Economic Evaluation of Advanced Winter Highway Maintenance Strategies

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Highway agencies face demands to maintain or improve the existing winter roadway level of service. The benefits of advanced winter highway maintenance strategies now become more attractive. This paper examines the potential benefits of applying advanced winter highway maintenance strategies. The Vermont Agency of Transportation conducted "Smart Salting," a study of de-icing salt effectiveness at different pavement temperatures. A recommended salt application curve was developed. As the pavement temperature goes down, it takes more salt to melt the ice. Iowa DOT snow removal and material costs were used to calculate the theoretical differential cost using the Vermont Study's recommendations and comparing to actual practice. A saving in materials exists when the Vermont Study material application rate curve is used for pavement temperatures above 25°F. Iowa DOT weather and pavement forecast verification reports were reviewed. The reports consisted of scenario-based questioning, and focused on cost savings and losses. The report calculations did reveal a loss for the 1996-1997 winter season, but preliminary figures for the 1997-1998 winter season are anticipating savings. Advanced winter maintenance strategies reduce the cost of winter maintenance. There is a cost to the roadway user when winter maintenance is lacking. Local economies will suffer, traffic accidents will escalate, and most activities of individuals, industries, utilities, schools, and governments are handicapped in social and economic ways. Key words: maintenance, economic, evaluation, costs, materials.

INTRODUCTION

Many highway agencies and state departments of transportation (DOTs) are facing staff cutbacks, are being called upon to maintain the existing or improve the level of service on their roadway system, and they face additional challenges involving increased productivity, quality, and environmental sensitivity. This paper will complete a study of the potential benefits from the application of advanced winter maintenance technologies—technologies which, when working together, have the potential to provide economic benefits to both the state DOTs and to the highway users. The potential benefits supported by this study include reduction in winter chemicals and abrasives, equipment usage, and labor costs. This paper will examine the use of pavement temperature provided by the advanced technology applications. According to the Transportation Research Board, "Demands on highway agencies for fast and effective deicing, however, sometimes results in indiscriminate salting. However, new developments in winter maintenance including deicer application techniques (e.g. salt prewetting), plowing and spreading equipment, and weather and roadway monitoring (e.g., pavement sensors) are making these priorities less confusing" (*1*).

Pavement temperature is the controlling item in the treatment of highways during winter storms (*2*). Using this fact, pavement temperature data provided by advanced technologies may be used to customize the rates of material application and the type of material utilized to match road conditions, and thus provide treatment for only those sections of the road which require it. This paper will examine two methods to use pavement temperature in advanced winter highway maintenance strategies—the first method involves observation of pavement temperature from stationary sensors and moving vehicles, and the second method involves pavement temperatures obtained from weather forecasts. This paper will use a salt application curve adapted from "Smart Salting: A Winter Maintenance Strategy" provided by the Vermont Agency of Transportation (*3*). Vermont has used the salt application curve to effectively treat their roads with a quality at or above that achieved by conventional treatment methods. This curve is included at the end of this paper. This study will compare the actual amounts of material used on highways to those amounts prescribed by the Vermont study, and determine if a potential material (and thus cost) savings estimate exists.

To estimate potential savings in labor and equipment costs, weather and pavement forecast verification reports for Council Bluffs, Des Moines, and Cedar Rapids maintenance garages were reviewed for the winter of 1996-1997. These reports contained sections outlining savings or losses in both material and labor, related to forecasts provided concerning a particular winter storm event. These savings or losses were obtained from a comparison between conventional National Weather Service (NWS) and media forecasts, and specially tailored forecasts provided by Surface Systems, Incorporated (SSI). From the savings or losses in labor costs, savings or losses in equipment were also calculated for each garage for each winter storm event. Then, using the road mileage (in lane miles) for which each garage is responsible, a value of savings or losses per lane mile of road was calculated to enable equal comparison among garages.

THE VERMONT STUDY

During the winter of 1993-1994, the Vermont Agency of Transportation (VAT) conducted a study concerning the application of pave-

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TABLE 1 Melting Capacity of Salt (*3*)

Temperature (°F)	Pounds of Ice Melted Per Pound of Salt
30	46.3
25	14.4
20	8.6
15	6.3
10	4.9
5	4.1
0	3.7

ment temperature information to winter highway maintenance. Titled "Smart Salting," the Vermont Study was a combination anti-icing and deicing strategy. It called for winter maintenance crews to do two things. First, determine pavement temperature before and during a storm through the use of infrared thermometers mounted on supervisors' vehicles; and second, determine salt application rates based upon the relationship between pavement temperature, melting capacity of salt, and the thickness of ice or snow on the pavement.

The anti-icing concept, as identified in the Vermont Study, refers to the application of liquid chemicals and materials to road surfaces early in the storm or during plowing operations to prevent the bonding of snow/ice to the road surface. The lack of a bond between snow/ice and the road surfaces makes the task of removing the snow and ice much easier. The "Smart Salting" strategy was adopted statewide in Vermont for the winter of 1994-1995.

The Vermont Study generated a Snow and Ice Control Plan, including a figure correlating recommended salt application rates with pavement temperatures. This figure is separated into areas for 1/4" snowpack or 1/8" ice; 1/8" snowpack or 1/16" ice; and 1/16" snowpack or 1/32" ice. Prewetted salt requires less application amount per lane mile than does dry salt because the liquid element in the prewetted solution speeds up the reaction process to remove snow/ice from the road by creating a slurry which sticks to the pavement better than does dry salt. The Vermont Study also identified an "economic salting range" which extends from 30°F down to 20°F. The Iowa DOT estimates that 75 to 80 percent of winter storms occur with pavement temperatures above 20°F. For temperatures below this range down to 10°F, the salt becomes less effective in its ability to melt ice or snow: only spot treatment is recommended unless snow pack or ice begins to form ñ in which case salt should again applied. Ultimately, salt can melt snow/ice down to 6°F.

IOWA DOT SNOW REMOVAL COSTS

Iowa DOT 1996 budget figures for snow and ice removal indicate that, on average, statewide material usage costs average $35,000 per hour, and statewide labor and equipment costs average $19,000 per hour and $16,000 per hour, respectively. These three figures add to

Material + Labor + Equipment = Cost / hour

$35,000 / hour + $19,000 / hour + $16,000 / hour = $65,000 / hour

Thus the average snow removal cost for the state of Iowa is $65,000 per hour. This figure assumes that, during any given winter storm which moves across the state and involves all the mainte-

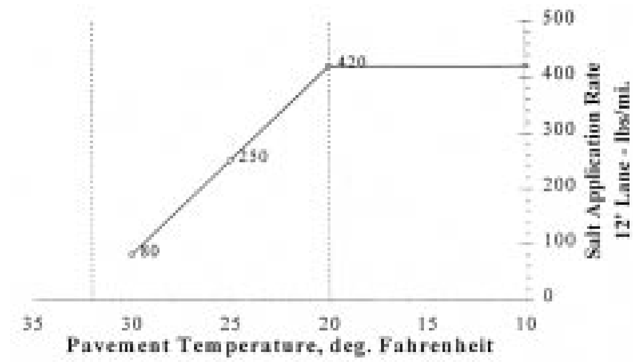

FIGURE 1 Vermont study recommended application rates.

nance areas, the entire state of Iowa is involved in some way in the treatment process.

IOWA DOT MATERIALS

Conversations with maintenance supervisors in Iowa revealed that normal salt application rates are 200 pounds per lane mile (pplm). Three hundred pplm is used for the heavy snowpack and generally occurs 20% of the time. Since the greater application rate is generally used 20% of the time, the lighter application rate is then used 80% of the time. Thus, using the proportion method for total application rate, the average application rate becomes

(0.20) (300 pplm) + (0.80) (200 pplm) = 220 lbs salt

Thus the average application amount is 220 pounds of salt per lane mile of road.

According to the salting curve developed by the VAT, salt application rates could be as low as 80 pplm at 30°F. Current practice in Iowa doesn't include this relatively low application rate. One reason for the current Iowa practice is that the proper treatment of roads is dependent upon the proper amount of material and the trend in temperature. A lapse in proper treatment may result in deterioration of the road condition and may require a considerable amount of time, material, and equipment to re-establish the previously existing level of service. Another reason for the current Iowa practice is apprehension in the recommended low application amounts by maintenance supervisors and equipment operators. The belief that "if you can't see the salt on the road then it's not enough" exists for many supervisors and equipment operators.

Therefore the material cost in salt to treat one lane mile of road, at 220 pplm, is

(220 pplm) (1 ton / 2000 lbs) ($32.50 / ton) = $3.58 per lane mile

Assuming a pavement temperature of 30°F, the Vermont Study recommends a salt application rate of 80 pplm. The material cost would then be

(80 pplm) (1 ton / 2000 lbs) ($32.50 / ton) = $1.30 per lane mile

The total material cost savings when comparing the Vermont Study recommendations to the present rates used by the Iowa DOT is

$3.58 pplm - $1.30 pplm = $2.28 per lane mile savings

According to the Iowa DOT, the Iowa DOT is responsible for maintaining 25,698 lane miles of road. Applying the material cost savings to one pass over the entire Iowa highway network at 30°F, for example, represents savings of

($2.28 pplm savings) (25,698 lane miles) = $58,591.44 savings

Greater savings in salt are realized at temperatures closer to freezing (generally above 25°F) and at lower temperatures, the savings are not as great because the Vermont Study recommends higher application rates with decreasing temperature. At lower temperatures the Vermont Study's recommended application rates are similar to the ones used in practice. For example, at 26°F the Vermont Study recommends a salt application rate of 220 pounds per lane mile, the same as the average application rate used by the Iowa DOT. Below 26°F the recommended application rates are equal to or greater than the ones already used in practice.

PAVEMENT FORECAST VERIFICATION REPORTS

To estimate potential savings in labor and equipment costs, weather and pavement forecast verification reports for Council Bluffs, Des Moines, and Cedar Rapids maintenance garages were reviewed for the winter of 1996-1997. The Matrix Management Group in Seattle, Washington administered these reports. The reports consisted of scenario-based questioning, focusing on cost savings and losses. The purpose of these reports was to measure the effectiveness of RWIS. The purpose of the weather and pavement forecast verification reports was to determine the accuracy of specifically tailored forecasts (through advanced technology) and their utility to Iowa DOT maintenance garages in enhancing snow and ice control operations. The reports also contained cost savings or losses in materials and labor for each winter storm event.

According to the reports, "to determine a loss or savings (in cost), a [maintenance] garage must determine what they would have done with only National Weather Service (NWS), television, radio, or other general media forecasts available. Actual winter maintenance decisions made using Surface Systems, Incorporated (SSI) [ScanCast] forecasts are then compared to what the maintenance managers would have done without the tailored forecast services. Additionally, the value of having RWIS equipment and atmospheric sensors that provide site-specific highway weather and pavement conditions must also be considered in overall savings/loss determinations" (*4*). Savings or losses in both material and labor were provided in the reports, and these figures were tabulated into a spreadsheet for easier calculation. Using the total lane miles of road for which each maintenance garage is responsible, a statistic of savings per lane mile was used to provide equal cost comparisons among maintenance garages.

Savings or losses in costs of equipment were derived from the labor information through some assumptions. The first assumption was a staffing of one equipment operator per maintenance truck so that a one-to-one relationship exists between labor hours saved or lost, and equipment operation hours. The second assumption dealt with the cost of equipment operation. According to 1998 Iowa DOT budget figures, the average cost to operate medium- and heavy-duty maintenance trucks equipped for snow treatment and removal is $11.36 per hour and $17.67 per hour, respectively. These figures are true averages because they were calculated based on trucks of varying ages and reliability. In addition, nearly 40% of the maintenance truck fleet are medium-duty trucks and nearly 60% are heavy-duty trucks. Thus, the average equipment operation cost becomes

(0.40) ($11.36 per hour) + (0.60) ($17.67 per hour) = $15.15 per hour

This cost figure was multiplied by total labor hours saved or lost in each winter storm to find the equipment savings or losses. See Table 2 for savings resulting from the use of advanced technology for Winter 1996-1997.

A summary of the reports for the 1996-1997 winter season revealed an overall loss when using the advanced technology (total losses of over $15,000, or a loss of $2.38 per lane mile). Most of these losses occurred in the last two dates, for the same winter storm. There is an explanation. Since the 1996-1997 season was the first time the verification reports were used, everyone was learning how to utilize them. And, in spite of the upward trend in weather forecast accuracy, situations still do occur where certain storms elude forecasters and prove to be "forecast busters." The latter explanation appears to be the best explanation for the losses, as preliminary figures for the 1997-1998 winter season indicate overall cost savings and no "forecast buster" storm events. During the 1996-1997 "forecast buster" storm system, weather forecasts called for increasingly heavier snowfall as the storm proceeded but, due to warmer than expected pavement temperatures, snow did not accumulate as forecast. (Both the NWS and SSI issued "busted" forecasts.) This situation made it very difficult to manage crews and apply salt and sand in a timely and effective manner. The totals for the winter season are calculated without and with the last storm system of the season. These totals indicate that, including the last storm system, an overall loss was realized from the use of advanced technology. Not including the last storm system, however, result in savings.

CONCLUSION

Winter maintenance is an important issue facing state DOTs. During a time when budgets are decreasing, DOTs are being called upon to provide improved levels of service. Thus, close attention must be paid to the condition of roads. According to Hanbali, "without close attention to the effective removal of snow and ice from streets, roads, and highways during periods of snow and icy conditions, local economies will suffer, traffic accidents will escalate, and most activities of individuals, industries, utilities, schools, and governments are handicapped in social and economic ways" (*5*). This paper explored the economic evaluation of the use of advanced winter highway maintenance strategies, in terms of material, labor, and equipment expenses. The results obtained from the Vermont Study indicate that, above about 25°F, potential savings in materials exists when the material application rate curve is used.

Pavement forecast verification reports were examined to determine the savings or losses in material, labor, and equipment, for maintenance garages in the Iowa DOT, when using advanced technology for winter maintenance decision-making. Although these reports revealed a loss for the 1996-1997 winter season, the losses were due mostly to a "forecast buster" storm system near the end of the season. Preliminary figures for the 1997-1998 winter season revealed a savings when using the advanced technology.

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TABLE 2 Cost Savings Resulting from Advanced Technology, Winter 1996-97

Storm Event Date(s)	Garage	Lane Miles of Road	Material Savings	Labor Hour Savings	Labor Savings	Equipment Savings	Total Savings	Savings Per Lane Mile
12/23/1996	Cedar Rapids	285.19	$825.00	0.0	$0.00	$0.00	$825.00	$2.89
12/25/1996	Des Moines N	424.06	1,620.00	50.0	587.50	757.50	3015.00	7.11
12/25-26/1996	Cedar Rapids	285.19	0.00	0.00	0.00	0.00	0.00	0.00
01/09/1997	Cedar Rapids	285.19	0.00	0.00	0.00	0.00	0.00	0.00
01/14-15/1997	Des Moines N	424.06	0.00	0.00	0.00	0.00	0.00	0.00
01/14-15/1997	Cedar Rapids	285.19	0.00	44.0	686.72	666.60	1397.32	4.90
01/23-24/1997	Council Bluffs N	210.34	0.00	0.00	0.00	0.00	0.00	0.00
01/23-24/1997	Des Moines W&N	863.86	540.00	32.0	741.39	484.80	1,798.19	2.08
01/24/1997	Cedar Rapids	285.19	825.00	0.0	0.00	0.00	825.00	2.89
01/26/1997	Council Bluffs N	210.34	0.00	0.0	0.00	0.00	0.00	0.00
02/03-04/1997	Des Moines W	439.80	0.00	-96.0	-1,999.04	-1454.40	-3,549.44	-8.07
02/03-04/1997	Des Moines N	424.06	0.00	-60.0	-1,249.40	-909.00	-2,218.40	-5.23
02/03-04/1997	Council Bluffs N	210.34	0.00	0.00	0.00	0.00	0.00	0.00
02/26-27/1997	Des Moines W&N	863.86	540.00	0.00	0.00	0.00	540.00	0.63
04/10-12/1997	Cedar Rapids	285.19	1080.00	33.0	901.77	499.95	2514.72	8.82
Sum		5781.86	5430.00	3.0	-331.06	45.45	5147.39	0.89
04/09-12/1997	Council Bluffs N	210.34	-2700.00	-20.0	-326.60	303.00	3,349.60	-15.92
04/10-12/1997	Des Moines W	439.80	-3,472.80	-372.0	-7,633.64	-5,635.80	-17,114,24	-38.91
Sum		6432.00	-742.80	-389.0	-8291.30	-5,893.30	-15,316.45	-2.38

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