

SaMS: Operational Best Management Practices – Pros & Cons

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Plowing Practices

All Audiences

1. **Plowing early and often** is the best defense to prevent snow and ice from bonding to pavement. To the extent possible, it is better to remove snow/ice by plowing than using deicers to “burn off” any accumulations. Additionally, depending on the conditions (i.e., precipitation rate/type), keeping up with snow/ice accumulations through frequent plowing limits the time for snow/ice to compact and bond with the pavement. When plowing, avoid placing snow into bodies of water, wetlands, or stormwater infiltration/retention structures.
 - **Pros:**
 - As a core practice in all snow and ice management operations, implementation comes with no start-up costs.
 - Plowing at a rate appropriate to minimize the bonding of snow/ice to the surface reduces the need for deicing to break that bond. This cuts material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.¹
 - **Cons:**
 - Challenges to plowing early and often may include resource limitations (e.g., equipment, staff, etc.) and the rate and type of precipitation. Overcoming these resource limitations increases equipment and/or staff costs.
 - More frequent plowing may cause damage to surfaces and equipment (e.g., blades, trucks, etc.)

Transportation Audiences

2. **Coordinate plowing activities** to prevent plowing off another operator’s material.
 - **Pros:**
 - Maintains levels of service and public safety by keeping the applied deicer working.
 - Reduces the need for more deicers to replace those plowed off. This cuts material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.
 - **Cons:**
 - Requires advanced planning and coordination, which may not always be possible in certain storm events.
3. **Plow Train:** On multilane highways use a plow train to remove as much snow as possible in one coordinated sweep. In this practice, trucks are arranged in a staggered order and continue down all lanes of the highway in a coordinated sweep.
 - **Pros:**
 - Reduces the need for successive passes of the same highway, allowing for increased public safety and potential cost savings.
 - Reduces the need for more deicers, by more effectively clearing snow/ice. This cuts material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.
 - **Cons:**
 - Requires cost investment in specialized training so that deicer is applied in areas that won’t be plowed up by trucks behind the lead trucks.
 - Requires multiple plows on one route, thereby taking plows off other routes.

¹ A case study in Otterburn Park, Quebec reported a significant salt reduction of 73% through the implementation of effective plowing practices and improved training (Environment Canada, 2000). Actual citation no longer available; case study reported in http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_FINAL.pdf

Audiences managing parking lots, sidewalks, and properties

4. **Snow Placement:** Store snow plowed from properties downhill from deicer storage areas. Stops melt water from interacting with deicers.
 - **Pros:**
 - Prevents melt water from transporting deicer into storm drains and the environment.
 - Eliminates the waste of deicer transported in melt water, and not used for deicing/anti-icing.
 - **Cons:**
 - Viable spaces for snow storage may limit parking or other property use. Property manager may not accept this loss of use.
 - Viable spaces for snow storage may be in areas that drain directly to a waterbody. Since the snow may have salt and/or other pollutants in it, this may increase the impacts to the waterbody.

Calibration

All Audiences

5. **Calibrate equipment** (solid and liquid dispensers) in the preseason, mid-season, and any time changes are made to equipment or change is made to the material (including dry deicer to pretreated/pre-wetted salt). Calibrate application rates for minimum required deicer output. Document settings, rates, and maximum deicer output in manuals, site binders, and include in training. Calibrate/test new material.
 - **Pros:**
 - Relatively simple process that requires only a few pieces of inexpensive equipment (e.g., tarp, bucket, and scale).
 - Calibrated spreaders help to achieve target application rates, especially when equipment is calibrated for the minimum required deicer output. This promotes efficient use of deicer and enables a more precise actual application rate, which allows for a more efficient achievement of levels of service and safety. Efficient deicer use reduces material costs and reduces the impacts (public health, environmental, and infrastructural) from the deicers.^{2,3}
 - Direct costs for additional staff/contractor time to calibrate equipment (typically 1-3 staff members for 10-60 minutes, based on a nationwide survey)⁴ may offset through a reduction in excess deicer use (from uncalibrated spreaders).
 - **Cons:**
 - Requires cost investment in training.
 - Calibrating equipment requires additional staff/contractor time to complete, and therefore may involve an increase in direct costs.
 - For operations with a large equipment fleet, significant resources are needed to calibrate equipment, especially over multiple times in the season.
6. **Establish a calibration process** for all salt application equipment that takes into account flow settings, conveyor/auger and spinner speeds, ground speed, and material (size, density, etc.). Standardize application rates across equipment types.

² The City of Waconia, MN reduced salt use by 70% by implementing calibration and equipment changes (MPCA, 2016). <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

³ A small agency in Wisconsin saved \$75,000 after calibrating their spreaders and realizing a huge discrepancy in application rates (Nixon, 2017). https://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/SaMS/MeetingMaterials/SAC1/SaMS_IP_SAC1_WNixon_Presentation.pdf

⁴ Fay et al., 2013a – <https://transportationops.org/research/revised-chapter-8-winter-operations-and-salt-sand-and-chemical-management-final-report>

- **Pros:**
 - Allows for flexibility across a diverse set of equipment, and provides certainty among similar equipment types.
- **Cons:**
 - Additional cost/time investment to address different equipment separately.

Measuring Deicer Use

All Audiences

7. **Measure and Record Deicer Use:** Using a standardized process, measure and record deicer use as frequently, accurately, and refined (e.g., per shift, site, etc.) as possible. To the extent possible, 1) use technology to accurately automate the process of measuring deicer use, and 2) measure deicer use using more than one method to verify values.
 - **Pros:**
 - Provides information to evaluate whether or not target application rates were achieved. Where target application rates were exceeded, this information can identify efficiency opportunities and reduce costs.
 - Provides information to evaluate deicer use, which can highlight areas (beyond application rates) where efficiencies can be realized and costs minimized.
 - Provides a record of performance, which may be useful in slip and fall law suits.
 - **Cons:**
 - Requires additional planning and administrative actions to measure, record, and maintain records of deicer use, with associated costs.
 - Significant costs for manual data tracking and recording for large operations. While new measurement/recording technology has promise, integrating new technology into operations requires additional training and investment costs.

Levels of Service

Transportation Audiences

8. **Internal Level of Service Knowledge:** Have all operations staff know the levels of service for the various routes.
 - **Pros:**
 - When all staff know the levels of service, the prescribed levels of service can best be achieved.
 - Best assures that public safety will be maintained at the level that is determined by the operation.
 - **Cons:**
 - Requires additional training investment.
9. **External Level of Service Knowledge:** Inform residents and political leaders of the different levels of service.
 - **Pros:**
 - Ensures that political leaders and the residents know what to expect in terms of levels of service, and expected levels of safety.
 - Helps to reduce the demand/request for levels of service greater than what is pre-determined.
 - Reduces additional costs over what is necessary to meet levels of service.
 - **Cons:**

- Additional costs to publish/promote public understanding of levels of service information.

Audiences managing parking lots, sidewalks, and properties

10. **Level of Service Agreement:** Property managers and service providers discuss and agree to levels of service standards for all winter service areas.

- **Pros:**
 - Ensures the contractor and property manager have a common expectation, which can reduce the need for revisits and additional treatments, and minimizes unnecessary treatment costs.
 - Allows for advanced planning prior to a storm event, to limit the potential overuse of deicers (i.e., exceeding level of service). Reduced over use of deicers saves material costs and reduces impacts to public health, environmental, and infrastructural.
- **Cons:**
 - Reaching agreement on levels of service may require additional time and costs.

Training Programs

All Audiences

11. **Training:** Train all staff including managers, operators, contract employees, seasonal employees, etc. on winter operations. Important elements of a training program for both classroom and hands on training include:

- Agency planning and policies for managers and operators
- Understanding weather and weather
- How materials work
- Materials selection for the given conditions
- Proper materials storage
- Proper snow and ice removal
- Proactive approaches, including liquids use
- Equipment choices and maintenance
- Calibration of equipment
- Environmental impacts
- Data collection and analysis
- **Pros:**
 - Provides the base-level knowledge for operators to get the job done, while also providing context to the benefits and impacts of deicer use.
 - Reduced confusion during storm events, making operations more efficient and effective.
 - Successful training can reduce material use while maintaining levels of service⁵, therefore reducing costs and impacts (public health, environmental, and infrastructural) from the deicers.⁶
 - Improved staff awareness of operations work, possibly identifying areas for improvement and cost savings.
 - When staff and leadership are all a part of the training, this allows for cross-pollination of ideas and comradery, and fosters a collaborative environment for continuous improvement.
- **Cons:**

⁵ Eckman et al., 2011. Conducted at a DOT in Minnesota –

https://conservancy.umn.edu/bitstream/handle/11299/182377/cfans_asset_340511.pdf?sequence=1&isAllowed=y

⁶ The City of Cottage Grove, MN saw a decline in salt used per event after attending training. In the 2011-2012 winter, there was a savings of 694 tons of salt which was equal to \$40,000 saved. <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

- Training programs that cover the recommended elements above likely come at a high upfront cost.
- Challenges around staff retention, mid-season hires, or contracted support may complicate the efficacy of a training program and its long-term sustenance.

Anti-Icing

All Audiences

12. **Anti-icing** surfaces with liquids or solids prevents or significantly reduces the bonding of snow and ice to pavement, which makes plowing/shoveling much more efficient and complete. Anti-icing with liquids (e.g., brines) is the most efficient form of anti-icing as it can be done up to 48 hours in advance of the start of snow/ice fall, and it uses significantly less deicer than solids. However, anti-icing with solids can work better if the event may start as rain or freezing rain since the salt crystals last longer. Anti-icing with solids is best done with pre-wet or pretreated deicer (see below).

- **Pros:**
 - Anti-icing returns surfaces to safe conditions faster, resulting in less delay/risk for accidents/slips and falls on surfaces. One study showed an 85% reduction in crashes compared to a de-icing only strategy.⁷
 - When anti-icing with liquids, the liquids stick to the surface and are not blown away, allowing deicers to be used efficiently.
 - Anti-icing is a proactive approach to snow and ice management that allows flexibility for mobilization since it starts working once the snow falls, even if the snow is delayed or comes earlier than predicted.
 - Reduction in material needs since the bond between snow and ice is prevented, and therefore reduced material costs⁸ and impacts (public health, environmental, and infrastructural).⁹
- **Cons:**
 - For liquids, the equipment for production, storage, and application is different than the equipment needed for solids. This capital investment in this equipment presents a significant additional cost.¹⁰
 - Pre-storm mobilization may come at an additional cost, but also may be offset by less need for plowing and deicing during/after the storm.

Use of Liquids

All Audiences

13. **Pretreat deicers** with a liquid, typically brine, to help material stick to surfaces and speed up the melting process. Pretreating the load in the spreader/truck bed allows for more uniform mixing. Alternatively, the

⁷ Clear Roads, 2015a – http://clearroads.org/wp-content/uploads/dlm_uploads/0537_2015-Clear-Roads-Best-Practice-Guide-WEB.pdf

⁸ Reported 75% savings versus deicing a roadway that has become ice bonded (Clear Roads, 2015a). http://clearroads.org/wp-content/uploads/dlm_uploads/0537_2015-Clear-Roads-Best-Practice-Guide-WEB.pdf

⁹ Six cities in the Rice Creek Watershed (MN) collaborated to purchase anti-icing equipment and hold training for the equipment. The six cities reduced their salt use by 32% as a result. At \$50/ton of salt, that equated to \$26,400 saved (MPCA, 2016). <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

¹⁰ Calculating the labor, equipment, and material costs, this example shows that brine is made at about \$0.21/gallon (Keep, 2015). <https://www.sima.org/news2/2015/08/01/calculating-true-costs-of-salt-brine>

entire stockpile can be treated as well, but may not be as uniformly mixed. While both pretreating and prewetting (see below) improve deicer efficiency, prewetting is the most efficient practice.

- **Pros:**
 - Pretreated deicers bounce less and stick more to surfaces, reducing material losses due to bounce and scatter. This allows for 20-30% less material to be used¹¹ and reduces material costs and impacts (public health, environmental, and infrastructural).
 - Allows for lower application rates and therefore can reduce material costs and impacts (public health, environmental, and infrastructural) from deicer use.
 - Allows for efficient use in cold temperatures by providing the water necessary for the deicer to begin working (i.e., does not need to be slowly melted to become available). Therefore, pretreating allows for reduced material costs and impacts (public health, environmental, and infrastructural) from deicer use.
- **Cons:**
 - When the stockpile is pretreated, it must be stored on a covered and impervious pad because the brine that leaches from the stockpile can impact the environment. Not all operations have these sorts of facilities available, and therefore may not be possible or may come at an increased cost.

14. **Prewet deicers** to help material stick to surfaces and speed up the melting process. Prewetting involves adding liquid, typically brine, to the salt as it is being applied. This approach can work particularly well with higher liquid to deicer ratios on heavy traffic routes since the slurry can be made at the point of application and will drop directly onto the surface, working immediately. While both pretreating and prewetting allow for efficient and effective use of deicers, prewetting is the most efficient.

- **Pros:**
 - Prewetted deicers bounce less and stick more to surfaces, reducing material losses due to bounce and scatter. This allows for 20-30% less material to be used^{12, 13} and reduces material costs and impacts (public health, environmental, and infrastructural).
 - Allows for lower application rates¹⁴ and therefore can reduce material costs and impacts (public health, environmental, and infrastructural) from deicer use.
 - Allows for efficient use in cold temperatures by providing the water necessary for the deicer to begin working (i.e., does not need to be slowly melted to become available). Therefore, prewetting allows for reduced material costs and impacts (public health, environmental, and infrastructural).
- **Cons:**
 - The equipment necessary to prewet deicers involves a significant investment in new and retrofitted equipment. Since prewetting happens at the auger or spreader, liquid tanks need to be added to the vehicle/machine (where space exists). Additionally, the options for mounting liquids may be driven by the type of vehicle/machine used for spreading salts, therefore limiting options for liquids and as a result the ranges of cost for the equipment.

¹¹ Minnesota Local Road Research Board, 2012 – <http://www.mnltap.umn.edu/publications/handbooks/documents/snowice.pdf>

¹² Minnesota Local Road Research Board, 2012 – <http://www.mnltap.umn.edu/publications/handbooks/documents/snowice.pdf>

¹³ A case study in Michigan observed that 96% of the pre-wetted materials were retained on the road surface, whereas only 70% of the dry material was retained on the road surface (Michigan DOT, 2012).

https://www.michigan.gov/documents/mdot/Final_ReportNov2012_404228_7.pdf

¹⁴ The City of Prior Lake, MN reduced their application rates on average from 500 pounds per lane mile of dry salt to 200-250 pounds per lane mile using prewet salt (MPCA, 2016). <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

15. **Direct Liquid Application:** Apply mixtures of water and deicer directly to a surface (Direct Liquid Application, or DLA) during or after a storm to deice immediately. Since the deicer is already in liquid, there is no lag time for the deicer solution to form as is the case when a dry (or even wet) deicer is applied.

○ **Pros:**

- Allows for efficient use in general and particularly in cold temperatures by providing the solution that performs the deicing (i.e., does not need to be slowly melted to become the solution). Therefore, direct liquid application allows for reduced material costs^{15, 16, 17} and impacts (public health, environmental, and infrastructural) from deicer use.
- Because the deicer can begin to work immediately, levels of service and safety can be achieved much faster than with other practices and across a wider variety of conditions.¹⁸
- If anti-icing with liquids, the equipment to perform this practice is already available.
- If standard practices or legal requirements require cleaning up deicer after a storm, direct liquid application minimizes post-storm cleanup, and therefore reduces associated costs.

○ **Cons:**

- For liquids, the equipment for production, storage, and application is different than that needed for solids. Therefore, the capital investment in this equipment presents a significant additional cost.¹⁹
- Since there may be dilution of the liquid deicer, the eutectic concentration may need to be enriched with a follow up, light application of solid deicer. This may add to operational costs/resource demands and complicate storm event logistics.
- This is a relatively new process, with limited. While promising, implementing this may involve more trial and error than other more tested practices.

Product Application Practices

All Audiences

16. **Dyed deicers:** Use dyed deicers to observe and show product presence.

○ **Pros:**

- Allows for a visual confirmation of deicer coverage. Often times, once the deicer has gone into solution, or even when it blends in with the snow/ice, more deicer than is necessary may be applied due to inaccurate visual assessments by third-parties (e.g., members of the public, customers, etc.). With dye in place, the extent of treated areas is easy to confirm, allowing for cost savings on deicers not applied in excess.

¹⁵ The Maryland Highway Safety Administration uses DLA on some routes, where the average application rate is 160 lbs/lane mile/inch. The reported cost is about 14.8 cents per gallon to make (MSHA, 2019).

<https://www.mwcog.org/file.aspx?&A=vG8T0kKoe21vtAc2C22WMtuDhFjmOWkZArTVhoqonaY%3d>

¹⁶ City of Prior Lake used an all liquid route, where application rates equated to 100 pounds per lane mile or less (MPCA, 2016). <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

¹⁷ Switching from solids rock salt to liquid brine was reported to have produced approximately 50% materials savings as compared to the use of solid rock salt (Fay et al., 2013b).

[https://www.in.gov/indot/files/Strategies to Mitigate the Impacts of Chloride Deicers.pdf](https://www.in.gov/indot/files/Strategies%20to%20Mitigate%20the%20Impacts%20of%20Chloride%20Deicers.pdf)

¹⁸ The Maryland Highway Safety Administration uses DLA on some routes, where it out performs granular salt form a Level Of Service perspective (MHSa, 2019).

<https://www.mwcog.org/file.aspx?&A=vG8T0kKoe21vtAc2C22WMtuDhFjmOWkZArTVhoqonaY%3d>

¹⁹ Calculating the labor, equipment, and material costs, this example shows that brine is made at about \$0.21/gallon (Keep, 2015). <https://www.sima.org/news2/2015/08/01/calculating-true-costs-of-salt-brine>

- Some dyed deicers are colored with an anti-corrosion inhibitor (e.g., Prussian Blue) and therefore may cause less damage to surfaces/property and reduce maintenance or mitigation costs.
 - Some dyed deicers are colored with anti-caking agents (e.g., Prussian Blue), which allows for more predictable deicer movement. Target application rates and levels of service are more obtainable with the anti-caking agents.
 - **Cons:**
 - Some dyed deicers are colored with pigments containing cyanide (e.g., Prussian Blue), which may become mobilized when in solution. While the environmental impact from the cyanide is not well studied, it may present human health and environmental impacts.
 - Some dyes can stain and/or be tracked into untreated areas, potentially causing damages with associated costs.
17. **Use of Abrasives:** Use abrasives or deicers, but not both combined. Do not mix deicers and abrasives (except to keep the abrasives from freezing/clumping) because one of the products will only be half as effective. Abrasives work best on top of snow/ice to provide traction. However, if deicer is mixed in significant proportions (e.g., 50/50) to the abrasive, the deicer will melt the snow/ice and the abrasive will no longer work as well. Use abrasives to provide traction during 1) freezing rain events, 2) in slow-moving traffic areas, and 3) when deicers are ineffective because it is too cold.
- **Pros:**
 - By only using abrasives when deemed appropriate, the function the abrasive will last until the snow/ice melts naturally. As a result, the abrasive material that was applied will function 100% of the time it is needed.
 - If temperatures are too cold for deicers to work, the use of only abrasives ensures that deicers will not be used in a situation where they are plowed up before ever melting the snow/ice.
 - **Cons:**
 - There are situations where an abrasive/deicer mix may maximize the operation's results, by strategically stretching resources. For example, storms with temperatures that start too cold for effective deicing, but that change to a temperature within the effective range of the deicer. In these cases, an abrasive/deicer mix may provide for an efficient return to levels of service with limited resources.
18. **Post-storm clean-up:** clean-up left over deicers/abrasives after the snow/ice has melted away.
- **Pros:**
 - By cleaning-up left over deicers/abrasives, the potential impacts (public health, environmental, and infrastructural) from the left over deicers/abrasives are prevented.
 - If routine post-storm clean-up is a practice, areas of excess application may be identified and practices can be refined in those areas. If this evaluation is possible, then there may be associated reductions in material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - Post-storm clean-up is an additional operational step in winter maintenance operations and comes at an additional cost.

Transportation Audiences

19. **Reduce deicer application rate on successive passes** to leverage deicing capacity of the remaining deicer.
- **Pros:**

- Allows for efficient use of deicers thereby reducing the associated material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - May involve some trial and error, and if the operation chooses to audit the experimental applications, there will be associated costs (e.g., staff time).
- 20. **Drive 17-25 mph** when applying deicer to keep material on road.
 - **Pros:**
 - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - May not be possible to maintain these speeds at all times and on all roads.
- 21. **On high-speed roads**, apply deicers in center of road or high side of curve
 - **Pros:**
 - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - May not be possible to apply in these locations at all times and on all roads.
- 22. **Spinner set-up:** Use a chute or set spinners closer to the ground to reduce bounce and scatter.
 - **Pros:**
 - Allows for efficient use of deicers therefore reducing material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - May not be possible on all equipment. If equipment presents a challenge, then new equipment purchases will come at a cost.
- 23. **Turn off auger, shoot, or conveyor when stopped**, even briefly
 - **Pros:**
 - Allows for more precise use of deicers, and reduces material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - May not be possible on all equipment. If equipment presents a challenge, then new equipment purchases will come at a cost.

Audiences managing parking lots, sidewalks, and properties

- 24. **Spread patterns:** Survey the property and develop and utilize a spread pattern that prevents applying deicers over areas that have already been treated.
 - **Pros:**
 - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - Requires advanced planning, which may not always be possible and may come at an additional cost.
- 25. **Spreaders for sidewalks:** Use drop spreaders or rotary spreaders with shields to prevent spreading deicer off of the sidewalk.
 - **Pros:**
 - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).

- **Cons:**
 - Requires specific equipment, which if not owned must be purchased at a cost.
26. **Managing stairways or areas with a small footprint #1:** Look for opportunities to close areas, and when that is not an option, use the proper tool for snow/ice removal such as a push shovel, scoop shovel, broom or blower (for light fluffy snow), ice scraper (for ice and compaction), or an ice chisel (for breaking open compaction/ice).
- **Pros:**
 - May reduce the area that requires management, thereby reducing associated costs and impacts (public health, environmental, and infrastructural). Allows for the most efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
 - When managing the snow/ice, using the proper tool cuts down on wasted time and associated costs while achieving intended levels of service and safety.
 - **Cons:**
 - Requires specific snow/ice removal tool(s), which if not owned must be purchased at a small cost.
27. **Managing stairways or areas with a small footprint #2:** To apply deicer in these small areas, calculate the area, and using an application rate chart calculate the total amount of deicer to be applied over that area (Amount = Application rate * Area). When applying deicer in these areas, use a hand-held spreader for more precise application.
- **Pros:**
 - Allows for the most efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - Requires specific equipment (hand spreader), which if not owned must be purchased at a small cost.

Varying Application Rates to Conditions

All Audiences

28. **Variable application rates:** Use recommended application rates that are based on the following factors: 1) pavement/surface temperature, 2) precipitation rate and type, and 3) cycle time/bare pavement regain time (i.e., levels of service). When considering these factors, target application rates will vary.
- **Pros:**
 - Allows for efficient use of deicers thereby reducing material costs and impacts (public health, environmental, and infrastructural).
 - Ensures that the appropriate amount of deicer is used to achieve levels of service and safety goals.
 - **Cons:**
 - Requires more training, the cost of which can increase if staff retention is a challenge.
 - Requires adaptable equipment (i.e., spreader settings), which if not owned come at a cost.

Pre- and Post-Storm Meetings to Review Plans and Performance

All Audiences

29. **Pre-storm meetings:** Before a storm begins, review operations plans, highlight any potential challenges and associated solutions that the forecasted storm may present, and revisit lessons learned from post-storm meetings (see below). Where possible hold these meetings with the maintenance crew, supervisors, and management/property manager(s), and any partner operations. Large and geographically spread operations may be better suited by having pre-storm meetings for each operations office.
- **Pros:**
 - Provides an opportunity to coordinate operations across different levels of the operation/region.
 - Provides an opportunity for advanced planning and a more strategic storm response.
 - It is possible that this process can lead to efficient achievement of levels of service and safety and/or efficiencies in deicer use, thereby reducing costs and impacts (public health, environmental, and infrastructural) related to deicers.
 - **Cons:**
 - Requires dedicated time for meeting, which may come at an additional cost.
 - It may be difficult to schedule a meeting with all operations staff.
 - Depending on the nature of the storm, there may not be time to hold a pre-storm meeting before each storm event.
 - May not be possible or productive for operations that rely heavily on contractual support. In such cases, preseason meetings to review plans and coordinate operations may be more appropriate.
30. **Post-storm meetings:** After the storm event is done, evaluate what was done, how well it worked, and what could be changed to improve operations. Where possible, hold these meetings with the maintenance crew, supervisors, and management/property manager(s), and any partner operations. Large and geographically spread operations may be better suited by having post-storm meetings for each operations office.
- **Pros:**
 - Provides an opportunity for all members of the operation to share insight/observations.
 - Provides a process for a continuous improvement.
 - Provides a group learning opportunity that may be more tailored and specific than general training.
 - Insights gained from this process can lead to efficient achievement of levels of service and safety and/or identified efficiencies in deicer use, and reduce costs and impacts (public health, environmental, and infrastructural) related to deicers.
 - **Cons:**
 - Requires dedicated time for meeting, which may come at an additional cost.
 - It may be difficult to schedule a meeting with all operations staff.
 - There may not be time to hold a post-storm meeting after each storm event.
 - May not be possible or productive for some operations that rely heavily on contractual support. In these cases, an end of season evaluation or informal storm performance assessment may be more appropriate.

Weather Forecasting/Surface Temperature Information

All Audiences

31. **Weather Forecasting:** Obtain accurate forecasts that detail the 1) start of precipitation, 2) type of precipitation, 3) total precipitation expected/storm intensity, 4) expected event length, 5) wind conditions (speed, gusts, directions), and temperature trends. Where possible share forecasts with partner operations and seek additional forecasts. Evaluate actual storm conditions relative to the forecasts.
- **Pros:**
 - Provides storm start information so that anti-icing can be planned and implemented, equipment can be staged, and other actions can be taken to minimize the time snow/ice has to bond to the pavement. A good forecast can allow operations to be efficient with resources, thereby reducing costs. Additionally, efficiencies realized in deicer use can minimize the associated impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - Weather forecasting, while frequently improving, is still only a prediction that is subject to change. This is especially the case for forecasts issued well in advance of a storm, which influence decisions around anti-icing (e.g., should an operation anti-ice, if so, how should it be done).
 - While there are free forecasting services (e.g., <https://www.weather.gov/>), some must be procured at an additional cost.
32. **Know the surface temperature:** Use equipment and/or remote technology to know the temperature of the surface that will/may be treated with deicers. Use this information to determine the appropriate application rate for the conditions (in addition to precipitation rate and type, and cycle time/bare pavement regain time – see #28 above). Options for measuring the surface temperature in the field include mounted infrared thermometers or hand-held infrared thermometers that can accurately measure in cold temperatures (important to verify). Additionally, infrared thermometers can be installed in the field and programmed to share surface temperature remotely through an internet connection. A sophisticated example of this is a Road Weather Information System (RWIS), which also measures and shares atmospheric data.
- **Pros:**
 - Knowing the surface temperature allows operators to determine the optimal application rate, therefore allowing for efficient use of deicers. With efficient use of deicers, the associated costs are reduced and the impacts (public health, environmental, and infrastructural) are minimized.²⁰
 - Although sophisticated systems like RWIS are large investments, studies looking at DOTs in Indiana and Idaho have shown that there is a 3.8 benefit cost ratio to the purchasing agency.²¹
 - **Cons:**
 - All sensors and technology if not currently owned, come at a cost. In particular, sophisticated systems like RWIS come at a large installation, maintenance, and operation cost.
 - The relationship between surface temperature and deicer application rate may involve training, with associated costs.

²⁰ A study conducted in Idaho found a 40% reduction in material savings due to the introduction of RWIS (ITD, 2009) Actual citation no longer available; case study reported in http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_FINAL.pdf

²¹ Veneziano et al., 2014 – https://www.researchgate.net/publication/262103948_A_Benefit-Cost_Analysis_Toolkit_for_Road_Weather_Management_Technologies

Enhanced Equipment/Technology (not previously mentioned)

All Audiences

33. **Plows:** Make use of plows that maximize the plow-able area. Examples include 1) side wing plows (to increase plow-able area per truck), tow plows (to increase plow-able area per truck), and flexible or sectional blades (to maximize the contact between the plow on uneven surfaces).²²
- **Pros:**
 - Provide the most efficient removal of snow/ice, therefore allowing for efficient use of deicers. Through both efficient plowing and deicing, there can be reduction in plow time and deicers used, thereby reducing their associated costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - If not owned, requires purchase, maintenance, and replacement costs.
34. **Spreaders:** Where possible, use spreaders that can deliver very low rates of deicers. Additionally, where possible, use electronic spreaders that can lock in specific application rates and can be used to collect data. For even more sophisticated and efficient deicing application, use ground controlled/speed-synchronized spreaders that are managed by a computer that uses the speedometer to determine auger or conveyor speeds for the spreader.
- **Pros:**
 - More sophisticated spreaders, allow for more versatile and precise the application of deicers. Sophisticated spreaders enable more efficient deicer use and reduce costs and impacts (public health, environmental, and infrastructural).
 - The more sophisticated the spreader, the more possible it is to attain levels of service and safety accurately and promptly.
 - If the spreader collects data on the deicer use, it is possible to evaluate whether or not target application rates were achieved and determine any areas where efficiencies can be realized and costs minimized (for more information see [#7 above](#))
 - **Cons:**
 - If not owned, requires purchase, maintenance, and replacement costs.
35. **Equipment needed for making liquid products:** In order to make and store liquid products, operations minimally need 1) an open top mixing tank, 2) a holding tank, 3) pumps to transport liquid from mixing tank to holding tank and from holding tank to the applicator tank, and 4) a salimeter or a hydrometer to measure the salinity or density of water, respectively. If the tanks are not double walled, then some sort of secondary containment structure is required.
- **Pros:**
 - With the proper equipment, liquid products can be made accurately and ready for use when needed. Accurately prepared liquid products (i.e., the proper eutectic concentration) allow efficient product use, and reduce associated costs and impacts (public health, environmental, and infrastructural).
 - Having liquid products on hand, [anti-icing](#), [pretreating](#), [prewetting](#), and [direct liquid application](#) are all possible. Click on the links to see the associated “Pros.”
 - **Cons:**
 - The equipment needed to make liquid products comes at a high cost. Because of the need for specific equipment, it may take more than one winter season to recover the investment.

²² Table 21 of Clear Roads 2015b shows the costs and benefits of various plowing types/techniques. http://clearroads.org/wp-content/uploads/dlm_uploads/Manual_ClearRoads_13-01_FINAL.pdf

Transportation Audiences

36. **Automated Vehicle Location (AVL)** can track the position, spreader rate, and plow activity of different snow plows in the fleet. With this information, it can show results live to supervisors, other plow operators, and the public. All of the data collected can be reported to a database.

- **Pros:**
 - Can increase efficiency/reduce waste in operations, reducing the costs and impacts of deicers (public health, environmental, and infrastructural).
 - Provides information to ensure and possibly improve the achievement of levels of service and safety.
 - Providing the location of plow trucks can inform the public of service expectations. This has the potential to limit resource strains during a winter storm event.
 - The City of Eagan, MN realized with AVL, snowplow operators could inform police of cars remaining on streets during emergencies. This improved the mechanical removal of snow.²³
 - Reduces the paperwork associated with operations, and associated costs.
 - Records deicer use, which provides information to evaluate whether or not target application rates were achieved, and highlights areas where efficiencies can be realized and therefore costs minimized (for more information see #7 above). Can also provide information for post-storm (see #29) or post-season meetings that can result in more efficient operations.
- **Cons:**
 - Costs associated with hardware and software are high, and therefore may take more than one winter season to recover.

37. **Maintenance Decision Support System (MDSS):** Using existing and new data (weather, road conditions, etc.) this tool, originally developed by the Federal Highway Administration, integrates data and generates diagnostic and prognostic maps of road conditions, in addition to a decision support tool that provides recommendations on road maintenance actions (e.g., treatment types, timing, rates, and locations).

- **Pros:**
 - Can reduce deicer use, improve scheduling/assignment of personnel, and generally improve decision making, thereby reducing associated costs and impacts of the deicer (public health, environmental, and infrastructural).²⁴
 - Can reduce the number of vehicle round trips to meet levels of service, thereby providing more prompt levels of service and safety at a reduced cost.
 - Can also work as an effective training tool through simulated services.
 - Provides an evaluation tool for performance measures, thereby providing information for post-storm (see #29) or post-season meetings that can result in more efficient operations.
- **Cons:**
 - Requires good weather prediction inputs and properly sited, appropriately maintained environmental sensor stations. If input information is inaccurate, then the MDSS will generate unreliable outputs.
 - There are costs associated with MDSS (unknown at this time as the vendor transitions from research to production), weather forecast provider, and internal agency support costs (e.g., computers, training, etc.).

38. **Precision Deicing:** This new technology is being piloted by [Oak Ridge National Laboratory](#) in Knoxville, and integrates LIDAR data, road condition index (severity based on road angles/curves and solar radiation),

²³ MPCA, 2016 – <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

²⁴ For the Minnesota DOT the use of MDSS in conjunction with AVL had an average savings of 53% or \$2,308,866, which is equivalent to a reduction of 38,000 tons of salt (MPCA, 2016). <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

precipitation data, AVL, and automated spreaders into a MDSS like system. In essence, precision deicing dynamically adjusts application rates of chemicals/liquids based on site-specific, local road conditions and characteristics.

- **Pros:**
 - Can reduce deicer use thereby reducing associated costs and impacts of the deicers (public health, environmental, and infrastructural).
 - Can reduce the number of vehicle round trips to meet levels of service, thereby providing more prompt levels of service and safety at a reduced cost.
- **Cons:**
 - Requires sophisticated and detailed data inputs (e.g., LIDAR) and the collection of that data comes at a high initial cost.
 - While promising and functionally similar to MDSS, the actual benefits and costs are unknown at this time since this is a pilot system.

Salt Storage and Handling

All Audiences

39. **Storage for deicer piles:** Enclose or cover storage piles to prevent exposure to precipitation and situated on an impervious surface. Have stormwater diversions for storage piles. Collect and contain all runoff from the pile and runoff that comes in contact with deicer (including under drain systems) within a bermed basin lined with concrete or other impermeable materials, or within an underground storage tank or tanks. Practice good housekeeping around storage piles.

- **Pros:**
 - Satisfies requirements for any permitted facility.
 - Limits or eliminates wasted product, thereby saving costs.
 - Prevents environmental and public health impacts from deicers that enter the environment.
 - Captured “green brine” can be reused in snow/ice management operations, which can save costs.²⁵
- **Cons:**
 - These storage protections come at a high initial cost.
 - Depending on space availability, these storage provisions may or may not be possible.

40. **Storage for liquid products:** Store liquids in double walled tanks or have secondary containment in case of a leak or spill. Similarly, know the freezing point of the liquid products and prevent product freezing.

- **Pros:**
 - Limits or eliminates wasted product, thereby saving costs.
 - Prevents environmental and public health impacts from deicers that enter the environment.
- **Cons:**
 - These storage protections come at an initial cost (see [#35 above](#)).

41. **Loading/hauling of deicers:** Load deicers under cover and on a level surface. Do not overload spreading equipment to avoid spilling deicer and cover the deicer on the spreader. Practice good housekeeping around the loading area. Where deicer has spilled, recover it and return it to the stockpile.

²⁵ In a Virginia DOT study, compared to the cost of disposal, significant financial benefits were observed when salt storage area stormwater was captured, processed into a brine solution, and used in road maintenance activities. All scenarios analyzed yielded a return on investment in 2-4 years. In this study, the return on investment was greater when the brine was applied directly such as in anti-icing, as opposed to pretreating/prewetting the dry salt (Craver et al., 2008).

- **Pros:**
 - Limits or eliminates wasted product, thereby saving costs.
 - Prevents environmental and public health impacts from deicers that enter the environment.
- **Cons:**
 - These loading protections may not always be possible depending on the site layout or equipment limitations.
 - The equipment needed to cover the deicer on the spreader comes at a cost if not already owned.

42. **Clean equipment and contain wastewater**

- **Pros:**
 - Limits or eliminates wasted product, thereby saving costs.
 - Prevents environmental and public health impacts from deicers that enter the environment.
 - Captured “green brine” can be reused in snow/ice management operations, which can result in cost savings.²⁶
 - Maintains equipment and limits the corrosive impacts of deicers on the equipment, thereby reducing costs and extending the life of equipment.
- **Cons:**
 - Requires additional staff time, which comes at a cost.
 - Requires specially designated wash areas with wastewater containment, which comes at a cost.
 - Management of wastewater comes at a cost. “Green brine,” which is reused for snow and ice management may require processing before it can be used, and this may come at a cost. Wastewater that is disposed of must be done so properly, which comes at a cost.²⁷

Audiences managing parking lots, sidewalks, and properties

43. **Storage of deicers and abrasive piles delivered to a property:** Place deicer and abrasive piles delivered to a property on an impervious surface, and if possible in a covered or indoors storage facility. If no covered or indoor storage facility is available, cover the pile with a waterproof material that prevents interaction between precipitation and stormwater. Locate deicer and abrasive piles delivered to a property up-gradient, out of the path of stormwater/meltwater and away from waterbodies, wetlands, storm drains, and stormwater capture areas.

- **Pros:**
 - Limits or eliminates wasted product, thereby saving costs.
 - Prevents environmental and public health impacts from deicers that enter the environment.
- **Cons:**
 - These storage protections come at a low cost, but may present logistical challenges.
 - Selecting the appropriate site may close off areas of the property that have high usage.

²⁶ In a Virginia DOT study, compared to the cost of disposal, significant financial benefits were observed when salt storage area stormwater was captured, processed into a brine solution, and used in road maintenance activities. All scenarios analyzed yielded a return on investment in 2-4 years. In this study, the return on investment was greater when the brine was applied directly such as in anti-icing, as opposed to pretreating/prewetting the dry salt (Craver et al., 2008).
<https://journals.sagepub.com/doi/pdf/10.3141/2055-12>

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<https://journals.sagepub.com/doi/pdf/10.3141/2055-12>

44. **Storage and handling of deicer bags:** Protect deicer bags from precipitation, and locate them up-gradient, out of the path of stormwater/meltwater and away from waterbodies, wetlands, storm drains, and stormwater capture areas. When done with the deicer bags, dispose of them in a lined/contained receptacle.
- **Pros:**
 - Limits or eliminates wasted product, thereby saving costs.
 - Prevents environmental and public health impacts from deicers that enter the environment.
 - **Cons:**
 - These storage protections come at a low cost, but may present logistical challenges.
 - Selecting the appropriate site may close off areas of the property that have high usage.

Winter Maintenance Planning

All Audiences

45. **Develop a Winter Maintenance Plan:** and Review the Winter Maintenance Plan with crew and managers. Include the following components:
- Defined service area(s), levels of service, and communication plans for the levels of service (see [#s 8-10 above](#)).
 - Outlined operational procedures for pre-winter activities, pre-storm planning procedures, during storm procedures (including application rate guidelines), post-storm procedures, and post-winter procedures.
 - Established goals for reducing negative impacts of deicers. In this evaluation identify any salt sensitive areas (e.g., drinking water source water watersheds) for special protection.
 - Inventory resources and evaluate improvement opportunities. Resources should include, but are not limited to existing equipment, types of winter materials and their use, storage facilities and storage/handling practices, and BMPs currently in use.
 - Identify opportunities for improvement and develop a timeline and objectives for achieving those improvements. Identify new equipment needs and develop a long-range capital investments plan.
 - Establishment of a training program to foster efficient operations and pursue long-term goals.
 - Plans for a continual improvement process specific to the operation.
 - **Pros:**²⁸
 - Provides a practical guide for all operational staff and managers to implement.
 - Plan can be communicated to applicable stakeholders (e.g., elected officials, property managers, attorneys, etc.), to improve understanding/support.
 - Outlines opportunities, goals, and plans to guide operational improvements for more efficient attainment of levels of service and safety. Additionally, the efficiencies will provide for more efficient deicer use, thereby reducing the associated costs and impacts (public health, environmental, and infrastructural).
 - **Cons:**
 - Requires an investment of time and planning, with associated costs.
46. **Preseason meetings:** Before the winter, hold a meeting to review the Winter Maintenance Plan, highlight any changes in operations, and revisit lessons learned from post-season meetings (see below). Where possible hold these meetings with the maintenance crew, supervisors, and management/property manager(s). Large and

²⁸ Many of the success stories in Minnesota's Chloride Management Plan reflect the benefits of holistic winter maintenance planning that identifies opportunities for new BMPs that can provide reductions in a number of areas (e.g., use of liquids before and during storms, AVL, training impacts on operator's practices, forecasting services, etc.). For examples of program benefits from the planned incorporation of multiple BMPs into an operation see section 3.5 of Minnesota's Chloride Management Plan for these success stories (MPCA, 2016). <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>

geographically spread operations may be better suited by having pre-season meetings for each operations office.

- **Pros:**
 - Provides an opportunity to coordinate operations across different levels of the operation/region.
 - Provides an opportunity for advanced planning and to identify changes or issues that need resolution prior to the season.
 - For operations that rely heavily on contractual staff, this may be a more viable opportunity to discuss coordination and plans than prior to storms.
 - This process can lead to more efficient achievement of levels of service and safety and/or more efficient deicer use, thereby reducing associated costs and impacts (public health, environmental, and infrastructural).
- **Cons:**
 - Requires dedicated time for meeting, with associated costs.
 - It may be difficult to schedule a meeting where all operations staff can attend.

47. **Postseason meetings:** After the season is done, evaluate how well the season went, what worked, and what could be changed to improve operations. Where possible hold these meetings with the maintenance crew, supervisors, and management/property manager(s). Large and geographically spread operations may be better suited by having postseason meetings for each geographically different office.

- **Pros:**
 - Provides an opportunity for all members of the operation to share insight/observations.
 - Provides a process for a continuous improvement.
 - Provides a group learning opportunity that may be more tailored and specific than general training.
 - For operations that rely heavily on contractual staff, this may be a more viable opportunity to discuss coordination and plans than prior to individual storms.
 - Insights gained from this process may lead to more efficient attainment of levels of service and safety and/or more efficient deicer use, thereby reducing costs and impacts (public health, environmental, and infrastructural) related to deicers.
- **Cons:**
 - Requires dedicated meeting time, with associated costs.
 - It may be difficult to schedule a meeting where all operations staff can attend.

48. **Accountability at every level** of the operation provides for shared ownership and insights into all parts of the operation. The Winter Maintenance Plan should clearly state everyone's accountability. Management is accountable for decisions on storm response (i.e., type of material, number of deployed operators, etc.). Operators are responsible to follow these decisions and work within the operation's guidelines/policy. Accountability is reinforced through pre- and post-storm meetings (see [#29 & #30 above](#)), measuring deicer use with as much detail as possible (see [#7 above](#)), and maintaining records of the deicer use and other objectives/performance measures. This information supports continual improvement, where storm-by-storm and season-by-season evaluations identify opportunities for improvement.

- **Pros:**
 - Provides a mechanism to evaluate performance and identify corrective actions/operational adjustments.
 - Provides a known structure of policy and accountability so that actions are planned and not reactive. In other words, the policy is known and decisions are accountable.

- In some cases with safety in mind, operators may choose to use more deicer than conditions and policy call for. Detailed measurement of deicer use provides a mechanism to identify these situations. In this way it has the potential to reduce the costs and impacts (public health, environmental, and infrastructural) related to excess deicer use
- **Cons:**
 - Challenges for holding pre-and post-storm meetings and measuring deicer use are described in [#7](#) and [#29 & #30 above](#).
 - Reducing flexibility to deviate from policy may result in delayed achievement of levels of service and safety. Operators may react poorly to reduced discretion in application rates.

Transportation Audiences

49. **Plan snowplow routes:** As a part of a Winter Maintenance Plan for an operation managing roads, plan each snowplow route strategically to maximize efficiency. Consider cycle time and levels of service when planning each route. Where possible, avoid having separate routes cross so that deicers are not plowed off and reapplied. Where routes must cross and where other special circumstances are known, highlight this information in the Winter Maintenance Plan.

- **Pros:**
 - Provides the operators with clear expectations and accountability.
 - By strategically planning snowplow routes, levels of service and safety can be achieved more efficiently. This allows for optimizing the amount of deicer used to meet the levels of service and safety, reducing associated costs and impacts (public health, environmental, and infrastructural).
- **Cons:**
 - It is not always possible to plan for efficient snowplow routes given the layout of the road network. Nonetheless, planning routes, documenting their characteristics, and identifying circumstances that may need special attention is beneficial.
 - Requires an investment of time and planning, which comes at a cost.

Audiences managing parking lots, sidewalks, and properties

50. **Visit the property before the season** and walk the property with the property manager. Inspect the property for challenging areas, deicer storage areas (if applicable), drainage issues (e.g., roof that drips on steps, downspout directed at a sidewalk, low spots/collection areas, etc.), and clogged storm drains. Inventory issues (particularly drainage issues) and report to property manager for repair.

- **Pros:**
 - Provides an opportunity to know the property and plan accordingly before the first storm of the season. With this advanced knowledge, spread patterns, equipment needs, and other considerations can be planned so that levels of service and safety can be achieved more efficiently, thereby reducing the associated costs and impacts (public health, environmental, and infrastructural) of deicers.
 - Provides an opportunity to highlight problems with the property manager, and document and resolve them. As a result it is more possible to achieve of levels of service and safety goals and minimize potential liability claims.
- **Cons:**
 - Requires an investment of time and planning, which comes at a cost.

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