Use Case: Curve Speed Warning Benefit-Cost Analysis

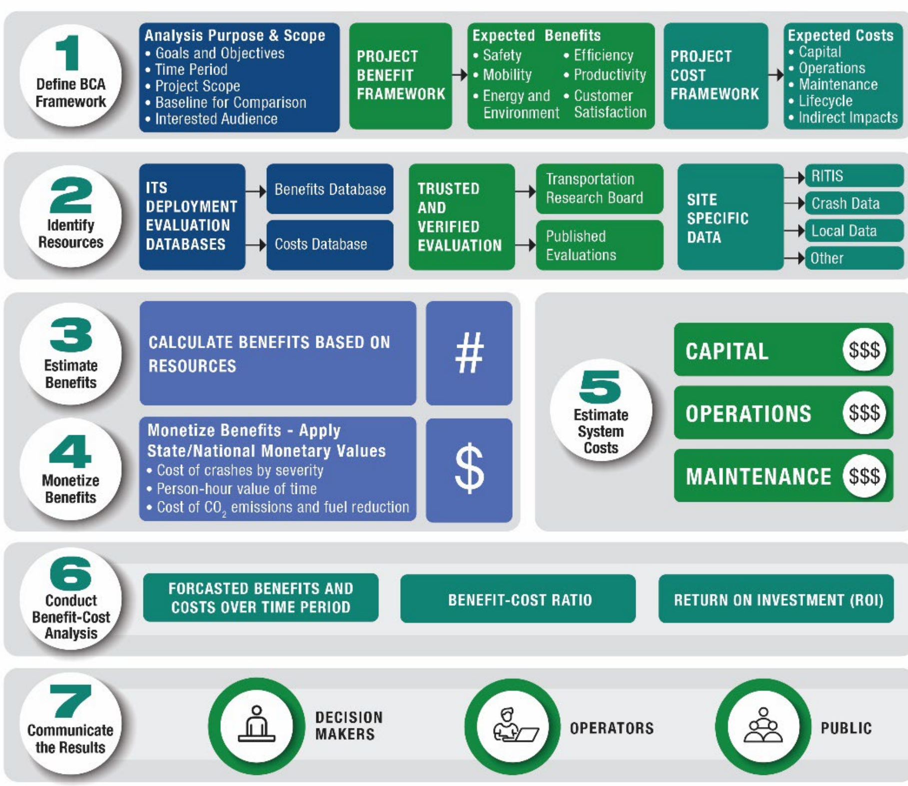
Intelligent Transportation Systems (ITS) Strategy Description

This document serves as a use case for conducting Benefit-Cost Analysis (BCA) for a hypothetical curve speed warning project. Crashes occurring at locations with curves are common with passenger vehicles as well as with heavy vehicles or trucks. When crashes occur, they often result in property damage, injury or a higher-than-average percent of fatalities. Curve speed warning systems provide warnings to drivers helping them select a safe and appropriate speed when approaching a horizontal curve. These systems consist of a speed detection device that activates a dynamic sign (DMS) advising motorists to slow down when vehicles are traveling above a certain speed threshold. Sequential dynamic chevrons may also be deployed throughout the curve. Horizontal curves can create safety concerns that result in vehicles and trucks running off the road, turning over or hitting the guardrail. Horizontal curves make up a small percentage of total road miles, yet account for one-quarter of all highway fatalities. Most curve-related crashes are attributed to speeding and driver error and involve lane departures. (Source: FHWA Low-Cost Treatments for Horizontal Curve Safety 2016). This use case assumes a system deployment at 10 high crash curve locations on rural two-lane roadways.

This use case is for a hypothetical curve speed warning project. Users should apply their own site-specific data to determine benefit-cost analysis (BCA) for their specific project.

Methodology

This use case applies the methodology from **A Guide for Leveraging ITS Deployment Evaluation Tools for Benefit-Cost Analysis**. The methodology is depicted in the graphic below.



Source: Kimley-Horn

Figure 1. Benefit-Cost Analysis Methodology

Applying the Methodology

The following steps provide an overview of the methodology conducted for the benefit-cost analysis.

1 Define BCA Framework

Step 1: Define BCA Framework

The first step in the process is to establish the framework for the study. The following information was defined prior to beginning the analysis:

- **Scope of the Project.** The use case includes a curve speed warning project for a corridor that has 10 locations with sharp curves.
- **Goals and Objectives for the Project.** For the proposed deployment locations, congestion is present, and crashes are also prominent along this corridor.
- **Time Period for Analysis.** A timeframe of 10 years was used for the analysis. This timeframe is based on the expected lifecycle for the signs and system to be implemented. This timeframe is long enough to capture the major impacts of the investment and aligns with the lifespan of the major assets. ITS projects typically have a shorter timeframe (7-15 years) than highway construction projects given the need to replace equipment.

  Note: *Projects involving construction of highways typically use an analysis period of 30 years.*
- **Evaluation Baseline Comparison.** A "no-build alternative" served as the baseline used to measure the incremental benefits and costs of the proposed project against.

A framework for project costs and benefits was also established. The framework identifies the types of project costs and benefits that will be assessed:

- **Types of Project Costs.** The types of potential project costs include planning and engineering costs, direct capital costs (i.e., costs for infrastructure, software, etc.), integration costs, operations and maintenance costs, and future lifecycle costs.
- **Types of Expected Benefits.** The ITS project aligns with agency goals to improve safety. Types of benefits expected from this project include:
  - **Safety.** Estimated reduction of crashes based on curve speed warning technologies similar to the proposed implementation and current crash data that an agency might have available.

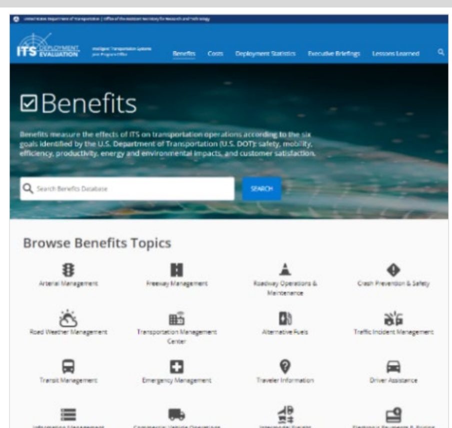
2 Identify Resources

Step 2: Identify Resources

Resources guiding the benefit-cost analysis are identified through readily available sources.

Research Resources

The ITS Deployment Evaluation Databases – Benefits Database (see Figure 2) includes research resources documenting benefits for curve speed warning systems. In addition, data is available from trusted and verified resources to support analysis of both, benefits, and costs. Specific resources are cited within the following analysis and provided as references at the end of the example.



Source: USDOT

Figure 2. ITS Benefits Database

Data Resources

There are various types of site-specific data for the corridor – such as crash data – that can be used as inputs in determining the benefits of curve speed warning systems. Site-specific data used for the curve speed warning use case include:

- Crash data obtained from a statewide and county agencies database for a period of 5 years.

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 or other inflationary factors like Consumer Price Index (CPI) and Producer Price Index (PPI).

3 Estimate Benefits Step 3: Estimate Benefits

Curve speed warning systems are deployed to provide situational awareness to motorists as they are approaching a curve. These systems are deployed to help reduce the likelihood of a crash at the curve.

Benefits data obtained from the ITS Deployment Evaluation Benefits Database and from agency crash data available for the 10 high-crash curve locations. Together these data are used to estimate the safety benefits of the strategy.

The curve speed warning use case estimated benefits include:

- **Safety.** Estimated reduction of crashes

Annual benefits are calculated using data from Step 2. Details of the calculations and assumptions are included in the example contained later in this document.

4 Monetize Benefits Step 4: Monetize 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 curve speed warning deployments can be estimated by applying state and national monetary values of the following:

- **Safety.** Value of preventing crashes by type (i.e., property damage only [PDO], injury, fatality). National, state, or local sources provide costs of crashes by relevant crash type.

The completion of this step results in monetized benefits for each applicable benefit area (i.e., safety). Monetized benefits are in current dollars.

5 Estimate System Costs Step 5: Estimate System Costs

ITS strategy 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. The curve speed warning use case system capital, operations, and maintenance costs are estimated by system component:

- Dynamic speed warning signs system per direction with speed detection
- Sequential dynamic chevron warning system – 8 LED chevron signs with solar power

Cost information from the ITS Deployment Evaluation Databases – Costs Database and State bids are referenced for the curve speed warning use case for non-recurring, capital component costs. Recurring, operations and maintenance component costs were estimated by calculating 10% of capital costs - -a standard rule of thumb used by many agencies.

Note: 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 done by converting past costs into a present value amount. For example, if costs are obtained for ITS equipment from a report in 2017, dollars should be adjusted for current dollars.

6 Conduct Benefit-Cost Analysis

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) for the project. Costs and benefits were identified for each year of the time horizon in order to calculate the BCR and ROI.

ITS and Transportation Systems Management and Operations (TSMO) projects incur a stream of expenditures and benefits over time. Initial capital costs may occur in the early project years with operations and maintenance (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) are extrapolated over the 10-year time horizon. Likewise, the capital, operations, and maintenance costs are also estimated for the same time horizon.

All costs and benefits are stated in **real dollars** using a common base year. Cost elements that were expended in prior years were updated to the recommended base year. Any future year constant dollar costs were appropriately discounted to the baseline analysis year to allow for comparisons with other BCA elements. Costs and benefits for future years are adjusted for discounting over the time period. In accordance with OMB Circular A-94, a discount rate of 7% was applied to discount streams of benefits and costs to the present value in their BCA.

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

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

It was assumed that capital investment will be maintained during the 10-year horizon, therefore capital replacement costs are not included.

Step 6 concludes with the calculation of the BCR and ROI. A BCR greater than 1:1 and a ROI greater than zero shows a positive return. The BCR and ROI for the managed lanes were calculated and demonstrated a positive impact is expected for the example project. The BCR was 18.8:1 and the ROI was 1780%. Both the BCR and ROI show a positive return on investment for the proposed project. For comparative purposes, roadway construction projects that build new capacity typically have a BCR of 2:1.

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 sound.

Step 7: Communicate the Results

Communicating the results of benefit-cost analysis provides an opportunity to demonstrate the value of ITS deployments in a tangible way. When communicating the results, the audience with whom the analysis results are being shared with should be considered to ensure that the information is relevant and relatable. An infographic was developed and included in the example that summarizes the key results for these audiences.

- **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.

Curve Speed Warning Benefit-Cost Analysis

This section documents the benefit-cost analysis for the example curve speed warning project. The numbers included in this example are hypothetical. Users should apply their own site-specific data to estimate BCR and ROI for their projects rather than simply using the results in this document. Resources used in conducting the analysis are denoted by a number in brackets. In addition, resources in the examples are color-coded (see image to the right) to denote the source of the data or resource.

User Provided Site Specific Data
Evaluation Database
Trusted/Verified Research and Resource

Estimating and Monetizing Benefits

The following analysis was performed to estimate and monetize the benefits for the project.

Benefits: Safety

2 Identify Resources	Curve speed warning locations (approx. 1000 ft)	10	
	Average annual PDO crashes at the 10 project locations =	12	PDO Crashes
	Average annual injury crashes at the 10 project locations =	10	Injury Crashes
	Average annual fatality crashes at the 10 project locations =	0.7	Fatal Crashes
	Average percent reduction of crashes using proposed strategy [2] =	34%	
3 Estimate Benefits	Estimated annual reduction of PDO crashes =	4.1	PDO Crashes
	Estimated annual reduction of injury crashes =	3.4	Injury Crashes
	Estimated annual reduction of fatal crashes =	0.2	Fatal Crashes
	Estimated Safety Benefit =	**7.7**	Crashes Reduced
4 Monetize Benefits	Average cost of a property damage only crash [1] =	$ 3,745	
	Average cost of an injury collision per crash [1] =	$ 287,526	
	Average cost of a fatal collision per crash [1] =	$ 12,216,548	
	Monetized Annual Safety Benefit =	**$ 3,900,000**	

Safety Benefit = (curve location average annual crashes) x (reduction %)

Monetized Benefit = $\sum(\text{cost of crash} \times \text{number of crashes})$

Estimating Costs

The following analysis was performed to estimate costs for the curve speed warning project. Project costs include direct capital costs (i.e., costs for infrastructure, software) and operations and maintenance costs as well as future lifecycle costs with an assumed base year of 2020.

When estimating costs, it was assumed that there is existing fiber coverage along the proposed corridor. Capital costs were obtained from the ITS Deployment Evaluation Cost Database [4]. To adjust the costs to 2020 dollars, an Inflation Factor was used. Annual operations and maintenance costs were assumed to be 10% of the capital costs.

System Costs: Curve Speed Warning System

System Component	Unit	Qty	Capital (Unit)	Annual O&M (Unit)
Sequential Dynamic Chevron Warning System 8 LED chevron signs with solar power *Capital Resources: TxDOT - Bid Prices [3]*	Each	10	$ 24,289	$ 2,429
Dynamic Speed Warning Signs with speed detection *Capital Resources: ITS Deployment Evaluation Database [4]*	Each	20	$ 35,065	$ 3,507
Total System Costs =			**$ 944,200**	**$ 94,420**

Costs adjusted to 2020 Dollars using Inflation Factor

Benefit Cost Analysis (BCA) and Return-on-Investment (ROI)

The annual monetized benefits and costs were used to calculate the BCR and ROI over a 10-year period. Capital costs were used for the first year and an annual O&M cost was applied for future years that accounted for inflation.

Benefits and costs for future years considered a discount rate of 7% starting in Year 2 (*t*=1). In the calculations below, the discount rate is applied to determine the present value (PV) for each year, Y1 (*t*=0) through Y10 (*t*=9). The discount rate recognizes 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. Future benefits and costs are discounted to reflect this fact.

Benefit-Cost Analysis: Curve Speed Warning

Annual Monetized Benefits:	
Safety	$ 3,900,000
Total Annual Benefit	$ 3,900,000
Total System Costs:	
Capital	$ 944,200
Annual O&M	$ 94,420
Adjustment Rates	
Real Discount Rate (i)	7%

Source: Kimley-Horn

Discount Rate Applied to Benefit and Costs

Year			Year		
Y1	Annual Monetized Benefit	$ 3,900,000	Y6	PV Annual Monetized Benefit	$ 2,780,646
Y1	Estimated Cost	$ 944,200	Y6	PV Estimated Cost	$ 67,320
Y2	PV Annual Monetized Benefit	$ 3,644,860	Y7	PV Annual Monetized Benefit	$ 2,598,735
Y2	PV Estimated Cost	$ 88,243	Y7	PV Estimated Cost	$ 62,916
Y3	PV Annual Monetized Benefit	$ 3,406,411	Y8	PV Annual Monetized Benefit	$ 2,428,724
Y3	PV Estimated Cost	$ 82,470	Y8	PV Estimated Cost	$ 58,800
Y4	PV Annual Monetized Benefit	$ 3,183,562	Y9	PV Annual Monetized Benefit	$ 2,269,836
Y4	PV Estimated Cost	$ 77,075	Y9	PV Estimated Cost	$ 54,953
Y5	PV Annual Monetized Benefit	$ 2,975,291	Y10	PV Annual Monetized Benefit	$ 2,121,342
Y5	PV Estimated Cost	$ 72,033	Y10	PV Estimated Cost	$ 51,358

10-Year Monetized Benefits	$29,309,406
10-Year Estimated Costs	$1,559,368

Present Value (PV) =

$$\sum \frac{Future\ Value}{(1+i)t}$$

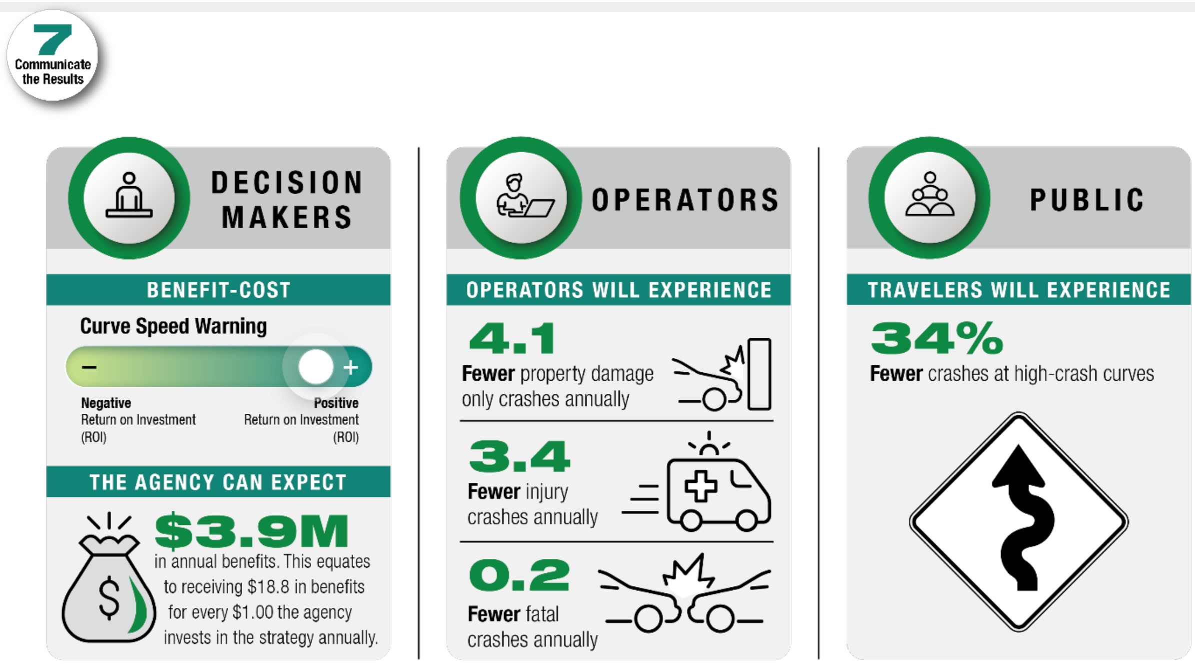
where,
i = rate of return
t = number of periods

10-Year Benefit-Cost Ratio (BCR) =	**18.8:1**
10-Year Return on Investment (ROI) =	**1780%**

Communicating the Results

Communicating the results of benefit-cost analysis provides an opportunity to prove the value of ITS deployments which can sometimes be difficult to demonstrate in a tangible way. It is important to consider the audience with whom the analysis results are being shared such that the information is relevant and relatable.

Communicating the Results: Curve Speed Warning



Source: Kimley-Horn

Figure 3. Curve Speed Warning Benefit-Cost Analysis Results

References

1. FHWA. Crash Costs for Highway Safety Analysis (page 12). 2018. https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf
2. Transportation Research Record: Journal of the Transportation Research Board. “Evaluation of Sequential Dynamic Chevron Warning Systems on Rural Two-Lane Curves” (page 1). 2020. https://journals.sagepub.com/doi/10.1177/0361198120935872
3. Texas DOT. Average Low Bid Unit Price -Statewide (Item # 6068 6001-2, page 3). https://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/bidprice/s_6003.htm
4. USDOT’s ITS Deployment Evaluation Benefit Database. “Colorado DOT deployed a truck speed warning system in Glenwood Canyon at a cost ranging from $25,000 to $30,000.” 2001. https://www.itskrs.its.dot.gov/its/benecost.nsf/ID/89dea53873ce91b085256dfa004b5c71