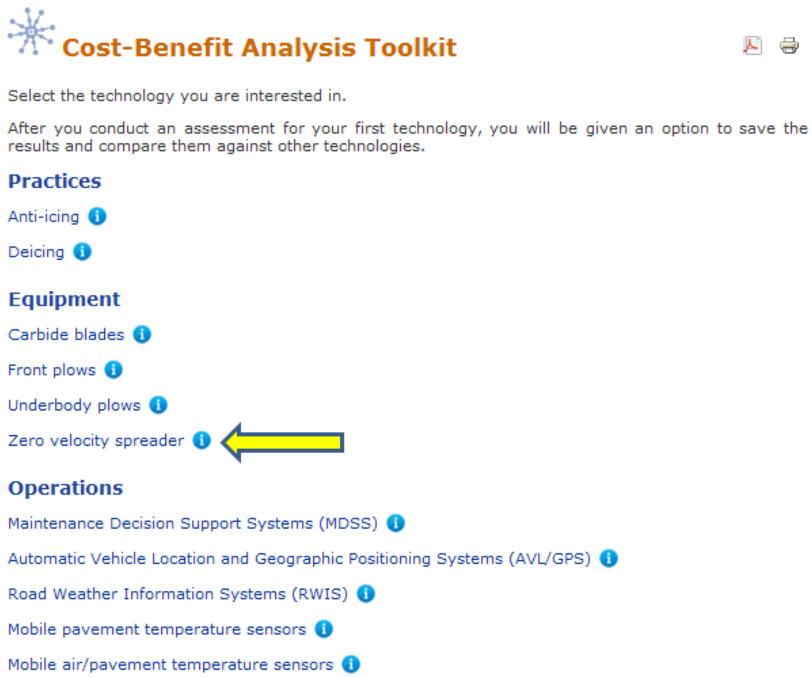


Figure 8-1: Zero velocity spreader selection

8.2. Project Parameters

Once the zero velocity spreader has been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (6 years). However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 6 year life cycle will be employed, as they are reasonable in the context of zero velocity spreaders.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Number of trucks to equip. For this example, 73 trucks will be equipped with zero velocity spreaders.
- Total number of trucks. For this example, there is a total fleet of 900 trucks.
- Loaded labor cost. For this example, the loaded labor cost is $21.42.
- Hours to install on vehicle. In this example, Iowa has indicated that installation takes one hour.

- Hours to maintain per year per vehicle. For this example, Iowa has indicated that each spreader requires 10 hours of maintenance throughout the year.
- Annual material costs for all trucks. For this example, the annual material cost is $15,598,288, which excludes the cost of liquid treatments which are not handled by zero velocity spreaders.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, a material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 8-2.

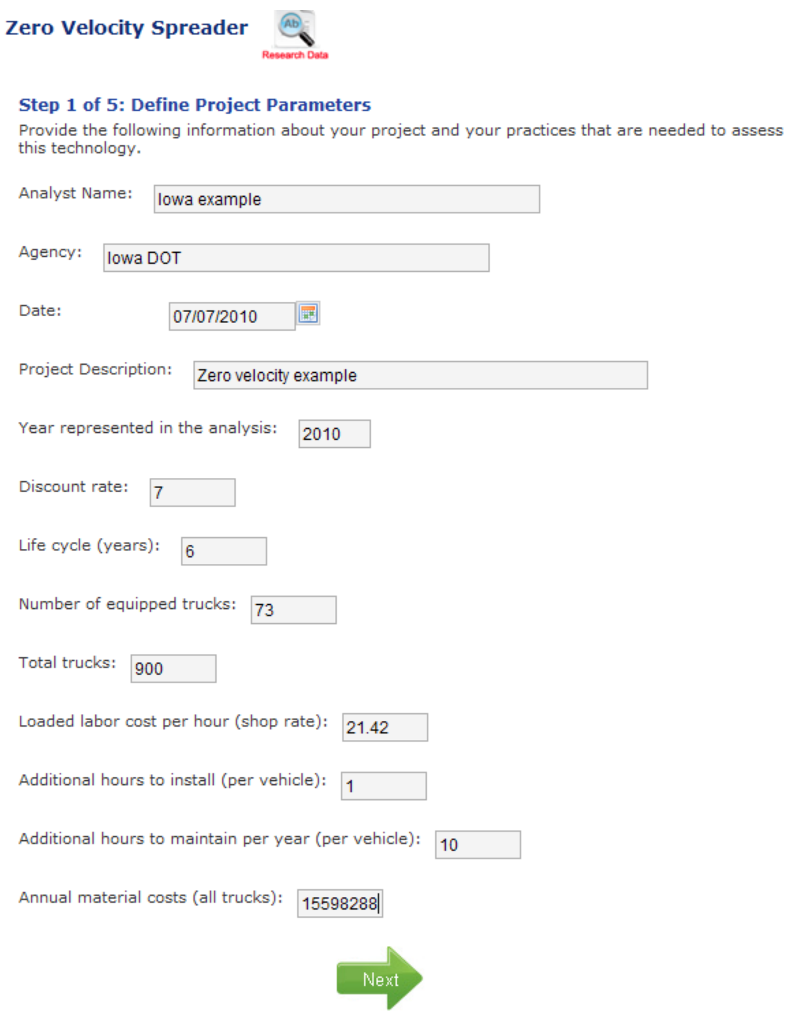


Figure 8-2: Project parameters data entry

8.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For zero velocity spreaders, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the in-vehicle equipment costs. The spreadsheet is designed to automatically populate using the data entered by the user previously, as shown in Figure 8-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the initial cost per zero velocity spreader is assumed to be $9,000 per vehicle. The assumed installation cost per spreader is $21.42 (1 hour of labor). Finally, the user may account for the cost of a standard spreader that may have been installed instead of a zero velocity spreader. In this example, a cost of $4,500 is attributed to a standard spreader. The premise is that the money for a baseline spreader would have been spent in any case, and so the true cost of the zero velocity spreader is that above and beyond the baseline (in this example, $4,500). Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.

Initial Costs Worksheet - Zero Velocity Spreader

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
Zero velocity spreader cost	9000	73	vehicles	657000	
Installation cost (additional time)	21.42	73	vehicles	1563.66	
Other 1 (define)	0			0	
Other 2 (define)	0	0		0	
Cost of Alternative					
Minus cost for standard spreader	-4500	73	vehicles	-328500	
Total initial expenditure				330064	

Figure 8-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet automatically populated with the project parameters. In this case however, the user does not need to specify any values. Instead, the only annual cost associated with zero velocity spreaders, maintenance hours, is already computed. As seen, this cost is approximately $214 per year per vehicle. Once the user has examined the spreadsheet, they should select the green check mark to return to the main cost page, which will be updated automatically.

Annual Costs Worksheet - Zero Velocity Spreader

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Equipment maintenance	214.20000	73	vehicles	15636.6	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annual O&M Costs				15637	

Figure 8-4: Annual costs spreadsheet, manually populated

In the cast of zero velocity spreaders, no tangible societal costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

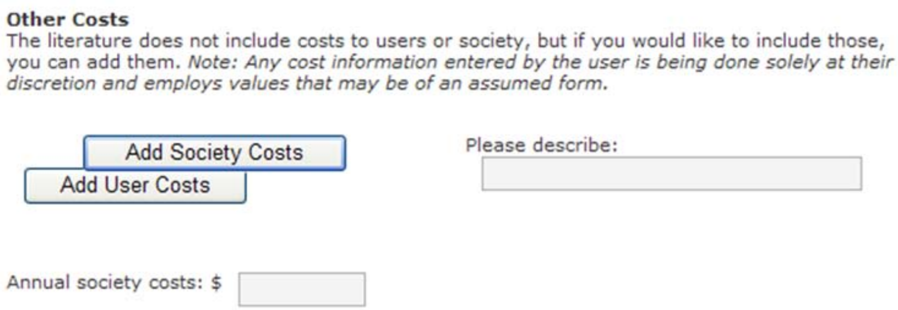


Figure 8-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the zero velocity spreader (in this case over a life of 6 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 8-6.

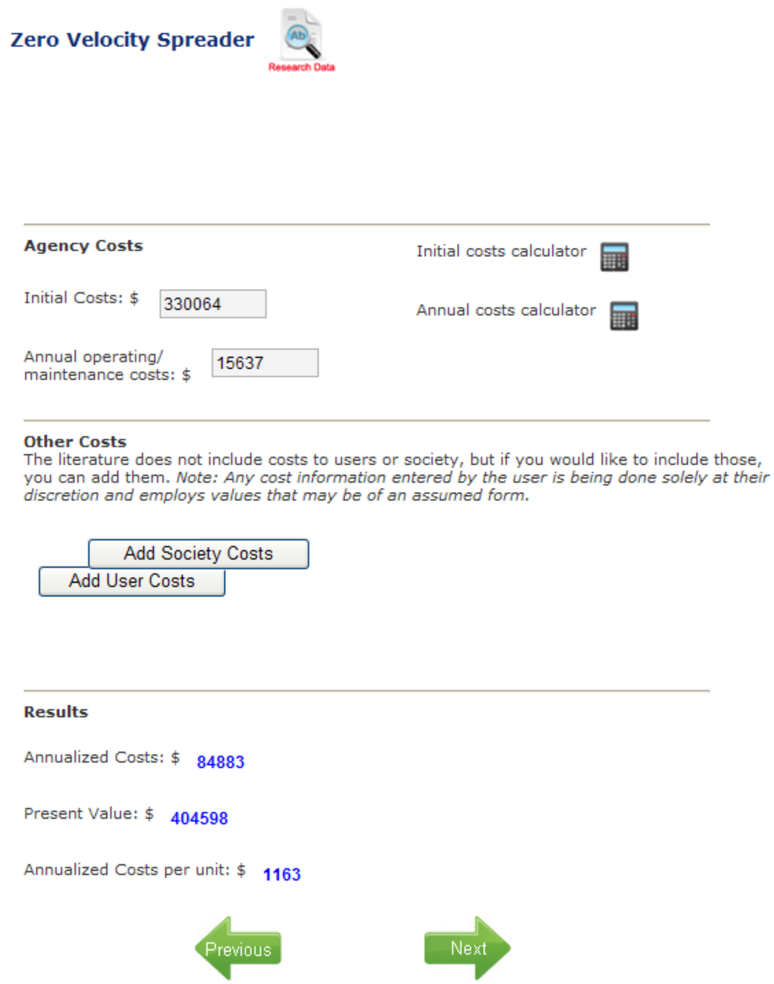


Figure 8-6: Completed cost page

8.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 8-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".

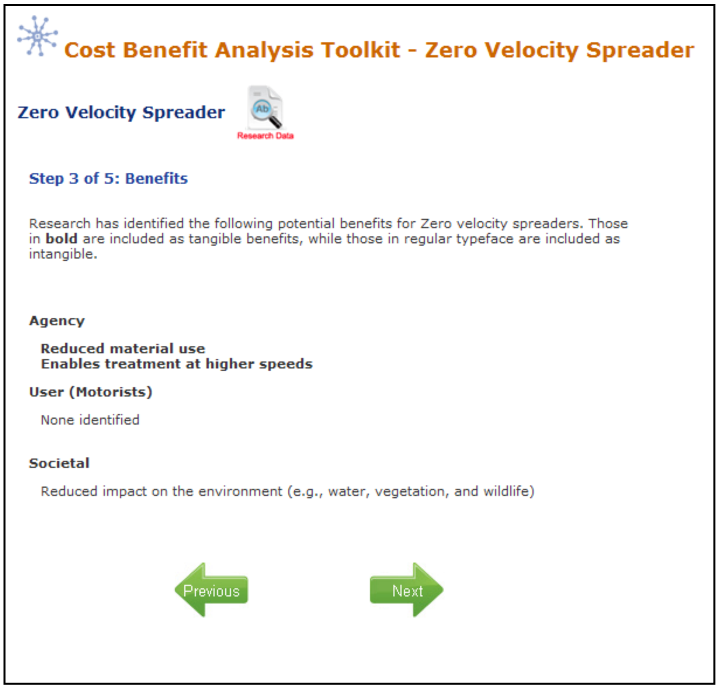
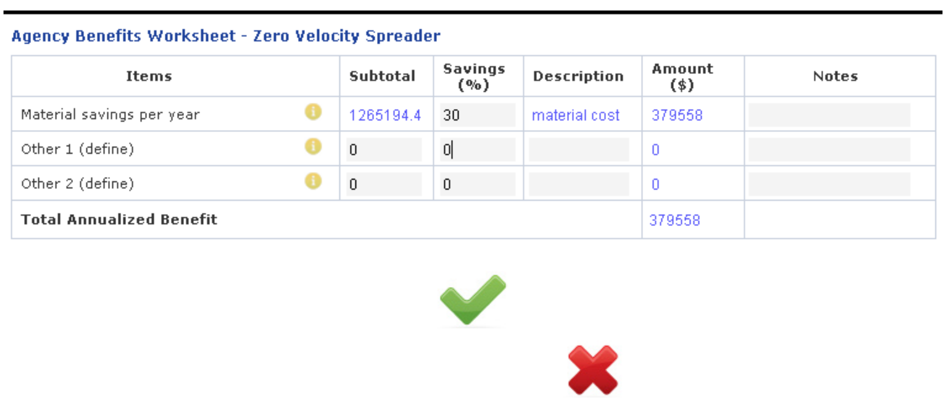


Figure 8-7: Benefits page

The “Benefit Quantification” screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In the case of zero velocity spreaders, the primary quantified benefit is improved retention of materials spread on the roadway (i.e. less materials required to be spread). In this example, a conservative material savings based on past research findings of 30 percent was employed.


Agency Benefits Worksheet - Zero Velocity Spreader

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Material savings per year	1265194.4	30	material cost	379558	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				379558	

Figure 8-8: Agency benefit calculator

In the case of zero velocity spreaders, no tangible user or societal benefits have been quantified, so the user will have completed benefits quantification at this point. Of course, if any additional societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 8-9. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

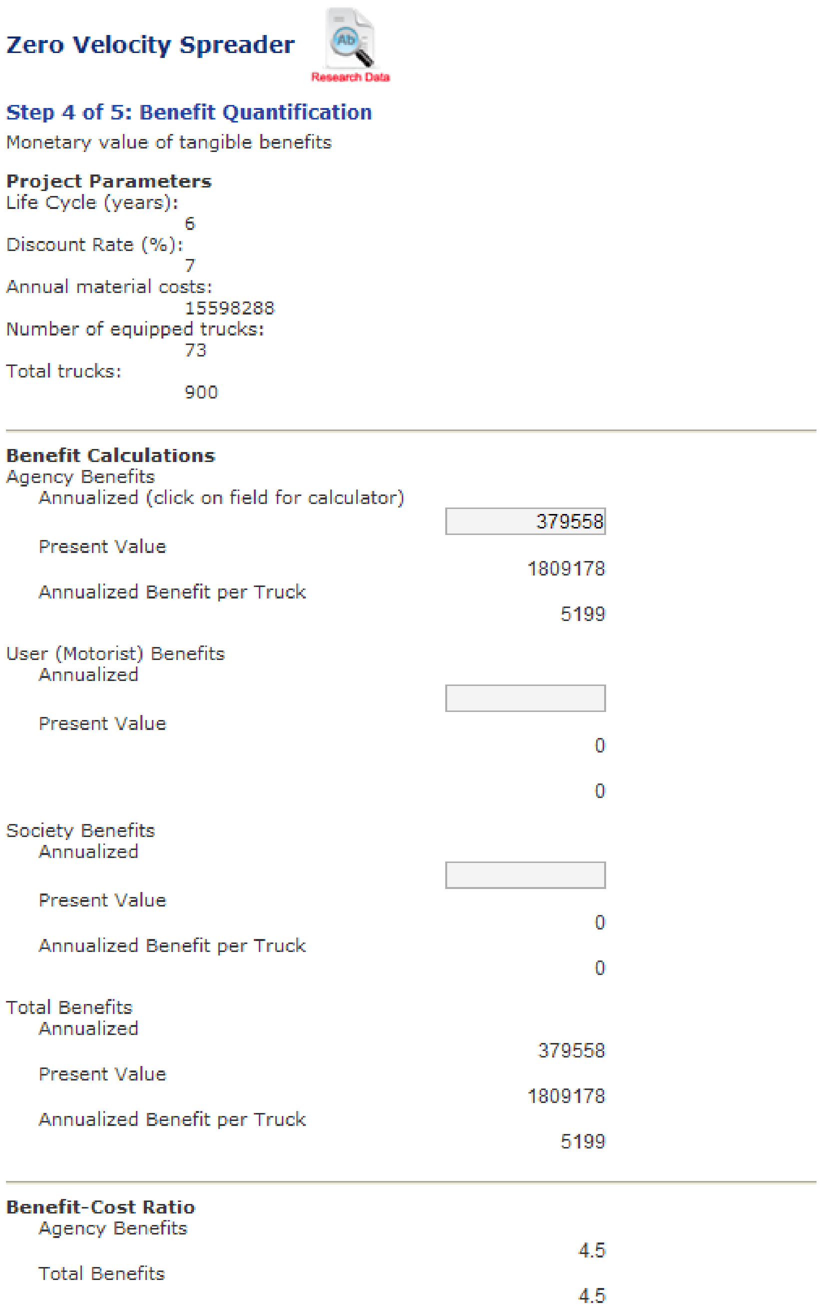


Figure 8-9: Completed benefit quantification screen

As Figure 8-9 indicates, both the agency and total benefit-cost ratios are 4.5. Note that both the agency and total benefit-cost ratios are identical in this case, as no user or societal costs or benefits were available to include in this analysis. This indicates that for each one dollar spent by the agency, a benefit of $4.50 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. In the case of a zero velocity spreader, it appears that their use offers a significant advantage in terms of material savings.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the "Results" page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

8.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 7-2.

Table 8-2: Underbody plow results

Agency Costs - Initial	Iowa	Indiana	Washington
Spreader ($9000)	$657,000	$27,000	$162,000
Installation cost ($21.42)	$1,564	$43	$555
Agency Costs - Annual			
Maintenance ($214)	$15,636	$433	$5,555
Total Costs - Summary			
Annualized cost	$84,883	$3,274	$22,665
Present value	$404,598	$15,607	$108,033
Annualized cost/truck	$1,163	$1,091	$1,259
Agency Benefits			
Material savings	$379,558	$12,548	$32,481
Total Benefits - Summary			
Annualized benefit	$379,558	$12,548	$32,481
Present value	$1,809,178	$59,811	$154,822
Annualized benefit/truck	$5,199	$4,183	$1,805
Cost-Benefit Ratios			
Agency	4.5	3.8	1.4
Total	4.5	3.8	1.4

As the results indicate, depending on the specific agency parameters entered, similar benefit-cost ratios were generated between each state. In the case of zero velocity spreaders, benefit-cost ratios exceeding 1.0 have been achieved. This indicates that in the example scenario presented in this chapter, based on the agency-specific parameters entered into the toolkit, zero velocity spreaders would be a technology that should be pursued.

8.6. Report Conversion

While step 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 8-10. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

Figure 8-10: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [8]) or installed on their machine (if available).

8.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate zero velocity spreaders. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for zero velocity spreaders. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[8] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

9. MAINTENANCE DECISION SUPPORT SYSTEM

This chapter outlines the steps involved in completing a cost-benefit analysis for Maintenance Decision Support Systems (MDSS). Note that the process employed in computing the benefit-cost ratio for MDSS employed the approach developed by the Western Transportation Institute (WTI) for the MDSS Pooled Fund (3). While the exact ratio outputs may slightly differ due to the use of different input metrics by the present work, the results produced during the course of testing this toolkit generally match those of the MDSS study. In this manner, the process developed for this project is in agreement with the one developed specifically for MDSS.

9.1. Sample Data

For this example, data provided by the Indiana Department of Transportation will be employed. This data, along with that of Iowa and Washington are also presented in Table 9-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Indiana at the conclusion of the chapter.

Table 9-1: MDSS sample data

MDSS	Iowa	Indiana	Washington
Project Parameters			
Number of maintenance units	110	*1*	17
Number of computers per unit	2	4	30
Number of vehicles with MDC	*110*	*5*	79
Total number of vehicles	900	23	79
Total material cost per season	$17,291,152	$373,186	$2,224,114

Italics denote an assumed value for demonstration purposes
Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed come from one subdistrict in Indiana. The data reflect the actual values for an existing deployment of MDSS in this subdistrict. To begin, the user will select the MDSS link under the Operations heading on the Technology Selection page. This is displayed in Figure 9-1.

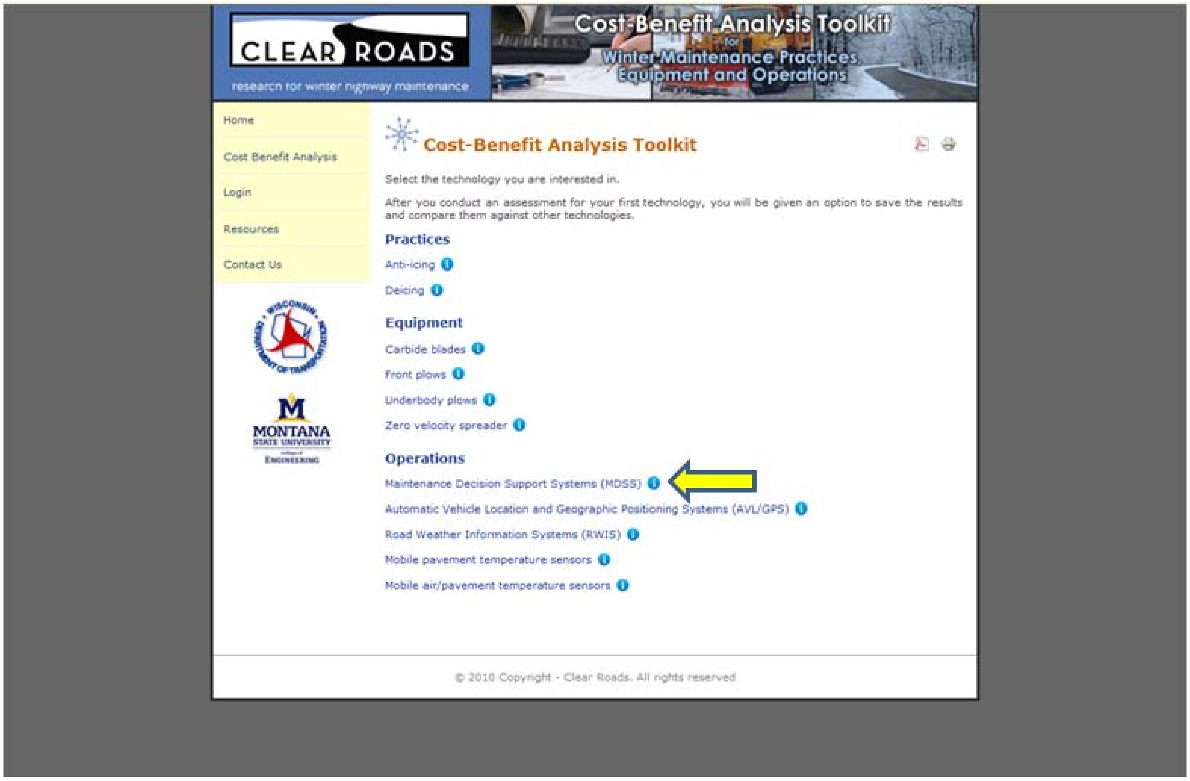


Figure 9-1: MDSS technology selection

9.2. Project Parameters

Once MDSS has been selected as the technology to evaluate, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (5 years). For most of the items in the toolkit, these represent conservative values. However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 5 year life cycle will be employed, as they are reasonable in the context of MDSS.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Number of maintenance units (garages, sheds, etc.). In this example, there is one subdistrict.
- The number of computers to receive MDSS software. In the subdistrict example, four computers will receive software.

- Number of vehicles to receive Mobile Data Collection (MDC) equipment. For this example, five vehicles will receive MDC.
- Total number of vehicles in the maintenance fleet. For this subdistrict, there are a total of 23 vehicles.
- Total winter maintenance materials cost per season. In this subdistrict, the total cost of winter maintenance materials is $373,186.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, the maintenance material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 9-2. Additionally, note that when holding the screen pointer over the "Total material cost per season" entry box, the user will be presented with example data from past research reports.

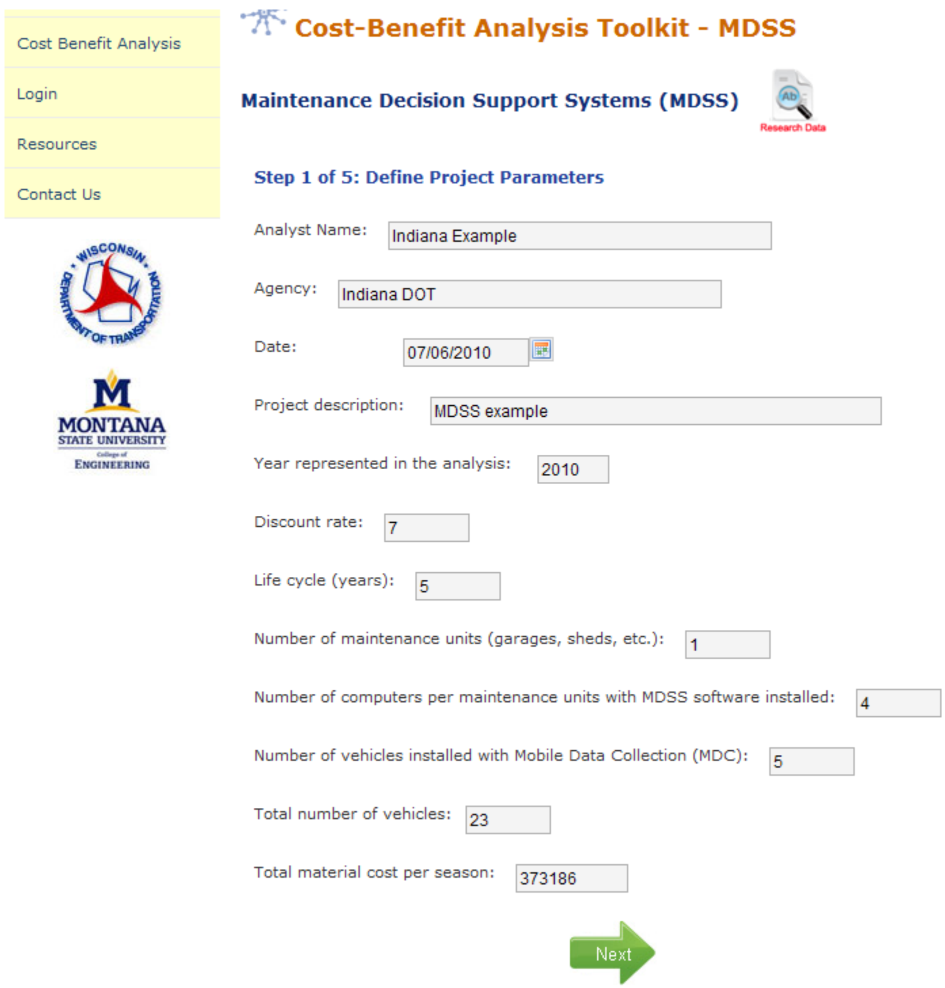


Figure 9-2: Project parameters data entry

9.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For MDSS, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the in-vehicle equipment costs. The spreadsheet is designed to automatically populate using the data entered by the user previously, as well as default costs associated with MDC equipment identified in past research, as shown in Figure 9-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the only initial cost is that of the MDC for five vehicles, totaling $10,000. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.

Initial Costs Worksheet - MDSS

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
In vehicle unit hardware	2000	5	vehicle	10000	
In vehicle unit software		5	vehicle		
In vehicle unit sensors		5	vehicle		
RWIS software initial investment		4	computer		
Communications setup					
Infrastructure investment					
Other 1 (define)					
Other 2 (define)					
Total initial expenditure				10000	

Figure 9-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet partially populated with the project parameters. In this case however, the user will need to specify the annual cost of software ($110 in this case), communications cost ($40 per month times 5 months, or $200) and the maintenance costs associated with the system (guidance suggests that this is 10% of capital costs, in this case a conservative value of 7% is employed, yielding an equation of 0.07 times $2000, the initial MDC cost per unit).

Training costs are the next item the user must determine and enter. In the Indiana example, a total fleet of 23 vehicles was employed. Assuming an identical number of operators, as well as four management employees, plus a trainer, then an annual training cost for 28 employees should be added to the "training" row. In this example, the average hourly rate of employees of $14.42 times 28 yields a cost of $403.76. Of course, the particular user may have figures available from other training at their agency with which to estimate costs. Finally, administrative costs associated with the use of MDSS should be determined and entered. In the case of this example, the general figure of 25% of the total sum of the MDC's, software costs, communications maintenance and training were employed ([$10,000 + $440 + $1,000 + $720 + 404] * .25 = $3,141).

Note that as the specific values are entered, the spreadsheet will update to display total costs. The user should enter only individual costs for each item, as these costs will then be multiplied by the number of units specified previously. Again, once completed, the user should select the green check mark to return to the main cost page, which will be updated automatically.

Annual Costs Worksheet - MDSS

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Software costs or fees	110.00	4	computers	440	
Communications	200.00	5	vehicles	1000	
Vehicle maintenance	144.00	5	vehicles	720	
Additional weather forecast provider costs	0.00	0		0	
Administrative costs	3141.00	1		3141	
Training	403.76	1		404	
Other 1 (define)	0.00	0		0	
Other 2 (define)	0.00	0		0	
Total annual expenditure				5705	

Figure 9-4: Annual costs spreadsheet, manually populated

In the cast of MDSS, no tangible societal or user costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

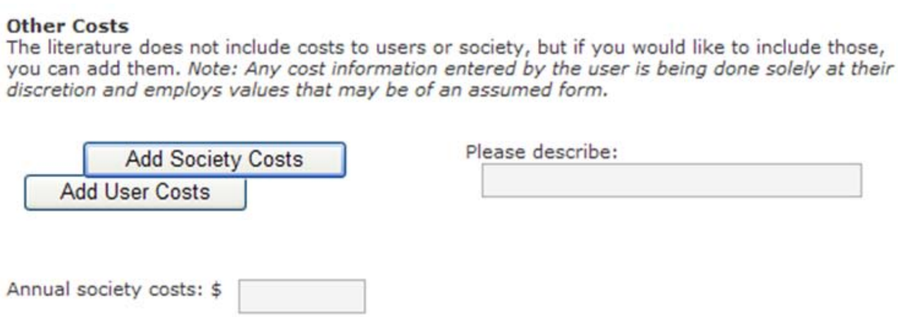


Figure 9-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the system (in this case over a life of 5 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 9-6.

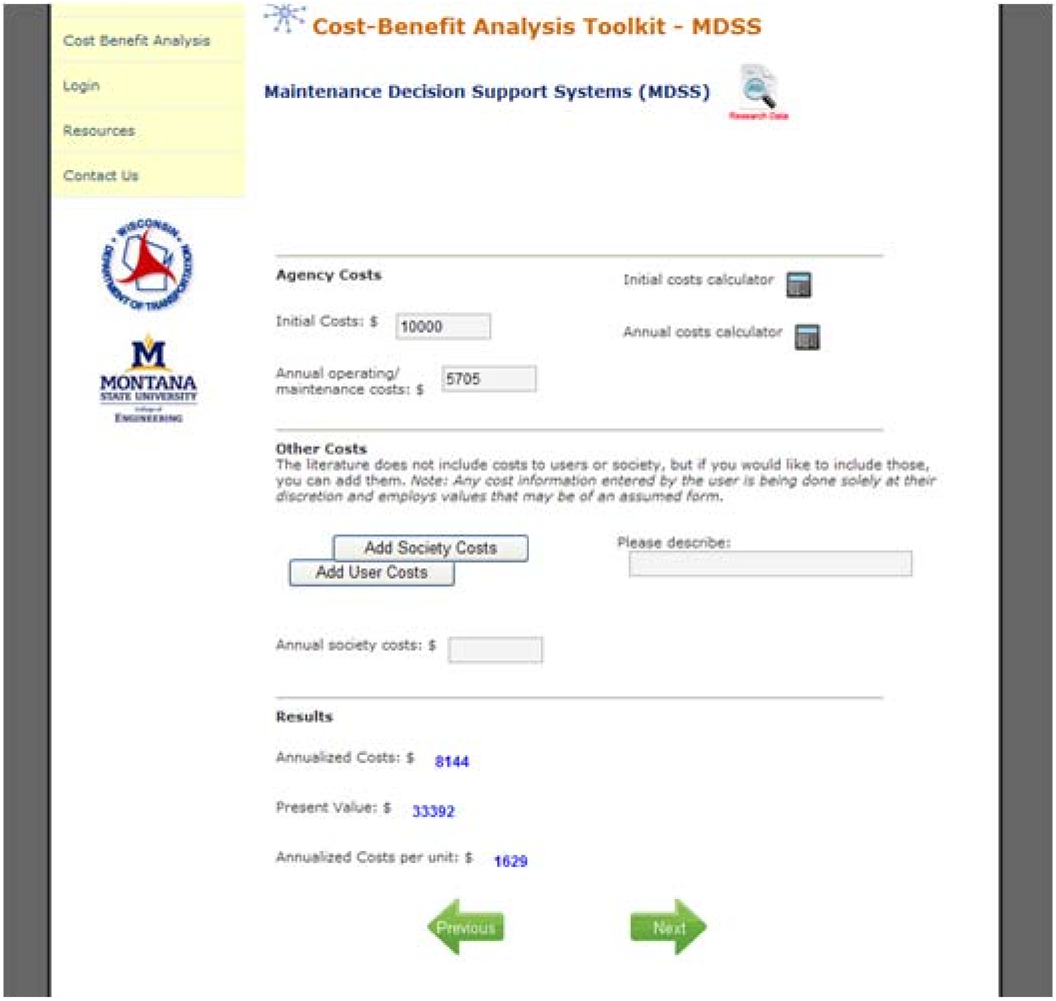


Figure 9-6: Completed cost page

9.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 9-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".

Maintenance Decision Support Systems (MDSS) Supporting Information

Step 3 of 5: Benefits

Research has identified the following potential benefits for MDSS. Those in **bold** are included as tangible benefits, while those in regular typeface are included as intangible.

Agency

Reduced material costs
Reduced negative impacts to transportation infrastructure due to road salts
Reduced labor costs
Reduced equipment costs
Reduced fleet replacement costs
Provides agencies with additional information
Allows better decision making
Useful training tool
Demonstration of environmental stewardship and policy compliance

User (Motorists)

Improved safety
Reduced traffic delay
Reduced corrosion to personal vehicles and trucks
Better road customer satisfaction

Societal

Reduced impact on the environment (e.g., water, vegetation, and wildlife)

Figure 9-7: Benefits page

The “Benefit Quantification” screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In the case MDSS, the user will need to enter an expected percent reduction in material costs. For this example, a figure of 15 percent was employed.

Agency Benefits Worksheet - MDSS

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Material savings per year	81127	15	material cost	12169	
Other 1 (define)				0	
Other 2 (define)					
Total Annualized Benefit				12169	

Figure 9-8: Agency benefit calculator

In the case of MDSS, user benefits can also be factored in based on the findings of past work. In this example, a user savings of 15 percent of total material costs has been employed. To include this benefit, the user will select the user benefits calculator by clicking inside the user benefits textbox. The completed user benefits calculator is shown in Figure 10-9.

No known tangible societal benefits have been quantified for MDSS. Of course, if any societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 9-10. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

User Benefits Worksheet - MDSS

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Improved safety and reduced traffic delay	81127	15	material cost	12169	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				12169	

Figure 9-9: User benefit calculator

5
Total number of vehicles:
23

Benefit Calculations
Agency Benefits
Annualized (click on field for calculator) 12169
Present Value 49895
Annualized Benefit per Truck 2434

User (Motorist) Benefits
Annualized (click on field for calculator) 12169
Present Value 49895
Annualized Benefit per Truck 2434

Society Benefits
Annualized 0
Present Value 0
Annualized Benefit per Truck 0

Total Benefits
Annualized 24338
Present Value 99791
Annualized Benefit per Truck 4868

Benefit-Cost Ratio
Agency Benefits 1.5
Total Benefits 3

Figure 9-10: Completed benefit quantification screen

As Figure 9-10 indicates, the agency benefit-cost ratio for MDSS is 1.5, while the total benefit-cost ratio is 3. For agency benefits, the ratio suggests that for each one dollar spent by the agency, a benefit of $1.50 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. For user benefits, the ratio indicates that for each one dollar spent by the agency, a benefit of $3.00 may be obtained. In the case of MDSS, it appears that the cost of the system over its lifespan is justified by the benefits produced, both to the agency individually, as well as when user benefits are factored in.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the “Results” page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

9.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 9-2.

Table 9-2: MDSS results

Agency Costs - Initial	Iowa	Indiana	Washington
In vehicle hardware ($2000)	$220,000	$10,000	$158,000
Agency Costs - Annual			
Software ($110)	$24,200	$220	$56,100
Communications ($200)	$22,000	$1,000	$15,800
Maintenance (~10% of capital costs)	$15,840	$720	$11,376
Admininstrative (25% of direct costs)	$76,422	$3,141	$57,738
Training	$23,650	$404	$1,054
Total Costs - Summary			
Annualized cost	$194,346	$7,924	$180,603
Present value	$796,857	$32,490	$740,507
Annualized cost/truck	$1,767	$1,585	$2,286
Agency Benefits			
Material savings (15%)	$317,004	$12,267	$333,617
User Benefits			
User savings	$317,004	$12,267	$333,617
Total Benefits - Summary			
Annualized benefit	$634,009	$24,534	$667,234
Present value	$2,599,562	$100,594	$2,735,791
Annualized benefit/truck	$5,764	$4,907	$8,446
Cost-Benefit Ratios			
Agency	1.6	1.5	1.8
Total	3.3	3.0	3.7

As the results indicate, depending on the specific agency parameters entered, similar benefit-cost ratios were generated between each state. In the case of MDSS, benefits are greatly enhanced when those accrued by society are taken into account. Still, when solely agency costs and benefits are accounted for, benefit-cost ratios exceeding 1.0 are achieved. This indicates that in the example scenario presented in this chapter, based on the agency-specific parameters entered into the toolkit, MDSS would be a technology that should be pursued.

9.6. Report Conversion

While page 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 9-11. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

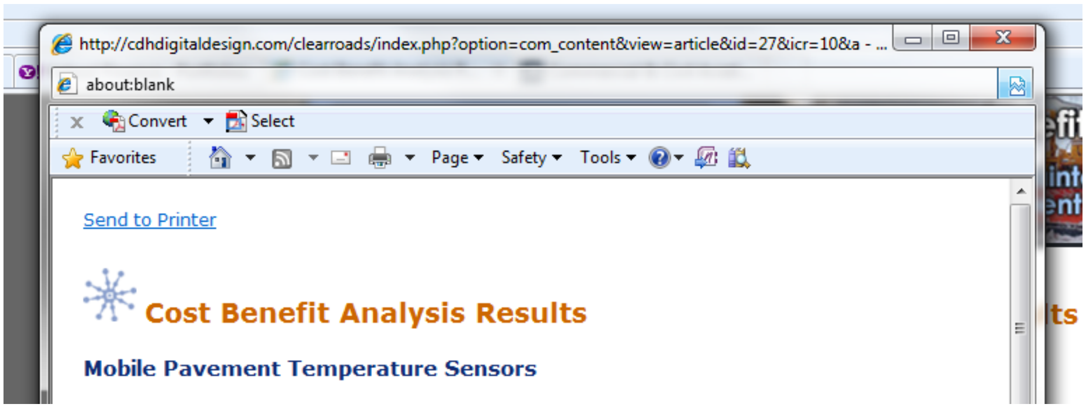


Figure 9-11: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [9]) or installed on their machine (if available).

9.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate MDSS. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for MDSS. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[9] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

10.ROAD WEATHER INFORMATION SYSTEM

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of a Road Weather Information System (RWIS).

10.1. Sample Data

For this example, data provided by the Iowa Department of Transportation will be employed. This data, along with that of Indiana and Washington are presented in Table 10-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 10-1: RWIS sample data

RWIS	Iowa	Indiana	Washington
Project Parameters			
Current weather costs	$450,000	*$2,710*	$15,000
Planned/existing stations	68	1	49
Number of users	*900*	*1*	200
Labor rate	*$21.42*	*$19.70*	$30.86
Hours of training	*2*	2	2
Annual material costs	$17,291,152	$373,186	$2,224,114
Storm-related labor costs	$4,626,720	$65,246	*$333,032*
Total storm crashes	8346	0	383

Italics denote an assumed value for demonstration purposes
Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed are for the entire state of Iowa. To begin, the user will select the “Road Weather Information System” link under the Operations heading on the Technology Selection page. This is displayed in Figure 10-1.

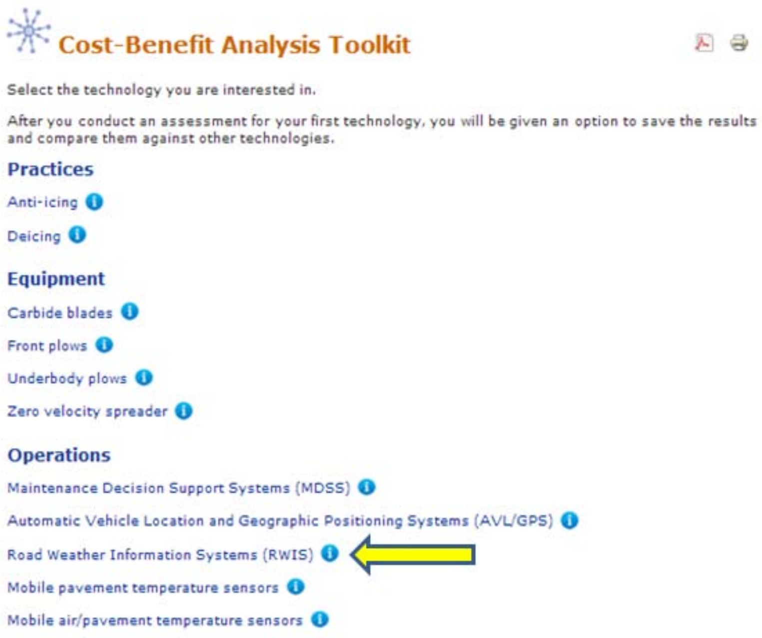


Figure 10-1: RWIS selection

10.2. Project Parameters

Once RWIS has been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (10 years). However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 10 year life cycle will be employed, as they are reasonable in the context of RWIS.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Current weather information cost. For this example, the current cost of weather information is $450,000.
- Number of planned stations. For this example, there are 68 RWIS stations.
- Expected number of users. For this example, there are 900 users.
- Loaded labor cost. For this example, the loaded labor cost is $21.42.
- Average hours of training per user. For this example, each user will receive 2 hours of training.
- Annual material costs. For this example, the annual material cost is $17,295,152.

- Storm related labor costs per season. For this example, an estimate of $4,626,720 is employed.
- Annual number of storm related crashes. For this example, a total of 8,346 crashes is employed.
- Average crash cost. For this example, the cost of $33,700 employed by Ye. et.al. (**Error! Bookmark not defined.**) is employed.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, a material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 10-2.

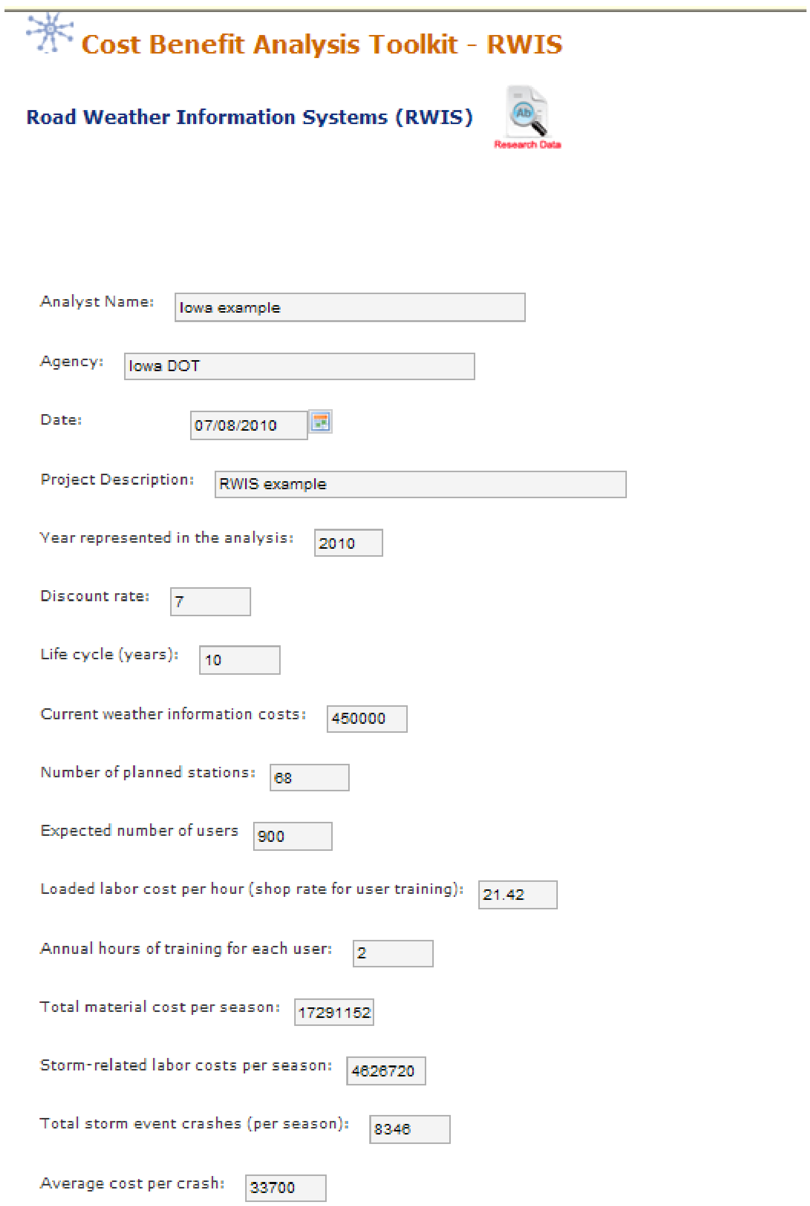


Figure 10-2: Project parameters data entry

10.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For RWIS, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the costs associated with the RWIS station, installation, site preparations, communications and the central processing unit (CPU). The spreadsheet is designed to automatically populate using the data entered by the user, as shown in Figure 10-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the cost per RWIS station is $50,000, installation $3,000, site preparation $0 (considered to be included under installation in this case), communications $50, and a CPU $4,000. Note that the value associated with current forecast cost is subtracted from these costs, as RWIS would replace such information in the future. If the agency intends to retain forecasts in the future entirely or at a reduced rate, the user should use the previous feature to return to the project parameters page and enter that future value. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.

Initial Costs Worksheet - RWIS

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
RWIS station - including on-site equipment	50000	68	stations	3400000	
Installation cost	3000	68	stations	204000	
Site preparations	0	68	stations	0	
Communications installation	50	68	stations	3400	
Central processing unit	4000	2	forecast	8000	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Cost of Alternative					
Minus cost for baseline condition	-450000	1	forecast	-450000	
Total initial expenditure				3165400	

Figure 10-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet automatically populated with the project parameters. In this case the user will need to enter the annual cost of communications and maintenance. For this example, the annual cost per site for communications is estimated to be $200. Similarly, the user will enter the cost of maintenance per site, which is $2,550 for this example. Once the user has examined the spreadsheet, they should select the green check mark to return to the main cost page, which will be updated automatically.

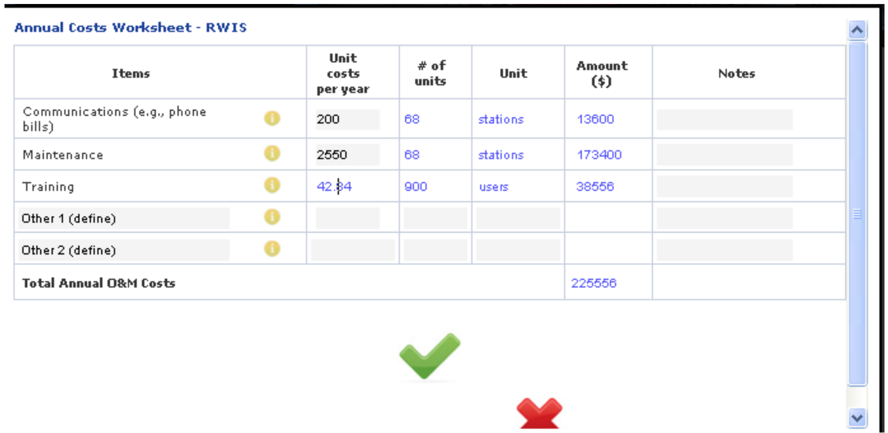


Figure 10-4: Annual costs spreadsheet, manually populated

In the case of RWIS, no tangible societal costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

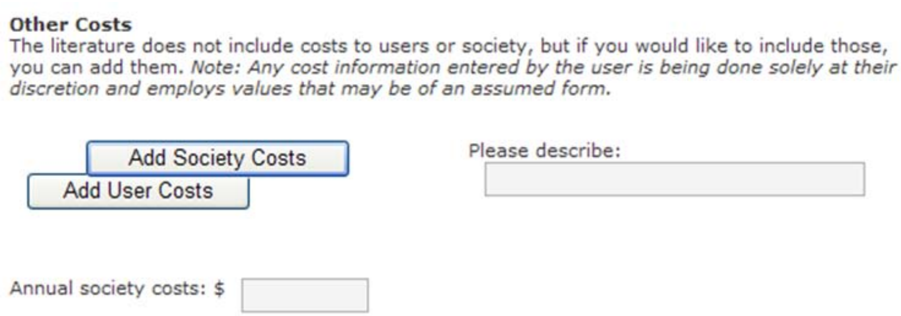


Figure 10-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the RWIS (in this case over a life of 10 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 10-6.

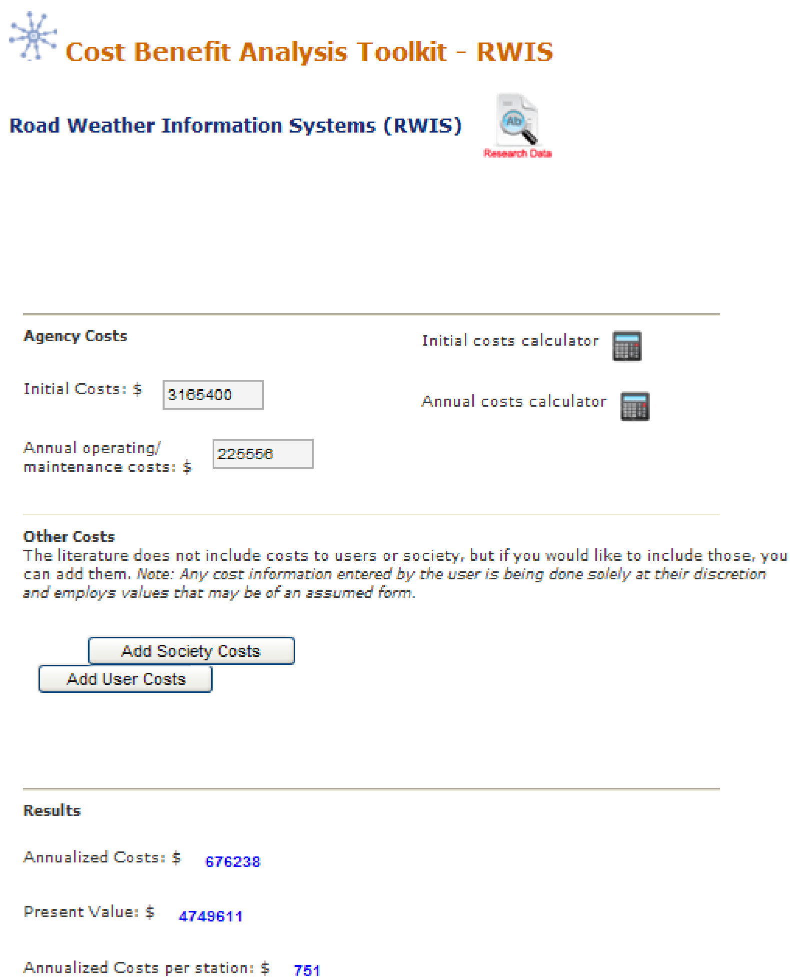


Figure 10-6: Completed cost page

10.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled "Benefits". This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 10-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, "Benefit Quantification".

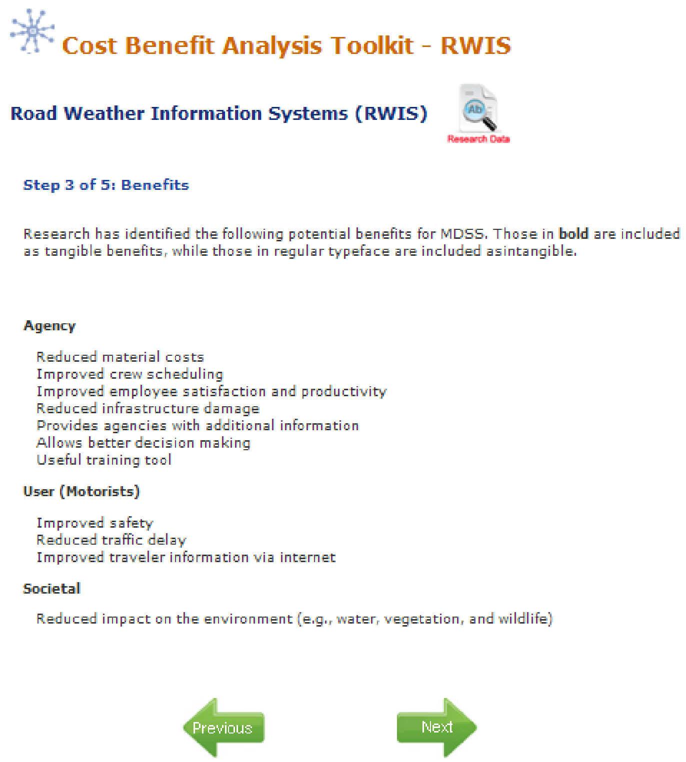


Figure 10-7: Benefits page

The “Benefit Quantification” screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In the case RWIS, the user will need to decide whether their application will employ material savings alone, or whether the expected material and labor savings combined are of interest. ***Note that the user should only employ one of these two approaches in the calculator. If a percent reduction is employed for both material savings and labor and material savings, an erroneous benefit-cost ratio will result, as material savings will be double counted***.

In this example, the primary quantified benefits will be only material savings. A conservative value of 15 percent material cost savings has been employed. This reduction is the result of less passes being required on a given roadway, allowing for less materials to be spread over time.

Agency Benefits Worksheet - RWIS

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Material savings per year	17291152	15	Material costs	2593673	
Labor and material savings per year	17291152	0	Labor and ma	0	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				2593673	

Figure 10-8: Agency benefit calculator

In the case of RWIS, user benefits, specifically crash reductions, have also been quantified. To include this benefit, the user will select the user benefits calculator by clicking inside the user benefits textbox. In the case of RWIS, a conservative crash reduction of 10 percent has been employed, although research has shown that reductions of up to 17 percent have been observed (4). The completed user benefits calculator is shown in Figure 10-9.

No known tangible societal benefits have been quantified for RWIS. Of course, if any societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 10-10. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

User Benefits Worksheet - RWIS

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Crash reduction per year	28126020	10	Crashes	28126020	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				28126020	

Figure 10-9: User benefit calculator

Step 4 of 5: Benefit Quantification

Monetary value of tangible benefits

Project Parameters

Life Cycle (years):
10

Discount Rate (%):
7

Loaded labor cost per hour (shop rate for user training):
21.42

Annual hours of training for each user:
2

Total material cost per season:
17291152

Storm-related labor costs per season:
4626720

Total storm event crashes (per season):
8346

Average cost per crash:
33700

Benefit Calculations

Agency Benefits	
Annualized (click on field for calculator)	2593673
Present Value	18216874
Annualized Benefit per station	38142
User (Motorist) Benefits	
Annualized (click on field for calculator)	28126020
Present Value	197545395
Annualized Benefit per site	413618
Society Benefits	
Annualized	
Present Value	0
Annualized Benefit per station	0
Total Benefits	
Annualized	30719693
Present Value	215762269
Annualized Benefit per station	451760

Benefit-Cost Ratio

Agency Benefits	3.8
Total Benefits	45.4

Figure 10-10: Completed benefit quantification screen

As Figure 10-10 indicates, the agency benefit-cost ratio for RWIS is 3.8, while the total benefit-cost ratio is 45.4. Note that the total benefit-cost ratio is significantly higher based on the large number of statewide storm-related crashes employed in this example, combined with the average crash value of $33,700. A 10 percent reduction in such crashes at that average value would result in a significant cost savings, hence the large total benefit-cost ratio.

For agency benefits, the ratio suggests that for each one dollar spent by the agency, a benefit of $3.80 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. For user benefits, the ratio indicates that for each one dollar spent by the agency, a benefit of $45.40 may be obtained. In the case of RWIS, it appears that the large initial cost of the system is more than outweighed over its lifespan by the benefits produced, both to the agency individually, as well as when user benefits are factored in.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the “Results” page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

10.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 10-2.

Table 10-2: RWIS results

Agency Costs - Initial	Iowa	Indiana	Washington
Station ($50000)	$3,400,000	$50,000	$2,450,000
Installation ($3000)	$204,000	$3,000	$147,000
Communications ($50)	$3,400	$50	$2,450
Central Processor ($4000)	$8,000	$4,000	$8,000
Agency Costs - Annual			
Communications ($200)	$13,600	$200	$9,800
Maintenance ($2550)	$173,400	$2,550	$124,950
Training ($42.82)	$38,556	$39	$12,334
Total Costs - Summary			
Annualized cost	$676,238	$11,095	$516,201
Present value	$4,749,611	$77,929	$3,625,577
Annualized cost/truck	$751	$11,095	$2,581
Agency Benefits			
Material savings	$2,593,673	$55,978	$333,617
User Benefits			
Crash savings	$28,126,020	$0	$1,290,710
Total Benefits - Summary			
Annualized benefit	$2,593,673	$55,978	$1,624,327
Present value	$18,216,872	$393,166	$11,408,593
Annualized benefit/truck	$38,142	$55,978	$33,150
Cost-Benefit Ratios			
Agency	3.8	5.0	0.6
Total	45.4	5.0	3.1

As the results indicate, depending on the specific agency parameters entered, benefit-cost ratios above 1.0 were generated between each state, with the exception of the agency ratio for Washington. This exception appears to be the result of lower annual existing weather forecast costs, as well as a smaller material cost relative to the other test cases. In the case of RWIS, benefits are greatly enhanced when those accrued by society are taken into account. Still, when solely agency costs and benefits are accounted for, benefit-cost ratios exceeding 1.0 were typically achieved. This indicates that in the example scenario presented in this chapter, based on the agency-specific parameters entered into the toolkit, RWIS would be a technology that should be pursued.

10.6. Report Conversion

While page 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 10-11. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

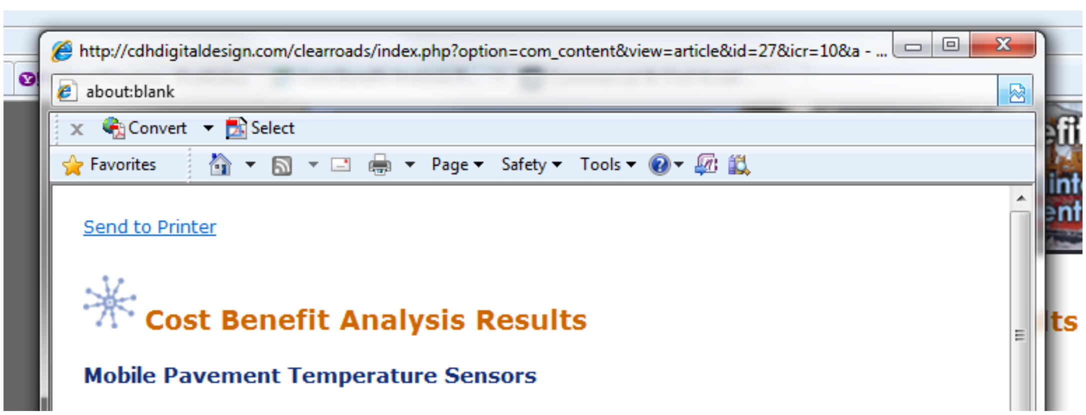


Figure 10-11: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [10]) or installed on their machine (if available).

10.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate RWIS. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for RWIS. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[10] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

11.MOBILE TEMPERATURE SENSORS

This chapter outlines the steps involved in completing a cost-benefit analysis for a mobile temperature sensor system. Note that practitioners were interested in two different types of temperature sensor systems: one collecting strictly pavement temperatures, and a second collecting both pavement and ambient temperatures. The process employed in determining the benefit-cost ratio for either type of system is essentially the same, with the only difference in inputs being the cost of the sensor itself. As a result, only the process employed in calculating benefit-cost ratios for a pavement temperature sensor system will be presented in this chapter. However, the results generated for both types of systems will be presented at the conclusion of this chapter.

11.1. Sample Data

For this example, data provided by the Iowa Department of Transportation will be employed. This data, along with that of Indiana and Washington are also presented in Table 11-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 11-1: Temperature sensor sample data

Mobile Pavement Temperature Sensors	Iowa	Indiana	Washington
Project Parameters			
Number of vehicles to equip	640	20	*19*
Total number of fleet vehicles	900	23	72
Labor rate	$21.42	$14.42	$30.86
Annual material costs	$ 17,291,152	$ 373,186	$ 2,224,114
Installation time (hours)	2	2.5	3
Maintenance time (hours)	0	0	0.5

Italics denote an assumed value for demonstration purposes
Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed come from the entire state of Iowa. To begin, the user will select the “Mobile pavement temperature sensors” link under the Operations heading on the Technology Selection page. This is displayed in Figure 11-1.

Figure 11-1: MDSS technology selection

11.2. Project Parameters

Once pavement temperature sensors have been selected as the technology to evaluate, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (2 years). These represent conservative values. However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 2 year life cycle will be employed, as they are reasonable in the context of a pavement temperature sensor.

Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Number of equipped trucks. In this example, there are 640 trucks equipped with sensors.
- Total number of vehicles in the maintenance fleet. For this example, there are a total of 900 vehicles.
- Total winter maintenance materials cost per season. In this example, the total cost of winter maintenance materials is $17,291,152.
- Hourly labor rate. In this example, hourly labor rate is $21.42.

- Hours to install. In this example, a pavement temperature sensor takes two hours to install (1 hour using two personnel).
- Hours to maintain. In this example, the sensor requires no maintenance.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included***. For example, the maintenance material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 11-2.

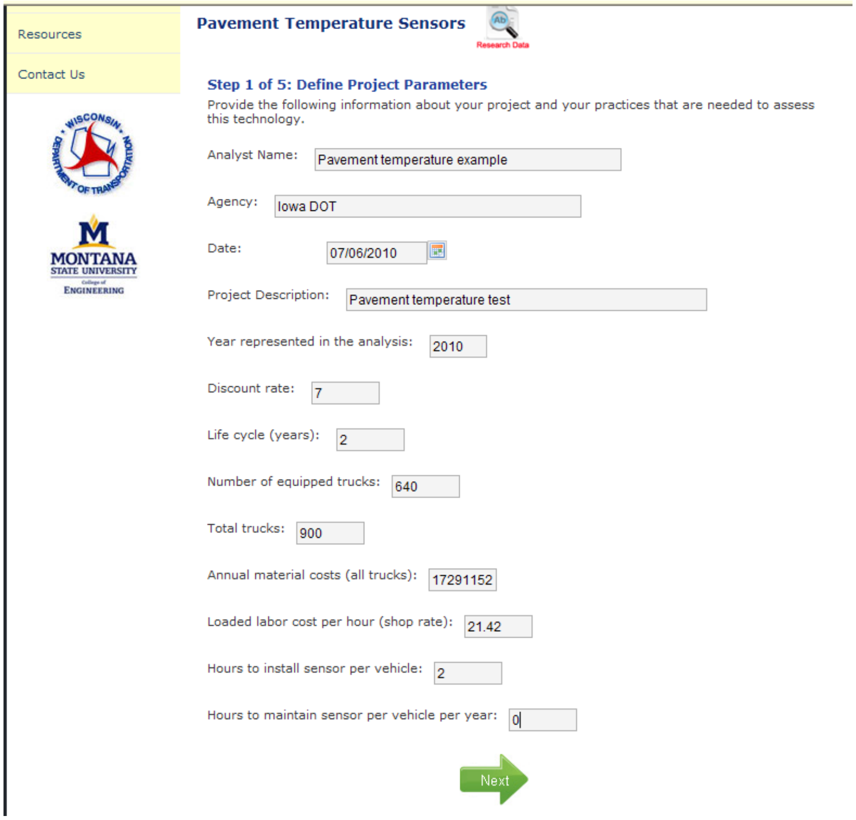


Figure 11-2: Project parameters data entry

11.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For pavement temperature sensors, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the in-vehicle equipment costs. The spreadsheet is designed to automatically populate using the data entered by the user previously, as well as default costs associated with sensor equipment identified in past research, as shown in Figure 11-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the only initial cost that the user must enter is that of the sensor for 640 vehicles. For this example, the sensor cost was specified as $575. Note that in this example, the spreadsheet has automatically updated the labor cost associated with an installation time of two hours. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.

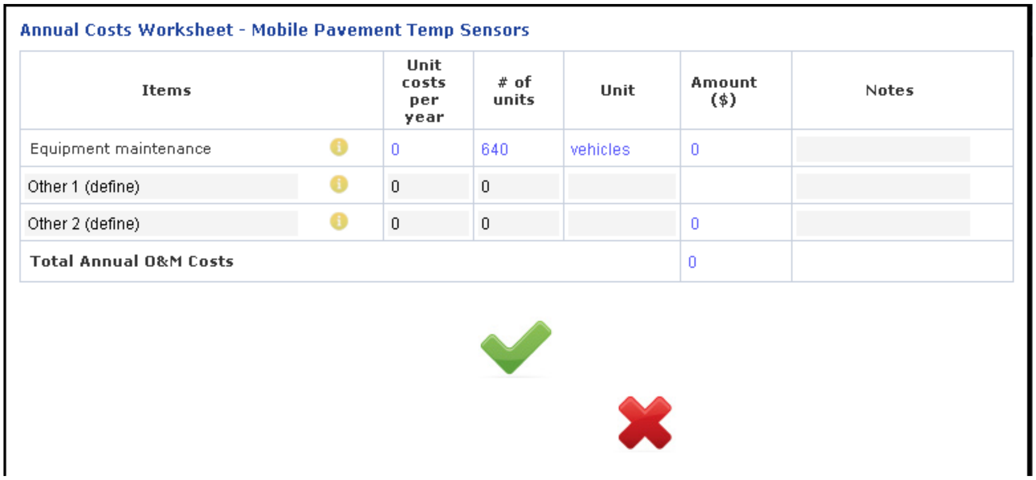
Initial Costs Worksheet - Mobile Pavement Temp Sensors

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
Mobile sensors cost (including accessories - wiring)	575	640	vehicles	368000	
Installation cost (additional time)	43	640	vehicles	27418	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Cost of Alternative					
Minus cost for baseline condition	0	640	0	0	
Total initial expenditure				395418	

Figure 11-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet partially populated with the project parameters. In this case however, there is no expected need for sensor maintenance, so the default of zero hours has been populated in the spreadsheet.

Note that as the specific values are entered, the spreadsheet will update to display total costs. The user should enter only individual costs for each item, as these costs will then be multiplied by the number of units specified previously. Again, once completed, the user should select the green check mark to return to the main cost page, which will be updated automatically.



Annual Costs Worksheet - Mobile Pavement Temp Sensors

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Equipment maintenance	0	640	vehicles	0	
Other 1 (define)	0	0			
Other 2 (define)	0	0		0	
Total Annual O&M Costs				0	

Figure 11-4: Annual costs spreadsheet, manually populated

In the case of pavement temperature sensors, no tangible societal or user costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

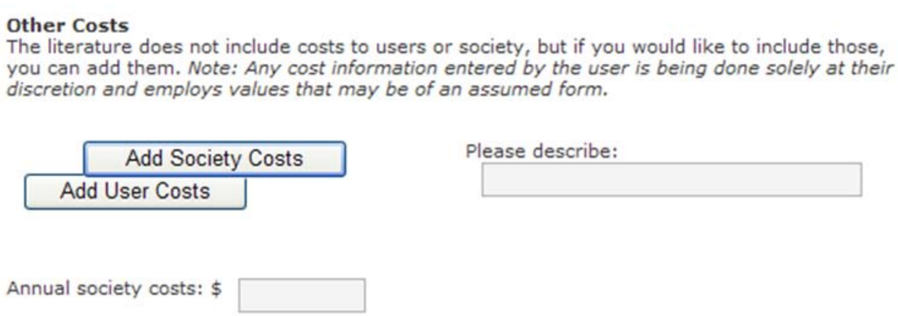


Figure 11-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the system (in this case over a life of 2 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 11-6.

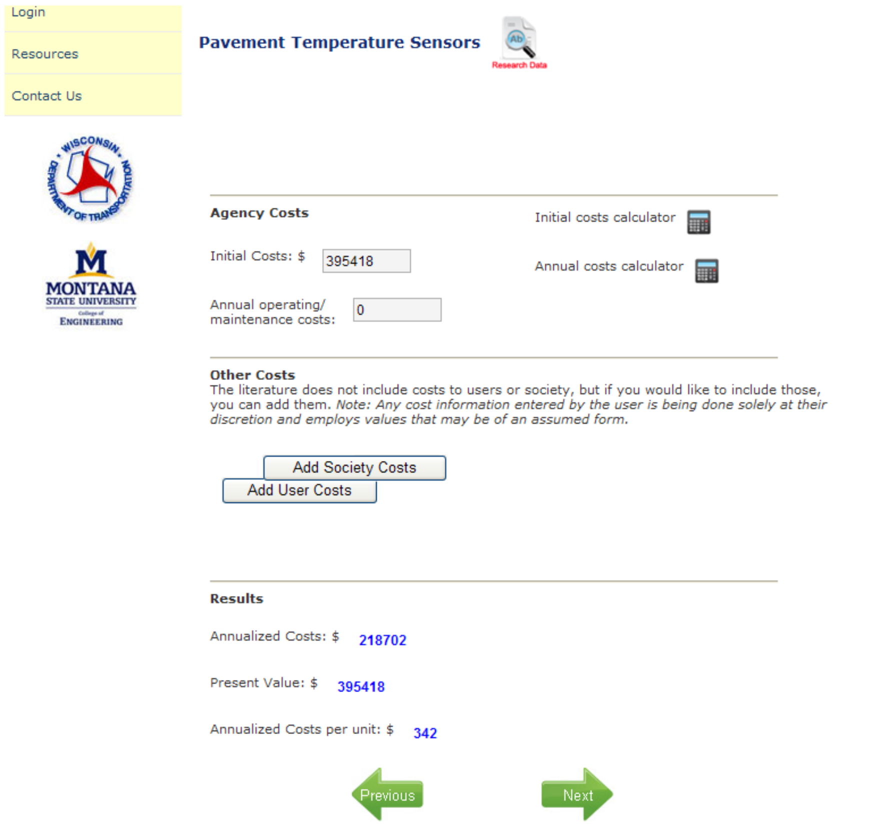


Figure 11-6: Completed cost page

11.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled “Benefits”. This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 11-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, “Benefit Quantification”.

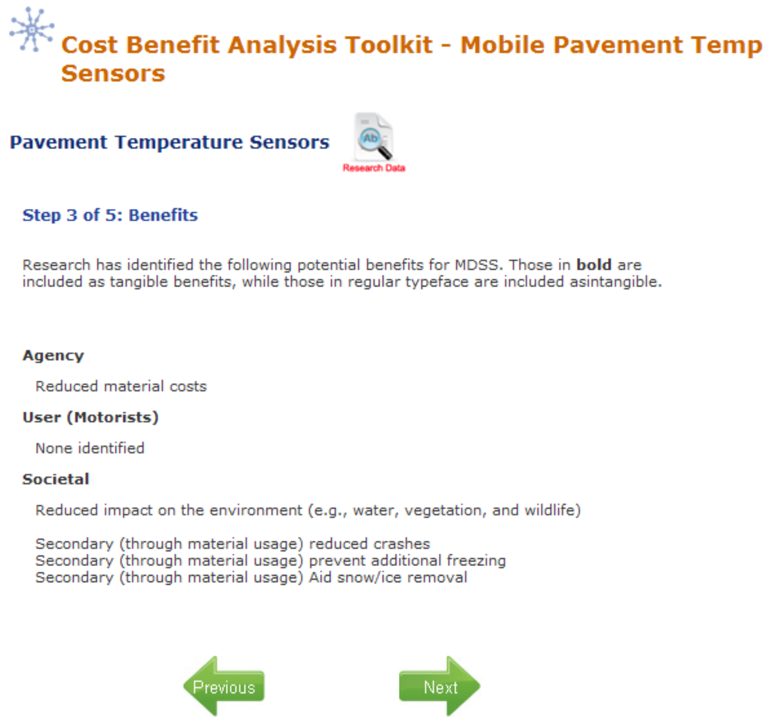
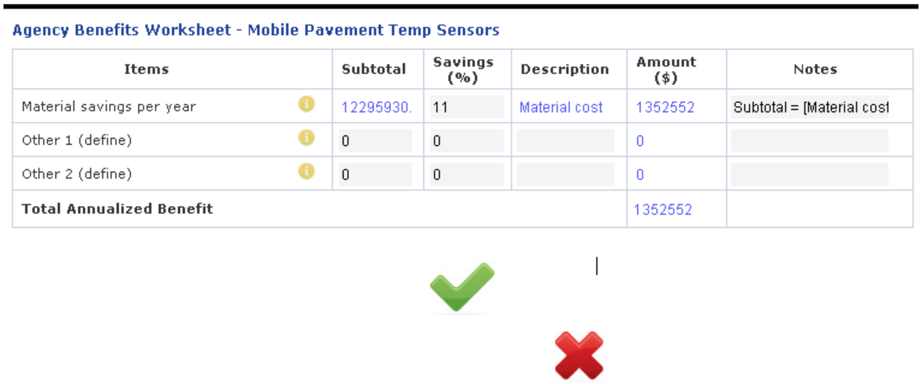


Figure 11-7: Benefits page

The "Benefit Quantification" screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In determining agency benefits, the user will be required to enter an expected percent material savings achieved through the use of pavement temperature sensors. Based on existing research results, a conservative savings range is between 11 percent and 14 percent. For this demonstration, a figure of 11 percent will be employed. The entry of this figure is made through a calculator accessed through the agency benefits text box and is displayed in Figure 11-8.

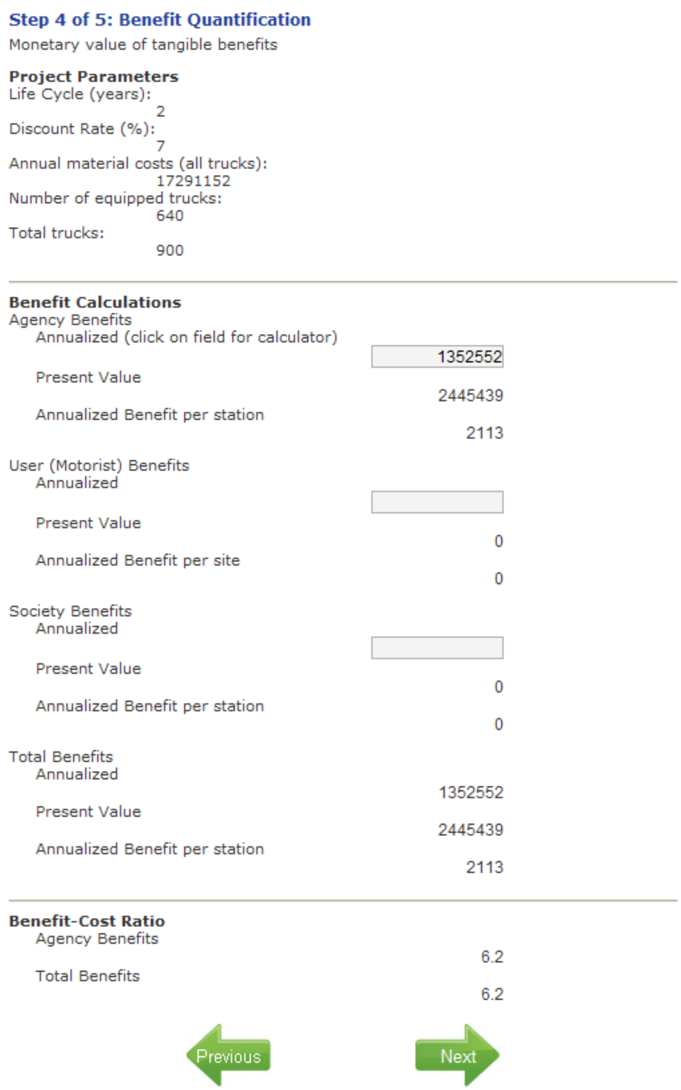
As agency benefits are the only benefits which have been quantified for mobile temperature sensors, the user will have completed benefits quantification at this point. Of course, if any additional tangible user or societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text boxes on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 11-9. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.



Agency Benefits Worksheet - Mobile Pavement Temp Sensors

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Material savings per year	12295930.	11	Material cost	1352552	Subtotal = [Material cost
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				1352552	

Figure 11-8: Agency benefit calculator



Step 4 of 5: Benefit Quantification

Monetary value of tangible benefits

Project Parameters

Life Cycle (years): 2

Discount Rate (%): 7

Annual material costs (all trucks): 17291152

Number of equipped trucks: 640

Total trucks: 900

Benefit Calculations

Agency Benefits

Annualized (click on field for calculator) 1352552

Present Value 2445439

Annualized Benefit per station 2113

User (Motorist) Benefits

Annualized

Present Value 0

Annualized Benefit per site 0

Society Benefits

Annualized

Present Value 0

Annualized Benefit per station 0

Total Benefits

Annualized 1352552

Present Value 2445439

Annualized Benefit per station 2113

Benefit-Cost Ratio

Agency Benefits 6.2

Total Benefits 6.2

Previous Next

Figure 11-9: Completed benefit quantification screen

As Figure 11-9 indicates, both the agency and total benefit-cost ratios are 6.2. This indicates that for each one dollar spent by the agency, a benefit of $6.50 may be obtained over the life of the system. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. In the case of Iowa, the potential savings in material usage statewide through the use of pavement temperature sensors would produce a large benefit, as indicated by the ratio of 6.2. Both the agency and total benefit-cost ratios are identical in this case as no user or societal costs or benefits were available to include in this analysis.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the “Results” page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

11.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 11-2 and Table 11-3.

Table 11-2: Comparison of pavement temperature sensor cost-benefit analysis

Agency Costs - Initial	Iowa	Indiana	Washington
Sensors ($575)	$368,000	$11,500	$10,925
Installation cost	$27,418	$721	$1,760
Agency Costs - Annual			
Equipment maintenance	$0	$0	$293
Total Costs - Summary			
Annualized cost	$218,702	$6,759	$7,308
Present value	$395,418	$12,221	$13,214
Annualized cost/truck	$342	$338	$385
Agency Benefits - Initial			
Material savings	$1,352,552	$35,696	$64,561
Total Benefits - Summary			
Annualized benefit	$1,352,552	$35,696	$64,561
Present value	$2,445,439	$64,539	$116,727
Annualized benefit/truck	$2,113	$1,785	$3,398
Cost-Benefit Ratios			
Agency	6.2	5.3	8.8
Total	6.2	5.3	8.8

Table 11-3: Comparison of air and pavement temperature sensor cost-benefit analysis

Agency Costs - Initial	Iowa	Indiana	Washington
Sensors ($1228)	$785,920	$24,560	$23,142
Installation cost	$27,418	$721	$1,760
Agency Costs - Annual			
Equipment maintenance	$0	$0	$293
Total Costs - Summary			
Annualized cost	$309,924	$9,633	$9,782
Present value	$813,338	$25,281	$25,670
Annualized cost/truck	$484	$482	$515
Agency Benefits - Initial			
Material savings	$1,352,552	$35,696	$64,561
Total Benefits - Summary			
Annualized benefit	$1,352,552	$35,696	$64,651
Present value	$3,549,524	$93,678	$169,428
Annualized benefit/truck	$2,113	$1,785	$3,398
Cost-Benefit Ratios			
Agency	4.4	3.7	6.6
Total	4.4	3.7	6.6

As the results indicate, depending on the specific agency parameters entered and the technology being evaluated, benefit-cost ratios above 1.0 were generated by each state. In the case of temperature sensors, benefits are not enhanced by societal savings, as no quantified values are available related to these. Still, when solely agency costs and benefits are accounted for, benefit-cost ratios exceeding 1.0 were typically achieved. This indicates that in the example scenario presented in this chapter, based on the agency-specific parameters entered into the toolkit, temperature sensors would be a technology that should be pursued.

11.6. Report Conversion

While page 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 11-10. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

Figure 11-10: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [11]) or installed on their machine (if available).

11.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate mobile temperature sensors. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for mobile temperature sensors. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[11] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

12.AUTOMATIC VEHICLE LOCATION

This chapter outlines the steps involved in completing a cost-benefit analysis for the use of Automatic Vehicle Location (AVL).

12.1. Sample Data

For this example, data provided by the Indiana Department of Transportation will be employed. This data, along with that of Iowa and Washington are presented in Table 12-1. It represents the basic information that the user must have available for input during the course of the evaluation. The data from all of these states will not be employed in the overview of this chapter. However, results generated using data from these states will be provided along with that of Iowa at the conclusion of the chapter.

Table 12-1: AVL plow sample data

Automatic Vehicle Location	Iowa	Indiana	Washington
Project Parameters			
Number of computers w/ software	110	3	30
Number of vehicles to equip	900	5	79
Total number of fleet vehicles	900	23	79
Labor rate	$21.42	$14.42	$30.86
Lane miles covered /storm/truck	*165.78*	*177.13*	*112.5*
Annual number of storm events	*20*	*12*	19
Average labor hours/storm/vehicle	*12*	*12*	16
Operating cost/mile	*$5.20*	$5.23	*$5.20*
Paperwork hours/storm (min/vehicle)	*40*	*40*	*40*
Total storm crashes	8,346	0	383
Crash cost	$33,700	$33,700	$33,700

Italics denote an assumed value for demonstration purposes

Information from Iowa is at the statewide level; Indiana is at the subdistrict level; Washington is at the district level.

Note that in this example, the data being employed come from one maintenance subdistrict in Indiana. To begin, the user will select the “Automatic Vehicle Location and Global Positioning Systems” link under the Operations heading on the Technology Selection page. This is displayed in Figure 12-1.

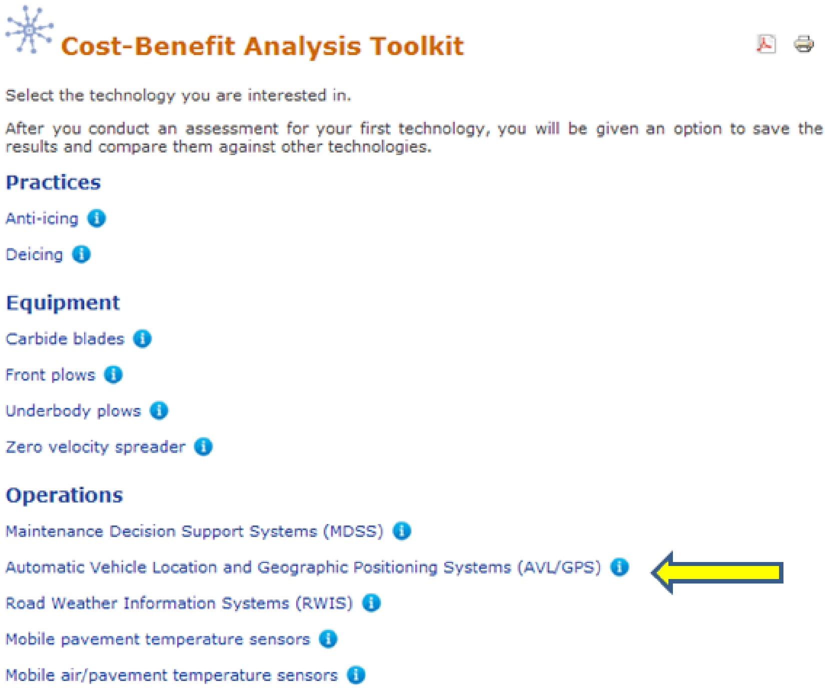


Figure 12-1: AVL/GPS selection

12.2. Project Parameters

Once AVL has been selected for evaluation, the user will be directed to the Project Parameters page. Here the user will define basic information for report purposes, including their name, their agency, and a brief project description. Note that certain items are set to default values, including the date, discount rate (7%), and life cycle (5 years). However, ***the user is encouraged to employ the values presently employed by their respective agency***. For this example, the 7% rate and 5 year life cycle will be employed, as they are reasonable in the context of zero AVL.

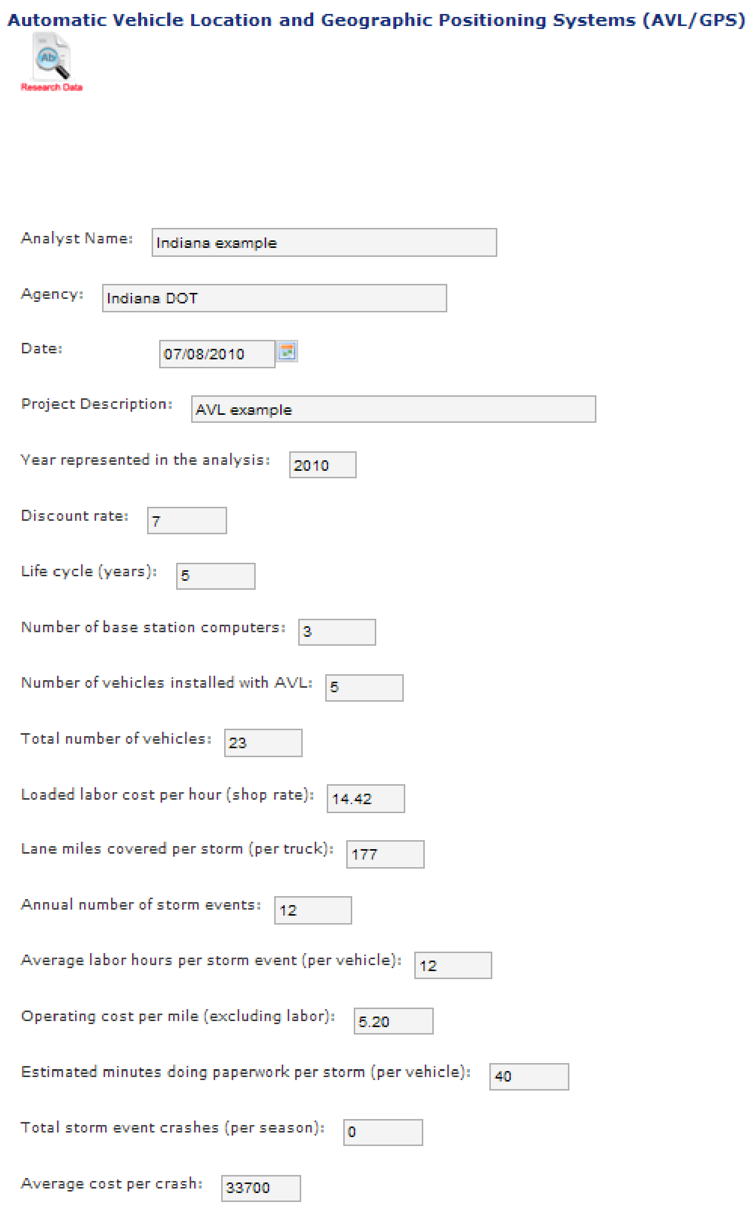
Note that when establishing an interest rate and service life for an item, different approaches will yield different benefit-cost ratios. For example, if a low interest rate and longer life are employed/assumed for an item, a higher benefit-cost ratio will typically result. The same is true for when a high interest rate and long life are employed, as the costs and benefits of that item are being accrued over a longer time frame. Conversely, when a high or low interest rate is combined with a short life for an item, benefit-cost ratios will fall.

In addition to basic reporting information, this page also requires the user to enter specific data input parameters for later calculations. These include:

- Number of base station computers. In this example, there will be three base station computers.
- Number of vehicles installed with AVL. In this example, five vehicles will receive AVL.
- Total number of trucks. For this example, there is a total fleet of 23 trucks.
- Loaded labor cost. For this example, the loaded labor cost is $14.42.
- Annual number of storm events. For this example, it is assumed that there are 12 storm events per year.

- Average labor hours per storm event per vehicle. For this example, an average of 12 hours per storm per vehicle is assumed.
- Operating cost per mile, excluding labor cost. For this example, a value of $5.23 is used.
- Estimated paperwork time, per storm per vehicle. For this example, a figure of 40 minutes, or 0.6 hours is employed. Paperwork hours refer to the total hours spent completing paperwork at the location employed in the analysis. If a district is the level of analysis, then all hours spent on storm-related paperwork for that district per storm should be entered. Other levels could be statewide, garage, shed, etc.
- Total storm event crashes per season. For this example, crash information was unavailable, so a value of zero is used.
- Average cost per crash. While there was no crash information available for this example, an average value of $33,700, based on the work of Ye, et.al. (3) has been used.

These various data items are entered into their respective places on the project parameters screen, with the user selecting the next arrow at the bottom of the screen when complete. The Tab key may be used to progress through the data entry boxes. ***Note that when entering values in, commas and dollar signs should not be included.*** For example, a material cost should be entered as 373186, as opposed to $373,186. The completed data entry is displayed in Figure 12-2.



Automatic Vehicle Location and Geographic Positioning Systems (AVL/GPS)

Research Data

Analyst Name:	Indiana example
Agency:	Indiana DOT
Date:	07/08/2010
Project Description:	AVL example
Year represented in the analysis:	2010
Discount rate:	7
Life cycle (years):	5
Number of base station computers:	3
Number of vehicles installed with AVL:	5
Total number of vehicles:	23
Loaded labor cost per hour (shop rate):	14.42
Lane miles covered per storm (per truck):	177
Annual number of storm events:	12
Average labor hours per storm event (per vehicle):	12
Operating cost per mile (excluding labor):	5.20
Estimated minutes doing paperwork per storm (per vehicle):	40
Total storm event crashes (per season):	0
Average cost per crash:	33700

Figure 12-2: Project parameters data entry

12.3. Cost Entry

Following the entry of initial project parameters, the user is required to costs associated with their prospective application. Toolkit costs are divided into three categories: Agency costs, User costs, and Society costs. Agency costs are those associated with the purchase, maintenance and use of the specific item. User costs are those carried by the motorist, such as delay or crash costs. Society costs are those associated with the entire society, such as environmental degradation (i.e. the impacts of salt on the environment).

For AVL, the initial steps for the user are to establish initial and annual costs to their agency. This is accomplished through the use of the two calculators provided under Agency costs. In clicking on the initial costs calculator icon, the user will be presented with a spreadsheet which determines the in-vehicle, communication system and office equipment costs. The spreadsheet is designed to automatically populate using the data entered by the user previously, as shown in Figure 12-3. However, the user is encouraged to enter information, specifically manufacturer quotes, obtained specifically for their evaluation scenario. These specifics can be entered in any of the grayed boxes displayed by the spreadsheet. In the example below, the initial cost for in-vehicle AVL equipment is assumed to be $1,400 per vehicle. The system being considered relies on cellular communications, as opposed to a radio system or other mechanism, with data presented on a dedicated website. Other costs associated with AVL (base stations for radio, if used, communications, general infrastructure, and so forth) are also provided for optional cost inputs. However, in this example, the only cost associated with AVL initially will be the in-vehicle equipment. Once the user has completed data entry or verified automated data population, the green check mark may be selected to return to the main cost screen. Upon doing so, the initial agency costs will appear on the page.

Initial Costs Worksheet - AVL/GPS

Items	Unit rate ($)	# of units	Unit	Amount ($)	Notes
In vehicle unit	1400	5	vehicles	7000	
Base station - initial investment per computer	0	3	computers	0	
Communications setup	0	1	lump sum	0	
Infrastructure Investment	0	1	lump sum	0	
System lump sum initial investment	0	1	lump sum	0	
Training	0	0	locations	0	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total initial expenditure				7000	

Figure 12-3: Initial costs spreadsheet, automatically populated

Next, the user will complete a similar procedure for annual costs. The Annual costs calculator is selected, and the user will be presented with spreadsheet automatically populated with the project parameters. In this case the user will need to enter a few values, based on the assumption that the system being considered employs cellular communications. Again, no software costs are necessary, as the system will operate via a dedicated website. Monthly communications are assumed to cost $50 per vehicle over a 5 month season; consequently, the user will enter a cost per vehicle of $250 (50 * 5). Maintenance is assumed to require 1 hour per month over a 5 month season, or $72.10 (14.42 *5). As no radio communications are employed, no cost is associated with the maintenance of base stations. Administrative costs are assumed to be 25% of the initial system cost, in this case $1,750 ($7000 cost of in-vehicle equipment * 0.25). Finally, as the system is internet-based, it is assumed that no yearly training in its use will be required. Once the user has examined the spreadsheet, they should select the green check mark to return to the main cost page, which will be updated automatically.

Annual Costs Worksheet - AVL/GPS

Items	Unit costs per year	# of units	Unit	Amount ($)	Notes
Software costs (e.g. recurring annual fee)	0	3	computers	0	
Communications (e.g., phone bills)	250	5	vehicles	1250	
Maintenance - in vehicle unit	72.10	5	vehicles	360.5	
Maintenance - base station	0	3	computers	0	
Administrative costs	1750	1	lump sum	1750	
Training	0	3	maintenance u	0	
Other 1 (define)					
Other 2 (define)					
Total Annual O&M Costs				3361	

Figure 12-4: Annual costs spreadsheet, manually populated

In the cast of AVL, no tangible societal costs have been identified. As a result, the user will not need to enter any information for these items, unless they choose to do so. At present, the toolkit is set up to accept a brief description of what the cost being entered is, as well as what the value of that cost is. Note that if the user chooses to add a societal or user cost, they will need to determine the entire value associated with it; the toolkit cannot calculate such costs given the lack of published information on the subject. Each cost button works in an identical fashion.

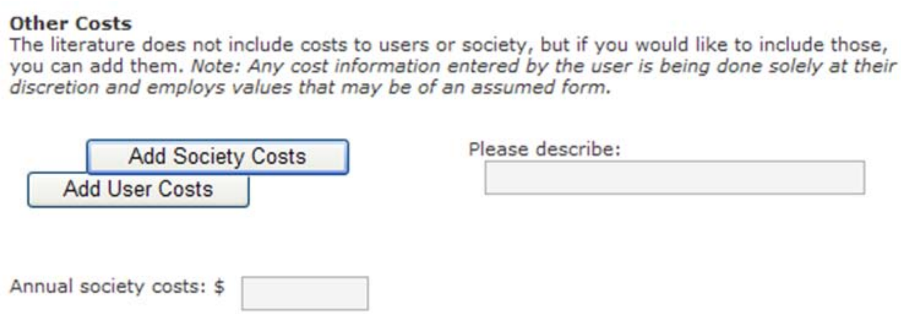


Figure 12-5: Other costs buttons, Add Society Cost button selected

Once any potential societal or user costs have been entered, the cost entry page is complete. At the bottom of the page, a summary of the annualized costs associated with the zero velocity spreader (in this case over a life of 5 years), present value of the system and per unit cost (i.e. per vehicle cost) are displayed, as shown in Figure 12-6.

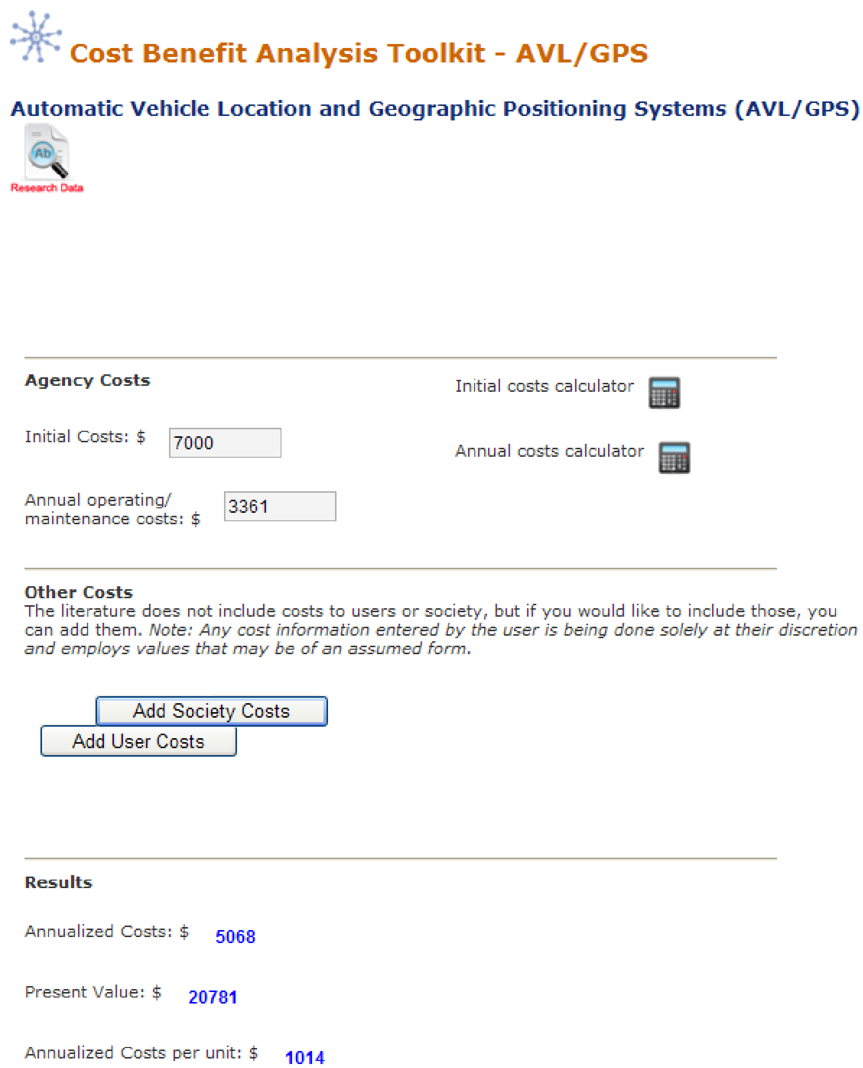


Figure 12-6: Completed cost page

12.4. Benefits Entry

Next, the user will be presented with a screen associated with step 3 of 5, simply labeled “Benefits”. This screen presents the user with a list of quantified and non-quantified benefits associated with mobile temperature sensors. A screen shot of these is presented in Figure 12-7. At this point, the user should select the next arrow and proceed to screen 4 of 5, “Benefit Quantification”.

Automatic Vehicle Location and Geographic Positioning Systems (AVL/GPS)

Supporting Information

Step 3 of 5: Benefits

Research has identified the following potential benefits for MDSS. Those in **bold** are included as tangible benefits, while those in regular typeface are included as intangible.

Agency

Reduced material costs
Reduced labor costs
Reduced equipment costs
Reduced fleet replacement costs
Provides agencies with additional information
Allows better decision making
Reduced paperwork
Increased security for drivers
Reduced legal costs from tort claims allegedly involving maintenance vehicles
Streamlined report generation
Reduced reliance on radio communications - less driver distraction
Better management of in-house and contracted services on a year-round basis

User (Motorists)

Improved safety
Reduced traffic delay
Better road customer satisfaction

Societal

None identified

Figure 12-7: Benefits page

The "Benefit Quantification" screen allows the user to specify agency, user and society benefits. Agency benefits are the expected savings that an agency might expect through the use of an item. User benefits are savings that motorists might receive, such as reduced crashes or improved mobility. Societal benefits are savings such as reduced damage to the environment.

When quantifying benefits, the user will often only be able to quantify those at the agency level. This is because of the lack of existing, published research detailing the accrued user and societal benefits of many toolkit items. In the case AVL, the primary quantified benefits are reduced operating costs and reduced paperwork. In this example, conservative values of 5 percent savings in operating costs and 10 percent paperwork savings have been employed.

Agency Benefits Worksheet - AVL/GPS

Items	Subtotal	Savings (%)	Description	Amount ($)	Notes
Reduced operating cost	65606	5	Equipment op	3280	
Reduced paperwork	125	10	Paperwork cos	13	
Other 1 (define)	0	0		0	
Other 2 (define)	0	0		0	
Total Annualized Benefit				3293	

Figure 12-8: Agency benefit calculator

In the case of AVL, an estimate of reduced crashes attributed to the use of AVL can be factored into the analysis. Based on past work, a conservative value of 5 percent at the greatest may be employed. The entry of this value is facilitated by a calculator accessed through the user benefits text box. In this example, Indiana did not have storm-related crash data available, so the user benefits value will remain zero, even with the entry of a 5 percent crash reduction.

No tangible societal benefits have been quantified, so the user will have completed benefits quantification at this point. Of course, if any additional societal benefits are known to the user, a cumulative dollar value for these may be entered in the appropriate text box on the present screen. Once all data entry related to quantified benefits is complete, the user will be presented with a screen such as that shown in Figure 12-9. As this figure shows, the user is presented with calculations of the agency and total benefit-cost ratios. The agency ratio is derived strictly from the costs and benefits associated with the agency's expenditures and savings. The total ratio is derived from the agency's costs and benefits, as well as the costs and benefits associated with users and society.

Step 4 of 5: Benefit Quantification

Monetary value of tangible benefits

Project Parameters

Life cycle (years): 5

Discount rate (%): 7

Number of vehicles installed with AVL: 5

Total number of vehicles: 23

Loaded labor cost per hour (shop rate): 14.42

Lane miles covered per storm (per truck): 177

Annual number of storm events: 12

Operating cost per mile (excluding labor): 5.20

Estimated minutes doing paperwork per storm (per vehicle): 40

Total storm event crashes (per season): 0

Average cost per crash: 33700

Benefit Calculations

Agency Benefits	
Annualized (click on field for calculator)	3293
Present Value	13502
Annualized Benefit per Truck	659
User (Motorist) Benefits	
Annualized (click on field for calculator)	0
Present Value	0
Annualized Benefit per Truck	0
Society Benefits	
Annualized	0
Present Value	0
Annualized Benefit per Truck	0
Total Benefits	
Annualized	3293
Present Value	13502
Annualized Benefit per Truck	659

Benefit-Cost Ratio

Agency Benefits	0.6
Total Benefits	0.6

Figure 12-9: Completed benefit quantification screen

As Figure 12-9 indicates, both the agency and total benefit-cost ratios are 0.6. Note that both the agency and total benefit-cost ratios are identical in this case, as no user or societal costs or benefits were available to include in this analysis. This indicates that for each one dollar spent by the agency, a benefit of $0.60 may be obtained. Any benefit-cost ratio greater than 1.0 is considered to result in a savings (benefit) for an agency. In the case of AVL, it appears that when potential crash cost savings are not factored in, its use based is not entirely beneficial. That is not to say that the use of AVL is not justified; there are several other non-quantified benefits which are likely to produce cost savings and justify its use. These include potential savings accrued from more efficient route planning, as well as savings from reduced tort claims.

In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits, which could be significant. It is important to note that only the quantifiable benefits and costs are shown as a ratio here. In addition, nonquantified benefits listed earlier in the report were not included in this calculation.

Once the user has completed all data entry, including any modifications which may have required using the previous arrow, they may proceed to screen 5 of 5, the “Results” page. The user should note that they need to be absolutely certain they are finished entering or modifying input data, as there is no mechanism to move back from the report page without losing all entered data.

12.5. Results

The final screen, page 5, presents the results of the analysis in a report format. This includes a description of the item, its components, complimentary items (e.g., other items it can be used in conjunction with), and a summary of the potential benefits the item offers. Additionally, the report presents the project parameter, cost and benefit data entered by the user. This includes all values and text entered, as well as the results of calculations made by the toolkit. Finally, the user is presented with the calculated benefit-cost ratios for both the agency and in total (including user and societal inputs, if available). Due to the length of this report, a screen shot of this final page cannot be presented here. However, a summary of input and output information is presented in Table 12-2.

Table 12-2: AVL results

Agency Costs - Initial	Iowa	Indiana	Washington
In-vehicle unit ($1400)	$1,260,000	$7,000	$110,600
Agency Costs - Annual			
Communications ($250)	$225,000	$1,250	$19,750
Maintenance ($72.10)	$96,300	$360	$5,695
Administrative	$326,000	$1,750	$27,650
Total Costs - Summary			
Annualized cost	$954,602	$5,068	$80,070
Present value	$3,914,058	$20,781	$328,304
Annualized cost/truck	$1,061	$1,014	$1,014
Agency Benefits - Initial			
Reduced operating cost	$1,003,536	$3,280	$81,156
Reduced paperwork	$25,704	$13	$3,088
User Benefits			
Crash savings	$14,063,010	$0	$645,355
Total Benefits - Summary			
Annualized benefit	$15,092,250	$3,293	$729,599
Present value	$61,881,205	$13,502	$2,991,500
Annualized benefit/truck	$16,789	$659	$9,235
Cost-Benefit Ratios			
Agency	1.1	0.6	1.1
Total	15.8	0.6	9.1

As the results indicate, depending on the specific agency parameters entered and the technology being evaluated, benefit-cost ratios above 1.0 were generated by each state, with the exception of Indiana. The lower benefit-cost ratio generated by that sample data is primarily result of the small scale of the system itself. In the case of AVL, when societal benefits are accounted for, specifically crash savings, the benefit-cost ratios generated rise significantly. Still, when solely agency costs and benefits are accounted for, benefit-cost ratios exceeding 1.0 were typically achieved. This indicates that in the example scenario presented in this chapter, based on the agency-specific parameters entered into the toolkit, AVL would be a technology that should be pursued.

12.6. Report Conversion

While page 5 presents the results of the analysis in a report format, it does so in html. In most cases, the user will likely wish to present the final output in a Word or .pdf document. This initial version of the toolkit was not able to create such output formats due to programming issues; however, the user is still able to convert the report output of page 5 to either of these formats if they wish. The process to do so is straightforward and is explained in the following text.

Once results of an analysis are generated and presented on page 5 of the toolkit, the user should open a Word document. On the top of the report page of the toolkit, the user will see a printer icon (). The user should click on this icon, which will open a new screen view. Depending on the software an agency has installed on the user's machine, an option to convert the opened document to .pdf may be available, as shown in Figure 12-10. If this option is available to the user, the convert button may be selected, and the user will be taken through the steps to convert the file to .pdf. This will consist of being prompted for a location to save the file and a file name. Once these are provided, the .pdf conversion will be made and the user will be finished.

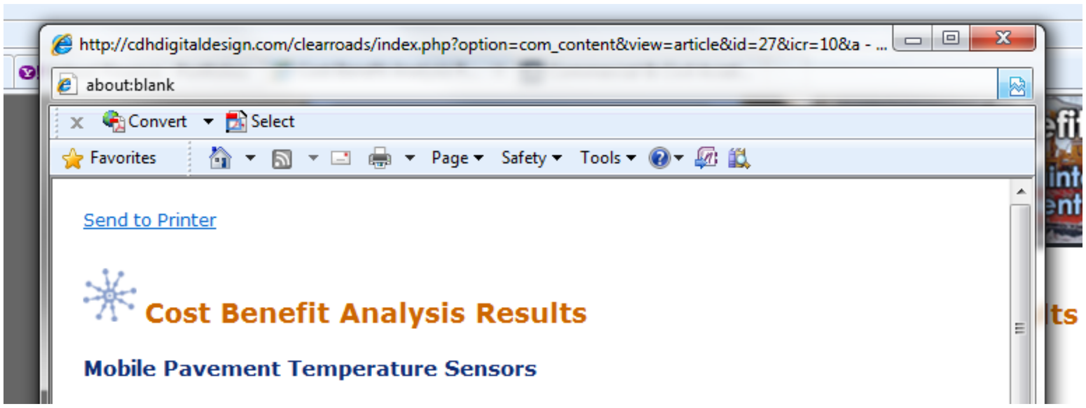


Figure 12-10: Conversion to .pdf file

If the .pdf conversion option is not available to the user, they will need to save the file as a Word document. First, they will need to select the text in the report pane by left clicking at the top of the page and dragging their mouse down to the end of the page. Then, the user will right click and select the copy option. Next, the user will select the Word file they have opened, and paste the copied text from the report pane into that document. Unfortunately, the content management system which supports the toolkit website does not facilitate a clean paste into Word, so the user will find a need to perform some formatting work to clean up the report. This includes deleting icon revenants (such as), add borders around tables, delete unwanted information, and change font types and sizes as desired.

Once the report has been converted into a Word format, the user may save it as a .pdf either via a .pdf writer online at various websites (e.g. http://www.freepdfconvert.com/ [12]) or installed on their machine (if available).

12.7. Conclusion

This chapter has presented a step by step overview of the process employed in using the cost-benefit toolkit to evaluate AVL. The agency parameters and values (monetary values and percentages) used as inputs are for demonstration purposes only. These values, as well as the benefit-cost ratios consequently generated only represent a potential outcome under a theoretical scenario and do not represent a recommended configuration for AVL. Rather, they are intended to provide prospective users with an overview of the process necessary to complete an analysis using the toolkit.

[12] This link is provided for user reference only. The authors of this manual do not recommend one conversion website over another.

13.CONCLUSIONS

This user manual has presented an overview of the toolkit developed to facilitate cost-benefit analysis for winter maintenance practices, equipment and procedures. It has been developed in a manner which allows the user to follow, step by step, the process necessary to complete a cost-benefit analysis for each of the specific toolkit items. Based on feedback from practitioners and the project panel, an initial series of ten items were selected for inclusion in the toolkit. Toolkit items include:

- Anti-icing
- Deicing
- Carbide blades
- Front plows
- Underbody plows
- Zero velocity spreader
- Maintenance Decision Support Systems (MDSS)
- Automatic Vehicle Location and Geographic Positioning Systems (AVL/GPS)
- Road Weather Information Systems (RWIS)
- Mobile pavement or air/pavement temperature sensors

Based on their selection, information was gathered from research results and vendors in order to quantify the various cost and benefits associated with each item. This included both tangible (monetized value) and intangible (non-nomonetized value) costs and benefits.

With monetary values value assigned to most cost and/or benefit items, it was possible to compute a benefit-cost ratio. This procedure was employed to show the extent to which an investment will result in a benefit to the investor. Benefit-cost ratios greater than 1.0 are generally desired, as they show a positive benefit for every dollar of cost expended on an item over time. To facilitate this cost-benefit analysis, the Clear Roads pooled fund undertook the development of the toolkit discussed in this manual.

Note the benefit-cost ratio only considers quantified benefits. The non-quantified intangible costs and benefits can be significant and should be considered in decision making. In interpreting the benefit-cost ratio, it is important to note that it excludes the intangible benefits. In addition, nonquantified benefits listed earlier in the report are not included in calculations.

The toolkit itself has been developed to be as user-friendly as possible. It is a website-based application which requires a series of data inputs (based on real-world information from an agency or, as necessary assumed data). Data elements are input via a series of text boxes. In some cases, conservative default values are provided by the toolkit itself; the user is free to change these to whatever value is warranted in their particular case. Information buttons and calculators are present throughout the toolkit to assist the user in determining when particular elements might be included, as well as what the financial implications might be. Information provided in the toolkit related to the cost of specific practices, equipment and operations is presented by various information buttons/icons. This information came from a variety of manufacturers and practitioners during this project. The information provided in this toolkit is for user reference and guidance only. ***The user is strongly encouraged to obtain individual cost quotes specific to the application they plan to evaluate/analyze using this toolkit.***

The initial step in the toolkit seeks project parameter information, or the basic information required to complete the analysis (analyst name, number of vehicles in fleet, etc.). Next, cost information is entered, with the user selecting specific costs that will be employed (in some cases, different elements of a practice, equipment, and operation are not required, so their costs can be excluded). This is followed by the selection and entry of specific anticipated benefits, functioning in a similar manner to the cost component of the toolkit. Based on the benefits selected, the next step is the quantification of those benefits. The toolkit concludes with a presentation of cost and benefit results, including the benefit-cost ratio. For users that wish to have more information for reference or presentation, a brief white paper is also provided summarizing the results of existing research related to the particular item.

In summary, this manual has presented a step-by-step overview for the conduct of a cost-benefit analysis for each toolkit item. These case studies were presented for user reference and education only. In following through the examples provided for each toolkit item, the user will have a better idea of how the website works and how they would go about conducting a cost-benefit analysis for their own agency using it. Through the use of this toolkit, it is hoped that agencies will be in a better position to assess justify expenditures on the practices, equipment and operations they are considering for their winter maintenance programs.

The current version of the toolkit does not record the cost and benefit information provided by the agency user once the user leaves the website. Such a function, i.e., using the toolkit as a data-collector, is desirable and may be implemented in the future version of the toolkit. As such, it would help address the data gaps related to winter maintenance practices, equipment and operations and make the toolkit more useful. Such data gaps are briefly listed in the following chapter.

14. IMPLIMENTATION RECOMMENDATIONS

The following recommendations are related to users, agencies, and data, in light of findings and lessons learned from this project.

14.1. Users

The primary recommendation for implementation related to users is the need for initial training. It is not possible for the research team to train each potential user of the toolkit from a cost and time standpoint. In a broad sense, the toolkit, its user guide, and training materials have been developed in a manner that allows them to be used by any maintenance manager to conduct cost-benefit analysis with minimal training and effort in lieu of such training. This manual is designed to provide high-level training for toolkit users, although its primary purpose is to walk users through the use of each specific item in an example cost-benefit analysis scenario. The applications being examined are going to vary from state to state, and every conceivable scenario which may be encountered cannot be addressed in this manual. While the toolkit has been designed in such a manner that it is easy to use with minimal training, the user should perform some practice analyses in order to become familiarized with the toolkit.

In light of this fact, it is recommended that each member state in Clear Roads designate one or more users to be their “expert”. This user would endeavor to learn the intricacies of the toolkit in such a manner that they could then undertake the training of other users in their state. The training materials generated by the research team for this project would also be provided to this user for use in their subsequent training sessions.

Aside from these, users are encouraged to learn more about the specific costs and benefits associated with the toolkit item they are interested in evaluating. This, in part, is facilitated by the toolkit through the provision of various information sheets throughout the website itself. However, the user should also educate themselves to the extent that time permits on the existing practice employed by other agencies through discussions with peers. Finally, the if the user proceeds with cost-benefit analysis of a specific toolkit item, they are encouraged to obtain manufacturer price quotes specific to their application. As costs vary based on the units being purchased (e.g., volume discounting), the values provided in the toolkit itself represent only general values, and these are likely to change over time due to inflation and other factors.

14.2. Agencies

As stated in the prior section, agencies that intend to use the toolkit will need to conduct training for their staff. To accomplish this, one or more “experts” for a state should endeavor to learn the toolkit extensively in order to lead training sessions. These sessions would allow for more detailed training to occur beyond the capabilities of this project’s time and budget.

Secondly, from the agency standpoint of Clear Roads, a decision must be made regarding the short and long term hosting of the toolkit website. Consideration of issues such as available bandwidth, expected number of concurrent users and other issues must be taken into consideration when making the hosting decision.

Aside from website hosting, Clear Roads must also decide who will be able to access the website. A significant amount of funds have been spent to develop this toolkit, and Clear Roads members may want to limit access to it based on that investment. Conversely, the toolkit provides a tool that is of benefit to all winter maintenance professionals, and limiting its use minimizes the potential benefits it could provide to the community of practice. Clear Roads members will need to discuss these issues and decide whether the toolkit will be restricted or not.

Finally, as the next section will discuss, agencies should consider the collection of additional data items that will facilitate future benefit-cost analysis. During the course of this work, the research team identified several data elements that are not presently collected by agencies but which would greatly facilitate such analysis.

14.3. Data

One of the issues encountered during the course of development and testing of the toolkit is that the data measured and collected by agencies varies greatly. In some cases, agencies keep detailed records, while in other cases, information is tracked sporadically. The states employed as example case studies in this manual do an excellent job of tracking information; however, as the information provided throughout the document shows, they did not collect all of the information required for input in the toolkit. Rather, assumptions were required in a number of cases.

In the future, agencies should consider tracking additional data, if they do not already do so. In the context of what has been learned in developing the toolkit, this additional tracking might include:

- Average labor hours associated with all storm event activities;
- Average labor hours per truck associated with storm event activities;
- Average hours spent annually maintaining specific equipment items;
- Average annual number of storm-events requiring winter maintenance;
- Storm-related crashes on roads maintained by the agency;
- Storm-related damage tort claims;
- Quantified/observed benefits accrued (e.g. material savings) when changes in practices, equipment or operations are made, even if these are tracked in a rudimentary manner. Such information would provide baseline data for valuing benefits;
- Lane miles covered per storm (i.e. entire mileage covered during a storm duration) per truck and all trucks;
- Lifespan of blade inserts in miles, storms or both;
- Average time associated to change an item (e.g. blade inserts);
- Paperwork hours associated with a storm event;
- Storm intensity or another measure/ranking of a storm event. This would be a useful data point, as each storm varies and consequently, so do the treatment strategies, materials used, and so forth; and
- Operating cost per mile (with or without loaded labor rate include).

The toolkit itself was developed using the best information available related to costs and benefits; however, as this information was sometimes obtained from research sources, it did not necessarily conform to standard agency practice regarding the information presently being recorded. Generally, information related to the average labor hours expended per storm, the average time spent on paperwork and similar information was where data was lacking.

However, if the toolkit is to be used by an agency and they do not presently record a necessary data input, they will need to devise some estimate in the place of hard data. The use of this estimate must be documented and presented to decision-makers if the toolkit is being used to justify a purchase.

Aside from existing data input needs, one of the foremost lessons learned during the course of this project is that cost-benefit analyses have not been performed for a number of items included in this toolkit. Instead, bits and pieces of cost information, and to a much more limited extent, benefit values were available to incorporate into the toolkit. In light of this, the toolkit required the use of reasonable assumptions in order to lace a monetary value on many benefits, as well as costs in some cases.

To address this issue in the future, two approaches are recommended. First, agencies are encouraged to move toward the recording of more detailed storm-related cost information. This would be facilitated by the use of technologies gaining greater acceptance/application, namely AVL and on-vehicle sensors and controllers. Secondly, it is clear that basic research which quantifies the specific costs and benefits of various winter maintenance practices, equipment and operations is necessary in order to conduct cost-benefit analysis that is free of extensive assumptions.

15.APPENDIX A: GLOSSARY OF TERMS

[Additional] Annual hours per vehicle to maintain [item of interest] – This is an estimate of the hours expected to be spent per vehicle maintain the specific item being analyzed.

Additional hours to install (per vehicle) – The time required to install the item on a vehicle.

Agency costs – costs incurred by an agency through the use of an item.

Analysis period – The expected lifetime for the toolkit item to be analyzed.

Annual hours of training for each user – The expected number of hours that will be spent each year training Road Weather Information System users.

Annual material costs – This is the annual winter maintenance material expenditure for a unit. The user should use an expenditure that is coincides with the scale of their analysis. For example, if an item is being examined for use at the shed level, then the annual material expenditure for that shed should be employed.

Annual number of storm events – This is the average number of storms experienced by a jurisdiction (state, garage, shed, etc.) that require winter maintenance activities.

Annual operating and maintenance costs – The annually recurring costs associated with the use of an item (ex. maintenance).

Annualized benefits – The value of benefits achieved in some future year stated as a present dollar value.

Annualized costs – The value of costs incurred in some future year stated as a present dollar value.

Average application rate – This is the average amount of treatment materials applied per unit (typically lane mile). This is expressed by the user in gallons or tons per mile, depending on the treatment currently being applied or analyzed.

Average cost per crash – This is the average value of crashes in a state. Typically, most crashes are PDO or involve minor injuries, hence this value is generally below $50,000. For some toolkit items, this value is set to the default of $33,700 employed in MDSS research. The user should consult their state's safety engineer if they are unsure of what value to employ. NOTE: this average value does not take into account outside factors, such as the cost of traffic delays related to an accident.

Average labor hours per storm to produce materials – This is the average time spent producing brine or other liquid treatment materials prior to a storm event.

Average labor hours per storm event [per vehicle] – This is the average time that an operator spends out in the field per storm performing winter maintenance activities.

Average plowing duration – the average number of hours a plow is in the field performing plowing functions per storm event.

Benefit-Cost ratio – A ratio showing the value of benefits achieved for every dollar of cost incurred on an item. It is employed to show the extent to which an investment will result in a benefit to the investor. Cost-benefit ratios greater than 1.0 are generally desired. May also be referred to as a cost-benefit ratio.

Cost Benefit Analysis – The process employed to calculate a benefit-cost ratio. May also be referred to as cost-benefit analysis/

Blade lifespan – This is the observed and/or expected time duration that a blade will last between changes, expressed in miles.

Chosen measure of lifespan – Some toolkit items, such as blade inserts, have lifespans that can be measured in multiple ways, including miles, fractions of a season, hours or snow events. Miles refers to the average number of miles a blade lasts between changes. Fractions of a season refers to the proportion of the season that a blade lasts, for example 1/4th. Hours are the average number of vehicle operating hours between blade changes, while snow events are the average number of storms between blade changes.

Current annual material costs – This is the annual winter maintenance material expenditure for a unit. The user should use an expenditure that is coincides with the scale of their analysis. For example, if an item is being examined for use at the shed level, then the annual material expenditure for that shed should be employed.

Current weather information costs – This is the cost that an agency is presently paying for weather forecasts or similar information.

Discount rate - The discount rate is an interest rate at which funds that might be spent on the toolkit item to be analyzed could be alternatively invested (for example, in a certificate of deposit, etc.).

Estimated minutes doing paperwork per storm (power vehicle) – This is the total time that may be required following a storm to record information such as material used, fuel used and other reporting requirements for each plow vehicle.

Expected number of users – The number of users expected to work with Road Weather Information Systems in some fashion. This input is required to estimate user training needs per year.

Fatal crash – A crash that involves at least one fatality. An average value from the FHWA for such a crash is approximately $3,391,000.

Hours to [perform activity] – This input refers to the average time (may be an estimate) to perform installation or maintenance for the item being analyzed.

Initial costs – The initial expenses related to the purchase of an item.

Injury crash – A crash that involves at least one injury to a vehicle occupant. Note, some states classify injury crashes as major (hospital treatment necessary) and minor (bumps and bruises). An average value from the FHWA for such a crash is approximately $102,000.

Intangible benefits – A benefit that is achieved but that a value cannot or has not been assigned to (ex. reduced environmental harm).

Intangible costs – A cost that is incurred but that a value cannot or has not been assigned to (ex. degraded mobility).

Lane miles covered per jurisdiction – The lane miles that are maintained by the jurisdiction being employed in the analysis.

Lane miles covered per storm (all vehicles) – This is the total number of lane miles covered by all operations during a storm. Note that if a particular route is covered more than once, those miles need to be included. For example, if a route is two lanes, two miles long and covered twice during a storm event, the total lane mile entered by the user would be 2 lanes*2 miles*2 passes = 8 lane miles. This input is the sum of all vehicle activity.

Lane miles covered per storm (per truck) - This is the total number of lane miles covered one truck during a storm. Note that if a particular route is covered more than once, those miles need to be included. For example, if a route is two lanes, two miles long and covered twice during a storm event, the total lane mile entered by the user would be 2 lanes*2 miles*2 passes = 8 lane miles.

Loaded labor cost – The average hourly pay of labor, including benefits, etc.

Miles per truck per year – this is the average number of miles a vehicle travels performing winter maintenance activities during a season. As most agencies do not track the exact miles attributed to winter maintenance operations versus other activities during a season, a reasonable estimate should be employed.

Nonquantified – An item that does not have a financial value available.

Number of base station computers – This is the number of computer terminals that are expected to be used to view AVL data.

Number of computers per maintenance unit with [item] software installed – The number of computers per garage/shed/other to have software related to the item of interest installed. This is an estimate.

Number of equipped trucks – This is the number of vehicles which would be equipped with the item of interest or perform an operation of interest.

Number of facilities – This refers to the number of sties (ex. garages, sheds) that would be engaged in some aspect related to the item of interest. For example, the number of sheds to be equipped with brink making plants, or the number of garages that will have desktop computers set up to view AVL data.

Number of planned stations – The expected number of deployed Road Weather Information System stations that an agency is considering.

Operating cost per mile – this is the total cost (excluding labor) to operate a plow in winter maintenance activities. For example, the IRS recommends a conservative figure of $0.50 per mile for the operation of a passenger vehicle.

Present value – the value at the present time of a cost incurred or benefit achieved at a future date.

Property Damage Only (PDO) crash – A crash that involves only damage to a vehicle, but no injury to occupants. An average value from the FHWA for such a crash is approximately $2,600.

Quantified – An item that has a financial value available.

Society/Societal benefits – The benefits obtained by society through the use of an item (ex. reduced impact on the environment).

Society/Societal costs – The costs inflicted on society as the result of a specific item (ex. increased impact on the environment).

Storm-related labor costs per season – The total value of all labor related to winter maintenance activities throughout an entire season. Such information may not be tracked by an agency; in such a case, an estimate should be employed.

Tangible benefits – A benefit that is achieved and that has had a value assigned to it (ex. material savings).

Tangible costs – A cost that is incurred and whose value is known (ex. the purchase price for an item).

Total trucks – This is the size of the entire vehicle fleet that performs winter maintenance activities before, during and/or after a storm.

Total storm crashes (per season) – This is the total number of storm-related crashes that occurred within a jurisdiction during the most recent winter season. Storm-related crashes are those which occurred during a storm or immediately following a storm that were the direct result of it. The agency will need to define what constitutes the post-storm period. Only crashes occurring along routes maintained by the jurisdiction should be included in this analysis.

User benefits – The benefits achieved by users due to the use of an item (ex. improved mobility).

User costs – The costs incurred by users due to the use of an item (ex. degraded mobility).

16.REFERENCES

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