A Business Case for Winter Maintenance Technology Applications: Highway Maintenance Concept Vehicle

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ABSTRACT

The purpose of this paper is to demonstrate, from a business perspective, the benefits of using technology applications in winter maintenance operations. This paper documents the business case to be made for the technology applications on the Highway Maintenance Concept Vehicle (HMCV) project by examining the business implications of many benefits such as increased safety, reduced environmental impacts, and increased efficiency.

The use of commercial-off-the-shelf (COTS) and prototype technologies to improve winter maintenance operations has been in practice for several years; however, it has been very difficult to quantify the benefits achieved by adopting these technologies. A benefit-cost framework is established whereby the current methods of performing the analysis can be compared to other proposed winter maintenance technology improvements.

Applying new technology to winter maintenance operations can

- Reduce accidents
- Reduce chemical use
- Provide return on investment

The benefit-cost analysis demonstrated that the integration of the newer emerging technologies does indeed play a beneficial role in reducing accidents, increasing mobility, reducing adverse environmental impacts and having a direct bearing on the economic impacts in the area.

Key words: benefit-cost analysis—business case—technology—winter maintenance

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INTRODUCTION

This report updates the Highway Maintenance Concept Vehicle, Phase IV report by providing a business case for technology applications on the Highway Maintenance Concept Vehicle. The case to be made examines many benefits such as increased safety, reduced environmental impacts, and increased efficiency. A benefit-cost framework is established whereby the current methods of performing the analysis can be compared to other proposed winter maintenance technology improvements.

The objectives of applying new technology to winter maintenance operations are:

- Reduction in accidents:
- Reduced chemical usage
- Return on investment

A literature review available on winter anti-icing operations using advanced technology by different agencies indicates reduction or eliminating of accident rates by 73-80 per cent. The Pennsylvania DOT reported an accident reduction of close to 100 percent using anti-icing techniques (*1*) but given certain allowances a presumed 80 percent or a .2 resultant factor rate was used (*1*).

Reduced chemical usage: The Benefit Cost Ratio also suggests that although costs savings are definitely possible with the usage of anti-icing technologies, the level of service to the travelers are increased with the same or less usage of materials. Some of the other benefits are in less chemical usage, less time on equipment and increase in the efficiency of the system.

A similar study was done at the City of Kamloops, British Columbia. Reduced chemical usage: The Benefit Cost Ratio also suggests that although costs savings are definitely possible with the usage of anti-icing technologies, the level of service to the travelers are increased with the same or less usage of materials. Return on investment: The sensitivity analysis parameters for accident reduction/elimination included a wide range of numbers – from the reported close to an 80% accident eliminated (Pennsylvania DOT and Kamloops, British Columbia study) to a range of 50% reduction. Even at the low 50% range, the Benefit Cost Ratio was still favorable at 2.31 and 2.37 indicating a 131% and 137% (depending upon the discount rate) rate of investment (ROI) return for the project.

Return on investment: The sensitivity analysis parameters for accident reduction/elimination included a wide range of numbers – from the reported close to an 80% accident eliminated (Pennsylvania DOT and Kamloops, British Columbia study) to a range of 50% reduction. Even at the low 50% range, the Benefit Cost Ratio was still favorable at 2.31 and 2.37 indicating a 131% and 137% (depending upon the discount rate) rate of investment (ROI) return for the project.

The investigation also examined some of the secondary benefits and risks associated with these technology applications to winter maintenance operations.

BACKGROUND

The entire Highway Maintenance Concept Vehicle project encompassed four phases over a six–year period. Phase I of this project focused on describing the desirable functions of a maintenance concept vehicle and evaluating its feasibility. Phase II was the proof of concept phase that included development, operation, and observation of three prototype vehicles. Phase III included, conducting the field evaluation of three prototype vehicles, and identifying method(s) and cost to integrate the data and information generated by the vehicle into the state's snow and ice control management process. The research quickly pointed out that investments in winter storm maintenance assets must be based on benefit/cost analysis and related to improving level of service. If the concept vehicle and data produced by the vehicle are used to support decision-making leading to reducing material usage and the average time by one hour, a reasonable benefit/cost will result. In Phase IV we, at CTRE, as well as our partners at Iowa DOT, Wisconsin DOT, and Pennsylvania DOT, long considered the benefits of advanced technology to enhance winter maintenance activities. The HMCV demonstrated near term benefits of the technologies for winter maintenance operations.

WHY BUSINESS CASE?

A business case is one way to organize, evaluate, and present information about the actions that governments take to improve public safety. In this report, all benefits and costs each year between 2000 and 2001 are included in the benefit–cost analysis (BCA) and all values are discounted back to 2000 using both a 4 percent and a 7 percent real discount rate to calculate the present values of the benefits and costs in 2002 dollars.

The Benefit–Cost Ratio suggests that although costs savings are definitely possible with the usage of anti-icing technologies, the level of service to the travelers is increased with the same or less usage of materials.

DETAILED RESEARCH

The first step in developing the business case was to analyze the data and information technology in the Iowa DOT maintenance operations and determine their impact on the cost of conducting those activities. Reductions in resource costs, labor, trucks, and materials, are achieved by identifying cost factors and by taking actions to influence those factors. Certainly the severity of the winter affects winter maintenance costs. A "bad" winter is very expensive and requires using a large amount of labor, trucks, and materials to achieve an acceptable level of service.

Every year, state agencies spend an estimated two billion dollars plowing snow, sanding and spreading chemicals on icy roadways. Approximately 20,000,000 metric tons of sodium chloride (road salt) is used annually for deicing. The demand for salt has doubled in the last ten years. To keep roads clear and safe for travel, the Iowa DOT, for example, spends approximately $35 million every year on winter maintenance spending an average of $65,000 to $70,000 per hour to fight the winter storms, (*2*).

This Benefit Cost Analysis (BCA), conducted as part of the overall goal of the pooled fund study's Highway Maintenance Concept Vehicle project to "examine and test newly emerging technologies that have the potential for improving the level of service defined by policy during the winter season at the least cost to taxpayers."

Benefits of anti-icing techniques have been summarized in the table below. Based upon the perception of maintenance personnel, most benefits were related to improved safety and improved productivity (i.e., reduced maintenance costs), (*3*).

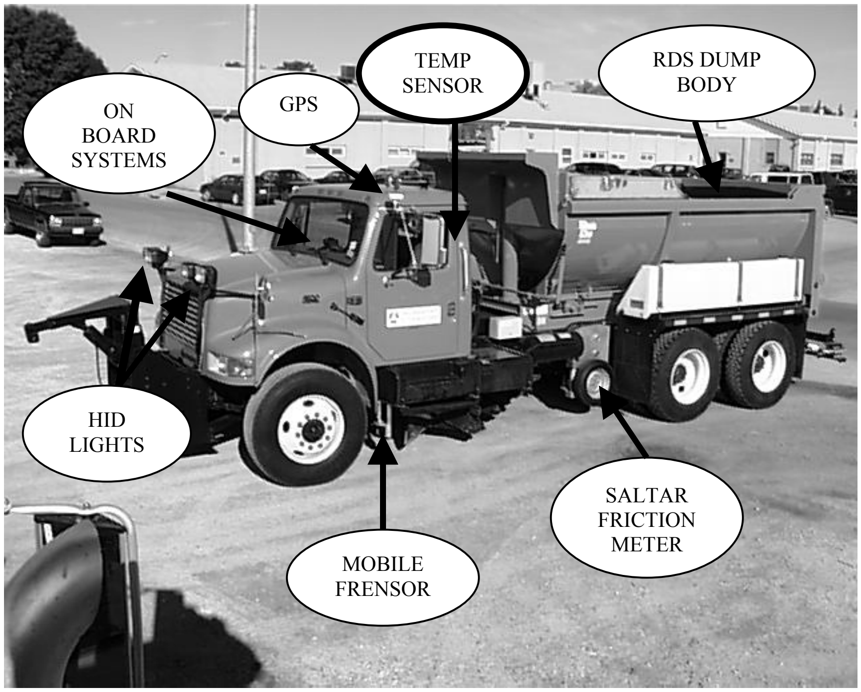

FIGURE 1: Phase IV Highway Maintenance Concept Vehicle (2001-2002)

METHODOLOGY

The methodology for conducting the BCA is based on the guidelines outlined for generally accepted practices for federal projects and on the Benefit/Cost Analysis of ITS Applications for Winter Maintenance conducted by Robert Stowe, P.E., previously with the Washington DOT. Using information obtained from the DOT officials from the Washington and Arizona DOT, it was established that the BC Worksheet for Collision Reduction was an appropriate and a valid tool in computing the benefits and costs for collision reduction.

The BCA considered two different alternatives for this study.

Do nothing Alternative. The first alternative is the 'do-nothing' alternative where the status quo approach of using traditional method of winter application was considered. Although this practice has worked successfully over the past years, this system is not very efficient in terms of safety, consumption of materials and labor. This inefficient system uses the outdated reactive deicing approach in solving winter road surface conditions. A study by the Iowa DOT suggests that 30 percent of the salt is wasted using existing techniques. Also, excessive chemical run-offs contaminate soil and ground water contributing to environmental degradation. Although the 'do-nothing' alternative has the advantage of low implementation cost, it carries high operational efficiencies and perhaps much higher costs in terms of societal benefits.

The second alternative considered was to study the benefit cost analysis of deploying and integrating anti-icing strategies on HMCVs during winter applications. A comprehensive BCA would include quantification and monetization of various elements of the analysis; safety in terms of accidents reduced or eliminated, reduction in salt, chemical and labor usage, environmental equity, savings in time due to increased mobility, etc. Since no historical or relevant data on environmental, mobility and labor usage was available, this BCA was conducted on two counts viz. Safety and Material usage (salt). The crash report was based on information available at the Iowa Traffic Safety Data Service and CTRE for crash severity data for years 1998-2000. The Iowa DOT provided the salt usage data at the Des Moines North Garage.

One of the basic concepts of Benefit–Cost analysis is not to consider sunk costs (money already spent). This appears to be consistent with one of the purposes of the HMCV, which is to determine whether or not to proceed with the project according to the plan outlay. Because this analysis is being done after the development costs have been incurred, the purpose of this BCA is not to determine development and operational costs of the system will be justified by the projected benefits, but rather to evaluate whether the projected costs and benefits (starting with fiscal year 2000) justify continuation of the project, (NIH. 1998).

The BCA analysis undertaken in this study differs marginally from the original model envisaged in Task 3 of the Phase IV study Work Plan dated February 28, 2002 for the following reasons.

1. Discounting: In the original model, discounting, where future cash flows are reduced to equivalent present-day values, is not addresses. Discounting is important element of a BCA whereby the costs and benefits of each year of the system cycle is estimated and is then converted to a common unit of measurement to properly compare competing alternatives.

2. Start –up costs or sunk costs are usually not part of the BCA analysis for an ongoing project.

Data were available on safety and materials, specifically, usage of salt. This provided the basis to conduct the BCA based on these data.

ASSUMPTIONS

BCAs should be explicit about the underlying assumptions used to arrive at estimates of future benefits and costs. For our analysis, these are some of the assumptions:

1. Wet conditions have been included in the element of surface conditions for winter driving conditions. Since anti-icing materials are applied to the roadway immediately before or at the beginning of a storm, the road becomes wet or slushy rather than icy. This wet road conditions are considered part of the surface condition under analysis.

2. The BCA time period should match the system life cycle. The system life cycle includes the following stages/phases: a) Feasibility study b) Design c) Development d) Implementation e) Operation. The system life cycle or technological obsolescence is considered five years.

3. The BCA computation has been done on two factors, that of Safety and salt usage. The Iowa DOT has specific information on crash severities. Literature reviews indicated that

specific data was available for crash severities and value of life matrix. Not much data was available for the mobility, efficiency, productivity and environmental quality of the areas under analysis.

4. Based on the data available, it was determined that accidents were eliminated by almost 80% when anti-icing techniques were used. This was the case in Pennsylvania and British Columbia, Canada. Resultant factor has been computed on different range of values. The first at 0.2 (80% accidents were eliminated) and the second at 0.5 (50% of the accidents were eliminated).

HMCV

A portion of the equipment used in this research was provided to the study, some had to be purchased and some was included in the cost of upgrading the snowplow that was done during the normal course of normal vehicle replacement schedule at Iowa DOT.

The chart below lists the costs of the equipment, along with the vendors that supplied those equipment items.

TABLE 1: Costs of HMCV

Equipment Item	Cost	Vendor
Chassis – International	$65,500	Monroe Snow & Ice Control
RDS Dump Box	5,500	Same
Front Plow	4,000	Same
Sander/Salter	2,600	Same
Underbody Blade	6,600	Same
Added Features for HMCV		
On board pre-wetting	2,500	Monroe
Anti Icing Spray bar	14,000	Monroe
Surface Temp. Sensor	800	Sprague
AMS 200 Data Management	2,500	Raven Industries
DCS 710 Ground Speed Controller	8,000	Raven Industries
Trakit AVL	13,000	IDA Corp
DGPS Antennae	1,400	Communications Systems International
HID Plow Lights	1,100	Speaker
Saltar Friction Meter	15,000	Norsemeter
Frensor Mobile Freeze Point Detection	10,500*	AeroTech-Telub
Total	**$153,000**	

BENEFIT COST CALCULATIONS

All benefits and costs each year between 1998 - 2000 are included in the BCA and all values are discounted back to 2000 using both a 4 percent and a 7 percent real discount rate to calculate the present values of the benefits and costs in 2000 dollars. Planners and economists have traditionally followed the use of 4 percent real discount rate in these benefit/cost calculations using the guidelines published in the ‘red book,’ by AASHTO. (A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, 1977) published by the American Association of State Highway and Transportation Officials. The 7 percent real discount rate is a federal Office of Management and Budget guideline for calculating a BCA for federal projects.

DISCOUNTING

Future cash flows need to be reduced to equivalent present-day values, because the value of a dollar in the future is less than the value of a dollar today. This is referred to as discounting. After the costs and benefits for each year of the system cycle have been estimated, it is converted to a common unit of measurement to properly compare competing alternatives. That is accomplished by discounting future dollar values, which transforms future benefits and costs to their “present value.” The PV (also referred to as the discounted value) of a future amount is calculated with the following formula:

$P = F (1 / (1 + I)^n$ where,

P= Present Value
F=Future Value
I=interest rate &
n=number of years

Government policies or projects typically produce streams of benefits and costs over time rather than in one-shot increments. Commonly, in fact, substantial portions of costs are incurred early in the life of the project, while benefits may extend for many years. Yet, because people prefer a dollar today than ten years from now, BCA typically discounts future benefits and costs back to present values. The system life cycle for this study is considered 5 years.

SENSITIVITY ANALYSIS

At its most rudimentary, a Sensitivity Analysis demonstrates the impact of variations on the discount rate on the final analysis. But to put in a broader perspective, a sensitivity analysis tests the impact of changes in input parameters on the results obtained from the benefit-cost analysis. For example, how much change in the value of the benefits is required before the costs of the proposed system exceed the benefit.

An appraisal should always be subject to a sensitivity test to assess how robust the result is to changes in the assumptions used in calculating it. In particular, a range of expected accident reductions should be assessed, since one can never be certain as to what the actual outcome will be; using a low and a high estimate of possible and realistic outcomes is always good practice. In our case study, although literature review suggests that the resultant factor of 0.2 is safe to use (80% of accidents were eliminated), the range was expanded to include a conservative value of 0.5 resultant factor (50% of the accidents were eliminated).

If the outcome is favorable even if a pessimistic forecast is used, we can be confident that the project is worthwhile. Conversely, if the outcome is unfavorable even with optimistic assumptions, we can be confident that the project is unlikely to be worthwhile. The middle ground—favorable under optimistic assumptions and unfavorable under pessimistic assumptions—requires us to do more work to try and get a better forecast.

CONCLUSIONS

The BCA demonstrates that the integration of the newer emerging technologies in the concept vehicle does indeed play a beneficial role in reducing accidents, increasing mobility, reducing adverse environmental impacts and having a direct bearing on the economic impact in the area. The sensitivity analysis parameters for accident reduction/elimination included a wide range of numbers – from the reported close to an 80% accident eliminated (Pennsylvania DOT and Kamloops, British Columbia study) to a range of 50% reduction. Even at the low 50% range, the Benefit Cost Ratio was still favorable at 2.31 and 2.37 indicating a 131% and 137% (depending upon the discount rate) rate of investment (ROI) return for the project.

The Benefit Cost Ratio also suggests that although costs savings are definitely possible with the usage of anti-icing technologies, the level of service to the travelers are increased with the same or less usage of materials. Some of the other benefits are in less sand and chemical usage, less time on equipment and increase in the efficiency of the system.

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APPENDIX A. BENEFIT COST WORKSHEET

For collision Reduction

Safety Improvement Location: Select Corridor I –35 Polk County, Iowa (appendix C)
Safety Improvement Description: Technology add-ons on HMCV

1. Initial Project Costs, I: $50,691
2. Net Annual Operations and Maintenance Costs, K: $ 5,000
3. Annual Safety Benefits in Number of Collisions:

Before (historic) Collision type	Nos.	Yrs.		- Rate	After (estimated) Resultant	Rate Factor		= Annual Benefits
a) Fatality	0	3	=	0.0	.2	0.00	=	0.00
b) Major Injury	4	3	=	1.33	.2	0.27	=	1.06
c) Minor Injury	17	3	=	5.67	.2	1.13	=	4.54
d) Possible Injury	18	3	=	6.0	.2	1.20	=	4.80
e) Property Damage Only	51	3	=	17.0	.2	3.40	=	13.60

1. Costs Per Collision:

5. Annual Safety Benefits by Costs of Collision

Collision Type	Cost				
a) Fatality	$ 1,000,000	a)	(3a)(4a)	=	$ 0
b) Major Injury	$ 150,000	b)	(3b)(4b)	=	$159,000
c) Minor Injury	$ 10,000	c)	(3c)(4c)	=	$ 45,400
d) Possible Injury	$ 2,500	d)	(3d)(4d)	=	$ 12,000
e) Property Damage Only	$ 2,500	e)	(3e)(4e)	=	$ 34,000
			TOTAL, B	**=**	**$250,400**

6. Service life, n = 5 years 7. Salvage Value, T = $1,000 8. Interest rate, I = 4%

9. Present Worth of Costs, PWOC:

Present Worth Factor of a uniform series, SPWin = 4.4518
PWOC = I + K(SPWin) – T(PWin) = 67,786

10. Present Worth of Benefits, PWOB =B(SPWin) = 1,114,731

11. Benefit Cost Ratio, B/C = PWOB/PWOC = **16.45**

12. Net Benefit = PWOB – PWOC = **1,046,945**

Sensitivity Analysis based on a) accident savings of 80% (.2 resultant factor) and b) interest rate at 4% (A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements 1977, page 14). SPWin rates from Appendix A, page 118).