# Making Winter Driving Safer – Establishing Performance Standards for Winter Maintenance

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**ABSTRACT**

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In a series of collaborative trial projects that started in the winter of 2013/14, Alberta Transportation and the province's highway maintenance contractors developed and tested performance standards for winter highway maintenance. Drivers will benefit from the introduction of performance standards for winter maintenance through anticipating, and experiencing, more consistent driving conditions during the winter. Performance standards will also allow consistent educational and public awareness messaging, which will in turn promote safer trip planning.

Various types of performance measures are either in place or are being tested in Alberta, ranging from input measures (i.e. material stockpiling) through process measures (i.e. response times), output measures (i.e. time to return to specified conditions), surrogate outcome measures (i.e. surface friction) and true outcome measures (i.e. travel speeds). Alberta benefited from experience with established technologies like Automated Vehicle Location Systems, Traveler Information Systems, and precision forecasting/Maintenance Decision Support Systems when developing the trial performance standards. In addition, supporting management tools were developed as part of the performance standards trials. These include a Winter Severity Index that can be used on both provincial & local scales, and Storm Classification that allows the contractors to work towards different performance targets, depending on the severity of each storm event.

The paper will describe performance standards that are under development for various phases of winter maintenance work planning and execution, and discuss some of the implications of using performance standards in a contracted delivery system. Results of the different trial projects are presented, with concluding remarks on the safety benefits from the introduction of formal performance standards.

# Making Winter Driving Safer – Establishing Performance Standards for Winter Maintenance

## Introduction

Winter weather conditions create seasonal hazards for drivers and affect traffic flow (Camacho *et al*, 2010), and the risk of collisions can be directly related to maintenance of roads and highways (Kuemmel & Hanbali, 1999). Adverse winter driving conditions have been shown to result in slower travel speeds (Roh *et al*, 2013), while effective winter maintenance can restore travel to normal conditions and reduce the risk of collisions (Fu, 2012: Usman *et al*, 2012).

Since 1996, Alberta's provincial highway maintenance services haves been delivered by contractors working for the province. The contractors are required to do regular inspections and report on highway conditions, provide snow removal and ice control equipment and trained operators, then plan and deliver the optimal maintenance strategy to remove snow and icy sections. Alberta's contracts pay for snow removal and ice control work on a unit price basis – the contractors are paid an hourly unit rate to do the work. Our contracts do not have an outcome performance standard for winter maintenance, and it is common to have inconsistent driving conditions between contracts, and even between shops within a contract. Without a performance standard that identifies when the highways are in the desired condition, there have also been instances where the contractor continues working past the point where the department feels that it is necessary, at an unnecessary cost to the taxpayer. To address these concerns and promote improved safety and consistency in winter highway maintenance, Alberta Transportation initiated a series of trial projects during the winter of 2013/2014 to identify potential improvements to improve safety and winter driving conditions by introducing performance standards.

## Performance Standards for Winter Highway Maintenance

For winter highway maintenance, performance standards (also known as key performance indicators) are an objective measurement used as part of a performance management system. Table 1 describes how performance standards can be used to measure all stages of maintenance work, with examples for

winter maintenance (Otto & Ariaratnam, 1999). A performance standard can be used to measure the input, process, output, or outcome of maintenance work.

Alberta Transportation has input and process performance standards in maintenance contracts, with examples shown in Table 1. The trial projects started in 2013/14 were developed as "proof of concept" for new output, surrogate outcome and outcome performance measures.

Input and process performance standards

Like many other transportation agencies, Alberta Transportation has used input and process performance measures for many years without specifically identifying them as part of a performance standard-based management system. Table 1 gives examples of performance standards for common maintenance activities. These activities are all widely practiced steps that help the agency to prepare for efficient winter operations (The Salt Institute, 2013), and the measurement of these activities can range from a simple note in the foreman's diary that the work was completed by a certain date, to formal data entry into an agency financial tracking systems as milestones are reached.

Input performance standards measure things that have to be done to get ready to do winter maintenance. Process performance standards measure accomplishments while the maintenance work is being done.

Alberta Transportation did not conduct any trial projects of input or process performance standards.

Output performance standards

An output performance standard measures the condition of the highway when the contractor has completed winter snow removal and ice control work, or measures the time required to meet an output condition.

Examples of output performance standards are "bare pavement", "100% of arterial roads plowed within 6 hours", and "returning the road to a specified condition within a specified time limit".

Bare pavement Alberta Transportation has two output standards for winter maintenance. In our Private/Public Performance (P3) contracts on the Edmonton and Calgary ring roads, the performance

standard is bare pavement in the travel lanes and all loose snow removed from the rest of the paved surface, within a specified number of hours after the end of the storm. For most of the winter, the contractor is able to meet the performance standard, but each winter there are a handful of storms where bare pavement is not possible in a few hours, no matter how well the contractor has done the work during and immediately after the storm. The major issue with this performance standard is that the "end of the storm" is not defined in the contract, so there can be a difference of opinion when the allowed time is over. A winter storm often has precipitation taper off over several hours while there is still active drifting, or can have snow start and stop several times as flurries move across the area. And local conditions may vary within the contract area, so that the start of the allowable time can vary widely depending on where an observer is checking.

Good Winter Driving Conditions On our rural highway maintenance contracts, the performance standard is similar to the P3 contracts, but the contractor is expected to try to return the highway to a defined "good winter driving condition" within a certain number of hours after the end of the storm. This performance standard is not a contractual requirement, and the highway maintenance contractors are not required to meet the standard. Table 2 shows this output performance standard, from the Alberta *Highway Maintenance Guidelines and Level of Service Manual (2010)*. Table 2 has not been updated since 1994, when the department did the work with its own employees and equipment.

There are several problems with Table 2 as an output standard. As in the P3 contracts with the bare pavement standard, the "end of the storm" is not defined. Another drawback is that it does allow for atypical weather events. It is normal to have several heavy snowstorms every winter, where the level of precipitation or drifting is greater than the contractor can handle. Even when the contractor is doing the best possible work with the resources required in the contract, there will be times when this performance standard cannot be met.

As a trial, one contractor is classifying winter storm on a scale of severity. The idea for this came from the City of Toronto, which allows a different number of hours for clearing sidewalks depending on weather conditions during a snowstorm. The Alberta trial scale, shown as Table 4, has been used for 1 winter and has been accepted by the equipment operators as a realistic goal. Table 4 also describes the definition of "end of the storm" used in this trial.

Output Performance Standard Trial Project The times in Table 2 have not changed for decades, and are not representative of how the work is actually being done in Alberta. Part of a trial project involved the

contractor recording the exact time that each section of highway had returned to a bare condition after a storm. In this trial, the performance standard included a new definition for the 'end of the storm', shown in Table 3. The end of the storm is taken at each shop, resulting in different times recorded across the contract area. Even though the official 'end of storm' time changes for each shop, it is manageable for shop-based record keeping and is very understandable by the foreman and crew. The performance standard for pavement condition was chosen as reported "bare" (either bare & wet or bare & dry) as defined in the TAC *Road Condition Vocabulary Study Phase 1 (Final Report, 2010)*. The contractor is already reporting using the TAC condition vocabulary, so it made sense to use those highway conditions to define the desired standard, rather than "good winter driving conditions" as shown in Table 2.

Alberta's contractors use an automated vehicle locator system (AVLS), and the check on the time that the highway was in "'bare" condition was confirmed by monitoring when the plow trucks stopped work. Pavement conditions observed at Road Weather Information System (RWIS) stations were used as another way to spot check that the highway condition was being updated accurately.

This trial project started in the winter of 2014/15, and preliminary results are given in Table 3. A major observation from the trial to date is that there is much less variation between highway classes defined by traffic volume alone; several classes of highway shown in Figure 1 had the same performance. Another observation is related to the time required to reach "bare" conditions and how the contractor reports on road conditions: shops where the foreman is the only person authorized to update condition reports showed a greater range of times than in shops where operators were also able to update the reported condition. In the future, it is likely that the contractor will train all employees to report on highway conditions. This trial was only able to record data for a small number of storms in the late winter, when shorter storms and more isolated flurries are common. It is expected that these results could change slightly as more data is collected next winter and the data set will include the multi-day, low intensity storms characteristic of the December – February period. It is interesting to note that the time to restore all highways to bare conditions was about 2 hours after the end of the storm, which is the same performance standard used for winter maintenance on Ohio interstates.

The trial is planned to continue next winter, with a simpler performance standard using fewer highway classes, based on the highway's functional classification.

Outcome performance standards

An outcome performance standard measures the direct benefits of doing winter maintenance work. The obvious performance standard, with a direct relationship as described in several of the references quoted in the introduction, is the reduction of collisions and subsequent economic benefits to the public from not having to travel on roads that are snow covered or slippery. Having an outcome performance standard using collision rates can be a valid part of long-term management of resources and funding for the highway network, but has limited application for the management of maintenance operations – the number of collisions is not large enough to show measurable differences on anything but a long time-frame. There just aren't enough collisions in the short term to accurately indicate whether a particular day's winter maintenance had a statistically significant effect on collision rates.

Another option is to choose an outcome performance standard that is directly related to the effect of winter conditions on the driver. Theoretically, perfect winter maintenance would mean that there was no effect on driver behaviour, trip planning or travel times. At least in Alberta, it certainly seems that the public's expectations are that there should not be any difference between driving conditions year-round; field staffs from both the contractors and department regularly recount of hearing from frustrated drivers that winter conditions on the highway were unexpected, and the fact that the driver had to slow down or change trip plans meant that there must not have been any effort to do effective maintenance.

It is important to link outcome performance standards with the priorities of the road user; drivers in private and commercial vehicles. It can be difficult to find a performance standard that can be measured objectively and often enough to provide data that is useful to the agency (Transportation Research Board, 2010). Public expectations are usually linked to the effect that winter road conditions have on drivers – if drivers can travel at the same speed and level of safety during the winter as they would during the rest of the year, then the road agency can reasonably conclude that winter maintenance has been effective. Obviously, some winter conditions (i.e. long dark nights, ice fog, increased number of wildlife traveling along the highway) will affect drivers in ways that cannot be helped by any amount of maintenance work. But effective and timely winter maintenance can result in conditions that allow travelers to plan a trip with the expectation that winter travel is effectively the same as summer travel. A performance standard that measures when drivers can travel at the same speed, on the same route, is an effective indicator of the effective outcome from winter maintenance.

An earlier research project in Alberta looked at the reduction in travel speed as a result of winter weather. Earlier research had indicated that this was a promising but subtle measurement of the outcome of winter maintenance (Kilpeläinen & Summala, 2007 and McClintock, 2014), with drivers slowing down by only a few kilometres per hour as compensation for snow covered or slippery conditions. The research project involved the use of cellular phone probe data to calculate average vehicle speeds on selected sections of highway. Unfortunately, the project could not be completed when the cellular phone data was not supplied by the phone company in a usable format. Further research may be scheduled if other surrogate outcome performance standards are not feasible.

Surrogate outcome performance standards

Pavement friction A surrogate outcome performance standard measures a condition or achievement that is not directly related to the desired result of doing winter maintenance, but can be useful if it is difficult or impossible to measure the desired result directly using a cost-effective and robust method.

Alberta trials in 2013/14 and 2014/15 looked at the use of surface friction as a surrogate measure. The theory is that if drivers can feel that their tires have similar grip on a highway in winter, they will use the same driving habits as they do in summer conditions. Mobile road condition sensors from Vaisala 2013/14 and 2014/15) and Luft (2014/15) were used to collect surface friction in all seasons, to establish a 'good weather' benchmark and the surface friction of both untreated and treated highways during winter events. Figure 1 shows the Vaisala sensor mounted on a small truck. To date, most of the data collected was using the Vaisala sensor, with the Luft sensor being added to the trial to evaluate the variation between different manufacturer's products.

Figure 2 gives the preliminary friction measurements from the Vaisala sensor for various pavement conditions. The initial results indicate that a mobile pavement sensor gives continuous, consistent measurement of air and pavement temperatures and the presence of snow, ice, liquid film thickness and a proprietary friction measurement, for all conditions when operated at highway speeds. While the trials are continuing, the preliminary conclusion is that pavement friction is a valid surrogate outcome performance standard.

There are drawbacks to using a mobile pavement condition sensor to measure a surrogate performance standard. The most obvious problem is that the sensor only measures pavements that it has passed

over, and it is not possible to collect network-wide data in real time without deploying a very large number of sensor-equipped vehicles. Another, less obvious drawback is that the sensor calculates pavement condition based on reflected light energy, and the algorithm does not take into account the positive effect of abrasives on tire friction – in other words, the sensor doesn't give any credit for a sanded surface. Especially in very cold conditions when de-icing chemicals are marginally effective, the current practice in Alberta is to use sand for an immediate improvement in surface friction until the pavement/ice can be broken chemically. If mobile sensors are adopted as the way to measure a surrogate outcome performance standard of pavement friction, then the allowance for below-standard conditions will have to be increased in compensation for benefits of maintenance treatments that cannot be measured by the sensor.

Visual inspection Another way to measure a surrogate outcome performance standard is the use of visual condition rating. The basis for using visual ratings as a surrogate measure is that drivers will experience less effect from winter conditions on bare or partially covered surfaces, compared to snow or ice covered roads. Visually rating the road condition is a valid, low tech way to measure a performance standard that requires restoring the network to a specified condition within a certain amount of time. Proper training and a quality assurance process can ensure that the visual ratings are consistent and accurate.

Using visual condition ratings has the same drawback as a mobile pavement sensor, in that it requires someone to drive over the road in order to rate it. This could be partially addressed by expanding the number of trained persons who can report conditions, using crowd-source reporting like the Utah Department of Transportation's "Citizen Report" app for mobile phones. This app allows members of the public, who have taken on-line training and demonstrated the skill to correctly make visual condition ratings, to submit reports at any time directly to the state Traveler Information System. In 2015, Alberta Transportation is planning to build a similar capability into the 511Alberta traveler information system.

Management Support Tools

Maintenance Decision Support System (MDSS) In 2013, Alberta Transportation added an MDSS service to the precision forecasting provided to all contractors. At this time, use of the MDSS is not a contract requirement, but the recommendations of the system are used by the department in post-storm reviews and several contractors use the MDSS heavily to confirm their daily work assignments. Alberta's

MDSS experience is that the system still has a lot of unrealized potential, but even with the current inconsistent use it already provides a cost-effective tool to improve winter maintenance.

Winter Severity Index In the winter of 2013/14, Alberta Transportation and the University of Waterloo started a pilot research project to adapt the Winter Severity Index developed by the Transportation Association of Canada in 2007 for Alberta conditions. The earlier work had used salt consumption as the independent variable to test the model, but in Alberta the variable was the daily total plow truck hours of operation. The pilot project for the Grande Prairie district had very promising results, and the project was expanded in 2014/15 to test the Index on larger geographic scales, from sub-sets of a regional network to the whole province. With modifications developed in the second year of the project, the Index gave a very reliable indication of the differences in winter conditions across space and/or time Figure 3 shows a representative match between plow truck hours and the Index within a contract area, calculated on 2-week intervals, in north-central Alberta. Alberta Transportation have adopted the Index for regular use, starting the winter of 2015/16. The initial use of the Index will be for public communications, to describe objectively how the winter weather compares to previous years. Not part of the current contracts, but a possibility in future contract specifications, is using the Index as the basis of a seasonal reconciliation of contractor payments to reflect the increase, or decrease, in the total amount of work required over the winter.

The MDSS and Winter Severity Index are not performance standards, but they do provide additional information for managing winter maintenance to meet a performance standard. For example, if a shop is consistently not meeting an output performance standard (i.e. clearing 100% of all roads within a specified number of hours), managers can review whether the crew in that shop have been doing winter maintenance treatment at similar times and application rates as recommended in the MDSS. This review could identify gaps in training and maintenance decision making at the local level that contribute to the failure to meet a performance standard.

## Implications for use of performance standards in contracted delivery of winter highway maintenance

When the road agency delivers highway maintenance services using contractors to do the work, the terms of the contract must clearly describe the agency's expectations for what the contractor has to do. Traditionally, this has been done through a process specification, which assumes that if the contractor does the work exactly as described in the specifications, the quality of the finished product will meet the

agency's expectations. Another option is to use an end-product specification, where the work procedures and materials used by the contractor are not specified; instead the contract specifies quantitative measures for the finished product or condition. This is an output performance standard, and has been used quite successfully by Alberta Transportation for paving and grading projects since the early 1990s. One drawback of an output performance standard is that once the finished product has been accepted by the agency, the contractor is no longer responsible for long-term condition of the work (although there may be warranty provisions in the contract to set standards for the condition of the finished work for a short time after completion).

As noted previously, outcome performance standards, or surrogate outcome performance standards, are more difficult to develop since there is not always a clear relationship between the finished product and the customer's expectations (for highway maintenance, how drivers are effected by winter maintenance). The potential advantage of an outcome (or surrogate outcome) performance standard is that it allows the contractor complete freedom to choose work procedures and select materials, as long as the performance standards are met. This gives the contractor an incentive to develop a culture of innovation and efficiency that is not possible in a contract with process or end-product requirements.

For performance management in a highway maintenance contract, performance standards must clearly describe the following criteria:

1. The road agency's expectations for the results of the maintenance activity,
2. The specific conditions that will be measured,
3. How the measurement will be done,
4. Consequences to the contractor for failure to meet the performance standard within the specified deadline, and
5. Any special considerations required to protect the safety of the traveling public.

The fourth criteria does not apply if maintenance is done by agency employees and equipment. The last criterion is necessary to ensure that the performance standard is met in a way that does not increase the risk to the public.

> An example from summer maintenance is for the line painting activity; in Alberta line painting crews must use vehicles with warning signs and flashing lights, and the contractor is expected to use highway accesses to keep the line painting equipment out of the travel lanes as much as possible. These requirements protect the public who are driving near the work zone, but are

not needed to meet a performance standard for the lines themselves (i.e. width, colour, uniform application and retro-reflectivity).

Next Steps for Alberta Transportation

Alberta Transportation will start development of new specifications and contract administration procedures in the fall of 2015, with revisions and supplementary changes introduced as more data is collected and the new specifications are tested in actual contract conditions. Based on the results of the winter maintenance trials, it is likely that winter maintenance contract requirements will be based on a combination of performance standards:

- Input performance standards for material stockpiling, regular inspections and seasonal preparation for winter, to address the risk to public safety if the contractor is not prepared for, or aware of, winter conditions,
- Process performance standards, like dispatch times once snow or slippery sections have been identified, and time between plowing or spreading treatments,
- Output performance standards using visual condition ratings that require the contractor to reach bare conditions within a specified number of hours after the end of the winter event, and
- Surrogate outcome performance standards for pavement friction, that require the contractor to keep working, whether they meet the output performance standard or not, until the network has reached an overall minimum surface friction score (likely 0.5 on the Vaisala sensor scale).[1]

Because the contractor knows ahead of time how Alberta Transportation will measure success in meeting the performance standard, the contractor's employees can do their own measurements in advance of the department's and adjust their work plans accordingly. Using objective performance standards removes the potential for conflict between individual interpretations of conditions and the contract requirements.

[1] This performance standard applies to paved highways. Alberta Transportation is not working to develop a outcome performance standard for gravel surface highways at this time.

Performance Standards and Traveler Safety

Drivers can be held accountable for not adjusting their behaviour to actual, or foreseeable, conditions (Legal Tree Project, 2015). When a road agency uses a performance standard for winter maintenance, it allows the agency to consistently communicate to drivers what highway conditions they can expect for different winter weather. This communication can be general, on a traveler information system or through the media, tailored to a specific audience, and used during one-on-one conversations. For a performance standard that does not need specialized equipment or training to measure, the general public may be able to make their own, unofficial, measurement of local conditions. This would allow drivers to judge whether the performance standard is being met, and adjust travel plans accordingly. The biggest benefit to the introduction of a comprehensive set of performance standard for winter maintenance will be increased consistency of road conditions. As noted in the introduction, Alberta highways frequently different driving conditions because different maintenance supervisors and foremen make their own, individual decision when enough work has been done and it is acceptable to take a break. An objective performance standard will not be affected by the amount of experience of an individual measuring conditions, the history of maintenance practices in the area, or the cost of materials and labour. More consistent driving conditions will lead to more consistent trip planning and driving habits, contributing to safer winter travel.

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Table 1: Performance Standards for phases in the maintenance work cycle

| Type of Performance Standard | Description | Typical winter highway maintenance activities | Examples of Performance Standards |
|---|---|---|---|
| Input | Measures conditions necessary to begin work | 1. Tonnes of salt in stockpile* | Stockpiling completed by specified date |
| | | 2. Preparation of equipment for winter work* | % of fleet serviced and rigged for winter operations by specified date |
| | | 3. Winter Road Patrols* | % of Road Condition Inspection Reports submitted on time |
| | | 4. Inspect plow circuits for hazards | Snowfighting Plan prepared & approved |
| | | 5. Pre-season stakeholder consultation* | Meetings with police, other departments, media, etc. completed by specified date |
| | | 6. Contracted equipment lined up to supplement core fleet | Number of contracted pieces of equipment on stand-by as of certain dates. |
| | | 7. Cost-effective preparation for winter operations * | Cost of materials, training and equipment preparation |
| Process | Measures condition while work is under way | 1. Timely reaction to winter events * | Response time to dispatch equipment |
| | | 2. Circuits done on time | Time that circuits completed |
| | | 2. All roads plowed or treated on time | % of network treated by specified deadline |

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|---|---|---|---|
| | | 3. Effective use of winter equipment * | Number of snowplows, graders, loaders and sander/anti-icing units in use |
| | | 4. Quantity of winter materials used | Tonnes of salt and abrasives used |
| | | 5. Cost for operations* | Expenditures reported regularly, in approved format |
| | | 6. Efficient planning of winter work | Use of precision forecasts and MDSS for prioritizing tasks |
| Output | Measures the condition of the completed work | 1. All roads plowed or treated in desired amount of time | Time that plowing or spreading completed on the last road in a shop or district area |
| | | 2. All roads plowed or treated in time desired | Number of kilometres of road cleared by a specified deadline |
| | | 3. All roads returned to specified condition by a specified deadline | Time last road reported in specified condition (i.e. Centre – bare) |
| | | 4. Removal of accumulated snow | Tonnes of snow removed, as of certain date |
| | | 5. Roads open for travel | Number of road closures during specified time frame (week, month or whole season) |
| | | 6. Snow & ice removed from driveways, gores, ramps, alleys, etc. | Time that post-storm cleanup reported complete on last road |
| Surrogate Outco*m*e | Indirectly measures improvements that result from completing the work | 1. Slippery conditions are treated quickly after a winter event | # hours that roads are below a specified friction value following the end of the winter event |

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|---|---|---|---|
| | | 2. Meeting public expectations for winter maintenance | # complaints from public / police / elected officials |
| | | 3. Meeting public expectations for winter maintenance | # hours overtime worked by postal delivery employees (or civic garbage crews), to complete their regular routes during the winter event |
| Outcome | Directly measures the improvements that result from completing the work | 1. Travel not affected by winter conditions | Total hours of public travel delay as a result of the winter event |
| | | 2. Drivers not affected by winter road conditions | Reduction in average travel speed as a result of highway conditions |
| | | 3. Drivers not affected by winter road conditions | Number of transit routes experiencing delays during the winter event |
| | | 4. Drivers not affected by winter road conditions | Time that scheduled inter-city buses and commercial transport is late as a result of the winter event |
| | | 5. Travel not affected by winter road conditions | Economic cost from lost production (i.e. late deliveries, absenteeism & cancelled shifts, postponed shipments) |
| | | 6. Travel in winter is as safe as any other time of year | Vehicle collision rate in winter months |

NOTE: * indicates performance standard currently in use by Alberta Transportation

Table 2: Winter Level of Service (Rural Highways)

| Class of Highway | Traffic Volume (AADT) | Maximum Reaction Time• (hrs) | Maximum Time to Good Winter Driving Conditions•• (hrs) | Typical reaction Time (hrs) |
|---|---|---|---|---|
| A | > 15,000 | 2 | 6 | 1 |
| B | 7,000 – 15,000 | 4 | 6 | 1 |
| C | 5,000 – 7,000 | 4 | 8 | 2 |
| D | 2,000 – 5,000 | 4 | 8 | 2 |
| E | 1,000 – 2,000 | 6 | 12 | 3 |
| F | 500 – 1,000 | 8 | 12 | 3 |
| G | 100 – 500 | 12 | 18 | 4 |
| H | < 100 | 16 | 24 | 5 |

• Maximum time allowable for equipment to have commenced work from the time of a 3cm accumulation. This value represents the maximum time that will be required to respond after an average winter storm. Normally, equipment will begin work during most storm events and as a result most roads are cleared faster than the maximum time indicated.

•• Good winter driving conditions exist when snow and ice have been removed from the driving lanes and excessive loose snow has been removed from the shoulders and centreline of highway. Short sections of ice and packed snow are acceptable and can be expected within the driving lanes between the wheel paths, as well as on centreline.

An average winter snowstorm is defined as one in which snowfall amounts range between 3 and 8 centimetres, the air temperature is lower than -10°C, the wind velocity is less than 15 kilometres per hour and the road surface is frozen.

From: Alberta Transportation *Highway Maintenance Guidelines and Level of Service Manual (2000)*

Table 3: Results of the Outcome Standard Trial Project

| Class of Hwy | Average Duration of Storm (Hours) | Range of storm durations (hours) | Average recovery to bare conditions (hours) | Range of times to restore bare conditions (hours) |
|---|---|---|---|---|
| A | 7.9 | 1.25 – 10.5 | 2.1 | 0.5 – 6.0 |
| B | 7.1 | 1.5 – 11.0 | 2.3 | 0 – 4.5 |
| C | 6.7 | 2.5 – 10.5 | 1.2 | 0 – 2.5 |
| D | 7.2 | 1.5 – 14.5 | 2.8 | 0.5 – 4.5 |
| E | 6.0 | 1.5 – 14.5 | 2.4 | 0 – 6.0 |
| F | 6.8 | 1.75 – 13.5 | 2.6 | 0.25 – 5.5 |
| G | 6.9 | .25 – 18.0 | 3.0 | 0.5 – 8.0 |

Note: A time to restore to bare conditions = 0 hours means that the surface was bare before the end of the storm

Table 4: Winter Storm Severity and "End of Storm" used in Trials

| *Class of Winter Storm* | *Description of conditions* | *Typical Maintenance Strategies* | *Response Times to normal conditions* *(bare/dry & bare/wet)* |
|---|---|---|---|
| Type 1: Normal | • Total snowfall accumulations less than 5 cm<br>• Snowfall intensity less than 1 cm/hour (may have short periods, less than 45 mins, with heavy snowfall)<br>• Temperature change less than $10^{o}$ from start to end of the storm<br>• Average wind speed less than 15 km/hour, with short periods, less than 45 mins, of gusty or stronger winds (= limited drifting onto travel lanes) | • Regular plowing and spreading of sand/salt<br>• Scheduled inspections continue as normal<br>• Conditions updated on 511Alberta, only local travel advisories for isolated conditions | 4 – 8 hours |
| Type 2: Severe | • Total snowfall accumulations 5 to 20 cms / 24 hour period<br>• Extended period of snow, more than 16 hours of continuous snow or more than 12 hours of precipitation per day for 3 days or more in a row<br>• Snowfall intensity around 1 cm/hour but frequent periods with heavy snowfall > 2cm/hour<br>• Temperature change more than $10^{o}$ from start to end of the storm<br>• Temperature at end of the storm - $20^{o}$ or lower, with daily max temperatures following the storm less than $-15^{o}$ for 3 or more days<br>• Average wind speed 15 to 30 km/hour, with frequent periods of gusty or stronger winds (= widespread drifting covering short sections of the whole highway) | • Priority for plowing on travel lanes & ramps<br>• Increased ad-hoc inspections<br>• Class 1 highways continuous treatment<br>• Class 2 highways treated 3 – 4 times/day<br>• Class 3 & 4 highways treated at least once/day<br>• 511Alberta updated with general travel advisories | 12 – 24 hours |
| Type 3: Extreme | • Total snowfall accumulations greater than 30 cm<br>• Extended period of snow, more than 24 hours of continuous snow or more | • Class 1 highways continuous treatment, travel lanes only<br>• Class 2 highways | 48 – 72 hours |

| | | | |
|---|---|---|---|
| | than 16 hours of precipitation per day for 3 days or more in a row<br>• Snowfall intensity around 1 cm/hour with frequent periods with heavy snowfall > 2cm/hour<br>• Temperature change more than 15$^{o}$ from start to end of the storm<br>• Temperature at end of the storm -20$^{o}$ or lower, with daily max temperatures following the storm less than -15$^{o}$ for 3 or more days<br>• Average wind speed 20 km/hour or higher, with frequent gusts winds (= widespread drifting across all travel lanes for 1 km or more)<br>• Highway closure required for safety of the operators | treated 2 times/day, if physically possible (may be blocked by drifting)<br>• Class 3 & 4 highways not treated until Class 2 highways open<br>• Coordination with local emergency services for snow removal/ clearing on an emergency basis<br>• 511Alberta updated with highway closures, regional travel advisories recommending no travel | |

Definition of the "End of the Storm": W**hen** less than 0.5 cm of snow has accumulated on the travel lane 1 hour after a plow has passed over, **then** the storm ended when the plow passed over that highway.

*Commentary on the Definition: Alberta has a dry cold climate, and snowfall rates of more than 2 centimetres/hour are rare. Whether the snow ends up in the travel lane as precipitation or by drifting, it is normally possible to restore and keep the pavement in a bare & wet or bare & dry condition when there is less than 0.5 centimetres of accumulation in an hour.*

Figure 1: Vaisala DSP310 sensor mounted on small truck

Figure 2: Results of mobile pavement condition sensor measurements

(Vaisala DSP310 sensor, scale of 0 – 1.0)

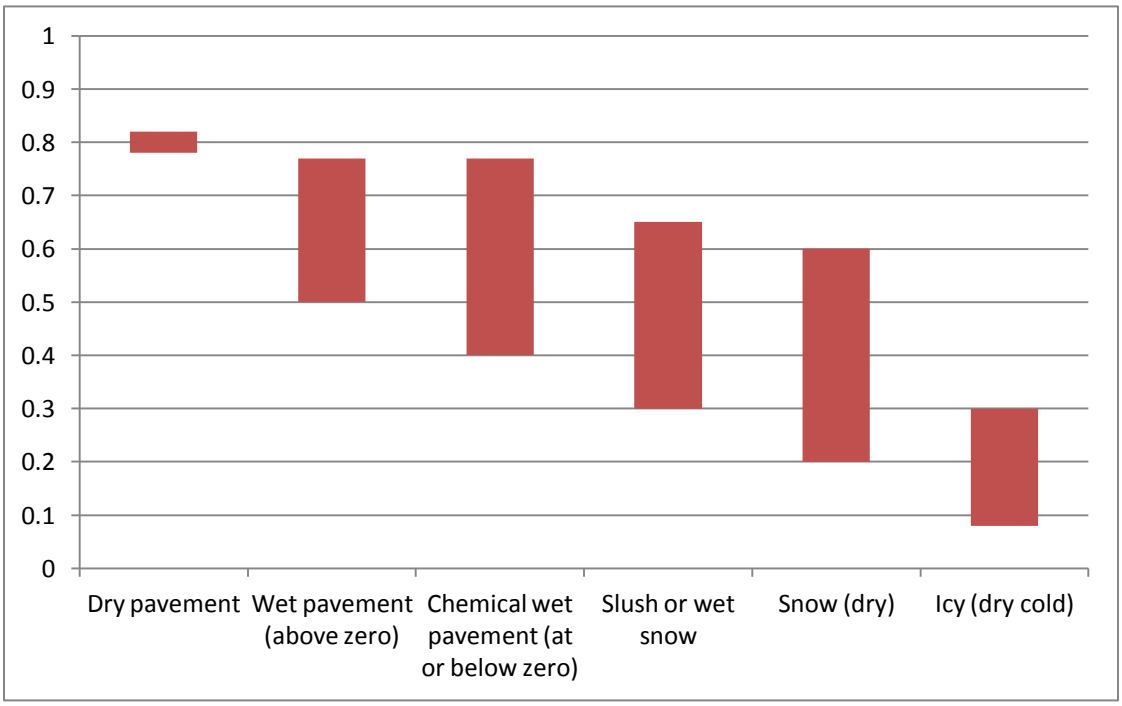
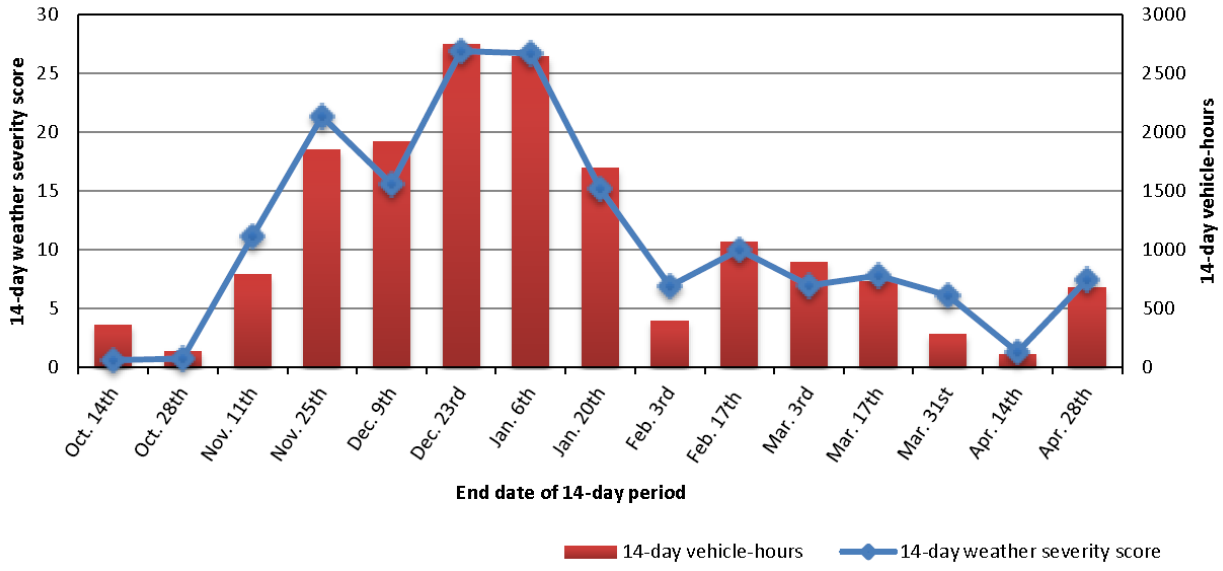


Figure 3: Winter Severity Index for the Carillion Contract area in North-Central Alberta




From: A Winter Severity Index for Alberta Highways (University of Waterloo, Jan 15, 2015)