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Benefit-Cost Assessment of Automatic Vehicle Location (AVL) in Highway Maintenance

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ABSTRACT

AVL has been used extensively in public transit, law enforcement, and EMS applications (among others), and is garnering more and more interest with the highway maintenance community. Sponsored by the Kansas DOT, The University of Kansas conducted a study of the use of AVL for highway maintenance activities, especially snow removal. State DOTs and other transportation agencies were surveyed with respect to their use or potential use of AVL. At the time of the survey, only 8 states had deployed AVL, in addition to several municipalities and one Canadian province. None of the surveyed agencies had conducted quantitative assessments of the benefits of system deployment.

Qualitative and perceived benefits taken from the aggregated survey data were used to develop estimates of benefits likely to be realized from an AVL deployment. Savings from improved fleet management, paperwork reductions, and reductions in snow-related crashes were compared with the system investment and maintenance costs. Costs for system wide deployment were estimated to be about $9,000,000 with about $800,000 needed for maintenance annually. Benefit/cost ratios were calculated for three deployment schedules based on conservative assumptions and then based on moderate assumptions. The analysis estimated B/C ratios would be at least 2.6 and probably closer to 25.

This paper elaborates on the results of the survey and details the methodology used in the analysis.

Key words: AVL — benefits—ITS—maintenance—snow removal

INTRODUCTION

Automatic Vehicle Location (AVL) systems are a fleet management tool that integrates several technologies to allow a fleet manager or dispatcher to see the location of their vehicles at any given time. Many systems can also indicate the status of each vehicle. For example, a law enforcement dispatcher can be informed whether a vehicle is in service, on break, or in hot pursuit. A snowplow can automatically report whether the plow is up or down and when it is spreading sand or salt. Putting this kind of information at the hands of managers enables them to make more efficient use of their resources. Both public and private agencies are taking advantage of AVL to enhance both the efficiency and the effectiveness of their operations. AVL has been widely used in the trucking industry for several years. Many transit and emergency services agencies have also implemented AVL. Use among highway departments has been sparse, possibly because the benefits in that context are less obvious. Even so, several state Departments of Transportation and municipal Public Works departments have implemented AVL and found it to be a valuable tool for maintenance and operations activities.

HISTORICAL PERSPECTIVE

The AVL services industry was born when Qualcomm launched its OmniTRACS service in 1988. Providing vehicle tracking and data messaging, the service primarily targeted the long-haul trucking industry. Although OmniTRACS continues to hold a commanding share of the AVL market, especially in the trucking industry, a number of rivals emerged, including Highway Master, InTouch Communication, American Mobile Satellite Corporation (AMSC) and Orbcomm. (*1*)

Most of these companies rely on the same technology, Global Positioning System (GPS), for their geolocation function. In contrast, a variety of wireless technologies are used for communications. OmniTRACS, for example, leases capacity on geo-stationary satellites. HighwayMaster and InTouch use analog cellular telecommunications. AMSC relies on a hybrid system that operates over both its geo-stationary satellite and the ARDIS terrestrial data network. In November 1998, Orbcomm began offering commercial vehicle tracking services that use its constellation of 28 Low-Earth Orbit (LEO) satellites for communications. Teletrac uses a dedicated radiolocation network. (*1*)

HIGHWAY MAINTENANCE APPLICATION OF AVL/MDT

In 1998, the Virginia Department of Transportation (VDOT) implemented an AVL system that allowed snowplow managers to better manage snow removal in four counties. (*2*) The Smart Plows utilize ITS technologies to monitor vehicle location, road surface condition, and apply the appropriate amount of chemicals or sand to treat the roadway. The goal of the system was to facilitate the following functions.

- Continuous location of snowplow fleet operations
- Ability to identify vehicles with abnormal behavior
- Increase safety for the vehicle operator
- Ability to detect and minimize waste and fraud

- Ability to capture statistical data
- Improved communications efficiency.

These benefits are typical of those expected by other highway departments who have deployed AVL. In general, the consensus seems to be that AVL can deliver all of these benefits, although quantitative data is not yet available.

AVL/MDT COST-BENEFIT ANALYSES

Without formal evaluation studies, it can be difficult to judge whether or not the benefits outweigh the costs of implementation and operation. AVL and MDT technologies have been deployed around the world by various types of agencies, but predominantly by transit agencies and commercial trucking companies. All too frequently, once an agency obtains approval to implement AVL, justifying the costs becomes a low priority. Evaluation plans are often sacrificed at the first signs of a budget shortfall. While that is understandable, it is often the result of a near-sighted perspective and is very unfortunate for the transportation community at large, particularly in the longer term as agencies have difficulty justifying investments in AVL because of the lack of documentation of benefits.

Many transit operators experience strong pressure to upgrade their fleet management systems with the latest AVL technologies. The many benefits of such systems have been very well publicized in numerous U. S. Department of Transportation (USDOT) publications. With a 45% annual return on investment reported as the cost effectiveness, these systems quickly end up paying for themselves. In that light, it is not surprising that there is a strong push for system procurement (*3*). But it is noteworthy that this return of investment applies for transit fleet management systems, but not necessarily for highway maintenance and operation purposes.

There are, however, some general principles that are worth considering in developing a strategy for assessing the potential benefits of AVL in a highway maintenance context. Schweiger C. L., and Marks J. B. (*4*) have outlined four critical parameters that should be considered. Their particular concern was the use of AVL in public transit, but the principles have broad application across contexts. They recommended the following four components be included in cost-benefit analysis.

- Determination of Life-Cycle Costs
- Methodological Approach to Cost/Benefit Analysis
- Quantification of Risks
- Assignment of Dollar Values to Intangible Benefits

If these components can be effectively applied to AVL in a highway maintenance context, valuable information can be gleaned for transportation agencies considering AVL. Toward that end, in Spring 2000, the Kansas Department of Transportation contracted with The University of Kansas to conduct a study of the costs and benefits associated with implementing AVL in their maintenance and operations.

APPROACH

An initial survey was conducted to determine the level of involvement of highway agencies in AVL deployment. Those agencies identified by the survey as having deployed an AVL system were contacted with a more extensive survey related to their experiences. The results of the survey were used to establish parameters for the benefit-cost analysis.

Two risk perspectives (low risk and very low risk) were examined to provide insight into the likely magnitude of the benefits. Costs were constant across scenarios. Benefits in the very low risk perspective were calculated using all conservative assumptions. The results of this analysis represent the minimum benefits that can reasonably be expected. In other words, the actual benefits are highly likely to be equal to or greater than the calculated benefits, and likely to be much greater. Benefits in the low risk perspective were calculated using more moderate (though still somewhat conservative) assumptions. The resulting figures more closely approximate what could be expected. For these scenarios, the actual benefits are likely to be close to but slightly greater than the calculated benefits. For both perspectives, the results were used to calculate a cost-benefit ratio based on three different implementation scenarios, conservative, moderate, and aggressive, with the full implementation occurring in 20, 10, and 6 years, respectively.

SURVEYS

The literature discusses a number of AVL/MDT deployments among highway maintenance agencies, but no formal cost-benefit assessment is available. Costs vary widely from implementation to implementation, and benefits are largely anecdotal and undocumented. To exacerbate the problem, most deployments in the highway maintenance arena are so recent that even the anecdotal reports of benefits are speculative. It is very likely that some agencies have implemented AVL without having published information about the systems, though it is unlikely that such an implementation would include a formal evaluation.

Based on results of the literature review, a survey was developed to help identify agencies that have had experience with AVL. Initially, all 50 state DOTs, Canadian provinces, and 6 municipal public works departments were contacted regarding their deployment of AVL/MDT technologies for tracking maintenance vehicles. Several of the municipal applications were identified by contacting technology integrators (i.e., consultants) that are prominent in the field. The survey was also made available over the Internet and various organizations were asked to bring it to the attention of their constituents. Organizations contacted included ITS America, ITS Australia, ERTICO, and VERTIS. Regretfully, no responses were received as a result of involving the ITS organizations.

The preliminary survey revealed that fifteen agencies had already deployed AVL/MDT technologies for tracking their highway maintenance vehicles, eight of which were State DOTs. A detailed questionnaire was developed to further explore the experiences of these agencies. This questionnaire included questions regarding the technology being used, costs and benefits experienced, and obstacles encountered. All surveys—both preliminary and detailed—were followed up via Email and telephone until all responses were received.

Results Summary

Figure 1 shows a time line of the AVL deployments that were identified in the preliminary survey. Among the deployments, the number of vehicles outfitted with *in-vehicle units* (IVUs) ranged from 4 to 150, with an average of 36. Half of the deployments involved 20 vehicles or more. 12 of the 15 agencies cited snow removal as their primary application. The most frequently cited benefit was improved snow removal. The agencies were asked to cite the most significant obstacle encountered during the deployment process. The most common issue seemed to be funding, although several other obstacles were mentioned. The majority of the deployments (10) utilized CDPD for transmitting data. Two used satellite, two used analog cellular (one of these two also used satellite), and two used LMR. When asked whether they thought the system was cost-beneficial overall, two agencies said their systems were cost-beneficial, and the rest indicated in some way that they could not yet tell. These responses were not surprising given that, at the time of the survey, none of the systems had been in operation for more than four years, and most were much more recent.

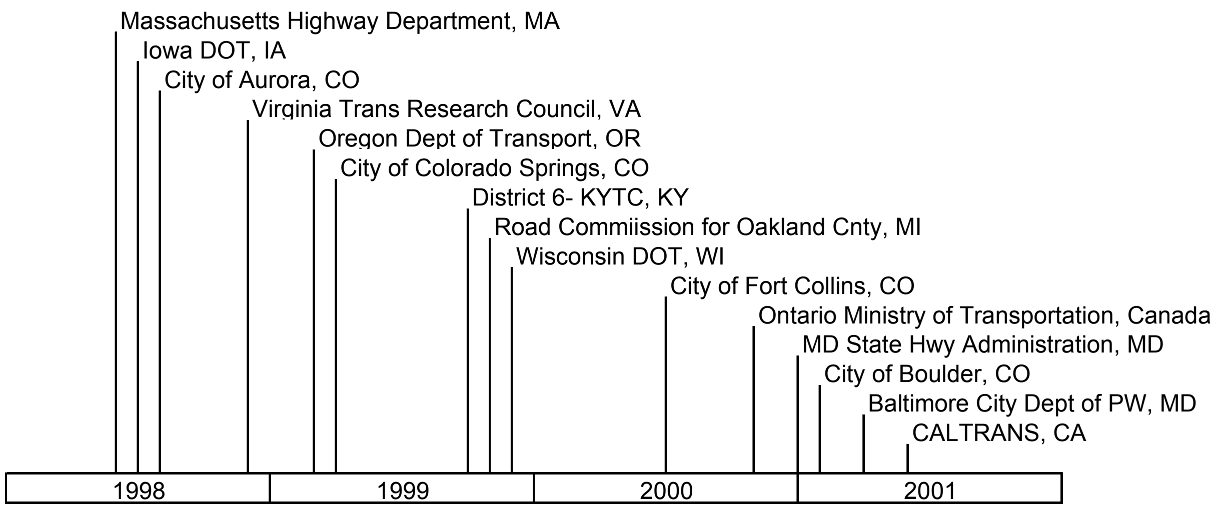

FIGURE 1. Time Line of AVL Deployments

COST ASSESMENT

Two categories of system costs were considered, investment costs and operation and maintenance costs. Costs were estimated for a small scale pilot project and for statewide deployment.

Investment Costs

It was assumed that KDOT's existing 800 MHz radio system would be used, and a dedicated channel would be added for data transmissions. The implementation cost for the dedicated data channel was approximately $750,000 for a pilot project and $6,000,000 for a statewide deployment. These estimates were provided by the KDOT Bureau of Maintenance and Construction based on current equipment costs. Consistent with other deployments, the communications costs are by far the most significant portion of the total system cost. Cost estimates for other components of the pilot test and subsequent statewide implementation were drawn from the data collected through the survey of transportation departments. Various considerations were used to determine each number, including the consistency of the costs for that component across implementations, how recent the costs were (i.e., when the implementation began), and the similarities and differences between the characteristics of the implementations described in the survey and the expected characteristics of an application to KDOT needs. The scope of the pilot project and the statewide deployment in terms of administrative areas and vehicle counts is shown in Table 1.

TABLE 1. Pilot Project and Statewide Deployment Scope

	Pilot	Statewide
Areas	1	26
Subareas	6	112
Maintenance Vehicles	23	585
Paint Trucks	1	6

In the vehicle, three different types of expenditures were considered. An In-Vehicle Unit (IVU), comprising a GPS receiver, a data modem, and a Mobile Data Terminal (MDT), was estimated to cost approximately $3,500, including installation. A total of 24 units were considered for the pilot project—23 maintenance vehicles and one paint truck. Road and air temperature sensors were estimated to cost $600 per vehicle. However, it was assumed in this analysis that the existing sensors would be used. Considering the communications, in-vehicle, other costs, the total cost for a pilot deployment was estimated to be $957,000. The costs associated with a statewide deployment are shown in Table 2.

TABLE 2. Statewide Implementation Costs

Items	Unit Rate ($)	No. of units	Amount ($)
Base station hardware	7,000	26 (1/area)	184,000
Software (licensing)	25,000 for the first computer 5,000 per additional	26 (1/area)	150,000
Sensors and software integration	15,000 (software)		15,000
In-Vehicle Units	3,500/unit	585 units	2,047,500
Training (3 days on site)	3,000/area	26 areas	78,000
Repair and Maintenance	4,000/year/area	26 areas	104,000
System integration	15,000/area	26 areas	390,000
Add data channel to radio system[1]			6,000,000
Total initial expenditure			8,968,500

[1] Includes $750,000 expended during pilot project.

Operation and Maintenance Costs

The operating costs generally involve the monthly fees for the CDPD connection, if a CDPD based communication system is used. For an implementation of AVL using KDOT's radio system, operation and maintenance costs are comprised primarily of maintenance and repair for the radio system's dedicated data channel, the in-vehicle units, and the base station equipment.

Annual maintenance costs were estimated to be the purchase price of the equipment divided by the typical service life. Only equipment unique to the AVL system was considered. That is, the cost of maintaining the 800 MHz radio system is a cost that would be incurred regardless of whether or not an AVL system were implemented. Consequently, the implementation of AVL adds no incremental cost to the maintenance of the existing radio system. The cost of the in-vehicle units is estimated to be $3,500 each. Assuming the statewide implementation would involve 585 KDOT vehicles, and assuming a 7-year service life based on Schweiger, et al. (1999), the average annual maintenance cost of the in-vehicle units would be $292,500. Assuming one base station at each area office with an initial cost of $7,000, also with a service life of 7 years, the annual maintenance cost of the base stations would be $26,000.

The incremental maintenance costs incurred by the addition of a dedicated data channel were estimated based on the KDOT Replacement Life Cycle of 12 years, assuming that an average of 1/12 of the equipment will be replaced each year. Under this assumption, each year's maintenance would be equal to the cost of the entire system times the percentage of the system deployed divided by 12. The total annual maintenance cost of the system, once fully deployed, would be $818,500.

EXPECTED BENEFITS

The nature of the expected benefits can be drawn from the experience of other agencies combined with the operational characteristics of KDOT maintenance crews. Benefits that can be expected to include the following.

- More timely response to emergencies.
- Improved resource management by analyzing past activities to improve efficiency.
- Reduced snow-related accidents due to reductions in snow removal times.
- Increased security for drivers.
- Reduced legal costs from tort claims allegedly involving KDOT maintenance vehicles.
- Reduced material costs with more efficient application strategies.
- Reduced time associated with routine paperwork.
- More timely pavement condition information.
- Enhanced locational accuracy of various inventories and map segments.
- Increased completeness of various inventories (e.g., PMS).
- Automatic and continuous updates of pavement conditions for KDOT maintenance.
- Potential feed of near real-time information to KDOT Advanced Traveler Information Systems (ATIS) (e.g., web site, dial in, 511 (eventually)).
- Improved efficiency and effectiveness of roadside maintenance.
- Reduced fleet maintenance costs due to improved fleet management

To develop an objective comparison of the costs and benefits associated with the implementation of AVL, a subset of the benefits listed above were quantified and compared with the maintenance costs over a 20-year period. The benefits considered in the cost-benefit analysis are shown in bold type in the list above. The other benefits listed were omitted from the analysis either because they are difficult to express in monetary terms or because the information gleaned from the surveys was insufficient to estimate their magnitude.

Benefits Survey

In the detailed survey, 7 of the 15 agencies contacted provided estimates of their efficiency savings in snow removal due to the implementation of AVL. The values cited ranged from 5% to 50% improvement, with an average of just over 20%. Only 3 agencies provided estimates of savings due to reduced paperwork. The values were 10% and 20%, with one agency citing an increase of 15% in paperwork to facilitate analysis. The minimum and average values were used for the cost/benefit analyses discussed in the following sections (the increase in paperwork to facilitate analysis was ignored).

Two sets of estimates of benefit magnitudes are presented in each of the sections that follow. Conservative estimates are detailed, representing the least magnitudes cited in the follow-up survey. The probable benefits are represented by moderate estimates, using the average of the values cited in the follow-up survey.

It should be noted that because only one agency provided a value for savings in materials, this factor was not included in the costs/benefit analysis. The efficiency improvement cited was 25-50 percent, which would represent a substantial monetary savings in addition to those included in the analysis.

Savings in Paperwork

The savings resulting from reduced paperwork were calculated on the basis of the daily and weekly reports filed by maintenance crews and paint crews. Based on estimated averages provided by KDOT, the calculations assumed that the reports require 25 minutes daily for each maintenance vehicle and 20 minutes weekly for each sub-area supervisor. An hourly wage of $10 was used, and the AVL system was assumed to reduce the time required to fill out the paperwork by 10%, which was the smallest of the values reported in the benefits survey. The conservative estimate for savings in paperwork was $67,908 per year. A moderate estimate of 15% time savings—the average of the values reported in the benefits survey—would result in an annual savings of $101,862.

Savings from More Efficient Fleet Management

By recording and analyzing fleet activities, vehicles can be used more efficiently, reducing the overall mileage incurred and the associated costs. For maintenance vehicles, annual mileage was estimated by dividing the service life in miles by the service life in years. 200,000 miles / 11 years = 18,182 miles/yr. An operational cost of $0.47/mi was assumed. The conservative and moderate estimates of savings were taken as the minimum and average values, respectively, that were reported in the benefits survey. The conservative estimate of 5% savings would result in an annual savings of $398,864, while the moderate estimate of 20% savings would result in an annual savings of $1,595,455.

For paint trucks, a similar calculation was performed using the same percent savings estimates (none of the agencies surveyed were using AVL in paint trucks). Using the vehicle service life, an annual average was calculated for the hours of use. 10,000 hours / 15 years = 667 hrs/yr. Assuming an operational cost of $71.88/hr (from a KDOT estimated average) and a 5% improvement in efficiency due to the implementation of AVL, an annual savings of $17,336 would be realized. The moderate estimate of annual savings was $69,344.

Savings from Reduced Accidents

Accident costs were calculated based on USDOT recommendations. (USDOT, 1994) Costs per accident were adjusted to 2002 dollars using the implicit outlay deflators recommended by the US Bureau of Economic Analysis. (2001) The accident counts used were statewide counts taken from the Kansas Accident Records System (KARS) for the year 2000. (KDOT, 2001) To ensure a conservative estimate, the number of accidents was used, rather than the number of parties involved. If more than one party was injured in any given accident, only the maximum injury as indicated by KARS was considered. The data was filtered to extract only accidents in which the reported pavement condition was snow covered, snow packed, or ice covered. It should be noted that while winter maintenance operations planning is done in terms of winter seasons which span two consecutive years, both weather records and accident records (as well as economic parameters) are archived based on the calendar year. Consequently, snow-related accidents for the year 2000 will involve accidents that occurred in two different winter seasons. The calculations performed are valid, however, so long as the time frame used is consistent.

To estimate the effects of AVL implementation on accident costs, it was assumed that efficiency in snow removal would be improved by 5% for the conservative estimate, with a corresponding 5% reduction in snow-related accidents in each severity category. For each of those accidents affected, it was assumed that injury accidents would have fallen into the next less severe category (property damage only accidents would be averted). For example, for every 100 accidents resulting in a debilitating injury to at least one occupant, it was assumed that implementing AVL would result in five of those accidents (5%) being classified as non-debilitating injury instead of debilitating injury. Downgrading accident severity was used rather than simply reducing the number of accidents in each category in order to ensure a conservative estimate. Based on these assumptions, the total annual statewide savings in accident costs due to AVL implementation is conservatively estimated to be $5,865,296, as shown in Table 3.

TABLE 3. Statewide Savings in Accident Costs (Conservative Estimate) (*5, 6, 7*)

KARS severity code	F	D	I	P	N	
Description	Fat	Debilitating	Non-Debilitating	Possible	PDO	Notes
Cost per event (1994 dollars)	$ 2,600,000	$ 180,000	$ 36,000	$ 19,000	$ 2,000	1
Cost per event (2002 dollars)	$ 2,981,557	$ 206,415	$ 41,283	$ 21,788	$ 2,294	2
Accidents	24	100	516	600	5421	3
Involved Parties	43	134	794	967	8185	4
Total Weather Costs	$ 71,557,369	$ 20,641,549	$ 21,302,078	$ 13,072,981	$ 12,433,093	
Accidents Affected	5%	5%	5%	5%	5%	5
Savings	$ 3,330,170	$ 825,662	$ 502,966	$ 584,844	$ 621,655	6

Total Accident-Related Savings $ 5,865,296

1) Data Source: FHWA, 1994 Technical Advisory
2) Adjusted for 2002 using deflators from the Bureau of Economic Analysis
3) Source: 2000 KARS Data
4) Shown for comparison only. To ensure a conservative estimate, accidents are used in calculations.
5) Percentage of accidents affected was arbitrarily set as a conservative estimate.
6) Savings result from 1% of accidents in each category being downgraded to the next lesser severity.

Because the amount of snowfall can vary widely from year to year and from one location in the state to another, historical records were examined to determine what relationship the snowfall in the year 2000 has to the average annual snowfall. Data was obtained from the High Plains Regional Climate Center at the University of Nebraska, Lincoln. (HPRCC, 2002) The data shows that the winter of 2000 was a relatively mild winter compared to historical averages for Kansas, at least with respect to snowfall. Eleven locations spread across the state were used as representative samples of the snowfall in their respective regions. Of the eleven locations considered, nine experienced snowfalls below normal in 2000, five of them by more than 6 inches. Wichita and Yates Center, the two locations that experienced snowfall above normal for the year, exceeded the annual averages by just 4.1 and 3.7 inches, respectively. Based on this data, the use of snow-related accident data from the year 2000 is likely to be a conservative estimate of what can be expected annually.

To generate a moderate estimate of accident savings, a percent reduction of 20% was used, the average value reported in the benefits survey. Additionally, the number of parties involved in accidents was used in place of the number of accidents. For example, an accident involving two cars in which 4 people were injured would count as 1 in the conservative estimate and 2 in the moderate estimate. Some adjustment for snowfall was merited, though the data available is not sufficiently detailed to provide any statistically based adjustment. The average percent difference between the average annual snowfall and the year 2000 snowfall for the locations considered was a little more than a 27% decrease. Because one of the more heavily populated areas, Wichita, had above normal snowfall, a conservative adjustment was warranted. For the moderate estimate of cost savings due to AVL implementation, it was assumed that the typical year would experience 13.6% more snowfall than occurred in 2000 (half of the average across the locations), and a corresponding increase in snow-related accidents would occur. The resulting calculations are tabulated in Table 4.

TABLE 4. Statewide Accident Savings (Moderate Estimate) (*5, 6, 7,)*

KARS severity code	F	D	I	P	N	
Description	Fat	Debilitating	Non-Debilitating	Possible	PDO	Notes
Cost per event (1994 dollars)	$ 2,600,000	$ 180,000	$ 36,000	$ 19,000	$ 2,000	1
Cost per event (2002 dollars)	$ 2,981,557	$ 206,415	$ 41,283	$ 21,788	$ 2,294	2
Accidents	24	100	516	600	5421	3
Involved Parties	43	134	794	967	8185	4
(Adjusted for avg snowfall)	49	152	902	1099	9298	5
Total Weather Costs	$ 145,643,098	$ 31,421,391	$ 37,236,693	$ 23,934,711	$ 21,325,380	
Accidents Affected	20%	20%	20%	20%	20%	6
Savings	$ 27,112,023	$ 5,027,423	$ 3,516,799	$ 4,283,053	$ 4,265,076	7

Total Accident-Related Savings $ 44,204,374

1) Data Source: FHWA, 1994 Technical Advisory
2) Adjusted for 2002 using deflators from the Bureau of Economic Analysis
3) Source: 2000 KARS Data
4) Shown for comparison only. To ensure a conservative estimate, accidents are used in calculations.
5) Increased by 13.6% to account for below average snowfall in 2000, the year from which accident data was used.
6) Percentage of accidents affected was arbitrarily set as a conservative estimate.
7) Savings result from 1% of accidents in each category being downgraded to the next lesser severity.

Based on the moderate assumptions, the total annual savings in snow-related accident costs resulting from a statewide AVL implementation would be $44,204,374.

COST-BENEFIT COMPARISON

Three implementation scenarios were considered. After the pilot test completion in 2004, the aggressive implementation assumes one district is added to the system each year until the system is complete. The moderate implementation assumes full implementation occurs over 10 years, and the conservative implementation assumes the full implementation occurs over 20 years. Table 5 shows the net annual savings, net present value (NPV), and benefit-cost ratio (B/C) for each implementation scenario based on moderate assumptions. The investment cost figures shown in the tables are based on the total implementation cost shown in Table 2, converted to 2002 dollars to account for the differing implementation schedules.

It should be emphasized that this analysis considered only those benefits that could be foreseen and could be quantified with reasonable confidence. Some benefits, such as reductions in response time for emergency situations, cannot be reliably expressed in monetary figures, but are nonetheless real benefits. They should be considered in addition to those represented in the quantitative cost-benefit analysis. Additionally, there will almost certainly be benefits that cannot be foreseen. AVL is a mature technology, but its development has occurred mostly in the commercial vehicle, transit, and emergency services communities. The application of AVL to highway maintenance is relatively recent, and the spectrum of potential benefits is still being explored.

TABLE 5. Moderate Estimate of NPV for Statewide Implementation

Disc. Rt. 5%	Aggressive Implementation		Moderate Implementation		Conservative Implementation	
Year	Pct Complete	Net Savings (2002 Dollars)	Pct Complete	Net Savings (2002 Dollars)	Pct Complete	Net Savings (2002 Dollars)
2003	0%	$ -	0%	$ -	0%	$ -
2004	17%	$ 6,825,780	10%	$ 4,095,468	5%	$ 2,047,734
2005	33%	$ 13,001,485	20%	$ 7,800,891	10%	$ 3,900,446
2006	50%	$ 18,573,551	30%	$ 11,144,130	15%	$ 5,572,065
2007	67%	$ 23,585,461	40%	$ 14,151,277	20%	$ 7,075,638
2008	83%	$ 28,077,930	50%	$ 16,846,758	25%	$ 8,423,379
2009	100%	$ 32,089,063	60%	$ 19,253,438	30%	$ 9,626,719
2010	100%	$ 30,561,012	70%	$ 21,392,709	35%	$ 10,696,354
2011	100%	$ 29,105,726	80%	$ 23,284,581	40%	$ 11,642,290
2012	100%	$ 27,719,739	90%	$ 24,947,765	45%	$ 12,473,883
2013	100%	$ 26,399,751	100%	$ 26,399,751	50%	$ 13,199,876
2014	100%	$ 25,142,620	100%	$ 25,142,620	55%	$ 13,828,441
2015	100%	$ 23,945,353	100%	$ 23,945,353	60%	$ 14,367,212
2016	100%	$ 22,805,098	100%	$ 22,805,098	65%	$ 14,823,314
2017	100%	$ 21,719,141	100%	$ 21,719,141	70%	$ 15,203,399
2018	100%	$ 20,684,896	100%	$ 20,684,896	75%	$ 15,513,672
2019	100%	$ 19,699,901	100%	$ 19,699,901	80%	$ 15,759,921
2020	100%	$ 18,761,810	100%	$ 18,761,810	85%	$ 15,947,539
2021	100%	$ 17,868,391	100%	$ 17,868,391	90%	$ 16,081,552
2022	100%	$ 17,017,515	100%	$ 17,017,515	95%	$ 16,166,639
2023	100%	$ 16,207,157	100%	$ 16,207,157	100%	$ 16,207,157
Total		$ 439,791,381		$ 373,168,650		$ 238,557,229
Inv. Cost		$ 7,225,610		$ 6,595,465		$ 5,322,254
NPV		**$ 432,565,771**		**$ 366,573,185**		**$ 233,234,975**
B/C		**28.4**		**27.4**		**24.3**

Based on the moderate assumptions, the agency savings in reduced paperwork and improved fleet management total $1,766,660/year. Annual maintenance costs are estimated to be $818,500/year. According to these numbers, the system would more than pay for its operational costs in efficiency savings.

The Benefit-Cost Ratio would be at least 2.6 (based on the conservative assumptions) and would probably be 24 or higher (based on the moderate assumptions). Depending on the implementation schedule, AVL would likely result in a net benefit of between $233 million and $433 million over 20 years (Net Present Value, 2002 dollars).

CONCLUSIONS

Because the application of AVL to highway maintenance is a relatively recent phenomenon, quantitative data that defines the benefits are not available. In the FHWA's most recent report on ITS benefits, when AVL and other operations and maintenance applications are discussed, the authors summarize the state of the practice, "As implementation of these systems expands, quantified benefits of their use will become apparent. However, there are no benefits data available at this time." (*8*) This lack of data emphasizes the need for including the evaluation from the outset of the implementation planning. As an afterthought, evaluation seldom gains the momentum necessary to generate funding.

In spite of the lack of quantitative studies, the evidence seems clear that there are real benefits and that the likely magnitudes of those benefits are large enough to justify deployment from a cost-effectiveness perspective. The literature and the results of the survey conducted during this study suggest that AVL can provide a significant benefit to highway maintenance operations. The cost-benefit ratio is almost certainly greater than 1, and probably greater than 20. A moderate estimate of the net present value of statewide implementation ranges from $233 million to over $433 million over 20 years, depending on the implementation schedule. The annual efficiency savings for the Department are estimated to be nearly twice the annual maintenance cost of the system. So, in addition to paying for itself, the system will provide excess fiscal benefit that can be used to improve other aspects of maintenance.

The potential for AVL to improve the efficiency and effectiveness of highway maintenance operations appears to be significant. Because the technology is well established and there is some precedent among transportation agencies from which to learn, AVL implementation can be done cost-effectively and with a high level of confidence that the system will prove beneficial. The agency and user cost savings afforded by AVL make the technology a very appealing tool for highway maintenance activities, and the state of the practice is ready to support reliable deployment. With proper attention to planning and evaluation, AVL can help KDOT and other transportation agencies further improve the quality of highway transportation.

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