Task Work Order 20, Sub Task 4

Tool for Operations Benefit/Cost (TOPS-BC) for Florida DOT Applications

TOPS-BC Florida Guidebook

prepared for

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Contents

1.0 Introduction

The Federal Highway Administration (FHWA) has developed a methodology for assessing the benefits of operations projects and for producing a benefit/cost (B/C) ratio for these projects. An operations B/C decision support tool, called the Tool for Operations Benefit/Cost (TOPS-BC) was developed for this purpose. This spreadsheet-based tool is designed to assist practitioners in conducting benefit/cost analysis by providing several key capabilities, including:

- Ability for users to investigate the expected range of impacts associated with previous deployments and analyses of many transportation systems management and operations (TSM&O) strategies.
- Screening mechanism to help users identify appropriate tools and methodologies for conducting a B/C analysis based on their analysis needs.
- 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.
- Framework and suggested impact values for conduct simple B/C analysis for selected TSM&O strategies.

Florida DOT desires to adapt the TOPS-BC tool for use in Florida by identifying and tailoring input that is specific to Florida deployments and context.

The objectives of this task were to:

- Define input data needed for the TOPS-BC spreadsheets;
- Identify Florida specific data that is available as input to TOPS-BC;
- Conduct tests of TOPS-BC in Florida scenarios; and
- Develop a Florida DOT TOPS-BC Guidebook, revised Florida specific TOPS-BC spreadsheets and provide technical support to FDOT Districts.

This document is the Florida DOT TOPS-BC Guidebook. The remaining sections in this Guidebook are:

- Section 2 – Overview of TOPS-BC;
- Section 3 – Florida DOT Specific TOPS-BC Data and Case Studies;
- Section 4 – Lessons Learned and User Hints; and
- Appendix containing references.

2.0 Overview of TOPS-BC

Due to an increasingly competitive fiscal environment, state, regional, and local transportation planning organizations around the country are being asked more than ever to justify their programs and expenditures. Intelligent Transportation Systems (ITS), and Transportation System Management and Operations (TSM&O) programs have not escaped this scrutiny and planners/operators are routinely asked to rank their projects against traditional capacity 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 analysis. Often many of the established tools and data available for conducting benefit/cost 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 benefit/cost analysis for many specific TSM&O strategies. It often remains difficult, however, for practitioners to weed through the multiple information and guidance sources in order to understand and apply an appropriate methodology for meeting their own specific analysis needs.

FHWA, recognizing this need, had a decision support tool, called the Tool for Operations Benefit/Cost (TOPS-BC) developed. The tool with a supporting *User's Manual* and Desk *Reference* was published in June 2013. This spreadsheet-based tool is designed to assist practitioners in conducting B/C analysis by providing four key capabilities, including the following:

- 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 2-1 shows the opening screen of TOPS-BC, which provides navigation to the capabilities within the support tool. Florida DOT users are encouraged to read the TOPS-BC *User's Manual* and the *Desk Reference*, which include much more detail on the B/C analysis and specific steps for using the spreadsheet tool. The *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* [1] and contains many references to that publication. The *Desk Referen*ce is intended to serve as an overview primer for practitioners that may be unfamiliar with either benefit/cost analysis or the often-unique characteristics and benefits of operations strategies. Subsequent sections build on this basic information to provide more detailed, often systematic guidance on particular aspects of conducting B/C analysis for operations planning.

Transportation planning activities and associated Federal planning requirements can be generally categorized into the following four stages[1]:

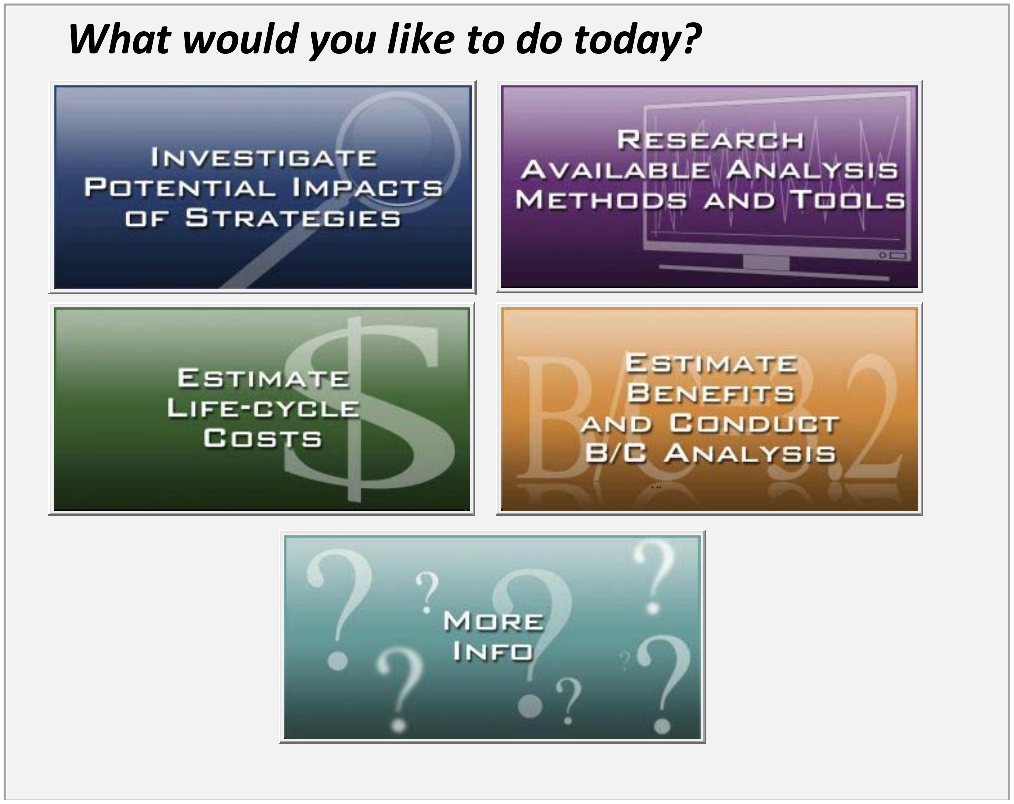
1. Visioning and Screening;
2. Long Range Planning;
3. Transportation Improvement Program Development; and
4. Project Development.

The sketch planning capabilities 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 screen and identify appropriate tools and methodologies for conducting a B/C analysis based on analysis needs and may recommend application of more rigorous tools for more complex analyses.

It must be noted that TOPS-BC was created to be a simplified B/C tool and it is only applicable to high level planning and estimating. If more preciseness is required then a more robust B/C tool is recommended. The *Desk Reference* can assist in choosing an appropriate tool.

[1] http://www.ops.fhwa.dot.gov/publications/fhwahop12028/index.htm

Figure 2-1 Capabilities Provided by TOPS-BC



2.1 Operations Strategies Covered in TOPS-BC

Together the *Desk Reference* and the TOPS-BC tool are intended to support the analysis of a wide range of the available TSM&O strategies. These strategies include the direct application of technologies and infrastructure to roadside application (e.g., deployment of freeway service patrol vehicles), as well as many harder-to-define, nonphysical strategies (e.g., interagency coordination).

It is not possible to provide comprehensive guidance on every type and variation in application of all the many diverse TSM&O strategies (especially in light of the fact that new strategies and technologies are constantly emerging). However, TSM&O strategies covered in the TOPS-BC tool and/or the *Desk Reference* document include strategies from the following categories (see Chapter 3 of the *Desk Reference* for a more complete description of the TSM&O strategies and sub-strategies that comprise each category):

TOPS-BC includes Physical Strategies, such as:

1. Arterial Signal Coordination – Improves the coordination of traffic signal timing to improve flow and reduce delay.

2. Arterial Transit Signal Priority – Provides the capability to expand or accelerate the green time allotted to traffic signals when the transit vehicle is detected approaching the intersection.
3. Transit Automatic Vehicle Location – Uses transponder and Global Positioning System (GPS) technologies to track the real-time location of transit vehicles. Compiled information is typically used to better manage the transit assets or provide traveler information to passengers.
4. Ramp Metering – Applies signals to on-ramp or freeway-to-freeway ramp locations to control and manage the flow of vehicles into the merge area.
5. Incident Management – Various combinations of incident detection, location verification, communication/coordination, and response strategies designed to lessen the time required to respond and clear traffic incidents.
6. Pretrip Traveler Information – Traveler information provided through several different available channels (e.g., telephone, web-based, broadcast-media, social-media) intended to reach individuals prior to the initiation of their trip so that they may make informed decisions on destination, mode, route, time of travel, and even whether to forego the trip.
7. En-route Traveler Information – Traveler information intended to reach the recipients while they are traveling. The information may be provided through several different channels, including telephone, in-vehicle system, roadside Dynamic Message Signs (DMS) or Highway Advisory Radio (HAR), or broadcast-media.
8. Work Zone Management – Lessens the congestion, delay, and safety issues associated with construction or maintenance work zones.
9. High-Occupancy Toll (HOT) Lanes – Allows single-occupancy vehicles (SOV) to pay a toll to use underutilized high-occupancy vehicle (HOV) lane capacity. The tolls charged may vary according to time-of-day schedules, or may be dynamically assessed in response to traffic conditions and available HOV lane capacity.
10. Speed Harmonization – Involves the implementation of variable speed limits and the communication of those limits through roadside signs. The speed limits are modified according to congestion levels to lessen stop-and-go conditions and lower the speed of vehicles as they approach downstream bottlenecks.
11. Hard Shoulder Running – Allows vehicles to travel on the shoulder facilities of roadways, often for isolated sections of roadway or limited times of operation. The availability of the shoulder for use is often communicated using overhead gantries or roadside DMS.
12. Travel Demand Management – Includes a number of strategies that may be employed to lessen travel demand (number of trips). These may include physical strategies (e.g., employer-based vanpools), as well as nonphysical, policy-based strategies (e.g., alternative work hours).

Supporting strategies, such as:

1. Traffic Surveillance – Seeks to collect, compile, and analyze traffic data.
2. Traffic Management Centers – Physical- or virtually-based centers designed to provide the backbone management and operations capability to monitor and operate the deployed systems and technologies.
3. Communications – Landline- and mobile-based systems designed to provide communication between different roadside components, and provide communication between the components and any centralized management structure.

Nonphysical strategies, such as:

1. Active Transportation and Demand Management (ATDM) – The dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities. Using available tools and assets, traffic flow is managed and traveler behavior is influenced in real time to achieve operational objectives, such as preventing or delaying breakdown conditions, improving safety, reducing emissions, or maximizing system efficiency. Under an ATDM approach, the transportation system is continuously monitored. Using archived data and or/predictive methods, actions are performed in real time to achieve or maintain system performance.
2. System Integration – Involves the coordination and integration of two or more strategies to allow for the sharing of data or capabilities to provide for the betterment of the combined system.
3. Interagency Coordination – The integration of efforts, resources, knowledge, or technologies across various agencies, departments, or entities to improve the coordinated management and operation of the transportation system.
4. Regional Concepts for Transportation Operations – Involves the coordination of various stakeholders responsible for operating one or more components or jurisdictions in order to develop sets of policies, procedures, and operating parameters that may be implemented according to specific identified conditions to improve the efficiency and effectiveness of operational strategies during those conditions.

Chapter 3 of the *Desk Reference* provides expanded discussion of these various strategies, as well as sub-strategies and variations in application within the general categories. Chapter 3 also identifies the typical benefits and impact measures associated with the deployment of the strategies.

2.2 What Are Considered Benefits/What Are Considered Costs?

Benefits

Within B/C analysis of transportation operations projects, the benefits represent the monetized estimates of the changes in the Measures of Effectiveness (MOEs) identified for the project that are directly attributable to the project investment. These benefits may accrue to the transportation system users (e.g., travel time savings, reduction in crash risk, decreased operating costs), the deploying agency (increased agency efficiency), or society at large (reductions in emissions). The benefits may be either positive (e.g., a net decrease in travel time) or negative (a net increase in travel time) in value. Negative benefits are known as disbenefits. Chapter 3 in the *Desk Reference* provides an expanded discussion of MOEs and benefits used in assessing transportation operations projects.

Costs

For analyzing TSM&O projects, it is recommended that costs (or the denominator value in B/C analysis) represent the life-cycle costs of implementing and operating the project. This is important for TSM&O projects since they typically incur a greater proportion of their costs in years after deployment to operate and maintain the system, and replace obsolete equipment, when compared to improvements that are more traditional. These life-cycle costs represent:

- The upfront capital costs of implementing the project or improvement, including planning, design, construction/installation, and equipment costs;
- The continuing operations and maintenance (O&M) costs necessary to keep the project operational, including items, such as power, communications, labor, and routine maintenance (excludes replacement costs);
- The replacement cost of equipment that reaches the end of its useful life during the time horizon of the analysis; and
- The end of project costs necessary to close down temporary projects or any residual or salvage value of equipment at the end of the time horizon of the analysis.

These project life-cycle costs should include an accounting of all public sector and private sector costs, if applicable. Chapter 5 in the *Desk Reference* provides additional detail on identifying and estimating the costs associated with a project. In addition, the TOPS-BC application supporting the *Desk Reference* has the capability to estimate life cycle costs associated with many types of TSM&O strategies. The use of these capabilities is discussed in the TOPS-BC *User's Manual*.

2.3 How is TOPS-BC Used in the Operations Planning Process?

B/C analysis provides several capabilities that are vital in supporting different planning needs throughout the Operations planning process. B/C analysis is typically performed to provide one or both of the following capabilities:

- To determine if a project represents a sound investment (i.e., that the benefits of the project outweigh the costs – and to what degree); and
- To compare alternative projects to identify the most efficient projects for ranking/prioritization purposes.

These capabilities are invaluable in supporting planning activities throughout the entire cycle of the Operations planning process. The robustness of the B/C analysis may be scaled to fulfill different needs within the planning cycle. B/C analysis may be performed at a simple sketch-planning level to provide order of magnitude estimates of benefits and costs appropriate for early screening of projects, but also may be made much more rigorous to meet the more detailed analysis demands of later project prioritization or design activities. TOPS-BC is useful in the sketch planning level to obtain order of magnitude costs. If more rigorous analysis is required then other more sophisticated B/C tools such as IDAS should be used.

The sections below provide discussions of several specific phases of the planning process, where opportunities for comparing and prioritizing TSM&O strategies alongside more traditional strategies most often exist; and explore issues that the TSM&O analyst should be aware of when conducting these activities.

Project Screening

Project screening provides the initial assessment of the viability of various projects. Typically, this process is performed at an order-of-magnitude-assessment level, not to specifically rank projects in any absolute order, but instead to provide a general categorization of projects (e.g., high, medium, or low priority) or sort out projects likely to be inefficient. Therefore, scarce planning resources can be focused in later phases on those projects more likely to provide the greatest benefit.

This analysis for TSM&O projects is often performed using sketch-planning analysis tools or readily available methods and data. The TOPS-BC tool, developed to support this *Desk Reference*, maintains the ability to conduct screening-level B/C analysis for many Operations strategies, and is described in the tool's *User's Manual*. *Desk Reference* Chapter 4 presents additional discussion of other sketch-planning tools and methods appropriate to the project-screening task.

Analysts should take care in evaluating TSM&O strategies alongside more traditional improvements to ensure that the MOEs used in the analysis are appropriate to the strategy (see *Desk Reference* Chapter 3 for more information on the likely impacts of TSM&O strategies); and are consistent to the degree possible for the traditional and the TSM&O strategy. The input data and the tool/method used for analysis should also be made as consistent as possible to avoid introducing bias to the analysis.

Project Prioritization

The project prioritization process often requires more robust analysis than required during the preliminary project screening process. As such, project prioritization is more likely to include the analysis of project impacts using more rigorous and complex analysis tools and methods. Analysis of traditional infrastructure projects is often conducted using the regionally accepted travel demand model. As discussed above, however, regional travel demand models may present challenges to the assessment of any strategies designed to have greater impact during periods of incidents, inclement weather, or construction activity. Therefore, it is critical to be aware of these limitations and modify the travel demand model analysis to better incorporate these impacts (see *Desk Reference* Chapter 5 for additional discussion), or consider other compatible methods or combinations of methods that may better support the analysis.

Congestion Management Process

For many regions, the Congestion Management Process (CMP) is the focus of activities designed to fully consider and integrate TSM&O strategies alongside more traditional transportation capacity projects. The TSM&O analysts and managers should strongly coordinate with the CMP process to ensure that TSM&O sensitive MOEs are considered, and that any analysis structure established within the CMP to assess and compare the relative effectiveness and efficiency of various strategies in mitigating the identified regional deficiencies.

Additionally, many times within the CMP process, the opportunity exists to move beyond the analysis of individual strategies and evaluate various combinations of strategies and their effectiveness in mitigating deficiencies and providing efficient management and operations of the transportation system. This opportunity may require the analysis of combinations of TSM&O strategies, as well as the combination of TSM&O and strategies that are more traditional. The combinations of strategies may present analysis complexities. While many traditional capacity-enhancing strategies have been in use for years and their impacts are well documented, many TSM&O strategies have only been more recently deployed, and often have been deployed in limited applications. Therefore, it can be difficult to identify the likely impacts of combining different TSM&O strategies, particularly those that still represent emerging technologies.

2.4 Challenges and Limitations of B/C Analysis

Although B/C analysis provides a robust and comprehensive framework for comparing the relative efficiency of different projects, there are many challenges and limitations to its overall use, as well as specific challenges in assessing TSM&O projects. These challenges and limitations include:

- **B/C analysis provides a key piece of information that may be used in analyzing and prioritizing projects, but it is not the only information that should be considered.** The B/C ratio and net benefit information is a powerful element in the comparison of different investment opportunities; however, as discussed below, there are limitations to the analysis and many project considerations that may be difficult to capture within a B/C analysis. The user should remember that TOPS-BC is one of many available tools to assess benefits, see the *Desk Reference* for details of several tools. Hard-to-capture benefits such as improvements in community livability, changes in housing values, or impacts to disadvantaged communities, are difficult to fully assess and will not be assessed by TOPS-BC. Further, other project prioritization considerations such as political will and public acceptability will not be captured in the TOPS-BC analysis, yet may still play a role in prioritizing projects being considered for investment. Therefore, it is critical that the results of the B/C analysis be carefully combined with other non-quantifiable inputs in making final decisions regarding the relative effectiveness of various projects. The B/C ratio, while a critical input, but only one of many factors in the investment decision-making process.

- Many TSM&O strategies have been recently deployed or include emerging technologies, making it difficult to estimate their true impact. While many traditional capacity-enhancing strategies have been in use for years and their impacts are well documented, many TSM&O strategies have only been more recently deployed, and often have been deployed in limited applications. Therefore, estimates of the likely impact TSM&O strategies, particularly those that still represent emerging technologies, may need to be based on limited empirical data. *Desk Reference* Chapter 3 contains additional information about the impacts and benefits of various operations strategies. More benefits data is found on the U.S. DOT Joint Program Office (JPO) website benefits page at http://www.itsbenefits.its.dot.gov. Additionally, the TOPS-BC application maintains a number of look-up tables on the observed impacts of many TSM&O strategies related to a number of MOEs, as highlighted in Figures 2 through Figure 6.

- **Maintaining consistency in the analysis of TSM&O strategies and traditional capacity projects is frequently complex** due to varying analysis tools and methods, different MOEs, different analysis data inputs and sources, and different cost structures that are typically used to assess the various projects. As discussed further in *Desk Reference* Chapter 2, the analysis of varying strategies needs to be carefully planned in order to provide comparable and consistent results.

- **The quantification of benefits needs to be carefully planned and structured to avoid the double counting of benefits.** Double counting can occur in situations where there are overlaps in different benefits, or when a change to one benefit results in a direct change to another benefit. For example, a project to replace or upgrade traditional traffic signals to more efficient light emitting diodes (LED) signal lighting may be expected to result in a cost savings of $150,000 in electricity costs to an agency. In conducting a benefit/cost analysis of this project, the analyst should be cautious in not accounting for this impact, both as a benefit (a $150,000 gain to the agency), as well as a cost (a reduction of $150,000 in operating costs). This would result in a doubling of the actual benefit.

- **There may be difficulty in assessing hard-to-quantify impacts within the analysis.** Although B/C analysis should strive to be as comprehensive as possible in the MOEs and benefits quantified in the analysis, there are often some measures and benefits that prove extremely hard to quantify. In some cases, these hard-to-quantify benefits may include emerging measures, where a firm consensus has yet to be reached regarding the relationship between a change in transportation system performance and the long-term monetized benefit amount. Many agencies struggling to include better assessment of global climate change within their B/C analysis have faced this challenge. In other cases, the measure or benefit may be somewhat esoteric, complicating efforts to place a value on the benefit. As a result, many times the B/C analysis is supported by a more qualitative analysis of other impacts seen as benefits or disbenefits in the region, such as impacts on community livability or urban sprawl.
- **There are often challenges in weighing the analysis comprehensiveness against the available analysis resources.** Like many other types of analyses, there are substantial tradeoffs between the comprehensiveness of the analysis with the resources necessary to achieve that comprehensiveness. Likewise, achieving a higher level of confidence in the accuracy of the results often requires additional resources be made available for the analysis. The analyst must make decisions early in the design and set up of the analysis to balance these competing needs. For preliminary screening purposes, it may be acceptable to consider a few key MOEs – presumably those measures likely to be most significantly impacted by the projects being compared – and assessed at an order of magnitude scale. For more complex prioritization and in consideration of design, the analysis may need to be much more rigorous, involving multiple tools to support the assessment of many varying MOEs, and providing a high level of confidence in the analysis results. Chapter 4 of the Desk Reference provides a discussion of the tools and methods available for conducting B/C analysis, and previews the level of resources needed to conduct analysis using these methods.
- **TSM&O strategies that are targeted at mitigating unique, nonrecurring conditions may require additional analysis beyond the "average day" analysis typically used for recurring congestion projects.** TSM&O strategies, such as incident management systems, weather systems, evacuation strategies, and other strategies focused on nonrecurring or special events, may require special treatment in the analysis to assess the strategy's impact during these conditions and the likely frequency in which those conditions will be observed in order to quantify the benefits of the strategy. This is a

major departure from analysis of traditional capacity projects that are assessed during a typical day or peak period, and the results are anticipated to be identical on all other days. *Desk Reference* Chapter 5 provides an enhanced discussion of how the strategies affecting nonrecurring conditions may be evaluated.

- **It can be difficult in developing the B/C analysis framework to decide if particular impacts represent a new benefit (to users, society or the agency), or if the impacts represent a transfer of benefits from one group to another.** In a B/C analysis, transfers can occur if one group or segment of the population enjoys a new benefit, but does so at the expense of a new disbenefit or additional cost accruing to another group. For example, a deployment of a HOT lane on a corridor could likely increase the amount of revenue that an agency receives. This should not be treated as a benefit in the B/C analysis, however, since the added revenue to the agency is directly offset by the additional cost paid by the HOT lane users. This impact would be considered a transfer; and since the impacts of the increased revenue and the increased costs cancel the other out in the analysis, they should not be included in the B/C framework.

2.5 Data Items in TOPS-BC

The TOPS-BC spreadsheets were analyzed and all the costs and benefits data items were identified. The cost data items are listed in Table 1, the Benefits data items are listed in Table 2, and general parameters for TOPS-BC are listed in Table 3. Default values are available within the TOPS-BC program for most of these parameters where local data are not available. Supporting information for the default values is documented in the U.S. DOT's ITS Benefits and Costs databases.

http://www.itscosts.its.dot.gov/

Note that in Table 2-1, each cost item includes an element of deployment and components that comprise that element.

Table 2-1 List of Input Data Needed for Cost Estimates

Strategy	Element	Element Components
Traffic Management Center	Field communications and devices - communications	Communications hardware, installation, integration
	Field communications and devices - surveillance	CCTV cameras hardware, structure, installation, integration
	Field communications and devices - detectors	Detector hardware, structure, installation, integration
Traffic Management Center	TMC/TOC software	Control Software and systems integration
	TMC/TOC hardware	IT and communications hardware, installation and integration

Strategy	Element	Element Components
Traveler Information	Dynamic Message Signs (DMS)	Sign, structure, installation
	Highway Advisory Radio (HAR)	Radio, structure, installation
	Pre-Trip Traveler Information	System hardware, software, integration and labor
Traffic Signal Coordination Systems	Pre-set Timing	
	Traffic Actuated	Detector installation and maintenance
	Central Control	System software, integration and detector installation and maintenance
	Transit Signal Priority	System software, integration and transit vehicle device installation and maintenance
Ramp Metering	Pre-set Timing	
	Traffic Actuated	Detector installation and maintenance
	Central Control	System software, integration and detector installation and maintenance
Traffic Incident Management	TIM System	System hardware, including video wall, software, integration, labor costs, incident response vehicles
Advanced Travel Demand Management (ATDM) Speed Harmonization	Lane Speed Control system	Lane control signs, structures, installation, control system software, integration, VMS signs, structures installation, TMC labor
Employer Based Travel Demand Management	Trip planning and ride sharing program	Information Center hardware, installation, software, integration, labor
ATDM Hard Shoulder Running	Lane Control system	Lane control signs, structures, installation, control system software, integration, VMS signs, structures installation, TMC labor
ATDM High Occupancy Toll Lanes	HOT Lane Control System	Lane control signs, structures, installation, control system software, integration, VMS signs, structures installation, TMC labor, detectors. Toll processing hardware, software, integration, installation and labor
Road Weather Management	Weather information system	Weather stations, system hardware, software, integration and labor costs
Work Zone Management	Work zone control system	Portable DMS, camera, detector equipment, software, integration and labor costs

Table 2-2 List of Input Data Needed for Benefits Estimates

Benefits Category	Parameter	Units
Facility Characteristics	Link facility type	Functional classification
	Link length	Miles

Benefits Category	Parameter	Units
	Total number of lanes	Lanes
	Lane capacity	Vehicles per hour
	Free flow speed	Miles per hour
Facility Performance	Link volume	Vehicles per hour
	Congested speed (as defined by FDOT)	Miles per hour
	Vehicle miles traveled	Miles
	Volume to capacity ratio	N/a
	Vehicle hours traveled	Hours
	Incident related delay per vehicle per mile	Hours
	Number of fatality crashes	Crashes
	Number of injury crashes	Crashes
Facility Performance	Number of Property Damage Only Crashes	Crashes
	Fuel consumption	Gallons
Impacts due to Strategy	Change in capacity	Percent
	Change in speed	Percent
	Change in number of lanes	Percent
	Reduction in crash rate	Percent
Impacts due to Strategy	Reduction in Crash Duration	Percent
	Reduction in fuel use	Percent
	Percent time traveler information device is disseminating useful information	Percent
	Percent drivers using traveler information	Percent
	Minutes saved by drivers saving time	Minutes
Travel Time	Average person hours saved per period	Hours
	Value of person hour – "on the clock" auto for recurring traffic	Dollars per hour
Travel Time	Value of person hour – other auto for recurring traffic	Dollars per hour
	Value of person hour – truck for recurring traffic	Dollars per hour
	Value of person hour – "on the clock" auto for non-recurring traffic	Dollars per hour
	Value of person hour – other auto for non-recurring traffic	Dollars per hour
	Value of person hour – truck for non-recurring traffic	Dollars per hour
Advanced Traveler Information Systems (ATIS) Time Savings	Total hours saved due to ATIS deployments	Hours
Travel Time Reliability	Average total person hours of non-recurring delay saved per period	Hours

Benefits Category	Parameter	Units
Energy	Average cost of fuel (excluding taxes)	Dollars per gallon
Safety	Value of a fatality crash	Dollars
	Value of an injury crash	Dollars
	Value of a property damage only crash	Dollars

Table 2-3 List of General Input Parameters for Benefit and Cost Estimates

Category	Parameter	Units
General Parameters	Year of dollar in calculation	Year
	Annual inflation rate	Percent inflation
	Adjustment factor	
	Animalization factor	Number of periods per year
	Net present value calculation – time horizon	Years
	Traffic mix – percent trucks	Percent
	Traffic mix – percent "on the clock" autos	Percent
	Average auto occupancy	Persons per vehicle
	Discount rate	Percent
	Analysis time horizon	Years
Other Benefits Valuations	Non-fuel operating costs per VMT - auto	Dollars
	Non-fuel operating costs per VMT - truck	Dollars
	Emission pollutant cost per ton - CO	Dollars
Other Benefits Valuations	Emission pollutant cost per ton - CO	Dollars
	Emission pollutant cost per ton – CO_2	Dollars
	Emission pollutant cost per ton - Nox	Dollars
	Emission pollutant cost per ton – PM_{10}	Dollars
	Emission pollutant cost per ton - VOC	Dollars
Category	Parameter	Units
Other Benefits Valuations	Noise costs per VMT - auto	Dollars
	Noise costs per VMT - truck	Dollars
Energy	Fuel economy - autos	Miles per gallon
	Fuel economy - trucks	Miles per gallon
Performance	Speed/flow relationships table	
Safety	Crash rates table	Crashes per million VMT

3.0 Florida DOT Specific Applications of TOPS-BC

This section identifies the location of Florida DOT specific data and provides a detailed description of two Florida case studies using the TOPS-BC analysis tool.

3.1 How Can TOPS-BC Fit Into the FDOT Sketch Planning Process?

The TOPS/BC tool and reference manual would be appropriate for use in the following offices and agencies:

- FDOT Central Office Systems Planning;
- FDOT Central Office Operations;
- FDOT Environmental Management Office;
- District Planning units;
- District Operations units;
- District TSM&O units; and
- MPOs.

The applicability for each office is described below.

Systems Planning Office

The Florida DOT Systems Planning Office monitors a statewide and metropolitan planning process; performs various economic and demographic analyses, and evaluates transportation system performance. The programs and services conducted by the Office include Strategic Intermodal System (SIS) planning, Systems Management planning and travel demand modeling. Systems Management Planning has several aspects:

- Access Management;
- Multimodal Mobility Review;
- Interchange Access Request;
- Highway Capacity/Level of Service;
- Corridor Development;
- Site Impact Analysis; and
- Systems Management Training.

TOPS-BC is primarily applicable to the FDOT Corridor Development process, particularly in identifying potential alternatives and in evaluating operations alternatives.

The Systems Planning Office conducts corridor development studies that fall within the following categories:

- **Corridor:** A corridor study is the first step in planning for the future of a transportation facility. By defining the corridor's needs, the corridor plan will help focus planning efforts on the most significant problems and act as catalyst for discussion about how best to invest in the corridor.
- **Alternatives**: An alternatives study involves studying specific corridors and special study areas and developing recommended strategies or alternatives to implement improvement projects and programs. An alternate route analysis studies are conducted when an existing route may need realignment due to capacity or other constraints where further improvements of the route may be prohibitively expensive or impossible to construct. These studies generally explore the development of new state routes that would bypass urban congested areas.
- **Feasibility**: A Feasibility Study represents a definition of a problem or opportunity to be studied, an analysis of the current mode of operation, a definition of requirements, an evaluation of alternatives, and an agreed upon course of action. As such, the activities for preparing a Feasibility Study are generic in nature and can be applied to any type of project.

Table 3-1 compares the types of corridor development studies and highlights the studies that have alternative identification and evaluation components.

Table 3-1 Sketch Planning Studies Comparison

Study	Corridor	Alternative	Feasibility
Problems and Needs *Defining the key issues and opportunities*			
Existing Conditions and Needs Conduct technical analysis & data collection of existing conditions, including gathering relevant work performed in previous studies.	X	X	X
Future Conditions and Needs Develop future conditions based on various forecasted traffic and land use projections.	X	X	X
Alternative Options *Understanding and defining a range of options - including land use solutions*			
Identify range of alternative options	X	X	
Develop alternative options with concepts, planning level cost analysis and associated impacts.		X	
Evaluation *Comparing and initial screening of the proposed alternative options*			

Study	Corridor	Alternative	Feasibility
Identify criteria to evaluate and compare alternative options on a system level and alternative options performance			X
Narrowing alternative options down to which alternatives should be considered/compared in Project Development & Environment (PD&E)			X
Cost-Benefit Analysis			X
Implementation *Identify and itemize an implementation action plan including defining the appropriate phasing*		X	
Documentation			
Findings	X	X	X
Recommendations *(Short-term, mid-term and long-term)*	X	X	
Coordination and Outreach	X	X	X

*Source: http://www.dot.state.fl.us/planning/systems/programs/sm/corridor/default.shtm

For corridor studies, TOPS-BC provides information on the range of operations strategies available for deployment and can be used to help identify the range of alternative options. For alternatives studies, TOPS-BC will assist in identifying the range of available operations strategies and developing alternative options along with providing planning level cost estimates of operations strategies. TOPS-BC in feasibility studies provides more detail for the evaluation phase including a benefit-cost analysis for operations strategies.

The TOPS-BC is also useful in SIS corridor planning activities.

Operations Office

The Traffic Operations ITS Office will also find TOPS-BC useful when identifying and evaluation strategies for corridors and comparing various alternative packages. The benefits analysis can be useful to evaluate individual operations projects and for the development of the Ten Year Cost Feasible Plan.

Environmental Management Office

Project development and alternative evaluation occurs during the Project Development and Environmental (PD&E) process. Current efforts are underway to further integrate operational strategies into planning's project development process. The TOPS-BC tool can be used to evaluate TSM&O strategies during the project development process.

District Planning Units

FDOT Districts follow the same general process for planning and evaluating projects as the Systems Planning Office, described above. TOPS-BC will be useful in conducting corridor planning studies, PD&E studies and SIS corridor analysis.

TOPS-BC is useful when identifying project needs and for evaluation alternative strategies.

District Operations Units

The District Traffic Operations ITS Office will also find TOPS-BC useful when identifying and evaluating strategies for corridors and comparing various alternative packages. The benefits analysis can be useful to evaluate individual operations projects and for the development of the Districtwide Ten Year Cost Feasible Plan.

District TSM&O Units

The District Traffic Operations Transportations Systems Management and Operations (TSM&O) units will also find TOPS-BC useful when identifying and evaluating strategies for corridors and comparing various alternative packages. The benefits analysis can be useful to evaluate individual operations projects and for the development of the districtwide TSM&O plan.

Metropolitan Planning Organizations

MPOs will find TOPS-BC useful in developing the operations and ITS sections of the Long Range Transportation Plan (LRTP) and the Transportation Improvement Program (TIP). TOPS-BC provides the data needed for comparing operations/ITS projects with traditional capacity projects in the MPO project slating process.

3.2 Florida DOT Specific Data for TOPS-BC Input

There is Florida specific input data for almost all data items in the TOPS-BC spreadsheet. Some of the Florida DOT data is readily available while many data items will be difficult and expensive to obtain. The user should determine the difficulty of obtaining Florida data and the impact that data might have on the B/C output before initiating a major effort to collect that data item. As the user conducts the B/C analysis using TOPS-BC, only one or two strategies will likely be analyzed at one time. While the following lists of data items appear daunting, the user will likely only need a few items for their analysis.

An effort was made to identify a location for Florida specific data that can be input into the TOPS-BC analysis spreadsheets. Resources for Florida specific input were identified for each of the TOPS-BC data items listed in Tables 1, 2 and 3. Most of the data are in databases managed by various offices within Florida DOT. A contact is listed for the data items where one is known. Tables 4, 5 and 6 list the data items with resource locations and contacts for the costs, benefits, and general parameters. Local (or District specific) costs should be used for each element whenever possible. The statewide pay item can be used when a local item is not available. The TOPS-BC spreadsheets also include national default values for most elements, which may be used if no local or Florida specific data is available.

Note that in Table 3-2, each cost item includes an element of deployment, components that comprise that element and the FDOT source to obtain costs of that element.

Table 3-2 Florida Resources for TOPS-BC Cost Input Data

Strategy	Element	Element Components	Data Source
Traffic Management Center	Field communications and devices - communications	Communications hardware, installation, integration	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
	Field communications and devices - surveillance	CCTV cameras hardware, structure, installation, integration	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
Traffic Management Center	Field communications and devices - detectors	Detector hardware, structure, installation, integration	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
	TMC/TOC software	Control Software and systems integration	ITS Office Contact: Clay Packard (850) 410-5623 clay.packard@dot.state.fl.us
	TMC/TOC hardware	IT and comm hardware, installation and integration	FDOT District TMCs
Traveler Information	Dynamic Message Signs (DMS)	Sign, structure, installation	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
	Highway Advisory Radio (HAR)	Radio, structure, installation	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
	Pre-Trip Traveler Information	511 System hardware, software, integration and labor	ITS Office Contact: Gene Glotzbach (850) 410-5616 gene.glotzbach@dot.state.fl.us
Traffic Signal Coordination Systems	Pre-set Timing	Signal hardware	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
Traffic Signal Coordination Systems	Traffic Actuated	Detector installation and maintenance	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
	Central Control	Software, integration detector installation and maintenance	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
	Transit Signal Priority	System software, integration and	ITS Office by pay item

Strategy	Element	Element Components	Data Source
		transit vehicle device installation and maintenance	Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
Ramp Metering	Pre-set Timing		ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
Ramp Metering	Traffic Actuated	Detector installation and maintenance	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
	Central Control	System software, integration and detector installation and maintenance	In District 6 Contact: Rory Santana rory.santana@dot.state.fl.us
Traffic Incident Management	TIM System	System hardware, including video wall, software, integration, labor costs, incident response vehicles	ITS Office Contact: Paul Clark (850) 410-5607 paul.clark@dot.state.fl.us.
Advanced Travel Demand Management (ATDM) High Occupancy Toll Lanes	HOT Lane Control System	Lane control signs, structures, installation, control system software, integration, VMS signs, structures installation, TMC labor, detectors. Toll processing hardware, software, integration, installation and labor	In District 6 Contact: Rory Santana rory.santana@dot.state.fl.us
Road Weather Management	Weather information system	Weather stations, system hardware, software, integration and labor costs	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us
Work Zone Management	Work zone control system	Portable DMS, camera, detector equipment, software, integration and labor costs	ITS Office by pay item Contact: Missy Hollis (850) 414-4182 Melissa.hollis@dot.state.fl.us

Table 3-3 shows the Florida resources for TOPS-BC benefits input data. The table includes a benefits category, the parameters that will be assigned a value within each category, the units of the parameter, and a Florida data resource for local values of the parameter. The right hand column indicates a recommended value to be used in FDOT TOPS-BC applications. The recommendation is based on the practical availability (ease of the resource office to provide the data), experience in developing TOPS-BC evaluations, and whether the parameter will likely cause any discernable change in the TOP-BC results (many parameters can be changed to a local value, however, the results typically show no sensitivity to that change).

Table 3-3 Florida Resources for TOPS-BC Benefits Input Data

Benefits Category	Parameter	Units	Data Source	Recommended Value
Facility	Link facility type	Functional	Roadway Characteristics	FDOT RCI

Benefits Category	Parameter	Units	Data Source	Recommended Value
Characteristics		classification	Inventory feature 121	
	Link length	Miles	State Transportation Improvement Plan (STIP) Online STIP report or on-line mapping	FDOT RCI or on-line mapping
	Total number of lanes	Lanes	State Transportation Improvement Plan (STIP) Online STIP report or on-line mapping	FDOT RCI or on-line mapping
	Lane capacity	Vehicles per hour	LOSPLAN analysis outputs adjusted capacity	LOSPLAN output or TOPS-BC default
	Free flow speed	Miles per hour	Roadway Characteristics Inventory feature 311 - Posted speed plus 5 mph	Posted speed plus 5 mph
Facility Performance	Link volume	Vehicles per hour	Florida Traffic Online	Florida Traffic Online
	Congested speed (as defined by FDOT	Miles per hour	LOSPLAN analysis outputs congested speeds	LOSPLAN output, or SunGuide
Facility Performance	Vehicle miles traveled	Miles	FDOT Public Road Mileage (DVMT) and Travel Report	FDOT Public Road Mileage (DVMT) and Travel Report
	Volume to capacity ratio	N/a	LOSPLAN analysis outputs v/c ratio	LOSPLAN output or TOPS-BC default
	Vehicle hours of travel	Hours	LOSPLAN analysis outputs vehicle travel time	LOSPLAN output or TOPS-BC default
	Incident related delay per vehicle per mile	Hours	RITIS or SunGuide report	TOPS-BS default
	Number of fatality crashes	Crashes	Florida Traffic Safety Portal – All Roads Crash Analysis	TOPS-BS default
	Number of injury crashes	Crashes	Florida Traffic Safety Portal – All Roads Crash Analysis	TOPS-BS default
	Number of Property Damage Only Crashes	Crashes	Crash Analysis Reporting (C.A.R.) internal system	TOPS-BS default
	Fuel consumption	Gallons	Use defaults	TOPS-BS default
Impacts due to Strategy	Change in capacity	percent	LOSPLAN analysis outputs adjusted capacity	TOPS-BS default
	Change in speed	percent	LOSPLAN analysis outputs speeds	TOPS-BS default

Benefits Category	Parameter	Units	Data Source	Recommended Value
	Change in number of lanes	percent	State Transportation Improvement Plan (STIP) Online STIP report	TOPS-BS default
	Reduction in crash rate	percent	Either the HSM or Safety Analyst software	TOPS-BS default
	Reduction in crash duration	percent	Either the HSM or Safety Analyst software	TOPS-BS default
	Reduction in fuel use	percent	Use defaults	TOPS-BS default
	Percent time traveler information device is disseminating useful information	percent	Use defaults	TOPS-BS default
	Percent drivers using traveler information	percent	Survey travelers	TOPS-BS default
Travel Time	Minutes saved by drivers saving time	minutes	Before and after LOSPLAN speed analysis	TOPS-BS default
	Average person hours saved per period	hours	LOSPLAN analysis outputs vehicle travel time	TOPS-BS default
	Value of person hour – "on the clock" auto for recurring traffic	Dollars per hour	Regional median annual wage converted to hourly dollars - US Census	TOPS-BS default
	Value of person hour – other auto for recurring traffic	Dollars per hour	60% regional median annual wage converted to hourly dollars - US Census	TOPS-BS default
	Value of person hour – truck for recurring traffic	Dollars per hour	Regional median annual wage converted to hourly dollars - US Census	TOPS-BS default
	Value of person hour – "on the clock" auto for non- recurring traffic	Dollars per hour	Regional median annual wage converted to hourly dollars - US Census	TOPS-BS default
	Value of person hour – other auto for non-recurring traffic	Dollars per hour	60% regional median annual wage converted to hourly dollars - US Census	TOPS-BS default

Benefits Category	Parameter	Units	Data Source	Recommended Value
	Value of person hour – truck for non-recurring traffic	Dollars per hour	Regional median annual wage converted to hourly dollars - US Census	TOPS-BS default
Advanced Traveler Information Systems (ATIS) Time Savings	Total hours saved due to ATIS deployments	hours	CORSIM to gather before and after travel times	TOPS-BS default
Travel Time Reliability	Average total person hours of non-recurring delay saved per period	hours	HERE or INRIX ITS data	HERE or INRIX ITS data
Energy	Average cost of fuel (excluding taxes)	Dollars per gallon	www.floridastategasprices.com	www.floridastategasprices.com
Safety	Value of a fatality crash	dollars	Federal Highway Administration website	TOPS-BS default
	Value of an injury crash	dollars	Federal Highway Administration website	TOPS-BS default
Safety	Value of a property damage only crash	dollars	Federal Highway Administration website	TOPS-BS default

Table 3-4 shows the Florida resources for TOPS-BC general parameter input data. The table includes a general parameter category, the parameters that will be assigned a value within each category, the units of the parameter, and a Florida data resource for local values of the parameter. The right hand column indicates a recommended value to be used in FDOT TOPS-BC applications. The recommendation is based on the practical availability (ease of the resource office to provide the data), experience in developing TOPS-BC evaluations, and whether the parameter will likely cause any discernable change in the TOPS-BC results (many parameters can be changed to a local value, however, the results typically show no sensitivity to that change).

Table 3-4 Florida Resources for TOPS-BC General Parameter Input Data

Category	Parameter	Units	Data Source	Recommended Value
General Parameters	Year of dollar in calculation	Year	Year of study, or user defined	User defined
	Annual inflation rate	Percent inflation	http://www.usinflationcalculator.com/	http://www.usinflationcalculator.com/

Category	Parameter	Units	Data Source	Recommended Value
	Adjustment factor		Calculated by TOPS-BC tool	TOPS-BC default
	Annualization factor	Number of periods per year	User defined	User defined
	Net present value calculation – time horizon	Years	User defined	User defined
	Traffic mix – percent trucks	percent	FDOT Roadway Characteristics Inventory	RCI
	Traffic mix – percent "on the clock" autos	percent	Percent work or business trips from travel demand model	TOPS-BC default
	Average auto occupancy	Persons per vehicle	Travel demand model	Regional travel demand model
	Discount rate	percent	Office of Management and Budget (OMB) in Circular 94C	OMB or TOPS-BC default
	Analysis time horizon	Years	User defined	User defined
Other Benefits Valuations	Non-fuel operating costs per VMT - auto	dollars	http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_03_17.html	TOPS-BC default
	Non-fuel operating costs per VMT - truck	dollars	*An Analysis of the Operational Costs of Trucking: An Analysis of the Operational Costs of Trucking: A 2012 Update.*	TOPS-BC default
	Emission pollutant cost per ton - CO	dollars	Use defaults	TOPS-BC default
Other Benefits Valuations	Emission pollutant cost per ton – CO_2	dollars	Use defaults	TOPS-BC default
	Emission pollutant cost per ton - Nox	dollars	Use defaults	TOPS-BC default
	Emission pollutant cost per ton – PM_{10}	dollars	Use defaults	TOPS-BC default
	Emission pollutant cost per ton - VOC	dollars	Use defaults	TOPS-BC default
	Noise costs per VMT - auto	dollars	Use defaults	TOPS-BC default
	Noise costs per VMT - truck	dollars	Use defaults	TOPS-BC default
Energy	Fuel economy - autos	Miles per gallon	http://www.fueleconomy.gov/	TOPS-BC default
	Fuel economy - trucks	Miles per gallon	http://www.fueleconomy.gov/	TOPS-BC default
Performance	Speed/flow relationships table		TOPS-BC spreadsheet, user can modify	TOPS-BC default
Safety	Crash rates table	Crashes per million VMT	Florida Traffic Safety Portal – All Roads Crash Analysis	TOPS-BC default

3.3 Case Study 1: I-95 Express Lanes in Miami

95 Express Lanes Project Overview

95 Express Managed Lanes began operating Phase 1A in December 2008, providing travelers with an alternative to the congested general purpose travel lanes between downtown Miami and the Golden Glades Interchange to the north. The project was funded by U.S. DOT's Urban Partnership Agreement Congestion Reduction Demonstration program. The Urban Partnership Agreement (UPA) is an agreement between the U.S. DOT and the U.S. DOT's Miami-Area Urban Partner, consisting of the FDOT, the Miami-Dade and Broward MPOs, MDT, BCT, the Miami-Dade Expressway Authority, and Florida's Turnpike Enterprise. The UPA was formed to address the problem of congestion, and it consists of two components: (1) converting HOV lanes into Managed Use Lanes (MULs) and (2) implementing Bus Rapid Transit services within the portions of the newly converted lanes. The UPA funded the construction of the MULs and the capital portion of the transit using Federal Funds. Revenue generated from 95 Express tolls support the Operations & Maintenance of the transit service.

95 Express was scheduled to be constructed in the following phases:

- Phase 1A opened in December 2008 and runs northbound on I-95 from I-195/SR-112 to the Golden Glades area just north of 151st Street in Miami-Dade County. Phase 1B opened for tolling in January 2010 and runs southbound on I-95 from just south of Miami Gardens Drive/NW 186th Street to just north of I-395/SR-836. Phase 1B also extended the northbound express lanes further to the south from just north of I-195/SR 112 to I-395/SR-836. In this report, where it states Phase 1, it refers to both Phase 1A and Phase 1B.
- Phase 2 construction started on November 28, 2011, and will last approximately three years. Phase 2 will extend the express lanes to provide a continuous facility between I-395/SR-836 in Miami-Dade County and Broward Boulevard in Broward County. Phase 2 Express Lanes should be operational near the end of 2014.

The UPA calls for additional Bus Rapid Transit service as part of Phase 2 implementation, and FDOT will be working closely with BCT and MDT to plan the additional service.

The 95 Express project involved replacing one high occupancy vehicle (HOV) lane in each direction with two variable-priced managed lanes in each direction that allow registered carpools of three or more occupants to travel free, together with enhanced express bus services. The number of general purpose lanes and shoulders were restriped in order to provide for the same number of lanes as before, four in each direction, with the lanes and shoulders being slightly narrower. The result was to improve the peak-period operations on this corridor through:

- Increased vehicle and person throughput;
- Increased travel speeds;
- Improved travel time reliability; and
- Enhanced transit service.

These improvements resulted largely from increased capacity due to the addition of one travel lane in each direction. This was accomplished within the existing right-of-way by relying on design variances for roadway lane and shoulder widths. However, the addition of 12 peak hour express buses and accommodating registered vanpools and carpools have been a valuable contributor to the successful management of this corridor for reliable peak period travel.

I-95 Express Lanes – TOPS-BC Analysis Assumptions and Limitations

There were many assumptions that went into the TOPS-BC analysis for the 95 Express Lanes case study. In addition, several limitations should be noted:

Costs

- Total Phase 1 construction cost from FDOT District 6 = $132,000,000 (includes roadway construction, ITS and tolling equipment installation.
- Tolling software cost for adding module to FDOT SunGuide = $2,000,000
- Project life cycle is 25 years
- Expected life cycle is 10 years for ITS equipment, project start was 2008
- Replacement costs, assumes two replacements over the 25 year life cycle.
  - CCTV = 40 x 2 x $24,000 = $1,920,000
  - MVDS = 54 x 2 x $10,000 = $1,080,000
  - DMS (brick) = 18 x 2 x $50,000 = $1,800,000
  - DMS (full matrix) = 22 x 2 x $135,000 = $5,940,000
- Total Capital + replacement cost = $142,740,000
- Express lane = 9 miles, D6 total ITS Miles Managed = 48.1, Express lanes are 18.7% of total miles managed by ITS, use 25% of total ITS budget (Express Lanes are more tightly managed.
- 2012-2013 FDOT District 6 ITS Operating cost = $17,100,950
- Assumed 95 Express Lanes annual operating cost = 25% x $17,100,950 = $4,275, 237

Benefits

- Current volume and speed data was obtained from the 95 Express Monthly Operations Report provided by FDOT District 6. The volumes and speeds used in the analysis were from the December 2013 report.
- The monthly operations report provides volumes in terms of 3-hour peak periods. The reported periods are 6:00-9:00 a.m. for southbound and 4:00-7:00 p.m. for northbound. The length of analysis period is then 3 hours.
- The number of general-purpose lanes throughout the corridor is four lanes in each direction. There are two express lanes in each direction.
- The FDOT Systems Planning Office standard for free flow speed is the speed limit plus 5 mph. The speed limit in all lanes in the I-95 corridor is 55 mph. The free flow speed should then be 60 mph. In this case study it is important to use the differential speeds in the express lanes and in the general purpose lanes. The speed used is the 95 Express Monthly Operations Report is an average overall speed by direction (for GP lanes - 57 mph SB, 56 mph NB, for Express lanes – 66 mph SB, 64 mph NB). This study used the speeds reports in the 95 Express December 2013 monthly report.
- The case study corridor length is 9 miles.
- FDOT District 4 and 6 has been monitoring the I-95 High Occupancy Vehicle lanes for many years. The 2008 HOV Monitoring Report provided an analysis of the HOV and GP lane operations (before tolling was initiated) just prior to opening the Express Lanes. The baseline congested speeds were obtained from this 2008 HOV Monitoring Report. The speeds reported were from two segments: Golden Glades Interchange to 125th Street and 125th Street to I-195 (SR 112), these two sets of reported speeds were averaged. The baseline speeds used for the a.m. SB period were 15.0 mph in the GP lanes and 20.5 mph in the HOV lane. The baseline speeds used for the p.m. NB period were 20.9 mph in the GP lanes and 27.2 mph in the HOV lane.
- The number of analysis periods was assumed 250, which is the average number work days in a year (total days minus weekends and holidays). This assumption is because most benefits are accrued during the peak periods in the peak direction.
- National average (default) input data was used for crashes, fuel price, and the value of time. This was due to that data being difficult to collect and summarize or not being available.

Limitations

- While TOPS-BC does includes the benefits due to time savings in recurring and non-recurring travel during each analysis period, the impacts of improvements due to improved travel time reliability are not included.
- TOPS-BC does not have a trip assignment or mode choice module, therefore the operations strategy analysis only accounts for the number of trips given

for each corridor, there are no trip diversions or mode changes due to congestion.

- TOPS-BC will provide conservative estimates of benefits because only the benefits accrued during the selected time period are calculated. In many cases, additional benefits may be produced in off-peak times that are not included.
- Changes in air quality due the operations strategies are not accounted for in TOPS-BC.

Conducting the FDOT District 6 I-95 Express Lanes Case Study

The following are the steps to enter input data for the 95 Express Lanes case study. Note that separate TOPS-BC calculations are required for each of the northbound and southbound directions. The steps are the same for each direction but the volumes and speeds input are different. The same cost figures were calculated for each direction; however, the actual cost must be divided by two so that a separate B/C ratio can be calculated for each direction. The costs are then added back together to obtain a total project B/C ratio.

Costs

1. Open the TOPS-BC spreadsheet template
2. Click on the ATDM High Occupancy Toll Lanes page under section 3 – Estimate Costs
3. Since this analysis assumes that the Express Lanes were added to the existing I-95 roadway, we will assume that there is no cost for the existing road and ITS equipment and the Express Lanes project is an incremental addition
4. Change the title under the Incremental Deployment Equipment first row to Project Total Cost
5. Using the cost assumptions described in the preceding Assumptions sections, enter $144,740,000 in the Capital/Replacement Costs column
6. Using the cost assumptions described in the preceding Assumptions sections, enter $4,275,237 in the O & M Costs column
7. Enter 25 years into the Useful Life column. This assumes a relatively long life for the project. Actually, after 25 years some type of reconstruction or repair, which will cost less than the original investment, will be more likely than a complete reconstruction.
8. Enter zero into the Number of Infrastructure Deployments green box
9. Enter one into the Number of Incremental Deployments green box
10. Enter 2008 into the Year of Deployment green box

The spreadsheet immediately calculates the Average Annual Cost as an output. This is the annualized initial capital cost plus the annualized replacement cost (for two equipment replacements over the 25 year life of the project) plus the annual operating and maintenance costs for the portion (assume to be 25%) of the total District 6 ITS O&M budget.

See Figure 3-1 and Figure 3-2 for a screenshots of the costs page for this case study.

Figure 3-1 TOPS-BC ATDM High Occupancy Toll Lanes Costs Page (part 1)

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

Other Strategies: ATDM High Occupancy Toll Lanes

Equipment	Useful Life	Capital / Replacement Costs (Total)	O&M Costs (Annual)	Annualized Costs
Basic Infrascture Equipment				
TMC Lane Control Hardware	5			$ -
TMC System Integration	20		$ -	$ -
TMC Lane Control Software	2			$ -
TMC Labor		$ -		$ -
Toll Processing Center Hardware	10			$ -
Toll Processing Center Software	10			$ -
Toll Processing Center Labor		$ -		$ -
Communications	20			$ -
TOTAL Infrastructure Cost		$ -	$ -	$ -

Figure 3-2 TOPS-BC ATDM High Occupancy Toll Lanes Costs Page (part 2)

Incremental Deployment Equipment					
Incremental costs for HOT lane deployments are extremely variable depending on the type of deployment.					
User should enter and edit costs appropriate to their planned strategy. Example costs include:					
Project total cost		25	$142,740,000	$ 4,275,237	$ 9,984,837
					$ -
					$ -
					$ -
					$ -
TOTAL Incremental Cost			$142,740,000	$ 4,275,237	$ 9,984,837
INPUT	Enter Number of Infrastructure Deployments	0			**$ -**
INPUT	Enter Number of Incremental Deployments	1			**$ 9,984,837**
INPUT	Enter Year of Deployment	2008			
Average Annual Cost					**$ 9,984,837**

Benefits

The steps for the benefits calculations are described for the southbound direction. The step for the northbound direction must use a separate TOPS-BC spreadsheet template, but they are identical. Refer to the benefits assumptions described above.

1. Click on ATDM HOT Lanes under Section 4 - Estimate Benefits. Input data into the Facility Characteristics section.
2. Enter 3 into the Length of Analysis Period (hours) green box. The volumes were provided by District 6 for a three hour (6:00-9:00 a.m.) peak period for the SB direction.
3. Enter the volume for the general purpose lanes, in this case it is 17397, as reported in the Express Lanes Operations December 2013 Monthly Report. Enter the volume into the Freeway General Purpose Volume green box
4. Enter 4 into the Freeway General Purpose Number of Lanes green box
5. Enter 57 into the General Purpose Free Flow Speed green box. This is the overall average speed report in the Express Lanes Monthly Operations Report for December 2013 for the GP lanes.

6. The capacity for the general purpose lanes is then calculated by the TOPS-BC spreadsheet as an output.
7. Enter 9 into the Freeway Link Length green box. This is the total project corridor length in miles. This covers phase 1 of the Express Lanes project, which what is operational at this time (March 2014).
8. Enter the volume into the Freeway HOV Volume green box. In this case, it is 8877, as reported in the Express Lanes Operations December 2013 Monthly Report.
9. Enter two into the Freeway HOV Number of Lanes green box.
10. Enter 66 into the Freeway HOV Free Flow Speed green box. This is the overall average speed report in the Express Lanes Monthly Operations Report for December 2013 for the Express Lanes.
11. Enter 6600 into the Baseline Override for Freeway HOV Capacity. This is the capacity of the "before" condition for one HOV lane.
12. The capacity for the freeway HOV lanes is then calculated by the TOPS-BC spreadsheet as an output.
13. Now input data into the Facility Performance section.
14. First for the Freeway General Purpose Performance area, enter the GP lanes speed for the corridor obtained before the project was implemented (in this case, prior to 2008) into Congested Speed row for the Baseline Override column. If that baseline speed is not known, it could be estimated by using the MPO's modeled speed for that corridor. In this case, the 2008 speed was found in the I-95 HOV Monitoring Report, which is 15 mph.
15. Then in the Congested Speed row, enter the current corridor speed (in this case the SB a.m. peak period speed) into the Improvement Override column, which is 46 mph.
16. Repeat these two steps for the Freeway HOV Performance area. Insert 2008 corridor speed (20.5 mph) into the Congested Speed row, Baseline Override column and the current corridor speed (64 mph) into Congested Speed row, Improvement Override column.
17. Enter 250 into the Number of Analysis Periods per Year green box.

The spreadsheet output is that it immediately calculates the Total Average Annual Benefit. All of these steps are repeated for the northbound TOPS-BC spreadsheet using the appropriate northbound volumes and speeds.

All of the green boxes may be used to enter additional local data if data is available. In this case study, there may have been crash data and value of time data available by conducting extensive analysis. However, previous studies have indicated that local data does not usually vary significantly from the national default data and it was decided that the effort to obtain local for crashes and time value was not worthwhile. Additionally there is a need for data collected over a long period of time, especially for injuries and fatalities, since small sample can skew the results.

See Figure 3-3 for a screenshot of the benefits page for the southbound direction in this case study.

Figure 3-3 TOPS-BC ATDM High Occupancy Toll Lanes Benefits Page (part 1)

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

Estimate Benefits of TSM&O Strategies

Strategy: HOT Lanes

Restore

Length of Analysis Period (Hours): 3

Cost Information

Facility Characteristics

Link Facility Type: Urban Freewa

	Input	Default	Baseline Override	Baseline	Improvement Override	Improvement	Change
Freeway General Purpose Volume	17397						
Freeway General Purpose Number of Lanes	4						
Freeway General Purpose Capacity		26400		26400		26400	0
General Purpose Free Flow Speed (MPH)	57	55					
Freeway Link Length	9						
Freeway HOV Volume	8877						
Freeway HOV Number of Lanes	2						
Freeway HOV Capacity		13200	6600	13200		6533.643123	0
HOV Free Flow Speed (MPH)	66	55					

Facility Performance

Freeway General Purpose Performance	Baseline Override	Baseline	Improvement Override	Improvement	Change
Congested Speed	15.000	51.376	48.000	51.320	33.000
Volume		17397.000		17486.250	
Vehicles Miles Traveled (VMT)		156573.0000		157376.2500	803.2500
V/C		0.6590		0.6624	0.0034
Vehicle Hours of Travel		10438.2000		3278.6719	-7159.5281
Incident Related Delay (hours) per vehicle per mile		2.39513E-07		0.000454976	0.000454737
Number of **Fatality** Crashes		1.03338E-05		1.03868E-05	5.30145E-08
Number of **Injury** Crashes		7.45757E-04		7.49583E-04	3.82588E-06
Number of **Property Damage Only** Crashes		9.66212E-04		9.71169E-04	4.956686E-06
Fuel consumption (Gallons)		7370.2155		7408.0262	37.8106

Freeway HOV Performance	Baseline Override	Baseline	Improvement Override	Improvement	Change
Congested Speed	20.500	22.115	64.000	22.684	43.500
Volume		8877.000		8787.750	
Vehicles Miles Traveled (VMT)		79893.0000		79089.7500	-803.2500
V/C		1.3450		1.3315	-0.0135
Vehicle Hours of Travel		3897.2195		1235.7773	-2661.4422
Incident Related Delay (hours) per vehicle per mile		0.000206346		0.026913347	0.026707001
Number of **Fatality** Crashes		5.27294E-06		5.21992E-06	-5.30145E-08
Number of **Injury** Crashes		6.43977E-04		6.34401E-04	-9.57617E-06
Number of **Property Damage Only** Crashes		9.62323E-04		9.43803E-04	-1.85201E-05
Fuel consumption (Gallons)		3760.7291		3722.9184	-37.8106

Figure 3-4 TOPS-BC ATDM High Occupancy Toll Lanes Benefits Page (part 2)

Impacts Due to Strategy	**Facility improvement models**			
	Change in HOV Capacity (%)		-1.00541%	
Travel Time	Average Person Hours of Travel Saved per Period			16401.0204
	$ 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	
	Total Recurring (Non-delay) Travel Time Benefit per Period			$ 298,498.57
TTR	Average Total Person Hours of Incident Related Delay Saved per Period			-3682.1862
	$ 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	
	Total Incident Related Delay Benefit per Period			$ (67,015.79)
Energy	Average cost per gallon of fuel (excluding taxes)		$ 3.67	
	Total Fuel Savings Benefit			$ (0.00)
Safety	$ Value of a Fatality Crash		$ 6,500,000	
	$ Value of a Injury Crash		$ 67,000	
	$ Value of a Property Damage Crash		$ 2,300	
	Total Modeled Crash Related Benefit per Period			$ (0.61)
	User Entered Benefit (Annual $'s)			
	Number of Analysis Periods per Year	250	250	
TOTAL AVERAGE ANNUAL BENEFIT				$ 57,870,542.57

Findings of the FDOT District 6 I-95 Express Lanes Case Study

Based on the northbound and southbound benefits and costs calculations using the TOPS-BC spreadsheet, the results are shown in Table 7 below.

Table 3-5 Benefits and Costs for the I-95 Express Lanes Case Study

Corridor	Peak Time / Direction	Benefits	Costs	B/C Ratio
I-95	PM NB	$11,723,238	$4,992,418	2.35
I-95	a.m. SB	$57,870,543	$4,992,419	11.59
Total System		$69,593,591	$9.984,837	6.97

The large difference between the AM and PM peak numbers is due to the AM SB direction experiencing greater congestion (slower congested speed) than the PM NB peak period.

3.4 Case Study 2: Palm Beach County Living Laboratory Arterial Management System

Palm Beach County Living Laboratory Arterial Management System Overview

FDOT District 4 in collaboration with Palm Beach County Traffic Engineering Department (PBC TED)initiated the "Living Lab" pilot project in 2012 to actively monitor, manage, and improve arterial operations along three major east-west corridors – Okeechobee Boulevard, Belvedere Road, and Southern Boulevard between SR 7 and I-95. As part of this initiative, FDOT District 4 installed several CCTV cameras and BlueTOAD vehicle detection devices along these corridors to monitor traffic conditions and collect travel times in real-time. In addition, FDOT District 4 provided staffing resources at the Palm Beach County Traffic Management Center to monitor real-time traffic conditions, detect incidents, and support Palm Beach County Signal Timing staff in implementing real-time signal timing changes to improve traffic flow and reduce motorist delay. Also, FDOT District 4 Freeway ITS staff and Palm Beach County Signal Timing Engineers work together to improve freeway-arterial coordination during incidents on I-95 in Palm Beach County. The hours of operation are Monday through Friday from 7a.m. to 7p.m.. Figure 3-5 and Figure 3-6 shows the location of the Living Lab and device locations along the instrumented roadways.

Figure 3-5 Palm Beach Living Lab Coverage

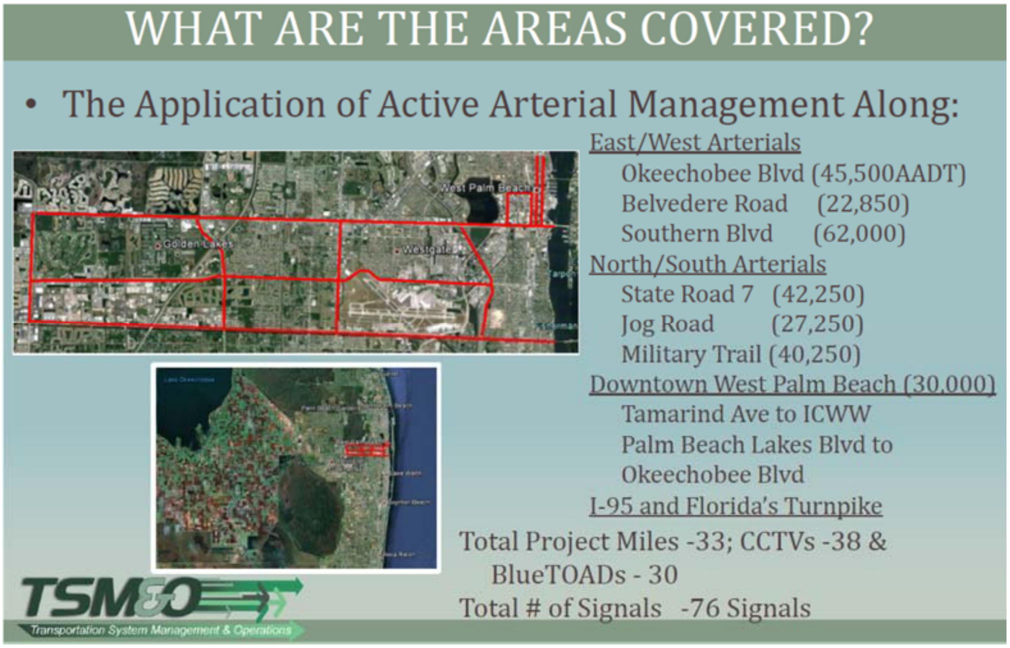
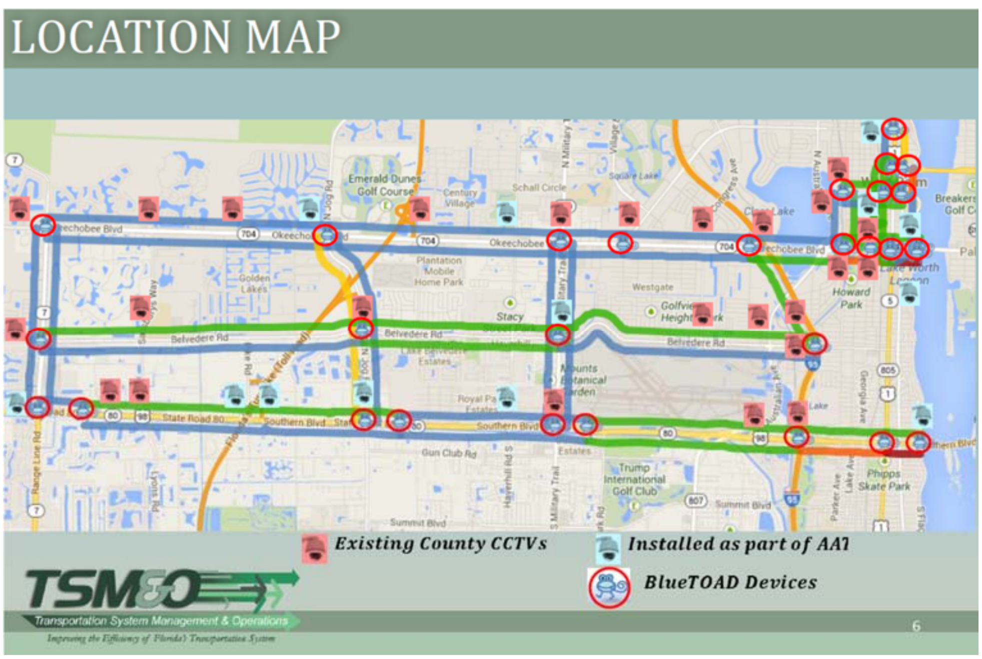


Figure 3-6 Palm Beach Living Lab Device Locations



Palm Beach Living Lab– TOPS-BC Analysis Assumptions and Limitations

There were many assumptions that went into the TOPS-BC analysis for the Palm Beach Living Lab case study. Also, several limitations should be noted. These are listed below.

Costs

- Costs for implementing and operating the Living Lab project were provided by the PBC TED. The costs of equipment and devices installed in the study area (along with operations and maintenance costs) were assigned to the Incremental Deployment cost. Several costs were also provided by PBC that are used to manage the entire countywide traffic control system, i.e. TMC operators, incident management software, ATMS.now license, and INRIX data subscription. These costs were assigned to the basic infrastructure costs because they are needed to operate the countywide traffic signal system with or without the Living Lab project.

Benefits

- It is not possible to analyze more than one corridor at time using TOPS-BC. For this case study, separate TOPS-BC spreadsheet was set up for each of the six primary corridors in the study area. A process to determine and overall B/C ratio for the Living Lab program is described later in this section.
- Link volume data was obtained from intersection counts conducted periodically by the Palm Beach County Traffic Engineering Department. The volumes are part of a countywide traffic count program and were counted on a rotating basis between 2010 and 2013. The link volume used in the calculation was determined by averaging the approach volumes of each intersection available in the intersection count program for the corridor (considering the east/west approaches on Okeechobee, Belvedere and Southern and the north/south approaches on Military, Jog and SR 7) and using the highest average volume as the volume in the spreadsheet. An example of the volumes for Okeechobee Blvd. is shown in Table 3-6. The volumes in the count program are defined by approach, EA is the east approach or westbound. The peak volume is the p.m. peak hour in the east approach (westbound).

Table 3-6 Okeechobee Blvd. Volume Counts

Okeechobee Blvd Volume Counts									
Road	**Intersection**	**AM NA**	**AM SA**	**AM EA**	**AM WA**	**PM NA**	**PM SA**	**PM EA**	**PM WA**
Okeechobee Blvd	at I-95	0	1497	2667	2141	0	1730	3082	2474
Okeechobee Blvd	at Australian Avenue	grade separated							

Okeechobee Blvd Volume Counts									
Road	**Intersection**	**AM NA**	**AM SA**	**AM EA**	**AM WA**	**PM NA**	**PM SA**	**PM EA**	**PM WA**
Okeechobee Blvd	at Congress Avenue	581	556	1825	1775	695	665	2182	2123
Okeechobee Blvd	at Military Trail	1257	1251	2172	2110	1468	1461	2536	2464
Okeechobee Blvd	at Haverhill Road	851	754	2104	2138	960	850	2373	2412
Okeechobee Blvd	at Jog Road	1169	1196	2249	2261	1216	1245	2341	2354
Okeechobee Blvd	at Sansbury's Way	139	311	2148	1974	147	329	2277	2092
Okeechobee Blvd	at SR 7	805	1513	1909	1668	1296	2437	3074	2687
Sum Total				15074	14068			17866	16606
Average				2153	2009			2552	2372

- The highest total volume is the sum of the east approaches. The average peak approach volume is 2552, this is a one hour volume. Each of the other corridor volume inputs was determined in this manner.
- Speeds were obtained from the Palm Beach County Traffic Engineering Department (PBC TED) also. The FDOT Systems Planning Office standard for free flow speed is the speed limit plus 5 mph. The speed limit varies in sections of the corridors between 35 and 50 mph. The free flow speed should then be between 40 and 55 mph. In this case study PBC TED provided data that allowed the free flow speed to be determined by averaging off-peak travel times along each corridor using the Bluetooth detectors and calculating the average speed over several months. The baseline speed is based on historic travel time data collected prior to the implementation of the Living lab project. The Baseline Override speed shown is the speed for the peak hour and direction of the highest volume, in the Okeechobee case above the speed used in the spreadsheet is for the p.m. east approach. The Improvement Override speed was collected after implementation of the Living Lab project by PBC TED using the Bluetooth detectors and reported in the PBC TMC Active Arterial Management Program Performance Measures Monthly Report. The speeds used were from the November 2013 report.
- The case study east/west corridors are approximately 8 miles in length. The north/south corridors are approximately 2 miles long.
- The number of analysis periods is different from for the 95 Express Lanes case study. The benefits are accrued for the peak hour in the peak direction, which is represented by 250 analysis periods, which are the average number work days in a year (total days minus weekends and holidays). However, while the p.m. peak hour was found to have the highest volumes, significant

benefits are also accrued for the a.m. peak hour. In a case where the a.m. peak hour has the highest volumes, the p.m. peak hour should be included in the same manner. In order to account for those benefits the peak volume in the a.m. peak period was identified and a ratio of that volume to the highest peak hour volume was determined. That portion of the 250 analysis periods was added to the 250 original analysis periods. Using the Okeechobee example in Table 3-6, the corresponding peak period is the a.m. peak hour. The east approach was the highest volume approach in the a.m. period so that volume (2153) was used. The a.m. peak to p.m. peak hour volume ratio is 2153/2552 or 0.844. The a.m. peak should account for 84.4% of the amount of analysis periods that the p.m. peak hour provides, so 250 X .844 is 211; 211 + 250 is 461. The amount of benefits accrued in both the a.m. and p.m. peak hours is accounted for by using 461 analysis periods. The other corridors' benefits were calculated in the same manner. This methodology provides a conservative estimate of benefits since only two peak hours of benefits are accounted. Volumes for periods other than the peak hour were not available.

- National average (default) input data was used for crashes, fuel consumption, and the value of time. This was due to the difficulty in collecting and summarizing data or the fact that data were not available at all.

Limitations

- While TOPS-BC does include the benefits due to time savings in recurring and non-recurring travel during each analysis period, the impacts of improvements due to improved travel time reliability are not included.
- TOPS-BC does not have a trip assignment or mode choice module, therefore the operations strategy analysis only accounts for the number of trips given for each corridor, there are no trip diversions or mode changes due to congestion.
- TOPS-BC will provide conservative estimates of benefits because only the benefits accrued during the selected time period are calculated. In many cases, additional benefits may be produced in off-peak times that are not included.
- Changes in air quality due the operations strategies are not accounted for in TOPS-BC.

Conducting the FDOT Palm Beach Living Laboratory Case Study

The following are the steps to enter input data for the Palm Beach Living Lab case study. Note that separate TOPS-BC calculations are required for each of the six corridors in the study area. The steps are the same for each corridor but the volumes and speeds input are different.

Costs

1. Click on Traffic Signal Coordination Systems – Central Control under Section 3– Estimate Costs.
2. The incremental deployment costs are entered in each item row, both for capital/replacement cost and for operations and maintenance costs. Each item cost is the cost per intersection multiplied by the number of intersections. The signal controller cost includes the cost of any in-pavement presence loops.
3. The basic infrastructure costs are not included in the benefit/cost calculation, as this case is considering only the benefits of the incremental improvement by the Living Lab project.
4. Each item is assigned a useful life. The project life cycle is 20 years, so there are no replacement costs for the traffic signal and communications lines. There is one replacement assumed for the cameras and detectors. The useful life is entered for each cost item.
5. The annualized total project cost is then calculated by the spreadsheet as an output.
6. The total cost for the incremental deployment was determined and each corridor was assigned a percentage of the total project cost based on the ratio of the traffic signals along that corridor to the total number of traffic signals in the study area. Using Okeechobee as an example, there are 23 traffic signals in the Okeechobee corridor, which is 29.1% of the total 79 traffic signals in the study area. Therefore, Okeechobee was assigned 29.1% of the project cost. Using the total cost will account for the deployment in both directions even though the benefits are accrued for one direction in the peak hour. This will provide a conservative estimate of the B/C ratio.
7. The calculated costs of each corridor are then added back together to obtain a total project B/C ratio.

See Figure 3-7 for a screenshot of the Costs page for the Okeechobee Blvd. corridor in this case study.

Figure 3-7 TOPS-BC Traffic Signal Coordination Systems Costs Page

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

Traffic Signal Coordination Systems: Central Control

Equipment	Useful Life	Capital / Replacement Costs (Total)	O&M Costs (Annual)	Annualized Costs
Basic Infrastructure Equipment				
Linked Signal System LAN	20	$ 55,000	$ 1,100	$ 3,850
TMC Hardware for Signal Control	5	$ 35,000	$ 2,000	$ 9,000
ATMS.now license (1)	1	$ 200,000	$ 15,000	$ 215,000
TMC Operators	1	$ -	$ 408,000	$ 408,000
Incident Managaemen Database (1)	1	$ 29,000		$ -
INRIX data subscription (1)	1		$ 7,000	$ 7,000
TOTAL Infrastructure Cost		$ 319,000	$ 433,100	$ 642,850
Incremental Deployment Equipment (per Intersection)				
Signal Controller (130)	15	$ 821,500	$ 377,000	$ 431,767
Communication Line (184,800 LF)	20	$ 809,424	$ 80,900	$ 121,371
Loop Detectors (with signal controllers)	5		$ -	$ -
CCTV cameras (35)	10	$ 140,000	$ 14,000	$ 28,000
Bluetooth detectors (30)	10	$ 165,000	$ 16,500	$ 33,000
Speedinfo detectors (6)	10	$ 30,000	$ 3,000	$ 6,000
				$ -
				$ -
				$ -
				$ -
TOTAL Incremental Cost		$ 2,105,924	$ 491,400	$ 620,138

INPUT	Enter Number of Infrastructure Deployments	0	**$ -**
INPUT	Enter Number of Incremental Deployments	1	**$ 620,138**
INPUT	Enter Year of Deployment	2013	
	Average Annual Cost		**$ 620,138**

Benefits

The Okeechobee Blvd corridor will be used as an example for providing input data to the spreadsheet.

1. Click on Signal Coordination under Section 4 - Estimate Benefits. Input data into the Facility Characteristics section.
2. Enter one into the Length of Analysis Period green box because the traffic volume data is for a one hour period
3. Select Central Control for the Signal Timing Type, the Living Lab project provided central control in the study area.

4. Select Principal Arterial for the Link Facility Type since the corridors are principal arterials.
5. Enter 8 in the Link Length, which is the length of the east/west corridors.
6. Enter 4 in the Total Number of Lanes, which is the number of basic lanes in each direction in most segments along the corridor.
7. TOPS-BC will calculate the roadway capacity as an output.
8. Enter 41.5 into the Free Flow Speed green box, that speed was provided by PBC TED based on analysis of off-peak travel times using Bluetooth readers. The speed limit should not be used as the free flow speed arterials, it will not account for traffic stopping at signals. The correct method to obtain free flow speed is to measure travel time over the length of the corridor in uncongested times of day and divide by the corridor length.
9. In the Facility Performance section, enter 2552 into the Link Volume green box, which was provided PBC TED as described above from Table 3-6.
10. Enter 26.0 into the Congested Speed, Baseline Override box, which the p.m. peak hour speed collected by PBC TED prior to implementation of the Living Lab project.
11. Enter 29.6 into the Congested Speed, Improvement Override box, which is the most current corridor p.m. peak hour speed reported by PBC TED in their monthly performance measures report.
12. Enter 461 into the Number of Analysis Periods per Year box, which accounts both the p.m. and the a.m. peak hours per year as described in the Assumptions section above.
13. As an output TOPS-BC will calculate the annual benefits to the corridor. For Okeechobee Blvd. the annual benefits were found to be $1, 419,812.

See Figure 3-8 and Figure 3-9 for a screenshot of the Benefits page for the Okeechobee Blvd. corridor in this case study.

Figure 3-8 TOPS-BC Traffic Signal Coordination Systems Benefits Page (part 1)

Length of Analysis Period (Hours): 1

Signal Timing Type: Central Control

Cost Information

Facility Characteristics

Link Facility Type: Principal Arter

	Input		Baseline Override	Baseline	Improvement Override	Improvement	Change
Link Length (Miles)	8						
Total Number of Lanes	4			4		4	0
Link Capacity (All Lanes - per Period)		7200		7200		8064	864
Free Flow Speed (MPH)	41.5						

Facility Performance

Link Volume (during the time period of analysis): 2552

	Baseline Override	Baseline	Improvement Override	Improvement	Change
Congested Speed	26	40.658	29.6	40.788	3.600
Vehicles Miles Traveled (VMT)		20416.0000		20416.0000	0.0000
V/C		0.3544		0.3165	-0.0380
Vehicle Hours of Travel		785.2308		689.7297	-95.5010
Incident Related Delay (hours) per vehicle per mile		4.54056E-06		4.36076E-06	-1.79806E-07
Number of **Fatality** Crashes		3.61363E-06		3.54136E-06	-7.22726E-08
Number of **Injury** Crashes		3.46868E-04		3.39930E-04	-6.93736E-06
Number of **Property Damage Only** Crashes		5.05010E-04		4.94910E-04	-1.01002E-05
Fuel consumption (Gallons)		961.0234		912.9723	-48.0512

Figure 3-9 TOPS-BC Traffic Signal Coordination Systems Benefits Page (part 2)

Impacts Due to Strategy	**Facility improvement models**		
	Change in Capacity (%)	12%	
	Change in Speed (%)	0%	
	Change in # of Lanes	0	
	Reduction in Crash ***Rate*** *(%)*	2%	
	Reduction in Crash ***Duration*** *(%)*	0%	
	Reduction in Fuel Use (%)	5%	
Travel Time	Average Person Hours of Travel Saved per Period		159.4867
	$ 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	
	Total Recurring Travel Time Benefit per Period		$ 2,902.66
TTR	Average Total Person Hours of Non-Recurring Delay Saved per Period		-0.0061
	alue 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	
	Total Non-Recurring Delay Benefit per Period		$ (0.11)
Energy	Average cost per gallon of fuel (excluding taxes)	$ 3.67	
	Total Fuel Savings Benefit		$ 176.35
Safety	$ Value of a Fatality Crash	$ 6,500,000	
	$ Value of a Injury Crash	$ 67,000	
	$ Value of a Property Damage Crash	$ 2,300	
	Total Modeled Crash Related Benefit per Period		$ 0.96
	User Entered Benefit (Annual $'s)		
	Number of Analysis Periods per Year	461	
	TOTAL AVERAGE ANNUAL BENEFIT		$ 1,419,812.06

Findings of the FDOT Palm Beach Living Laboratory Case Study

Based on the six corridors benefits and costs calculations using the TOPS-BC spreadsheet, the results are shown in Table 3-7.

Table 3-7 Benefits and Costs for the Palm Beach Living Laboratory Case Study

Corridor	Peak Time/Direction	Benefits	Cost	B/C Ratio
Southern Blvd	AM EB	$2,179,220	$149,454	14.58
Belvedere Road	PM WB	$1,270,182	$133,330	9.53
Okeechobee Blvd	PM WB	$1,419,812	$180,460	7.87
Military Trail	PM NB	$972,212	$47,130	20.63
Jog Road	PM NB	$235,011	$55,192	4.26
SR 7	PM NB	$159,651	$55,192	2.89
Total System		**$6,236,088**	**$620,758**	**10.05**

4.0 TOPS-BC User Hints and Lessons Learned

After conducting these and other TOPS-BC case studies and applications, several "lessons learned" have been identified. There are also a few hints to setting up the spreadsheet that will help TOPS-BC users achieve better results.

- Speed is the most important factor affecting the benefits of an operations strategy. A difference in "before" and "after" speed is the primary way to account for congestion and delay and improvement benefits in TOPS-BC. In the 95 Express Lanes case study, the speed differential between before and after deployment provided the data to calculate the vehicle hours of travel and delay in the corridor. In the Palm Beach Living Lab case study, before and after speed was the only way to account for the operations of the traffic signal system along the corridor, it is the overall travel time (converted to speed) that accounts for the stop delay in a corridor. The number of traffic signals is not part of the calculation. It is relatively easy to collect current travel times using GPS travel time runs or Bluetooth detectors. However, it is more difficult to obtain historic corridor speeds for project already implemented or to estimate speeds for a project being planned. When actual historic data is not available, it is best to consult with the local MPO and obtain model speeds for the corridor.
- The free flow speed is important. The FDOT Planning Office free flow speed is the posted speed limit plus 5 mph. When conducting operations analysis and when historic data is available the free flow may be determined from collected data. For freeways, the average off-peak (uncongested) speed collected over time from detectors is the calculated free flow speed. For arterials the stop time at traffic signals must be accounted for, so the operations method of determining free flow speed is to average off-peak corridor travel times over time, as was done in the Palm Beach case study. When conducting planning studies the speed limit plus 5 mph should be used as the free flow speed.
- Volume and volume/capacity ratio are also important factors in TOPS-BC calculations. The current volume is the only volume input, however, when needed (such as an intersection improvement) the capacity can be overridden for both the baseline and the improvement scenarios. Volume and V/C are used to calculate vehicle miles traveled and crash rates and affect the benefits calculation.
- The period of analysis must be correct in order to obtain accurate results. The number of hours of the analysis must match the length of the period of the volume data, that is, if the volumes are for a peak one hour, the period of analysis must be one. In the I-95 Express Lanes case, the volumes were for a three hour peak period, so the period of analysis was entered as three.

- The number of analysis periods per year can be used to account for additional benefits not measured directly by data input. In the Palm Beach case study, the number of analysis periods was increased to account for the other peak hour of the day. The ratio of the a.m. peak hour to the p.m. peak hour was multiplied by the number of workday peak hours per year (250) to account for the benefits of both peak hours. Additional hours of benefits could have been added in the same manner if the volumes were known.
- In conducting several case studies, it has been determined that the crash data and value of time factors do not often vary significantly from the national data used as the default in each data item. The data for these factors are difficult and expensive to collect and a large amount of data collected over a period of time is needed. It is suggested that the effort to collect these data are not usually worth the amount of impact to benefits that local data would make on these factors. Likewise, the cost of fuel will not create a measurable change to benefits unless the price is significantly different from the default price. It must be noted that the price of fuel is not the cost of regular grade gasoline, but a blended cost of all grades of gasoline, diesel, and liquefied natural gas (LNG) fuel.
- For the cost calculations, there are several important considerations. The costs of providing basic services – services that would be provided whether or not the project being studied was implemented – and the cost of the incremental services enabled by the project must be sorted out and correctly assigned. Each cost item should have a corresponding operations and maintenance cost entered in the spreadsheet.
- It is also important to match the cost of a project to the benefits being calculated. For example, in the Palm Beach case study the cost of the project in a corridor was halved in the B/C calculation because the benefits were only calculated for one direction along that corridor.
- The user must be careful to pay close attention to the units that are assumed in the spreadsheet cells, i.e. be sure determine if the model is assuming a daily rate vs. an annual rate for a factor.

A. References

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, FHWA, June 2013, http://ops.fhwa.dot.gov/publications/fhwahop13041/

Providing Guidance to Practitioners in the Analysis of Benefits and Costs of Management and Operations Projects (TOPS-BC Desk Reference), FHWA, May 2012, http://ops.fhwa.dot.gov/publications/fhwahop13004/