Strategies for Winter Highway Maintenance

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PREFACE

Winter is a powerful force to reckon with in the northern portion of the United States, and the harsh effects of winter weather can take quite a toll on transportation infrastructure and its users. It is therefore important for winter maintenance practices to be as efficient and cost-effective as possible. This report examines the current state of practice in winter maintenance, reviews current and relevant literature, and suggests strategies to improve current winter maintenance practices.

Two surveys were conducted in the course of this study: the first was mailed to all Iowa counties and all cities in Iowa with populations greater than 25,000; the second surveyed state DOTs. The response rate was very high, and the data collected have proven extremely useful toward understanding how winter maintenance is conducted at present and pinpointing major problems. Survey results were cross-referenced with our review of current literature to identify areas where research is being conducted to meet the needs expressed by survey respondents.

Not surprisingly, we found a fair amount of overlap between areas of research and areas of need. Still, some needs are not being met, particularly in the areas of innovative management methods (methods that incorporate new technology into winter maintenance in an optimal way) and "blue sky" (high-risk, high-payoff) research.

Because winter maintenance, like most activities, can benefit from new directions and new methodologies, the information gathered in the course of this study has been synthesized into a proposed strategy for winter maintenance that consists of a series of suggestions. These suggestions, if implemented, could substantially improve winter maintenance practices.

ACKNOWLEDGMENTS

This project involved the assistance and support of many people. We are especially grateful to the five members of our project advisory committee, who provided extremely useful input and insight throughout the project. The chair of our committee, Lee Smithson of the Iowa Department of Transportation, deserves special thanks. We also greatly appreciate the contributions of the other committee members: Tom Donahey of the Iowa Department of Transportation; William Giles of Ruan Transportation Management System; Doug Frederick, County Engineer for Johnson County, Iowa; and Rick Fosse, City Engineer for the City of Iowa City.

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Finally, we owe a large debt of gratitude to all those people who replied to our surveys. Without their time and input, this project could not have been completed.

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CHAPTER 1
INTRODUCTION

With the annual appearance of winter in northern states, come a host of transportation problems that carry severe costs to society. These costs impact in four major ways.

First, roads covered with ice or snow are slippery and inherently less safe for driving. The number of accidents always increases during and just after winter storms (Hanbali 1994), and while it has been shown that good road maintenance can keep this increase small, the safety aspects of winter highway maintenance are real and major. Safety concerns provide a major stimulus to improvements in winter maintenance methods.

Second, the most common method of dealing with ice and snow on the roads is to apply salt (sodium chloride, generally in the form of rock salt) as a deicing chemical. Sodium chloride lowers the freezing point of ice and snow, so that it melts at a lower temperature. But salt can cause significant damage to pavement, causing spalling and corrosion of reinforcing bar (rebar) and bridge superstructures (Transportation Research Board 1992). It also damages the bodywork and mechanical systems of vehicles. Further, there is some indication that as the salt is washed off the road (in melted snow and during thaws) it causes a buildup in salt levels in roadside vegetation and in nearby lakes and streams. While there is at present no financially feasible alternative to salt as a deicing chemical (Transportation Research Board 1992), its continued use at present levels carries costs that must be addressed. How these issues are addressed will also drive changes in winter maintenance methods.

Third, as U.S. industry strives to maintain competitiveness in the global economy, techniques such as "just-in-time" manufacturing are becoming more prevalent. These techniques require that transit times (from supplier to assembler) be predictable and regular, but do not necessarily require that they be as short as possible (see Forkenbrock et al. 1993). In effect, a small standard deviation on transit times is more desirable than a low mean transit time. In order to achieve such predictable transit times, a high level of road service must be maintained. Winter storms must be handled efficiently with respect to their effects on major routes; states that pay attention to such details will derive long-term economic benefits from such attention. Clearly, this need for increased competitiveness adds an impetus for greater predictability in handling winter storms.

A fourth aspect likely to have very real impact on winter highway maintenance methods is the current trend toward reducing government spending at all levels (federal, state, county and municipality). Because winter maintenance is such a costly activity, it may be a tempting target for budget cuts. If winter maintenance budgets are reduced, those charged with managing winter highway maintenance operations will be required to do more (or at least maintain current levels of service) with fewer resources. The only feasible way to do this is to use appropriate modern technology. The trick is to separate ideas that are appropriate and effective from ideas that are merely new.

Considered together, these forces make this a highly appropriate time to study new methods of tackling ice and snow on highways. A major goal of this study is to determine which new technologies have potential to be useful and effective in winter highway maintenance, and to indicate strategies for the development, incorporation and deployment of new technologies into current methods of winter maintenance. In this report, we review the current state of practice and present the results of surveys that explore the needs of state departments of transportation (DOTs) as well as counties and large cities in Iowa. On this basis, several promising approaches and directions are recommended in Chapter 6, the strategy section of this report.

CHAPTER 2
CURRENT STATE OF PRACTICE

In discussing the current state of practice in winter highway maintenance, it is important to realize that current practices are incredibly diverse. Geographical differences will produce very different responses. Mountainous regions must deal with heavy snowfalls during which more than one meter of snow can accumulate in under 24 hours, and such storms may occur several times a year. Methods for dealing with winter maintenance in such a region will of necessity differ from those in "high plains" states, where drifting snow may be a major and recurring concern. In turn, areas in the Midwest (e.g., southern Iowa), where the most serious winter weather condition is freezing rain, will require a yet different approach. This diversity of geography and meteorological conditions dictates that care be used in describing current practice and developing future strategies.

Demographics and economics also have a strong impact on winter maintenance methods. A county with a large population and a number of high-traffic roads will have different priorities and driving forces than a very rural county with low population density. The wealth of a county will also have an impact, although wealthy counties do not necessarily spend more on winter maintenance.

Perhaps a more critical factor is what might be termed philosophical diversity. In discussing innovative winter maintenance methods with DOT officials from various states, it became clear that some districts welcome experimental and innovative techniques more than others. This also seems to be true at the city and county levels. It is important to note that a conservative approach is not necessarily bad. There is much to be said for a strategy of not fixing things that are not broken. As the forces of change discussed in Chapter 1 come into play, however, the pressure to change will increase. When this happens, the most dramatic changes are likely to be in areas where there has been little change for many years.

It is important to note that changes in practice cannot be uniformly applied. Differences in initial conditions (geography, meteorology, demographics, economics, and philosophy) always necessitate differences in practice. Still, general observations can be made with the understanding that some locations employ radically new and different methodologies. For further information, see Kuemmel (1994).

WINTER MAINTENANCE POLICIES

Winter maintenance policies define the approach to be taken by an authority (whether state, county, or municipality) in dealing with the effects of winter weather on roads. A typical policy document describes the desired level of service for various classes of roads. For example, the busiest roads might have to be cleared to bare pavement within 24 hours after a storm has ended. Typically, three classes of roads are defined based on average daily traffic (ADT), and more time is allowed to clear a road with a lower ADT. Some roads may require clearing to some degree, but not to bare pavement. Others may be defined as receiving no winter maintenance at all, though this usually applies only to gravel roads, and does not apply universally to these.

Typically, policy documents do not define how a road is to be brought to its required level of service, but do outline a process to document both the steps taken to meet policy requirements for each storm and any deviations from policy. Liability issues are clearly the driving force behind this documentation process whereby documentation of deviations implies compliance. In some states, including Iowa, if an authority has followed the procedures set forth in a policy document, it cannot be held liable for accidents related to winter weather. The benefits of such legal structures are clear.

Policies often include a year-round timetable of "off season" activities such as checking equipment, training operators, and ordering chemical supplies. A significant number also schedule a media day, although this is more prevalent at the state level than at the county or city level. Such media days (typically held in late October) provide a chance to display hardware and expertise, while also providing an opportunity to remind the public of the forthcoming hazards of winter driving.

While winter maintenance policies or handbooks are not universally used, they are growing in popularity and the consensus is that they can be extremely effective for a number of reasons.

ROUTE PLANNING

Winter maintenance is usually operated out of a central location called a depot or garage (or for states and some larger cities, a number of such facilities). Each truck dispatched from a depot or garage is given a pre-assigned route to follow, along which it is responsible for achieving the level of service required by the snow policy (if there is one). These routes have been developed over a number of years and are not often changed. While it might be quite possible to effect positive change in this area, there are a number of obstacles to such change.

Recent work has examined the possibility of optimizing both the routes and the placement of depots or garages (Wang And Wright 1994; Kandula and Wright

1995; Wang, Kandula, and Wright 1995). Such changes could bring about significant reductions in the number of vehicles required, but changing the locations of depots or, worse, reducing the number of depots, is a highly-charged political issue. Public response to the notion of closing a garage in a given location tends to be rapid, negative, and vituperative (Forkenbrock, Personal Communication), reinforcing the philosophy that proposed changes to winter maintenance methods should be implemented in a way that will be acceptable to all parties concerned. This requires excellent communication of the rationale behind proposed changes.

STORM FORECASTING

The current practice is for most organizations to obtain storm warning information from public media (radio or TV). If these sources indicate that a storm is approaching, "spotter patrols" may be dispatched to sites expected to receive first precipitation. These patrols then radio in the first signs of snowfall, at which point trucks are dispatched to begin the winter maintenance process. Some organizations work closely with local police or highway patrol units to provide additional information. Winter maintenance authorities could make great strides in their forecasting efforts by making use of weather information beyond that readily available to the general public.

APPLICATION OF CHEMICALS AND ABRASIVES

Chemicals are applied to the road surface in an attempt to lower the melting point of accumulating snow and ice. When such chemicals are applied, snow and ice will melt at temperatures below freezing.

A wide variety of chemicals are available, but the most common by far is salt (sodium chloride), generally deployed as small rock salt particles. These gradually dissolve in the ice and snow, "melting" their way through the ice and snow cover, to the pavement. Other chemicals are seldom used, primarily because they are much more expensive than salt. Chemical alternatives are discussed in greater detail later in this report.

Sand (or another abrasive) is placed on the road surface in an attempt to increase friction between vehicle tires and the road surface. Intuitively, this approach seems appropriate, but we should note that there is no conclusive evidence that application of abrasives actually increases road surface friction.

A growing trend is to apply a mixture of sand and salt simultaneously, reducing the amount of salt used. Another trend is to reduce use the overall amount of chemicals and abrasives used because of concerns about possible negative environmental effects.

PLOWING EQUIPMENT

Standard plowing equipment is a front-mounted blade attached to a truck. There are a variety of options that may be associated with this blade, such as quick-mounting systems, tripping moldboards, or carbide insert cutting edges, but these are not used widely enough to be considered standard. Additionally, there is some use of underbody plow blades, especially for removal of ice and compacted snow. These underbody blades may be attached to regular trucks or to graders, the latter especially at the county level. For both front mounted and underbody blades, the standard cutting edge is a hardened steel. The use of carbide insert cutting edges has been increasing over the years, but is still not very common.

OTHER

Other aspects of winter highway maintenance may enhance the ability of an organization to meet its winter maintenance goals. Comprehensive training programs for operators and managers, media days to prepare the general public for the onset of winter, and comprehensive, year-round equipment management plans are a few examples. Such programs and plans are generally available at the state level, but do not appear to be at all widespread at the county or city level. This may be true in part because resources at these levels tend to be scarce and such expenditures may seem non-essential. Still, education and information dissemination efforts have the potential to reap significant benefits. This issue is considered in greater detail in the "management studies" section of Chapter 5 on page 25.

CHAPTER 3
SURVEY OF IOWA COUNTIES AND CITIES

To determine the current state of practice at county and city levels, a survey was sent to each of the 99 counties in Iowa and each of the 30 Iowa municipalities with populations greater than 25,000. The survey used is included in this report as Appendix A.

The survey attempted to gauge respondents' awareness of innovative winter maintenance techniques. As we will discuss, there is some awareness of new research, but there is clearly room for much better communication between those doing the research and developing new products and the end users. Chapter 6 includes a discussion of how such links might be established.

The survey also attempted to determine perceived winter maintenance needs at the county and city levels. There was a surprising level of consensus, providing an excellent starting point for communication between researchers and end users.

In this chapter, we present the responses to our survey of Iowa counties and cities and discuss the implications of the survey results. The response rate was very high: 88 completed surveys out of 129 were returned, for a 68 percent response rate. Many respondents also sent additional information (such as snow policy documents) with their surveys; these documents are an extremely valuable source of information. Such a high response rate may indicate that winter maintenance is a matter of considerable concern to county and city engineers.

NUMERICAL RESPONSES

A number of questions on the survey invited numerical responses; these have been analyzed to provide insight into the workings of winter maintenance operations. The budgetary numbers provide a useful starting point. Figure 3–1 shows the breakdown of budget amounts for the 80 agencies from which replies to this question were received. The average (mean) budget for FY 1993 winter maintenance was $161,300, with a low of $8,500 and a high of $649,800. The median budget was $135,200 and the standard deviation of the mean was $122,000. The budgets did not include equipment costs, only time and materials. Perhaps most interesting is the number of agencies indicating they were over or under budget. Of 81 responses, 54 indicated they were over budget, ten were on budget, and only 17 were under budget. This suggests that winter maintenance

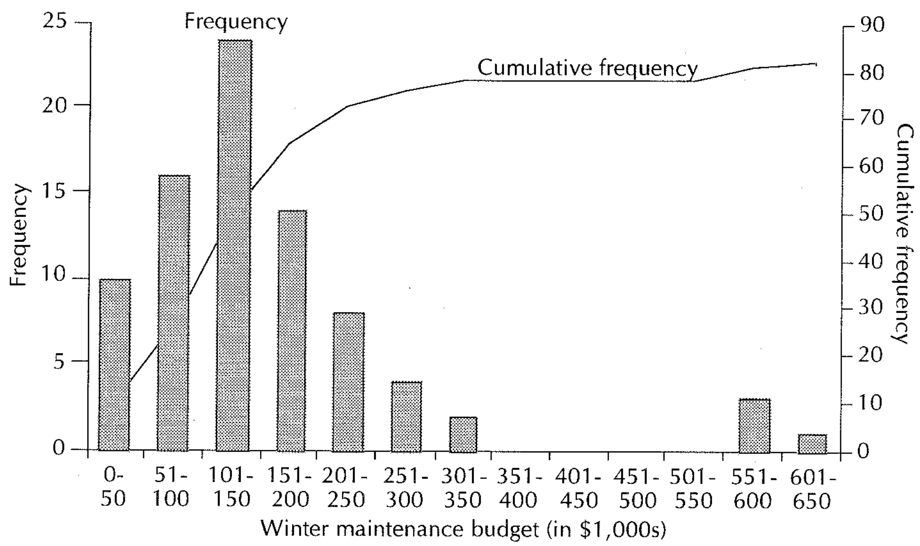

Figure 3–1. Winter maintenance budgets for cities and counties in Iowa, FY 1993

may be an area that budget setters find convenient to cut, while of course expecting the same high level of service. There is thus strong interest in technologies that can maintain levels of service at reduced cost.

The requirements or workload for each authority can be estimated from the number of paved and gravel road miles each authority must clear (question 1). The average number of gravel road miles (635) was considerably higher than the average number of paved miles (219), as one might expect from a survey that concentrates on counties. In general, paved roads were required to be cleared sooner than gravel roads, and the most common requirement for paved roads was that they be cleared within 12 hours of a storm, whereas most gravel roads were not required to be cleared in less than 24 hours.[1] The majority of these requirements were set forth by counties in their winter maintenance policies.

Two other factors vary widely among responding authorities: the reported number of workers performing winter maintenance tasks and the nature of the tasks performed by these workers. While the average number of winter workers was 25, the standard deviation was 10.75 and the number of workers ranged from five to 61. In some places, foremen are responsible for loading trucks and mixing salt and sand, while in others they may assign and check routes. Training is one way to make progress in this area. Although the American Public Works Association offers some training through their annual snow conferences, it would be useful to

[1] One factor that makes it expensive to convert gravel roads to paved roads is that paved roads are likely to require more rapid clearing, thus placing a greater burden on the county's winter maintenance crews. This extra cost should be taken into account when conversion from gravel roads to paved roads is under consideration.

develop a statewide training program and a statewide operations manual to standardize the level of expertise and duties of workers across the state.

Reported truck types in use were also quite diverse (question 5). Most city and county winter maintenance fleets were comprised primarily of vehicles with front-mounted plows and few (if any) underbody plows; however, the make of these trucks varied widely. While such diversity ensures a competitive market and probably keeps costs low, it may not be as conducive to the development of innovative equipment. The diversity found in truck types is mirrored in the range of cutting edges used on plows. Although carbide inserts are used by many of the authorities, their use is far from universal and authorities that do use carbide inserts do not use them exclusively. There was also wide variation in the number of cutting edges used in one winter: up to 250 standard edges and up to 90 carbide edges. Even though the number of carbide edges used was less than the number of standard edges, this should not be taken as an indication that carbide cutting edges necessarily last longer. In the context of this survey, it is more likely to reflect the incomplete penetration of carbide edges into the market.

One final aspect of the numerical data concerns the use of salt and sand. The amount of salt used in a year varied from zero to 6,000 tons. More meaningful, however, is the amount of salt per mile of paved road, shown in Figure 3–2. A number of counties reported that they do not use salt at all, instead using sand alone or with calcium chloride as needed. The average amount of salt per mile of road was 5.06 tons/mile, ranging from zero to 37.48 tons/mile. The use of sand on paved roads ranged from zero to 184 tons/mile, with an average of 15.12 tons/mile and a standard deviation of 22.96 tons/mile. The high standard deviations for both salt and sand use indicate a very high variability of practice.

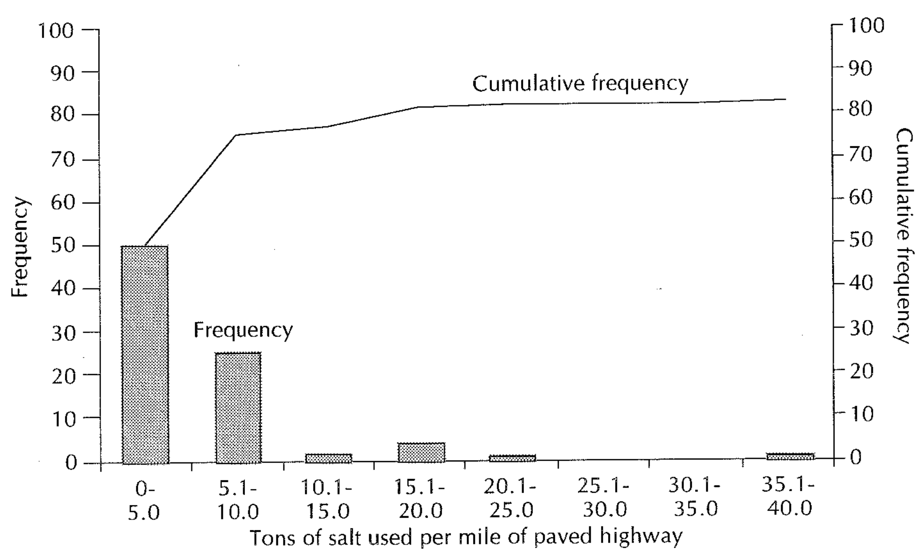

Figure 3–2. Salt usage for cities and counties in Iowa

NONNUMERICAL RESPONSES

A number of the questions in the survey were intended to elicit more anecdotal responses. The main aim of these questions was to determine the needs of county and city engineers in terms of new technology. What changes have occurred recently in your practice? What changes do you perceive as being needed? What are your major problems? Although the responses to these questions are more difficult to express in numerical terms, they nonetheless provide extremely useful anecdotal information. A summary of these responses is provided in Appendix B.

Changes in strategy

When asked what changes had occurred in their winter maintenance strategy over the past five years (question 14), only 21 of the 82 responses indicated that their policy had essentially not changed, suggesting that nearly three quarters of those responding *had* implemented change.

Of those indicating changes in policy, 23 indicated that one area of change had been in usage of chemicals and materials.[2] The changes here included more extensive application of chemicals and sand (e.g., from just applying at intersections, to applying along the whole road), use of calcium chloride instead of salt, pretreating sand and/or salt with liquid chloride or with calcium chloride, and new or increased use of salt. The driving force behind these changes appeared to be the need to achieve a higher level of service.

Thirty-two respondents indicated they had changed their equipment substantially during the past five years. One piece of new equipment often mentioned was a tailgate spreader system, which seems to have made the process of applying salt and sand much easier and more effective. A number of respondents indicated that computer controls were used in materials application.

Twenty respondents noted that they had changed their operational timing. Most of the responses indicated that they now started snow clearing operations earlier and completed them later, but a number said they had reduced hours of operation due to budget constraints.

Innovations in equipment

The first part of question 15 ("What innovative equipment would you like to use but have not yet acquired?") elicited 63 responses, of which 13 indicated either "none" or "don't know." One or two items only received one mention, but seven equipment categories were mentioned more than once (see Figure 3–3).

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[2] Note that a number of responses indicated more than one change, thus the totals in separate categories will exceed 82.

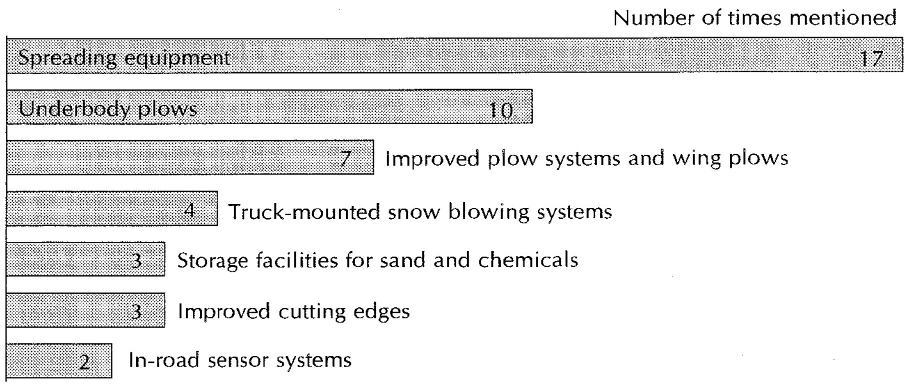


Figure 3–3. Innovative equipment respondents would like to use but have not yet acquired

The second part of question 15 asked why the equipment had not yet been acquired. An overwhelming majority (40 of the 51 respondents) cited budget concerns as the primary reason for not trying innovative equipment. Of the other replies, six respondents indicated they were waiting for equipment to need replacing before they could try innovative solutions, four cited concerns over training personnel or persuading them to accept new methods, and three were in the process of putting out bids for the equipment.

Clearly respondents were aware of at least some of the new equipment and techniques available for winter maintenance. The primary barrier to implementation of these new methods is cost.

Responses to question 16 (about more innovative equipment) were more tentative, as might be expected. There were 22 responses (other than "no" or the equivalent) to this question. Five major technologies were cited more than once. Some sort of improved sanding or chemical application system was mentioned five times. This included computer control of the application system, pre-wetting the salt and/or sand, and control of the application process through zero velocity sanders. Cutting edges designed specifically for ice removal were cited four times. Road sensor systems and deicing chemical alternatives to salt were each mentioned three times, and means for improving truck visibility were mentioned twice. These five areas are all receiving attention at the national and international level, and an awareness of them as problem areas clearly extends down to the county and city levels.

Problem areas

The final two questions on the survey (17 and 18) were intended to find the major problem areas in winter maintenance for those at the county and city level. There were 69 responses to question 17 ("What are your greatest equipment problems for winter maintenance?"). The vast majority of responses centered on equipment maintenance or corrosion problems. Many cited problems with aging equipment difficulties keeping that equipment operational during storms and in very cold weather. Breakdowns were mentioned frequently (often followed by a number of exclamation marks). Some of the responses (e.g., "spreader boxes flying apart") conjured rather dire pictures, but clearly the major problem is that of keeping a maintenance fleet that is old operating in a highly corrosive environment and under severe weather conditions. Improvements in serviceability and maintainability would be very welcome.

Question 18 asked, "If you could solve one winter maintenance problem, what would it be?" Of the 66 responses, the top two choices were ice (24 respondents) and the traveling public (11 respondents). The major concern with the traveling public was the need to increase their awareness of the importance of driving more slowly in the winter, keeping streets clear, and not expect everything to be cleared as soon as the snow stops falling. Six respondents offered more creative responses (e.g., "have it quit snowing"). Other responses included equipment maintenance (ten responses), a noncorrosive deicer (five responses), and improved weather forecasting (two responses). Clearly, ice is seen as a major problem for which existing solutions are less than ideal.

IMPLICATIONS

A number of implications can be drawn from responses to the county/city survey.

- The high response rate indicates that winter maintenance is of strong concern to the city and county engineers surveyed.
- Despite the wide range in workload size (i.e., number of miles of road needing to be kept free of ice and snow), there was a high level of consistency among responses.
- The possibility of developing (and maintaining over time) a manual that codifies current practice throughout the state might be of value to cities and counties in Iowa.
- City and county engineers seem well versed in areas that are currently "hot" research topics. In particular, they are reasonably aware of new products, but are limited in their ability to try these new products because of cost constraints.
- Low cost solutions to winter maintenance problems are critical for city and county engineers.
- Two major problems for city and county engineers are clearing ice from the road and keeping their (often aging) equipment operating, especially during storms.

These responses provide very useful starting points from which useful information can be developed and new solutions delivered to those performing winter maintenance at the city and county levels.

CHAPTER 4

SURVEY OF STATE DEPARTMENTS OF TRANSPORTATION

A copy of the survey shown in Appendix C was sent to the Department of Transportation in each of the 50 states of the United States. Forty-two of the 50 receiving agencies returned completed forms. A number of agencies that did not return completed forms indicated that their lack of response was because they did not have any significant snow or ice. As with the survey of counties, this survey was designed to determine the current state of practice, and highlight particular areas of need.

NUMERICAL RESPONSES

As with the county survey, a number of questions asked for numerical responses. Question 8 investigated the number and types of trucks owned and operated by the agencies. The number of state-owned trucks with front-mounted plows varied from zero to 2,200, with a mean of 655 trucks. The number of trucks with underbody blades varied from zero to 700, with a mean of 133. Standard deviations are not very meaningful because the distribution of the numbers of trucks is not particularly normal (see Figure 4–1a, b). It is worth noting that 23 of the 39 states that provided data on this issue said that their fleet size was determined by winter maintenance needs. Clearly, an increase in the efficiency with which trucks are used would have significant payback for those states.

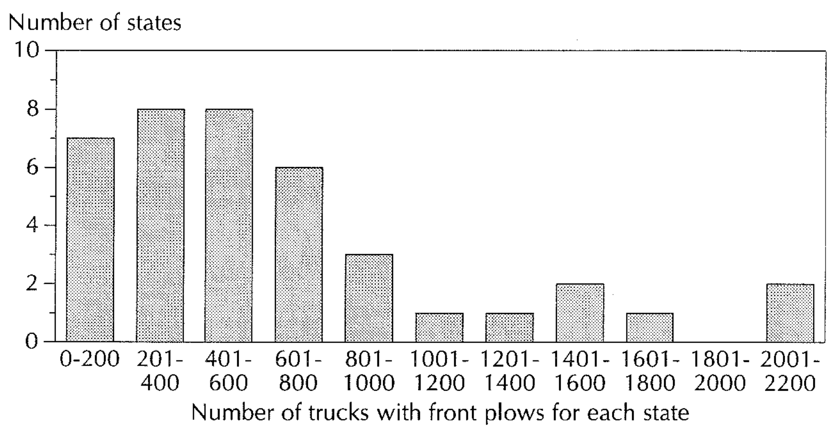


Figure 4–1(a). Distribution of trucks by state (front-mount plows)

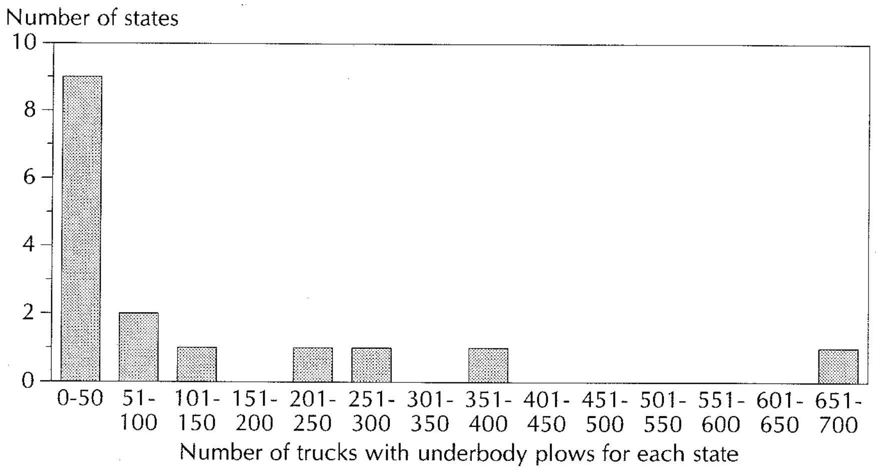


Figure 4–1(b). Distribution of trucks by state (underbody plows)

Among the states that responded, the number of lane miles that must be kept clear of ice and snow varied significantly from a low of 400 miles to a high of 115,000 miles. The average number of lane miles to be kept clear is 21,624 miles. The distribution of lane miles is shown in Figure 4–2.

The use of salt (question 12) and sand (question 13) varied considerably from state to state. One state reported no salt use at all; the remainder of the responses ranged up to 770,000 tons with an average of 178,000 tons. Usage per lane mile varied from a maximum of 46.9 tons per lane mile to zero, with a mean of 9.85 tons per lane mile.

Sand use varied as much as salt use, from zero use (reported by four states) to a maximum of 1,300,000 tons, with an average use of 211,000 tons. These figures in combination give an indication of the materials handling problem that winter

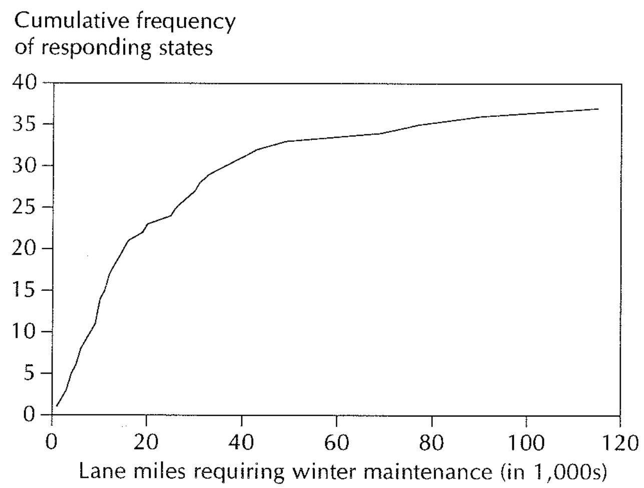


Figure 4–2. Lane miles for the states

maintenance poses, as well as indicating the scope of the possible environmental problems caused by salt and sand usage in winter maintenance.

Application rates for salt varied between 50 and 500 lbs per lane mile, with values in the range of 200–300 lbs per lane mile being most common. These values reflect the amount of salt deposited in a single pass, rather than a single storm event. A comparison with the total salt usage above indicates that states might apply salt as much as 80 times in a winter. Sand application rates vary between 120 and 2,000 lbs per lane mile, with the most common application rates between 500 and 750 lbs per lane mile.

When considering these figures for salt and sand use, it should be noted that they cannot be directly compared to numbers obtained for the Counties in Iowa. The roads considered in the state survey are from a wide variety of winter climates, many of which may be considerably harsher than Iowa's, especially in terms of freezing rain. Further, the roads that state agencies are required to maintain are generally high volume (high ADT) roads, and thus a very high level of service must be maintained.

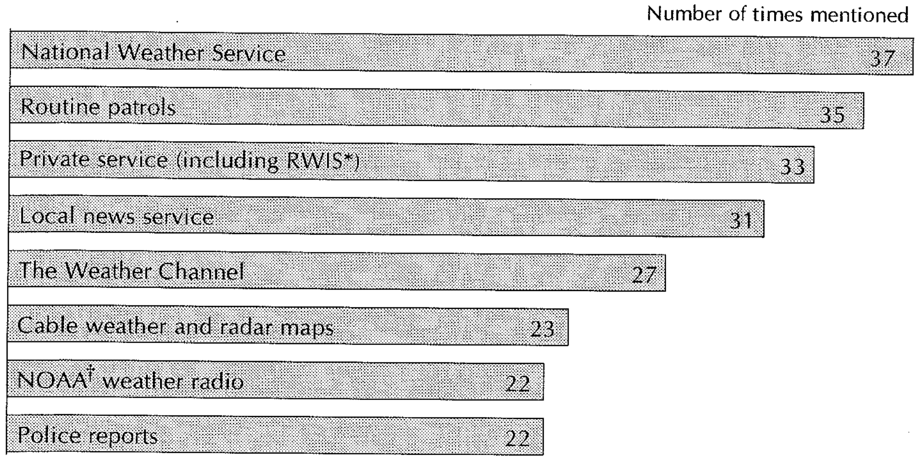
NONNUMERICAL RESPONSES

Most of the questions in the state survey did not require numerical responses per se, but indicated trends, materials used, and different approaches. These responses are considered here.

Of the 42 responding states, 31 have some kind of policy or procedures manual that governs their winter maintenance. In general, the manuals are more sophisticated than those found at the county level, in that they indicate more levels of response. Thus, in most cases, the number of trucks deployed is related to storm severity. In other words, the whole maintenance department does not start plowing at the sight of the first snowflake. Standards for the amount of time allowed before roads are expected to be cleared are also more stringent than at the county level, again in keeping with the higher volume roads cleared by state agencies. Thus, 95 percent of state cleared roads must be cleared within 12 hours (or "as soon as possible").

Regarding implementation, about half of the responding states (20 out of 42) have a methodology for implementation and testing of new technology for snow and ice removal, but only one state is required to post warnings when new techniques are being used. Thirteen states reported that liability concerns limit their testing and implementation. Appendix D lists survey responses regarding the effects of policies and procedures on the implementation of new technology.

Weather forecasting is, not surprisingly, a tool that most states use extensively in their winter maintenance activities. The most popular sources of information are shown in Figure 4–3.



*Road Weather Information System
†National Oceanic and Atmospheric Association

Figure 4–3. Sources of forecast information

Twenty-eight states reported that they had weather sensing equipment for use in winter maintenance. The number of sites ranged from one through 72 sites, and most sites recorded both weather data and pavement data. The sensors appear to work reasonably well, as only two states noted that their sensors gave many "false alarms" in contrast to 25 states who said they did not.

States were asked what chemicals (other than salt) they use in winter maintenance. Of the chemicals we listed (see question 17) only sodium formate was not reported as being used by any state. The most popular alternative chemical was calcium chloride (used by 30 states), with liquid magnesium chloride (14 mentions) and calcium magnesium acetate (CMA, 13 mentions) being the next most popular choices. No other chemicals received more than five mentions.

Eleven states reported that they had conducted studies on the effects of salt or other deicing chemicals on the environment. In contrast, only two states reported having performed studies on the problems of airborne particulates arising from the use of sand as an abrasive. Fifteen states have areas in which salt use is limited, and eight states report that in at least some of those areas they do not use any chemicals at all for winter maintenance. Further, two states report that in these "no chemical" areas they must maintain a "bare pavement" for travel. This represents perhaps the most vexing situation for the winter maintenance community.

Salt use is clearly an area that raises concerns for states. Thirty-one states apply salt mixed with sand, 21 use a pre-wetting process when applying salt, and 30 monitor the application rates of salt. Fourteen states pretreat roads (apply chemicals before the first frozen precipitation) as part of their standard practice, while 18 report that they are currently evaluating pretreatment methods. All of these processes are designed to minimize salt use while maintaining a safe driving surface, but it is also clear that other options to salt are limited. Only three states have tried using special pavement surfaces to reduce ice formation, and only one state reported any pavement heaters. The main technical methods for snow and ice control are still salting sanding, and scraping.

IMPLICATIONS

Several implications of this survey come across fairly clearly. Salt is the best chemical from the point of view of removing snow and ice from the roads, and is used extensively in this role. Sand is also used extensively as an antiskid material. These two materials, combined with mechanical removal of snow and ice (plowing or scraping) are the major tools available for winter maintenance. Because of the problems they can cause, salt, sand, and other abrasives are already restricted in some areas (Parker, Personal Communication 1995).

Alternative chemicals for salt are being actively considered, but their cost and availability make it unlikely that any existing chemical will be a replacement for salt. Techniques such as pretreatment, mixing salt with sand, and pre-wetting salt are all being considered as ways to reduce the amount of salt used. Although these methods are somewhat successful, it is likely these methods alone will not be enough. Current technologies for forecasting storms are becoming more sophisticated (a necessity for techniques such as pretreatment). While that trend is likely to continue, the benefits derived from these new technologies will be limited unless there are significant changes in operations and management to go along with new information flows. While there is clearly a need for new technologies in winter maintenance, there are also concerns about testing that new technology. The new technologies and strategies discussed in the next two chapters should be considered in this context.

CHAPTER 5
NEW TECHNOLOGIES

Technological innovation can potentially improve winter maintenance practices and, in some cases, reduce costs associated with that maintenance. This chapter presents a review of new technologies related to winter maintenance, some of which are still under development. Methods for integrating these technologies into current practice are considered in Chapter 6.

MATERIALS APPLICATION

As noted in Chapter 2, current practice is to apply salt to the roadway in a crushed solid form, often mixed with sand. As noted elsewhere in this report, however, there is a strong movement away from traditional modes of salt usage. Although the most obvious alternative is to find another chemical to use as a deicer, efforts along these lines have not been particularly successful to date. Other alternatives being explored keep the salt on the road longer once it is applied or apply the salt before precipitation occurs (termed anti-icing or pretreatment). Recent work in materials application is discussed below.

New deicing chemicals

The search for a better deicing chemical than salt is not new, and most of the chemicals under consideration today have been available for some years. A new approach to evaluating these chemicals, however, was more recently developed as part of a Strategic Highway Research Program (SHRP) study (Chappelow et al. 1992). A comprehensive series of tests were designed to objectively and rationally evaluate the environmental impact of chemicals and how effective they may be at removing ice from roads. These tests can be performed in the laboratory at relatively low cost.

Perhaps inspired by this new evaluation method, a number of studies that consider alternative chemicals have been published in recent years. One study conducted in Illinois (Gingrich et al. 1993) considered the total costs of various deicers, including the costs of vehicular damage and highway structural damage. Using the techniques described in Transportation Research Board Special Report 235 (1992), the study found that methanol was the optimal deicer. Even so, the use of methanol in Illinois has not yet begun on a large scale for reasons that are not quite clear but that may be both political and related to end-user perceptions. Other studies have looked at field trials of alternative deicers, as in Manning and Perchanok (1993), who found that CMA could be a suitable alternative to salt under a limited range of conditions.

Other studies examine the possibility of developing new types of chemicals such as sodium carboxylate (see Johnston and Huft 1993), or reducing the cost of producing existing deicers (especially CMA, which is very expensive). Recent studies of how to produce CMA from various waste products include Chollar et al. (1996) and Yang and Chollar (1996).

Innovative application methods

When salt or sand is applied to highways in the traditional way, a great deal bounces off the road or is later swept off by the air turbulence of passing vehicles. This wasted salt fails to melt ice on the road while still adding to the environmental burden.

There are three basic ways to minimize this problem. In Europe it is quite popular to use liquid brine rather than dry salt (Stotterud and Reitan 1993; Raukola et al. 1993). There are a number of benefits of liquid brine:

- the deicing process starts more quickly than with pellets,
- brine can be applied more uniformly across the road surface, and
- brine does not bounce and is less likely to be swept off the road.

The difficulties of using brine include:

- mixing and storage,
- delivery (tanks cost more than dump boxes), and
- corrosion (liquid brine can cause greater corrosion problems than crushed salt).

While brine is becoming more accepted in the U.S., the major barriers seem to be capital costs, inertia, and resistance to change.

Another method is to wet the crushed salt prior to application. Pre-wetting helps the salt to "stick" to the road surface, thus reducing the amount that bounces off or is swept away by air turbulence. Again, this is a technique that has been popular in Europe (Gustafson 1993; Raukola et al. 1993; Kuusela et al. 1993; Mergenmeier 1995). A variety of solutions can be used to pre-wet the salt, including water, brine, and calcium chloride. Pre-wetting also accelerates the deicing process, in a manner similar to the use of liquid brine. The drawbacks of using pre-wet chemicals are twofold:

- pre-wet chemicals require a more complex delivery system and
- salt can form into clumps that clog spreading mechanisms.

Such problems can be overcome, but often deter trials of the system.

While neither method (pre-wetting or brine application) is a panacea, both can dramatically decrease salt use and each can be useful in specific situations. Their primary value is on lower volume roads and in preventive measures. Although not appear very effective during snowfall, they work quite well before and after snowfall. Part of the difficulty in changing to these systems is that it would require significant capital expenditure, but would not be effective in all circumstances. Winter maintenance operations have tended to use the same techniques in almost all situations because the prospect of changing equipment during a storm is not very attractive. Still, there needs to be a more flexible approach to winter maintenance at the management level.

The third method of minimizing the amount of salt and sand that bounces off the road is to use a "zero velocity spreader." Such devices (Fleege 1996a) are designed so that the velocity of the salt or sand when it is released from the vehicle is zero relative to the road surface. To accomplish this, the velocity of the salt or sand particles relative to that of the vehicle must match that of the vehicle relative to the road, but in the opposite direction. While the concept is simple, the execution is less so, but the system does seem to work. It greatly minimizes road bounce during the application process, but still leaves the particles vulnerable to being swept off the road by passing vehicles. A zero velocity spreader is somewhat more expensive than more traditional units, but because it can easily be attached to existing trucks, the required capital investment is low. It remains to be seen how readily this method will be adopted.

Anti-icing methods

One of the fundamental problems with ice is that it adheres so well most surfaces. Because the surface of highways is no exception in this regard, breaking the road-ice bond is a major problem in winter maintenance. An obvious approach is to apply a chemical to the road surface prior to precipitation so that the ice-road bond does not form, or is weakened and slowed in its formation. Although this concept (anti-icing) seems simple, its execution is not. A critical part of anti-icing is a reliable forecast of the start of a storm at least three hours in advance and accurate to within about twenty minutes. This nontrivial problem is further discussed on page 23.

In spite of the difficulties associated with anti-icing, considerable progress has been made in this area. SHRP devoted a project to anti-icing (H-208, Blackburn et al. 1994), and a recent FHWA project has continued this study. There is also considerable expertise overseas in anti-icing operations (Raukola et al. 1993; Alppivouri et al. 1995). Some of the findings of recent anti-icing research are summarized below.

- Anti-icing may not work in all situations, but in situations where it does work, it can attain the same level of service as traditional methods while using much less salt.
- Accurate and reliable forecasts are critical to the success of anti-icing efforts.
- Anti-icing requires a much more flexible and monitored approach than traditional winter maintenance methods. The manager must deploy resources in a more focused manner—it is not sufficient to "send out the plows until the roads are clear."
- To deploy resources in a more focused manner, a reliable pavement sensor is critical. A key finding of the SHRP study, however, was that such a sensor did not yet exist.

Clearly anti-icing methods show great promise, but also present many challenges. Perhaps the most critical challenge is the need to take a completely different approach to winter maintenance. Each truck would have to be able to switch from one route to another "on the fly" to keep ahead of freezing pavement conditions. Changing the philosophies of operators and managers would require extensive training and re-education, thus posing a considerable barrier to implementation. The benefits of implementing the new technology, however, appear to be considerable.

MECHANICAL REMOVAL METHODS

Mechanical removal has always been a primary method of snow and ice control. As winter maintenance methods change, this greater emphasis on mechanical methods is unlikely to change. The objective is to remove more snow and ice mechanically so that less needs to be removed chemically. SHRP reinforced this philosophy in two projects that studied mechanical methods of snow removal. One (H-206) examined the design of snow plows to identify a more effective way to remove snow from roads. This project resulted in the development of the snow scoop. Another project (H-204) looked at the cutting edges of snow plows to develop an edge that could remove snow and ice more effectively (Nixon 1993).

Later projects continued the work of this latter project, instrumenting trucks with underbody plows in a variety of configurations and testing their effectiveness in scraping ice (Nixon and Frisbie 1993). Conducted in concert with a laboratory study using a hydraulic scraping rig in a cold room (Nixon and Chung 1992), these studies are working toward an understanding of the physical processes that occur as ice is scraped from the road (Nixon 1995). This understanding is critical to further developments, and this area of study is currently extending to the instrumentation of front-mounted plows for closed-road experiments and to the gathering of data from in-service plows. The latter may develop into a real time operational system that can provide managers with instant information on plow performance, thus providing some of the information critical to anti-icing operations described above.

WEATHER INFORMATION SYSTEMS

Road weather information systems (RWIS) have been used to some degree in Europe and Japan for some years (Pilli-Sihvola et al. 1993; McClean and Wood 1993) and represent a growing area of technology likely to prove critical to improving winter maintenance methodologies. An RWIS is based on a network of sensors that provide data to a central location. Some sensors record general meteorological information while others monitor the condition of the pavement surface. Once the data are gathered, they can be integrated into a specific forecast for the roads being monitored.

There are a number of difficulties associated with such systems. First is the problem of applying point source information to a geographically diverse road network. Even if a network extends over fewer than 100 kilometers, there is likely to be sufficient topographical variation to give rise to significant microclimatic variations. It is important to note that differences on the order of one tenth of a degree can switch a safe road condition to a hazardous one. One way authorities address this issue is by using thermal mapping (Fleege 1996b), which determines the thermal signature of a road surface under a variety of conditions. By relating the road surface response at a specific location to the response at another location, one might determine that the road surface temperature at a danger spot (e.g., a local "dead man's corner") is about 0.5° C lower than the surface temperature at a nearby sensor location. Using this information, maintenance managers can identify more appropriate treatment strategies for such danger spots.

Another problem with RWIS is the sensors themselves. There are real difficulties associated with accurate measurement of surface temperatures and the freezing point of water on a given road surface (Burtwell 1996). The freezing point of water is complicated by the presence of deicing chemicals: if sufficient salt is present, a temperature of –1° C may pose no danger of ice formation. The sensors that currently perform such measurements are rather expensive, typically ranging from $25,000 to $75,000 per sensor site.

The biggest problem with RWIS is the nature of what it is trying to do: forecast the weather on a very local scale and in a very particular way. This is an extraordinarily difficult task that requires sophisticated tools not yet evident in the winter maintenance community. Kalman filtering and neural networks are only just beginning to make their way into the RWIS field (Shao and Lister 1996).

It is also becoming much more common to use nowcasting rather than forecasting to predict weather conditions. Nowcasting predicts future weather conditions at a given site using current weather conditions at a somewhat removed location. For example, if a storm hits Des Moines, Iowa, one might use information about the movements of that storm to predict when a storm might reach Iowa City, which is about 160 km east of Des Moines. While a single such predictor is not sufficient, nowcasting should be a critical part of any RWIS system once statewide sensor systems are in place. Tied in with innovative radar equipment that is becoming available, this will provide a more accurate level of forecasting for the winter maintenance community.

OTHER AREAS OF RESEARCH AND INNOVATION

A variety of other research areas and innovations may impact future winter maintenance operations. Some of these are briefly reviewed here.

Air quality

Air quality is a winter maintenance concern primarily because of the use of abrasives and studded tires (which grind up pavement surfaces). Some U.S. cities such as Portland, Oregon, have discontinued the use of abrasives altogether (Parker, Personal Communication 1995), and there is considerable concern about the health risks involved in the use of abrasives (Holnsteiner 1996). The economic and safety implications of changes in regulations concerning the use of studded tires have been studied in both Europe (Alppivouri et al. 1995) and Japan (Konagi et al. 1993). These and other concerns related to air quality can be expected to continue in the future.

Avalanches and drifting

Studies of avalanche behavior and management are important in areas that experience very heavy snowfall. There is great interest in this aspect of winter maintenance in Japan (Fujisawa 1996) and in the Rocky Mountain areas of the U.S. (Decker 1996). A related area receiving some attention is avalanche detection (Woodham et al. 1996).

Another aspect of snow control is drift control, a topic that received attention under SHRP project H-206. The objective of project H-206 was to develop a design guide for snow fences and examine ways to develop temporary snow fences. The study was considered successful and seems to have resulted in significant improvements (Tabler and Jairell 1993; Perchanok et al. 1993).

A third aspect is dealing with large quantities of snow in urban areas. Japan is the clear leader in this area, having developed very effective systems to channel removed snow to disposal sites (Koboyashi 1996; Morohashi and Umemura 1996).

Visibility studies

Two aspects of visibility are of particular concern to the operational side of winter maintenance: 1) the ability of other highway users to see winter maintenance vehicles and 2) the effects of blowing snow on general visibility. Again, Japanese authorities have taken the lead in this area (Takeuchi et al. 1993; Ishimoto et al. 1993), exploring the use of visibility sensors and intelligent systems to determine visibility levels and post effective warnings. More recent studies in the U.S. (Rajorski et al. 1996) are evaluating the effectiveness of various lighting schemes on trucks. Further developments in this area can be expected from a project recently funded by the National Cooperative Highway Research Program.

Management studies

Winter maintenance management has unfortunately not been the topic of a great deal of study to date. Although the new technologies discussed in this report could all fit into existing strategies of winter maintenance management, that would minimize their effectiveness. A completely new approach must be developed to make the most of anti-icing, RWIS, and other emerging techniques. The best approach would be very flexible would have clearly-defined goals against which performance can be measured. Some of the concepts used in Total Quality Management are beginning to be considered in winter maintenance (Pletan, Personal Communication 1995), changes must take place before these concepts can be fully realized. Clearly there are unmet needs in this area and steps should be taken in this direction.

Blue sky studies

Blue sky or "long shot" projects address problems from directions radically different from those characterized by standard practice. They are typically high risk (i.e., unlikely to succeed) with high payoffs (i.e., if they do succeed, they usually bring major benefits). Although there are few if any funding mechanisms for such projects, they are the long-term lifeblood of development and progress in any area, including winter maintenance. The marked absence of blue sky projects in the area of winter maintenance is a deficit that also needs to be addressed.

CHAPTER 6
PROPOSED STRATEGY

An overarching goal of this study is to develop strategies that can be used to develop winter maintenance practices in the future. While not all of the suggestions presented in this chapter are practical for all situations, they provide concrete ideas for future directions in winter maintenance.

WINTER MAINTENANCE POLICY

We strongly urge each authority responsible for winter maintenance activities to develop and publish a winter maintenance policy. Minimally, this policy should contain the following:

- a record of the roads that fall under the jurisdiction of that authority and for which they provide winter maintenance.
- a definition of levels of service, indicating what levels exist, how a road is classed to a certain level, and what each level of service implies. As much as possible, each level of service should imply reaching a certain drivability within a given time, and the classification of a road at a given level of service should be a function of the average daily traffic on that road.
- an explanation of how it will be determined that a road has reached its appropriate level of service. Again, as much as possible, the level of service should be determined by an objective and rational measurement.
- a description of the standard method of winter maintenance for the authority. This should clearly indicate and give explanations for any areas that do not receive standard methods (e.g., a new bridge that is not treated with salt because of corrosion concerns).
- a description of the procedure for reporting variances from standard methods of treatment. This should include a clear description of how innovative methods will be used in experimental trials and a description of how public safety will be ensured under such test conditions.
- a clearly defined and well documented training program for all personnel at all job levels, including training standards for contracted personnel.
- a clearly defined procedure for providing information to the public in a timely and effective manner. Authorities are strongly encouraged to consider special events such as Media Days (typically held in the late Fall) as these have been shown to be very effective.

- a procedure to allow the public to voice any complaints about the level of service being provided. This should include a clearly documented method for addressing these complaints.

Management of Winter Maintenance

As indicated earlier in this report, a host of innovative ideas and methods are being developed and applied in the field of winter maintenance, making it necessary to develop equally innovative management techniques to make optimal use of these diverse technologies. Accordingly, authorities should examine whether their current management structure makes the best use of these new technologies and if not, determine how it might change to a system that does allow for such use. While specific recommendations in management structure are beyond the scope of this work, structures that encourage flexibility are clearly needed.

Materials Applications

Authorities should strive to minimize the use of salt, while maintaining an acceptable level of service and a high level of road safety. Salt usage can be minimized by mixing salt with sand, pre-wetting salt, using liquid brine, or using zero-velocity spreaders to help keep the salt on the road surface. An anti-icing strategy may bring about greater benefits, although capital costs may be prohibitive for smaller authorities.

Authorities should attempt to maintain an awareness of alternative chemicals, and should keep track of the prices of such chemicals over time. Thus, if alternatives become more cost-effective, authorities will be able to change to them without being delayed because of a lack of information.

Care should be taken not to make excessive use of abrasives as a friction enhancer. The conditions under which abrasives provide significant benefit are not fully defined, and they may pose a health hazard under certain circumstances. Again, authorities should attempt to keep abreast of such information over time.

Mechanical Methods of Removal

The best way to remove ice and snow from road surfaces is mechanically. Mechanical methods use no chemicals and require relatively little in the way of expendables. Accordingly, strategies should be developed that make full use of mechanical methods of removal. Trucks should be thought of primarily as a means of scraping and plowing and secondarily as a means of delivering chemicals.

Innovation

A key goal of any winter maintenance strategy should be to encourage innovation. This can happen at all levels, from the gathering of information to the field testing of new techniques. It may also require some major changes in management, particularly in how items are purchased. While this issue is beyond the scope of this study, a philosophy of partnership with industry in the development of new equipment and technology needs to be explored much more fully than has hitherto been the case.

Measuring the Level of Service

There is a critical need to improve the mostly visual methods currently used to measure the level of service attained on a particular road. What is needed is a method by which the friction between the road surface and a typical traveling vehicle can be measured by the majority of service vehicles without any major effect on road traffic. Such a technique still needs to be developed.

Customer Care

While the surveys returned indicated a strong sense of public duty among those who have are responsible for winter maintenance, this is an area in which some development is needed. One step in this direction would be to provide more public information, but it may be that approaches similar to those involved in Total Quality Management may bring significant benefits to winter maintenance operations. Authorities should explore such opportunities as they are able and as seems appropriate.

Conclusion

Winter maintenance poses many challenges to those responsible for its administration. While these challenges are well met in most cases, a number of areas present opportunities for improvement. It has been the objective of this research to illuminate these challenges and suggest strategies for effecting positive change.

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APPENDIX A
WINTER MAINTENANCE SURVEY
OF IOWA COUNTIES AND CITIES

WINTER MAINTENANCE SURVEY

Thank you for participating in this survey. Please call Professor Wilf Nixon at (319) 335-5166 if you have any questions or comments about the survey.

1. For both paved and gravel roads, please indicate in the following table how many miles of each type of road in your jurisdiction you expect to clear of snow and ice within 4 hours, 12 hours, and 24 hours of a major winter storm.

	Our goal is to clear roads in			
Road type	Less than 4 hours	Less than 12 hours	Less than 24 hours	Over 24 hours
Paved	______ miles	______ miles	______ miles	______ miles
Gravel	______ miles	______ miles	______ miles	______ miles

2. What was your winter maintenance budget for FY93? $ __________

   Were you over or under budget as of June 30, 1993?
   - ❑ Over budget
   - ❑ Under budget
   - ❑ On budget

3. How many people work on winter highway maintenance in your organization? Please indicate the total number of people (including part-time) as well as the Full-time Equivalent (FTE) number:

   ______ total

   ______ FTE only

   Please describe briefly the job functions of each of the following types of workers:

   supervisors ______________________________

   foremen ______________________________

   drivers ______________________________

   other ______________________________

4. We are interested in the number of vehicles you use for winter maintenance. Please indicate how many trucks you used over the course of last winter.

Trucks used	Owned by county or city	Owned by contractor
Vehicles with front-mounted plows	_____ number	_____ number
Vehicles with underbody plows	_____ number	_____ number
Other	_____ number	_____ number

During the course of this study, we may find it helpful to communicate with some contractors involved in winter maintenance. Please indicate the names and addresses of up to three of your main contractors:

a. ______________________________

b. ______________________________

c. ______________________________

5. Please indicate the make, number and characteristics of all plows used and the trucks on which they are mounted, regardless of whether you own them or contract for them:

	Plow		Truck		
No. of units	Brand name	Number	Name/model	Weight	Type
e.g., 5	Henke	48R 12	International Fleetstar 2050	25 ton	Double rear axle
a. ____	____	____	____	____	____
b. ____	____	____	____	____	____
c. ____	____	____	____	____	____
d. ____	____	____	____	____	____
e. ____	____	____	____	____	____
f. ____	____	____	____	____	____

Please use a separate sheet if you have more than six types of plow and truck configurations.

6. We are interested in basic information about your snow management policy. If you have a written policy, please enclose a copy with this survey when you return it.

Please indicate which reply best describes your current policy:

	As soon as snow starts to fall	Two hours after snow starts to fall	Other (specify)
When do you go out to plow snow?	❑	❑	____
How many trucks do you normally deploy?	____	____	____

Is the number of trucks you deploy related to storm severity? ❑ Yes ❑ No

What is your goal (in hours) for clearing each type of road?

Road type	Goal
Trunk system	____ hrs.
Other roads	____ hrs.

7. What sort of cutting edges do you use? Please specify the brand name and type (e.g., kennametal hy90).

Edge type	Number	Brand name	Type
High speed steel	____	____________	____________
Carbide insert	____	____________	____________
Other (rubber slush blades, etc.)	____	____________	____________

8. How many edges did you buy in FY93? ________ number

How many edges do you buy in a typical year? ________ number

9. How much salt did you use last winter? ________ tons

Do you apply salt with sand? ❑ Yes ❑ No

Under what conditions do you apply **salt**? (check all that apply)			
every winter storm?	❑		
when a certain amount of snow has accumulated?	❑ →	If yes, how many inches?	_____ in.
when the temperature falls below a certain level?	❑ →	If yes, below what temperature?	_____ °F
other conditions	❑	____________________	

10. How much sand did you use last winter? ____________ tons

Do you put the sand down hot? ❑ Yes ❑ No

Under what conditions do you apply **sand**? (check all that apply)			
every winter storm?	❑		
when a certain amount of snow has accumulated?	❑ →	If yes, how many inches?	_____ in.
when the temperature falls below a certain level?	❑ →	If yes, below what temperature?	_____ °F
other conditions	❑	____________________	

11. What spreading equipment do you use to apply salt and/or sand? (List up to three types.)

	Number	Brand name	Model number
a. 1st type	____	____________	____________
b. 2nd type	____	____________	____________
c. 3rd type	____	____________	____________

12. What sources of information do you use for weather forecasting (to prepare for storms)?

Source	(check all you use)
radio or other media	❑
spotter crew	❑
computer system	❑ → Which one? ______________
road sensors (road temperature sensors, etc.)	❑ → What type? ______________

13. Do you pre-treat the roads prior to storms (apply salt/sand prior to first precipitation)?   ❑ Yes   ❑ No

What criteria do you use to determine when to pre-treat? (please describe)

____

____

____

We would like to elicit your views on innovative winter maintenance policies and recent changes you have made or contemplated. Because responses will vary so much, this last set of questions is more open-ended in nature. You may find that not all of these questions apply to your situation. Please answer only those questions that apply.

14. How has your winter maintenance strategy changed in the last five years, particularly in the areas of practice and equipment?

____

____

____

15. What innovative equipment would you like to use but have not yet acquired?

____

____

____

Why have you not yet acquired this equipment: for budget, training, or other reasons?

____

____

____

16. Are you aware of any innovative equipment and techniques for winter highway maintenance which you would like to investigate and/or deploy over the longer term (3 to 5 years)? If so, what innovative equipment and techniques are you interested in?

____

____

____

17. What are your greatest equipment problems **for winter maintenance**?

____

____

____

18. If you could solve one winter maintenance problem, what would it be?

____

____

____

____

____

Please return this survey in the enclosed envelope or sent to:

Professor Wilf Nixon (319) 335-5166
Public Policy Center
University of Iowa
227 South Quad
Iowa City, IA 52242

Thank you for your help.

Appendix B
Nonnumerical Responses
to Survey of Iowa Counties and Cities

NONNUMERICAL RESPONSES TO SURVEY OF IOWA COUNTIES AND CITIES

NOTE: Nonnumerical responses to questions 14 through 18 of the survey of Iowa counties and cities have been compiled and arranged into general categories below. Where the same response was given by more than one respondent, the number of *respondents* is indicated in parentheses. Likewise, the number of *responses* that fall under a given category are tallied and presented in brackets. Because some respondents gave more than one response to a single question, the bracketed numbers do not necessarily sum to the number of respondents.

14. How has your winter maintenance strategy changed in the last five years, particularly in the areas of practice and equipment?

- Level of service, hours of operation, timing [21]
  - Add a few more hours of operation: Start earlier in the morning; Start at 4:00 am to better prepare for commuter movements; Changed policy regarding starting time; Changed starting time to 5:00 to 6:00 am
  - Beat traffic to the road to avoid packing of the snow
  - Get more equipment out sooner
  - Go out earlier on surfaced (paved or bituminous) roads to remove snow and ice
  - Plow sooner (not waiting for a certain accumulation)
  - Community necessitated quicker response time
  - Because people commute to larger cities to work, they demand quicker response
  - Provide higher level of service (2)
  - Public demand for higher level of service due probably to greater travel
  - Spend less time out in the elements when it is a losing battle
  - With more equipment and manpower we have been able to get out on the roads more quickly and cover more areas
  - Treat suburban and near interstate areas first (4:30 am)
  - More weekend work
  - Rarely work nights
  - It has become more demanding
  - More demand as employment practices change for farm/rural families

- Chemicals and abrasives [21]
  - Use of liquid calcium chloride (3)
  - Use of calcium chloride instead of salt
  - Now use liquid calcium chloride rather than salt pellets (makes the sand pliable for mixing and salt more usable below 20 degrees)
  - Use of calcium chloride with salt to speed the melting process
  - Now use liquid calcium to treat our sand pile and have started to use salt (20 percent by weight of sand)
  - Addition of liquid $CaCl_2$ to truckload, prewetting the sand and salt if temperature requires
  - Pre-wet salt with $CaCl_2$
  - More pre-wetting with calcium chloride
  - Better use of salt, calcium chloride, and sand
  - Began using salt in 1992. Began treating sand piles with liquid chloride rather than flake in 1991 (cheaper but somewhat less effective).
  - Increased the amount of salt and calcium chloride added to sand
  - Higher use of salt versus sand
  - Have tried to use less salt to reduce the damage to concrete pavement and vehicles
  - More sanding on paved roads
  - Keep on hand and use more salt in the event we have ice and packed snow on our pavements
  - Liquid calcium assist with increased calcium flake and salt in the mix
  - Increased application of salt and sand
  - Changed to half and half mixture of salt and sand
  - Purchased salt building
- Spreaders [20]
  - Recently added calcium chloride unit to our arsenal
  - Purchased calcium chloride pre-wetting system with tank, spray bar and remote control to pre-wet material while loading
  - Tailgate spreaders (9)
    - Changed to tailgate type spreader (much easier to maintain)
    - Use of tailgate spreaders to "give operators opportunity to compete in a snow roadeo"
    - Added tailgate sanders to all trucks
    - All tailgate spreaders
    - Utilize tailgate sanders to plow and sand at the same time
    - Tailgate sanders

    - Changed from in-box sanders to tailgate type
    - More endgate sanders for fleet uniformity. Added one truck to normal fleet for "corporate line" routes.
    - Went from 5 to 12 tailgate spreaders so we can plow and spread salt and sand on our 150 miles of paved road in 5 hours instead of 10 hours
  - Increased the number of sanders
  - Buy more Epoke drop sanders
  - Larger 15′ sanders in tandems
  - Front dump trucks with sanders
  - Computerized sander controls
  - Increased use of two-way combination dump box/spreaders
  - Screens on top of sanders to prevent "chunks" getting onto sander chains and clogging them
  - Dual dump boxes versus slide-in sanders has been key to productivity
  - Using more material to deice paved roads
- No change, no major changes, has not changed much in last five years [20]
- Plows and blades [17]
  - More side wings
  - Light duty wings on tandem trucks
  - Added wings to tandem trucks
  - Added two tandem axle trucks with plows and wings
  - Use of carbide cutting edges
  - Added a poly face to our most recent plow purchase
  - Use of 2-way plows
  - Use carbide bit system for gravel road ice removal
  - Heavier reversible plows
  - Put underbody blades on all new trucks
  - Started using an underbody plow for ice control
  - Have a wing plow mounted on a tandem truck for increased plowing capability on arterial streets
  - Use ice blade motor graders
  - Use more Sandvik bits
  - Using more serrated and Sandvik type blades on maintainers
  - Changed from one-way plows to reversible plows
  - Increased the number of plows

- Other equipment [15]
  - The practice has stayed the same but the equipment has improved
  - Acquired more up-to-date equipment
  - Buying easier to maintain equipment
  - Have started using a snow blower to load in the downtown area
  - Studded front tires
  - Added one more truck to provide better service on some higher volume roads
  - Added heavier trucks with engines more suitable for plowing, thus allowing for more snow removal in less time
  - Two-way dump bodies
  - Moved to heavier trucks
  - Fuel tanks in all foreman pickups for "topping off" tanks of snow plows toward the end of the day
  - More efficient equipment: diesel trucks are much better than gas for snow plows; have motor grader with wing, now use all tailgate spreaders, two tailgate spreaders are set up to do edge rutting (one belt sander and one 9" auger)
  - Changed to completely hydraulic units
  - Basically had to adapt to more ice than normal
  - Continually updating our equipment (presently in our all-diesel fleet of 25 trucks, we have three 1986, ten 1987, seven 1991, and five 1993 trucks.
  - Run the trucks with chains more often than in the past
- Supervisory issues, policy, planning [14]
  - Closer monitoring of spreader settings
  - Spend additional time with supervisory personnel checking roads than in the past
  - Established emergency snow routes
  - Established set salting routes
  - Added two territories to existing paved miles to improve response time
  - Salting more of the total system (4)
    - Board of Supervisors requested more total road sanding (end-to-end, not just intersections)
    - From sand at intersections to sand and salt on entire system (2)
    - Apply treated sand to all paved roads
  - More aggressive maintenance of arterial streets
  - Deploy more trucks in residential areas
  - Plow residential streets with one truck in a zone instead of two

- Reduced hours of effort due to budgetary restrictions and an attempt to keep overtime to a minimum
- With trucks covering a certain area, we are better able to maintain clear streets all across town

- Technique [2]
  - Holding the wing process in speeds up coverage and keeps the height of the banks lower as drifting continues
  - Over the last 40 years, we sanded (crushed limestone) rock road hills, curves and intersections. Now, plowing rock roads with truck one-way plows enables us to open the total road system faster, but more rock ends up in the ditch.
- Other
  - Tracking and analyzing of data
  - Increased training
  - Still searching for good training aids
  - Making wind rows in farm fields to act as snow fences
  - Using a weather service

15. *What innovative equipment would you like to use but have not yet acquired?*

- Chemicals and abrasives [23]
  - Automatically activated heat tapes in bridge deck surfaces, to remove frost and ice when they occur
  - Tailgate/endgate sanders/spreaders (3); tailgate sanders for tandem trucks
  - Better salt/sand (2)
  - Equipment to blend salt/sand specifically for each storm
  - Use of liquid $CaCl_2$ (4); easy-to-use system for application of calcium chloride (2); $CaCl_2$ pre-wetting of sand and salt (2); pre-wet with $CaCl_2$ under certain conditions (2); treat trucks (spreaders) with liquid calcium chloride (2); calcium chloride applicator
  - Spreader for Pro-Patchers
  - Better hydraulic controls for tailgate sanders
- Plows and blades [18]
  - Underbody plows/scrapers (4); underbody plows for tandem trucks that presently have front plow and wings
  - Wing plows; skipper wings for trucks; short (5′) wing on single axle trucks
  - More hydraulic reversible snow plows: update new trucks purchased each year (5 to date)

- Belly blades for trucks; belly scraper
- More Sandvik type blades for our maintainers
- Carbon tip ice blades
- Plow shoes that work
- 2-way plows on the front of maintainers
- Adaptor blades with quick change, cemented carbide-tipped tips
- More carbide bit systems
- Possibly the addition of a snow scoop developed by SHRP, with poly-style mold boards instead of steel, to cast snow farther and prevent snow sticking to the mold

- Trucks and related equipment [13]
  - Two-way dump bodies; Oshkosh four-wheel drive dump truck; front dump
  - Six twin screw tandem trucks with underbody plows and two or three 3/4 ton pickups that could be equipped with plow and sander to use on isolated spot emergency call-outs
  - Six more tandem trucks to replace existing straight trucks; one additional truck, tandem axle
  - All trucks equipped with fuel heaters that will work with a minimum of maintenance
  - Wings single axle trucks
  - Heavier trucks with underbody plows; just acquired first underbody system
  - Five angle plows on small trucks
  - Front wheel assist motor grader
  - More maintainers
- Miscellaneous [7]
  - Subscribe to a computerized weather service (2); road sensors for weather forecasting (2); computerized forecasting and pavement condition detection systems
  - Preventive maintenance program
  - We are a bare-bones operation, as shown by our snow ordinance
- Snow blowers [4]
  - Snow blower; front-mounted snow blower on our JD loader; front end loader snow blower
  - It would not be innovative, but we feel it would be helpful to have a large snow blower. This would allow us to blow snow away from the roads, rather than trying to push the larger drifts back from the road with motor grader wings. It would also enable us to blow snow out of the hilltop drift areas on gravel roads, where we have difficulty trying to pack snow back against the earth backslopes along the roads.

- Storage [4]
  - Better storage building
  - Road de-icer storage building
  - Salt storage building to store non-blended salt and abrasives
  - Salt sheds/shelters
- None [8]; Don't know [4]

Why have you not yet acquired this equipment: for budget, training, or other reasons?

- Budget, money, cost; budgetary restrictions; legislative freeze on county property taxes; inflation; increased costs; two years of summer flooding [38]
- Future plans to implement [7]
  - Need time to implement (just new to the county)
  - Waiting for spreader boxes to wear out
  - Plan to take bids this spring
  - In the budget for FY94–95
  - In CIP budget for FY95
  - Appears to be a future investment
  - Newly developed (currently trying to budget for a new truck and may be able to spec. the new technology with the other new equipment)
- Cost-effectiveness [6]
  - Cost-effectiveness (2)
  - Limited need (for $CaCl_2$)
  - Too costly for our dispersed locations
  - A snow blower is a high maintenance, initial investment type of machine which would be economically hard to justify by its infrequent use
  - Scarce use
- Reluctance of employees and decision makers [5]
  - Training (convincing the employees)
  - Hard sell to operators and foremen
  - Not totally convinced I need a pre-wetting system
  - Operators slow to want different equipment
  - Board of Supervisors questions the need
- Other [5]
  - Have not found the perfect system
  - Inexperience

- Organizational changes
- System not that widely used
- Congestion of inner city routes

16. ***Are you aware of any innovative equipment and techniques for winter highway maintenance which you would like to investigate and/or deploy over the longer term (3 to 5 years)? If so, what innovative equipment and techniques are you interested in?***

- Deicers, chemicals and abrasives [7]
  - Need indoor salt storage
  - Batch plant for mixing sand, salt and calcium
  - Alternative chemical to use for deicing; alternatives to salt; non-corrosive deicers
  - Possibly looking at some sort of liquid calcium chloride applicator, either direct application to roadway or treating sand at time of spreading
  - The pre-treatment aspect
- More visible beacon lights; keeping trucks visible [2]
- Road sensors [2]
- Heat tapes for bridge decks, curves, stops, railroad crossings, and other areas where assured stopping is advisable
- Bridge sensors (too costly, however)
- Computerized controls for spreaders
- Computerized weather tracking system which would allow more accurate and localized forecasting
- IMAC Design Group Ltd. Ice Buster for motor graders
- Underbody ice blades; ice cutting blades [2]
- Ground speed control sanding
- Snow scoop developed and tested by SHRP as an add-on feature to our current plows
- More research to improve snow plow blades beyond HR-334; better types of quick hook-ups for plows; SHRP snow plow modifications [3]
- More ways for pavement plowing with wings
- No; none at this time [15]

17. What are your greatest equipment problems for winter maintenance?

- Breakdowns [20]
  - We operate this equipment under the worst possible conditions and breakdowns are the biggest cause of not meeting our objectives.
  - Breakdowns during storms
  - Down time
  - Wings on motor graders and trucks hitting shoulders or objects causing breakdowns
  - Breakdowns, mechanical breakdowns, motor grader breakdowns (8)
  - Reliability
  - Broken/bent bolts in plow trip mechanism, metal breakage, chain breaking (3)
  - Electrical systems on the trucks
  - Breaks in transmissions on our two Ford 8800 GVW pick-up trucks
  - Failure of snow removal equipment such as wings, plows and sanders
  - Breakage, wear and tear
- Temperature-related difficulties [19]
  - Hydraulic failures (5)
  - Warm-up of engines and brakes
  - Frozen air systems (solution: air dryers)
  - Gelling of fuel (4)
  - Frozen sand piles—spreader boxes flying apart
  - Heavy wet snows break plows
  - Metal stress and fatigue due to extreme cold (4)
  - Equipment kept outside (2)
- Effect of corrosion on equipment: Corrosive effects of salt and calcium chloride on electrical and mechanical systems, equipment clean-up, corrosion of sanding equipment [12]
- Maintenance [12]
  - Service (provided by another department)
  - Keeping chains tight on tires
  - Keeping all of our older equipment in good running condition (4)
  - Routine maintenance problems
  - Poor maintenance program
  - Repairs (2)
  - Equipment aged beyond its trouble-free use
  - Equipment fatigue

- Build-up, clogging, and other complications due to snow and ice [11]
  - Build-up of ice and snow on windshields and windshield wipers (3)
  - Air cleaners plugging with snow
  - Mechanical breakdown from heavy snow
  - Some air filter plugging with snow
  - Plugged spreaders
  - Tire chains, lights, sanders plug from wet sand (tailgate type)
  - Chains and ice scarify tips wearing
  - Ice on pavements cause problems with required number of blades if using motor graders
  - Traction on ice
- No specific problems [5]
- Resources [4]
  - Budget restraints (2)
  - High cost of equipment repair and replacement
  - Need more equipment to handle major storms
- Miscellaneous
  - Big trucks (2 FWDs, 1 Oshkosh)
  - Curb guards on plows
  - Warning light fixtures
  - Electrical connections for revolving lights and auxiliary equipment
  - Shoes on plows
  - Mailboxes
  - Keeping equipment running *during* storms

18. If you could solve one winter maintenance problem, what would it be?

- Ice [22]
  - Get rid of ice (5)
  - Heavy ice on gravel roads (2); granular roads; and in sheltered areas
  - Deicing, ice removal, ice removal at night (3)
  - Change the ice to either rain or snow!
  - Keep ice from sticking to the pavement
  - Fail-safe way to melt ice; procedure for 550+ miles of stone surface roads when covered with ice
  - Provide a better road surface during icy conditions when sleet and rain fall

- A good method of fighting ice, which requires more man-time and much more cost in chemicals
- Ice blocking flow into storm sewer intakes
- Ice problems along with slush
- Keeping ice off pavement from freezing rain
- Method of ice removal in sub-zero temperatures

- Snow [11]
  - Get rid of snow (8)
  - Keep snow from sticking to the pavement
  - Blowing and drifting of snow
  - Fail-safe way to melt snow
- Equipment [11]
  - Equipment breakdowns (2)
  - Preventive maintenance program
  - Newer, larger and more reliable equipment
  - Equipment damage
  - Get all equipment inside
  - Wiper blade ice-up
  - Replace our two Ford 8800 GVW pick-up trucks
  - Plugged air cleaners/hydraulics
  - Make operators more aware of the costs to repair the equipment(not a major problem, but sometimes a lack of good judgment causes unneeded breakdowns)
  - Wash rack and holding system for sander
- Chemicals and corrosives [10]
  - A better method of handling icing conditions without using excessive abrasives and chemicals
  - Eliminate the use of sand in weather above 10° and use all salt, so clean-up would not be so bad in the spring. We spend two months on clean-up of sand.
  - Remove chunks/lumps from bottom ash (used in lieu of sand)
  - Non-corrosive alternatives: alternative for salt that does not deteriorate concrete, non-corrosive replacement for salt and calcium chloride, non-corrosive deicing chemicals that cost about the same as salt (3)
  - Chemical deterioration of snow removal equipment
  - Protection from corrosion (2)
  - Storage of materials

WINTER MAINTENANCE SURVEY

Thank you for participating in this survey. Please call Professor Wilf Nixon at (319) 335-5166 if you have any questions or comments about the survey.

A. POLICY AND NEW TECHNOLOGY IMPLEMENTATION

1. We are interested in basic information about your snow management policy. If you have written policies, please enclose a copy of each with this survey when you return it.

   a. Does your organization have a ***Policy*** Manual for Snow and Ice Removal from Highways? Yes ❑ No ❑

   b. Does your organization have a ***Procedures*** Manual for Snow and Ice Removal from Highways? Yes ❑ No ❑

   If yes, is it a separate document from the Policy Manual? Yes ❑ No ❑

2. Please indicate which reply best describes your current procedures:

   a. When do you go out to plow snow?
   ❑ As soon as snow starts to fall
   ❑ Two hours after snow starts to fall
   ❑ Other (specify) ________________

   b. Is the number of trucks you deploy related to storm severity? Yes ❑ No ❑

   c. What is your goal (in hours) for clearing each type of road?

Interstates	Other roads
_______ hrs	_______ hrs

3. A major national concern is how new technologies are being implemented into state winter highway maintenance procedures.

   a. Do you have a methodology for implementation and testing of new technology for snow and ice removal from highways? Yes ❑ No ❑

   b. Are you required to post warnings when you are using "non-standard" techniques (i.e., novel technology) for winter highway maintenance? Yes ❑ No ❑

   c. Do liability concerns limit your testing and implementation of new technology? Yes ❑ No ❑

4. A manual of procedures provides useful information for improving current state winter highway maintenance procedures. Does your manual of procedures require you to record:

	check only one
all winter maintenance activities?	❑
just those in compliance?	❑
just those in deviation from the procedure or policy?	❑

5. Please comment on ways in which policies and procedures affect your implementation of new technology for state winter highway maintenance.

____

____

B. Weather Forecasting

6. What sources do you use to gather weather information?

Source	Yes	(check all that apply)
National Weather Service	❑	
State Meteorologist	❑	
Local news service	❑	
RWIS (Road Weather Information System) (please give name of provider)	❑	______________
Routine patrols	❑	
Police reports	❑	
Local observers	❑	
Observer networks	❑	
NOAA Weather Radio	❑	
The Weather Channel	❑	
Cable weather and radar observations	❑	
Private forecasting service (please list the supplier of said service)	❑	______________

7. Do you have any weather sensing equipment which you use to monitor weather and/or pavement conditions around your state? Yes ❑ No ❑

a. If yes, how many sites record weather only? ______
b. How many record pavement conditions only? ______
c. How many record both? ______
d. What types of pavement sensors do you have? (Please list the four most common types and their manufacturers.)
1. ______________________________________
2. ______________________________________
3. ______________________________________
4. ______________________________________

e. Do your pavement sensors give many "false alarms?" Yes ❑ No ❑

C. Equipment and Practices

8. We are interested in the number of vehicles your state uses for winter maintenance.

a. Please indicate how many trucks you used over the course of last winter.

Trucks used	Owned by state	Owned by contractor
Vehicles with front mounted plows	______ number	______ number
Vehicles with underbody plows	______ number	______ number
Other	______ number	______ number

b. Do winter highway maintenance needs govern the number of trucks that your state owns and operates? Yes ❑ No ❑

c. How many ***miles*** of state highway must you keep clear of snow and ice? ______

9. Please indicate the make, number and characteristics of the four most common plows used and the four most common types of trucks on which they are mounted, regardless of whether you own them or contract for them:

No. of units	Plow		Truck		
	Brand name	Number	Name/model	Weight	Type
e.g., 5	Henke	48R 12	International Fleetstar 2050	25 ton	Double rear axle
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____

How many snow routes must these trucks service? ____

10. What sort of cutting edges do you use? Please indicate the ***most common*** brand name and type for each category (e.g., kennametal hy90)

Edge type	Number	Brand name	Type
High speed steel	____	____	____
Carbide insert	____	____	____
Other (rubber slush blades, etc.)	____	____	____

11. How many edges did you buy in FY93? ____ number

How many edges do you buy in a typical year? ____ number

12. How much salt did you use last winter? ____ tons

Do you apply salt with sand? Yes ❑ No ❑

Under what conditions do you apply ***salt***? (check all that apply)

Every winter storm	❑		
After more than a certain amount of snow has fallen	❑→	If yes, after how many inches?	____in.
When the temperature falls below a certain level	❑→	If yes, below what temperature?	____°F
Other	❑	____	

13. How much sand did you use last winter? ____ tons

Do you put the sand down hot? Yes ❑ No ❑

Under what conditions do you apply ***sand***? (check all that apply)

Every winter storm	❑		
After more than a certain amount of snow has fallen	❑→	If yes, after how many inches?	____in.
When the temperature falls below a certain level	❑→	If yes, below what temperature?	____°F
Other	❑	____	

14. What spreading equipment do you use to apply salt and/or sand? (List up to three types.)

	Number	Brand name	Model number
1st type	______	______________________	______________
2nd type	______	______________________	______________
3rd type	______	______________________	______________

15. What rate of application do you use for sand? (lbs/lane mile) ______________

16. What rate of application do you use for salt? (lbs/lane mile) ______________

17. What other chemicals do you use? Indicate approximate annual amounts from list below:

Chemical	Use	Do not use	Amounts (lbs/lane mile)
Calcium Chloride—solid or liquid	❑	❑	________
Potassium Chloride	❑	❑	________
Urea	❑	❑	________
Calcium Magnesium Acetate (CMA)—solid or liquid	❑	❑	________
Magnesium Chloride—liquid	❑	❑	________
Ethylene Glycol	❑	❑	________
Potassium Acetate—liquid	❑	❑	________
Sodium Formate	❑	❑	________
CG-90™ Anti Corrosive Deicer (supplied by Cargill, Inc.)	❑	❑	________
CG-90™ Surface Saver Deicer	❑	❑	________
CG-90™ Surface Saver Liquid Deicer	❑	❑	________
Qwiksalt™ + PCI (supplied by the North American Salt Co.)	❑	❑	________
Freezgard™ + PCI (supplied by the Great Salt Lake Minerals and Chemicals Corp., and by Canadian Protective Products, Inc.)	❑	❑	________
Potassium Acetate, Cryotech C92/E36 (G92 is supplied by Cryotech Deicing Technology, E36 is supplied by Ashland Chemical)	❑	❑	________
Any other chemicals used (specify):			
______________________________	❑	❑	________
______________________________	❑	❑	________
______________________________	❑	❑	________

18. Do winter highway maintenance needs govern the number of trucks that your state owns and operates? Yes ❑ No ❑

Please list any such reports. (We would appreciate you enclosing a copy of each with this survey if you have copies available.) ______________________

____

____

19. Are there any areas within your state in which use of salt is restricted? Yes ❑ No ❑

If yes, do you use other chemicals in those areas? Yes ❑ No ❑

Which other chemicals do you use? ____________________

____

If yes, do you have some areas where you don't use chemicals at all? Yes ❑ No ❑

In those areas, do you have a "bare pavement" policy? Yes ❑ No ❑

20. Are there any areas within your state where you use special road surfaces to reduce ice formation? Yes ❑ No ❑

21. Do you have pavement heaters installed at any locations? Yes ❑ No ❑

22. Have you performed any studies on the problems of airborne particulates arising from the use of sand as an anti-skid material? Yes ❑ No ❑

Please list any such reports (we would appreciate you enclosing a copy of each with this survey if you have copies available). ______________________________

____

____

23. Do you apply salt on its own or mixed with sand? Alone ❑ Mixed ❑

If you apply salt and sand mixed, what are the proportions of the mix? (salt/sand by weight) ____________________

24. Do you pre-wet salt prior to use? Yes ❑ No ❑

25. Do you monitor the application rate of salt and sand? Yes ❑ No ❑
If yes, how? ______________________________

____

____

26. Pre-treatment of roads:

Do you pretreat the roads prior to storms (applying salt/sand prior to first precipitation)? Yes ❑ No ❑

What criteria do you use? (Please describe.) ____________________

____

If you pretreat:
What deicing chemical do you use? ____________________
Is it solid or liquid? ____________________
What rate of application do you use (lbs/lane mile)? ____________________

27. Do you have an ongoing experimental evaluation of anti-icing methods in your state? Yes ❑ No ❑

Please send us copies of any reports or other information you have at this time. Thank you.

D. Planning and Training

28. Do you have a regular training program for:

Plow Operators?	Yes ❑	No ❑
Supervisors?	Yes ❑	No ❑
Dispatchers?	Yes ❑	No ❑

29. Do you have an annual media day? Yes ❑ No ❑

30. Do you have an optimization method for planning your snow plow routes to minimize the number of plows you require (cf Indiana DoT CASPER system)? Yes ❑ No ❑

Please return this survey in the enclosed envelope, or send to:

Professor Wilf Nixon (319) 335-5166
Public Policy Center
227 South Quad
University of Iowa
Iowa City, IA 52242

Thank you for your help.

Appendix D
Nonnumerical Responses to Survey of State Departments of Transportation

Nonnumerical Responses to Survey of State Departments of Transportation

5. *Please comment on ways in which policies and procedures affect your implementation of new technology for state winter highway maintenance.*

- Policy is to do the best job possible with the resources available. In an effort to provide safer driving conditions, policy does not hamper but rather encourages the investigation of better methods to address winter weather problems.
- The law as it has evolved allows us to try new things as long as they are "reasonable."
- Current changes in policy allow front line supervisors greater flexibility, which should promote implementation of new technology.
- Procurement regulations restrict quick purchasing of materials. Must prove cost-effectiveness.
- New technology is tested and evaluated. If warranted, new technology is incorporated into procedures.
- A formal work plan is required for all demonstrations or evaluations, and a control section is incorporated for a baseline.
- A manual, currently being developed, will identify the best procedures for statewide implementation. Areas not using the "best practices" will retrain as necessary.
- We have guidelines only. This allows flexibility in the field to experiment with new technology and products. Research has been "institutionalized."
- Implementation of new technology is strictly resource-related. We maintain all state roads; any change in procedure or equipment is very costly. Only proven technology is seriously considered.
- Since the DOT contracts with local counties for highway maintenance, the county must get approval from district maintenance staff prior to implementation of new technology.
- New technology may be tried under close supervision and as long as current standards are maintained
- New products must go through an approval process in our materials lab before actual road testing.
- We revise the policies and procedures as necessary to implement new technology.
- It is updated every two years.

- The procedures do not specifically address the use of new technology. We, however, have not refrained from cautiously trying or implementing new technology. Often new methods/materials are addressed in public news releases to inform the public of what to expect and why we are trying something that the public may recognize as being new and different.
- Legislative mandate requires reduced use of salt and use of "environmentally safe" deicers.
- The Department has experimented with and used liquid calcium chloride as well as liquid magnesium chloride.
- Our policies and procedures do not restrict the use of new technology. (3)
- Lack of time, money and manpower
- No impact or effect (4)
- We do not experience enough ice and snow to access new technology.

Strategies for Winter Highway Maintenance was prepared by the Public Policy Center for the U.S. Department of Transportation's University Transportation Centers Program and the Iowa Department of Transportation. The Public Policy Center is an interdisciplinary research unit dedicated to the scholarly examination of social and economic policy alternatives.

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