Comparison of Material Distribution Systems for Winter Maintenance

Final Report

CLEAR ROADS
research for winter highway maintenance

Thompson Engineering Company

Project 01531/CR12-05
December 2014

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Comparison of Material Distribution Systems for Winter Maintenance – Phase I

CLEAR ROADS
research for winter highway maintenance

Minnesota Department of Transportation

FINAL REPORT

December 8, 2014

Prepared for

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Monday, December 8, 2014

Minnesota Department of Transportation
Attn: Ashley Duran, Contract Administrator
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395 John Ireland Boulevard
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Dear Ashley Duran,

Please find attached the deliverable FINAL REPORT for the project entitled "*Comparison of Material Distribution Systems for Winter Maintenance – Phase I*".

The final report serves as a compendium of the project deliverables, review of the study, and an executive summary.

Please contact me if you require additional information. Thank you for your consideration.

Sincerely,

Gregory E. Thompson

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I. Executive Summary

A. Challenge. In the winter season, Departments of Transportation (DOTs) need to maintain a certain level of service to keep the roadways safe for the motoring public. This coupled with budgetary and environmental constraints makes decisions challenging for snow fighters when it comes to purchasing, scheduling and managing their resources. Very important tools for keeping the roadways clear and safe are salt spreading systems. This study gathered and compared information about salt spreaders from state and local DOTs. The references, examples, comparisons, photographs and test proposals contained in this report seek to make the current practices of DOTs available to as wide an audience as possible.

B. Tasks. This goal was achieved by through four deliverables: (1) literature search, (2) survey and response analysis, (3) catalog of different systems, and (4) plan for testing/comparing these types of systems.

C. Results & Findings. Some general comments are as follows:

- Many studies were found during the literature search, however, specific local modifications or remedies were only found through emailing and surveying individuals.
- Several studies have been conducted on spreaders with mixed results and most are not comparison studies.
- The two most common modifications to manufacturer's systems were using some form of pre-wetting the salt and modifying (usually lowering) the spinner or chute to minimize bounce and scatter.
- Most respondents have confidence in the effectiveness of their spreader systems, but many thought their system was ineffective before the snow falls (suggesting the use of liquids for this purpose).
- The catalog provides photos of various spreader configurations.

D. Evaluation. The test plan & recommendations report provides descriptions of methodology, strategy and budgetary considerations. Several of the conclusions of the study are listed below.

- Evaluating spreader systems is important and has a direct impact on cost, environment, and public safety.
- Past tests of spreader systems for comparison with regards to type, accuracy, control, and effectiveness are rare.
- Test results that do exist are narrowly focused (one system) or data is not sufficient to extrapolate snow and ice removal conclusions.
- Snow professionals seek this information and require knowledge on the comparison of spreader systems by several parameters.
- Comprehensive and effective evaluation and analysis is expensive.

II. Introduction

A. Background. Departments of Transportation (DOTs) are constantly challenged to maintain safe, passable roadways through the winter season. Winter weather provides a variety of unique conditions that require specific and varying treatments in order to attain the desired results. They must provide a necessary level of service (distribute snow and ice removal chemicals) to keep the roadways as safe as possible for the motoring public. A significant cost in the process of spreading material is the cost of the material itself (Keltner-Iowa DOT). This coupled with the growing environmental concerns with these chemicals finding their way into sensitive eco-systems makes using snow and ice removal chemicals efficiently and effectively a very important subject. This study seeks to make the information and practices of state and local DOTs regarding material distribution systems available to as wide an audience as possible.

B. Project Purpose. The goal of this project is to identify as many solid material distribution systems as possible and develop a plan for field-testing them. The study included systems with pre-wetting capabilities, but did not include equipment for slurries or direct liquid applications.

There are two phases to this project, this report documents Phase I and prepares Clear Roads to enter Phase II. Figure 1 provides a Phase I project flow chart.

1. Phase I focused on identifying and cataloging these systems, as well as developing a field test plan and recommendations.
2. Phase II will conduct field-testing, identify the most effective systems and develop a recommended specification for a material distribution system.

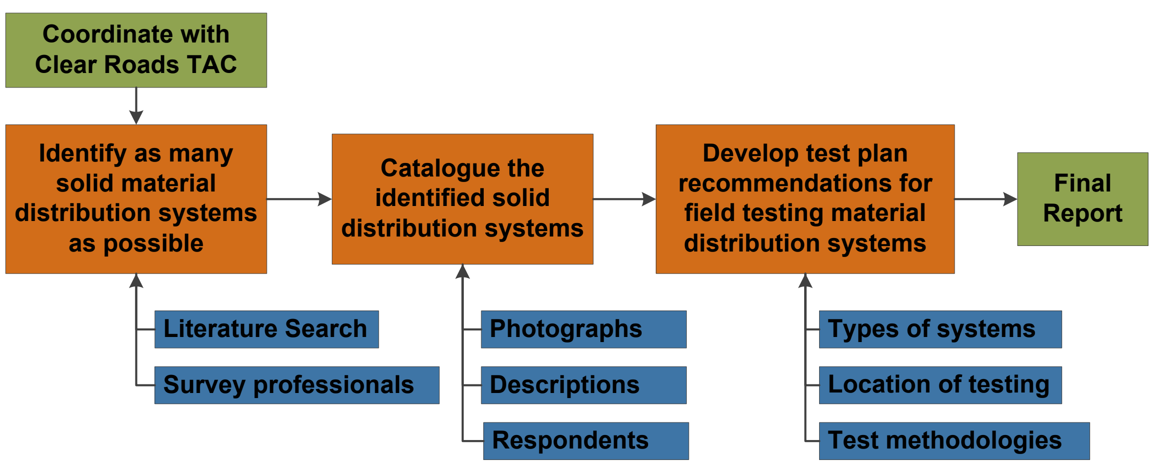

Figure 1: Project Flow Chart for Phase I

Clear Roads is an ongoing pooled fund research project aimed at rigorous testing of winter maintenance materials, equipment and methods for use by highway maintenance crews. Clear Roads will fund and oversee the contract for this project in coordination with the Minnesota Department of Transportation. Thompson Engineering Company was selected to perform the study and report to the Clear Roads Technical Advisory Committee through the program manager at MN/DOT and the project manager from CTC Associates.

C. Tasks. The tasks completed for this project are shown in the following list. Each of the deliverables from the assigned tasks is discussed in the next section.

1. Perform Literature Search of Existing Material Spreader Systems
2. Conduct Survey of Road Maintenance Professionals & Analyze Responses
3. Catalog Distribution Systems Submitted by Survey Respondents
4. Propose Field Testing Plans & Recommendations
5. Prepare Final Report
6. Submit Quarterly Progress Reports to Project Manager

The previously submitted three reports, Literature Search, Survey and Analysis, and Field Testing Plan in their most updated form are included as attachments to this final report. They retain their original figure/table numbering. The fourth report, Catalog of Distribution Systems was deemed too large to be conveniently attached here and remains as a separate report.

III. Literature Search

A. Background. The Clear Roads pooled fund research program (www.clearroads.org) has examined previous studies and research to determine information from other sources and/or to leverage previous investigations to accomplish the project goals. This literature search provided an update of previous studies and also sought descriptions and photos of modified systems and homemade components that have shown success in snow and ice removal efficiency, cost, and performance.

B. Task. The project team conducted a literature search on the effectiveness of different types of commercial and homemade material distribution systems used in the North America and Europe.

C. Purpose. The purpose of this literature review is to identify references that provide information on as many types of commercial and homemade material distribution systems as possible. In addition, one of the study's goals is to find information on the effectiveness of these different types of systems. Also, the study explores the literature to see if there have been comparison studies on these systems.

D. Scope. Many databases, journals, proceedings of national and international conferences and the Internet were searched for this study. Special emphasis was given to systems currently in use by the Clear Roads member states. The literature search report is included in this report as Attachment 1.

IV. Survey and Analysis

A. Survey and Implementation. The survey questions can be found in Attachment 2. The questionnaire has six sections; snow fighter information, information about spread controller systems that snow fighters employ, system functionality, effectiveness of the system, systems costs, final remarks and photos. The survey was tested on a small group and sent out to the Clear Roads general distribution list, and email lists. Although it was available as a hard copy no one used this option.

112 professionals completed the survey providing information on 170 different spreader systems. The survey was taken by a broad range of participants representing 27 state governments, 40 county and city governments, 3 from the federal government and 5 international professionals. Attachment 2 provides a detailed analysis of the survey responses.

B. Results. Here only the highlights of the results will be mentioned. Look at the full report (included here as Attachment 2) for more details.

First the vast majority of respondents were satisfied with the functioning of their spreader system(s). The respondents described systems representing 8 different spreader manufacturers with 8% having a homemade system. Five different spreader controllers were described as well. A summary of results follows:

- In terms of type of material only 35% used granular with the other 65% using pre-wet, slurry or liquid.
- 76% used some form of ground speed/closed loop system to control the rate.
- The most common truck speed for spreading is 30-34mph.
- The most common chute/spinner height is 20 inches.
- The most common modifications from manufacturer's equipment is changing the chute/spinner height and adding a pre-wet system.
- As stated earlier 70% rated their system as good, flexible and reliable.
- Some respondents mentioned that they would like a more effective system to use before the snow falls.
- Another area that was mentioned by many was a reliable procedure to use the data collected by GPS and other data loggers on-board the trucks to save costs and the environment.

V. Catalog of Material Spreaders

A. Description. This deliverable is a photographic catalog of different types of material distribution systems. Photos were gathered over an eight-month time period, June 2013 to February 2014. They were obtained in three ways:

1. Gathered as part of a survey professionals (an earlier step in this project)
2. Solicited in emails targeted to individuals and organizations
3. Collected from websites when suitable photos were not received in either of the first two ways

B. Categories. The categories used to sort and group the photos were suggested by the Clear Roads committee and then expanded to include some other categories given the content of the photos submitted. The categories are:

- Tailgate Spreaders
- Hopper Spreaders (slide in)
- Single Purpose Spreaders
- Pre-wetting Systems
- Salt Slurry Generators
- Spinners, Chutes, and Boots
- Zero Velocity Spreaders
- Controllers

C. Interest. There is significant interest in how systems were/are modified from factory models. The areas where most modifications were observed in this study are in the pre-wetting systems and the spinners, chutes and boots categories. For a more detailed discussion of these modifications see the Survey Analysis Report (Attachment 2) and the Catalog (Attachment 3; available separately, not included in this report because of file size).

VI. Field Test Plan & Recommendations

A. Purpose and Procedure. The task for part is to recommend a plan of study for assessing the effectiveness of material distribution systems, using information gathered in Tasks 1-3. Structure a plan for field-testing that includes details on how many different types of systems to test, test methodologies, test location considerations, etc. To compare salt spreaders (or any road maintenance equipment) there are two general ways to proceed:

1) Designate a few districts (states, counties or cities) with different spreader systems. Collect data throughout a winter season and compare the data from these districts.
2) Collect a few systems (actual spreader trucks) in one place and test them under identical circumstances.

Both methods have their strong and weak points. The first approach can be very effective, though with all of the variables in a snow fighting crew and their equipment and the vagaries of the weather it is very difficult to be able to make definitive conclusions. The focus of this study follows the second approach.

B. Numbers and Locations of Systems. When considerations of quantity and quality are considered 6-8 test systems seems to be a reasonable and prudent number for answering significant questions like, “Does pre-wetting the salt improve the coverage of the road surface?” or “How does the placement (height and lateral position) of the spinner affect slipperiness?” The best location for the test is probably a state DOT testing facility.

C. The actual test:
The following is a compendium of some tasks that need to be considered in the tests discussed in the test plan part of this paper (Attachment 4):

- Calibrate the spreader
- Record initial conditions
- Load the truck
- Weigh the truck
- Set the spread rate
- Ensure that the truck has enough time before to reach a spreading equilibrium before entering the grid
- Clean the areas thoroughly between test runs
- Change only one variable at a time; speed, position, height of chute, etc.
- Have a complete plan for the different maneuvers this test will execute; acceleration, deceleration, stopping, starting, etc.
- Take a video of each run to verify the maneuver

D. Budgetary considerations:
Some assumptions were made to calculate a budget of $252,000 to test eight trucks, four different brands, and four parameters to be varied.

- Trucks are provided by member organizations at no cost.
- Vendors participate for calibration, maintenance, & specification assistance only at no cost.
- A member state DOT provides a test track with enough availability and minimum costs.
- Eight trucks, four brands, four types, four variables are required.

- Sufficient personnel are available to operate equipment.
- Third party (consultant) assistance is required for training, establishing initial conditions, project management assistance, and data recording & analysis.
- The organization needs to assign one test director and supporting staff as needed.

VII. Summary & Conclusions

The techniques used to improve best practices for snow and ice removal are varied and locally driven by geography, weather, equipment availability, and cost. The study found that most agencies have confidence in the effectiveness of their spreader systems. Environmental concerns were very important to snow & ice removal agencies. There were many examples of how to tackle the problem of bounce and scatter, from industry produced products like zero velocity spreaders to homemade systems like added flaps, cages and lower salt release heights. Examples of solutions to the bounce and scatter problem can be seen in the catalog (Attachment 3, under a different cover). There are a couple of comparison studies about this problem, most notably, Croze, T. "MDOT 2012 SALT BOUNCE & SCATTER STUDY" (see Attachment 1 for more).

Some other general conclusions from the survey and analysis are:

- Most snow fighters are content with their equipment.
- Most garages are pre-wetting their salt.
- Most crews are trying to lower their chutes or spinners.
- Most maintenance crews collect data from on-board GPS or sensors.
- Many think that data gathered could be used to more advantage than is currently being done.

From the literature search it is clear that the need for testing these spreading systems is acute. There are a few studies on bounce and scatter, whether pre-wetting reduce bounce and scatter, etc. But there is not one domestic study that compares simple things like:

- What covers the road surface better a tailgate or a hopper spreader?
- Does GPS curtail salt usage?
- Does ground speed - closed loop control improve performance (of road coverage, salt usage, etc.).

There is a great need to test these systems, because many decisions have to be made daily about equipment purchases, road crew utilization and maintenance of the snow fighting fleet.

When gathering photos for the catalog some general things that were learned are:

- Crews are split 50-50 between tailgate and hopper type spreaders.
- There are many creative modifications used to change the chute/spinner height.
- Many different commercial and homemade pre-wetting systems are in use.

- The photos themselves are interesting in their variety.

The test plan has many variables that need to be sorted out by the testing group. The procedure for doing this is:

- Decide on the question to be asked.
- Find a location and the systems to be tested.
- Follow a plan that includes: test preparation, test operation, test execution and test results.
- Document the testing for later analysis and for reproducibility.
- Comprehensive and effective evaluation and analysis is essential.

Some budgetary challenges and time constraints for testing these systems include:

- Funding this type of project usually requires more than one organization; complicating the start and execution of the testing
- Testing takes time, prior planning, organization, structure, multi-discipline, multi-agency coordination. Impacts on several schedules often are not compatible
- Training of test personnel is effective, essential and expensive.
- Determine what support, funding, and no/low cost assistance is available from commercial, academic, governmental and industrial sources.
- In kind assistance from an academic institution (planning and analysis), a state DOT (for location and equipment) and vendors (for equipment and calibration) is important, time consuming and very important for the budget.

It is essential that these systems are tested and important that an effective team of professionals is assembled to be equal to the task.

Attachment 1: LITERATURE SEARCH

Attachment 1: LITERATURE SEARCH

Literature Search for Comparison of Material Distribution Systems
for Winter Maintenance – Phase I

I. Introduction

The goal of this project is to identify as many solid material distribution systems as possible and develop a plan for field-testing them. Systems with pre-wetting capabilities should be included in the study, although equipment for slurries or direct liquid applications is not included in the scope of this project. Phase I will focus on identifying and cataloging these systems, as well as developing a testing plan. Phase II would conduct field-testing, identify the most effective systems and develop a recommended specification for a material distribution system.

A. Background. The goal of this project is to identify as many solid material distribution systems used in winter road maintenance settings as possible and develop a plan for testing them. Systems with pre-wetting capabilities should be included. This information will be invaluable to Departments of Transportation (DOTs) that are constantly trying to provide a necessary level of service (distribute snow and ice removal chemicals) to keep the roadways as safe as possible for the motoring public. This study seeks to make the information and practices of state and local DOTs regarding material distribution systems available to as wide an audience as possible.

As the first part of the project, Thompson Engineering on behalf of the Clear Roads pooled fund research program (www.clearroads.org) has examined previous studies and research to determine information from other sources and/or to leverage previous investigations to accomplish the project goals. This document provides the results of this literature search.

B. Task. The task for this deliverable is as follows: the TEC team has conducted a literature search on the effectiveness of different types of commercial and homemade material distribution systems used in North America and Europe.

C. Purpose. The purpose of this literature review is to identify references that provide information on as many types of commercial and homemade material distribution systems as possible. In addition, one of the study's goals is to find information on the effectiveness of these different types of systems. Also, the study explores the literature archives to see if there have been comparison studies on these systems. Another goal of the study is to catalog these systems and studies, as well as develop a testing plan. Figure 1 provides an illustration of the project understanding.

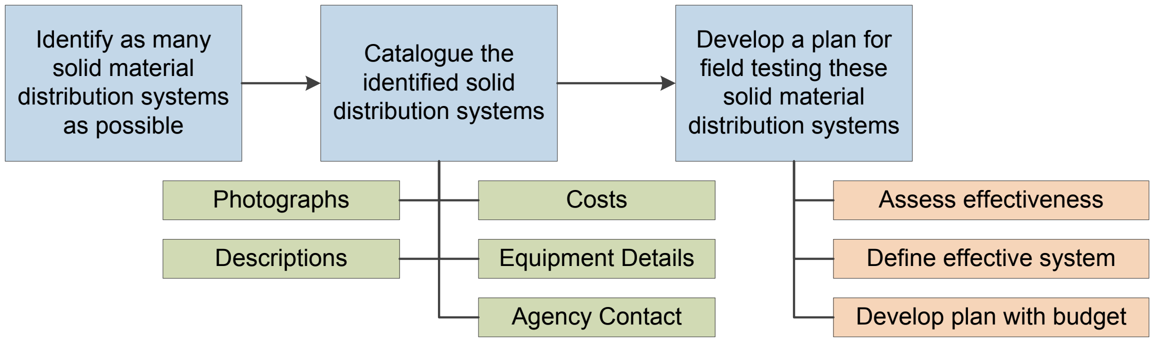

Figure 1: Project Plan

D. Scope. Many databases, journals, proceedings of national and international conferences and the Internet were searched for this study. Special emphasis was given to systems currently in use by the Clear Roads member states. Simultaneously with this search a survey of snowfighters about the spreader systems they use has been undertaken and references elicited from this survey were also investigated. The survey results report is included here as Attachment 2.

E. Literature Search Methodology. TEC prepared a literature search plan as a basis for conducting the investigation. A brief description of the plan's methodology is provided below.

1. Plan. The plan consisted of the following procedures: Identify the key words, phrases, & acronyms or winter maintenance community common terms. Group the keywords from above into concepts or ideas. Determine the relationships between the words. Use the Boolean operators OR, AND, & NOT when grouping keywords. Specify what we're not searching for by stating the limits of the search.

2. Sources. Determine where to search and document sources. Examples of sources used are provided below.

- Internet
- Libraries
- Periodicals
- Textbooks
- Universities
- Government Agencies
- Equipment Manufacturers

3. Search Engines. The following search engines were employed.

- Google
- Yahoo

- Transportation Research Board (both the TRID and the RIP databases)
- Winter maintenance search engines

4. Limitations & Boundaries. The scope of investigation was narrowed and/or broadened as needed to gain confidence that it was thorough. Examples of boundaries that were used are listed below.

- Time span
- Geographical areas
- Language
- Type of publications

5. Conference Proceedings. The search examined articles in conference proceedings; this was essential because most of the knowledge in this area has been developed within the last ten years.

II. Findings

The results of this literature search are organized in the Findings (a brief discussion) and Bibliography (the references) sections. There are many ways to organize the references encountered in this literature search. One-way would be by type of spreader; tailgate spreaders, hopper spreaders (slide in) and spreaders that are the primary (sole) function of the truck. This type of organization will be used for the catalog, but for clarity and usefulness, TEC chose to organize the references here by type of study (A-G as listed below).

A. General References about Salt Spreading. There are many sources of information about salt spreading in general. The bibliography has a couple of simple newspaper style articles that explain current practices and challenges on the simple end of the spectrum. On the end a number of DOTs have published a detailed manual or a set of directions for spreading policies and techniques.

B. Best Practices and Emerging Technologies. New technologies are always emerging in the materials distribution arena. A couple topics are briefly discussed in this paragraph and many others referred to in the bibliography.

An overall discussion of the technique of pre-wetting can be found in a publication by Wisconsin DOT (Wisconsin Transportation Bulletin, No. 22). Pre-wetting the granular material helps it work more effectively in 2 ways:

1. Wet material clings to the road instead of bouncing off or being swept off by traffic. This results in less material being distributed to the roadway, saving money and minimizing the threat to the environment.
2. To be effective, the granular material requires moisture. Wetting the material before spreading it onto the road jump starts the melting process. The moisture dissolves the material, releasing heat that melts the ice and snow and breaks the ice-road bond.

How and where to pre-wet the material is an ongoing field of research and experimentation. One interesting study from Michigan DOT (Colson) found the Monroe slurry maker operated well, but that actually making a slurry solution can be difficult. Another online discussion in the Wisconsin DOT (Jordan) discussed where to administer the pre-wet: in the spinner or in the auger.

A widely tested and used innovation over the past 15 years is zero velocity spreaders. These are systems designed to put salt on the road with a velocity in the opposite direction to the vehicle speed thus delivering the salt with no velocity with respect to the road. This reduces bounce and scatter. There are various models available (see for example Tyler Ice, Monroe and Henderson). These systems have been widely tested and proven to be very effective. Four different comparisons in the bibliography are Ulrich, Croze, Nantung and Sharock.

One of the newer technologies offered involves different types of sensors that are available for modern snowplow spreader systems. In addition to location (GPS) sensors there are devices that measure pavement temperature, pavement slickness, and just about anything regarding the vehicle from weight of salt left to the position of the plow to the coolant temperature.

A highlight of emerging techniques is the Golden Ice system which is a partnership formed to develop a completely automated and highly responsive spreading system. Their website describes it as follows. "The Golden Ice consortium was coordinated by SAET, which developed the new onboard unit. Arvel Industries, part of the Italian Giletta group, is a manufacturer of salt spreaders and snowplows. Istituto Superiore Mario Boella is an R&D institution that provided expertise in GNSS technologies GPS and Galileo, while the insurance company Allianz provided help with the integrated eCall system. Finally, Hanes in the Czech Republic supplied the actual vehicle."

C. Comparison Studies. A study by MnDOT (Ulrich) in 2010 conducted research with four different chemical additives and five delivery methods. The chemicals were; RoadGuard Plus +8, Geomelt, Ice Ban, and Thawrox. The delivery methods were: slurry system, chutes, salt skirts and zero velocity and conventional spinners. They found that the zero velocity system put the most salt in the desired area and also that the chutes improved salt placement accuracy.

A 2012 study by Michigan DOT (Croze, T.) tested different methods of delivering the salt to the roadways and its findings can be summarized as follows:

- Salt needs to be applied at speeds as slow as possible (25 mph or less is preferable but no faster than 35 mph).
- All salt should be treated with a liquid chloride product.
- Testing of additional distribution systems and chute heights would be valuable.
- Training and improved operator awareness are essential.

There are new electric powered spreaders being offered (Swenson for one). These offer some advantages in reaction time over hydraulic systems and they claim to be easier to install. See the bibliography for more information on this.

A Clear Roads study from 2010, showed Wisconsin's snow fighters use about half V-box spreaders and half tailgate spreaders. The choice between the two depends largely on the type of truck they are using and the costs (V-box are more expensive). From the Nevada DOT guidelines, "The primary limitation of tailgate spreaders is the inconvenience of raising the dump box and the possibility that the box will not be raised high enough to ensure that sufficient material is dumped in the hopper to provide consistent delivery. The rear discharge restricts the operator view of the operation and ability to ensure that the material is being discharged at the right location."

One of the big questions being asked currently concerns automation of the salt spreaders and material distribution systems. Employment of GPS receivers to track spreader information and control the spread rate based on location is a question DOTs must determine before deciding on a spreader system. Probably the best study on this question is the Danish study (Sommer, B.) where four different GPS automated spreaders were compared.

D. Agricultural Technologies. Spreaders used for agricultural purposes are divided into three categories: broadcast (spinners usually), drill type (like a simple lawn fertilizer) and pneumatic (long arms on each side of the vehicle) (see Government of New Brunswick and Samuel Roberts Foundation). These agri-spreaders face the same challenges that the salt spreaders do with spreading pattern and calibration (see University of Georgia).

Probably the biggest difference between the agriculture and road maintenance industries is the rate of speed of the distribution vehicle (tractor vs. truck) and the rate of changing conditions (weather vs. soil composition). Both rates are much faster in the winter maintenance field by necessity. Thus, the application of GPS and other data gathering and manipulation techniques is less problematic for agriculture. The term used for this technology based on accuracy, feedback, and calibration advances in the agricultural field is "precision farming" or "precision agriculture".

The agricultural industry is employing GPS receivers and achieving impressive results. One leading manufacturer that makes these claims is Trimble. The issue of accuracy and rate of response is critical (see Pfost and Casady). However, it is difficult to find articles that give quantitative information about rates and reliability. One article claims great results such as accuracies of plus or minus 1 inch or closer from an established row while moving at speeds up to 14 mph were possible with a GPS based system (see Straight Talk from Trimble in the bibliography section).

E. Environmental Concerns. There are many literature items about the environmental impact of snow and ice removal chemicals for winter maintenance. A few key resources on this topic are listed in the bibliography. The list of environmental concerns about too much "salt" on the roadways is extensive. The biggest issue is that the chlorides can leave the roadway and effect roadsides and natural resources. Some specific concerns are: impact on human health (clean drinking water), impact on wildlife, corrosion on automobiles, and concrete damage. The problems are compounded by the fact that chloride takes a long time to filter out of the ground water and in lakes the salt collects on the bottom and builds up.

Two good studies that discuss solutions are Keseley and the Maine DOT. The Maine DOT published these suggestions for reducing the environmental problem:

- Reduce overall salt use through improved practices, new materials and equipment, and changes in levels of service.
- Review the levels of service in municipalities to see if some roads can have reduced salt application through lower service priorities, for example residential low-speed-limit neighborhoods.
- Identify state and local roads near sensitive environments which should receive reduced salt.
- Expand monitoring of salt loading in key areas to establish baseline data on water quality.
- Expand monitoring of the environmental impacts of deicing materials in urban areas, particularly parking lots, located near sensitive environments.

F. Manufacturers. For the purposes of this literature survey, 13 domestic and 10 international manufacturers are listed here with their websites.

G. Video Resources. There are several homemade and department made videos of snowfighting using granular and liquid chemicals on roadways. The bibliography has numerous examples of each of the above categories.

III. Bibliography

A. Basic information about spreaders:
Newspaper article for the general public.
http://www.roadsbridges.com/ready-steady-spread

Clear Roads article about ground speed controllers and their effectiveness.
http://www.clearroads.org/downloads/ready-steady-spread.pdf

Another Clear Roads study that documents controller settings, actual salt usage and prewetting rate information from trucks with various types of controller units during winter storm events.
http://clearroads.org/project/calibration-accuracy-of-manual-and-ground-speed-control-spreaders/

DOT (and federal) guidelines:
The first published treatments were in the FHWA Manual of Practice for an Effective Anti-Icing Program, published in 1996. These were updated in NCHRP Report 526, which was developed in NCHRP Project 6-13 and published in 2004.

Nevada DOT "CHAPTER 8: Winter Operations and Salt, Sand, and Chemical Management" This is the most comprehensive has a great introduction to emerging technologies.
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CDUQFjAB&url=http%3A%2F%2Fenvironment.transportation.org%2Fdocuments%2Fnchrp25_25_files%2Fnchrp_chapter_8.doc&ei=pDO1UYnPBsa3ywG4wYHgDg&usg=AFQjCNEucxto7SlYRvvPyS2zfqNYPCiFEw&bvm=bv.47534661,d.aWc

A fairly comprehensive handbook from the Illinois DOT,
www.dot.state.il.us/blr/L026%20The%20Snowfighters%20Handbook.pdf

From FHWA: Manual of Practice for an Effective Anti-icing Program: A Guide For Highway Winter Maintenance Personnel,
www.fhwa.dot.gov/reports/mopeap/eapcov.htm

From the US DOT: Road Weather Management Performance Measures – 2012 Update,
http://ntl.bts.gov/lib/51000/51000/51065/26615E33.pdf

From Michigan DOT: Winter Road Maintenance - Improving Safety While Minimizing Environmental Impacts from 2006,
http://www.michigan.gov/documents/stormwatermgt/MDOT_MS4_Winter_Road_Maintenance_208467_7.pdf

From the Maine DOT. A bit old and the technology has certainly improved since then, but a good place to begin.
http://www.maine.gov/mdot/tr/documents/pdf/report0501final.pdf

Dated 2008 from the Idaho DOT, a good slide show about the basics of spreaders and their components.
http://pnsassociation.org/wp-content/uploads/Idaho.pdf

Ketcham, S., L.D., Minsk, R. R. Blackburn, and E.J. Fleege, "Manual of Practice for an Effective Anti-Icing Program," Report No. FHWA-RD-95-202, Federal Highway Administration, Washington D.C., June 1996. Available on-line at:
http://www.fhwa.dot.gov/reports/mopeap/eapcov.htm

Blackburn, R.R., K. M. Bauer, D.E. Amsler Sr., S.E. Boselly, and A.D. McElroy, "Snow and Ice Control: Guidelines for Materials and Methods," NCHRP Report 526, Transportation Research Board, Washington D.C., 2004.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_526.pdf

B. Emerging technologies:

Thompson, et al. Survey for the Development of a Totally Automated Spreading System" by Thompson Engineering for Clear Roads, 2013. Describes snowfighter and vendor responses to totally automated spreader systems.
http://clearroads.org/project/development-of-a-totally-automated-spreading-system/

An article from 2012 describes a system that claims, "Our new onboard unit allows us to use GPS navigation signals, augmented by EGNOS and EDAS, to track our salt-spreading vehicles at all times and to control the amount of salt being applied in a very precise way, based on real weather conditions and specific road morphology."
http://www.egnos-portal.eu/news/precision-salt-spreading-demonstrated-prague

Wisconsin Transportation Bulletin, No. 22 is a general discussion of pre-wetting technologies from 2005.
http://epdfiles.engr.wisc.edu/pdf_web_files/tic/bulletins/Bltn_022_Prewetting_Antiicing.pdf

Jordan, B. Wisconsin DOT, "Pre-wetting at the auger vs. at the spinner". This article discusses a lot of interesting work being done in the Wisconsin DOT.
http://www.aurora-program.org/knowledgebase/GetFile.aspx?Page=Road%20Weather.SICOP-list-serve-Discussion-

Strings&File=Prewetting_at%20the%20auger%20v%20at%20the%20spinner_11.29.2012.pdf

Many studies and products are touting the utility of slurries for spreading on the roads. Their anti-icing action saves salt and keeps the salt on the road better. Slurry technology is evaluated in this study using a Monroe Slurry Maker.
Colson. S., Peabody, D. from Maine DOT, "Evaluation of the Monroe Slurry Maker"
http://www.maine.gov/mdot/tr/documents/pdf/report0905f.pdf

Sharrock, M. Ohio Department of Transportation, "Zero velocity and salt brine: One state garage's experience"
http://www.apwa.net/Resources/Reporter/Articles/2002/10/Zero-velocity-and-salt-brine-One-state-garages-experience

Microsoft touts it's Windows embedded system in the golden ice project, which is an automated Giletta spreader.
http://www.microsoft.com/Presspass/emea/presscentre/pressreleases/december2011/12-13GoldenIceProject.mspx

Global Positioning System–Controlled Salt Spreading , From Idea to Implementation, by Freddy Knudsen and Bo Sommer from the Danish Road Directorate in the proceedings from the Seventh International
Symposium on Snow Removal and Ice Control Technology, June 16–19, 2008
http://onlinepubs.trb.org/onlinepubs/circulars/ec126.pdf

From Vaisalla, here is an overview of an early AVL semi-automated spreader system in use in Franklin County, OH.
http://www.vaisala.com/Vaisala%20Documents/Success%20Stories/RDS_Franklin%20County%20COMBAT_Surface%20Patrol.pdf

The Society of Automobile Engineers has produced recommended practices for temperature sensors. This SAE Aerospace Recommended Practice (ARP) covers the requirements for a combined Mobile Digital Infrared Pavement Surface, Ambient Air, and Dew Point Temperature Sensing System (referred to as the system). The system monitors real-time surface, air and dew point temperatures.
http://standards.sae.org/arp5623/

The Missouri DOT has researched a mirror mounted pavement temperature sensor.
http://library.modot.mo.gov/RDT/reports/TA97010/RDT99007.pdf

New research from Norway about hot water and sand/salt mixtures.
http://www.clearroads.org/downloads/tsrsnowremovcoldtemps.pdf

A study using a Cirus Controls automated spreader investigating savings due to automating spread rates: "Spreader Control Units with GPS Tracking" by Paul Wittau, Zach Zaranko, Greg Annis, University of Iowa

This study measures the accuracy of a salt measuring device, the SOBO-20 that measures salt concentration on pavement.
http://docs.trb.org/prp/13-2606.pdf

Salt on pavement measuring device prototype from 2002 that uses the spray from the tires.
http://www.uvm.edu/~transctr/pdf/netc/netcr17_97-1.pdf

C. Comparison Studies:

CTC and Associates LLC, "Material Spreader Use in Winter Maintenance Operations: A Survey of State Practice". (2010) In this Clearroads' study the practices of the state of Wisconsin were surveyed. Interesting results include; half of the state uses tailgate spreaders and half use V-box spreaders, and almost all of the agencies (98 percent) use spinners. Other delivery mechanisms used by respondents include dual spinners (45 percent), homemade chutes (39 percent), zero velocity spreaders (39 percent) and modified spinners (31 percent).
http://wisdotresearch.wi.gov/wp-content/uploads/tsrmaterialspreaders1.pdf

Keltner, B., Anamosa Highway Maintenance Supervisor, Iowa DOT, "Spreaders & Granular Deicing" In this study chutes, spinners and zero velocity deliveries are compared.
http://www.iowadot.gov/maintenance/pdf/3SpreadersDeicing.pdf

Ulrich, M. Minnesota DOT, Snow & Ice Chemical Scatter Test Research; (2010) This study from the Minnesota DOT tested 5 different delivery systems.
http://www.dot.state.mn.us/d3/business.html

Croze, T. "MDOT 2012 SALT BOUNCE & SCATTER STUDY" This study from the Michigan DOT investigates the problem of keeping the salt on the road and has consistent results with the Ulrich study above.
http://www.michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf

Nantung, T. E., INDOT Research Division, "Evaluation of Zero Velocity Deicer Spreader and Salt Spreader Protocol". (2001) In this study the author says, "Based on the tests, the Zero Velocity Systems will give excellent performance with a large number of cost savings due to the accurate placement of salt particles on the roadway. However, on the slower truck speed, a modified system such as the Y system or Muncie system, can

give a satisfactory result as well."
http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1566&context=jtrp

Bo Sommer authored this Danish study done in 2010 is the best published study on the accuracy of GPS "record a route" type spreaders. Four manufacturers products were tested; Nido, Falköping, Küpper-Weisser and Epoke.
http://www.nvfnorden.org/lisalib/getfile.aspx?itemid=4593

D. Agricultural Technologies:

From the Government of New Brunswick,
http://www.gnb.ca/0173/30/CalibrationFertilizer.pdf

From the The Samuel Roberts Noble Foundation, Inc.
http://www.noble.org/global/ag/pasture/drills-spreaders-carriers/drills-fertilizers-carriers.pdf

From the University of Georgia, Calibration of Bulk Dry Fertilizer Applicators,
http://www.caes.uga.edu/Publications/pubDetail.cfm?pk_ID=6393

Trimble, Inc. is a leader in the "precision agriculture" field and they have good information on their website, for example:
http://trl.trimble.com/docushare/dsweb/Get/Document-482338/

Pfost and Casady, Their Precision Agriculutre: Global Positioning System (GPS) products are summarized:
https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/9468/PrecisionAgricultureGPS.pdf?sequence=3

Straight Talk from Trimble:
http://trl.trimble.com/docushare/dsweb/Get/Document-224052/StraightTalk_Spring%202005.pdf

E. Environmental Concerns:

Best Management Practices to Protect Water Quality from Government of British Columbia,
http://www.env.gov.bc.ca/wat/wq/bmps/roadsalt.html

Keseley, S. IAPPO, "From Icy Roads to Salty Waters, Road Salt Effects on our Environment" This is an excellent report that details many concerns and has many suggestions for improving the situation.
http://www.iappo.org/pdf/IAPPO07_RoadSalt.pdf

This website by the New Hampshire Department of Environmental Services entitled: "Environmental, Health and Economic Impacts of Road Salt" is an excellent overview of the problem of road salt in the environment.
http://des.nh.gov/organization/divisions/water/wmb/was/salt-reduction-initiative/impacts.htm

The Salt Institute details environmental impact in this report, "Salt and the Natural Environment".
http://www.saltinstitute.org/Issues-in-focus/Road-salt/Road-salt-our-environment/Natural-environment

The Cary Institute's Special Report "Road Salt Moving Toward the Solution" has an interesting cost benefit analysis of the problem.
http://www.caryinstitute.org/sites/default/files/public/reprints/report_road_salt_2010.pdf

The DuPage River Salt Creek Workshop has a webpage entitled, "Chlorides and Winter Anti-Icing". It is an extensive study of the environmental impact of road salt on the DuPage River in Northeast Illinios.
http://www.drscw.org/winter.html

This is a report on "Strategic Planning for Reduced Salt Usage", which was prepared by Parsons Brinckerhoff for The National Cooperative Highway Research Program Transportation Research Council National Research Council in 2007.
http://onlinepubs.trb.org/onlinepubs/archive/notesdocs/25-25(29)_fr.pdf

Maine DOT published an overview of their winter maintenance procedures in 2010 where environmental concerns about salt use are covered.
http://www.mcapwa.org/MCSRoadSalt.pdf

Environmental concerns about salt spreading are covered in great detail here in a report prepared for the National Cooperative Highway Research Program.
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=13&ved=0CDoQFjACOAo&url=http%3A%2F%2Fenvironment.transportation.org%2Fdocuments%2Fnchrp25_25_files%2Fnchrp_chapter_8.doc&ei=zGyrUdwTgs_LAbOdgfAE&usg=AFQjCNEucxto7SIYRvvPyS2zfqNYPCiFEw&sig2=VMJ4KmeghjRFil4VikZlOQ

This as yet unpublished study presented at the "8th International Symposium on Snow Removal and Ice Control Technology" has three main focus areas 1) Environmental effects of road salt, 2) Techniques to reduce salt consumption, and 3) Salting policy.

Lysbakken, K., Sivertsen, A., Rosland, P. and Arntsen, J. with the Salt SMART Research Program have a study entitled, "Optimizing the Salt Use in Norway" . http://onlinepubs.trb.org/onlinepubs/Conferences/2012/Winter/paperlisting.pdf

Usually environmental concerns focus on ecosystems and wildlife but here is a video about Pennsylvania DOT and their new spreaders that protect cars. http://www.wpxi.com/videos/news/new-penndot-salt-spreaders-cause-less-damage-to/vDC7j/

E. Manufacturers:

Domestic Spreaders:

Flink
http://www.flinkco.com/

Warren
http://www.spreaders.com/aboutus.html

Snowex
http://www.snowexproducts.com/

Saltdogg
http://www.saltdogg.com/

Gledhill
http://www.gledhillonline.com/spreaders.html

Meyer
http://www.meyerproducts.com/

Highway Equipment Company
http://www.highwayequipment.com/

Swenson
http://www.swensonproducts.com/

Monroe
www.monroetruck.com

Henderson
http://www.henderson-mfg.com/

Tyler Ice
https://www.wausau-everest.com/brands/tyler-ice

Domestic Controllers and Accessories:

Force America
http://www.foreamerica.com/

Cirus Controls
http://www.ciruscontrols.com/

Vaisala
http://www.vaisala.com/en/products/surfacesensors/Pages/default.aspx

Certified Power
http://www.certifiedpower.com/

International Spreaders:

AEBI Schmidt (Germany)
http://www.aebi-schmidt.com/en/products/de-icing

Giletta (Italian)
http://www.giletta.com/

Epoke (Canada)
http://www.scarab-epoke.co.uk/eposat.html

Nido (Denmark)
http://www.svenningsens.dk/

Falkoping (Sweden)
www.friggeraker.se

Küpper-Weisser (Germany)
http://www.kuepper-weisser.de

Bosch-Rexroad (Canada)
http://www.boschrexroth.ca/

Teconer Oy (Finland)
http://www.teconer.fi/

Romaquip (Ireland)
http://www.romaquip.com/

CIMLINEYA (China)
http://e-sunhi.en.alibaba.com/
spreaders here:
http://e-sunhi.en.alibaba.com/product/510115165-213053601/Self_powered_hopper_spreader_CLYR_600.html

F. Videos cataloged with Youtube.com
These videos illustrate various aspects of salt spreaders.
MnDOTs
http://www.youtube.com/watch?v=KlWlqdCKoOY

GOLDEN-ICE Project: advanced concepts in salt spreading control and road safety
http://www.youtube.com/watch?v=8yRjYa15iQg

Swenson Electric V-Box Salt Spreader
http://www.youtube.com/watch?v=SKnPhYOm8F4

Romaquip Products:
http://www.youtube.com/watch?v=A6Xtg-bAkWk

Henderson Products: “Salt Spreader with No Central Hydraulics”
http://www.youtube.com/watch?v=5GC3r8FEs60

Henderson First Response Demo (Casper's Truck Equipment)
http://www.youtube.com/watch?v=-fMR9ByPN4c

SAND_SALT_SREADER_CALIBRATION with Paul Brown
http://www.youtube.com/watch?v=kzTIOG3MxNw

Winter Operations – installation and calibration of spreader
http://www.youtube.com/watch?v=fECdlZ_XDbc

Schmidt Stratos - installation
http://www.youtube.com/watch?v=bDiSU_hT9oI

Schmidt Stratos Spreader
http://www.youtube.com/watch?v=xI53F_YsM1Y

Rasco Snow Plough - Rasco Salt Spreader.mp4
http://www.youtube.com/watch?v=r2QLpTnjQzg

Minnesota Department of Transportation: Clear Roads Project – Field testing of de-icing chemicals.
Short version
http://www.youtube.com/watch?v=3kWmukTHphU
Longer version
http://www.youtube.com/watch?v=cIPTRCXRBDM

MnDOT's video channel
http://www.youtube.com/user/rfilipczak?feature=watch

Mn/DOT Winter Maintenance Chemical & Application Research
http://www.youtube.com/watch?v=KlWlqdCKoOY

Just Heavy Equipment #23 - Spreading Salt, Day in the life of a salt spreader,
http://www.youtube.com/watch?v=LXPKH_iPi5w

Falkoping_LB1000_spreader.wmv
http://www.youtube.com/watch?v=RWjBTwe3fZc

Pennsylvania DOT's new spreaders
http://www.wpxi.com/videos/news/new-penndot-salt-spreaders-cause-less-damage-to/vDC7j/

Attachment 2: SURVEY ANALYSIS

Attachment 2: SURVEY ANALYSIS

I. Executive Summary

This is a report analyzing the data received from a survey distributed to professional snow fighters inquiring about their salt spreaders and salt spreading practices. It is the second step in a four-step process comparing material distribution systems for winter maintenance. The project produced four reports: a literature search, a survey analysis (this report), a catalog of different systems and a plan for testing/comparing these types of systems. The survey, analysis and this report were carried out according to the following plan:

- After the literature search, a survey was prepared.
- The survey was tested first and then sent out to snow fighting professionals.
- The data was gathered and analyzed, and this report was written.
- Along with the survey, photos of different systems were gathered for a catalog.

The survey generated 112 responses from snow & ice removal experts, representing many state, county and municipal governments and a few foreign countries.

Many different types of spreading systems (8 different manufacturers and a few homemade systems) were represented in the survey. All were systems that delivered granular salt with and without pre-wetting (liquid applications were outside the scope of this study). Particular attention was paid to modifications made by departments of transportation that improved performance. The two most common modifications were using some form of pre-wetting of the salt and/or modifying (usually lowering) the spinner or chute to minimize bounce and scatter.

A number of different performance parameters were investigated in the survey under the broad categories of effectiveness, costs and environment. Most respondents have confidence in the effectiveness of their spreader systems, but many thought their system could be more effective by using pre-storm treatments, some suggested the use of liquids for this purpose. Effectiveness was found to depend on many factors including: the level of experience of the driver, the speed of the truck, and whether the salt was pre-wetted.

Some general conclusions include:

- Many respondents discussed a difference between two types of systems. One with high initial costs and low long-term maintenance costs and/or better performance. And the other with a lower initial cost, but higher maintenance costs and/or lower performance. Are the higher initial costs of some systems justified by better performance or by lower maintenance costs down the road?

- Many respondents wanted to find better ways to take advantage of the usage data generated from GPS systems or other on-board sensors and data loggers to lower costs and improve level of service.
- Environmental concerns were very important to respondents.
- There were many examples of how to tackle the problem of bounce and scatter, from industry produced products like zero velocity spreaders to homemade systems like added flaps, cages and lower salt release heights.

The survey questions (Appendix 1 of this attachment), and a list of respondents (Appendix 2 of this attachment) are included below.

II. Introduction

There are dozens of different types of solid material distribution systems used in winter maintenance such as chutes, spinners, zero velocity, augers, etc. These systems have a wide range of cost and effectiveness. Some agencies use commercially available systems and others combine commercially available products with attachments made of materials available at the maintenance garage. Agencies do not know which of these systems are most effective nor do they have a way to determine which type is best suited to their agency's needs. The results produced in this study are meant to be an aid in this research process for these professionals.

The goal of this project is to identify as many solid material distribution systems as possible and develop a plan for field-testing them. Systems with pre-wetting capabilities are included in the study, although equipment for slurries or direct liquid applications is not included in the scope of this project. This identification process will produce:

- A literature search report and bibliography
- A report on a survey of salt spreading professionals (this report)
- A catalog of photos of different salt spreading equipment
- A prognosis for field testing these different spreading systems

The goal of this survey report is to summarize the results of a survey sent out to road maintenance professionals inquiring about the solid material distribution systems they use for winter maintenance. This survey was distributed and responded to between May 2013 and March of 2014.

This survey report is divided into three sections, the survey instrument, the variety of different systems in use by respondents and the performance parameters that are useful for comparison. The survey section consists of a description of the survey instrument and an analysis of who took the survey. The variety of different systems section shows the breadth of different systems in use, how they operate and how they have been upgraded or modified. The performance parameters section is organized to help the professional determine what features are most important for their application. The parameters are divided into three broad categories; effectiveness, costs, and environmental impact. Two appendices are included; the survey instrument and a list of respondents.

III. The Survey

A. The survey instrument. The survey questions can be found in Appendix 1. It has six sections:

- Snow fighter information
- Information about spread controller systems that snow fighters employ
- System functionality
- Effectiveness of the system
- Systems costs
- Final remarks and photos

The survey was pre-tested on a small group to get feedback and then distributed. Photos to be included in the catalog were requested as part of the survey. Some photos were sent in this fashion but it was found that more were sent through email and a via cloud storage vehicles (like Dropbox) than through the survey. This may have been because the facility for sending photos through the survey was time consuming compared to email or cloud techniques.

B. Survey implementation. The survey was tested on a small sample set of likely respondents before it was sent out to the Clear Roads general distribution list and revised as needed. The survey was disseminated on the Iowa State snow and ice listserv and the Clear Roads email database. Selected individuals and organizations were invited to take the survey by telephone and email. It was available as a link online, as a hard copy, and as an email attachment.

C. Spectrum of respondents. 112 professionals completed the survey. These professionals provided information on 170 different spreader systems. The survey was available to be responded to multiple times by a single individual to represent more than one spreader system in use by their agency or organization. The survey was taken by a broad range of participants representing 27 state governments, 40 county and city governments, 3 from the federal government and 5 international professionals.

IV. Types of Systems

A. What types of spreaders and controllers are being used?

1. What spreader and/or controller model do you use?
There were many different spreading systems represented in the survey. About half of the respondents use or supervise the use of more than one type of spreader. The following sample response reply was common; "My comments are related to Flink. We use Swenson, Monroe, and Warren tailgates spreaders as well. We also use Hopper and Slurry grinders of various manufacturers." Figures 1 and 2 provide an idea of which systems are used more frequently by the survey participants.

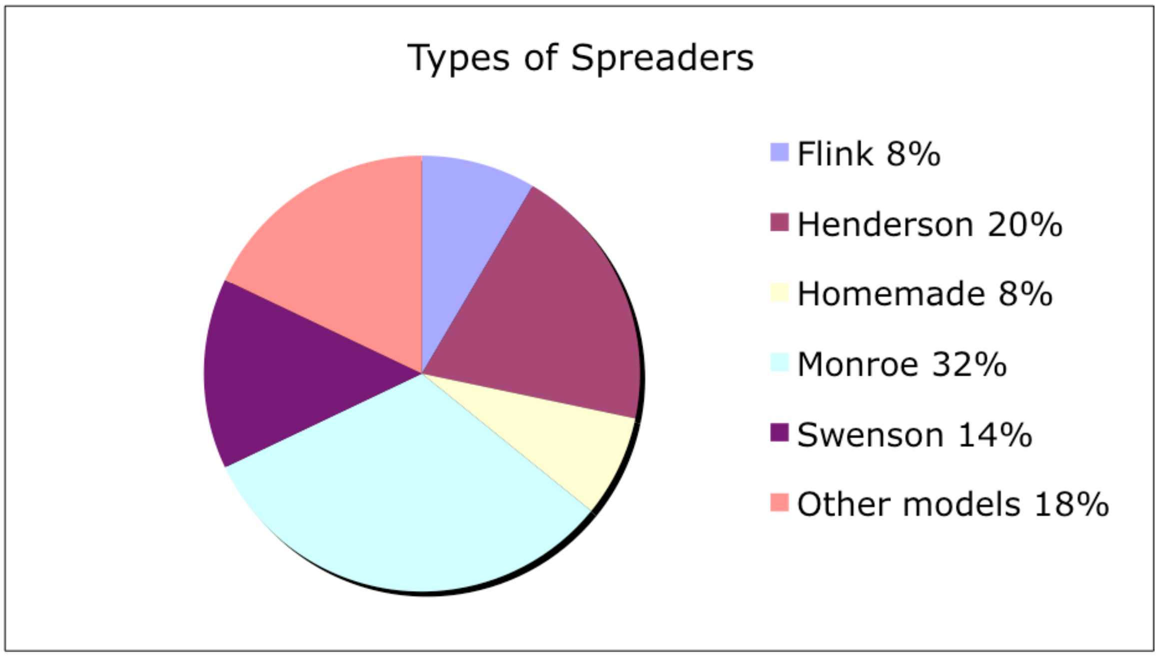

Figure 1: Manufacturers of the spreading systems represented in the surveys.

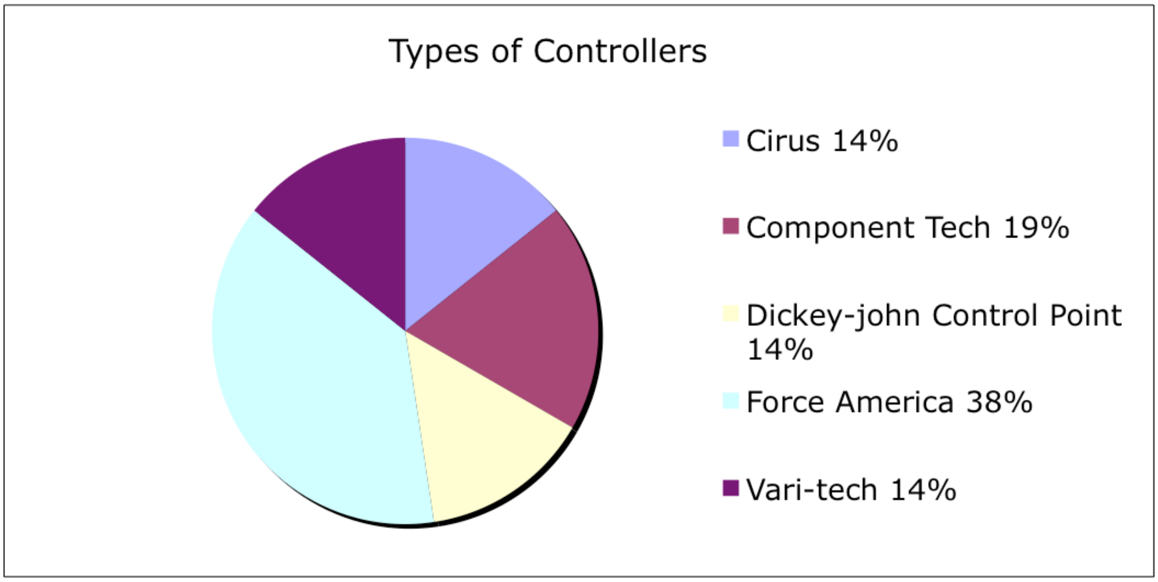

Figure 2: Summary of manufacturers of controllers used (in addition to the ones provided by the spreader manufacturers).

2. How is the spreader powered?

Not surprisingly, the vast majority of the units were hydraulically powered (94%) of that 94%, 14% said the hydraulic power was used in combination with another type of power, usually electric power.

3. What is the spreader location on the truck?

Most spreaders are located on the back of the truck as indicated in Table 1.

Location	Percent
Back	88%
Side	9%
Front	3%

Table 1: Summary of results for the spreading location on the truck

Two other respondents that have homemade side-delivery systems replied,

- "The distribution system is in an enclosed compartment between the cab and the box, elevated above and outside the frame rail on the driver's side."
- "Homemade-front dump driver side distribution system which allows us to distribute the salt behind the driver side and in front of the rear wheel, which helps with the traction, as well as seeing the material being distributed."

B. Delivery of chemicals

1. In what form is your salt delivered to the road?

The survey found many different responses to this question. One of the survey questions was, “If your chemical spreader system has some other unique features, take a minute now to describe them.” The following are some interesting responses:

- “We use a custom fabricated stainless auger we helped design to deliver salt brine or other chemical to center of auger under pressure to saturate the salt.”
- “We use the Rexroth 440RC chemical material distribution system which is a computer controlled solid material spreader which incorporates liquid application as well.”
- “ground speed built in, uses a slave wheel for power, equipped with pre-wet and GPS capability, utilizes a belt instead of a chain drag to convey material to the spinner, has integrated legs to facilitate loading into truck without special cranes or hoists.”
- “Heated pre-wet is our next adventure. I would like to use the equipment’s exhaust to heat the liquid prior to application to the granular material. I believe from initial testing that this will reduce bounce and prove invaluable when it comes to compacted snow or ice. Plus it’s FREE!”
- “I have also used a load monitor for 8 years and I think it makes it a perfect snow fighting unit!”

Use of pre-wetting systems is wide spread as indicated in Figure 3.

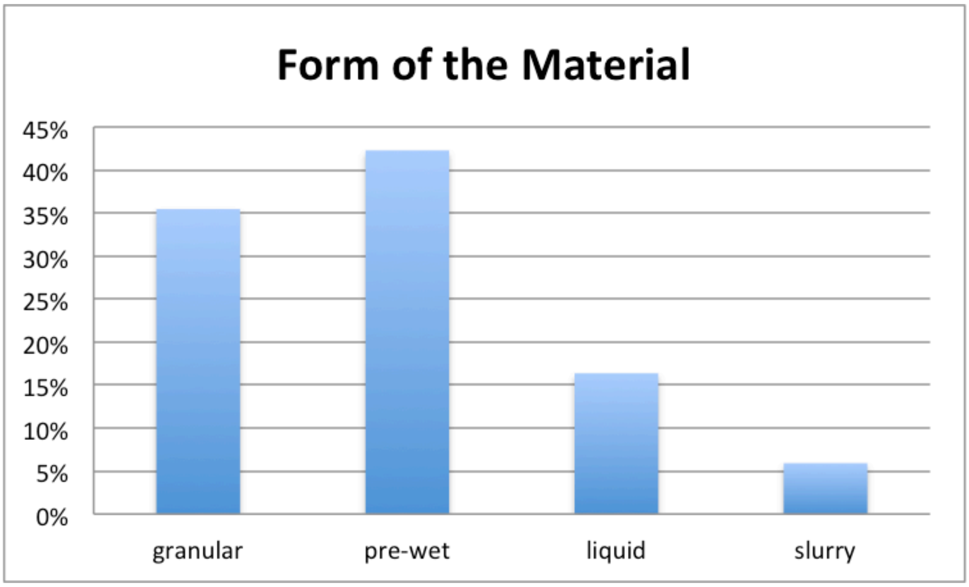

Figure 3: Summary of the results from the question, "In what form is the chemical/material when distributed by the system on the road surface during snow and ice removal procedures?"

Pre-wetting systems

Pre-wetting the salt has been done since the 1960s and has some well studied benefits. The advantages include:

- Reduced bounce and scatter (Savings of up to 30%).
- Reduced melting time.
- Better salt penetration into ice and snow pack.
- Fewer chemicals used.

In our survey, 42% of the systems mentioned have pre-wetting capability. One respondent replied, "we attempt to pre-wet, but given the time frame, manpower, and outsourcing to contractor constraints, it is rarely utilized."

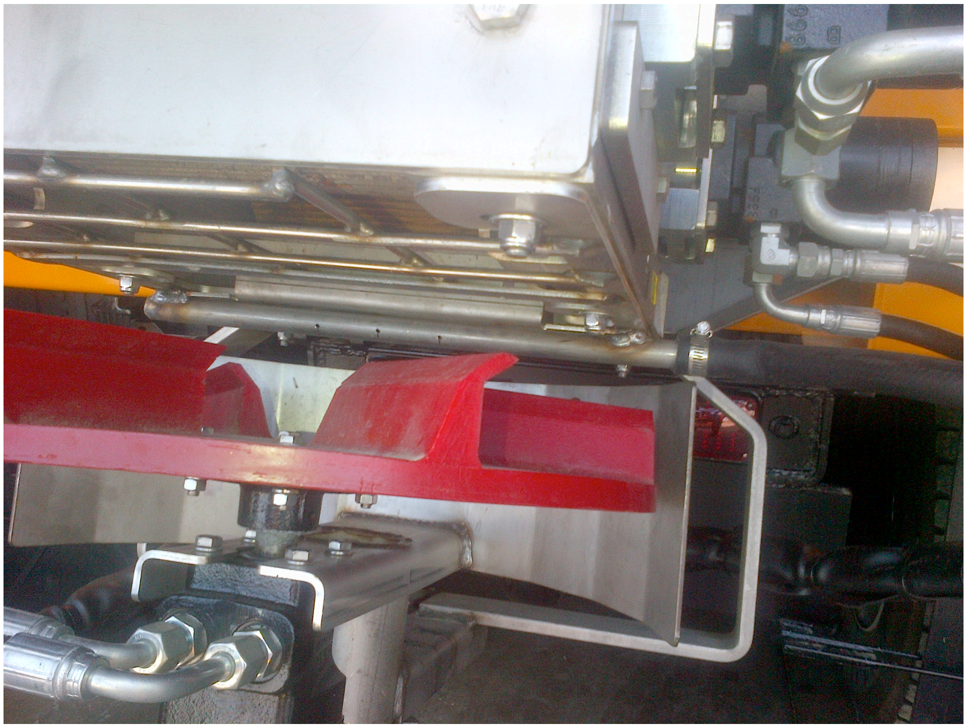

Figure 6: Spinner with pre-wetting nozzles directed over the spinner. See the catalog for many more examples of pre-wetting systems.

Another comment about modifying pre-wetting systems was, “Removed pre wet system from tunnel and placed on the outside of tunnel to eliminate bridging in tunnel.”

2. How is the spread rate controlled?

Most of the respondents use a ground speed closed-loop type of automation with their spreaders as illustrated in figure 4.

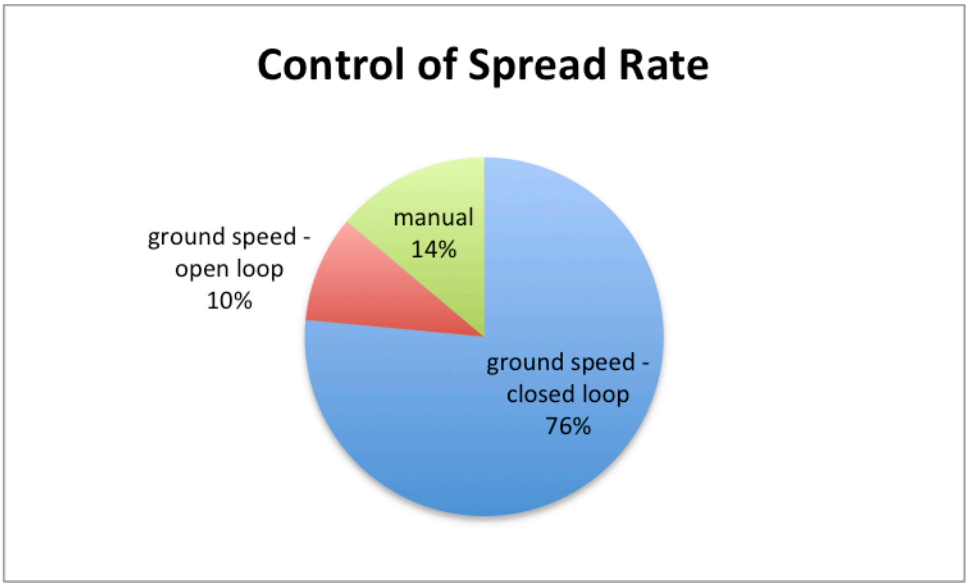

Figure 4: How is the spread rate controlled onboard the truck?

3. At what speed do you run your trucks?

Figure 5 sums up the responses to the question: "What is your typical operating speed for distribution (mph)?"

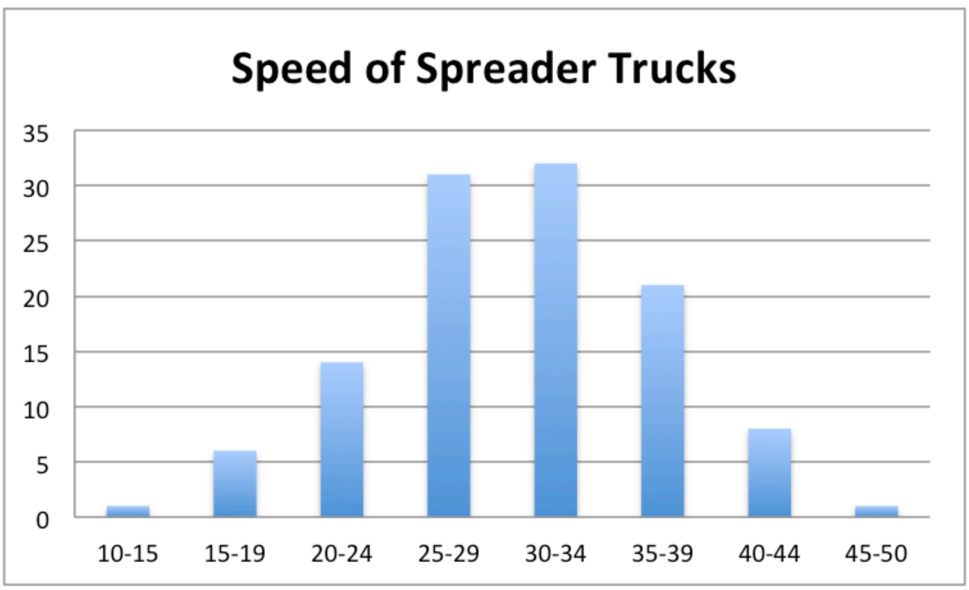

Figure 5: Typical truck speed during distribution.

4. How often do you calibrate your spreader?

83% of respondents calibrate their spreaders once a year. 12% more than once a year and 5% did not know how often it is calibrated.

C. Modifications to the Standard Setup (chute/spinner heights):

There are many types of modifications to the standard solid salt spreader. Modifications can be made for many reasons like reducing bounce and scatter, saving costs in man-hours or materials used, improving response time, etc.

When asked in the survey "Do you retro-fit systems to lower the chute height?" 22% of respondents said they did. The respondent claiming the lowest chute height explains, "The chute goes down to within a few inches of the road and rubber belting goes the rest of the way to lay the salt on the road." Another one replied, "There are several homemade designs. Most have the goal of keeping the salt in a very narrow strip, usually on the driver's wheel path. Some do this by using rubber flaps to try to pin the material down or keep it from bouncing. Others just try to funnel the material into a tight windrow." The following is a list of ways respondents lower the chute/spinner height to minimize bounce and scatter.

Lower spinner/chute height

- Change the mounting height on the bumper.
- Lower the spreader with brackets.
- Lengthen the spinner mounting bracket.
- Weld the chute height to 3.5 inches.
- Use a piece of 8" PVC pipe.
- We use a spinner with cutouts to drop the salt on a chute.
- Install a chute below the spinner.
- Use plastic boot or rubber mud flap or traffic cone.
- Fabricate a longer chute to bypass the spinner for a centerline drop.
- Install flaps to reduce bounce and scatter.
- Adjust the placement of the plastic liner.
- Take off the bottom door.
- Fold a mud flap into a U-Shape chute.
- Use a sander skirt to keep the salt in a confined area.

The following plot shows the height of the chute/spinner for all respondents. Notice the most common height is 18 inches the range of heights is from 1 inch to 58 inches.

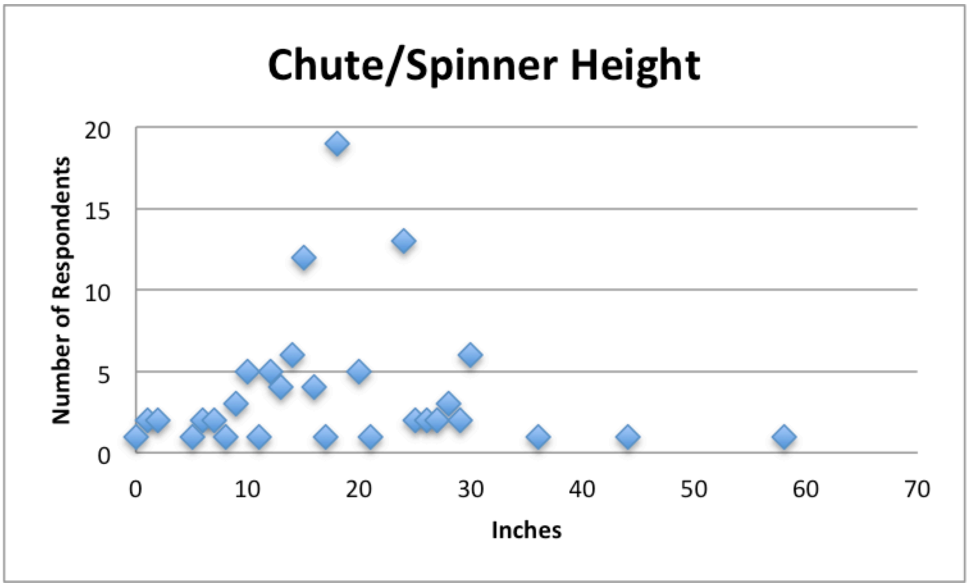

Figure 7: A plot of number of respondents versus inches shows that the most probable and average chute/spinner height is about 18 inches.

3. Some other interesting modifications to the spinner/chute are as follows:

- The chute is attached to a regular spreader motor and you are able to oscillate it or "point" it in the direction you want to spread your salt. It is also designed with a wider mouth or top of the chute and it narrows down to the road to give it a funnel look.
- Throw away the factory spinner and mount a paddle wheel.
- We have installed boom buster nozzle on one side to spray ditches to slow drifting.
- Some of our spreaders have an added 3rd drop chute. Most have added a center spinner.
- Iowa Spinner has sides, which block the broadcasted material and make it fall directly beneath the spinner.
- Many of our plate spinners have a DOT-designed chute, which can bypass the spinner for tighter material distribution.

V. Performance Parameters

One respondent replied, "Efficiency and effectiveness is greatly related to the amount of outsourcing/internal employees you have to use. The greater the dependence on outside contractors, the less ability you have to manage the salt usage and efficiency of the spreader itself." A state government snowfighter with a Schmidt system replied, "higher initial cost but excellent reliability." Another state government person with an Epoke system replied "Would like to have more of these. They are extremely efficient."

A. Effectiveness. In most road maintenance garages roadway safety is measured as a level of service. How clean and dry is the road surface and how quickly can this happen. Is the system flexible and responsive enough to handle different storm conditions? How effective is the system for putting the right chemicals on the road at the right times. See figures 8 and 9.

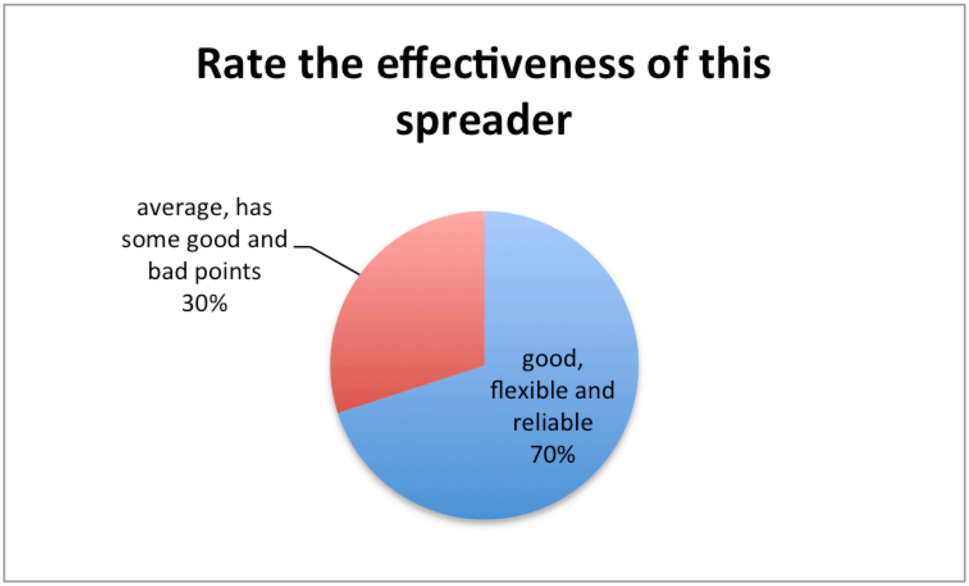

Figure 8: Overall effectiveness of Survey participants' spreader

The effectiveness of the spreaders was queried in a few different ways. Figures 8 shows the response to overall effectiveness and Figure 9 shows the response to effectiveness in particular storm situations.

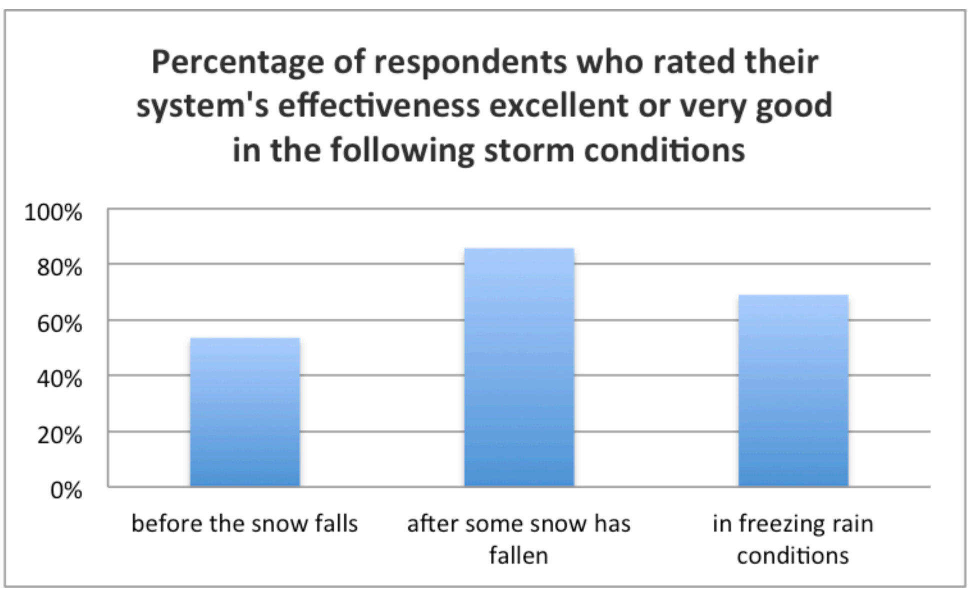

Figure 9: Effectiveness in different storm conditions for the granular and pre-wet systems of this study.

A representative comment from a respondent is: "Typically only pretreat with liquid equipment. Once snow begins, solely apply dry and pre-wet materials." There was a general consensus that the granular and pre-wet delivery was best after the snow had fallen and liquids or slurries were better before the snow had fallen (see figure 9).

B. Costs. When asked, "Was the purchase/making of this spreader system a good investment?", 99% said "yes, best value" or it was the "best available". In the comments that followed it was evident that respondents felt that there is a trade off between short-term savings on the price of the system and long-term savings on flexibility, upgradeability, material costs and maintenance. The following are representative comments on both sides of this issue.

1. Higher initial costs, long-term benefits: A few interesting responses are provided below.

- "Epoke 3500 has greater flexability in use, easy for operators to control, durable (well made), provides greatest amount of application control in environmentally sensitive areas."
- "The Force America spreader control gives consistent results. Calibration is easy enough for the operators to configure. The local customer service has been exceptional. The spreaders can be included in our AVL/MDSS systems."
- "The Rexroth 440RC closed loop system distributes material in a very efficient manner thus saving finances on material usage."
- "The Monroe Acuplace (zero-velocity) is expensive and has high maintenance cost, but effective for material conservation."

2. Lower initial costs: A few interesting responses are provided below.

- "Monroe and Henderson (Y-Chute) they are economical and have minimal moving parts and breakdowns."
- "Warren Spreader: Vendor chosen by low bid process. System meets our needs, but others would also. We use other brands based on who won contract and they do well also, with a few exceptions."
- "Y -chutes are cheapest and most common in our fleet."

3. Efficiency

Three areas of efficiency were queried in the survey, loading and unloading techniques, efficient use of personnel and maintenance. As shown in figure 10 about 35% of respondents thought improvement could be possible. The procedure most mentioned where improvement would be beneficial was unloading time.

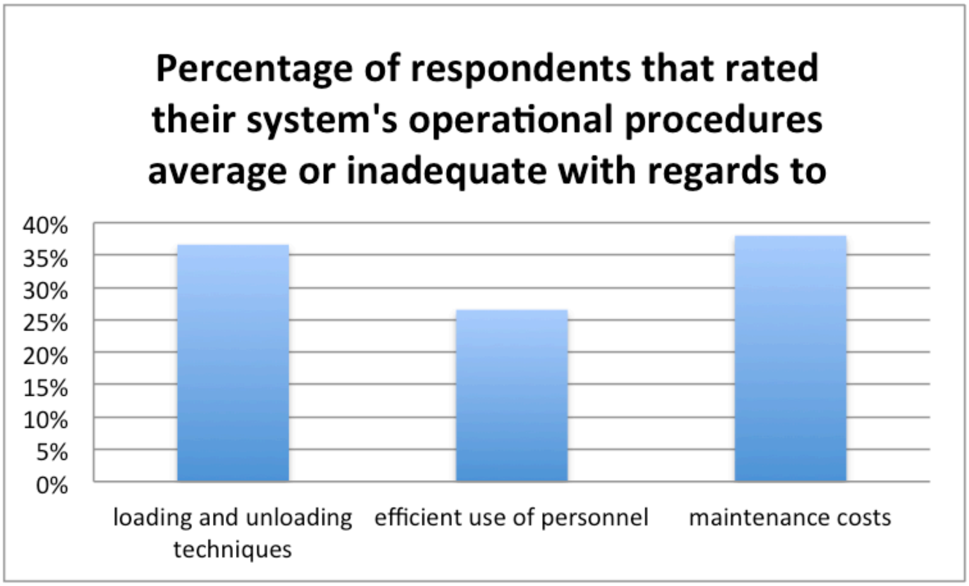

Figure 10: Operational procedures

4. Maintenance and Upgradeability

70 of 112 respondents rated their system's maintenance costs as "excellent" or "very good". 50 of 104 respondents rated their system's upgradeability at "excellent" or "very good". The following are some informative comments from the survey

- North Dakota DOT said, "NDDOT uses one manufacturer. Consistency makes it easier for the mechanics to learn only one system. Force America has good customer service in this area. That is a huge help."
- "Ease of maintenance, cost, and placement accuracy all really depend on what type of spreader we're talking about. Plate spinners are considered the 'old standard' and a lot are still in use although the other ZV, Chute, and experimental designs are considered better. But everything seems to have its trade-offs."

C. Environmental Impact. There was a great deal of concern about environmental issues regarding salt spreading. This section is divided into data usage and accuracy. 74% of the respondents replied "excellent" or "very good" to the query "In environmental terms, how would you rate this systems effective use of chemicals?" (see Figure 12). The majority of respondents feel their environmental efforts are adequate. Two areas where respondents showed interest in improving were in data usage and accuracy (bounce and scatter).

1. Data Usage

Collecting and tracking data from the salt spreaders/controllers has many benefits.

- Resources can be purchased and used more efficiently; reducing costs.
- Protects the environment in that fewer chemicals can be used.
- Provides a more consistent, reproducible and reportable level of service.

The following figure illustrates the response to the query, "Describe how usage data is retrieved from your system."

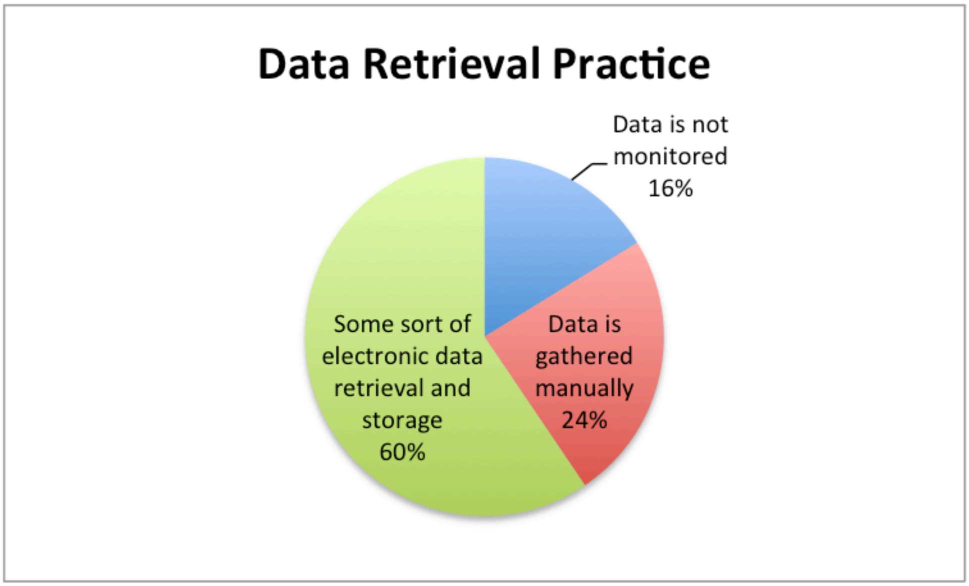

Figure 11: Data Retrieval Practices from spreader controllers

From the comments made this graphic (figure 11) is a bit misleading in that there is much more retrieval (collecting) than there is effective tracking of the data. A study of how the data is actually used would be very interesting. Currently 84% claim some sort of data retrieval but a much smaller percentage claim to use the data effectively. A challenge in the future will be to find more and better ways to track and use this data Figure 12 shows that 45% of respondents replied "average" or "needs improvement" to the query "In environmental terms, how would you rate this system's ability to report use of chemicals?"

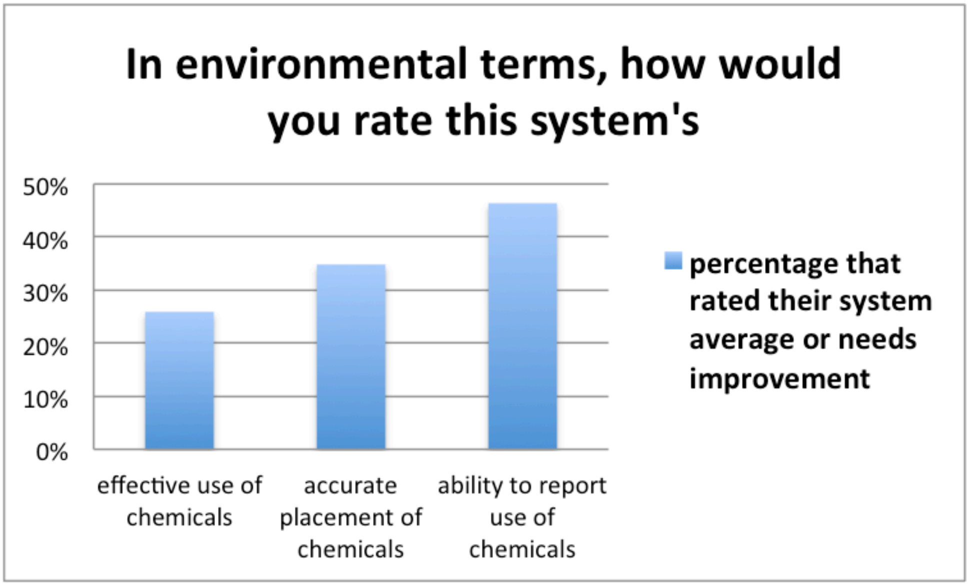

Figure 12: Rating chemical usage.

2. Accuracy

When asked, "Does this system satisfy your requirement for bounce and scatter of the granular material after application to the roadway?"; 80% of respondents answered "yes always" or "most of the time" and 20% replied "fifty percent of the time" or "needs improvement". One respondent replied, "It meets our requirements for bounce and scatter if the operator uses it correctly." Another replied, "Depends on the speed that the vehicle is operated at". This shows there is confidence in this technique but probably room for improvement. As stated earlier 22% of respondents use some retrofit of their chutes or spinners to lower delivery height thus reducing bounce and scatter. Along with lowering the point of release of the chemicals many respondents said, "if pre-wet is not used the rate for bounce increases". The following responses summarize the ideas put forth in the comment part of the answer to this question.

- "We would like to uniformly lower chute heights on all cross conveyors and y chutes. Zero velocity and salt slurry seem to work fine. Using Pre-wet salt also reduces bounce and scatter. "
- "We home built a step cage around the spreader. On this cage is placed rubber material that has a clearance of 4" from the ground. This acts like a big box around the spreader to trap the granular material that bounces. Plus it acts like a crash attenuator (Almost)."
- "The most important reason to obtain a good result (with bounce and scatter) is to keep the right speed."

VI. Conclusion

The techniques used to improve best practices for snow and ice removal are varied and locally driven by geography, weather, equipment availability, and cost. Snowfighter professionals make the most out of the resources they have regarding equipment, personnel, configuration, budget, and materials. This is shown by the variety of configurations and modifications illustrated in the tables and figures.

Many different types of spreading systems were represented in the survey. Particular attention was paid to modifications made by departments of transportation that improved performance. The two most common modifications were using some form of pre-wetting of the salt and/or modifying (usually lowering) the spinner or chute to minimize bounce and scatter.

A number of different performance parameters were investigated in the survey under the broad categories of effectiveness, costs and environment. Most respondents have confidence in the effectiveness of their spreader systems, but many thought their system was ineffective before the snow falls. Effectiveness was found to depend on many factors including: the level of experience of the driver, the speed of the truck, and whether the salt was pre-wetted.

Many respondents recognized a difference between systems with higher initial costs and lower long-term costs and/or better performance, versus low initial costs. Many respondents wanted to find better ways to take advantage of the usage data generated to lower costs and improve level of service.

Environmental concerns were very important to respondents. There were many examples of how to tackle the problem of bounce and scatter, with industry produced products like zero velocity spreaders or homemade systems like added flaps, cages and lower salt release heights.

One respondent requested, “Please share the results of this survey with us. I am on a State (Maine) committee looking at winter de-icing chemical options. Thanks”

VII. Appendix 1: The survey instrument

Comparison of Material Distribution Systems for Winter Maintenance – Phase I

Snowfighter Information

Please enter the following information about your organization

1. Your Name_______________________________

2. Your Email Address_______________________________

3. Your Organization________________________________

4. What type of agency are you representing for this survey?
___Federal government
___State government
___County government
___City/town government
___Out-source contractor working for local government
___Other: _____________________

5. Your Position_______________________________

6. How many different types of chemical spreader systems does your agency use in the winter time for snow and ice removal?
___1
___2
___3
___4
___5
___Other (please specify)_____

Information about the Spread Controller Systems that Snowfighters Employ

Please answer the following questions with one of your spreader distribution system(s) in mind. If you use more than one system, we ask that you take the survey once for each system that you use.

7. What is the manufacturer and model of your spreader system? Write "homemade" if yours is not a commercially available system. If you use more than one system, enter here the model of the one you are using to fill out this survey.

8. How is your spread control system powered?
___electric
___hydraulic
___fuel
___pneumatic
___combination
___don't know
___other (please specify)__________________

9. Where is the distribution system located on the truck?
___front
___side
___back

10. Do you retro-fit systems to lower chute height? If so how do you do it?
____

11. If your chemical spreader system has some other unique features, take a minute now to describe them.
____

12. Rate the effectiveness of this spreader system.
___Good, flexible and reliable
___Average, has some good points and bad
___Bad, don't recommend this combination
___If appropriate, explain____

System Functionality

Please enter the following information about you spread controller system functionality.

13. In what form is the chemical/material when distributed by the system on the road surface during snow and ice removal procedures?
___granular
___pre-wet
___liquid
___slurry
___other (please specify)________________________

14. At what height (inches) above the road surface is the chemical/material released?
___

15. What type of methodology does this system use to control the spread rate?
___ground speed - closed loop
___ground speed - open loop
___manual
Other (please specify)

16. What is your typical operating speed for distribution (mph)?
____

17. How often are your spreaders calibrated?
____

18. Describe how usage data is retrieved from you system.
____

Effectiveness of the System

Please enter the following information about your system's effectiveness.

19. Does this system satisfy your requirement for bounce and scatter of the granular material after application to the roadway.
___Always
___Most of the time
___Half the time
___Needs to improve
Further comments ____________________________

20. How would you rate the spread controller system's operational procedures with regards to

	Excellent	Very Good	Average	Needs to improve
loading & unloading techniques				
efficient use of man-power				
flexibility to change with the weather				

Other (please specify)_____________________________

21. Rate this spread controller system's effectiveness in the following storm conditions

	Excellent	Very Good	Useful	Not useful
All winter storm conditions				
Before the snow falls				
After some snow has fallen				
In freezing rain conditions				

Other (please specify)_______________________________

System Costs

Please enter the following information about your spreader system's effectiveness.

22. Was the purchase/making of this spread controller system a good investment?
___Yes; best value
___Best available
___No; don't recommend
___Why?______________________________

23. How would you rate this system's

	Excellent	Very Good	Average	Needs to improve
Maintenance costs				
Upgradeability				

24. In environmental terms, how would you rate this spread controller system's

	Excellent	Very Good	Average	Needs to improve
effective use of chemicals				
accurate placement of chemicals				
ability to report use of chemicals				
other environments				

Final Comments and Photos

25. Do you have any final comments or suggestions?
___yes (please explain)_______________________________________
___no

Clear Roads would like pictures of your spreader system. Two photo files can be uploaded below. If you have additional photos or want to upload them at a later time, please email them to: todd@statisticsinc.com
The following are examples of the types of photos to upload.

Upload first photo here___________________________
Text description: make/model, features, capabilities...
____

Upload second photo here________________________
Text description: make/model, features, capabilities...
____

VIII. Appendix 2: The respondents

The following is a list of names of the respondents that included their name. They are listed alphabetically:

Clay Adams, Pete Andera, Phillip Anderle, Thad Ash, Aaron Auer, John Bangart, Brandon Beise, Shawn Bennett, Mike Bohm, David Bowlby, Ray Branstiter, Gregory Brown, Paul Brown, Doug Burke, Brian Burne, Brandon Chandler, Tim Chojnacki, David Cook, Mark Crouch, Tim Cunningham, William Davenport, Bob Dawes, Mark de la O, Jeff DeMuri, Dennis Dickman, Jerry Dostie, Ben Dow, Doug Fortier, Paris Fotos, Thomas Fountain, Randy Franks, David Gerding, Craig Gertsema, Mike Gladu, Brian Glaeser, Greg Goldman, Don Grande, Tina Greenfield
Rick Grunewald, John Haase, Donald Harvey, Dallas Hayes, Gregory Heisel, Brandon Hill, Bill Hills, Bret Hodne, Dennis Hogan, Kevin Holden, Gregory Huffman, David Hundley, Jerry Jagmin, Tom Jean, Paul Johanik, Justun Juelfs, Gus Kabbara, Jerry Kaus, Mike Keichinger, Alan Kies, Jeff Koppa, Chris Landry, Ken Lange, Michael Lashmet, Mark Loxtercamp, Steven Lueken, Dan Lutz,
Richard Marti, Scott McIntyre, Tim McMillan, Monty Mills, John Mounier, Steve Mullenbach, Rick Nelson, Bill Nichols, Kurt Niemann, Emil Norby, Jason Ogle, Jan Ölander, Bryan Olson, Derek Parish, Jon Pauley, Jerry Pich, Jeff Pifer, Matt Pratt, Larry Price, Alastair Probert, Dan Raczkowski, Robin Ringler, Bill Rominske, James Rucker, Kip Rutledge, Jess Sackmann, Daniel Schacher, Dave Schettler, Steve Scholand, Phil Serafino, Don Sirianni, Jim Smith, Matthew Spina, Clifford Spoonemore, Steve Spoor, Carl Stevens, Leigh Stilwell, Michael Sutherland, Jeff Tatkenhorst, Mike Taylor, Jeffrey Tews, Jeff Tice, Toby Toombs, Mike Van Keuren, Roger Vigdal, Janie Vrtiska, Ken Washatko, Jay Wells, Allen Williams, Michael Williams, Steve Williams, Tom Williams, Tim Yamriska

The following are the organizations that the respondents represent. They are listed alphabetically.

Alaska DOT&PF- M&O
Army snow removal
Ashland County Highway Department
Barron county Highway Department
Bayfield County Highway Department
Colorado DOT
City of Augusta Maine Public Works
City of Beloit Wisconsin
City of Cedar Rapids Fleet Services Division
City of Fargo, ND
City of La Vista, NE
City of Milwaukee, WI

City of Mt. Juliet, TN
City of Omaha, NE
City of Overland Park, KS
City of West Des Moines, IA
Colorado DOT
Dane County Highway Department
Delaware DOT
Dodge Co Highway Department
Door County Highway
Eau Claire County Highway Department
Florence County Highway Department
Green county WI
Idaho Transportation Department
Illinois DOT
Iowa DOT
Juneau County Public Works
Kansas DOT
Kentucky Department of Highways
Lafayette County Highway Department
Langlade County Highway Department
Lincoln County Highway Department
Livermore Falls Public Works
Maine DOT
Manitowoc County Highway Department
Marathon County Highway Department
Massachusetts DOT
Maryland DOT State Highway Administration
Michigan DOT
Milwaukee County Highway Department
Minnesota DOT
Missouri DOT
Monroe County Highway Department
Montana DOT
Nevada DOT
Nebraska Dept. of Roads
Nebraska Department of Roads
Nevada DOT
New York State Thruway Authority
New Jersey DOT
North Dakota DOT
New York State DOT
Oconto County Highway Department
Ohio DOT

Oregon DOT
Pennsylvania DOT
Peoria, IL
Pierce County Public Works & Utilities
Polk County Highway Department
Price County Highway Department
Rhode Island DOT
South Carolina DOT
Sheboygan County Transportation Department
Springfield Township Public Works, (Montgomery Co, PA)
St. Croix County Highway Department
Summit County Engineer
Swedish Transport Administration
Sylvania Township
Taylor County Highway Department
Texas DOT
Town of Houlton Maine Public Works
Town of Milford Public Works
Town of Parker, CO
Town of Pownal Public Works Department
Village of Lisle. IL
Virginia Department of Transportation
Walworth County Public Works
Wisconsin DOT
West Virginia DOT
Wyoming DOT
Yworry Innovations

Attachment 3: CATALOG

This document was published separately and is not included in the final report. It's place is held here to indicate the order that these reports were generated and submitted.

Attachment 4: FIELD TEST PLAN & RECOMMENDATIONS

Attachment 4: FIELD TEST PLAN AND RECOMMENDATIONS

I. Executive Summary

The main objective of this study, "*Comparison of Material Distribution Systems for Winter Maintenance – Phase I*" is to identify as many solid material distribution systems as possible and develop a plan for field-testing them. This objective was achieved with four tasks.

- Literature search
- Survey of professionals with analysis
- Photographic catalog of spreader types
- Plan for field-testing these spreader systems

This report, the last task of the project, consists of using the information gathered in the previous reports along with a further literature search to devise recommendations for testing spreading systems. It is divided into three sections: methodology, strategy and budgetary considerations.

The methodology of testing spreading systems is illustrated using examples of questions that the investigator might ask. For example, "Do GPS or ground speed controls provide better coverage on the road surface?". This question is used as an example for determining the number of systems needed to be tested, key elements to consider in this type of test and then a strategy with diagrams for carrying out this test.

Finally a budget of $252K was proposed for a test of 8 systems with some assumptions about agency and vendor cooperation. Highlights of the conclusion are as follows:

1. There is a lack of testing of spreader systems for comparison of type, accuracy, control, and effectiveness.
2. For the actual testing it is important to follow a plan that includes: test preparation, test operation, test execution and test results.
3. Documenting the testing is very important for analysis later and for reproducibility.

I. Introduction

A. General. In the constant challenge of maintaining safe roadways Departments of Transportation are faced with an enormous number of decisions. There are dozens of different types of solid material distribution systems used in winter maintenance such as chutes, spinners, zero velocity, augers, etc. These systems have a wide range of costs and effectiveness. Some agencies use commercially available systems and others create their own systems out of scrap material available at a maintenance garage. Agencies do not know which of these systems is most effective or have a way to determine which type is best suited to their agency's needs.

There is a need to test these different systems for effectiveness, efficiency and cost considerations.

B. Task. The task for this deliverable is as follows: recommend a plan of study for assessing the effectiveness of material distribution systems, using information gathered in Tasks 1-3. Structure a plan for field-testing that includes details on how many different types of systems to test, test methodologies, test location considerations, etc.

C. Purpose. The purposes of this study is to gather methods, collect them into one document, recommend an evaluation or test plan and establish a set of considerations to assess their effectiveness. This was accomplished by collecting information, photographs, and descriptions of proven methods of material distribution techniques at the operator level. Many organizations have found particular modifications, techniques, and combinations of spreader components that improve the control, placement, and distribution of snow and ice removal chemicals from the roadway. Figure 1 provides an illustration of the project understanding.

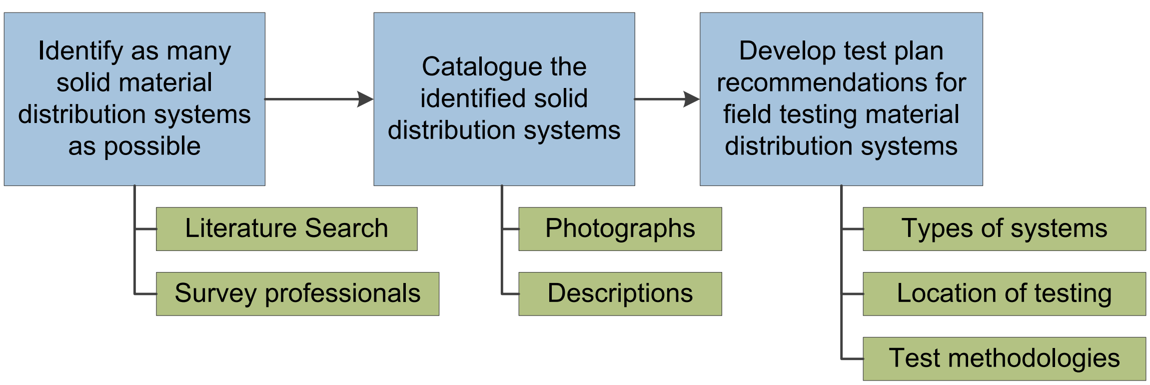

Figure 1: Project Understanding

Some of these procedures are dependent on location, weather, and snowplow or unique to a set of local best practices. These techniques may be of use to other snow fighter professionals.

D. Background. A literature search was done to gather as much pertinent information as possible about different spreader systems currently in operation. Simultaneously with the literature search, a survey of snow fighters about the spreader systems they use. References elicited from this survey were also investigated. The literature search and survey results are contained in two other documents and are published separately.

E. Scope. There are several references that were used to prepare this document (see Appendix 2, References). These references demonstrate significant interest in measuring the effectiveness of material distribution systems. Studies that have been conducted have found mixed results. For example, the Maine DOT study from 1999 (Appendix 2, reference 16) found that:

- Data collected in both field and controlled settings indicate a savings in material is possible when utilizing some form of material metering equipment.
- Testing performed for purposes of material placement using Zero Velocity and Precision Placement systems also shows promise in producing material savings.
- The IHRB report: Field Testing of Abrasive Delivery Systems in Winter Maintenance of 2009 (see Appendix 2, reference 1) found that "The experiments were not able to determine any significant difference in material placement performance between a standard delivery system and a chute based delivery system."
- Maine DOT Technical Report 05-1 from 2005 evaluated a single spreader system and found these results partial from their evaluation: "Four routes saw an increase in average tons per event; four saw a decrease and one remained relatively flat. Route . . . showed the most significant decrease in tons per event."

There are multitudes of snow and ice removal equipment that perform a myriad of material distribution functions. The Clear Roads study: "Material Spreader Use in Winter Maintenance Operations: A Survey of State Practice" for Clear Roads Pooled Fund Study of 2010 has documented the state of the practice for the use of material spreaders in winter maintenance operations in many of the snow belt states. There are a variety of system types including user-made spinners and modified chutes.

II. Methodology

A. Approach. To compare salt spreaders (or any road maintenance equipment) there are two general ways to proceed:

1) Designate a few districts (states, counties or cities) with different spreader systems. Collect data throughout a winter season and compare the data from these districts. Determine what data to collect and what outcomes are important to measure.
2) Collect a few systems (actual spreader trucks) in one place and test them under identical circumstances. Determine what parameters to vary and what outcomes to measure.

Both methods have their strong and weak points. The first approach can be very effective, though with all of the variables in a snow fighting crew and their equipment and the vagaries of the weather it is very difficult to be able to make definitive conclusions.

The focus of this study is essentially the second approach. It has the advantage of controlling some variables and therefore being able to compare systems under the same (or similar) conditions. Studies of this type can be true field tests driving the trucks on the same roads and under the same conditions that are present in winter conditions or they can be run in very controlled conditions on a test track in the summer time. A comparison on a test track has many advantages, as outcomes can be measured carefully and systems can be tested under the same conditions.

B. Number of types of different systems. An important question for the budget and the completeness of any comparison study is, “how many systems do we need to compare?” The first consideration is, “what is the question being asked?” This will be illustrated by examples.

Example 1, Quantity Test: Maybe the simplest of tests for a spreader would be to test the question, “Does a properly calibrated spreader actually deliver the amount of material that it says it does?” Here at least three systems would be needed to say something definitive about this question. If there were a couple of different types of spreaders in question then more systems would be warranted.

Example 2 Bounce and Scatter: There is a great deal of interest in minimizing the bounce and scatter of salt as it hits the road surface. Consider the question, "Does a homemade chute work as well as a zero velocity spreader in keeping the salt on the road?" (see Figure 2). To run a test to determine the answer to this question, two or three different chutes and two or three different zero velocity spreaders would need to be tested. For the best results three of each would be needed to be tested. This gives a total of six different systems that need to be tested for this example.

	
Example: Homemade Chute	Example: Zero Velocity Spreader

Figure 2: Comparison of a chute to a ZVS.

Example 3, Pre-wetting: A big trend in salt spreading is pre-wetting the salt. Consider the question "Does pre-wetting the salt save material or improve melting time?." Since most trucks that have the pre-wetting feature can turn it on and off only three systems may need to be tested. A test can be run with the pre-wetting turned on and another run with the same system with the pre-wetting feature turned off.

Example 4, Tailgate or Hopper: Tailgate spreaders in general are less expensive than the slide in, hopper spreaders. Is this added expense worth it? Therefore a question like, "Which type of spreader tailgate or hopper uses salt most efficiently?" OR "Which type of spreader tailgate or hopper covers the road more evenly?" would be appropriate (see figure 2). Here six systems would be an ideal number to test, three each of tailgate and hopper.

Example Tailgate Spreader	Example V-Box

Figure 3: Example Spreader Types

Example 5, GPS or Ground Speed Control: One of the leading new technologies is controlling the spread rate or pattern using GPS. Does this work better than the ground speed control with an occasional operator adjustment? Therefore questions like, "Does GPS or ground speed controls provide better coverage on the road surface?" OR "What kind of savings in material costs can I expect with a GPS controlled spreader over a ground speed controlled spreader?" Here six systems would be an ideal number to test, three each with GPS control and ground speed control.

Example 6, Chemicals: Different chemicals have different effectiveness depending on temperature and other conditions (they also have different costs). A difficult but very interesting test would be to test the different salts at low temperatures. Here one system may be enough if it could spread the different chemicals in question. But logistically, a different truck for each different chemical would be ideal, so they could be tested at the same time (or location) and under the same conditions.

The number of questions is endless, as is the number of variables that can be tested. There are many with a multiplier of combinations. The following is a list of different parameters that can be varied in the testing of salt spreading equipment. Each of these variables can generate a number of questions like the ones developed above in the examples.

Parameter	Unit	Comment
Cost	$	Several sources
Speed of the truck	mph	Usually, 15, 25, 35 & 50 mph
Rate of spreading	lbs/mi	For liquid gal/mi or gal/ton
Granular chemical	Symbol	NaCl, $CaCl_2$, CH_3CO_2K,
Liquid chemical	Symbol	$MgCl_2$, etc.
Pre-wet or no pre-wet	Yes/No	
Automatic or no automatic control	Yes/No	For high end spreaders
GPS capable	Yes/No	Record latitude, longitude, elevation
Pavement temperature sensor	Yes/No	Record pavement temperature
Placement of the spinner/chute	Front/back/ Right/left	Usually, left, center, right
With and without plow	Yes/No	Plowing, up or down
Number of drivers	1 or 2	Operators & A-drivers
Weather; wind, humidity, temperature, snow cover	Forecast	Record wind, temp, humidity, air pressure, etc.
Temperature	degrees F	
Method of delivery; spinner, chute, etc.	Symbol	S=spinner, C=chute, etc.
What type of pavement	Symbol	P=pavement, C=concrete
Configuration	Diagram	Graphic description
Spreader capacity	Tons, miles	
Speed of the truck, accelerating, decelerating, stopping and starting	Activity	Code for each type of activity including cornering, uphill, downhill, curve, etc.

Table 1: Examples of Testing Parameters

Once a question is devised, the planning of the test can begin. One of the first tasks is to finds systems to test. Candidate snowplows with spreader systems should be identified early on and will originate from interested agencies. Perhaps a future study will fund expenses such as, fuel, per diem, and/or materials. Costs vary depending on test location and number of test locations. An effective way to solicit systems to test is to ask agencies to provide their most trusted spreaders. Along with year, model, purchase price, maintenance costs, chemicals, controllers, etc. – including brand names. Use equipment from different government agencies (state, county, municipal).

C. Test location considerations. Selecting a test site is difficult because it involves several trade-offs; each of which require consideration and ultimately depend on several variables. Usually the cost drivers are availability, transportation, materials, and personnel travel. Other considerations are listed below.

- State DOT test track availability
- Selection of a section of public roadway
- Summer vs. winter seasons
- Private vs. academic vs. government administration of study
- Test personnel locations & travel
- Equipment operator location & travel
- Availability of ancillary test equipment, such as tarps, paint, vacuums, scales
- Calibration capabilities at the test site
- Data collection equipment, such as scanners, digital cameras, network access

Ideally, the test should reflect real snow and ice removal scenarios as much as possible. The test most likely will require staging (a test track) in order to ensure that only one variable is changed at a time for each run and that runs are repeatable to attain the needed number of iterations. Although the equipment would be more difficult to have donated for the test, it would be best to carry out the tests during the winter season, this of course depends somewhat on the variable being tested. For example bounce and scatter of dry salt as depended on truck speed might be okay to test in the summer time.

III. Strategy

A well-designed test will be accurate, reliable, consistent and be as realistic as possible. The following are some techniques that will help assure these qualities.

- Calibrate the equipment to manufacturer's and government standards prior to testing.
- Record the baseline conditions of each equipment suite or system prior to testing.
- Conduct training for the test personnel.
- Conduct training for the equipment operators.
- Run the same route under the same conditions with the different spreaders.
- Have multiple identical tracks so trucks can be assessed at the same time under exactly the same conditions.
- Use the same chemical in all trucks.
- Have a set of trials where just one variable is changed at a time.
- Use a radar gun to ensure that the speed is accurately measured.

- Use real drivers.
- Use a questionnaire with the drivers (see Appendix 1). Sometimes anecdotal information can be as valuable as statistical information.
- Use a street sweeper to vacuum up and a blower to clean the salt between trials
- Focus on having only one discriminator, making all other features similar or the same.
- Document each step to make the test reproducible, one example of this is illustrated in Figure 4.

Record or obtain a diagram of the test configuration for each set of runs based on single variable iteration. Make changes or modifications to diagrams as appropriate in order to document different configurations. This diagram will document each different system that is tested. This is done so the test can be reproduced in the future. In lieu of a manufacturer's diagram, a photograph of the spreader system or a drawing of other important features can suffice.

There are many ways to measure the effectiveness of the spread pattern that a given system generates. The following is a partial list. One or two of these methods must be chosen to prepare the test.

- Have an observer take notes and photographs of the coverage noting completeness, overlap, excess piles, etc.
- Use digital photography with analysis.
- Collect the chemical on a tarpaulin that is spread on the road before the truck spreads chemical in that spot, sweep up the material in each section, and measure coverage quantitatively by weighing the amount in each section.
- Clean the road and paint sections on the road. Let the truck spread on this area and then vacuum up the material in each of the sections and weigh each section of the test grid.
- If the test is done in the winter, after the truck has spread, measure friction with a friction meter or measure breaking distance with an actual car on the same track/road. This may be difficult if one is comparing solids (which take more time to work) versus liquids or pre-wet solutions.

How effectiveness is measured is just one of the decisions that goes into making a successful test. Figure 4 shows the logic of a well-executed test in the form of a flow chart. The flow is from left to right with test preparation, test operation, test execution and test results. It is important to follow these steps in order. For instance the location of the test will inform many of the other decisions down the line, like how to set up the test track or what type of consistency to expect.

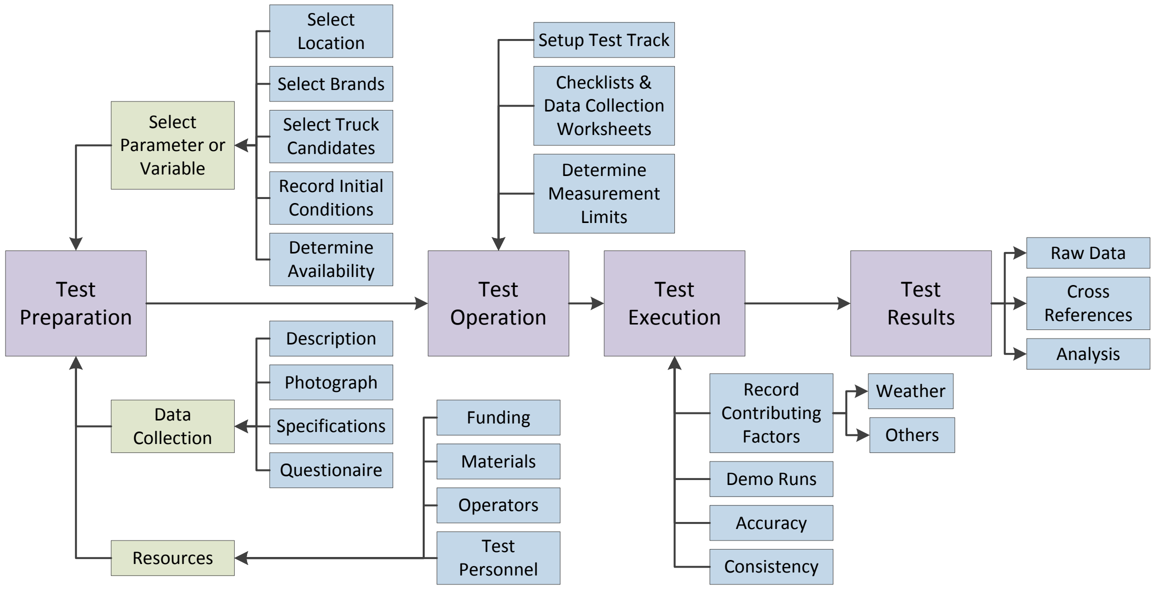

Figure 4: Test Flow Chart

Having the test designed, the investigator needs a strategy for each run of the test. The next flow chart (Figure 5) represents one run of the test.

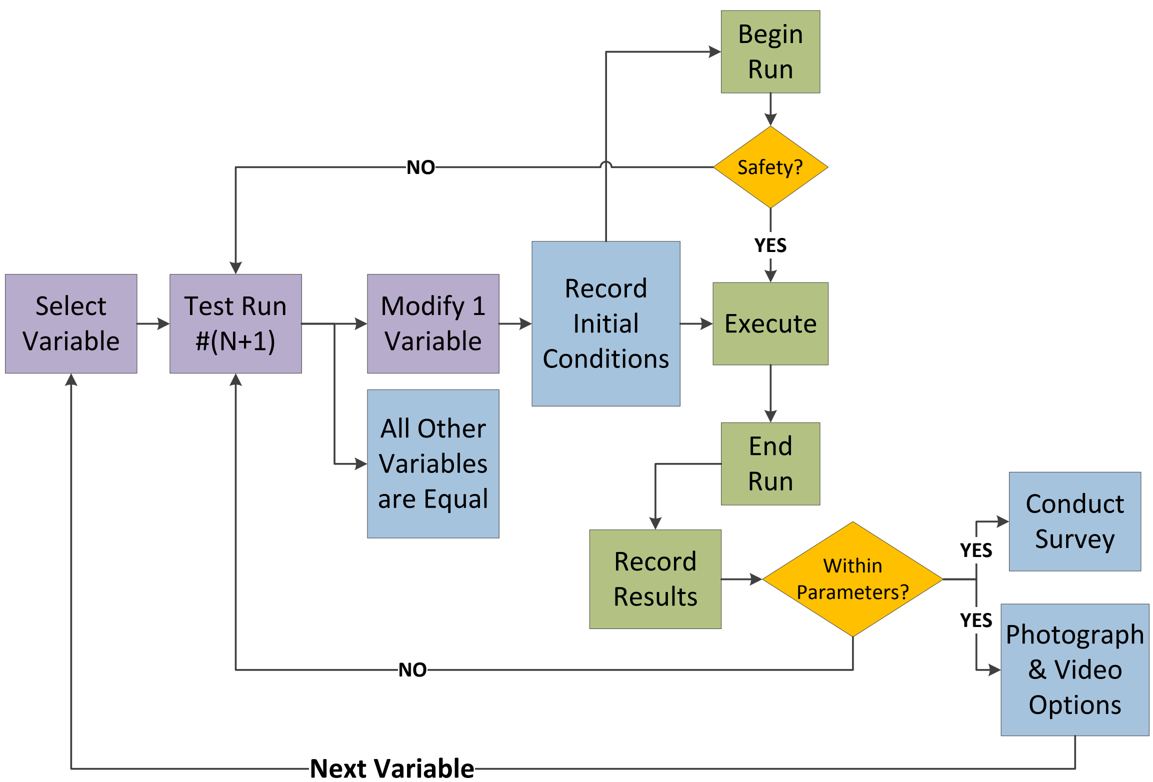

Figure 5: Example Test Run Flow Diagram

The investigator must be careful to maintain all variables constant except the one being modified. This can be very difficult with weather, recalibrations, cleaning between trials, etc. So, careful monitoring of the test variable is very important to assure the accuracy of a given test. These procedures will be illustrated by discussing further three of the examples that introduced above in the Number of Types of Different Systems" section.

Example #1: Quantity Test

Measure the amount of salt delivered by the truck for a given spread rate and a given time. From this, along with the area of pavement that has been covered, an amount spread per square foot can be calculated, the calibration can be checked and efficiency of spreading can be evaluated. The procedure is as follows:

1. Calibrate the spreader.
2. Record initial conditions.
3. Load the truck.
4. Weigh the truck.
5. Set the spread rate.
6. Drive the truck 5 miles, which would allow a significant amount of salt to be spread.
7. Weigh the truck
8. Document the information & results.
9. Photograph start & finish & events of interest.

Example #2, Bounce and Scatter:

To measure bounce and scatter the spread distribution is measured perpendicular to the direction of the truck. This is an example of a cross sectional test (the spread is measured at one instant of time). Here 12 areas, 3 feet by 40 feet are prepared on the pavement. After each run or pass of the truck the material is collected from each area (swept or vacuumed) and weighed. Thus a cross section of the spread from shoulder to shoulder can be calculated and analyzed. During the test it is important to

- Ensure that the truck has enough time before entering the grid to reach a spreading equilibrium
- Assure the speed of the trucks constant (use a radar gun)
- Clean the areas thoroughly between runs of the test
- Change only one variable at a time; speed, position, height of chute, etc.
- Record carefully all data

A study of this type was carried out by Colson and Peabody in 1999 (Appendix 2, reference 16)

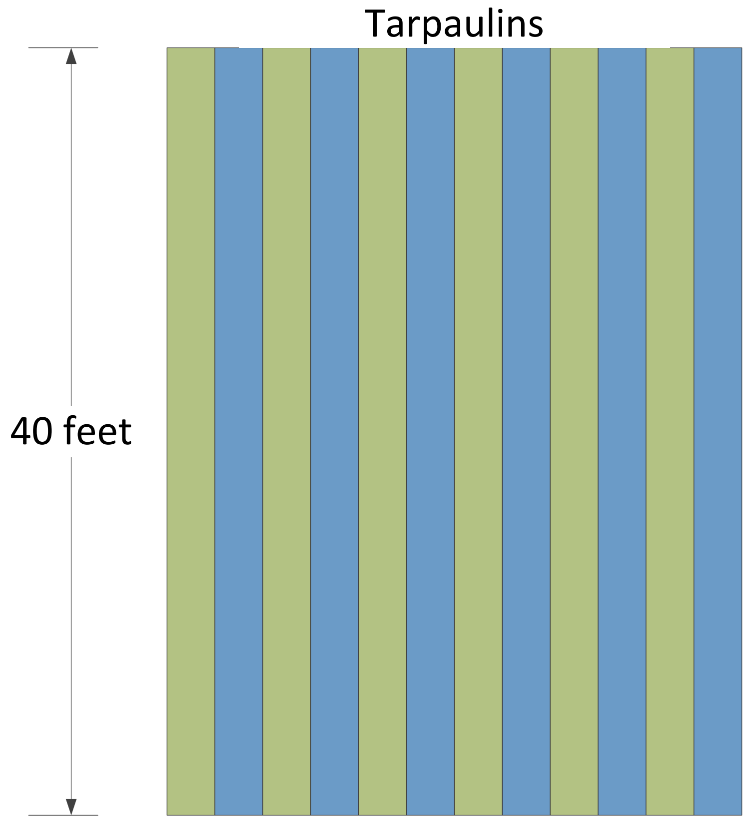

Figure 6: A 40 feet by 36 feet tarpaulin layout or paint pavement configuration for a cross-section type test. The truck will drive bottom to top (or vice versa)

Example #5, GPS or Ground Speed Control:

The test above, Bounce and Scatter is a cross-section test. The pattern of spread is measured at one point in time (and assumed to be similar the rest of the time). To effectively test this GPS vs. Ground Speed Control question a longitudinal test (a test in time) is needed as well. Therefore a grid like in figure 8 is needed. It is more work because more sections have to be collected and weighed, but this way information about how the system behaves when it accelerates, decelerates, stops and starts will also be collected. In this test it is important to

- Ensure that the truck has enough time before entering the grid to reach a spreading equilibrium.
- Clean the areas thoroughly between runs of the test.
- Have a complete plan for the different maneuvers this test will execute; acceleration, deceleration, stopping, starting, etc. The grid (Figure 6) will need to be at each location where there is a maneuver. So this plan is very important for planning.
- Take a video of each run to verify the maneuver.

Considering breaking distances for trucks approximately 200 feet of longitudinal distance would be needed to collect the data needed to ascertain the effectiveness of these types of automated control systems.

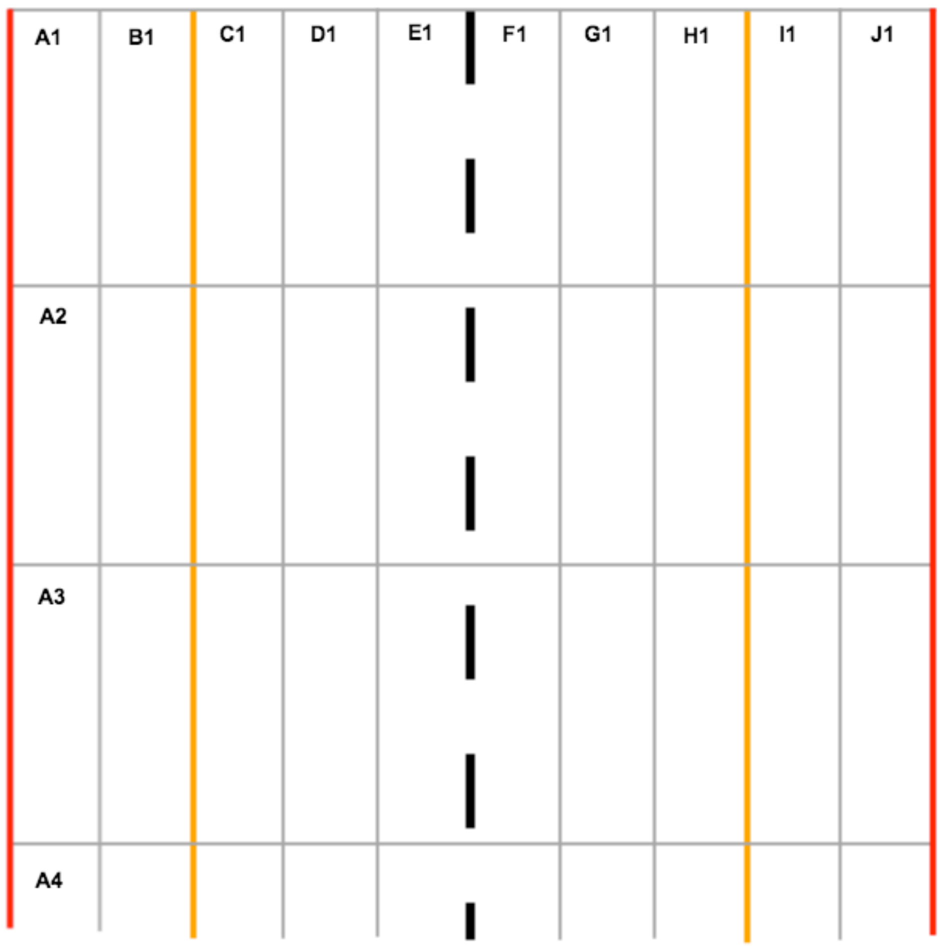

Figure 7: A sectioning of the road surface to execute both a cross-section and a longitudinal test. This testing grid is 30 feet (3X10) by 200 feet (20X10) – only 3.5 of the longitudinal sections are shown.

III. Budgetary Considerations

There have been a few attempts by organizations to test, evaluate and compare spreader apparatus based on brand, type, control, and effectiveness. Most of these tests have come up short of effective or compelling results that can assist snow fighting professional decision makers. Reviewing the available literature, test reports, and bibliography; the test personnel concur on the following:

- Testing of this type requires detailed, deliberate, and often expensive planning, organization, and logistics.
- Funding this type of project usually requires more than one organization; complicating the start and execution of the testing.
- Testing takes time, prior planning, organization, structure, multi-discipline, multi-agency coordination. Impacts on several schedules often are not compatible.
- Past testing has had severe limitations that force test personnel to compromise accuracy, number of variables, number of iterations, and scope of the evaluation.

The costs to conduct a comprehensive test or evaluation are considerable. Several considerations are provided below:

- Planning, test plan, test team, & engineering
- Vendor participation, if any, separate costs, at their own expense
- Site selection, availability, and agreement (lease, rental, gratis, insurance & liability)
- Equipment: selection, transportation, broad diversity by brand, type, organization, other, etc.
- Personnel: travel, per diem, lodging, and time away
- Training of test personnel & equipment operators
- Fuel for all vehicles
- Materials for spreading
- Ancillary equipment: vacuums, tarps, test track configuration
- Network access
- Data collection & storage; plus manipulation and analysis
- Third party consulting analysis & record keeping

Some testing constraints can be assisted by a few best practices, listed below:

- Define test expectations: What result is required; upper limit, lower limit; is this result measurable?
- Planning, trial runs or demonstration on small sample, even if it is only one sample.

- Determine what support, funding, and no/low cost assistance from commercial, academic, governmental and industrial sources.
- Designate one test director to be held accountable for results; provided they have the resources.
- Keep detailed record.
- Use third party analysis of the data to mediate bias, preconceptions, and predisposition is recommended.
- A limited but definitive result can be very valuable. Define strict limits in terms of number of systems tested, and parameters to be varied.

Proposed Budget *(Example only)*. The following table (Table 2) is a proposed budget based on the following assumptions:

- Trucks are provided by member organizations at no cost.
- Vendors participate for calibration, maintenance, & specification assistance only at no cost.
- A member state DOT provides a test track & availability at minimum cost with test track maintenance no cost.
- Eight trucks, four brands, four types, four variables are required.
- A rough estimate based on other studies is that about 3-5 days are needed for testing.
- Make certain sufficient personnel are available to operate equipment.
- Use of third party (consultant) assistance is required for training, establishing initial conditions, project management assistance, and data recording & analysis.
- Organization is to assigns one test director and supporting staff as needed.

These assumptions are general in nature by design. The testing depends on many dependencies. This budget overview is for example only and provides a glimpse at funding requirements.

Item	Cost Estimate
Planning, test plan, test team, & engineering	$40K
Vendor participation, if any, separate costs, at their own expense	$0K
Site selection, availability, and agreement (lease, rental, gratis, insurance & liability)	$60K
Equipment selection, transportation, and broad diversity by brand, type, organization, other, etc	$0
Personnel, travel, per diem, lodging, and time away	$25K
Training of test personnel & equipment operators	$5K
Fuel for all vehicles	$10K
Materials for spreading	$15K
Ancillary equipment; vacuums, tarps, test track configuration	$35K
Network access	$2K
Data collection & storage; plus manipulation and analysis	$30K
Third party and/or consulting analysis & record keeping	$30K
Total Estimate	**$252K**

Table 2: Cost Estimate for an Example

IV. Conclusions

The following conclusions are offered for consideration:

1. Evaluating spreader systems is important and has a direct impact on cost, environment, and public safety.
2. Past testing of spreader systems for comparison with regards to type, accuracy, control, and effectiveness is not in evidence.
3. Test results that do exist are narrowly focused (one system) or data is not sufficient to extrapolate snow and ice removal conclusions.
4. Snow professionals seek this information and require knowledge on the comparison of spreader systems by several parameters.
5. The questions to be answered by a test determine the number of systems needed for testing.
6. For the testing it is important to follow a plan that includes: test preparation, test operation, test execution and test results
7. Measuring cross-sectional or longitudinal spread patterns are important for different tests.
8. Documenting the testing is very important to later analysis and for reproducibility.
9. Comprehensive and effective evaluation and analysis is expensive.
10. Testing is beneficial to not only the snow fighter but to industry, motoring public, environmental organizations, and academic institutions.

Conducting this study required several contributions from Clear Roads road maintenance professionals; their assistance was all voluntary and helpful.

Appendix 1: Questionnaire

Typical questionnaire for the drivers of the spreading systems to be used for the drivers involved in the test .

1) Describe your spreading system (make, model, features and year).

2) Please list any problems you encountered with this equipment during this past winter. For example: wiring, hydraulics, bed chain sensors, speedometer sensors, plugging, radio, data gathering, etc.

3) What suggestions do you have to make the use of this equipment easier for the operator? For example: plug wiring locations, hydraulic hookup locations, control box location in the cab, etc.

4) Do you think your crew should purchase more of this type of equipment?

5) What materials did you spread with this system this year? (sodium chloride, calcium chloride, sand, etc.)

6) Do you think the test that was performed today will give accurate results so your spreader can be compared to other systems? Why or why not?

7) How could the test performed today be improved?

8) Additional comments.

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