TECHNICAL BRIEF #3

Benefit Cost Analysis Road Weather Management

Benefit Cost Analysis of Road Weather Connected Vehicle Applications

This information brief is a continuation of the Federal Highway Administration Office of Operations Transportation Systems Management and Operations Benefit-Cost Analysis technical briefing series. Earlier briefs were published in 2012 and are available online at: http://www.ops.fhwa.dot.gov/plan4ops/resources/brochures.htm.

Purpose

The purpose of this technical brief is to guide transportation managers and analysts in evaluating transportation systems management and operations improvements associated with road weather connected vehicle (RW-CV) applications. Benefit-cost analysis (BCA) plays a critical role in such evaluations.

In 2013, the Federal Highway Administration (FHWA) published *Road Weather Connected Vehicle Applications – Benefit-Cost Analysis*.[1] The report explains the goals and benefits of connected vehicle applications that support road weather management (RWM) practices. It provides a comprehensive description of RW-CV applications, the associated benefits and costs, and the methods that can be used to evaluate the economic impacts of those applications at the national level.

This brief is based mostly on the RW-CV report and consists of three sections. The first section provides an overview that summarizes the goals of the RWM program and explains the role of connected vehicle (CV) applications in achieving these goals. The brief then describes specific RW-CV Applications. Finally, a short summary of a BCA conducted for an RW-CV strategy is provided, including several figures to illustrate the procedure.

Overview of Road Weather Connected Vehicle Initiative

The Road Weather Management Program (RWMP) in the FHWA Office of Operations is focused on evaluating the impacts of weather on roadways and promoting strategies and tools to mitigate those impacts. The 2013 RW-CV applications BCA report cited earlier describes the RWMP's Connected Vehicle Initiative, including the products and activities being implemented to achieve these objectives, such as stakeholder coordination, road weather research and development, technology transfer, training and education, and performance evaluation. The report describes how the RWMP evaluated the effectiveness of CV technologies in improving the collection, dissemination, and application of road weather data to reduce weather-related delays and crashes.

Figure 1 shows a high-level overview of the RWM application evaluation process and how BCA procedures are used within this context. As shown in the figure, the role of BCA is crucial in evaluating safety, mobility and environmental improvements as well as in determining cost savings. First, the safety implications of a CV application are analyzed using BCA. Next, the BCA determines the cost effectiveness of the CV applications in terms of mobility, environment, and savings in agency operations costs. The BCA is used throughout the evaluation process and is an integral part of the RW-CV application assessment.

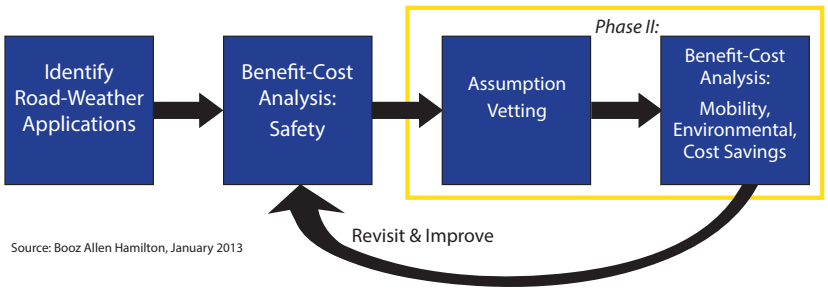

Figure 1. Diagram. The role of benefit cost analysis for road weather management applications.

1. Federal Highway Administration, *Road Weather Management Connected Vehicle Applications*, available at http://ntl.bts.gov/lib/54000/54400/54480/Road_Weather_Connected_Vehicle_Applications_Benefit-508-v8.pdf

Road Weather Connected Vehicle Applications

There are seven major RW-CV applications being promoted and advanced by the RWMP, which are identified and explained in another FHWA report titled *Concept of Operations for Road Weather Connected Vehicle Applications*.[2] Table 1 lists these applications and provides a brief description of each.

Table 1. Road weather connected vehicle applications and their descriptions.

Application	Description
Enhanced Maintenance Decision Support System (MDSS)	Road weather data collected through connected vehicle technologies from snow plows, other agency fleet vehicles, and other vehicles operated by the general public provide input data to Enhanced-MDSS, resulting in improved maintenance operations and increased safety.
Information for Maintenance and Fleet Management Systems	Road-weather connected vehicle data are key inputs to Maintenance and Fleet Management Systems and can, in turn, be passed on to an Enhanced-MDSS to refine the recommended winter weather response plans and treatment strategies.
Variable Speed Limits for Weather Responsive Traffic Management	Road-weather connected vehicle data can be used to inform Variable Speed Limits systems to provide real-time information on appropriate speeds for current conditions and warn drivers of coming road conditions; this application envisioned in particular work zones during a adverse driving conditions.
Motorist Advisories and Warnings	Road-weather connected vehicle data will provide advanced warning on deteriorating road and weather conditions on specific roadway segments to travelers pre-trip and en-route.
Information for Freight Carriers	Road-weather connected vehicle data will provide information on deteriorating road and weather conditions on specific roadway segments to both truck drivers and their dispatchers. This information can be used to improve scheduling decisions and parking availability and delivery schedules.
Information and Routing Support for Emergency Responders	Road-weather connected vehicle data will provide emergency responders, including ambulance operators, paramedics, and fire and rescue companied road-weather alerts and warnings. Road-weather conditions, especially road or lane closures due to snow, flooding, and windblown debris, for specific roadway segments will be used to determine response routes, calculate response times, and inform decision to hand-off emergency calls from one responder to another in a different location.
Weather Responsive Signal Timing	Road-weather connected vehicle data is used by signals to optimize timing for safety and mobility during adverse weather conditions.

Benefit-Cost Analysis of Road Weather Connected Vehicle Applications

To demonstrate the use of BCA for evaluating RW-CV applications, FHWA conducted hypothetical case studies for five of the strategies listed in Table 1, which include:

1. Enhanced maintenance decision support system.
2. Variable speed limits for weather-responsive traffic management.
3. Motorist advisories and warnings.
4. Information for freight carriers.
5. Weather-responsive signal timing.

[2] FHWA report *Concept of Operations for Road Weather Connected Vehicle Applications* is available at http://ntl.bts.gov/ib/47000/47300/47330/74CD2020.pdf.

By evaluating these strategies in a hypothetical State, the case studies provide guidance and examples on how to measure the costs and benefits of RW-CV applications, what information or data are needed to perform a BCA, and how the Tool for Operations Benefit Cost Analysis (TOPS-BC) can be used to conduct the evaluation. The RW-CV BCA report described earlier provides information on what cost and benefit items are associated with the various applications and should be included in the BCA. Those items were used in the hypothetical case studies.

In order to provide detailed guidance on BCAs for RW-CV applications, one of the case studies is presented here, including the required benefit and cost data. The RW-CV BCA case study selected is Motorist Advisories and Warnings, which can use road weather data from connected vehicles to determine existing or impending hazardous travel conditions and develop warnings and advisories that can be provided to motorists and the public at large. With this information, roadway users will be fully informed about adverse weather conditions along their route and can react in time, either by not making the trip, changing their travel plans, or adjusting their driving behavior.

For this hypothetical case study, TOPS-BC Connected Vehicle Beta Version was used to evaluate the RW-CV strategy.

Cost Estimation

The development and implementation of RW-CV Motorist Advisories and Warnings involves several basic infrastructure cost items that need to be included when conducting a BCA. The following cost items are associated with this CV application:

- Urban freeway roadside equipment (wireline & wireless).
- Urban signal roadside equipment (wireline & wireless).
- Rural interstate equipment (with & without power grid connection).
- Application development.
- System integration and back office costs.
- On-board equipment.

Table 2 shows these cost items in the TOPS-BC spreadsheet. In addition to these basic infrastructure costs listed, Table 2 also shows the costs of public education and outreach activities associated with this strategy. The average annual cost calculated for this strategy was $2.21 million.

Table 2. Annualized costs for motorist advisories and warnings in a hypothetical situation using the Tool for Operations Benefit Cost Analysis.

	EQUIPMENT	Useful Life	Capital/Replacement Costs (Total)	O&M Costs (Annually)	Annualized Costs	Quantity	Count	Unit Costs
Basic Infrastructure Equipment and Costs	Urban Freeway RSE w/ wireline	25	$230,400	$5,760	$14,976	24	1 per Mile	$9,600
	Urban Freeway RSE wireless	25	$1,948,800	$48,720	$126,672	96	1 per Mile	$20,300
	Urban Signal RSE w/ wireline	25	$2,331,600	$58,290	$151,554	201	2/3 of signals	$11,600
	Urban Signal RSE wireless	25	$17,951,500	$448,788	$1,166,848	805	2/3 of signals	$22,300
	Rural Interstate w/ powergrid connection	25	$7,647,300	$191,183	$497,075	261	1 per 2 Miles	$29,300
	Rural Interstate w/o powergrid connection	25	$2,411,500	$60,288	$156,748	65	1 per 2 Miles	$37,100
	Application Development Costs	1	$191,746	$-	$191,746	1	1 per Application	$191,746
	System Integration & Backoffice	35	$25,886	$3,835	$4,575	1	1 per Application per TMC	$25,886
	Vehicle On-Board Equipment	1	$4,800,000	$288,000	$5,088,000	48,000	1 per Vehicle	$100
	TOTAL Infrastructure Cost		**$37,538,732**	**$1,104,863**	**$7,398,193**			
Incremental Deployment Equipment	Vehicle Data Translator (This Item is RWM-specific only)	25	$-	$-	$-		1 per TMC	$1,000,000
	Maintenance Vehicle Costs	5	$-	$-	$-		1 per Maintenance Vehicle	$30,000
	Dynamic Message Sign	10	$-	$-	$-		*VSL ONLY*	$82,000
	Education & Outreach	1	$288,000	$-	$288,000	6,400,000	1 per capita	$0.045
	TOTAL Incremental Cost		**$288,000**	**$-**	**$288,000**			
	Enter Number of Infrastructure Deployments	1	$1,924,,530					
	Enter Number of Incremental Deployments	1	$288,00					
	Enter Year of Deployment	2020						
	Average Annual Cost	**$2,211,530**						

O&M = operations and maintenance. RSE = roadside equipment. RWM = road weather management. TMC = traffic management center. VSL = variable speed limit.

Benefit Estimation

Data available from the RW-CV BCA report was also used to estimate the benefits of this strategy in the case study. According to the report, the effectiveness of the Motorist Advisory and Warning strategy is estimated to be 20 percent, meaning that crashes are likely to be reduced by 20 percent when the strategy is in place. Along with this assumption is the increase in capacity due to a lower amount of incidents that slow down traffic. The report estimates this number to be 10 percent for all CV applications, including Motorist Advisory and Warning. The analyst can refine any TOPS-BC calculation using these spreadsheets if more specific data is available. Through this flexible user interface, more refined and accurate results can be generated.

The total average annual benefit is calculated automatically by TOPS-BC and can be found at the bottom of the benefit estimation sheet. Table 3 shows the total average annual benefit for this strategy at $13.32 million.

Table 3. Annualized safety benefits for motorist advisories and warnings in a hypothethetical scenario using the Tool for Operations Benefit Cost Analysis.

Safety	$ Value of a Fatality Crash		$10,433,467	
	$ Value of a Injury Crash		$77,671	
	$ Value of a Property Damage Crash		$2,656	
	Total Modeled Crash Related Benefit per Period			$2,765
	User Entered Benefit (Annual $'s)			
	Number of Analysis Periods per Year		250	
	TOTAL AVERAGE ANNUAL BENEFIT			$13,321,771

Benefit-Cost Analysis Results

Table 4 shows the section of TOPS-BC that compares benefits and costs for the RW-CV Motorist Advisory and Warning strategy. The table indicates that the deployment of this strategy in a hypothetical state is cost effective, since the resulting benefit-cost ratio for the strategy is 6.02. The resulting net benefits for this analysis are about $11.1 million.

Table 4. Benefit-cost analysis results for road weather connected vehicle motorist advisories and warnings in a hypothetical scenario.

Benefit/Cost Summary	
Annual Benefits	**Connected Vehicle Motorist Advisory & Warning**
Travel Time	$12,470,615
Travel Time Savings: Non-Recurring Delay	$159,940
Energy	
Safety	$691,250
Other	
User Entered	
Total Annual Benefits	**$13,321,771**
Annual Costs	**$2,211,530**
Benefit/Cost Comparison	
Net Benefit	$11,110,241
Benefit Cost Ratio	6.02

Technical Contacts

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