Operations Benefit/Cost Analysis TOPS-BC User's Manual

Providing Guidance to Practitioners in the Analysis of Benefits and Costs of Management and Operations Projects

TOP$ B/C

U.S. Department of Transportation
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Notice

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16. Abstract

This document provides guidance on the setup and application of the Tool for Operations Benefit/Cost (TOPS-BC), which was developed to provide key decision support capabilities including:

- The ability for users to investigate the expected range of impacts associated with previous deployments and analyses of many TSM&O strategies;
- A screening mechanism to help users identify appropriate tools and methodologies for conducting a benefit/cost (B/C) analysis based on their analysis needs;
- A framework and default cost data to estimate the life-cycle costs of various TSM&O strategies, including capital, replacement, and continuing operations and maintenance (O&M) costs; and
- A framework and suggested impact values for conducting simple sketch planning level B/C analysis for selected TSM&O strategies.

This User's Manual provides instruction on the installation and setup of TOPS-BC Version 1.0, instruction for using the basic capabilities, and discussion of adapting the available capabilities to the unique needs of an individual analysis.

The TOPS-BC tool was developed to support and complement the guidance developed as part of the FHWA Operations Benefit/Cost Desk Reference project. The Desk Reference provides more general discussion on the field of B/C analysis and methods for structuring analyses to overcome the many challenges often present when attempting to apply B/C analysis to Operations strategies.

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Chapter 1. Introduction

Project Background and Purpose

Due to the competitive fiscal environment, state, regional, and local transportation planning organizations around the country are increasingly being asked to justify their programs and expenditures. Transportation System Management and Operations (TSM&O) programs have not escaped this scrutiny and are routinely asked to rank their projects against traditional expansion projects, as well as conduct other "value"-related exercises.

This requirement can put TSM&O projects at a disadvantage since many specialists in this arena have limited experience in performing benefit/cost (B/C) analysis; and often, many of the established tools and data available for conducting B/C analysis for traditional infrastructure projects are poorly suited to analyzing the specific performance measures, project timelines, benefits, and life-cycle costs associated with operational improvements.

In response to the needs of system operators to conduct these analyses, a number of initiatives have been undertaken in recent years at the national, state, and regional levels to develop enhanced analysis tools, methodologies and information sources to support the conduct of B/C analysis for many specific TSM&O strategies. It often remains difficult, however, for practitioners to sift through the various information and guidance sources in order to understand and apply an appropriate methodology for meeting a specific analysis need.

The FHWA *Operations Benefit/Cost Analysis Desk Reference* Project

The Federal Highway Administration (FHWA) Office of Operations initiated this project in recognition of practitioners' need for relevant and practical guidance on how to effectively conduct B/C analysis for a wide spectrum of TSM&O strategies. The *Operations Benefit/Cost Analysis Desk Reference* [http://www.ops.fhwa.dot.gov/publications/fhwahop12028/index.htm] is intended to meet the needs of a wide range of practitioners looking to conduct B/C analysis of operations strategies. The guidance provided in the *Desk Reference* includes fundamental background information on B/C analysis, including basic terminology and concepts, intended to support the needs of practitioners just getting started with B/C analysis, who may be unfamiliar with the general process. Building off this primer base, the *Desk Reference* also describes some of the more complex analytical concepts and latest research in order to support more advanced analysts in conducting their analyses. Some of the more advanced topics include capturing the impacts of travel time reliability; assessing the synergistic effects of combining different strategies; and capturing the benefits and costs of supporting infrastructure, such as traffic surveillance and communications.

The Tool for Operations Benefit/Cost (TOPS-BC)

The *Operations Benefit/Cost Analysis Desk Reference* is supported by a decision support tool, called the Tool for Operations Benefit/Cost (TOPS-BC). This spreadsheet-based tool is designed to assist practitioners in conducting B/C analysis by providing four key capabilities, including the following:

Source: FHWA.

- Investigate Impacts – The ability to investigate the expected range of impacts associated with previous deployments and analyze many TSM&O strategies;
- Research Methods – A screening mechanism to help identify appropriate tools and methodologies for conducting a B/C analysis based on analysis needs;
- Estimate Costs – A framework and default cost data to estimate the life-cycle costs (including capital, replacement, and continuing O&M costs) of various TSM&O strategies; and
- Estimate Benefits – A framework and suggested impact values for conducting simple B/C analyses for selected TSM&O strategies.

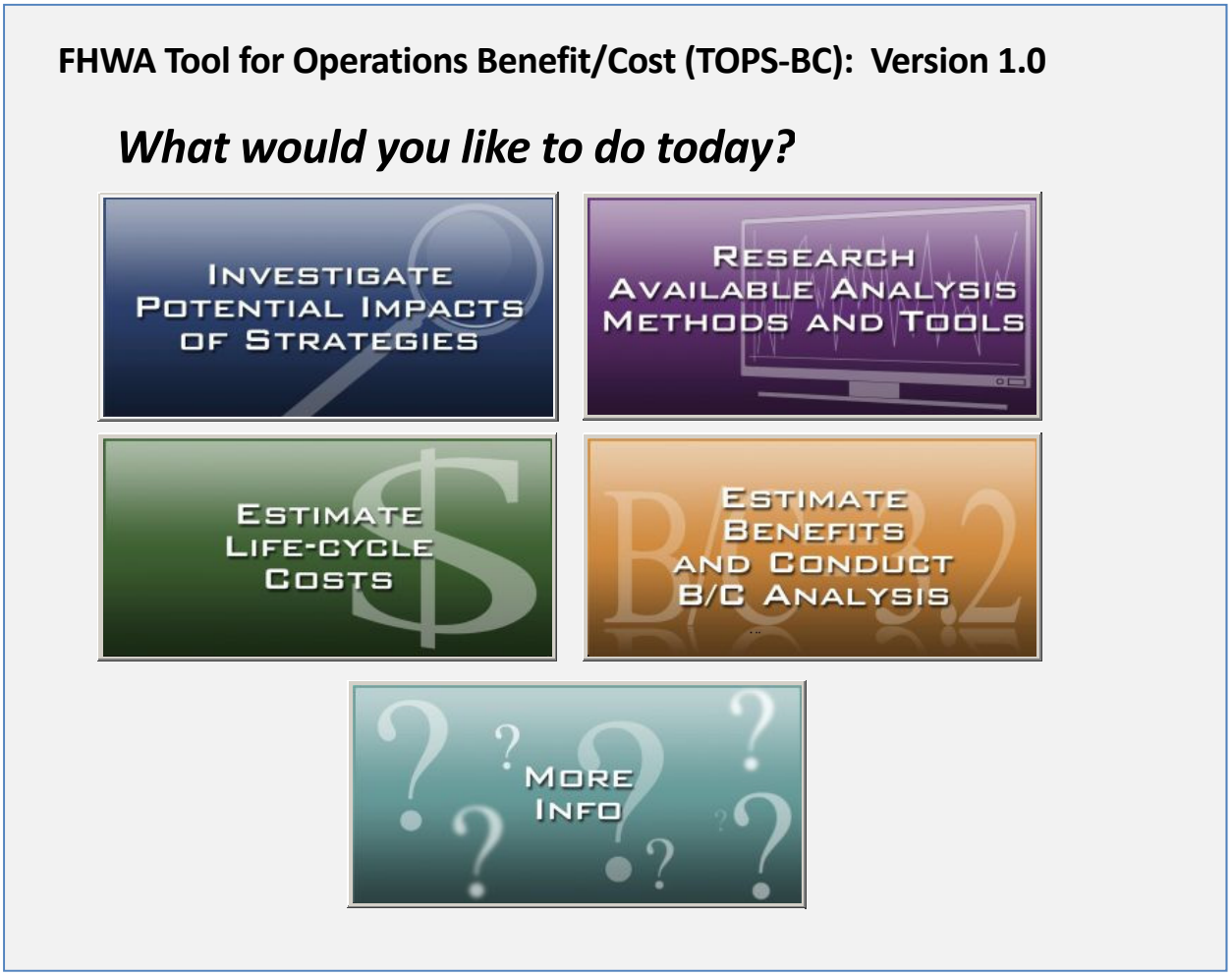
In addition to these capabilities, TOPS-BC also is intended to serve as a repository of relevant parameters and values appropriate for use in B/C analyses. Figure 1.1 shows the opening screen of TOPS-BC, which provides navigation to the capabilities within the support tool. This User's Manual provides specific guidance on the proper use and setup of the TOPS-BC application. It is intended to support the *Desk Reference* document and contains many references to that publication.

Transportation planning activities and associated Federal planning requirements can be generally categorized into the following four stages:

1. Visioning and Screening;
2. Long Range Planning;
3. Transportation Improvement Program Development; and
4. Project Development.

The sketch planning capabilities (Capability 4 "Estimate Benefits and Conduct B/C Analysis") within TOPS-BC are generally applicable for analyses in Stage 1 and partly Stage 2 for screening and estimating the order of magnitude of benefits. The more complex and detailed analysis required for program and project development in Stages 3 and 4 may warrant the application of a more robust analysis tool. TOPS-BC has the ability to help you screen and identify appropriate tools and methodologies for conducting a B/C analysis based on your analysis needs (Capability 2 "Research Available Analysis Methods and Tools") and may recommend you apply more rigorous tools for more complex analyses.

Figure 1-1. Capabilities Provided by TOPS-BC



Source: FHWA.

Operations Strategies Covered

Together the *Desk Reference* and the TOPS-BC tool are intended to support the analysis of a wide range of available TSM&O strategies. These "strategies" include the direct application of technologies and infrastructure as physical roadside applications (e.g., deployment of freeway service patrol vehicles), as well as many harder-to-define, nonphysical strategies (e.g., interagency coordination). While it is not possible to comprehensively provide guidance on every type and variation in application of all the many TSM&O strategies (especially in light of the fact that new strategies and technologies are constantly emerging), the TSM&O strategies covered in the TOPS-BC tool and/or the *Desk Reference* are identified in Table 1-1. Section 3.0 of the *Desk Reference* document provides expanded discussion of these various strategies, as well as sub-strategies and variations in application within the general categories. Section 3.0 of the *Desk Reference* also identifies the typical benefits and impact measures associated with the deployment of the strategies.

Table 1-1. Summary of Guidance on Various TSM&O Strategies

TSM&O Strategy	Discussed in *Desk Reference*	TOPS-BC Analysis Capability
Physical Strategies		
Arterial Signal Coordination	○	○
Arterial Transit Signal Priority	○	$
Ramp Metering	○	○
Traffic Incident Management	○	○
Pretrip Traveler Information	○	○
En-route Traveler Information	○	○
Work Zone Management	○	○
HOT Lanes	○	○
Speed Harmonization	○	○
Road Weather Management	○	○
Hard Shoulder Running	○	○
Travel Demand Management	○	$
Supporting Strategies		
Traffic Surveillance	○	$
Traffic Management Centers	○	$
Communications	○	$
Nonphysical Strategies		
Active Transportation and Demand Management (ATDM)	○	
System Integration	○	
Interagency Coordination	○	
Regional Concepts for Transportation Operations	○	

○ – Guidance or analysis capability provided.
$ – Life-cycle cost estimation capability only.

How to Use the TOPS-BC User's Manual

The TOPS-BC application is designed to be intuitive and easy to use. This User's Manual is intended to provide clarification on the proper setup and application of the tool. This User's Manual assumes that you are minimally familiar with B/C analysis and the unique challenges of applying B/C analysis to TSM&O strategies. The *Desk Reference* may be used by practitioners unfamiliar with fundamental B/C concepts and terminology to learn more about the basics of B/C analysis for TSM&O strategies.

This User's Manual also assumes that you have a basic knowledge of spreadsheet navigation and operation.

The User's Manual is divided into the following chapters that generally follow the major capabilities of the tool:

- **Chapter 2.0 Overview and Getting Started with TOPS-BC** provides an overview of the TOPS-BC application and describes the process for installing and initiating an analysis.
- **Chapter 3.0 Investigate the Range of Impacts Associated with Various Operations Strategies** summarizes the first of the major capabilities by illustrating the use of the tool to research TSM&O strategies and their likely impacts/benefits.
- **Chapter 4.0 Map B/C Methodologies to Your Organization's Needs** summarizes the capability of the tool to research different existing tools and analysis methods, and identify those methods that are most appropriate to the particular needs of a specific analysis.
- **Chapter 5.0 Estimate Life-cycle Costs** provides a description of the cost estimation framework and equipment cost data maintained in the tool.
- **Chapter 6.0 Estimate Benefits of Operations Strategies** provides step-by-step guidance for using the sketch planning framework for estimating major impacts and benefits of various operations strategies included in the tool. It also provides several innovative approaches and examples for overcoming common analysis challenges.
- **Chapter 7 Customizing and Maintaining TOPS-BC** provides guidance for utilizing the automated processes designed into TOPS-BC for updating information and adding new analysis capabilities.
- **Appendix A Frequently Asked Questions** provides a quick guide for addressing common questions about the tool and the required data inputs and outputs.

Chapter 2. Overview and Getting Started with TOPS-BC

What is TOPS-BC?

TOPS-BC is a spreadsheet-based tool designed to assist practitioners in conducting B/C analysis and support the guidance provided in the *Desk Reference*. TOPS-BC provides:

- The ability to investigate the expected range of impacts associated with previous deployments and analyze many TSM&O strategies;
- A screening mechanism to help identify appropriate tools and methodologies for conducting a B/C analysis based on analysis needs;
- A framework and default cost data to estimate the life-cycle costs (including capital, replacement, and continuing O&M costs) of various TSM&O strategies; and
- A framework and suggested impact values for conducting simple sketch planning level B/C analysis for selected TSM&O strategies.

The TSM&O strategies within TOPS-BC were listed in Table 1-1. TOPS-BC covers a long list of strategies; however, due to the environment of TSM&O, where new strategies are constantly emerging and being enhanced, the tool is designed to be flexible for easy adaptation and improvement by practitioners to meet the needs of a particular analysis. In fact, the tool contains capabilities designed to support the creation of new strategy analysis within the tool, as discussed in Chapter 7 of this manual. The following requirements were used in the development of the initial TOPS-BC application:

- Provide the tool in a macro-driven spreadsheet environment to provide easy distribution of the tool and easy customization by practitioners;
- Design the capabilities to be intuitive to use;
- Ensure default figures used in the tool are documented and understandable;
- Make all formulas reviewable so practitioners can understand the analysis process being applied; and
- Provide for easy maintenance and customization.

Installing and Using TOPS-BC for the First Time

The TOPS-BC application is distributed as a Microsoft Office 2007 Excel spreadsheet. Two separate versions are available:

- Standard Version – This is the most typical version and is available on-line. This version is provided with some of the key worksheets and mathematical formulas in a locked mode so that they may not be altered. Locked cells include critical input parameters and analysis calculation formulas. You may, in many cases, override the default input values if desired; however, you must do so by using the defined "user defined input" cells that clearly document changes made to the analysis. Use of this version ensures that all analysis conducted in the tool is completed using the parameters, values and formulas as they were developed in the original tool.
- Development Version – This version is identical to the Standard Version, with the exception that no security features have been added to any cells or code in the workbook. This version is not available on-line, but will be available upon special request. Advanced users will be able to freely modify and customize the tool to meet individual needs. It is your responsibility, however, to ensure that the modifications you make to the tool are appropriate, as there are no tracking mechanisms available within this version to document changes made to the original tool.

Note: This User's Manual is intended to support the typical user and is focused on describing functions available in the Standard Version of the software. Not all of the advanced internal features designed to support the future maintenance and updating of the tool are described in this document.

The file name of the distributed file indicates the version and version release number, as illustrated in the following examples:

- **TOPS-BC standard version 1.0.xlsm –** Represents a Standard (locked) Version of the tool with a version number of 1.0 (the number 1.0 is assigned to the initial release of the tool and will be increased as subsequent versions are released).
- **TOPS-BC development version 1.0.xlsm –** Represents a Development (open) Version of the tool with a version number of 1.0.

Note: the version number associated with the tool is also prominently displayed on each worksheet in TOPS-BC for reference.

You are encouraged to download the latest version of the spreadsheet file and save it to your computer's hard drive. You are also encouraged to make a copy of the file and rename it according to your own file keeping structure. You should then use the copied file as you move forward with your analysis. This will ensure that a "clean" copy of the file is preserved in case you wish to use it as a reference.

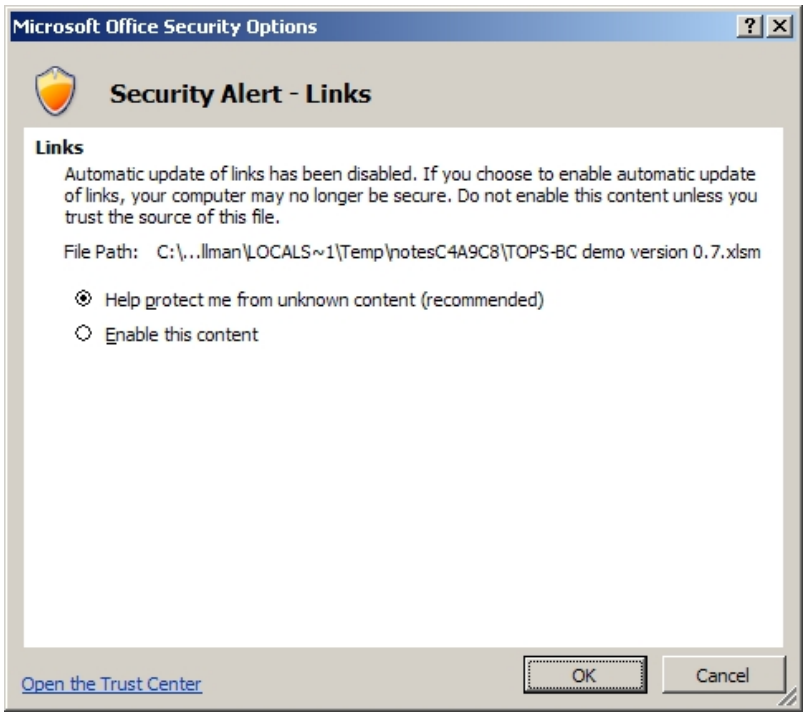
Further, there may be situations where you may want to keep multiple copies of the file. For example, if you are analyzing multiple projects, you may want to keep a separate file for each project being

analyzed. Chapters 4 and 5 covering the life-cycle cost and benefit estimation capabilities provide additional discussion of how to structure multiple project analyses.

Security Settings

The TOPS-BC application makes extensive use of Active-X macros. Depending on the individual security settings applied to your computer, the initial use of these capabilities may not be permitted. When TOPS-BC is opened for the first time on a new computer, you may receive a message indicating that certain applications are barred as shown in Figure 2-1.

Figure 2-1. Sample View of Security Settings Prompt



Source: FHWA.

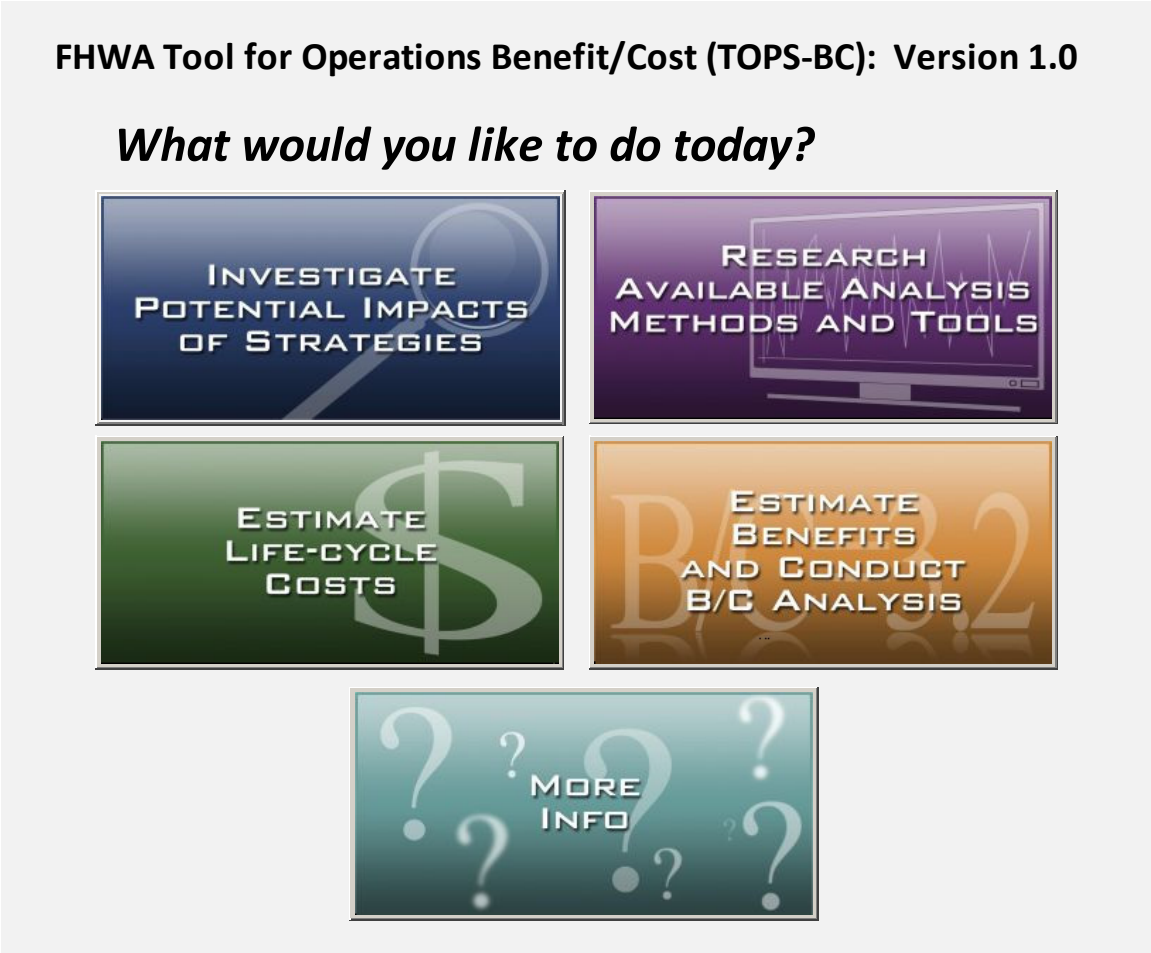
To allow TOPS-BC to work properly on the computer, you must select “Allow content” or “Enable this content” before proceeding with any analysis. Depending on individual computer settings, you may need to allow/enable more than one type of content (e.g., ActiveX and Links). Once allowed, you will be automatically taken to the opening screen of the tool.

Note, the macros within TOPS-BC are implemented automatically upon opening the file, and will direct you by default to the opening screen workbook. Once you open the file, automatic initiation of this macro alters the file. This will prompt a “Save Changes” prompt upon closing the file, even if you simply open and then immediately close the file without modifying any other data. As a result, the “Date Modified” associated with a TOPS-BC file viewed in Windows Explorer will also be updated every time the file is opened and subsequently closed/saved. Therefore, you are encouraged to not rely solely on the date the file was last modified to keep track of the latest version of working files. Instead, you are encouraged to save the file with unique naming conventions to track internal working versions of the file.

Basic Navigation within TOPS-BC

Upon opening the TOPS-BC spreadsheet, you will automatically be directed to the opening screen worksheet, as shown in Figure 2-2. This view allows easy access to the four key capabilities of the tool, as well as a "More Info?" link that provides basic instruction on the tool.

Figure 2-2. TOPS-BC Opening Screen



Source: FHWA.

Worksheets within TOPS-BC are organized by capability, and by individual strategies in some situations. The worksheet tabs are color coded according the capability provided. While the color coding may vary slightly from one computer to another, the general color coding scheme is as follows:[1]

- White/light gray – Opening Screen / General Info / Navigation;
- Blue – Capability 1: Investigate the Range of Expected Values Associated with Various TSM&O Strategies;
- Orange – Capability 2: Map Different B/C Methodologies to Your Organization's Needs;
- Green – Capability 3: Estimate Life-cycle Costs of TSM&O Strategies;
- Purple – Capability 4: Conduct Simple Spreadsheet-Based B/C Analysis for Selected TSM&O Strategies; and
- Red – These are typically hidden worksheets involved in the maintenance and updating of the worksheet. Most users will not have a need to use these worksheets and many of these spreadsheets are locked and not available for editing in the standard distribution version.

TOPS-BC may be navigated similar to most other spreadsheets simply by selecting the desired worksheets tabs within the workbook; however, a number of shortcut navigation tools are available. From the opening screen worksheet, you can click on any of the boxes to automatically be taken to the first worksheet related to the selected capability. In the case of Capability 1 (Investigate the Range of Expected Values Associated with Various TSM&O Strategies) and Capability 2 (Map Different B/C Methodologies to Your Organization's Needs), you will automatically be taken to the worksheet where you can use the particular capability. In the cases of Capability 3 (Estimate Life-cycle Costs of TSM&O Strategies) and Capability 4 (Conduct Simple Spreadsheet-Based B/C Analysis for Selected TSM&O Strategies) you will be directed to an overview screen for the particular capability that provides instruction and further navigation links to analyze specific strategies.

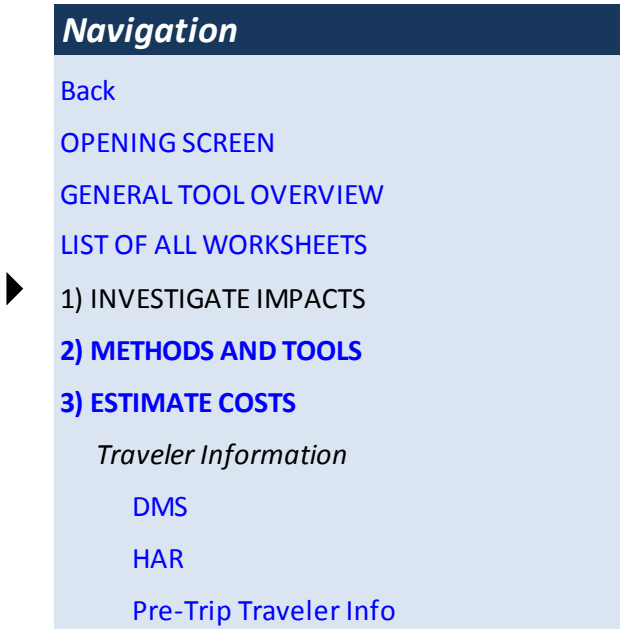
Within all individual analysis worksheets in the TOPS-BC workbook, a blue-shaded Navigation Menu is provided vertically along the left side containing hyperlinks that allow you to go Back to the previous page visited[2], return to the OPENING SCREEN, access the General Tool Overview, or go directly to any of the other worksheets. Figure 2-3 shows a sample of a portion of this Navigation Menu.

As you insert or delete rows or columns in any of the worksheets, the Navigation Menu will change. Adding a row will leave a blank row in the navigation menu; deleting a row will remove the link to a worksheet. TOPS-BC has been designed to auto correct this problem. When you leave a worksheet that has been edited, and then return, the navigation menu is recreated in its original form, ensuring that no links will accidentally be removed.

[1] The actual tab colors used on any individual computer may be viewed in a mapping shown on the "TOPS-BC INFO" worksheet.

[2] Note that if you are navigating through the tool using the worksheet tabs rather than the hyperlinks provided in the Navigation Menu, the "Back" function will return you to the last hyperlink selected.

Figure 2-3. Partial Screen View of the TOPS-BC Navigation Menu



Source: FHWA.

Chapter 3. Investigate the Range of Impacts Associated with Various Operations Strategies

Source: FHWA.

Overview

The first key capability provided in TOPS-BC is the ability to investigate the range of impacts associated with various operations strategies. Practitioners often have the need to research and identify the potential high level impacts of various operations strategies. For example, you may need to identify the typical range of speed change related to a ramp metering deployment. This information may be needed to fulfill a request to provide basic justification of the potential benefits of strategies to communicate to decision makers or the public, or may be needed to provide input parameters on the potential impacts for use in a B/C analysis. The TOPS-BC application is intended to provide guidance regarding the potential benefits of a wide range of TSM&O strategies in order to fulfill these needs.

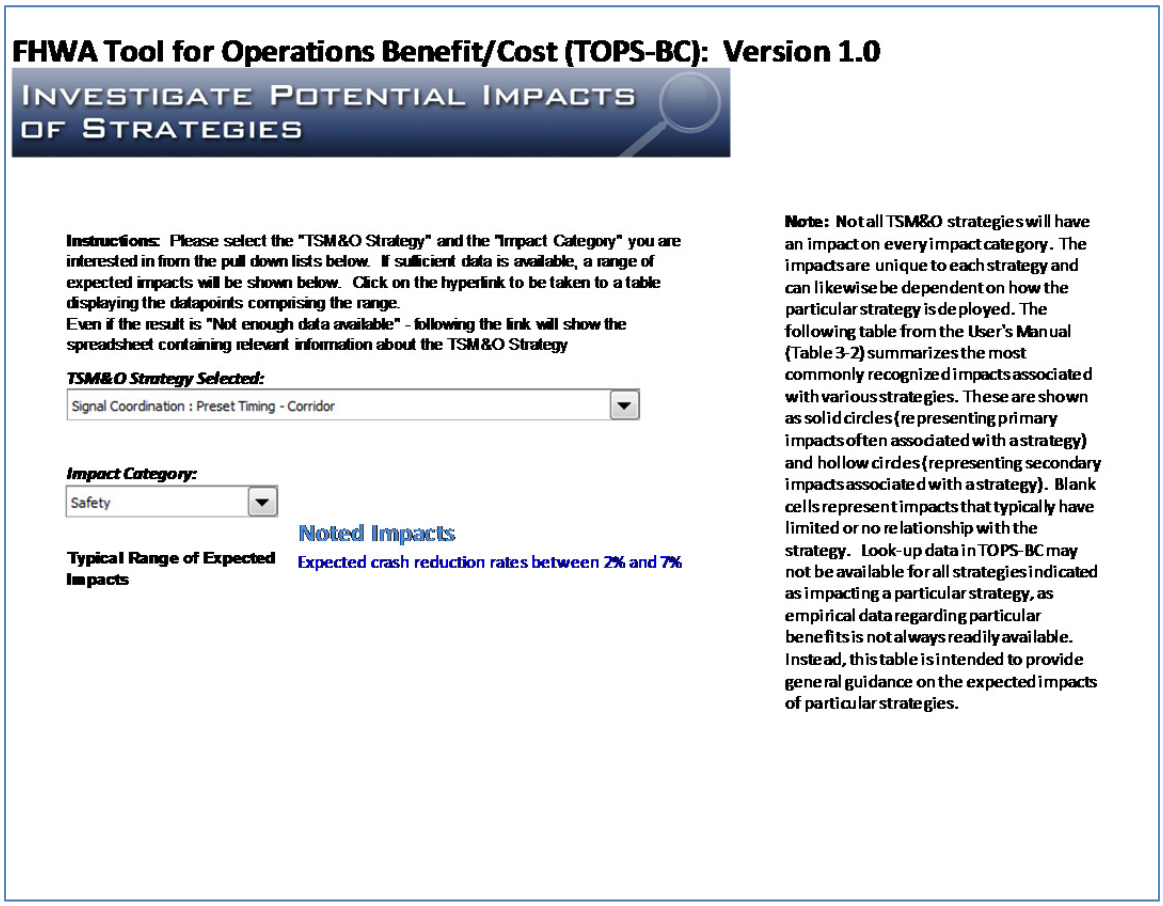
TOPS-BC maintains an internal database of impacts and benefits observed for specific strategies when deployed in various regions in the United States and abroad. This information has been compiled from the ITS Joint Program Office's Benefit Cost Database [http://www.benefitcost.its.dot.gov] and numerous other sources. Additionally, input parameters used in several operational analysis tools are also documented in the database for additional guidance.

The number of data points associated with any particular strategy and individual impact is often related to the maturity of the strategy and the number of real-world evaluations that have been conducted to date. Well established strategies may have many benefits data points available from multiple locations. New and emerging strategies may have only a limited number or no empirical data points available. Cells in the database have been reserved, however, to be populated at a later date as benefit information becomes available on these strategies. Similarly, not all strategies are anticipated to impact all types of benefits. Therefore, many impact categories for a particular strategy may not contain information.

Using Capability 1 to Investigate the Range of Impacts Associated with Various Operations Strategies

To navigate to the worksheet providing this capability, click on the appropriate box on the opening screen, or simply select the blue worksheet tab named “Impact Lookup.” The Impact Lookup sheet is shown in Figure 3-1.

Figure 3-1. Impact Lookup Worksheet



Source: FHWA.

On this worksheet, select a particular strategy and impact category you are interested in researching. When selecting particular strategies, you may be asked to define the sophistication of the strategy. For example, Ramp Metering has separated menu items in the pull down menu for pre-set, actuated and central control timing. Upon selecting these inputs, a range of observed impacts may be displayed under the “Noted Impacts.” This range is based upon a review of available data by the tool developers.

If insufficient data was available to identify an appropriate range of potential impacts, a message stating “Not enough data available” will appear. Figure 3-2, also presented in the *Desk Reference*, provides a mapping of the generally recognized benefits associated with various operations strategies. While not an absolute mapping of empirical data maintained in the database, the table provides a hint to where the most data is likely available.

Figure 3-2. TSM&O Strategies Mapped to Likely Impacts on MOEs

TSM&O Strategy	Mobility (Travel Time Savings)	Reliability (Total Delay)	Safety (Number and Severity of Crashes)	Emissions	Energy (Fuel Use)	Vehicle Operating Cost Savings	Agency Efficiency
Arterial Corridor Signal Coordination							
Preset timing Traffic actuated timing Centrally-controlled timing Arterial transit vehicle signal priority	●	○	●	●	●	○	
Freeway Management Systems							
Ramp metering Preset timing Traffic actuated timing Centrally-controlled timing	●	●	●	●	●	●	
Advanced Public Transportation Systems							
Fixed-route systems Transit AVL Transit automated scheduling Paratransit systems Transit AVL Transit automated scheduling	●	●	○	○	○	○	●
Incident Management Systems							
Freeway/arterial service patrols Incident detection and verification Incident response management	●	●	●	●	●	○	
Pretrip Multimodal Traveler Information Systems							
Web-based 511 Traveler Information Systems Phone-based 511 Traveler Information Systems Kiosk-based Traveler Information Systems	●	●	○	○	○		
En-Route Multimodal Traveler Information Systems							
In-vehicle 511 Traveler Information Systems (PDA/Web based or Telephone based) HAR DMS Transit Station Traveler Information Systems	●	●	○	○	○		
Transportation and Demand Management							
Congestion Pricing HOT Lanes	●	●	○	○	○		
Speed Harmonization	○	●	●	●	●		
Road Weather Management	○	○	●				
Work Zone Management	●	●	●	●	●	●	●

● – Primary MOEs associated with the strategy.
○ – Secondary MOEs associated with the strategy.

Ranges of data shown on the Impact Lookup worksheet are individual high-level summaries of the observed impacts from empirical studies and other data from existing B/C analysis tools. The message displayed under the "Noted Impacts" heading is hyperlinked directly to a summary of studies and existing tool input parameters used in developing the estimated range. Figure 3-3 shows a sample data point representing a view of the Speed/Travel Time impacts related to ramp metering deployments.

Figure 3-3. Sample Display of High-Level Empirical Data Maintained in TOPS-BC

U.S. state, regional, local studies/statistics	Austin - Travel time decreased by 37.5%	from ITS Benefits: Continuing Successes and Operational Test Results and ITS Benefits: 2001 Update - Mitretek
	Dallas - 7.6% to 55% increase in speed	from Overview of Ramp Metering Subsystem for Phoenix Freeway Management System - ITE
	Dallas (North Central Expwy) - 15% increase in speed, 15% decrease in delay	from The 2nd National Symposium on ITMS - TRB
	Detroit - Speeds increased by 8%	from PATH's Learning from the Evaluation and Analysis of Performance web site, 1998 - California PATH and Caltrans
	Detroit - Travel time decreased by 7.4%	from ITS Benefits: Continuing Successes and Operational Test Results - Mitretek
	Houston - 29% increase in speed	from ITS Benefits: Review of Evaluation and Reported Benefits - TTI, 1998 and Twin Cities Ramp Meter Evaluation - Cambridge Systematics, 2000
	Phoenix - 5% to 10% increase in speed	from Ramp Metering in Minnesota - TTI and Twin Cities Ramp Meter Evaluation - Cambridge Systematics
	Portland - 39% reduction in travel time, 60% improvement in speed	from ITS Benefits: 2001 Update - Mitretek
	Portland - Speeds increased from 16 to 41 mph NB and 40 to 43 mph SB (156% and 7.5% increase, respectively)	from PATH's Learning from the Evaluation and Analysis of Performance web site, 1998 - California PATH and Caltrans
	Portland - Travel time decreased by 7.4%	from ITS Benefits: Continuing Successes and Operational Test Results - Mitretek
	Seattle - Travel time decreased by 47.7% to 52.3%, speed increased by 20%	from ITS Benefits: Continuing Successes and Operational Test Results and ITS Benefits: 2001 Update - Mitretek

Source: FHWA.

The default data displayed in the database shows only very high-level summaries of the data. Data related to particular strategies is presented in rows, while columns display data related to specific impacts. The database is not intended to be a comprehensive presentation of data, but instead is intended to provide a "quick look" overview of the available data and observed impacts (generally expressed as a simple percentage change whenever possible).

The database does not document the specifics of the deployment or evaluation effort that produced the data point. Instead, a hidden column located to the right of each impact category column contains a reference for the data's source documentation, providing you the opportunity to further investigate the specifics of particular data points.

To view the reference data for each individual data point, follow the normal Excel process for viewing a hidden column. Highlight the entire column for the impact of interest and the column located immediately to the right of that column. Once selected, perform a right-mouse click, while the mouse is positioned over the alphabetical column headings, and select "Unhide" from the pop-up content menu.

Chapter 4. Map B/C Methodologies to Your Organization's Needs

Source: FHWA.

Overview

Dozens of individual analysis tools and methodologies designed for conducting B/C analysis of one or more TSM&O strategies have been developed to date. Chapter 4 of the *Desk Reference* document provides an overview of many of these tools and methods. These include tools developed by regional, state, and Federal agencies, as well as proprietary tools developed by many private-sector enterprises. These tools and methods range from simple methods intended for one-time analysis to more complex tools that are continually maintained and updated that form a continuing standardized framework for conducting B/C analysis for various agencies. Additionally, several emerging tools/methods are currently undergoing development as part of parallel efforts by U.S. DOT, American Association of State Highway and Transportation Officials (AASHTO), individual states and regions, and research organizations. Chapter 4 of the *Desk Reference* document provides a synthesis of many of the available tools and their specific capabilities and limitations.

No single tool or method is appropriate to address the requirements of all of the wide ranging needs for conducting B/C analysis, and it is critical that practitioners select the right tool for the job to produce meaningful analysis results within the resources available for the assessment. With the large and growing number of tools and methods available, however, it has become increasingly difficult for practitioners to know which tool to apply.

TOPS-BC includes the capability to research different tools and methods in order to quickly winnow out those methods that are not applicable and allow you to better focus on those tools that are most relevant to the needs of your analysis. This capability also is intended to provide practitioners with an enhanced understanding of how different criteria affect the needs of their analysis, and make them more aware of the many tradeoffs involved in selecting an analysis approach (e.g., greater level of analysis detail and more accuracy often requires more resources to complete the analysis). The process used by TOPS-BC to provide this capability is described in the section below.

Using Capability 2 to Map B/C Methodologies to Your Organization's Needs

TOPS-BC's capability of researching available analysis tools is designed around having you enter information related to several key criteria reflecting your analysis needs. The tool will match those criteria to the known capabilities of a number of publicly available tools and methods, and present you with a list of those appropriate methods for conducting the analysis. Where available, you will then be presented with links to more information regarding the method(s) in order to conduct additional research on the specifics of the suggested tool(s).

Figure 4-1 shows a sample screen view of the capability within TOPS-BC, located on the "Method Selection" worksheet. Upon opening this worksheet, an automated macro populates a table of selection criteria related to B/C criteria. These criteria include:

- Geographic scope of the analysis;
- Desired level of confidence in the results;
- TSM&O strategies to be analyzed;
- Key Measures of Effectiveness (MOEs);
- Travel modes to include;
- Level of resources to support the analysis; and
- Data/tools available to support the analysis.

As shown in Figure 4-1, TOPS-BC contains a list of some of the most widely distributed and applied tools used for conducting B/C analysis of TSM&O strategies. This listing summarizes those major tools developed by Federal, state, or regional transportation agencies (or affiliated research organizations) that are available within the public realm. This listing does not include proprietary offerings of private-sector vendors. Specific descriptions of the various tools are provided in Chapter 4 of the *Desk Reference*. The listing also includes general analysis approaches (not specific tools) such as travel demand modeling and simulation modeling methods. Methods for applying these analysis tools for supporting B/C analysis are provided in Chapter 5 of the *Desk Reference*.

To operate this capability, review the various input criteria and make selections that define your specific analysis needs on the Method Selection worksheet. For example, if the analyst wants to analyze performance on a corridor, select the "Corridor" option under the "What is the geographic scope of the analysis?" question. For each question, either "Select 1" by choosing from the defined radio buttons, or "Choose Multiple" by checking however many multiple selection boxes that are relevant. You are not required to enter information for each criteria question, and may leave any question answered as "No preference."

Figure 4-1. Partial Screen View of the Method Selection Worksheet

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.0

RESEARCH AVAILABLE ANALYSIS METHODS AND TOOLS

Instructions: Please indicate the needs of your analysis associated with the following options. As you select the options, a list of appropriate methodologies will be displayed to the right. Hyperlinks are provided for those tools with current websites. Tools/methods without a current website are denoted with an asterisk (*).

INPUT CRITERIA

What is the geographic scope of the analysis? (Select 1)

- (●) No Preference
- ( ) Statewide
- ( ) Regional
- ( ) Corridor
- ( ) Isolated Location
- ( ) Other

What is the desired level of confidence of the analysis results? (Select 1)

- ( ) No Preference
- ( ) High (extremely accurate)
- (●) Medium
- ( ) Low (order of magnitude)

What TSM&O strategy(ies) do you want to analyze? (Choose Multiple)

- [x] No Preference
- [ ] Arterial Corridor Traffic Signal Coordination Strategies
- [ ] Traffic Signal Priority Strategies
- [ ] Ramp Metering Strategies
- [ ] Traffic Incident Management Systems
- [ ] Transit AVL and Automated Scheduling
- [ ] Pre-Trip Traveler Information
- [ ] En-Route Traveler Information
- [ ] HOT Lanes
- [ ] Speed Harmonization
- [ ] Road Weather Management
- [ ] Work Zone Management
- [ ] Travel Demand Management - Employer Based
- [ ] Supporting Systems (Surveillance, TMC, Communications)

Suggested Methodologies:

Tools meeting ALL criteria	Also Consider: Tools meeting ALL BUT 1 criteria
TOPS-BC *	MicroBENCOST
BCA.net	Redbook Wizard *
CAL-BC	SCRITS
EMFITS *	SPASM *
FITSEval *	STEAM
HERS-ST	
IDAS	
Travel Demand Model Methods *	
Simulation Methods *	

Source: FHWA.

As you enter information for the criteria you feel is relevant, a macro is activated that will dynamically identify those tools and methods that meet all the criteria indicated, as well as those that meet all but one of the user defined criteria settings. Tools failing to meet two or more of the user defined criteria will be eliminated from further consideration. The results will be displayed in the Suggested Methodologies box located to the right of the criteria input selection area as shown in Figure 4-2. Tools meeting all user defined criteria are listed separately from tools meeting all but one criteria. Note: the order in which the tools are listed in either the "Tools meeting ALL criteria" or the "Also Consider: Tools meeting ALL BUT 1 criteria" listing is not intended to represent any prioritization of the tools listed under either category.

Figure 4-2. Partial Screen View of Suggested Methodologies Output

Suggested Methodologies:	
Tools meeting ALL criteria	**Also Consider: Tools meeting ALL BUT 1 criteria**
TOPS-BC *	HERS-ST
BCA.net	
CAL-BC	
EMFITS *	
FITSEval *	
IDAS	
MicroBENCOST	

Source: FHWA.

You may review this list and return to the input criteria selection to make modifications if necessary. By making changes to the input criteria and reviewing the automatically refreshed results, you may gain a better understanding of the contribution key criteria have in selecting a tool.

Once you have developed a list of tools to consider, the capabilities of the tools may be further investigated by reviewing the information contained in Chapter 4 of the *Desk Reference* document. Additionally, many of the tools listed under the Suggested Methodologies contain hyperlinks that will direct you to external websites or information sources related to the particular tool.

Chapter 5. Estimate Life-Cycle Costs of TSM&O Strategies

Source: FHWA.

Overview

Estimating the costs of TSM&O strategies is complex. Compared to more traditional infrastructure improvements, TSM&O improvements typically incur a greater proportion of their costs as continuing O&M costs, as opposed to upfront capital costs. Much of the equipment associated with TSM&O strategies typically has a much shorter anticipated useful life than many traditional improvements, and must be replaced as it reaches obsolescence. Further complicating the TSM&O cost estimation process is the fact that TSM&O deployment costs are greatly impacted by the degree to which equipment and resources are shared across different deployments and jurisdictions.

Despite these difficulties, it is critical that planners fully consider and account for all the costs of TSM&O strategies when evaluating and developing deployment and O&M plans. Failure to recognize and accurately forecast these costs may result in future funding or resource shortfalls, or worse, the inability to properly operate and maintain deployed TSM&O improvements. The cost estimation capability developed within the TOPS-BC support tool is intended to assist planners in estimating and predicting high-level cost and resource requirements of planned TSM&O strategies.

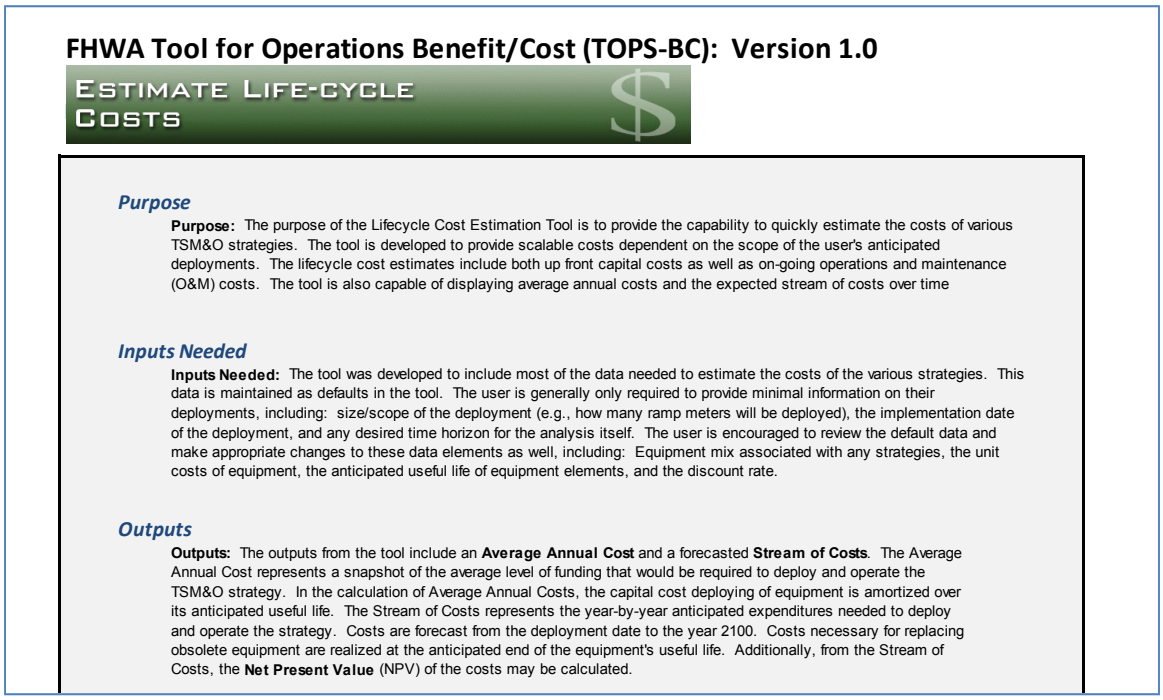
The prior two capabilities described in this User's Manual were primarily involved with conducting research in order to make more informed decisions. The life-cycle cost estimation capabilities provide the first example of analysis where you will be entering data representing an existing or planned improvement in order to generate values that will be directly used in the comparison of benefits and costs. As such, you are encouraged to carefully think about your file structure – multiple copies of the TOPS-BC file may be required to analyze different projects – as you will likely want to save the data you have entered separately for each one.

Using Capability 3 to Estimate Life-cycle Costs of TSM&O Strategies

The estimation of life-cycle costs is initiated by selecting the capability from the OPENING SCREEN worksheet, or selecting the COST ESTIMATION worksheet tab. This action takes you to an instructional sheet, as shown in Figure 5-1. This sheet also contains links to the worksheets where

individual strategies will be analyzed. You may also jump to a particular cost estimation worksheet for a specific strategy by selecting the appropriate hyperlink in the Navigation Menu.

Figure 5-1. Partial Screen View of COST ESTIMATION Worksheet Instructions



FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.0

ESTIMATE LIFE-CYCLE COSTS

Purpose

Purpose: The purpose of the Lifecycle Cost Estimation Tool is to provide the capability to quickly estimate the costs of various TSM&O strategies. The tool is developed to provide scalable costs dependent on the scope of the user's anticipated deployments. The lifecycle cost estimates include both up front capital costs as well as on-going operations and maintenance (O&M) costs. The tool is also capable of displaying average annual costs and the expected stream of costs over time

Inputs Needed

Inputs Needed: The tool was developed to include most of the data needed to estimate the costs of the various strategies. This data is maintained as defaults in the tool. The user is generally only required to provide minimal information on their deployments, including: size/scope of the deployment (e.g., how many ramp meters will be deployed), the implementation date of the deployment, and any desired time horizon for the analysis itself. The user is encouraged to review the default data and make appropriate changes to these data elements as well, including: Equipment mix associated with any strategies, the unit costs of equipment, the anticipated useful life of equipment elements, and the discount rate.

Outputs

Outputs: The outputs from the tool include an **Average Annual Cost** and a forecasted **Stream of Costs**. The Average Annual Cost represents a snapshot of the average level of funding that would be required to deploy and operate the TSM&O strategy. In the calculation of Average Annual Costs, the capital cost deploying of equipment is amortized over its anticipated useful life. The Stream of Costs represents the year-by-year anticipated expenditures needed to deploy and operate the strategy. Costs are forecast from the deployment date to the year 2100. Costs necessary for replacing obsolete equipment are realized at the anticipated end of the equipment's useful life. Additionally, from the Stream of Costs, the **Net Present Value** (NPV) of the costs may be calculated.

Source: FHWA.

Prior to initiating a life-cycle cost analysis in TOPS-BC, familiarize yourself with the cost structure and terminology used in the tool. TOPS-BC considers the following cost categories:

- **Capital costs** – Include the upfront costs necessary to procure and install equipment related to the TSM&O strategy. These costs will be shown as a total (one-time) expenditure, and will include the capital equipment costs, as well as the soft costs required for design and installation of the equipment.
- **O&M costs –** Include those continuing costs necessary to operate and maintain the deployed strategy, including labor costs. While these costs do contain provisions for upkeep and replacement of minor components of the system, they do not contain provisions for wholesale replacement of the equipment when it reaches the end of its useful life (see Replacement costs). These O&M costs will be presented as annual estimates.
- **Replacement costs** – Include the periodic cost of replacing/redeploying system equipment as it becomes obsolete and reaches the end of its expected useful life in order to insure the continued operation of the strategy.
- **Annualized costs** – Represent the average annual expenditure that would be expected in order to deploy, operate, and maintain the TSM&O strategy; and replace (or redeploy) any equipment as it reaches the end of its useful life. Within this cost figure, the capital cost of the equipment will be amortized over the anticipated life of each individual piece of equipment. This figure is added with the recurring annual O&M cost to produce the

annualized cost figure. This figure is particularly useful in estimating the long-term budgetary impacts of TSM&O deployments.

The complexity of many TSM&O deployments warrants that these cost figures be further segmented to ensure their usefulness. Within each of the capital, O&M, and annualized cost estimates, costs are further disaggregated to show the infrastructure and incremental costs. These are defined as follows:

- **Infrastructure costs** – Include the basic "backbone" infrastructure equipment (including labor) necessary to enable the system. For example, in order to deploy a camera (closed-circuit television (CCTV)) surveillance system, certain infrastructure equipment must first be deployed at the traffic management center to support the roadside Intelligent Transportation System (ITS) elements. This may include costs, such as computer hardware/software, video monitors, and the labor to operate the system. Once this equipment is in place, however, multiple roadside elements may be integrated and linked to this backbone infrastructure without experiencing significant incremental costs (i.e., the equipment does not need to be redeployed every time a new camera is added to the system). These infrastructure costs typically include equipment and resources installed at the traffic management center, but may include some shared roadside elements as well.
- **Incremental costs** – Include the costs necessary to add one additional roadside element to the deployment. For example, the incremental costs for the camera surveillance example include the costs of purchasing and installing one additional camera. Other deployments may include incremental costs for multiple units. For instance, an emergency vehicle signal priority system would include incremental unit costs for each additional intersection and for each additional emergency vehicle that would be equipped as part of the deployment.[3]

Structuring the cost data in this framework provides the ability to readily scale the cost estimates to the size of potential deployments. Figure 5-2 provides a sample view of the cost data organized according to the defined structure in the TOPS-BC application for a ramp meter deployment, as taken from the individual cost estimation strategy worksheet for centrally controlled ramp metering (the green tabbed worksheet named "RM-Central Control"). Infrastructure costs would be incurred for any new technology deployment. Incremental costs would be multiplied by the appropriate unit (e.g., number of intersections equipped, number of ramps equipped, number of variable message sign locations, etc.); and added to the infrastructure costs to determine the total estimated cost of the deployment. Presenting the costs in this scalable format provides the opportunity to easily estimate the costs of expanding or contracting the size of the deployment, and allows the cost data to be reused in evaluating other corridors.

[3] Note that many of the default unit costs for communications capabilities are based on figures originally developed for the ITS National Infrastructure. These communications costs typically represent the cost to lease the capabilities. You may want to review these cost assumptions and modify the values to best represent how you plan to deploy and operate communications systems.

Figure 5-2. Partial Screen View of Cost Data Organization for a Ramp Meter System

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.0

PURPOSE: Estimate Lifecycle Costs of TSM&O Strategies

WORK AREA 1 - ESTIMATE AVERAGE ANNUAL COST

Ramp Metering Systems: Central Control

Equipment	Useful Life	Capital / Replacement Costs (Total)	O&M Costs (Annual)	Annualized Costs
Basic Infrastructure Equipment				
TMC Hardware for Freeway Control	5	$ 22,500	$ 2,000	$ 6,500
TMC Software/Integration	5	$ 200,000	$ -	$ 40,000
Labor		$ -	$ 250,000	$ 250,000
TOTAL Infrastructure Cost		$ 222,500	$ 252,000	$ 296,500
Incremental Deployment Equipment (per Ramp Location)				
Ramp Meter (Signal, Controller)	25	$ 88,000	$ 2,000	$ 5,520
Loop Detectors (2)	25	$ 11,000	$ 500	$ 940
Communication Line	25	$ 750	$ 250	$ 280
TOTAL Incremental Cost		$ 99,750	$ 2,750	$ 6,740
INPUT Enter Number of Infrastructure Deployments	1			**$ 296,500**
INPUT Enter Number of Incremental Deployments	10			**$ 67,400**
INPUT Enter Year of Deployment	2013			
Average Annual Cost				**$363,900**

Source: FHWA.

In the ramp meter example shown in Figure 5-2, the *Annualized Costs* for any individual piece of equipment equals the *Capital Costs* (which represents the total cost to deploy or redeploy that piece of equipment) divided by the *Useful Life* (to amortize the cost of the equipment over the anticipated life), plus the annual cost of operating and maintaining the piece of equipment. This methodology assumes that the piece of equipment is replaced at the end of its useful life. For example, the Annualized Costs for the equipment called "TMC Hardware for Freeway Control" is calculated as:

Annualized Costs = (Capital Costs/Useful Life) + Annual O&M Costs
or
Annualized Costs = ($22,500/5 years) + $2,000 = $6,500

Some equipment does not have upfront Capital Costs, but only has recurring annual O&M Costs, as illustrated by the "Labor" costs in the Figure 5-2 example. In these situations, the annualized cost is simply the annual O&M Costs.

In the TOPS-BC application, you are able to enter the quantity of Infrastructure and Incremental equipment units you want to deploy, as shown in Figure 5-2; and the tool will calculate the total cost of the selected deployments based on these entries.[4] Average Annual Costs for the ramp metering example, assuming 10 ramp meter locations were included in the deployment, would be calculated as:

Average Annual Costs = (# of Infrastructure Deployments * Annualized Costs of Infrastructure Deployment) + (# of Incremental Deployments * Annualized Costs of Incremental Deployment)
or
Average Annual Costs = (1 * $296,500) + (10 * $6,740) = $363,900

Outputs from this process include the following:

- An **Average Annual Cost** – A single expected cost compiling upfront capital, ongoing O&M, and future equipment replacement costs in a single figure.
- A **Projected Stream of Costs** – An output showing year-by-year expected expenditures over the next 30-year timeframe. This output can be used to calculate Net Present Value (NPV) over any time horizon you choose, if you chose to use NPV instead of average annual costs in your analysis.

Figure 5-3 shows a sample view of the Projected Stream of Costs generated for the ramp meter strategy illustrated in Figure 5-2. In this view, the Capital Costs are not amortized over the life of equipment, but appear in the year they are incurred. Your Upfront Capital Costs appear in the first year of deployment, and Replacement Costs are incurred in future years, as equipment needs to be

[4] For most TSM&O strategies, the number of "Infrastructure" deployments will be one, as only one deployment of this equipment is necessary to support multiple deployments of the "Incremental" units. However, you have the opportunity to deploy more than one "Infrastructure" unit if planned deployment is configured in a nontypical manner (e.g., managed from multiple Traffic Management Centers) or enter zero if you already have the Infrastructure deployed. In situations where the infrastructure equipment supports more than one strategy (or multiple deployments of the same strategy on more than one corridor), a fraction may be entered in the User Input cell. For example, if in the sample deployment shown in Figure 5-2, the deployment of 10 ramp meters was meant to analyze one of four corridors that were being planned for deployment, you may want to enter a value of .25 as the number of infrastructure deployments, to represent that each corridor would be expected to incur one-fourth of the infrastructure costs.

replaced. In the ramp metering example, the full Capital Cost of deployment is incurred in year 2013, and the same value is incurred again in year 2018, since the equipment involved in the deployment has reached the end of its useful life by this date. Space is provided to view costs up to a 50-year time horizon. You may calculate the Net Present Value (NPV) of the costs by selecting a time horizon (in number of years) and an appropriate discount rate. Defaults are provided, but you may override those defaults by entering different values. The user is encouraged to review information in Chapter 5 of the *Desk Reference* for more information on calculating and using NPV. The Desk Reference also has information to guide you in selecting an appropriate discount rate to apply in your analysis.

Figure 5-3. TOPS-BC Projected Stream of Costs Output

FHWA Tool for Operations Benefit/Cost (TOPS-BC)

PURPOSE: Estimate Lifecycle Costs of TSM&O Strategies

WORK AREA 2 - PROJECT STREAM OF COSTS AND ESTIMATE NET PRESENT VALUE

Ramp Metering Systems: Central Control

Cost Item	2013	2014	2015	2016	2017	2018	2019	2020	2021
Infrastructure Costs	$ 474,500	$ 252,000	$ 252,000	$ 252,000	$ 252,000	$ 474,500	$ 252,000	$ 252,000	$ 252,000
Incremental Costs	$ 1,025,000	$ 27,500	$ 27,500	$ 27,500	$ 27,500	$ 27,500	$ 27,500	$ 27,500	$ 27,500
Total Annual Cost	$ 1,499,500	$ 279,500	$ 279,500	$ 279,500	$ 279,500	$ 502,000	$ 279,500	$ 279,500	$ 279,500
Cumulative Cost	*$ 1,499,500*	*$ 1,779,000*	*$ 2,058,500*	*$ 2,338,000*	*$ 2,617,500*	*$ 3,119,500*	*$ 3,399,000*	*$ 3,678,500*	*$ 3,958,000*

INPUT	Enter Number of Years in the Analysis Time Horizon	20	Source: TIGER Grant Application Recommendations
INPUT	Enter the Beginning Year of the Analysis	2013	
INPUT	Enter Discount Rate	7.0%	Source: Office of Management and Budget

NET PRESENT VALUE OF COSTS $3,490,036

2013 TO 2033

Source: FHWA.

The default view of the stream of costs shown in Figure 5-3 rolls up all Infrastructure and Incremental costs into single values for easy viewing; however, located in hidden rows underneath the display of the stream of costs, a separate working calculations sheet shows the breakout of costs by year, by equipment type for accounting purposes if needed. Figure 5-4 shows a view of this information (in an unhidden view). You are discouraged from directly editing any of the values in this calculations sheet.

Figure 5-4. TOPS-BC Cost Estimation Working Calculations Area

WORKING CALCULATIONS SHEET -- DO NOT MODIFY VALUES IN THIS SECTION

Cost Item	2013	2014	2015	2016	2017	2018	2019	2020	2021
Basic Infrastructure Equipment									
TMC Hardware	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TMC Software/	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Labor	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL Infrastr	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***
Incremental Deployment Equipment (per Ramp Location)									
Ramp Meter (S	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Loop Detectors	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Communicatio	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL Increm	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***	***$ -***

Source: FHWA.

To estimate the life-cycle cost of any individual strategy, visit the cost estimation sheet for the selected strategy and enter the appropriate information on the number of infrastructure and incremental units, as well as the Year of Deployment, as shown in Figure 5-5. The Average Annual Cost and Stream of Costs will automatically update based on the inputs.

Figure 5-5. Strategy Cost Estimation Data Input

INPUT	Enter Number of Infrastructure Deployments	1	$ 296,500
INPUT	Enter Number of Incremental Deployments	10	$ 67,400
INPUT	Enter Year of Deployment	2013	

Source: FHWA.

If you intend to use only the default data available in TOPS-BC, there is no need to make any further modifications, other than to enter the number of Infrastructure and Incremental units, and the Year of Deployment. You are strongly encouraged to carefully review the default cost data and make modifications as necessary. You may change the predicted useful life, base unit cost of equipment, or continuing O&M cost for any piece of equipment. You may also delete pieces of equipment or add pieces of equipment to better match your own anticipated equipment mix for the strategy.

Note that if an additional row(s) is needed in order to add a new piece of equipment, you should **insert an entire row by first copying an existing row of data**. You can do this by highlighting an entire row by clicking on the row number at the far left of the page, conducting a right click, and selecting "Copy." Right click on the highlighted row number again and select "Insert Copied Cells." This will

create a new row that is properly formatted and contains the cell formulas necessary to maintain the integrity of the analysis. (If you simply decide to "Insert" a new row, you will need to manually merge cells and copy/paste formulas to match the existing equipment rows.) If you are only interested in using the Average Annual Costs in your calculations, no further modifications are needed. If you are interested in viewing the Stream of Costs and calculating the Net Present Costs and Net Present Benefit, you will additionally need to **check and see if the added equipment has been added to the Working Calculations Sheet** at the bottom of the individual cost estimation sheet [Figure 5-4]. In some cases, due to the manner in which the row was added or the version of Excel being used, the added equipment may not have automatically been generated in the Working Calculations Sheet. Therefore, it is recommended that you check to see that the equipment has been added to the Working Calculations Sheet. If the new equipment is not there, simply follow the directions above for copying and inserting copied rows within the appropriate section of the Working Calculations Sheet to replicate the addition of the new equipment in this Working Calculations Sheet. (Again, you should first copy and "Insert Copied Cells" to ensure the formatting and calculations are maintained.)

As rows are added, the Navigation Menu will temporarily be distorted as gaps will appear in the content; however, once you leave the page where the rows have been added and then return, the Navigation Menu will once again correctly display.

When changing data, note that any modification to the default data requires that the modified data match the data format of the default data. For example, you may enter a new piece of equipment for a particular strategy; however, it must have supporting data on the useful life, capital cost, and annual O&M cost to work within TOPS-BC's estimation structure.

Chapter 6. Conduct Simple Spreadsheet-Based B/C Analysis for Selected TSM&O Strategies

Source: FHWA.

Overview

TOPS-BC provides an analysis framework and many default parameters in order to provide the capability to conduct simple sketch planning level B/C analysis for selected TSM&O strategies. This capability was provided in order to enable practitioners to conduct B/C analysis quickly, simply and with generally available input data. A number of sketch planning tools and analysis frameworks currently exist to assess the benefits of particular TSM&O strategies or small sets of strategies. TOPS-BC leverages many of these existing tools to identify best practices, and synthesizes their capabilities into a more standardized format for analyzing a broader range of strategies within a single tool.

TOPS-BC also links the estimation of sketch level benefits with life-cycle cost estimates provided by Capability 3 – this ability to directly estimate benefits and costs within a single tool is uncommon in existing tools to date. Further, the TOPS-BC benefit estimation methodology was developed to incorporate the assessment of new performance measures (e.g., travel time reliability) that are more capable of capturing the unique impacts of many operations strategies. Finally, the benefits estimation capability of TOPS-BC incorporated much of the latest research on the benefits of TSM&O, particularly for many new and emerging strategies.

TOPS-BC provides the ability to assess the sketch planning level benefits of various TSM&O strategies using minimal data input. Changes in performance measures, such as throughput, speeds, and number of crashes are based on simple and established relationships used in numerous other models. With generally available data such as corridor speeds, volumes and capacities, TOPS-BC can produce an estimate of the change in performance resulting from the implementation of TSM&O strategies. This change in performance can then be used to generate enhanced metrics, and the estimated benefits can be monetized within the tool and compared with estimated life-cycle costs for the strategy generated using Capability 3 (Discussed in Chapter 5 of the User's Manual).

While the sketch planning level analysis provided by TOPS-BC may be suitable for many planning studies, TOPS-BC was not intended to serve as a single analysis tool to be used for all situations. As

discussed in Chapter 4 and 5 of the *Desk Reference* and as highlighted in the discussion of Capability 2 (Chapter 4 of this User's Manual), analyses requiring detailed output and high levels of confidence in the accuracy of the results may require more advanced analysis capabilities than provided directly within TOPS-BC. Even in these situations, however, TOPS-BC may provide value in serving as a framework for monetizing benefits and comparing with costs. Outputs from more advanced simulation or dynamic traffic assignment tools may be used as inputs to TOPS-BC, overriding the performance impacts normally calculated within the tool.

TOPS-BC is intended to provide a framework for analysts to modify and configure to match the needs of their regions and the characteristics of the area being analyzed. Default data is provided for many impact parameters, performance relationships, and benefit valuations – typically based on national averages or accepted values; however, opportunities are provided, and you are encouraged, to use locally configured or regionally relevant data where appropriate and desired.

Similar to the life-cycle cost estimation capabilities discussed in Chapter 5, the benefit estimation capability has a common instructional worksheet with links to individual strategies housed on separate worksheets (purple tabs). The outputs from the benefits estimation include the Average Annual Benefit and the Stream of Benefits time horizon (up to 50 years). The estimated benefits for all strategy sheets are rolled up in a summary sheet that estimates the cumulative benefit for all strategies where data has been entered.

The individual strategy sheets pull data from the appropriate life-cycle cost estimation sheet to provide the basis for generating a B/C ratio and net benefit. For example, the benefit estimation worksheet for Traffic Incident Management will pull any cost data from the life-cycle cost estimation sheet for Traffic Incident Management to provide this comparison opportunity. From the combined benefit and cost data, the NPV of the strategy may be estimated using either default or user-defined parameters.

The following discussion highlights the steps required to conduct B/C comparisons using TOPS-BC.

Using Capability 4 to Conduct Simple Spreadsheet-Based B/C Analysis for Selected TSM&O Strategies

The estimation of benefits and comparison with costs is initiated by selecting the capability from the OPENING SCREEN worksheet or selecting the BENEFITS ESTIMATE worksheet tab. If you are on another sheet rather than the OPENING SCREEN, you may simply select the hyperlink for ESTIMATE BENEFITS on the Navigation Menu. This action takes you to an instructional sheet, as shown in Figure 6-1. Under ESTIMATE BENEFITS in the Navigation Menu, links are available that take you to the individual worksheets for estimating the impacts associated with the strategies available in the tool. You may also select the appropriate purple-tabbed worksheet with the strategy you wish to analyze.

Figure 6-1. Partial Screen View of BENEFIT ESTIMATE Worksheet Instructions

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.0

ESTIMATE BENEFITS AND CONDUCT B/C ANALYSIS B/C=3.2

Purpose

The purpose of the Benefits Estimation Tool is to provide the capability to quickly estimate the potential benefits of various TSM&O strategies. These benefits may then be compared with strategy costs estimated in the Lifecycle Cost Estimation Tool to produce the benefit/cost ratio and net benefit measures. The tool is designed to provide quick sketch planning estimates of TSM&O strategy benefits primarily targeted at fulfilling the needs of practitioners wanting to conduct preliminary screening and initial prioritization of TSM&O strategies.

Inputs Needed

The user is generally only required to provide minimal information on their deployments, and these data inputs are typically composed of readily available performance measures such as: roadway volumes, speeds, and capacities. The user may also be required to provide data on the operating parameters of the selected TSM&O strategy, such as: the percentage of time that a dynamic message sign is displaying data, or the sophistication of a signal coordination plan (e.g., pre-set, traffic actuated, or centrally controlled timing plans). The data required for any given analysis is dependent on the particular strategy selected.

The tool was developed to include most of the data needed to estimate the benefits of the various strategies. This data is maintained as defaults in the tool and is based on national averages of observed impacts and/or vetted parameters used in other existing operations analysis tools. However, the user may, and is encouraged to, review and override these defaults where they feel they have better or more locally relevant data. Many of the default data parameters that are commonly used in analyzing multiple strategies are housed in the PARAMETERS worksheet for easy access and review.

The data needed to provide the required inputs and/or refine the default parameters may be obtained from a variety of sources, including: periodic performance monitoring surveys and traffic counts, travel demand models, simulation models, automated archived data systems, among other sources. As typical with these types of analysis, the degree of confidence the user places in the input data will directly influence the confidence that may be placed in the benefit estimates output by the tool. The Users Manual (Section 6 of the Operations Benefit/Cost Desk Reference) provides additional discussion on determining and selecting the appropriate data sources.

Source: FHWA.

The TOPS-BC benefits analysis is generally unique to each strategy, based on the analysis approach and the anticipated benefit performance measures. All worksheets, however, follow a common structure as defined in the tool instruction page. The most critical part of the common structure is the coloring of the cells within TOPS-BC, as shown in Figure 6-2. This cell color scheme helps you to identify where data input is required and identify cases where you can input your own data to override the default values.

Figure 6-2. Instructions Regarding Cell Colors in the Benefit Estimation Worksheets

Within the individual worksheets, **color is used within individual cells** to highlight the source of the data in the cell according to the following guidelines:

Yellow cells represent **Default** data maintained by the tool.
Blue cells represent **Modeled** data or outputs calculated internally within the tool.
Green cells represent **User Input**. These cells may represent mandatory user inputs, which are typically indicated by the word "INPUT" along the left hand side of the sheet. Green cells may also represent optional user input. Note: inputting a value into an optional user input cell will override the values shown in the default data or calculated data cells in all subsequent analysis; however, the default or calculated values will still appear in those cells as a check on the user input value.

Source: FHWA.

As noted above, each of the different strategies covered by TOPS-BC varies slightly in the input data required, the benefits estimated for the strategy and the methodology used in calculating the benefits. This User's Manual is not intended to provide a comprehensive step-by-step guide for each of the individual strategies. The approaches operate similarly, so the guidance provided here covers several

example analyses rather than comprehensively covering each strategy individually. You are encouraged to review all examples in this section, as together they cover all the key steps.

Once you have selected a strategy to analyze, and navigated to that strategy's worksheet, review the methodology to understand which performance measures are being estimated. Usually, these impact methodologies are presented in sections including:

- Travel Time Savings;
- Travel Time Savings Due to Traveler Information (Advanced Traveler Information System);
- Travel Time Reliability;
- Energy; and
- Safety.

TOPS-BC may not include a methodology for estimating every possible impact associated with a particular strategy (as earlier highlighted in Figure 3-2). In these situations, the analysis framework and default parameters have not been directly provided in TOPS-BC for one or more of the following reasons:

- Difficulty in accurately assessing the level of these benefits in a spreadsheet based tool;
- Non-consensus among practitioners and researchers on the impact of the particular strategy on the benefit;
- Reliance on a non-typical manner of operating the strategy in order to gain the benefit;
- Difficulty in quantifying and identifying a value of the benefit; or other reasons.

If you want to include measurement of these other benefits within the TOPS-BC analysis, and you have an established methodology for estimating these benefits, you have the flexibility to value the benefit off-line and add the value as a line item "User Entered Benefit (Annual $'s)" in the analysis. Or, you may choose to customize the tool yourself by modifying the approach to incorporate your methodology and data for these particular benefits.

Default Parameters

A number of default parameters are used throughout the benefits estimation process. Some parameters are common to multiple strategies, such as the dollar value to be applied to an hour of travel time savings. Other parameters are linked to a specific strategy. For example, the crash rate reduction impact related to a traffic actuated ramp metering system is only applied to that single strategy. Parameters that are generally used across multiple strategies are housed in the "Parameters" worksheet, as shown in Figure 6-3. These default data include data items such as speed-flow relationships, crash rates, fuel economy, and valuations of benefits, among many other parameters. These parameters are generally based on national sources or represent national averages. The source and date of the individual parameters are available as comments within Excel, and may be viewed by hovering over the individual cell to view the attached comment.

Figure 6-3. Partial Screen View of the Benefits Estimation "Parameters" Worksheet

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.0 Restore

Estimate Benefits of TSM&O Strategies

Benefit Estimation Parameters

General Parameters

Year of Dollars Displayed	
Year of Dollar Display	2010
Inflation Rate	3%
Adjustment Factor	1.00
Annualization Factor	
Number of Periods per Year	250
Net Present Value Calculation	
Default Time Horizon (Years)	20
Traffic Mix	
Percentage Trucks	10%
Percentage "On-the-Clock" Travel Purpose (A	20%
Average Auto Occupancy	1.67
Discount Rate	
Discount Rate (for 20 year analysis)	7.0%
Analysis Time Horizon	

Benefit Valuations

Recurring Travel Time (per hour)		
"On the Clock" Travel Time	$	28.00
Other Auto Travel Time	$	14.00
Truck Travel Time	$	28.00
Non-Recurring Travel Time (per hour)		
"On the Clock" Travel Time	$	28.00
Other Auto Travel Time	$	14.00
Truck Travel Time	$	28.00
Crashes (per occurance)		
Fatality	$	6,500,000
Injury	$	67,000
Property Damage Only (PDO)	$	2,300
Fuel Use		
Per Gallon (Excluding Taxes)	$	3.67
Non-fuel Operating Costs (per VMT)		
Auto		0.25
Truck		0.37

Speed/Flow Relationships

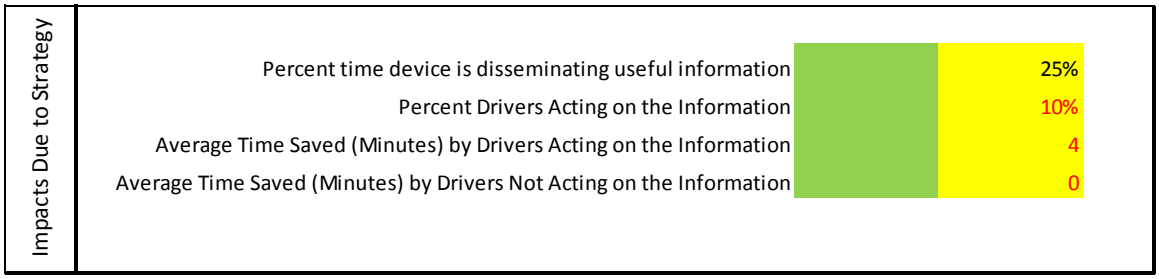
	V/C Ratio	Factor
Freeways	0.2	0.9878
	0.3	0.9781
	0.5	0.9471
	0.7	0.890
	0.8	0.8442
	0.9	0.7825
	1	0.6984
	1.1	0.5838
	1.2	0.4276
	1.4	0.300
	1.6	0.123
	1.8	0.090
	2	0.084
	2.5	0.072
	3	0.043
	4	0.01
	5	0.008
	6	0.004
	12	0.001

Source: FHWA.

You may choose to customize TOPS-BC by replacing the values presented in the Parameters worksheet with locally preferred values or data better configured to their own region. For example, you might want to replace the assumed "Percentage of Trucks" figure in the traffic mix based on national averages, with one obtained from local studies or analysis models. This customization of default parameters assumes that the new data matches the format and units of the data it is replacing. Modifying these default data on the Parameters worksheet will permanently alter this data for all strategies that use the parameters for the current and any future analysis that is conducted using that file or copies of that file. TOPS-BC does not currently have the capability to actively track changes made to the data contained on the Parameters worksheet. Therefore, use care in modifying these data. An unused version of the TOPS-BC tool may be used as a reference for the default data in the Parameters worksheet. Chapter 7 contains further instructions for restoring the original defaults for selected sheets, including the Parameters page.

Beyond the default data presented in the Parameters worksheet that are applied to multiple strategies, individual strategies often have default data associated with the benefit analysis for the strategy. These defaults are viewable on the individual worksheets analyzing the particular strategy in the section titled "Impacts Due to Strategy." Figure 6-4 provides a sample view of the defaults associated with a traveler information dynamic message sign analysis.

Figure 6-4. Sample View of Strategy Specific Default Impact Data



Source: FHWA.

Consistent with all individual strategy worksheets, the default data is always displayed in a yellow colored cell. These values may be based on national averages, recent research, impact values used in other existing tools, or the judgment of the tool developers where little data exists. The text in these cells is normally colored black; however, in situations where little consensus exists regarding the level of impact of a particular strategy may have on a metric, or situations where there are few existing data points with which to establish a default measure, the text is shaded red to indicate that discretion should be used in applying the default, particularly if you have local data that contradicts the default.

The default data in the yellow cells will automatically be used in any calculations unless you choose to override any of the default values where you may have more suitable parameters. If you choose to replace the data with your own figure, this value should be entered in the green cell located to the left of the default value, as has been done for the "Percent drivers using information" entry shown in Figure 6-4. Although the default value still appears in the yellow cell, all subsequent calculations will use the User Defined value.[5] If nothing is entered into the green cells, the default value will automatically be used.

In certain situations, a default impact may be set to zero. These situations represent impacts that many practitioners often wish to include in the analysis of the particular strategy, but where little consensus exists as to the actual impact. In these situations, the capability to analyze the impact has been provided within the framework, but by default, no benefit will be accrued unless you actively enter your own User Defined impact parameter.

For questions on the appropriate format of data to enter, a list of "Frequently Asked Questions (FAQ)" is provided at the bottom of the BENEFIT ESTIMATE instruction page, as shown in Figure 6-5. These FAQs are also presented in Appendix A.

[5] Although the default value is superseded in the analysis by any User Defined value input in a green cell, the default data remains displayed in the yellow cell to indicate what data has been replaced to provide a reality check on the user entered data.

Figure 6-5. Frequently Asked Questions (FAQ) on the BENEFIT ESTIMATE Sheet

Frequently Asked Questions

What is the appropriate capacity and volume to enter?

The values entered for capacity and volumes in the individual strategy analysis worksheets should repesent the average capacity or volume for the entire facility (all lanes) for the period being analyzed. For example, if the analysis is being conducted for a 3-hour peak period, the capacity should represent the 3-hour peak period for all roadway lanes. Ideally, the period of analysis will match the operating charactoristics of the strategy (i.e., a ramp metering strategy intended to be operated during the 3-hour afternoon peak commute period should use data representing the 3-hour PM peak period in the analysis.

What does the "Number of Periods per Year" entry represent?

The number of periods per year entry is used to annualize the impact estimated for a single day or period to a annual figure. The number entered should be dependent on the analysis period used and the expected operating charactoristics of the strategy being analyzed. A default value of 250 represents that the strategy is anticipated to be utiized on all non-holiday weekdays. This entry can be decreased to represent strategies that are anticipated to be used on fewer days per year (e.g., special events only), or increased to represent multiple periods per day (e.g., a doubling of the default value could be used in conjunction with input data from a single peak period to estimate the impacts of mutiple peaks per commute day). Operating charactoristics of the strategy (i.e., a ramp metering strategy intended to be operated during the 3-hour afternoon peak commute period should use data representing the 3-hour PM peak period in the analysis.

Where do the estimated cost figures come from?

Lifecycle cost estimates for the individual strategies are pulled from the Lifecycle Cost Estimation worksheet for the individual strategy. To estimate costs for an individual strategy, visit the cost estimation worksheet for the individual strategy and enter the deployment information as directed in the instructions.

Source: FHWA.

Structuring the Analysis

Before beginning the analysis, you should carefully structure the analysis. As discussed in more detail in Chapter 5 of the *Desk Reference*, you will need to consider many factors, such as:

- **What are the strategies to be analyzed?** You should consider the strategies and any combinations of strategies that will be analyzed. This has multiple implications on the analysis. For example, if strategies are to be analyzed as separate projects and the relative benefits compared, you will need to set up multiple spreadsheet files to conduct analysis of the different projects.
- **What are the time periods to consider?** You should consider the relevant time periods in which the operational strategy will be active. For example, if a traffic incident management deployment will only be operated in the peak periods, the input data should represent conditions for the period(s) in which the improvement is operating.
- **What data is available to support the analysis?** The availability of data will influence what actual data needs to be compiled to conduct the analysis. For example, if you only have basic baseline data (e.g., average volumes, capacities, posted speeds) available, you may be looking to TOPS-BC to estimate impacts to speeds, travel times, or other measures. If on the other hand, you have rich simulation data or archived data available, you may not need to compile and enter the basic data, but instead may want simply use your own speed and travel time outputs to replace the estimates provided within TOPS-BC.
- **What impact will the strategy have on non-recurring conditions?** If you want to analyze strategies focused on specific non-recurring conditions (e.g., incidents, weather, work zones, special events), you may want to set up the analysis using a multi-scenario approach. Chapter 5 of the *Desk Reference* provides a more detailed discussion of this method. With the multi-scenario approach, you will need to set up multiple spreadsheet files to conduct analysis of the different scenarios.

All users, particularly those conducting analysis of multiple projects or scenarios approaches that will require establishing more than one spreadsheet file, are encouraged to first set up a "base" file. In this approach, you would open a new copy of TOPS-BC. Prior to entering any strategy data, review and modify any of the default data, including data on the Parameters worksheet, the individual strategy worksheets of interest, and any default cost data if TOPS-BC also will be used to generate life-cycle cost outputs. Once the modifications are complete, save a copy of the base file (and archive a secure copy) before beginning the analysis. It is recommended that you create a new filename for this base file for easy reference and file organization purposes. All project analysis should then be conducted using a copy of this base file to ensure that the same modifications are carried forward to all projects or scenarios being analyzed. Copies of this base file can be distributed to multiple users to ensure all users within a particular agency are using the identical analysis data, for instance.

Sample Strategy Analysis

The benefit estimation analysis within TOPS-BC is performed similarly for most strategies, although the actual inputs, outputs and approach may vary slightly. The following sample provides a description of an analysis of a ramp metering deployment for illustration of how the general process is applied. Two separate scenarios are described:

- Scenario 1 – You have only limited input data and are looking to the TOPS-BC tool to forecast the changes in speed and travel time in the analysis; and
- Scenario 2 – You are conducting an evaluation using archived data based on real-world observations that will be used to estimate the benefits.

Scenario 1 – Limited Data Approach

In this sample analysis, you only have limited performance information available to conduct the analysis, including the average volumes, roadway capacity and free-flow (posted) speeds. The centrally controlled ramp metering strategy will be operated during the 3-hour afternoon peak period in a 4-mile study corridor. The proposed project will deploy ramp meters at five on-ramp locations in a single direction of travel.

For this analysis scenario, you would navigate to the Ramp Metering strategy worksheet in one of two ways:

- Click on the "Ramp Metering" link under ESTIMATE BENEFITS in the main Navigation Menu along the left side of any worksheet; or
- Click on the purple "Ramp Metering" worksheet tab.

Within the individual strategy worksheet for Ramp Metering or any other strategy selected, you are encouraged to review the general methodology and data that will be required. You should review the minimum data inputs required to complete the analysis. These minimum data requirements are identifiable as they are the only available green shaded entries for a particular row. In Figure 6-6, entries for the Length of Analysis Period, Freeway Link Length, Freeway Total Number of Lanes, Ramp Link Length, Ramp Number of Lanes, Freeway Link Volume, and Ramp Link Volume must all be filled in, as there are no default (yellow shaded) or calculated (blue shaded) cells in the row for the particular data input.

Figure 6-6. Reviewing the Minimum Required Data Input

Facility Characteristics

Freeway Link Facility Type	Urban Freewa						
Link Length (Miles)	1		Baseline Override		Improvement Override		
Total Number of Lanes	2			Baseline		Improvement	Change
Freeway Link Capacity (All Lanes - for the time period of analysis)		13200		13200		14256	1056
Free Flow Speed (MPH)		55					
Ramp Link Facility Type	Ramp						
Number of Metered Ramps							
Average Link Length (Miles)	0.25		Baseline Override		Improvement Override		
Average Ramp Number of Lanes	1			Baseline		Improvement	Change
Average Ramp Link Capacity (All Lanes - for the time priod of analysis)		4800		4800		3120	-1680
Average Ramp Free Flow Speed (MPH)		35					

Facility Performance

Freeway Link Volume (during time period of analysis)			Baseline Override		Improvement Override		
				Baseline		Improvement	Change
Congested Speed				55.000		55.000	0.000
Vehicles Miles Traveled (VMT)				0.0000		0.0000	0.0000
V/C				0.0000		0.0000	0.0000
Vehicle Hours of Travel				0.0000		0.0000	0.0000
Incident Related Delay (hours) per vehicle per mile				0		0	0
Number of Fatality Crashes				0.00000E+00		0.00000E+00	0.00000E+00
Number of Injury Crashes				0.00000E+00		0.00000E+00	0.00000E+00
Number of Property Damage Only Crashes				0.00000E+00		0.00000E+00	0.00000E+00
Fuel consumption (Gallons)				0.0000		0.0000	0.0000
Average Ramp Link Volume (during time period of analysis)			Baseline Override		Improvement Override		
				Baseline		Improvement	Change
Congested Speed				35.000		35.000	0.000
Vehicles Miles Traveled (VMT)				0.0000		0.0000	0.0000
V/C				0.0000		0.0000	0.0000
Vehicle Hours of Travel				0.0000		0.0000	0.0000

Source: FHWA.

You should ensure that the appropriate data is available to meet the minimum analysis input needs. Several key input requirements common to many strategies include:

- **Length of Analysis Period** – The length of the analysis period is entered as the length in number of hours. In order to provide a relevant analysis, the length of the analysis period will match as closely as possible to the expected period in which the strategy is intended to be operating. In the ramp metering example, the length of the analysis period should be set to three hours to represent the 3-hour afternoon peak period in which the ramp meters are expected to be operational. Once the length of the analysis period is determined, other data inputs should be matched to this analysis period. For example, data inputs such as capacities, volumes should represent totals and speeds should represent averages across the entire 3-hour peak period. The length of the analysis data should ultimately be matched with the input data. Do not enter three hours as the length of the analysis period and then enter peak hour or daily data for other required inputs. **TOPS-BC performs no internal conversion of the entered data, therefore, it is the responsibility of the user to correctly match the data**.
- **Capacity** – Many roadway strategies require the input of facility capacity. Although a default capacity is provided for many strategies, based on the Length of the Analysis

Period, Link Facility Type, and Number of Lanes you enter, this estimated value should be reviewed closely and modified as needed to match actual conditions.[6] In the case of the ramp metering example, TOPS-BC requires the input of different capacities for the freeway capacity and the average ramp capacity. The entered value for "Freeway Capacity" should represent the total facility (all lanes) across the entire analysis period (3-hour peak period in the ramp metering example). If a single direction of travel is being analyzed, the capacity should represent all lanes in that single direction of travel. If both directions are being analyzed, the capacity should represent all lanes in both directions. Per lane / per hour capacities are not appropriate for use in most analyses. For the "Average Ramp Capacity, you should average the capacity for all on-ramps (all lanes for the entire period of analysis). If there is a wide discrepancy in capacities on individual ramps, you may want to divide the corridor into segments to better capture the unique nature of the sub-corridors.

- **Volume** – Like capacity, the entered value for volume should represent all lanes of travel over the entire analysis period. This value should also represent total vehicle volumes across all travel modes.
- **Free Flow Speed** – The value entered for this input should represent the average speed of travel in the absence of congestion. In the absence of field data, you may consider using a convention such as the posted speed limit or 5 miles per hour (mph) above the speed limit.

The signal coordination and ramp metering strategies in TOPS-BC will require input defining the level of sophistication of the strategy to be deployed. In the ramp metering example shown in Figure 6-6, a pull down menu is shown that will enable you to pick from three options: Preset, Traffic Actuated, or Central Control. Selecting one of these levels of sophistication performs two functions:

1. Default impacts used later in the analysis are set to a level representative of the level of sophistication; and
2. The selection entered defines the corresponding life-cycle cost sheet to be used for the B/C comparison. TOPS-BC will only pull in life-cycle costs from the strategy sheet for the particular strategy and level of sophistication.

Once the required data has been gathered and entered, scroll down the sheet to view model defaults (shown in yellow cells) related to various impacts predicted by the tool, as shown in Figure 6-7. These default impacts were generally developed using ranges of impacts observed in deployments of these strategies gathered from national and international evaluation efforts of real-world implementations, combined with parameters identified for use in other existing analysis tools. Note: these default impacts may be sensitive to the level of sophistication of the strategy (if applicable). Review these predicted default impacts and modify them if you have more appropriate data by entering a value in the green cell immediately to the left of the value you want to replace.

[6] Default capacities mapped to various facility types are maintained in the hidden worksheet "Link Characteristics". You may change the default capacities (entered as hourly lane capacities). By changing these default capacities, you will modify the baseline capacity calculation for any analysis using that facility type.

Figure 6-7. Reviewing the Predicted Strategy Impacts

Impacts Due to Strategy

Facility improvement models

Change in **Freeway Link** Capacity (%)	8%
Change in **Ramp Link** Capacity(%)	-35%
Reduction in **Freeway** Crash ***Rate*** *(%)*	12%
Reduction in **Freeway** Crash ***Duration*** *(%)*	0%
Reduction in Fuel Use (%)	10%

Source: FHWA.

After entering the minimum required input data and reviewing (and modifying if desired) the default impacts, begin reviewing the predicted facility performance. Figure 6-8 shows this data for the example ramp metering project.

Figure 6-8. Reviewing the Predicted Facility Performance Impacts

Facility Performance

Freeway Link Volume (during the time period of analysis) 19000

	Baseline Override	Baseline	Improvement Override	Improvement	Change
Congested Speed		48.735		50.826	2.091
Vehicles Miles Traveled (VMT)		76000.0000		76000.0000	0.0000
V/C		0.9596		0.8568	0.1028
Vehicle Hours of Travel		1559.4649		1495.3123	-64.1526
Incident Related Delay (hours) per vehicle per mile		0.013824568		0.010705745	-0.003118823
Number of **Fatality** Crashes		5.01600E-06		4.41408E-06	-6.01920E-07
Number of **Injury** Crashes		5.27655E-04		4.03510E-04	-1.24145E-04
Number of **Property Damage Only** Crashes		6.73197E-04		5.16133E-04	-1.57064E-04
Fuel consumption (Gallons)		3577.4775		3219.7297	357.7477

Ramp Link Volume (during the time period of analysis) 3000

	Baseline Override	Baseline	Improvement Override	Improvement	Change
Congested Speed		34.117		30.985	-3.131
Vehicles Miles Traveled (VMT)		750.0000		750.0000	0.0000
V/C		0.6250		0.9615	-0.3365
Vehicle Hours of Travel		21.9834		24.2051	2.2217

Source: FHWA.

Often included in this portion of the analysis are summary traffic performance measures (e.g., congested speeds) shown both without improvement (under the “Baseline” column) and with improvement after deployment (under the “Improvement” column) predicted by the tool. These calculated values are displayed in blue colored cells in separate columns of the sheet. In the ramp metering example, calculated values are displayed for Freeway Congested Speeds and Ramp Congested Speeds both with and without the improvement. These congested speeds are calculated based on the volume / capacity ratio derived from the data you enter, which is used to look up the appropriate speed reduction factor from the Speed/Flow Relationships table on the “Parameters” sheet. Figure 6-9 presents a partial view of this speed-flow data. The speed reduction factor is applied to the free flow speed you enter to estimate the congested flow speeds. The estimated congested speeds do not by themselves represent a monetized benefit of the improvement. Instead, these changes in network performance are used in subsequent analysis to quantify other measures of effectiveness.

Figure 6-9. TOPS-BC Default Speed/Flow Relationship Table (Based on Highway Capacity Manual 2010 Formulas)[7]

Speed/Flow Relationships

	V/C Ratio	Factor
Freeways	0.2	0.9878
	0.3	0.9781
	0.5	0.9471
	0.7	0.890
	0.8	0.8442
	0.9	0.7825
	1	0.6984
	1.1	0.5838
	1.2	0.4276
	1.4	0.300
	1.6	0.123
	1.8	0.090
	2	0.084
	2.5	0.072
	3	0.043
	4	0.01
	5	0.008
	6	0.004
	12	0.001

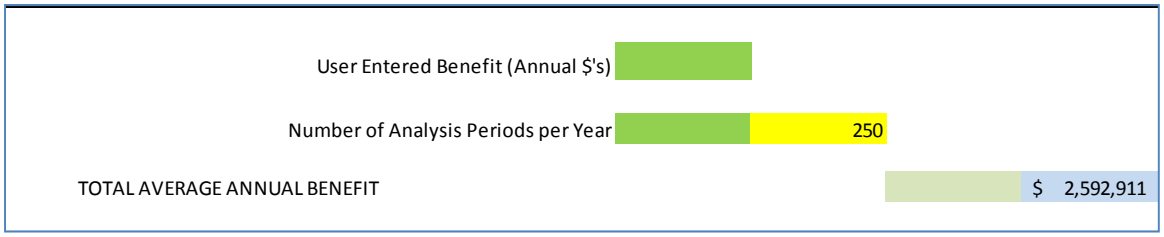
Source: FHWA.

[7] Note: The default speed-flow relationship is based on relationships from the 2010 Highway Capacity Manual (HCM), Chapter 25. Volume/Capacity (V/C) ratios are allowed to exceed one, as baseline capacities typically represent LOS E assumed capacity levels. Formulas from the HCM, particularly Equation 25-1, were used to calculate the speed reduction factor related to each possible V/C ratio presented in the table. The speed reduction factor is then applied to the free flow speeds you provided in the model to estimate congested speeds. These base speed reduction factors were calculated using an assumed typical segment analyzed using Equation 25-1 (e.g., the freeway example assumes an urban freeway with an unadjusted free flow speed of 65 mph). The Capacity Adjustment Factor was not applied as no incidents or inclement weather conditions were assumed. Relative capacities and volumes were then manipulated in the assessment to represent the various levels of V/C ratios used on the Parameters page. The resulting proportional change in speed from the original free flow speed was used to populate the table for each V/C ratio. You may wish, however, to instead use parameters customized to your own region. You may choose to adjust the input assumptions used with the HCM methods to estimate new factors (to represent speed/flow conditions during inclement weather conditions, for example), replace the factors with values representing values/relationships from the Bureau of Public Roads (BPR) methodology, or replace the values with customized relationships from an existing regional model. To implement the replacement curves, calculate the Speed Factor for the V/C ratios presented on the Parameters table using the desired equation and parameters. Use the resulting values to replace the default Speed Factors in the "Parameters" table.

The values in the Facility Performance section (Figure 6-8) such as change in volumes and speeds are used to estimate other benefits included in the sections that follow on the worksheet, including travel time, travel time reliability, energy and safety. Once all the benefits estimated by the methodology are calculated on a per period basis, (in the ramp metering example, each period represents a single 3-hour peak period), TOPS-BC multiplies the per period benefit with the factor for "Number of Periods Per Year" as presented at the bottom of the analysis sheet. The default value is pulled forward from the "Parameters" sheet. This factor represents the number of times per year the system is anticipated to be operational. In the case of the ramp metering example, it is assumed that the strategy will be operational on all non-holiday weekdays (or 250 days per year). Other strategies targeted at non-recurring conditions such as special events or inclement weather events might be expected to be activated only several times per year and this should be reflected in the Number of Analysis Periods per Year value entered.

As noted in a previous discussion, there are often possible benefits of strategies that are not explicitly captured within the base TOPS-BC analysis. If you have estimates of other benefits not captured in the analysis, you may enter the value of these benefits as a line item in the "User Entered Benefit" row, as shown near the top of Figure 6-10. Note: this entry must be an annualized estimate of the benefit value.

Figure 6-10. Display of User Entered Benefit, Number of Periods per Year, and Total Average Annual Benefit Values



Source: FHWA.

TOPS-BC then displays the TOTAL AVERAGE ANNUAL BENEFIT (the sum of calculated benefits plus any user entered benefits) as also shown in Figure 6-10.

Scenario 2 – Robust Data Approach

This sample analysis is identical to Scenario 1, except that you have more detailed performance information (particularly updated speed data) available to conduct the analysis from a recently completed microsimulation model analysis of the corridor. The centrally controlled ramp metering strategy will be operated during the same 3-hour afternoon peak period in a 4-mile study corridor and all other parameters of the analysis will be entered identically as in Scenario 1.

Since you have estimates of corridor speeds both with and without the improvement from the microsimulation analysis, you do not need to rely on the TOPS-BC estimation of these performance metrics. Instead, override the calculated value by entering your own data in the facility characteristics section of the worksheet.

Proceed with the analysis identically to what was done in Scenario 1. Enter all the required user input specified near the top of the Ramp Metering strategy worksheet. TOPS-BC will automatically use this data to calculate all subsequent performance measures and benefit estimations as you enter the data. Unlike Scenario 1, however, you will use different estimates for speeds obtained from the microsimulation model. In this situation, you would locate the row entry for Congested Speeds and enter the simulation output speed in the green cell in the Override column, directly to the left of the calculated value you want to replace. Figure 6-11 shows where a user has replaced the congested speed value for the Baseline with a new speed of 46 mph, and replaced the default calculated value for the improvement with a value of 54 mph obtained from the simulation model. Make sure to use the same units as the default value. Even though you have not directly overwritten or deleted the calculated speed estimate displayed in the blue cell for that data item, your input value will replace the calculated value in all subsequent analysis performed for the strategy. The value in the blue calculated cell remains displayed to provide the opportunity for comparison between the calculated value and the user input.

Figure 6-11. Example Replacement of Default Calculated Congested Speeds with Data From a Simulation Model

Facility Performance

Freeway Link Volume (during the time period of analysis): 19000

	Baseline Override	Baseline	Improvement Override	Improvement	Change
Congested Speed	46.00	48.735	54.000	50.826	8.000
Vehicles Miles Traveled (VMT)		76000.0000		76000.0000	0.0000
V/C		0.9596		0.8568	0.1028
Vehicle Hours of Travel		1652.1739		1407.4074	-244.7665
Incident Related Delay (hours) per vehicle per mile		0.013824568		0.010705745	-0.003118823
Number of **Fatality** Crashes		5.01600E-06		4.41408E-06	-6.01920E-07
Number of **Injury** Crashes		5.27655E-04		4.03510E-04	-1.24145E-04
Number of **Property Damage Only** Crashes		6.73197E-04		5.16133E-04	-1.57064E-04
Fuel consumption (Gallons)		3577.4775		3219.7297	357.7477

Ramp Link Volume (during the time period of analysis): 3000

	Baseline Override	Baseline	Improvement Override	Improvement	Change
Congested Speed		34.117		30.985	-3.131
Vehicles Miles Traveled (VMT)		750.0000		750.0000	0.0000
V/C		0.6250		0.9615	-0.3365
Vehicle Hours of Travel		21.9834		24.2051	2.2217

Source: FHWA.

TOPS-BC will automatically calculate the benefits estimations based on the speed data that you input. In the ramp metering example scenarios, this replacement of the TOPS-BC calculated speeds with the user defined speeds from the simulation model resulted in an increase in the recurring travel time benefit and an overall increase in the average B/C ratio. This methodology may be used whenever you have data that more closely matches the actual or likely operating conditions.

The User Input data or Override columns can also be used to provide a quick sensitivity check to any of the parameters used in the analysis. Simply enter a value in the user input column for any given line item (that is greater or less than the default or the calculated value) and immediately observe the results of this parameter change. To go back to using the original default or calculated value, delete the value entered in the user input column.

Summary of Analysis Inputs and Outputs

Although sample analyses are presented in previous sections, each analysis will differ depending on the strategy, or combination of strategies, deployed and on the type and source of data available for input. Below is a summary of the minimum data inputs required for each strategy included in the Benefits Estimation module.[8] Data beyond this minimum data may often times be used to override default or calculated values in the analysis, as highlighted in the Scenario 2 discussion above; however, the Summary of Analysis Inputs and Outputs presents the minimal data needed to fulfill the analysis requirements.

Also identified are the benefits that are monetized in the analysis and included in the B/C comparison, and the methodologies for estimating these benefits. As noted earlier in this Chapter, the benefits estimated by TOPS-BC may not represent a full accounting of all possible benefits associated with a particular strategy due to various technical and practical limitations; however, you are always able to add in these "Other Benefits that May Be Considered" if there is data or methods to support their inclusion. Likewise, only methodologies are presented for benefits that are actually monetized in the TOPS-BC analysis. Many additional measures of effectiveness (e.g., change in speed, change in VMT, changes in the number of trips) are often generated within the individual analyses, but are used as inputs to the calculation of other (monetized) benefits.

Summary of TOPS-BC Minimal Data Inputs and Benefits Measures

Arterial Traffic Signal Coordination

Data Inputs:
Length of Analysis Period
Average Volume
Number of Lanes
Roadway Capacity
Free Flow Speed
Arterial Link Length
Level of Timing Sophistication

- Preset Timing
- Traffic Actuated
- Central Control

Default Benefit Calculation:
Travel Time
Crashes
Fuel Use

Methodology:
Travel Time, **Crashes** and **Fuel Use** are the primary benefits calculated by TOPS-BC for this traffic signal coordination strategy.

[8] Note: Inputs for the "Year of Deployment" and the "Number of Periods Per Year" are common to all strategies and are not listed among the minimal data inputs in Table 6-1.

Travel Time – is calculated in TOPS-BC based on estimated link speeds in the corridor. By default, speeds are estimated using the speed-flow relationship shown on the Parameters page. This speed-flow relationship is based on the Highway Capacity Manual and provides a speed factor (to be applied to free flow speed) for varying degrees of congestion (as measured by volume/capacity ratio). Speed is estimated for the baseline (without improvement) scenario by determining the correct speed-flow factor to apply based on your inputs for capacity and volume and applying the factor to the free flow speed you provided. For the with improvement scenario, average capacities are adjusted based on default impact percentages (or user supplied impact values if available). The default impact values are sensitive to the Level of Timing Sophistication. The adjusted capacity value is used to determine an adjusted volume/capacity ratio used to look up the speed-flow factor from the Parameters sheet. The estimated speeds for the baseline and with improvement scenarios are used to estimate link travel time based on your inputs for link length and average volumes. The difference between the two scenarios in hours of travel time is monetized as the travel time benefit.

Crashes – an analysis is available to estimate the additional benefit of a reduction in crashes resulting from the deployment of Traffic Signal Coordination strategies. A relatively small rate factor is supplied due to the highly variable ranges in the available research of this impact. If you have additional information to support this impact, a factor can be entered in the User Input cell for this impact to override the default. This entry will reduce the crash rates applied to all crash severities (applied to corridor VMT). Dollar values will be applied to the change in the number of crashes to estimate this benefit.

Fuel Use – is estimated by applying a standard fuel economy rate to the VMT on the facility. The impact of the strategy is the reduction in the fuel use rate to represent fuel savings due to the smoothing of traffic and reduction in the number of stops.

Other Benefits – Other benefits that are often associated with Traffic Signal Coordination strategies, but are not currently included in the benefits calculated by TOPS-BC include Customer Satisfaction, Agency Efficiency, and Emissions. The first two of these benefits are difficult to valuate in B/C analysis. The Emissions benefits are inherently difficult to estimate within a spreadsheet based model (e.g., spreadsheet based models are generally incapable of estimating the vehicle acceleration/deceleration profiles to accurately assess these impacts). You are free to modify the analysis framework to include these benefits, or simply to add the estimated value of these benefits to the “User Entered Benefit” if you have data to support their inclusion.

Ramp Metering Strategies

Data Inputs:
Length of Analysis Period
Freeway Volume
Freeway Number of Lanes
Freeway Capacity
Freeway Free Flow Speed
Freeway Link Length
Number of Metered Ramps
Average Ramp Volume
Average Ramp Capacity
Ramp Free Flow Speed
Average Ramp Link Length
Level of Metering Sophistication

- Preset Timing

- Traffic Actuated
- Central Control

Default Benefit Calculation:
Travel Time
Travel Time Reliability
Crashes

Methodology:
Three primary benefits are calculated by TOPS-BC for this strategy: **Travel Time**, **Travel Time Reliability**, and **Crashes**.

Travel Time – is calculated in TOPS-BC based on estimated link speeds in the corridor – both for the freeway and ramp links. By default, speeds are estimated using the speed-flow relationship shown on the Parameters page. This speed-flow relationship is based on the Highway Capacity Manual and provides a speed factor (to be applied to free flow speed) for varying degrees of congestion (as measured by volume/capacity ratio). Speed is estimated for the baseline (without improvement) scenario by determining the correct speed-flow factor to apply based on your inputs for capacity and volume and applying the factor to the free flow speed you provided. These analyses are performed separately for the freeway and ramp links. For the with improvement scenario, average capacities are adjusted based on default impact percentages (or user supplied impact values if available). These default impact values are sensitive to the Level of Timing Sophistication. The adjusted capacity value is used to determine an adjusted volume/capacity ratio used to look up the speed-flow factor from the Parameters sheet. The estimated speeds for the baseline and with improvement scenarios are used to estimate link travel time based on your inputs for link length and average volumes. The difference between the two scenarios in hours of travel time is monetized as the travel time benefit.

Travel Time Reliability – is calculated in TOPS-BC based on the non-recurring delay estimation methodology developed for the Strategic Highway Research Program (SHRP 2 projects L03 and L05).[9] The approach uses factors (applied to VMT) representing the expected amount of incident related delay based on the number of lanes on the facility, the length of the analysis period, the facility volume and the facility capacity. This analysis is only performed on the freeway links. The impact of the ramp metering strategy on incident related delay is two-fold – it is impacted by the change in facility capacity (discussed under the Travel Time impact above) and by a reduction in the number of crashes (discussed in the Crashes section below). The change in capacity results in a different volume/capacity ratio (between the without improvement and with improvement scenarios) being used to look up the incident related delay factors on the Parameters page. The look-up incident related delay factor is multiplied with the VMT estimated for the facility. Further, the resulting estimated number of hours of incident related delay for the with improvement scenario are further reduced by the percentage decrease in the default crash rate. Additionally, according to the SHRP 2 research, the resulting recurring delay and incident delay values are applied in an additional algorithm, along with the volume/capacity ratio to factor total non-recurring delay for the facility. The incremental change in hours of non-recurring travel time delay between the baseline and with improvement scenario is assigned a dollar value from the Parameters page to calculate the benefit.

[9] Strategic Highway Research Project (SHRP 2) Project L05: Guide to Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes – Technical Reference, Section 5.0, Prepublication Draft, March 2013.

Crashes – represent the benefit in the reduction in crashes resulting from the smoothing of traffic conflicts in the merge area. A default crash rate factor is supplied; however, if you have local data to support this impact, enter a factor in the "Reduction in Freeway Crash Rate (%)" cell. This impact factor will reduce the crash rates applied to all crash severities. Dollar values will be applied to the change in the number of crashes to estimate this benefit. The reduction in the number of crashes is also fed back into the calculation of incident related delay, producing a greater benefit level for Travel Time Reliability.

Other Benefits – Other benefits often associated with Ramp Metering strategies, but are not currently included in the benefits calculated by TOPS-BC are Emissions and Fuel Use. These two benefits are inherently difficult to estimate within a spreadsheet based model (e.g., spreadsheet based models are generally incapable of estimating the vehicle acceleration/deceleration profiles to accurately assess these impacts). You are free to modify the analysis framework to include these benefits, or simply to add the estimated value of these benefits to the "User Entered Benefit" cell if there is data to support their inclusion.

Traffic Incident Management

Data Inputs:
Length of Analysis Period
Average Volume
Number of Lanes
Roadway Capacity
Free Flow Speed
Link Length

Default Benefit Calculation:
Travel Time Reliability
Fatality Crashes
Secondary Crashes (Optional)
Fuel Use (Optional)

Methodology:
Two primary benefits are calculated by TOPS-BC for this strategy: **Travel Time Reliability** and **Fatality Crashes**. There are also options for you to estimate a reduction in all Crashes due to a reduction in secondary crashes and estimate a change in **Fuel Use**.

Travel Time Reliability – is calculated in TOPS-BC based on the incident related delay estimation methodology originally developed as part of the SHRP 2 research. The approach uses factors (applied to VMT) representing the expected amount of incident related delay based on the number of lanes on the facility, the length of the analysis period, the facility volume and the facility capacity. The impact of the TIM strategy is applied as a percentage reduction in the incident response time – the default impacts are sensitive to the level of TIM sophistication. The response time factor is applied to the baseline incident related delay estimate to calculate the delay value with the strategy. The change in hours of incident related delay is used to represent non-recurring travel time delay and is assigned a dollar value to calculate the benefit.

Fatality Crashes – A reduction in Fatality Crashes is calculated to represent the reduced severity of some crashes due to the improved response time of critical care providers. The number of crashes is estimated by applying the crash rates (by severity) to facility VMT. A default fatality crash rate

reduction factor is applied to the crash rate before calculation of the improvement condition. The change in the number of fatality crashes between the baseline and the improvement scenario is added to the number of injury crashes estimated to represent the reduction in the severity of the crash (i.e., a potential fatality crash has now become an injury crash). The change in the number of fatality and injury crashes is assigned a dollar value to estimate the benefit. Note: the change in injury crashes will often be displayed as a disbenefit; however, the net benefit (fatality plus injury) will be positive.

Secondary Crashes (Optional) – an optional analysis is available to estimate the additional benefit of a reduction in secondary crashes resulting from the deployment of TIM strategies. No default crash rate factor is supplied due to insufficient consensus in the available research of this impact. If you have information to support this impact, you may enter a factor in the "Reduction in Non-Fatality Crash Rate" cell. This entry will reduce the crash rates applied to all non-fatality crash severities. Dollar values will be applied to the change in the number of crashes to estimate this benefit. When available, you can enter a factor "Reduction in Crash Duration" cell. The reduction in the number and duration of crashes is also fed back into the calculation of incident related delay, producing a greater benefit level for Travel Time Reliability.

Fuel Use (Optional) – a placeholder analysis capability is provided to allow you to enter a reduction factor on the fuel use calculated on the facility; however, due to a lack of consensus on research associated with this impact, the default is set to zero. You may override this default if you have better supporting data.

Other Benefits – Other benefits that are often associated with TIM strategies, but are not currently included in the benefits calculated by TOPS-BC are Customer Satisfaction, Agency Efficiency, and Emissions. The first two of these benefits are difficult to valuate in B/C analysis. The Emissions benefits are inherently difficult to estimate within a spreadsheet based model (e.g., spreadsheet based models are generally incapable of estimating the vehicle acceleration/deceleration profiles to accurately assess these impacts). You are free to modify the analysis framework to include these benefits, or simply to add the estimated value of these benefits to the "User Entered Benefit" cell if there is data to support their inclusion.

Pre-Trip Traveler Information

Data Inputs:
Length of Analysis Period
Average Number of Travelers Accessing the Information (per period)
% of Travelers that Access the Information that Act on the Information
Average Time (Minutes) Saved by Travelers Acting on the Information

Default Benefit Calculation:
Travel Time Reliability

Methodology:
Travel Time Reliability is the primary benefit calculated by TOPS-BC for this strategy:

Travel Time Reliability – is calculated in TOPS-BC based on the average amount of time saved by travelers that access and act on the information provided by the Pre-Trip Traveler Information system. The Number of People Accessing the Information (per period) is multiplied with the Percent of the People Acting on the Information to estimate the number of travelers benefiting from the information

provision. The resulting figure is multiplied with the Average Time (Minutes) Saved by Drivers Using the Information. The sum of this travel time calculation is assigned a dollar value from the Parameters worksheet to calculate the monetized benefit.

Other Benefits – Other benefits that may often be associated with pre-trip traveler information strategies, but are not currently included in the benefits calculated by TOPS-BC are Crash, Fuel Use and Emission reductions caused by individuals changing modes or foregoing trips, thus reducing VMT, Customer Satisfaction and Agency Efficiency are also benefits that are difficult to capture for this strategy and are not included in TOPS-BC.

En-Route Traveler Information – Dynamic Message Sign (DMS) and Highway Advisory Radio (HAR)

Data Inputs:
Length of Analysis Period
Average Number of Vehicles Passing DMS/HAR Location(s) (per period)
% of Time DMS/HAR is Communicating Information
Average Time (Minutes) Saved by Drivers Acting on the Information
Average Time (Minutes) Saved by Drivers Not Acting on the Information
Type of Information Being Communicated

- Comparative Travel Times
- Congestion Warning
- Alternative Route/Mode Recommendations

Default Benefit Calculation:
Travel Time Reliability

Methodology:
The benefits for both En-Route Traveler Information strategies – DMS and HAR – are estimated using a similar methodology. The factors and default values in the analysis may vary depending on the strategy and the type of information communicated. **Travel Time Reliability** is the primary benefit calculated by TOPS-BC for this strategy.

Travel Time Reliability – is calculated for this strategy based on the average amount of time saved by travelers that access and act on the information provided by the various types of En-Route Traveler Information systems. An optional analysis is available to assess secondary impacts to travelers not acting on the communicated information. The average number of travelers passing by the DMS or HAR location (per period) you supply is multiplied with % of the time that the DMS or HAR is communicating information. The Percent time device is disseminating useful information (per period) is multiplied with the Percent of Drivers Acting on the Information to estimate the number of travelers benefiting from the information provision. The resulting figure is multiplied with the Average Time (Minutes) Saved by Drivers Acting on the Information. The sum of this travel time calculation is assigned a dollar value from the Parameters worksheet to calculate the monetized benefit.

Other Benefits – Other benefits that are often associated with En-Route Traveler Information strategies, but are not currently included in the benefits calculated by TOPS-BC are Customer Satisfaction, Agency Efficiency, Emissions and Fuel Use. The first two of these benefits are difficult to valuate in B/C analysis. The second two benefits are inherently difficult to estimate within a spreadsheet based model. You are free to modify the analysis framework to include

these benefits, or you may simply add the estimated value of these benefits to the "User Entered Benefit" if data is available.

ATDM – HOT Lanes

Data Inputs:
Length of Analysis Period
Freeway General Purpose Volume
Freeway General Purpose Number of Lanes
Freeway General Purpose Capacity
Freeway Free Flow Speed
Freeway Link Length
Freeway HOV Volume
Freeway HOV Number of Lanes
Freeway HOV Capacity
Freeway HOV Speed
Change in HOT Lane Volume
Percent Change in HOT Lane Volume from General Purpose Volumes
Average Vehicle Occupancy General Purpose Lanes
Average Vehicle Occupancy HOV Lanes

Default Benefit Calculation:
Travel Time
Travel Time Reliability
Crashes

Methodology:
Three primary benefits are calculated by TOPS-BC for this strategy: **Travel Time**, **Travel Time Reliability,** and **Crashes**.

Travel Time – is calculated in TOPS-BC based on estimated link speeds in the corridor – both for the freeway general purpose and HOV links. By default, speeds are estimated using the speed-flow relationship shown on the Parameters page. This speed flow relationship is based on the Highway Capacity Manual and provides a speed factor (to be applied to free flow speed) for varying degrees of congestion (as measured by volume/capacity ratio). Speed is estimated for the baseline (without improvement) scenario by determining the correct speed flow factor to apply based on the user supplied inputs for capacity and volume and applying the factor to the user provided free flow speed. These analyses are performed separately for the freeway general purpose and HOV links. For the with improvement scenario, average volumes for the HOT lane are adjusted by default to reflect the baseline level of available capacity in the HOV lane. This is primarily intended only as a target value, as the user is encouraged to carefully adjust the HOT lane volume to reflect the proposed change in operating parameters. The volume change for the general purpose lane is also adjusted depending on the HOT volume impact supplied by the user multiplied with the default Percent Change in HOT Lane Volume from General Purpose Volumes (or your input for impact values, if available). The resulting volume change is subtracted from the general purpose lane volumes for the improvement scenario. The adjusted volumes are used to determine an adjusted volume/capacity ratio used to look up the speed flow factor from the Parameters sheet. The estimated speeds for the baseline and with improvement scenarios are used to estimate link travel time based on link length and average volumes. The difference between the two scenarios in hours of travel time is monetized as the travel time benefit.

Travel Time Reliability – is calculated in TOPS-BC based on the non-recurring delay estimation methodology developed for the Strategic Highway Research Program (SHRP 2 projects L03 and L05). The approach uses factors (applied to VMT) representing the expected amount of non-recurring related delay based on the number of lanes on the facility, the length of the analysis period, the facility volume and the facility capacity. This analysis is only performed on the freeway links. The impact of the HOT lane strategy on incident related delay is two-fold – it is impacted by the change in facility volumes (discussed under the Travel Time impact above) and by a change in the number of crashes (discussed in the Crashes section below). The change in capacity results in a different volume/capacity ratio (between the without improvement and with improvement scenarios) being used to look up the non-recurring related delay factors on the Parameters page. The look-up incident related delay factor is multiplied with the VMT estimated for the facility. Additionally, according to the SHRP 2 research, the resulting recurring delay and incident delay values are applied in an additional algorithm, along with the volume/capacity ratio to factor total non-recurring delay for the facility. The incremental change in hours of non-recurring travel time delay between the baseline and with improvement scenario is assigned a dollar value from the Parameters page to calculate the benefit.

Crashes – represent the benefit from the change in the number of crashes resulting from changing facility volumes and thus VMT. Crash rates will be applied to the change in VMT for both the HOT and general purpose facilities to estimate the change in the number and type of crashes. Dollar values will be applied to the change in the number of crashes to estimate this benefit.

Other Benefits – Other benefits often associated with HOT lane strategies, but not currently included in the benefits calculated by TOPS-BC are Emissions and Fuel Use. These two benefits are inherently difficult to estimate within a spreadsheet based model (e.g., spreadsheet based models are generally incapable of estimating the vehicle acceleration/deceleration profiles to accurately assess these impacts). You are free to modify the analysis framework to include these benefits, or simply to add the estimated value of these benefits to the "User Entered Benefit" cell if there is data to support their inclusion.

ATDM – Hard Shoulder Running

Data Inputs:
Length of Analysis Period
Freeway Volume
Freeway Number of Lanes
Freeway Capacity
Freeway Free Flow Speed
Freeway Link Length

Default Benefit Calculation:
Travel Time
Travel Time Reliability
Crashes (Optional)

Methodology:
Two primary benefits are calculated by TOPS-BC for this strategy: **Travel Time** and **Travel Time Reliability**. An optional analysis is provided for assessing **Crashes**.

Travel Time – is calculated in TOPS-BC based on estimated link speeds in the corridor. By default, speeds are estimated using the speed-flow relationship shown on the Parameters page. This speed-

flow relationship is based on the High way Capacity Manual and provides a speed factor (to be applied to free flow speed) for varying degrees of congestion (as measured by volume/capacity ratio). Speed is estimated for the baseline (without improvement) scenario by determining the correct speed flow factor to apply based on your inputs for capacity and volume and applying the factor to the free flow speed your provided. For the with improvement scenario, average capacities are adjusted based on default impact percentages (or user supplied impact values if available) based on the addition of a lane (or portion of a lane). The adjusted facility capacity value is used to determine an adjusted volume/capacity ratio used to look up the speed flow factor from the Parameters sheet. The estimated speeds for the baseline and with improvement scenarios are used to estimate link travel time based on user supplied link length and average volumes. The difference between the two scenarios in hours of travel time is monetized as the travel time benefit.

Travel Time Reliability – is calculated in TOPS-BC based on the non-recurring delay estimation methodology developed for the Strategic Highway Research Program (SHRP 2 projects L03 and L05). The approach uses factors (applied to VMT) representing the expected amount of non-recurring related delay based on the number of lanes on the facility, the length of the analysis period, the facility volume and the facility capacity. This analysis is only performed on the freeway links. The impact of the shoulder running strategy on incident related delay is two-fold – it is impacted by the change in facility volumes (discussed under the Travel Time impact above) and by a change in the number of crashes (discussed in the Crashes section below). The change in capacity results in a different volume/capacity ratio (between the without improvement and with improvement scenarios) being used to look up the non-recurring related delay factors on the Parameters page. The look-up incident related delay factor is multiplied with the VMT estimated for the facility. Additionally, according to the SHRP 2 research, the resulting recurring delay and incident delay values are applied in an additional algorithm, along with the volume/capacity ratio to factor total non-recurring delay for the facility. The incremental change in hours of non-recurring travel time delay between the baseline and with improvement scenario is assigned a dollar value from the Parameters page to calculate the benefit.

Crashes (Optional) – an optional analysis is available to estimate the additional benefit of a reduction in crashes resulting from the deployment of Hard Shoulder Running strategies. No default crash rate factor is supplied due to insufficient consensus in the available research of this impact. If the user has information to support this impact, a factor can be entered in the “Reduction in Crash Rate” and/or “Reduction in Crash Duration” cell. These entries will reduce the crash rates applied to all crash severities. Dollar values will be applied to the change in the number of crashes to estimate this benefit. The reduction in the number and duration of crashes is also fed back into the calculation of incident related delay, producing a greater benefit level for Travel Time Reliability.

Other Benefits – Other benefits often associated with hard shoulder running strategies, but not currently included in the benefits calculated by TOPS-BC are Emissions and Fuel Use. These two benefits are inherently difficult to estimate within a spreadsheet based model (e.g., spreadsheet based models are generally incapable of estimating the vehicle acceleration/deceleration profiles to accurately assess these impacts). You are free to modify the analysis framework to include these benefits, or simply to add the estimated value of these benefits to the “User Entered Benefit” cell if there is data to support their inclusion.

ATDM –Speed Harmonization

Data Inputs:
Length of Analysis Period
Freeway Volume

Freeway Number of Lanes
Freeway Capacity
Freeway Free Flow Speed
Freeway Link Length

Default Benefit Calculation:
Travel Time Reliability
Crashes
Travel Time (Optional)

Methodology:
Two primary benefits are calculated by TOPS-BC for this strategy: **Travel Time Reliability** and **Crashes**. An optional analysis exists to evaluate recurring **Travel Time**.

Travel Time Reliability – is calculated in TOPS-BC based on the non-recurring delay estimation methodology developed for the Strategic Highway Research Program (SHRP 2 projects L03 and L05). The approach uses factors (applied to VMT) representing the expected amount of incident related delay based on the number of lanes on the facility, the length of the analysis period, the facility volume and the facility capacity. This analysis is only performed on the freeway links. The impact of the speed harmonization strategy on non-recurring delay is primarily related to a reduction in the number of crashes (discussed in the Crashes section below). The resulting estimated number of hours of incident delay, used in the calculation of total non-recurring delay, is reduced by the percentage decrease in the default crash rate. The incremental change in hours of non-recurring travel time delay between the baseline and with improvement scenario is assigned a dollar value from the Parameters page to calculate the benefit.

Crashes – represent the benefit in the reduction in crashes resulting from the smoothing of traffic conflicts in the queue formation areas. A default crash rate factor is supplied; however, if you have local data to support this impact, a factor can be entered in the "Reduction in the Crash Rate (%)" and/or "Reduction in Crash Duration" cells. These impact factors will reduce the crash rates applied to all crash severities. Dollar values will be applied to the change in the number of crashes to estimate this benefit. The reduction in the number and duration of crashes is also fed back into the calculation of incident related delay, producing a greater benefit level for Travel Time Reliability.

Travel Time (Optional) – You have the ability to enter an impact for a change in speed if they have data to support this impact for this strategy. The default impact is set to zero.

Other Benefits – Other benefits often associated with speed harmonization strategies, but not currently included in the benefits calculated by TOPS-BC are Emissions and Fuel Use. These two benefits are inherently difficult to estimate within a spreadsheet based model (e.g., spreadsheet based models are generally incapable of estimating the vehicle acceleration/deceleration profiles to accurately assess these impacts). You are free to modify the analysis framework to include these benefits, or simply to add the estimated value of these benefits to the "User Entered Benefit" cell if there is data to support their inclusion.

Road Weather Management

Data Inputs:
Length of Analysis Period
Freeway Volume

Freeway Number of Lanes
Freeway Capacity
Freeway Free Flow Speed
Freeway Link Length

Default Benefit Calculation:
Travel Time
Travel Time Reliability
Crashes

Methodology:
Three primary benefits are calculated by TOPS-BC for this strategy: **Travel Time**, **Travel Time Reliability** and **Crashes**.

Travel Time – is calculated in TOPS-BC based on estimated link speeds in the corridor. By default, speeds are estimated using the speed-flow relationship shown on the Parameters page. This speed-flow relationship is based on the Highway Capacity Manual and provides a speed factor (to be applied to free flow speed) for varying degrees of congestion (as measured by volume/capacity ratio). Speed is estimated for the baseline (without improvement) scenario by determining the correct speed flow factor to apply based on your inputs for capacity and volume and applying the factor to the free flow speed you provide. You are encouraged to override the default speed based on typical conditions if in order to more effectively analyze conditions for a particular inclement weather condition (e.g., rain, snow, fog, ice). The speed entered to override the default speed should be reflective of speeds during these conditions. For the with improvement scenario, average speeds are adjusted based on default impact percentages (or impact values you provide, if available) based on an increase in speeds representing the restoration of speed lost to the inclement weather conditions. The adjusted facility speed value is used to determine an adjusted speed. The incremental change in the estimated speeds between the baseline and with improvement scenarios is used to estimate link travel time based on the link length and average volumes you provide. The difference between the two scenarios in hours of travel time is monetized as the travel time benefit.

Travel Time Reliability – is calculated in TOPS-BC based on the non-recurring delay estimation methodology developed for the Strategic Highway Research Program (SHRP 2 projects L03 and L05). The approach uses factors (applied to VMT) representing the expected amount of non-recurring related delay based on the number of lanes on the facility, the length of the analysis period, the facility volume and the facility capacity. This analysis is only performed on the freeway links. The impact of the road weather management strategy on non-recurring related delay is impacted by a change in the number of crashes (discussed in the Crashes section below) and the duration of incidents. The incremental change in hours of non-recurring travel time delay between the baseline and with improvement scenario is assigned a dollar value from the Parameters page to calculate the benefit. The sum of this travel time calculation is assigned a dollar value from the Parameters worksheet and added to the monetized benefit.

Crashes – represent the benefit in the reduction in crashes resulting from Road Weather Management. A default crash rate factor is supplied; however, if you have local data to support this impact, a factor can be entered in the “Reduction in the Crash Rate (%)” and/or “Reduction in Crash Duration” cells. This impact factor will reduce the crash rates applied to all crash severities. Dollar values will be applied to the change in the number of crashes to estimate this benefit. The reduction in the number and duration of crashes is also fed back into the calculation of incident related delay, producing a greater benefit level for Travel Time Reliability.

Work Zone Systems

Data Inputs:
Length of Analysis Period
Freeway Volume
Freeway Number of Lanes
Freeway Capacity
Freeway Free Flow Speed
Freeway Link Length

Default Benefit Calculation:
Travel Time
Travel Time Reliability
Crashes

Methodology:
Three primary benefits are calculated by TOPS-BC for this strategy: **Travel Time**, **Travel Time Reliability**, and **Crashes**.

Travel Time – is calculated in TOPS-BC based on estimated link speeds in the corridor. By default, speeds are estimated using the speed-flow relationship shown on the Parameters page. This speed-flow relationship is based on the Highway Capacity Manual and provides a speed factor (to be applied to free flow speed) for varying degrees of congestion (as measured by volume/capacity ratio). Speed is estimated for the baseline (without improvement) scenario by determining the correct speed flow factor to apply based on your inputs for capacity and volume and applying the factor to the free flow speed you provided. It is recommended for work zone systems analysis that the baseline capacity be reduced to reflect the loss due to construction/maintenance activities, or alternatively the Congested Speeds could be altered if the data exists to support this entry. For the with improvement scenario, average congested speeds are adjusted based on the default impact percentages (or user supplied impact values if available) based on an increase in travel speed representing the restoration and smoothing of traffic flow due to the reduction in stop-and-go conditions. The estimated speeds for the baseline and with improvement scenarios are used to estimate link travel time based on user supplied link length and average volumes. The difference between the two scenarios in hours of travel time is monetized as the travel time benefit.

Travel Time Reliability – The impact of the work zone strategy on non-recurring related delay is two-fold – it is impacted by a smoothing of the traffic flow (discussed under #1 below) and by a change in the number of crashes (discussed under #2 and in the Crashes section below).

1) Corridor travel time typically is calculated in TOPS-BC based on estimated link speeds in the corridor and used to represent recurring travel time. However, since any change in travel time due to work zone systems is anticipated to result in a reduction in the amount of non-recurring delay experienced by drivers in the work zone, this calculation is included under travel time reliability for this particular strategy. By default, speeds are estimated using the speed-flow relationship shown on the Parameters page. This speed-flow relationship is based on the Highway Capacity Manual and provides a speed factor (to be applied to free flow speed) for varying degrees of congestion (as measured by volume/capacity ratio). Speed is estimated for the baseline (without improvement) scenario by determining the correct speed flow factor to apply based on your inputs for capacity and volume and applying the factor to the free flow speed you provided. It is recommended for work zone systems

analysis that the baseline capacity be reduced to reflect the loss due to construction/maintenance activities, or alternatively the Congested Speeds could be altered if the data exists to support this entry. For the with improvement scenario, average congested speeds are adjusted based on the default impact percentages (or impact values you entered, if available) based on an increase in travel speed representing the restoration and smoothing of traffic flow due to the reduction in stop-and-go conditions. The estimated speeds for the baseline and with improvement scenarios are used to estimate link travel time based on user supplied link length and average volumes. The difference between the two scenarios in hours of travel time is monetized as the travel time benefit.

2) Travel time reliability is calculated in TOPS-BC based on the non-recurring delay estimation methodology developed for the Strategic Highway Research Program (SHRP 2 projects L03 and L05). The approach uses factors (applied to VMT) representing the expected amount of non-recurring related delay based on the number of lanes on the facility, the length of the analysis period, the facility volume and the facility capacity. This analysis is only performed on the freeway links. The additional impact of the work zone strategy on non-recurring related delay is related to any change in the number of crashes (discussed in the Crashes section below). The amount of non-recurring related delay attributable to incidents is calculated for the baseline and improvement scenarios. The identified reduction in crashes factor is applied to the improvement scenario to assess change in incident related delay. This is added to the non-recurring delay identified in #1 above. The sum of this travel time calculation is assigned a dollar value from the Parameters worksheet and added to the monetized benefit.

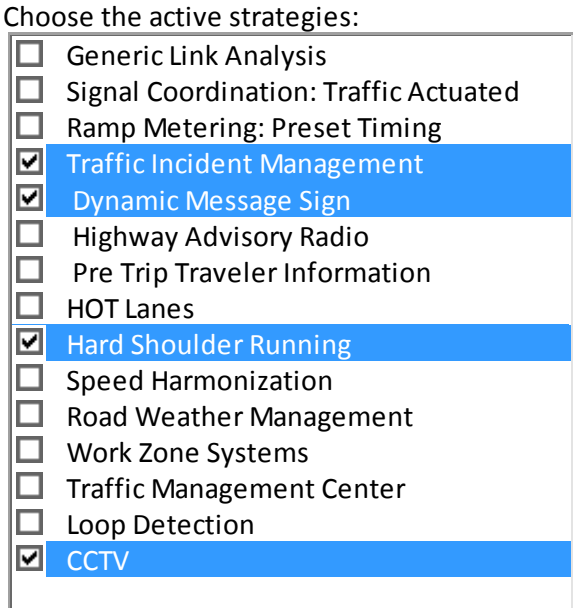
Crashes – represent the benefit in the reduction in crashes resulting from Work Zone Systems. A default crash rate factor is supplied; however, if you have local data to support this impact, a factor can be entered in the “Reduction in the Crash Rate (%)” and/or “Reduction in Crash Duration” cells. These impact factors will reduce the crash rates applied to all crash severities. Dollar values will be applied to the change in the number of crashes to estimate this benefit. The reduction in the number and duration of crashes is also fed back into the calculation of incident related delay, producing a greater benefit level for Travel Time Reliability.

Comparing Benefits and Costs of Different Combinations of Strategies Using the My Deployment Page

The My Deployment sheet is used to view the results of the analysis. This is true whether you want to view the B/C results from a single strategy or view results from different combinations of strategies. You are given the ability in this sheet to select different strategies that they have analyzed and combine them in order to quickly calculate the total combined B/C for that combination of strategies.

Figure 6-12 shows a portion of the My Deployments screen showing the available strategies for analysis. In this example, the user has selected several strategies, indicated by the checked boxes, to combine into a total B/C ratio. By selecting only particular strategies, you can quickly view the combined B/C ratios of different strategies, assuming you have previously entered the required data into the individual benefit estimation sheet for each strategy you want to compare. The My Deployments sheet will display the individual B/C results for each strategy you selected for viewing, as well as a combined B/C analysis for all selected strategies.

Figure 6-12. Selecting Strategies to Combine for Viewing in the My Deployments Sheet



Source: FHWA.

The My Deployments page also provides the opportunity to conduct quick sensitivity tests of may common input values used in B/C analysis, such as the value of travel time or crash reductions. At the top of the sheet, many commonly used benefit values are displayed, as shown in Figure 6-13. Defaults for these values are pulled from the Parameters page and will be applied unless you input a value into the green shaded User Input cell. If you enter values in the User Input cells it will override the default value for all instances where that value is used on the My Deployments sheet. This provides the opportunity to quickly modify global values and view the results without having to toggle back and forth between the My Deployments sheet and the Parameters sheet. Note that entering a new user defined value on the My Deployment page will not alter the underlying default on the Parameters page, nor impact the benefits results displayed on benefit worksheets for individual strategies.

Figure 6-13. Viewing the Value Parameters in the My Deployments Sheet

$ Value of Person Hour (per hour) "On-the-Clock" Auto	$	28.00
$ Value of Person Hour (per hour) Other Auto	$	14.00
$ Value of Vehicle Hour (per hour) Truck	$	28.00
$ Value of Person Hour (per hour of ***Delay***) "On-the-Clock" Auto	$	28.00
$ Value of Person Hour (per hour of ***Delay***) Other Auto	$	14.00
$ Value of Vehilce Hour (per hour of ***Delay***) Truck	$	28.00
Average cost per gallon of fuel (excluding taxes)	$	3.67
$ Value of a Fatality Crash	$	6,500,000
$ Value of a Injury Crash	$	67,000
$ Value of a Property Damage Crash	$	2,300

Source: FHWA.

Using the Corridor Based Analysis in TOPS-BC to Evaluate Regional Projects

For most strategies, TOPS-BC is designed to analyze performance on a single corridor; however, you may have a need to analyze strategies deployed on multiple corridors or even regionwide. These types of analyses are typically best performed using more robust traffic analysis tools. In situations where the analysis resources do not allow for full modeling or data collection on all the regional facilities impacted by the deployments, you may want to consider the use of representative corridors for analysis. In this approach, one or more representative corridors are selected for detailed analysis, and the results are then extrapolated to other regional facilities. For example, if you were considering deploying more advanced traffic signal coordination throughout a region, but didn't have the resources to apply a travel demand model analysis or to individually model all the regional corridors in TOPS-BC, you might consider this representative corridor approach.

Using this approach, you would first select several representative corridors that signify different arterial types (e.g., 2 lanes vs. 4 lanes), settings (e.g., urban vs. suburban), or other operational conditions (e.g., average spacing of signalized intersections). Each of the representative corridors would be analyzed separately in TOPS-BC; then the resulting measures of effectiveness could be extrapolated to a region wide basis by weighting the amount of regional travel that proportionately occurs on each of the different representative corridor types. More information on the use of representative corridors is provided in Chapter 5 of the *Desk Reference*.

Conducting Sensitivity Analysis

Given the sketch planning nature of TOPS-BC and the order of magnitude results it produces, it is recommended you conduct a sensitivity analysis to gain a better understanding of the impact of input

assumptions. Fortunately, the spreadsheet based analysis framework within TOPS-BC provides for relatively easy sensitivity analysis with near immediate results.

You are encouraged to review and scrutinize all the input assumptions regarding their analysis, including:

- All required input data;
- Assumptions regarding impacts of particular strategies;
- Default rate data included on the Parameters worksheet; and
- Benefit valuation data included on the Parameters worksheet.

You may perform sensitivity analysis on any input assumption; however, the focus of the analysis should be on any input or default data in which the you have less confidence. You can gain a better understanding of the impact that particular input variables have on the results of the analysis by modifying selected input variables after the initial analysis has been completed and comparing the changes in output results.

To conduct a sensitivity analysis in TOPS-BC, you may simply enter a value in the User Input column of the individual strategy worksheet for any given line item (that is greater or less than the default or the calculated value) and immediately observe the results of this parameter change. Alternatively, inputs can be modified in the appropriate cell on the Parameters worksheet if you want to test the sensitivity simultaneously across several strategy analyses. You may change any single input variable or multiple variables at once to gauge the impact on the results.

Sensitivity analysis is useful for enhancing the your understanding of how the results are influenced by the input data, providing greater confidence in the analysis results, thereby providing the ability to answer critical questions such as, “What would be the results if traffic levels were 10 percent greater?”.

Chapter 7. Customizing and Maintaining TOPS-BC

Overview

TOPS-BC provides a framework for analysis that is adaptable to many analysis needs. It is not designed to be a rigid, inflexible tool that forces users to follow the default methodology or input data according to a formally prescribed format. Instead, TOPS-BC has been developed in an open format to encourage practitioners or researchers (anyone with a reasonably firm understanding of spreadsheet analysis) to customize the tool to their individual needs and improve the tool as more and better data become available.

Consistent with this objective, many of the analyses conducted by TOPS-BC are structured in a manner that allow you to easily modify the tool – adding rows or columns to the structure to add in new analysis methods and data, or simply making minor modifications to existing formulas. Further, knowing that you may want to configure the tool to your region's needs by incorporating your local data, and knowing that more data and new strategies may need to be added to the tool over time to maintain the usefulness of the tool, TOPS-BC has been developed with a number of innovative automated processes for updating and modifying the tool.

This Chapter highlights several of these customization and maintenance capabilities, including:

- Adding new rows to a spreadsheet;
- Adding new data or strategies to the Impact Look Up capability;
- Adding new capabilities or tools to the Methodology Mapping capability;
- Modifying equipment or adding new strategies to the Cost Estimation capability; and
- Adding new strategies to the Benefit Estimation capability.

Adding New Rows to a Spreadsheet

In order to customize TOPS-BC to individual situations, you may have the need to add rows to particular worksheets to add new cost elements or enhance benefit estimation capabilities. Rows may be added to any of the individual cost estimation and benefit estimation sheets for the various presented strategies.

When inserting a row into a sheet, it is important to always insert a complete row, not a partial one, by highlighting the row by clicking on the row number on the far left of the screen, performing a right mouse click and selecting "Insert." After one or more rows are added, the Navigation Menu will temporarily contain a gap showing blanks where the new rows were inserted. However, the Navigation Menu will automatically correct itself to the new configuration once you visit another

worksheet and then return to the modified sheet. This feature keeps the Navigation Menu identical across all of the worksheets.

Note that if you are inserting rows in a cost estimation sheet to add new equipment, additional processes may be required as detailed in a subsequent section and also in Chapter 5.

Adding New Data or Strategies to the Impact Look Up Capability

New data on the impacts and benefits of TSM&O strategies is constantly emerging as more agencies deploy and evaluate these strategies and as new technologies are tested and implemented. Likewise, new strategies are constantly emerging. Therefore, there is the likely need to be able to update the impact data and the strategies that are included in the Impact Look Up capability to ensure the information does not become stale.

Automated capabilities have been provided within TOPS-BC to easily update and maintain this data within the tool. These capabilities may be used to simply update the tool with new data points, add a new strategy, or to wholesale reconfigure the data look up to customize the capability to your agency's needs (i.e., only include selected data which your agency is interested). The capability to update the impact database is provided on a hidden worksheet titled "ImpactData," as shown in Figure 7-1. You can access the ImpactData worksheet by right-clicking on any worksheet tab, selecting "unhide" and then selecting "ImpactData" from the list of hidden worksheets.

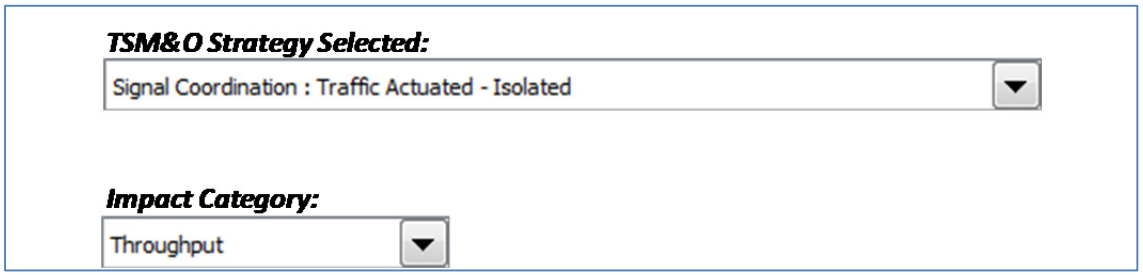
Figure 7-1. Partial Screen View of the ImpactData Worksheet

	Go	Clicking on "Go" will activate a macro that will populate the individual formatted impact display sheets based on the information currently displayed in this consolidated database. This process may take some time to complete.		Travel Time and Speed	
				Impact	Comment 1
ATMS - Signal Coordination	Signal Coordination	Traffic Actuated - Isolated	Typical Range of Expected Impacts	Expected travel time reductions range between 10% - 20%. Expected delay reductions	
			National studies/statistics	No Data Available	from Transportation Research Record #1572
			U.S. state, regional, local studies/statistics	PATH (Berkeley) - Floating car studies obta	from Benjamin Coifman, Michael Cassidy, C
				PATH (Berkeley) - Floating car studies obtained for 76 projects in California showed dela	
			Default Impact Values from Existing B/C Tools	SCRITS suggests a 20% improvement in average speeds	
				SCRITS suggests a 17% reduction in travel time	
			Simulation Results	Simulation - 15% reduction in delay compared with pre-timed signals	
				Simulation - Wide-area controller reduced delay by 30% on two-way streets	
				Simulation - Wide-area controller reduced delay by 50% on one-way streets	
				TRANSYT (Berkeley PATH) - 13.8 % reduction in delays	
				TRANSYT (Berkeley PATH) - 7.7% reduction in travel time	
			International and Misc.	No Data Available	from Benjamin Coifman, Michael Cassidy, C

Source: FHWA.

Information on the ImpactData worksheet drives the structure and provides the data available for the Impact Look Up capabilities provided by TOPS-BC. Columns A-C in the body of the worksheet define the name and sophistication of strategies to be included in the look up capabilities. Column A provides the highest level identification of the strategy. Any strategy named in Column A will have a separate look up worksheet created to organize impact data regarding this category. If data is present in Columns B-C, additional subcategories or levels of sophistication will be listed for the strategy in the pull-down strategy menu shown on the IMPACT LOOKUP worksheet, as illustrated in Figure 7-2.

Figure 7-2. Pull Down Menus on the IMPACT LOOKUP Worksheet



Source: FHWA.

Column E in the ImpactData worksheet provides the opportunity to categorize the impact data according to the source or type of data (e.g., National versus international results). By default, consistent categories are used for all strategies, regardless of whether there is data available to support that category. You are free, however, to delete or add categories according to your needs and available data. All data listed to the right of Column E on the ImpactData worksheet represents the impact data organized according to impact category. Every third column represents the name of an Impact Category that will be displayed in the pull-down menu on the IMPACT LOOKUP worksheet as shown in Figure 7-2. Two Comment columns are provided to the right of each Impact Category column to provide you the opportunity to add reference data on the source of the impact information and/or other useful information.

Data is entered in rows on the ImpactData worksheet. If you wish to add new impact data regarding a particular strategy, you should first check to see if an existing empty cell exists in the target location for the data. If yes you should enter the information in the target location. If no, you should:

- Add an entire row of data to the worksheet under the appropriate strategy heading;
- Enter the impact data under the appropriate impact category;
- Enter any relevant source or reference data in the comments column immediately to the right of the newly added data; and
- Leave other cells in the row empty (TOPS-BC will ignore empty cells in this database).

When all data in the ImpactData worksheet has been modified, you should select the “Go” button located at the top of Column B, which will activate a macro to update TOPS-BC with the new data. Note: this activity may take some time to complete. The macro will update the pull-down menus on the IMPACT LOOKUP worksheet according to any changes made in the data on the ImpactData worksheet. Further, this macro will format the data into individual strategy impact worksheets according to the strategy categories supplied. The formatting of the individual strategy worksheets is based on another hidden worksheet titled “ImpactTemplate.” Any changes made to this ImpactTemplate worksheet will modify the format in which the data is organized on the individual worksheets.

Adding New Capabilities or Tools to the Methodology Mapping Capability

TOPS-BC provides the capability to map different B/C methodologies to an organization’s needs. This capability is based on a list of existing methodologies along with information regarding the appropriateness of each methodology in addressing several potential criteria regarding B/C analysis.

Over time, the capabilities of the existing tools are likely to change, new tools and methods may come on-line, and even the criterion that defines which tools are most appropriate may change. TOPS-BC has several automated features to adjust to these future changes and keep the tool up to date.

Data driving the methodology mapping capability is provided on a hidden worksheet titled "MethodData" as partially shown in Figure 7-3.

Figure 7-3. Partial Screen View of the MethodData Worksheet

Topic	Category	SubCategory	Item	TOPS-BC *	BCA.net	CAL-BC
What is the geographic scope of the analysis? (Select 1)					http://www.	http://www
	No Preference			Y	Y	Y
	Statewide			N	N	N
	Regional			N	N	N
	Corridor			Y	Y	Y
	Isolated Location			Y	Y	Y
	Other			Y	Y	Y
What is the desired level of confidence of the analysis results? (Select 1)						
	No Preference			Y	Y	Y
	High (extremely accurate)			N	N	N
	Medium			Y	Y	Y
	Low (order of magnitude)			Y	Y	Y
What TSM&O strategy(ies) do you want to analyze? (Choose Multiple)						
	No Preference			Y	Y	Y
	Arterial Corridor Traffic Signal Coordination Strategies			Y	Y	Y

Source: FHWA.

The data on this worksheet is generally organized with the various analysis criteria presented across the vertical axis (rows) and the available methodologies listed across the horizontal axis (columns). Column A titled "Topic" presents the questions that will be asked regarding the analysis needs. Entries listed in Column B (Category) in subsequent rows form the multiple choice answers that will be associated with each "Topic" question. You may modify both the "Topic" questions and the "Category" answers may to customize the analysis to your needs.

Within the entry for each "Topic" question, one of two specific phrases, presented in parenthesis, is required to instruct TOPS-BC how to collect data on the question from the user. These phrases include:

- **(Select 1)** presented as radio buttons (allowing only one selection to be made at a time; or,
- **(Choose Multiple)** presented as multiple selection allowing the user to select any number of answers simultaneously.

The available analysis tools and methods are arranged in columns starting in Column E. Note that by default, tools listed further to the left will be listed first when the prioritized lists are displayed. For each tool, the first row of data presents the tool name as it will appear on the METHOD SELECTION worksheet lists. The second row of data presents a web link for the tool. If no web link is available, this cell may be left blank. The remaining rows of data under an individual tool provide a yes (Y) or no (N) response to whether that tool meets the specific criteria presented in that row. If capabilities are added to a particular tool in the future, you may easily reflect this change by modifying the Y or N entry in any given cell.

You may modify the criteria ("Topic" questions asked) or modify the list of available tools simply by adding the appropriate information to complete the mapping within the matrix. This

information is automatically updated to the METHOD SELECTION worksheet each time that particular worksheet is accessed.

Modifying Equipment or Adding New Strategies to the Cost Estimation Capability

The COST ESTIMATION worksheet provides the gateway to the individual cost estimation sheets related to individual TSM&O strategies. The life-cycle cost estimation analysis is driven off default assumptions regarding:

- Equipment packages associated with each strategy;
- Unit costs of capital and O&M costs associated with each piece of equipment; and
- Useful life expectancy of each piece of equipment.

These default data, as illustrated in Figure 7-4, are generally based on national level averages and assumptions. Therefore, you may wish to configure these cost items to your region's practices and experiences. TOPS-BC has been developed to support and encourage this customization.

Within the individual cost estimation worksheets associated with given strategies, you may modify the unit cost figures or the useful life associated with any particular piece of equipment. You may also delete pieces of equipment or add pieces of equipment to better match your own anticipated equipment mix for the strategy.

Note that if an additional row(s) is needed in order to add a new piece of equipment, you should **insert an entire row by first copying an existing row of data**. You can do this by highlighting an entire row by clicking on the row number at the far left of the page, conducting a right click, and selecting "Copy." Right click on the highlighted row number again and select "Insert Copied Cells." This will create a new row that is properly formatted and contains the cell formulas necessary to maintain the integrity of the analysis. (If you simply decide to "Insert" a new row, you will need to manually merge cells and copy/paste formulas to match the existing equipment rows.) If you are only interested in using the Average Annual Costs in your calculations, no further modifications are needed. If you are interested in viewing the Stream of Costs and calculating the Net Present Costs and Net Present Benefit, you will additionally need to **check and see if the added equipment has been added to the Working Calculations Sheet** at the bottom of the individual cost estimation sheet [Figure 5-4]. In some cases, due to the manner in which the row was added or the version of Excel being used, the added equipment may not have automatically been generated in the Working Calculations Sheet. Therefore, it is recommended that you check to see that the equipment has been added to the Working Calculations Sheet. If the new equipment is not there, simply follow the directions above for copying and inserting copied rows within the appropriate section of the Working Calculations Sheet to replicate the addition of the new equipment in this Working Calculations Sheet. (Again, you should first copy and "Insert Copied Cells" to ensure the formatting and calculations are maintained.)

As rows are added, the Navigation Menu will temporarily be distorted as gaps will appear in the content; however, once you leave the page where the rows have been added and then return, the Navigation Menu will once again correctly display.

When changing data, note that any modification to the default data requires that the modified data match the data format of the default data. For example, you may enter a new piece of equipment for a particular strategy; however, it must have supporting data on the useful life, capital cost, and annual O&M cost to work within TOPS-BC's estimation structure.

Figure 7-4. Sample Screen View of a Cost Estimation Worksheet

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.0

PURPOSE: Estimate Lifecycle Costs of TSM&O Strategies

WORK AREA 1 - ESTIMATE AVERAGE ANNUAL COST

Ramp Metering Systems: Central Control

Equipment	Useful Life	Capital / Replacement Costs (Total)	O&M Costs (Annual)	Annualized Costs
Basic Infrastructure Equipment				
TMC Hardware for Freeway Control	5	$ 22,500	$ 2,000	$ 6,500
TMC Software/Integration	5	$ 200,000	$ -	$ 40,000
Labor		$ -	$ 250,000	$ 250,000
TOTAL Infrastructure Cost		$ 222,500	$ 252,000	$ 296,500
Incremental Deployment Equipment (per Ramp Location)				
Ramp Meter (Signal, Controller)	25	$ 88,000	$ 2,000	$ 5,520
Loop Detectors (2)	25	$ 11,000	$ 500	$ 940
Communication Line	25	$ 750	$ 250	$ 280
TOTAL Incremental Cost		$ 99,750	$ 2,750	$ 6,740
INPUT Enter Number of Infrastructure Deployments	1			**$ 296,500**
INPUT Enter Number of Incremental Deployments	10			**$ 67,400**
INPUT Enter Year of Deployment	2013			
Average Annual Cost				**$363,900**

Source: FHWA.

Further, TOPS-BC maintains a blank cost estimation worksheet that you may use to create cost estimation capabilities for new strategies that may not currently be included. A blank cost estimation worksheet is provided as a hidden sheet titled COST TEMPLATE, shown as Figure 7-5. This worksheet has all the analysis capabilities present in all other strategy worksheets, but lacks any default equipment or cost data. You may copy the data in this worksheet in its entirety and paste it into a new worksheet. This new worksheet may then be renamed and populated with your customized defined equipment and cost data to create new strategies, assuming that the new data is entered in the same format (e.g., equipment name, capital cost, useful life, annual O&M costs).

Unneeded rows may be deleted. You will need to manually modify the navigation capabilities and link the new worksheet to the SUMMARY sheet or other worksheets where they intend to use the output cost data.

Figure 7-5. Partial Screen View of the Blank COST TEMPLATE Worksheet

FHWA Tool for Operations Benefit/Cost (TOPS-BC): Version 1.0

PURPOSE: Estimate Lifecycle Costs of TSM&O Strategies

WORK AREA 1 - ESTIMATE AVERAGE ANNUAL COST

Strategy: Generic Costs

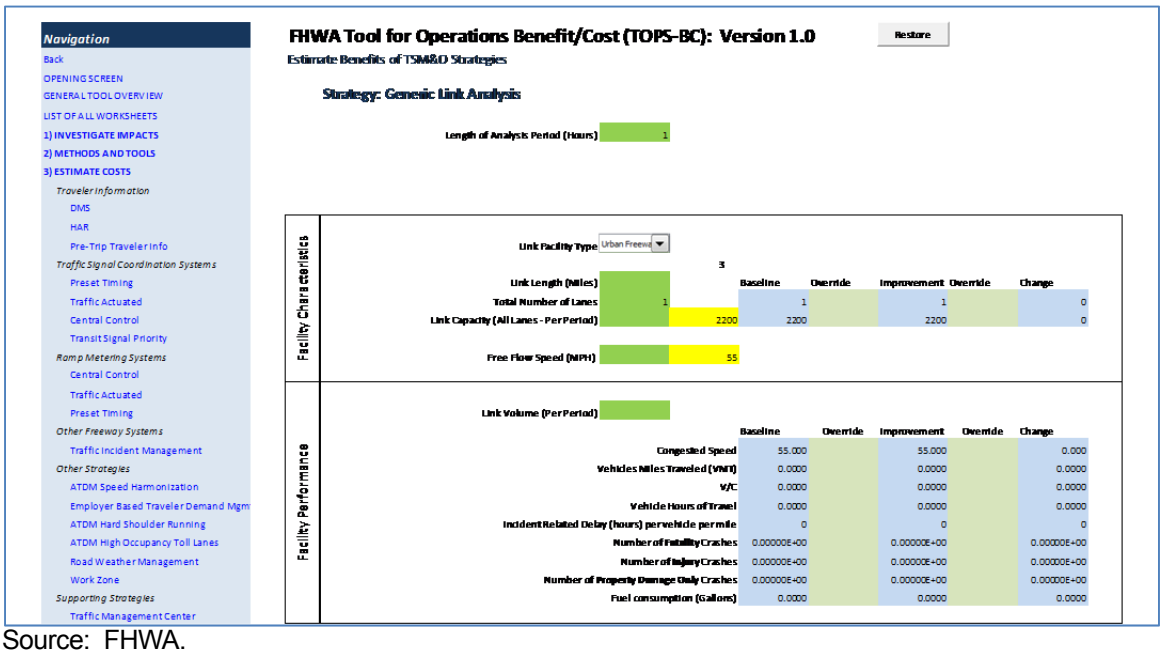
Equipment	Useful Life	Capital / Replacement Costs (Total)	O&M Costs (Annual)	Annualized Costs
Basic Infrastructure Equipment and Costs				
Infrastructure Item 2		$ -	$ -	$ -
Infrastructure Item 3		$ -	$ -	$ -
Infrastructure Item 4		$ -	$ -	$ -
Infrastructure Item 5		$ -	$ -	$ -
Infrastructure Item 6		$ -	$ -	$ -
Infrastructure Item 7		$ -	$ -	$ -
Infrastructure Item 8		$ -	$ -	$ -
Infrastructure Item 9		$ -	$ -	$ -
Infrastructure Item 10		$ -	$ -	$ -
Infrastructure Item 11		$ -	$ -	$ -
Infrastructure Item 12		$ -	$ -	$ -
Infrastructure Item 13		$ -	$ -	$ -
Infrastructure Item 14		$ -	$ -	$ -
Infrastructure Item 15		$ -	$ -	$ -
Infrastructure Item 16		$ -	$ -	$ -
Infrastructure Item 17		$ -	$ -	$ -
Infrastructure Item 18		$ -	$ -	$ -
Infrastructure Item 19		$ -	$ -	$ -
Infrastructure Item 20		$ -	$ -	$ -
Infrastructure Item 21		$ -	$ -	$ -
Infrastructure Item 22		$ -	$ -	$ -
Infrastructure Item 23		$ -	$ -	$ -
Infrastructure Item 24		$ -	$ -	$ -
Infrastructure Item 25		$ -	$ -	$ -
Infrastructure Item 26		$ -	$ -	$ -
Infrastructure Item 27		$ -	$ -	$ -
Infrastructure Item 28		$ -	$ -	$ -
Infrastructure Item 29		$ -	$ -	$ -
Infrastructure Item 30		$ -	$ -	$ -
Infrastructure Item 31		$ -	$ -	$ -
Infrastructure Item 32		$ -	$ -	$ -
Infrastructure Item 33		$ -	$ -	$ -
TOTAL Infrastructure Cost		$ -	$ -	$ -
Incremental Deployment Equipment				
Equipment Item 2		$ -	$ -	$ -
Equipment Item 3		$ -	$ -	$ -
Equipment Item 4		$ -	$ -	$ -
Equipment Item 5		$ -	$ -	$ -
Equipment Item 6		$ -	$ -	$ -
Equipment Item 7		$ -	$ -	$ -

Source: FHWA.

Adding New Strategies to the Benefit Estimation Capability

Similar to the addition of a new strategy within the Cost Estimation capability described in the previous section, you may add new worksheets to provide the ability to analyze new strategies by copying an existing worksheet. You are given two options for creating a new strategy: 1) you may carefully review and consider the various strategies that are available, and select one to copy that most closely resembles the analysis capabilities desired for the new strategy; or 2) you may create a new strategy from the Generic Link Model worksheet that contains many common analysis methodologies for link based analyses, as well as the Navigation Menu, pre-incorporated into the worksheet. Figure 7-6 shows a partial view of the Generic Link Model sheet.

Figure 7-6. Partial View of Generic Link Model Sheet



Source: FHWA.

To create a new strategy, you should follow these steps;

1. Navigate to the Generic Link Model worksheet (or other specific strategy worksheet);
2. Perform a right mouse click on the tab for the sheet to be copied;
3. Select “Move or Copy” from the pop-up menu;
4. A second pop-up menu will appear;
5. Select the “Create a copy” box at the bottom of the menu;
6. Select a location to place the sheet in the tool by indicating which existing sheet the copy should be placed before (note this location should be after the BENEFIT ESTIMATE sheet and before the SUMMARY OF MY DEPLOYMENTS sheet);
7. Rename the new copy of the worksheet with a unique name on that worksheet’s tab;
8. Change the name of the strategy contained in cell J5.

Once the generic (or other) sheet has been copied and renamed, you may add or modify default values to the copied worksheet and delete rows of data or impact measures not needed for the analysis if desired.

In these situations, **it is your responsibility to configure and modify the new strategy worksheet to provide the analysis capabilities and impact data appropriate to the strategy being evaluated**. You will also need to modify the navigation links (see description of this process in the subsequent section) and links to the SUMMARY and cost estimation worksheets if you want to share this information with these other sheets.

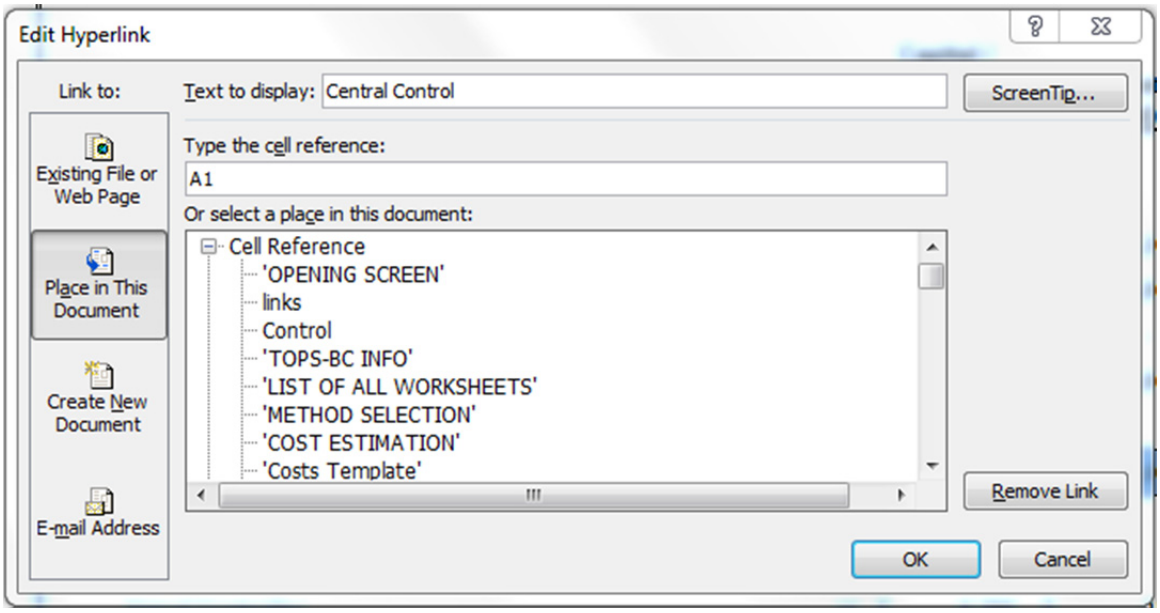
Modifying the Navigation Menu

As noted in previous descriptions of capabilities, TOPS-BC maintains a common Navigation Menu that is used on nearly all sheets in the workbook. This Navigation Menu automatically regenerates on each page when the sheet is opened; therefore, it can not be directly edited on the individual sheets as any changes would be overwritten the next time the sheet is opened.

It is recommended that the modification of the Navigation Menu be performed by users with a firm understanding of Excel and spreadsheet functions, as changes made to the menu will impact all sheets in the tool.

The Master Navigation Menu is maintained on a hidden worksheet named “links.” To modify the menu, you should unhide and navigate to this sheet. The Navigation Menu is displayed along the left hand side similar to other worksheets, except that the menu is divided into two sections, with many of the benefit estimation worksheets listed in a separated section shown below the initial menu listings. New strategy worksheets can be added to the Navigation Menu by inserting an entire row in the desired location and entering the desired name of the worksheet. You will then need to create a hyperlink for the new entry by performing a right mouse click in the cell for the new entry and selecting “Hyperlinks” from the pop-up menu. You should ensure that “Place in this document” option is selected in the “Link to” setting box as Shown in Figure 7-7. You then select the name of the worksheet from the list of worksheets shown near the top of the “Or select a place in this document:”box, and then click “OK.”

Figure 7-7. Creating a New Hyperlink in the Master Navigation Menu



Source: FHWA.

These actions will modify the Navigation Menu that is presented on all sheets simultaneously. It is recommended that you hide the "links" sheet following modification to the menu to avoid unintended editing of the Master Navigation Menu.

Restore Feature

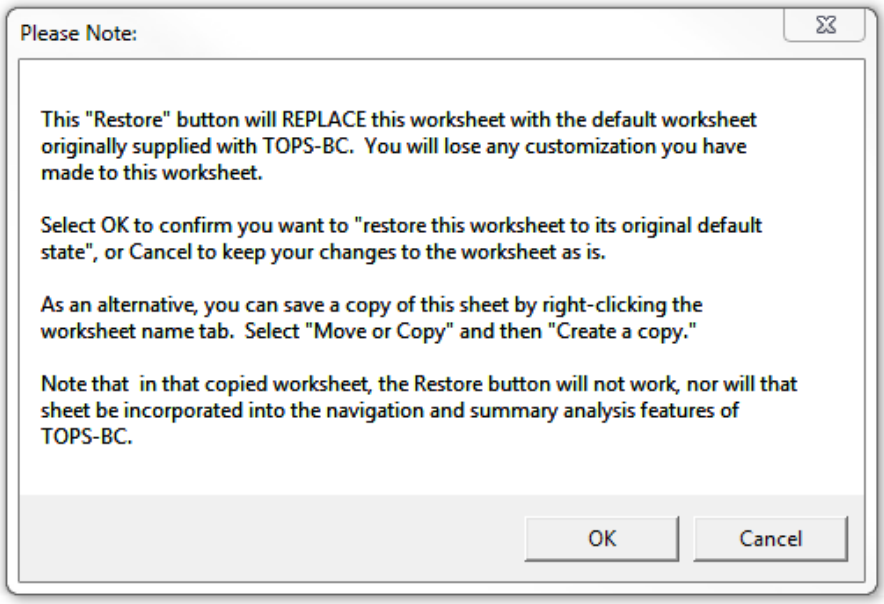
As recommended in Chapter 2, you are encouraged to download the latest version of the spreadsheet file and save it to the hard drive on their computer. You are subsequently encouraged to make a copy of the file and rename it according to your own file keeping structure. You should then use the copied file as you move forward with your analysis. This will ensure that a "clean" copy of the file is preserved in case you wish to use it as a reference.

However, there may be an instance when you would like to reset a particular worksheet back to the original default settings and conditions. This function has been built into select worksheets and is accessible via a gray "Restore" button at the top right of the worksheet. The following worksheets have this capability: the Estimate Costs worksheets for each of the individual strategies, the Estimate Benefits worksheets for each of the individual strategies, the Parameters worksheet, and the My Deployments worksheet.

When used, the "Restore" feature will completely replace the active worksheet with its default worksheet that was originally supplied within TOPS-BC Version 1.0. Any customization you have made to that worksheet will be lost. As this function cannot be undone, a pop-up window is provided with a warning message, as shown in Figure 7-8. Before using the Restore feature, you can create a copy of the worksheet to save it for future reference. This can be accomplished by right-clicking the worksheet name tab, selecting "Move or Copy" and then "Create a copy." Note that the Restore button in the copied worksheet will not work, nor will that copied sheet be incorporated into the navigation and summary analysis features of the tool.

The Restore button is not intended for frequent use, but rather serves as a safety function should you wish to undo changes they made to a worksheet. Again, it is always recommended that a new file be created from the preserved “clean” copy when you plan to begin a new analysis scenario.

Figure 7-8. Restore Feature Pop-up Message



Source: FHWA.

Appendix A Frequently Asked Questions

The following represent frequently asked questions regarding TOPS-BC. They are arranged according to the four primary capabilities of the tool. This FAQ sheet is meant to provide a quick guide to common issues that may be encountered by users, such as the correct format for user entered data. Many of these guidance items are also incorporated in the tool itself and may be queried when using the tool by clicking on the FAQ hyperlink associated with many data items

1) Investigate the Range of Expected Values Associated with Various TSM&O Strategies

What is the source of the individual impact information listed in the look up table?

A reference for all data points in the lookup table is included in a hidden column to the immediate right of each data item in the table. Unhide the appropriate column to view the listing of the data sources. See Chapter 3 of the User's Manual for more information.

Can new impact data sources or new strategies be added to the look up table?

Chapter 7 of the User's Manual provides guidance on how the user may update the table or add new strategies to the look up capabilities.

2) Map Different B/C Methodologies to Your Organizations Needs

Do I need to indicate responses to all of the listed criteria?

No. You may select as few as one criterion to indicate their preferences.

What happens if I've entered my preferences for multiple criteria categories, but now no Suggested Methodologies are listed?

This likely indicates that are no tools that meet all of the criteria supplied by the user. You should consider modifying their criteria to focus on a smaller number of high-priority criteria for their analysis. Also, you should review their responses for any outwardly incompatible responses (e.g., an analysis needing a high level of confidence in the accuracy of the results but also a low level of resources available to support the analysis).

3) Estimate Life-cycle Costs of TSM&O Strategies

What is the source of cost information?

The equipment packages comprising each of the strategies is originally based on data in the ITS National Infrastructure. Equipment cost and useful life information is based on cost data maintained in the U.S. DOT ITS JPO ITS Cost Database [http://www.itscosts.its.dot.gov/] .

Can the list of equipment associated with a strategy be modified?

Yes. If you have better or more locally configured equipment data you want to use, you may replace the default equipment, assuming that the new data is entered in the same format (e.g., equipment name, capital cost, useful life, annual O&M costs). Chapter 7 of the User's Manual provides a description of how cost items may be added for new strategies the user wants to add to their analysis.

4) Sketch Planning Benefits Estimation and Comparison with Costs

What is the appropriate Length of Analysis Period to use?

The length of analysis period is entered as length in number of hours. In order to provide a relevant analysis, the length of the analysis period will match as closely as possible to the expected period in which the strategy is intended to be operating. For example, a ramp metering deployment that is expected to only be operated during a 3-hour peak period should be analyzed using data representing that 3-hour peak period. Once the length of the analysis period is determined, other data inputs should be matched to this analysis period (e.g., capacities, volumes and speeds should represent totals/averages across the entire 3-hour peak period). The length of the analysis data should ultimately be matched with the input data. You should not enter 3-hours as the length of the analysis period and then enter peak hour or daily data for other required inputs. **TOPS-BC performs no internal conversion of the entered data, therefore, it is the responsibility of the user to correctly match the data.**

What is the appropriate capacity and volume to enter?

The values entered for capacity and volumes in the individual strategy analysis worksheets should represent the average capacity or volume for the entire facility (all lanes) for the period being analyzed. For example, if only one direction of a roadway is being analyzed, the data should be only for that direction. If both directions are included in the analysis, data representing the entire roadway should be used. Likewise, if the analysis is being conducted for a 3-hour peak period, the capacity should represent the 3-hour peak period for all included roadway lanes. Ideally, the period of analysis will match the operating characteristics of the strategy (i.e., a ramp metering strategy intended to be operated during the 3-hour afternoon peak commute period should use data representing the 3-hour PM peak period in the analysis.

What does the "Number of Periods per Year" entry represent?

The number of periods per year entry is used to annualize the impact estimated for a single day or period to an annual figure. The number entered should be dependent on the analysis period used and the expected operating characteristics of the strategy being analyzed. A default value of 250 represents that the strategy is anticipated to be utilized on all non-holiday weekdays. This entry can be decreased to represent strategies that are anticipated to be used on fewer days per year (e.g., special events only), or increased to represent multiple periods per day (e.g., a doubling of the default value could be used in conjunction with input data from a single peak period to estimate the impacts of multiple peaks per commute day).

Where do the TOTAL AVERAGE ANNUAL COST figures come from in the benefit/cost comparison?

Life-cycle cost estimates for the individual strategies are pulled from the Life-cycle Cost Estimation worksheet for the individual strategy. To estimate costs for an individual strategy, visit the appropriate cost estimation worksheet for the individual strategy being analyzed and

enter the deployment information as directed in the instructions. If you want to use your own estimated costs in the analysis, you may enter their estimated average annual cost in the green User Input cell for this line item.

Appendix B List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ATDM	Active Transportation and Demand Management
AVL	Automatic Vehicle Location
B/C	Benefit/Cost
CAD	Computer-Aided Dispatch
CAL-BC	Caltrans Benefit Cost Analysis Tool
CARB	California Air Resources Board
CBA	Cost-Benefit Analysis
CCTV	Closed-Circuit Television
CMAQ	Congestion Mitigation and Air Quality
CMP	Congestion Management Process
CMS	Changeable Message Sign
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CUTR	Center for Urban Transportation Research at the University of South Florida
DMS	Dynamic Message Signs
DOT	Department of Transportation
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FITSEval	The Florida ITS Evaluation
FSP	Freeway Service Patrol
GPS	Global Positioning System
HAR	Highway Advisory Radio
HC	Hydrocarbons
HCM	Highway Capacity Manual
HERS	Highway Economic Requirements System
HERS-ST	Highway Economic Requirements System – State Version
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
HPMS	Highway Performance Monitoring System
ICM	Integrated Corridor Management
IDAS	ITS Deployment Analysis System
ITS	Intelligent Transportation Systems
LED	Light Emitting Diodes
M&O	Management and Operations
MOE	Measure of Effectiveness
MPO	Metropolitan Planning Organization
MTC	Metropolitan Transportation Commission
MTP	Metropolitan Transportation Plan
NO_x	Nitrous Oxide
NPV	Net Present Value
O&M	Operations and Maintenance
OKI	Ohio-Kentucky-Indiana

PHT	Person Hours of Travel
$PM_{2.5}$	Fine Particulate Matter
PM_{10}	Particulate Matter
RITA	Research and Innovative Technology Administration
ROG	Reactive Organic Gases
RTP	Regional Transportation Plan
SCRITS	Screening for ITS
SHRP	Strategic Highway Research Program
SO_2	Sulfur Dioxide
SOV	Single-Occupancy Vehicle
STEAM	Surface Transportation Efficiency Analysis Model
TDM	Travel Demand Management
TIM	Traffic Incident Management
TIP	Transportation Improvement Program
TOPS-BC	Tool for Operations Benefit/Cost
TRB	Transportation Research Board
TSM&O	Transportation System Management and Operations
TRIMMS	Trip Reduction Impacts of Mobility Management Strategies
V/C	Volume-to-Capacity
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles of Travel

U.S. Department of Transportation
Federal Highway Administration
Office of Operations (HOP)
1200 New Jersey Avenue, SE
Washington, D.C. 20590

www.ops.fhwa.dot.gov

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