U.S. Department of Transportation

A Guide for Leveraging ITS Evaluation Tools for Benefit-Cost Analysis (BCA) and Return-on-Investment (ROI)

Background

Across the United States, state and local agencies have established Intelligent Transportation Systems (ITS) and Transportation Systems Management and Operations (TSMO) programs that are deploying operational strategies to improve safety, enhance mobility, reduce emissions (and fuel use), improve agency efficiency, increase productivity, and improve customer satisfaction.

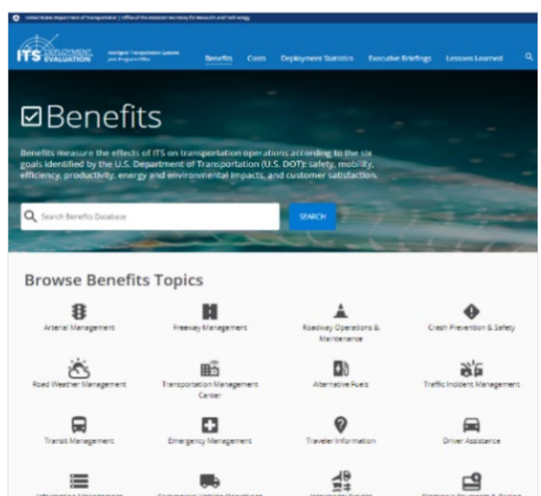
While these advanced technology and operational strategies have shown significant value, conveying the business case for ITS and TSMO continues to be a challenge. For many decision makers there continues to be a tendency to address transportation problems by funding major capital projects, such as adding lanes or building new interchanges and roads, to address transportation challenges. The benefits of traditional road capacity improvement projects come with high costs. Moving forward, most agencies understand that that they cannot build their way out of congestion. Faced with limited financial resources and increasing demands for transportation improvements from the public and politicians, many agencies are turning to strategies that focus on ways to better operate and manage the transportation system.

Decision makers are increasingly seeking data-driven approaches to better understand their return-on-investment (ROI). ITS and TSMO projects are being assessed and evaluated against traditional road capacity projects. While research has shown that TSMO strategies typically have much higher returns than traditional roadway projects, agencies still struggle to demonstrate the benefits of these strategies.

The Purpose of this Guide

This document serves as a guide to state and local agencies, as well as industry professionals, for leveraging the ITS Joint Program Office's (JPO) ITS Deployment Evaluation Databases for the purpose of analyzing ITS benefit-costs. The purpose of this guide is to convey a high-level methodology that agencies can tailor for their own projects. Examples are also provided to convey how analysis results can be shared with a variety of stakeholders to gain support, commitment, and excitement for the deployment.

This Guide is accompanied by Use Cases that demonstrate how the methodology can be applied for a range of ITS and TSMO strategies, including: Adaptive Traffic Signals, Curve Speed Warning, Managed Lanes, Smart Work Zone Technologies, and Transit Signal Priority. The Use Cases are examples leveraging existing resources applied to hypothetical corridors. **Agencies applying the methodology should not simply use the results from the use cases; instead they should apply the methodology to their own specific projects**.



Source: USDOT

Figure 1. ITS Benefits Database

USDOT's ITS Benefit & Cost Resources

The ITS industry has a rich history of collecting benefits and cost data, encouraging agencies to evaluate and document the performance and value being provided by their ITS deployments. The United States Department of Transportation (USDOT) has been capturing these data in the [ITS Evaluation Benefits & Costs Databases].

Historically, agencies have performed studies to evaluate new technology strategies that are submitted to the JPO for inclusion within the ITS Deployment Evaluation Databases. The ITS Deployment Evaluation Databases provide a brief summary of the resource, key information and findings, date of the resource, and a link to the full document all of which can be filtered and sorted so that the user may efficiently research the database.

A Data-Driven Approach for Calculating Benefit-Cost

The USDOT has a number of existing resources to support the analysis of benefit-costs for specific strategies and grant requirements. For example, the [Tool for Operations Benefit Cost Analysis (TOPS-BC)]() is available as a sketch-planning level tool which can be used to estimate the benefits of traditional TSMO deployments. The basic approach and methodology for calculating benefit-costs is similar throughout these resources, including this one.

The figure below provides a step-by-step process for conducting a high-level benefit-cost analysis. The methodology presented herein leverages the ITS Deployment Evaluation Databases, trusted and verified research and evaluation data, and readily available site-specific data to analyze benefits and costs.

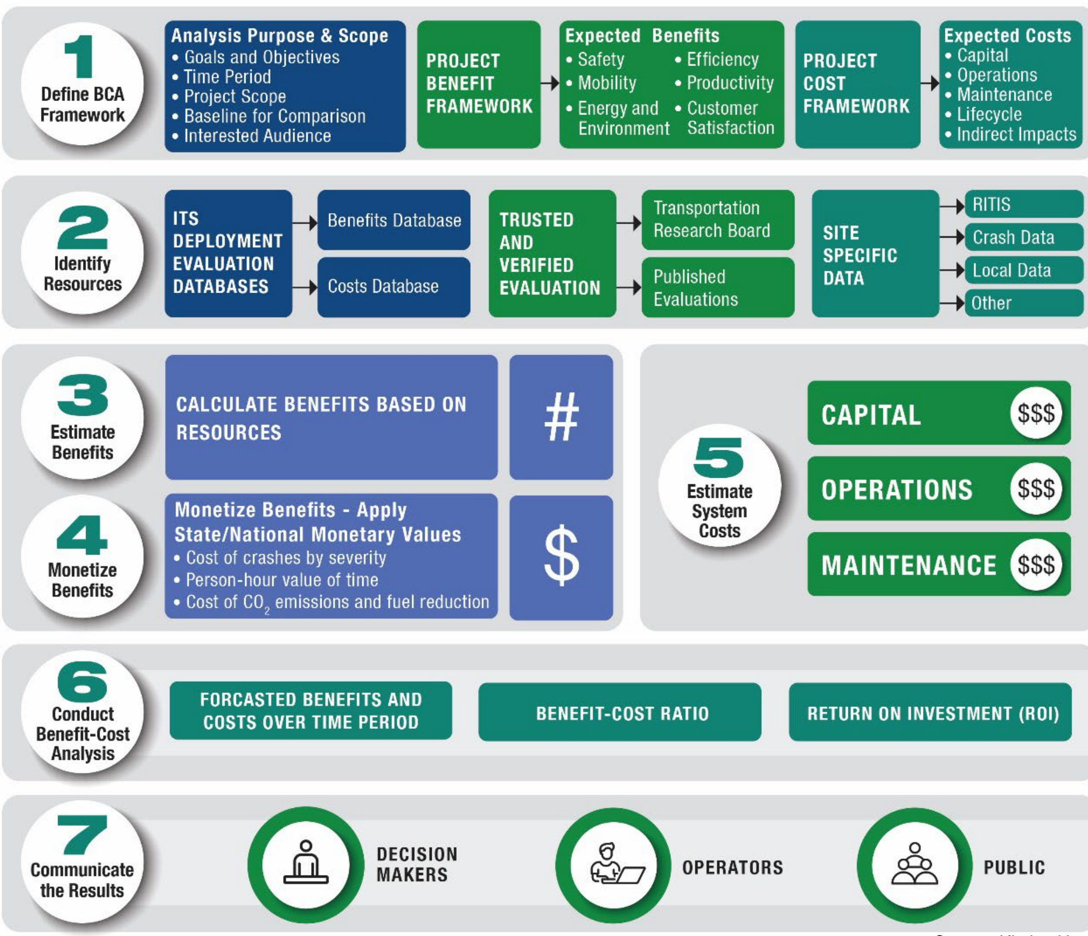


Figure 2. Benefit-Cost Analysis Methodology

The following sections provide an overview of each step identified above and guidance on how to apply the methodology. Specific, detailed examples that apply the methodology are included in the Use Case documents that were developed along with this guide.

1 Define BCA Framework

Step 1: Define BCA Framework

The first step is to establish a framework for analysis that includes the following information:

- **Scope of the Project.** The scope of the project should be defined. It should include details on the location and of the project, ITS or TSMO technology strategy(ies) being considered, number of devices or infrastructure components, number of vehicles to be equipped with a technology, software and systems, and any other information that defines the scope of the project.
- **Goals and Objectives for the Project.** The problem the proposed solution is trying to solve should be identified as well as the goals and objectives for the project. Example goals for a project may include improving safety; enhancing mobility; reducing emissions or fuel consumption; improving agency efficiency and productivity; and/or improving customer satisfaction. Projects may address one or more goals.
- **Time Period for Analysis.** The time period for the analysis should be defined. This time period is the duration (i.e., number of years) that will be used for the analysis. Practitioners may decide to conduct the analysis over a 5-year, 10-year, 20-year, or some other time period. The time period should be long enough to capture the major impacts of the investment and should align with the lifespan of the major assets. ITS projects often have a shorter timeframe (7-15 years) than highway construction projects given the need to replace equipment. ***Note:*** *Projects involving the initial construction of highways typically use an analysis period of 30 years.*
- **Evaluation Baseline for Comparison.** Analysis needs to include a well-defined baseline to measure the incremental benefits and costs of a proposed project against. A baseline is sometimes referred to as the "no-build alternative" and defines the conditions if the proposed project was not implemented. As the status quo, the baseline should incorporate factors, including future anticipated changes in traffic volumes and ongoing routine maintenance, that are not brought on by the project itself and would occur in its absence.

The analysis framework should identify the types of anticipated framework for project costs and benefits:

- **Identification of the Types of Project Costs.** The types of potential project costs may include planning and engineering costs, direct capital costs (i.e., costs for infrastructure, software), integration costs, operations and maintenance costs as well as future lifecycle costs.
- **Identification of the Types of Expected Benefits.** Practitioners should determine the expected benefits that the project is expected to provide. Benefits should align with goals and objectives. Benefits may include those accruing to the transportation agency directly, those accruing to travelers or businesses, or all societal benefits, even those that have no direct market value. As a starting point, ITS Deployment Evaluation Program identified six Benefits Goal Areas that might be considered. These Goal Areas are safety, mobility, energy and environment, efficiency, productivity, and customer satisfaction. Similarly to the costs, effects of discounting will need to be established. Examples of potential benefits are provided below.
    - **Safety.** Expected safety benefits may include the reduction of crashes (i.e., percent reduction in crashes)
    - **Mobility.** Expected mobility benefits may include the reduction of travel times or reduction in delay for the location being assessed.
    - **Energy and Environment.** Expected benefits may include the reduction of emissions and fuel consumption based on the mobility benefits. Fuel savings and reductions in emissions can be derived from travel time savings to estimate the energy and environmental benefits.
    - **Efficiency, Productivity, and Customer Satisfaction.** Benefits may also be estimated for efficiency, productivity, and customer satisfaction based on the intent of the strategy and availability of the data.

Practitioners should clearly define the types of benefits in this category and ensure that there are no overlaps – or double-counting – of the benefits.

2 Identify Resources Step 2: Identify Resources

Identifying Resources is the next step in conducting the analysis. In this step, practitioners should identify relevant resources that can be used to conduct the analysis. Information collected should be assessed to ensure that it is commensurate with the ITS strategy that an agency is assessing. This includes ensuring that the types of technologies being considered, and the geographic area are consistent with the resources identified.

Potential resources agencies might consider are summarized below:

- **ITS Deployment Evaluation Databases.** For over 20 years, the ITS JPO has been tracking the evaluation of ITS technologies including identifying studies documenting the benefits, costs, and lessons learned of ITS. Benefits measure the effects of ITS on transportation operations according to the six goals identified by the USDOT: safety, mobility, efficiency, productivity, energy and environmental impacts, and customer satisfaction. The Costs database is a national clearinghouse of cost estimates for ITS deployments. These costs can be used to develop project cost estimates during the planning or preliminary design phase, and for policy studies and cost-benefit analyses. Both capital and operating and maintenance costs are provided in the database.
- **Tool for Operations Benefit Cost Analysis (TOPS-BC).** TOPS-BC is a sketch-planning level decision support tool developed by the FHWA Office of Operations. It is intended to provide support and guidance to transportation practitioners in the application of benefit-cost analysis for a range of ITS and TSMO strategies. The tool was developed based on guidance and input from planning and operations practitioners with the primary purpose to help in screening multiple TSMO strategies and for providing "order of magnitude" benefit-cost analysis estimates.
- **Trusted and Verified Research and Evaluation Data.** Benefits and costs data obtained from trusted and verified research may also be leveraged for the analysis. These data include benefits documented by practitioners when evaluating ITS strategies. These results may be documented in reports published by organizations such as Transportation Research Board (TRB). Agencies may also have developed their own evaluations – or have cost data from bid tabs or vendors – that are not contained in the ITS Deployment Evaluation Databases. ***Note:*** *If information is identified that is not in the ITS Deployment Evaluation Databases, agencies are encouraged to share their data with the ITS JPO so that peer agencies can leverage the data.*
- **Site Specific Data.** Site specific data includes data about the location being assessed. It may include safety data (e.g., crash data), mobility data (e.g., delay data), or any other data that are captured for the location being assessed. These data may be collected from a variety of tools including those used to monitor the performance of the transportation system. Site specific data needs to be collected for the specific corridors being assessed.

At the completion of this step, practitioners will have identified resources and data that can be applied for calculating costs and benefits for the project. For example, data may be captured from reports that articulate the potential reductions in crashes or delay reductions from implementing a variable speed limit (VSL) system on a corridor. Likewise, data may be collected that capture the costs for deploying a VSL system as well as the operating and maintenance costs for such a system.

Note: To analyze costs and benefits, it is necessary to have costs and monetized benefits on a common unit basis. The BCA should be conducted in real dollars using a specified base year. Expenditures that occurred in prior years may need to be adjusted. If data collected in this step is obtained from studies conducted in earlier years, it may be required to adjust costs to current dollars by accounting for inflation. Inflation is the increase in prices for goods and services over time. If adjustments need to be made, practitioners should clearly define their methodologies for converting them to current dollars such as using the Inflation Factors provided by the Bureau of Economic Analysis.

3 Estimate Benefits Step 3: Estimate Benefits

Once resources are identified, the next step is to apply data from those resources (Step 2) to estimate benefits for the specific ITS project or application being proposed for deployment. Practitioners should apply the information identified in Step 2 to calculate the benefits for the ITS strategy being assessed. Both benefits data and site-specific data (i.e., number of crashes in the corridor or delay in the corridor being assessed) should be used.

Analysis requires the estimation of benefits which will be monetized in Step 4. These benefits may accrue to the transportation system users (e.g., travel time savings, reduction in crashes, decreased operating costs); the deploying agency (increased agency efficiency); or society at large (reductions in emissions). Examples of estimating benefits are provided below.

- **Safety.** Calculate the reduction of crashes using benefits data (i.e., percent reduction in crashes) and applying site specific data for the location being assessed (i.e., number of annual crashes per year). Calculated safety benefits may include the reduction in annual crashes, fatalities, and/or injuries along the corridor.
- **Mobility.** Calculate the reduction of travel time using relevant benefits data (i.e., percent reduction in delay) and applying that reduction to site specific delay data for the location being assessed. Calculated mobility benefits may include the reduction of travel time, reduced delay, or reduced traveler wait times.
- **Energy and Environment.** Calculate the reduction of emissions and fuel consumption based on mobility benefits. Fuel savings and reductions in emissions can be derived from mobility benefits.

4 Monetize Benefits Step 4: Monetize Benefits

Step 4 includes monetizing the benefits. Estimating the monetary value of strategy deployment benefits provides the ability to analyze and compare benefits and costs. Using the estimated benefits from Step 3, the monetary value of the ITS application benefits can be estimated by applying state and national monetary values of the following:

- **Safety.** Value of preventing crashes by assigning values to preventing crashes by severity type (i.e., property damage only [PDO], injury, fatality). Practitioners should identify relevant values to apply for safety benefits. Practitioners should use national, state, or local sources for values associated with crashes by relevant type of crash. This will be determined by how an agency reports crash data within their jurisdiction. The value of safety may be expressed as the monetary savings from reducing the number of crashes.
- **Mobility.** Person-hour value of time is categorized by personal and commercial vehicular travel or transit traveler wait time. Practitioners should use trusted and verified sources when applying value of time for person travel time savings. These sources may include nations, state, or local sources.
- **Energy and Environmental.** Cost of CO_2 emission reductions and fuel savings can be derived using data that estimates the amount of fuel burned when a vehicle is idling – and the amount of emissions associated with the fuel burned. To determine the monetary value of the benefits, costs of gasoline and costs of emissions from trusted and verified sources such as the U.S. Environmental Protection Agency (EPA) can be applied to the energy and environmental costs.

At the completion of this step, practitioners should have monetized benefits for each applicable benefit area (i.e., safety, mobility, etc.). Monetized benefits should be in current dollars.

Step 5: Estimate System Costs

Costs can be estimated using a variety of resources depending on access to current agency construction bids, vendor quotes, and relevant information within the ITS Deployment Evaluation Databases – Costs Database. Users should identify the system capital, operations, and maintenance costs estimated by system components. When estimating costs, it is important to ensure that all relevant capital costs are included. Practitioners should identify the components of the proposed ITS application that make up the entire system. For example, costs for a closed-circuit television (CCTV) camera project should consider the costs of the camera, pole, cabinet, foundation, power, communications, and integration into the traffic management system. Operating and maintenance costs should also be considered. Finally, depending on the duration of the analysis, the replacement cost of equipment that reaches the end of its useful life during the time horizon of the analysis should also be considered.

In many instances, cost data collected during Step 2 will be collected from a variety of sources and studies. These sources and studies are likely to include costs from different time periods. It is important to put these values into a common, apples-to-apples framework that adjusts for costs over time. All relevant costs should have a common temporal footing. This is often done by converting past costs into a present value amount. For example, if costs were obtained for ITS equipment from a report in 2017, those dollars should be adjusted for current dollars (i.e., 2022 dollars). It is also important to note that the costs of some technologies may be cheaper over time as technology becomes cheaper. For example, roadside unit (RSU) costs may reduce in the future as the technology becomes more mature.

Step 6: Conduct Benefit-Cost Analysis

Step 6 uses the monetized results from Steps 4 and 5 to determine a Benefit-Cost Ratio (BCR) and Return on Investment (ROI). Costs and benefits should be identified for each year of the time horizon and the BCR and ROI should be calculated. ITS and TSMO projects entail a stream of expenditures and benefits over time. Initial capital costs may occur in the early project years with O&M costs continuing over the project life. Benefits start accruing once the project is implemented and accrue over time (i.e., for the duration of the time horizon). The estimated monetized applicable benefits (e.g., safety, mobility, energy & environmental) should be extrapolated over a time horizon (e.g., 10 years). Likewise, the capital, operations, and maintenance costs should also be estimated for the same time horizon. In extrapolating costs over a time horizon, several assumptions may need to be made. For example, users may assume that devices will be able to be maintained during the time horizon and therefore, capital replacement costs do not need to be included. When identifying costs, it is important to include not only initial direct costs, but also future lifecycle cost and indirect cost impacts.

All costs and benefits used for the BCA should be stated in **real dollars** using a common base year. Cost elements that were expended in prior years should be updated to the recommended base year. Any future year costs should be appropriately discounted to the baseline analysis year to allow for comparisons with other BCA elements.

Costs and benefits for future years should be adjusted for discounting over the time period. In accordance with OMB Circular A-94, a discount rate of 7% should be applied to discount streams of benefits and costs to their present value in the BCA. **Discounting** is the recognition that a dollar today is worth more than a dollar five years from now, even if there is no inflation because today's dollar can be used productively in the ensuing five years, yielding a value greater than the initial dollar. This concept reflects the principle that benefits and costs that occur sooner in time are more highly valued than those that occur in the more distant future, and that there is a cost associated with diverting the resources needed for an investment from other productive uses in the future. This process, known as discounting, will result in future streams of benefits and costs being expressed in the same present value terms.

Once costs and benefits are calculated for the time-period, the benefit-cost analysis can be reported as:

- Benefit-Cost Ratio (BCR) $= \sum benefits \div \sum costs : 1$
- Return-on-Investment (ROI) $= (\sum benefits - \sum costs) \div (\sum costs) \times 100\%$

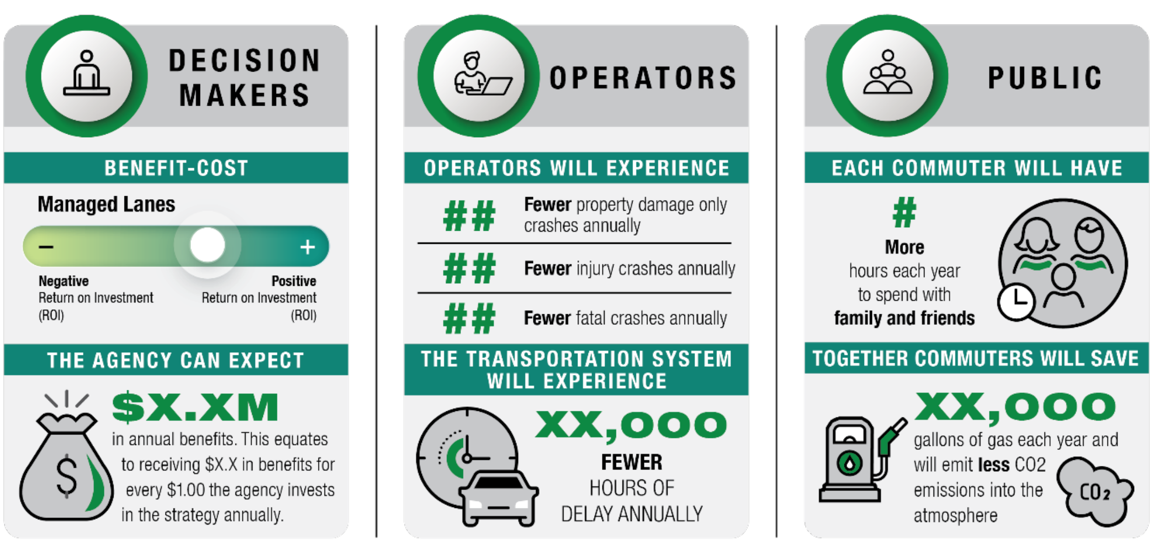
A BCR greater than 1:1 and a ROI greater than zero shows a positive return.

Note: While the equation listed above is common for ROI, there are additional definitions/equations used. Net Present Value (NPV) is another metric that may be useful. To calculate NPV, all benefits and costs over an alternative's lifecycle are discounted to the present, and the costs are subtracted from the benefits. If benefits exceed costs, NPV is positive and the project is considered economically justified.

7 Communicate the Results — Step 7: Communicate the Results

Communicating the results of benefit-cost analysis and ROI provides an opportunity to demonstrate the value of ITS deployments in a tangible way. When communicating the results, the audience should be considered to ensure that the information is relevant and relatable. Decision makers, operators, and the public may each find different aspects of the benefit-cost analysis and ROI results more helpful in understanding the impact of a given deployment.

- **Decision Makers.** Decision makers are responsible for prioritizing projects and determining where funds are invested. This group may consider using BCR or ROI as a way to compare all transportation projects including, traditional roadway projects and ITS deployments. Demonstrating fiscal responsibility with BCR and ROI is a good way to communicate with this group. Results may help decision makers better assess and align ITS and TSMO projects with traditional roadway capacity improvement or multi-modal projects.
- **Operators.** Operators optimize the management of their systems and monitor performance metrics. Communicating key performance indicators (KPI) such as crashes or hours of travel time reduced is relevant to how an operator will increase the efficiency of their system.
- **Public.** Communicating benefits in a way that is relatable and tangible to the public is critical to demonstrating the value and gaining support for ITS deployments. Sharing with the public how many additional hours a year they will be able to spend with family and friends or how much fuel they will save is a good way to communicate with this group.



Source: Kimley-Horn

Figure 3. Communicating Benefit-Cost Analysis Results

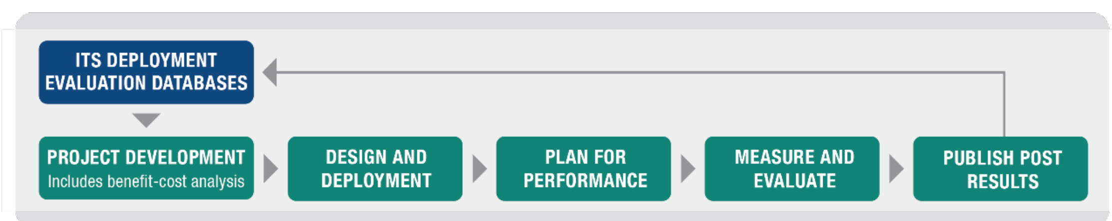
The infographic above provides an example of how the benefit-cost analysis results can be communicated with various stakeholder groups. In addition to sharing benefit-cost results, it can also be impactful to share select tangible benefits associated with efficiency, productivity, and customer satisfaction.

Applying the Results

Benefit-cost analysis results may be leveraged further to guide verification of anticipated deployment outcomes, provide insights for future agency deployments, and share the results with partners throughout the industry. Data can be leveraged throughout each phase of a project lifecycle such that data resources and operational metrics are integrated within agency processes and procedures leading to more efficient operations and smarter investments.

The following figure provides an overview of how elements of benefit-cost analysis results can be applied and leveraged throughout the project lifecycle.

- **Project Development.** Benefit-cost analysis is used to guide the development of a project. Benefit-cost analysis results can be used to document fiscal responsibility or may be required to seek different funding sources such as the Congestion Mitigation and Air Quality (CMAQ) funds.
- **Design and Deployment.** Implementing the performance plan within the design and deployment will ensure that data are available to not only support efficient management and operations, but also to evaluate the success of the project.
- **Plan for Performance.** Unlike traditional transportation projects, ITS and TSMO deployments typically require more involved management and operations. Planning for how key performance indicators (KPIs) and operational data will be leveraged to optimize performance also provides an opportunity demonstrate the value of the deployment.
- **Measure and Evaluate.** Agencies are encouraged to monitor, measure, and evaluate the performance of their deployments. Considering metrics that can also be leveraged to verify benefit-cost analysis results will build confidence and improve accuracy for future deployments.
- **Publish / Post Results.** Sharing evaluation results with partners through the ITS Deployment Evaluation Database by submitting information to be published and/or posted will strengthen the industry. Users are encouraged to submit their data and results to the ITS JPO's ITS Deployment Program. All submissions are reviewed prior to publishing within the ITS Deployment Evaluation Database.



Source: Kimley-Horn

Figure 4. Applying Benefit-Cost Analysis Results within the Project Lifecycle

This guide was developed to document the methodology for practitioners to follow as they leverage ITS Deployment Evaluation Tools for benefit-cost analysis. As a companion to this guide, five example Use Cases were developed that demonstrate how the methodology can be applied to ITS applications. Agencies applying the methodology should not simply use the information in the use cases. Instead, they need to use their own site-specific data and apply the methodology to their own projects.

For more information on the ITS Deployment Evaluation Program – and to access the Use Cases – visit: https://www.itskrs.its.dot.gov/