Review of the Economics of Winter Focused Safety Investments

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ABSTRACT

Past advances in winter maintenance technology have been motivated by a desire to improve operational effectiveness whilst minimizing the impact on the environment. These investments in technology have also resulted in significant improvements to road safety.

This paper considers the impact of investments in Intelligent Transportation Systems (ITS) and Salt Management, including Road Weather Information Systems (RWIS) and Fixed Automated Anti-icing Spray Technology (FAAST). Both technologies have resulted in significant improvements in safety and in the level of service, while reducing the harmful environmental effects of de-icing chemicals. Examples outlined in this paper will include the FAAST site located at the Ontario Highway 416/401 Interchange and the Renfrew Salt Management Plan (SMP) where investments have been made to monitor post deployment performance.

The paper will discuss the objectives, methodologies, and conclusions for both the Highway 401/416 and Renfrew County examples as related to the economics of road safety investments.

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INTRODUCTION

Winter driving conditions are a fact of life in Canada. However, the provision of winter driving countermeasures, their effectiveness, their cost and their impact on the environmental still remain major areas of concern for all stakeholders. Snow removal and de-icing operations are essential to ensure the safety, mobility, and efficiency of winter highways. More than $1 billion is spent annually on winter maintenance including road salts (Transportation Association of Canada, 2002).

Winter weather conditions present increased safety hazards for those who are travelling. The FHWA has stated that “each year there are approximately 1.57 million weather related crashes” and that “about 25% of the non-recurring delays on freeways are due to weather; total system delay is 1 billion hours per year; weather affects about 1/3 of the national GDP and chemical anti-icing and de-icing accounts for roughly 1/3 of the expenditures for snow and ice control.”

Pubic administrators are continually challenged during these times of limited financial resources to make tough decisions on which projects, programs, and winter driving countermeasures provide the greatest benefit and should be candidates for the limited funding available. This paper outlines why advances in winter maintenance approaches and technology should be evaluated in terms of their overall benefit. The advances should be evaluated in terms of their ability to allow safe travel during adverse winter conditions in addition to improvements in maintenance efficiency, productivity and reduction in environmental impacts.

WINTER MAINTENANCE

Although significant advances in winter maintenance have been made in the last decade, both the travelling public and commercial interests continue to demand more improvements. They desire consistent driving conditions and expect that driving conditions will be restored to normal as quickly as possible after winter weather events.

From the maintenance service provider’s perspective, most advances in winter maintenance practices have been primarily motivated by a desire to improve operational efficiency (the same target level of safety at less cost) while minimizing their impact on the environment. A secondary, but no less important, motivation is the desire to improve safety through an increased level of service – as experienced by the drivers (more safety at the same or less cost).

Typically, winter maintenance service providers determine the requirements for the routes within a network and select maintenance treatments which are appropriate for the entire route. From a management, efficiency, and risk management perspective, it is difficult to individually treat select problem locations. However, where these locations have been identified, advanced technologies have helped to mitigate the concerns.

These advanced technologies have been employed to detect critical conditions and then allow the problem locations to be individually (pre) treated. A review of the documentation on the performance of advanced winter maintenance technologies has shown that, in many instances, significant improvements to road safety has been achieved. Although these improvements to safety have been made, safety is not yet one of the more commonly used performance measures for winter road maintenance.

The most commonly used performance measure is the prescribed minimum maintenance standard. This standard is different for each class of roadway. In the case of Ontario, the maintenance level of service is generally defined in terms of the start and frequency of the snow and ice control treatment response. The response must be appropriate for the weather condition.

This being the case, the deployment of advanced winter maintenance technology has historically been sponsored by the maintenance service providers; the primary objective being to assist them with efficiency and environmental management. The improvement of safety during adverse winter conditions should also be considered as a performance measure.

SAFETY

Both the Canadian Road Safety Audit Guide and the companion Canadian Guide to In-service Road Safety Reviews, provide a framework for undertaking reviews on new facilities and existing problem locations. The Guide also provides a mechanism for evaluating and quantifying the potential benefits and costs of a range of countermeasures.

Section 1.3 of **The Canadian Guide to In-service Road Safety Reviews** states :

> *"Collisions are caused when a failure occurs in the interaction between the road user, the vehicle, and the road environment. Incompatibility between a road's intended function and the current demands placed upon it can contribute to this failure. Approximately 30% of collisions are fully or partially attributed to the road environment. However many of the collisions that are attributed to road user errors can be prevented or made less severe by improving the road environment."*

Further, in Section 6.3, of the Guide a wide range of potential countermeasure applications are proposed along with an estimation of their effectiveness. The countermeasure applications do not appear to address improvements to the roadway environment during adverse weather conditions. The suggested countermeasures appear to have only been considered in the context of relatively good weather conditions. Weather has the effect of degrading the road environment from the conditions for which we normally design. Roadway and bridge designs which consider winter conditions provide mechanisms to proactively improve the roadway environment during adverse weather. Advanced technologies, suitability designed and installed can act as a countermeasure for adverse winter road conditions by:

- improving awareness of road conditions by the road maintainer, leading to improved response tactics (eg. RWIS, artificial intelligence);
- improving awareness of road conditions by the driver, leading to improved travel and driving decisions (eg. enroute and pre-trip traveller information systems); and
- dynamic real-time physical improvement to the road condition (eg. FAAST which changes the precipitation state from a solid state to a more manageable wet state - anti-icing instead of de-icing).

This suite of countermeasures extends the designer's capacity to achieve greater safety when geometric design and traffic operations countermeasures have reached their practical or economical limits.

COUNTERMEASURE SELECTION

The dilemma faced by maintenance service providers is that, for each problem location, they must determine to what extent winter driving conditions should improve and how they can detect and treat the condition. In Ontario, the legislated requirement is a minimum maintenance standard which establishes the starting conditions and a frequency of treatment. The standard does not specifically focus on re-establishing optimal driving conditions within a period of time appropriate with the speed of travel, traffic volume, and traffic mix. Rather, minimum standards are established on a network basis and, in certain situations, even meeting those minimum standards may leave residual hazardous driving conditions at critical high risk locations. Without technological assistance, it may be difficult for the road maintainer to remain aware of and treat conditions in a timely fashion.

Having been called on regularly to design these counter measures, Mark F. Pinet & Associates (MFPA) have developed a systematic approach to identifying these high risk locations and selecting appropriate responses from a range of available winter maintenance countermeasures. These countermeasures have proven to provide the appropriate levels of response to produce the desired quality of winter driving conditions.

On a number of projects, MFPA has had the opportunity to evaluate the effectiveness of several of the countermeasures. This paper will review and quantify the economic benefit of various winter maintenance countermeasures which have been implemented and monitored by MFPA.

It is hoped that the information presented in this paper will allow decision makers and safety advocates to work more closely with maintenance service providers in undertaking advanced winter maintenance initiatives and countermeasures. The purpose being to improve operational efficiencies, reduce the resulting impacts on the environment and, at the same time, improve safety on our roadways.

USER NEEDS

The key stakeholders affected on an ongoing basis by adverse winter weather conditions include: maintenance service providers, traffic management and operations personnel, travellers and commercial vehicles.

Table 1 describes the respective stakeholders' concerns and possible countermeasures.

Table 1 - Icing Segments/ Locations

Stakeholder	Concern	Possible Countermeasures
Maintenance Service Providers	• Return to normal LOS quickly • Minimizes Maintenance cost • Maintain safety • Minimum Environmental Impact • Minimize staff resources • Monitor /document conditions	• Basic Reactive Maintenance • Decision Supported de-icing/Plowing • Anti-icing • Automated Anti-icing • Salt Management • Traveller Information • Advanced Warning Signs
Traffic Management and Operations	• Maintain LOS • Minimize event driven congestion • Minimize accident rates • Monitor /document conditions	• Adaptive Traffic Signal Control • Incident Management • Ramp Metering • Traveller Information • Asset management • Variable Speed Limit (VSL) Signs
Travellers	• Predictable travel time • Minimize travel time • Maximize productivity • Consistent, save driving conditions	• Customized traveller information via internet/wireless/ PDAs • En-route alternate route diversion info • Variable Speed Limit (VSL) Signs
Planning and Design	• Analyze condition data • Investigate potential deficiencies • Return to reasonable LOS • Maintain safety • Minimum Environmental Impact • Minimize costs	• Intersection modifications • Corridor reconstruction • New Corridor • Improved alignment • Improved blowing snow screening/storage • Integrated ITS • Maintenance operations plan • Integrated ice detection • Integrated automated de-icing • Improved automated warning signage • Improved friction

Table 2 highlights the potential measures that can be used before and during hazardous winter weather conditions.

Table 2 - Potential Measures		
Users	**Measures**	**Mitigation**
Maintenance Service Providers	• Planning • Detecting • Execute Plowing • Execute De-icing • Monitoring /Reapplying • Address hotspots quickly	• Custom forecasts & MDSS • Patrolling, RADAR, RWIS, infrared • Combination units & plow trailers • De-ice, anti-icing, auto anti-icing • RWIS/CCTV/AVL • FAAST
Traffic Management and Operations	• TDM to minimize traffic • Direct traffic fr incidents & problems • Clean-up incidents quickly	• Traffic Signal Optimization • Incident management planning • Pre-trip traveller information • En-route traveller information
Travellers	• Trip Plan • Select efficient routes • Differ or select effective mode • Select safe mode • Improve awareness of hazards	• Pre-trip planning • Select efficient routes • Differ or select effective mode • Select safe mode • Improve awareness of hazards
Planning and Design	• Analyze condition data • Investigate potential deficiencies • Return to reasonable LOS • Maintain safety • Minimum Environmental Impact • Minimize maintenance and operations costs	• Asset management • Safety reviews /audits • Risk assessment model • TDM • Winter sensitive design guidelines • Winter sensitive corridor planning • Value Engineering

NETWORK SCREENING

RISK ASSESSMENT

To determine the type and severity of mitigation required, a risk assessment should be completed as part of a warrant review. In performing a risk assessment, a number of factors need to be taken into consideration. Risk factors include:

- Topography
- Geography
- Meteorology
- Land-use
- Traffic volumes & mix
- Geometry
- Alignment
- Grades
- Road structure
- Water resources
- Vegetation
- Sun exposure

An effective tool has been developed for performing a risk assessment which uses Geographical Information Systems (GIS) to analyse a road, segment by segment. The Winter Maintenance Road Model (WMRM) helps to determine which road segments share similar winter conditions and which require similar winter maintenance. The WMRM is then analysed and representative maintenance zones are established. The analysis takes into consideration microclimates, roadway geometry, topography, and other factors important to winter maintenance.

COUNTERMEASURE SELECTION

The representative maintenance zones as identified above are then assessed for risks and appropriate mitigation determined. Often, mitigation includes changes to winter maintenance practices, supported by Intelligent Transportation System (ITS) technology.

Typically, minimum maintenance standards specify the criteria for initiating operations; however, the mechanisms to complete these operations are left to the road agencies who usually customize their practices to suit their location. Largely in response to Environment Canada's encouragement, most agencies have developed salt management plans which document how the agency intends to meet their minimum maintenance standard requirements in the context of the environmental management of salt use.

Current synthesis of best practices advocate an approach which increasingly relies on technology to support the management of resources - materials, equipment, and labour. The technology also supports providing the appropriate countermeasure at the right time, in the right quantity, and at the right location.

From the perspective of maintenance service providers, it is desirable to have maintenance applications uniformly applied across the entire route. Spot treating of individual locations is not particularly desirable. As such, specialized prediction, detection, and treatment may be necessary for these locations.

As a result of working with winter maintenance personnel and addressing specific problems, we have designed, studied and optimized a number of winter maintenance treatments. The range of treatment options can match most risk levels. The treatment option selected must be scaled to match the risk of the individual road segments but it is preferred to group segments with similar maintenance requirements.

COUNTERMEASURES

WINTER MAINTENANCE PLANNING - SALT MANAGEMENT

In the past, basic levels of winter maintenance required minimal technological support. The concept of the day was "more is better". The response to improve road conditions was to put more sand and/or more salt down; no longer an acceptable concept.

Control of salt use is not a new concept. The control and reduction of road salt has previously been employed with the objectives of reducing maintenance costs and increasing efficiency by speeding up the time and reducing the effort required to return ice covered roads to safe conditions. A later impetus to improving winter maintenance practices has been to reduce the harmful effects of de-icing chemicals on the infrastructure, particularly bridges.

For some time, an emerging driving force behind the need for better salt management was the concern for the impacts of inorganic road salts on natural environments. With this additional pressure to reduce the amount of salt used for environmental reasons, public works departments are faced with the challenge of what often appears to be conflicting objectives: reduce salt use and cost versus maintaining the roads in a safe condition in the minimum amount of time.

Cost

In the past, the goal of salt management was to reduce operating costs. Rock salt is the largest material cost in most agencies' winter maintenance budget. Even with the variability of winter taken into account, both the cost of salt and its application have been steadily increasing.

Rock salt is the component of a maintainer's material cost that has the most potential for optimization. Overtime labour costs can also be reduced using salt management techniques such as Road Weather Information Systems (RWIS). Information and environmental data from RWIS sites can be used to generate a 24-hour forecast of pavement temperature and conditions. These forecasts can help determine when temperatures will likely drop below freezing. This advanced warning can provide sufficient time to plan operations and reduce unnecessary costs while ensuring the safety of the roads.

Safety
Improved safety has also played a large part in driving salt management techniques. The effective and timely application of de-icing chemicals is an expectation of the public. It is widely known that the ability of the road maintainer to react and anticipate is paramount in preventing accidents.

Road agencies have received a number of judgments against them, which reinforce the concept that the road maintainer has an obligation to know when roads will be getting icy and react accordingly. Article 1 and Article 2, tabulated on page 16 of this paper, summarize two of these judgements. Clearly, the courts have made a statement about the public's right to safe roads as well as the role and responsibilities of the road agencies.

Environmental
Snow and ice control is a key part of winter maintenance operations. Road salts, particularly sodium chloride, are the preferred de-icing/anti-icing chemicals for maintaining winter road safety. This is because of their cost, effectiveness, and ease of handling.

The benefits of using salt on roadways has prevailed notwithstanding the damaging effects to vehicles, roadside vegetation and groundwater. Salt use should be carefully controlled and used within the context of a larger plan; this plan should include proper tools and proven guidelines and procedures. Just as a doctor diagnoses health problems, winter maintenance operators identify road problems caused by winter weather and develop appropriate treatments to remedy the situation. It is helpful to use diagnostic tools and follow proven guidelines and procedures to ensure that the treatment is appropriate for the problem.

The Transportation Association of Canada (TAC) has been a leader in responding to Environment Canada (EC) requests for improved environmental stewardship. EC, together with TAC, assembled a task force that has developed, by consensus, a suitable and approved process for the management of road salt.

TAC has, in turn, published numerous documents to assist road authorities in their winter maintenance efforts. The Road Salt Snow and Ice Control Primer provides an executive summary of the TAC project which was written for the public and underlines the significant role that salt plays in the provision of safe roads. The Salt Management Guide (1999) is a comprehensive reference guide providing details on all facets of road salt use.

DE-ICING VS ANTI-ICING
In the past, minimum maintenance standards have required that maintenance service providers wait for precipitation to accumulate on the road before treatment with rock salt was commenced. This approach was necessitated by the material and equipment used for de-icing. Rock salt requires moisture before it can start to work. On its own, it cannot be pre-applied, since it has a tendency to bounce and blow off the road. Unfortunately, if the service provider waits for precipitation to start and then begins his treatment route on a circuit taking from one to three hours to complete, the conditions on the last section can become extremely deteriorated before it is reached.

Data collected in the past from other jurisdictions (refer to Figure 3 on page 15) supports the hypothesis that collision rates can be reduced by advancing the time at which de-icing chemicals are applied. Since many of the advanced approaches involves the use of liquid de-icing chemicals on their own or in combination with solid chemicals, it is imperative that trends in pavement temperatures into the future be predicted with some confidence. RWIS can assist in making decisions as to the type and timing of a countermeasure. An approach which employs proactively treating the pavement with an appropriate material (usually a liquid) using appropriate equipment at the appropriate time is desirable to prevent the formation of ice on the road surface. Practitioners term this approach as "anti-icing".

De-icing:
- is reactive
- takes longer to get roads back to acceptable condition
- uses more effort once ice has bonded to road surface

- uses more material

Anti-icing is:
- proactive and systematic approach
- objective to prevent hardpack
- uses less material to benefit environment
- just in time

Decision Making
With a move to anti-icing and pre-wetting, the reliance of staff on pavement condition forecasting is increasingly more important. The modern, well equipped, road maintainer should have the following information available to make critical decisions:
- Existing real-time road conditions
- Weather condition forecasts (typically longer term – 3 hours to 3 days)
- Pavement condition forecasts (typically longer term – 3 hours to 3 days)
- Weather "now-casting" (current weather observations compared against forecast to generate short term weather projections)
- Traffic information

Pavement Condition Forecasting
Pavement condition forecasting is important to the road maintainer. The instant when the road surface temperature crosses below freezing point defines the point when the de-icing chemical must be applied. Pavement temperatures are often substantially different from air temperatures.

Good pavement condition forecasts assist with crew scheduling and permit more effective planning. Reliable forecasts are also critical in selecting an optimum de-icing method. Different pavement temperatures require a change in approach and equipment used. Good forecasts enable the maintainer to use less de-icing material if applied before ice bonding takes place.

RWIS also plays an important role in the remote sensing of atmospheric conditions and pavement conditions. Onsite information from RWIS is given to the agency's weather forecaster to prepare accurate pavement condition forecasts.

The objective of the agencies is to have the above sources of information at the fingertips of the patrol supervisors. Use of this information is becoming standard practice as one of the items in the decision-making toolbox to help the supervisors determine what and when treatment is to be applied to the roads.

With access to more information, better-informed fleet mobilization decisions can be made. More informed decisions leads to increased efficiency and decreased manpower/chemical cost. It also maximizes safety.

UTILIZATION OF RWIS FOR THE PRESCRIPTION OF ROAD TREATMENT
The second objective of an RWIS system is to provide sufficient information to support the treatment type decision. The following are discussions on how some road treatments may be better prescribed with the use of the RWIS network.

Conventional Rock Salt
There are general winter maintenance guidelines as to when salt should be applied. Most agencies advocate its use with temperatures above -11°C and with caution down to -18°C. Rock salt should not be used below -18°C. As mentioned earlier, rock salt cannot be applied until precipitation is present. An RWIS station will give pavement surface and subsurface temperatures, which provide a real indication of when salt is required. However, pavement temperatures are often distinctively different from ambient air temperatures; these differences can work for or against the application. If the subsurface temperature is greater than freezing temperature, as an example, then salt may not be required. The heat stored in the ground may be sufficient to prevent ice from forming on the road surface. This situation may occur in the fall when the temperature in the ground has not reached freezing or in the winter when the sun is warming

the surface of the pavement and ground underneath. By using the information provided by the RWIS network, salt can be added at the most opportune time. Alternatively, in the dead of winter and in the spring, although air temperatures may be just above freezing, precipitation or moisture can still freeze on the surface because the frozen underground is acting as a heat sink.

Pre-wetting

De-icing chemicals can be applied in either a solid or liquid form. Solid chemicals (i.e. road salt) need to absorb moisture before beginning to work. Pre-wetting is the application of moisture to the solid chemical prior to dispensing it on the roadway. Its purpose is to immediately begin to break the bond between the ice/snow layer and the road surface. Pre-wetting allows the granules of salt to adhere to the road surface more readily than if it were applied in the dry form. As a result of pre-wetting, less chemical is lost due to bounce and scatter when it is applied to the road. If less chemical is lost, then less chemical needs to be applied to achieve the same effect.

Chemicals, other than salt brine, tend to change the properties of the dry rock salt; depressing the freeze point so it may be possible to use it effectively beyond its normal range of –11ºC.

It is important to view the information given by RWIS and the forecasts to determine if pre-wetting is required or feasible. If not used in the right conditions, attempts at pre-wetting could be counterproductive.

Anti-icing

Anti-icing is a winter maintenance strategy that involves preventing or minimizing the formation of a bonded snow and ice layer. De-icing chemicals are applied to the road shortly before a storm hits, so that the precipitation is less likely to bond to the road surface. For this application, timing is very important. The anti-icing chemical must not be applied too long before the storm, and certainly not after the ice has formed. The RWIS station network can provide the necessary information to ensure these decisions are made correctly.

Fixed Automated Anti-icing Spray Technology

Fixed Automated Anti-icing Spray Technology (FAAST) represents the next generation of RWIS. FAAST consists of a localized system of nozzles permanently embedded in road or bridge infrastructure which draws upon a reservoir of liquid anti-icing chemical piped to the nozzles and activated to spray the road surface automatically in response to pavement and atmospheric sensor readings. An RWIS system predicts pending freezing conditions several minutes before freezing occurs and the FAAST hydraulic system automatically applies the liquid de-icing chemical to the road surface. This is the ultimate in anti-icing with the exact amount of required material applied at exactly the right time at exactly the right location. While FAAST has proven to provide impressive results, it is only warranted and practical in a limited number of high-risk locations due to its relatively high implementation cost.

EVALUATION CASE STUDIES

HIGHWAY 401/416

Canada's first FAAST for a highway/roadway application was installed in the fall of 2000 on the eastbound to northbound high speed interchange ramp from Highway 401 to Highway 416 near Prescott, Ontario.

The construction of this new bridge was completed in September, 1999. During the first winter of operation, 14 weather related collisions occurred on the structure. For a number of years previously, MTO had been investigating anti-icing and RWIS as independent approaches and systems to complement maintenance practices for roads during winter storms.

MTO believed that there was an opportunity to reduce the potential for icing on the structure by installing a FAAST system. The structure in question is a 165 meter super-elevated, high speed, freeway-to-freeway ramp with a design speed of 130km/hr and a 3000 AADT. Since putting the system into service, there have been no winter weather related accidents at the structure.

Economic Evaluation
Capital cost corrected to 2007 dollars is estimated to be $810,000. The estimated annual cost for a complete system is $127,000 which is made up of an annualized capital cost of $54,000 and an annual operating cost of $73,000.

Benefit Analysis
Using the 14 collisions at this location in its first year of operation (2000), the collision costs are estimated to be $420,000/year ($30,000 x 14). The annual estimated cost associated with the delay is $245,000 ($17,500 x 14). The following table summarizes the annual costs and benefits discussed.

Costs		**Benefits**	
Annualized Capital Cost	$54,000	Collision Avoidance Benefit	$420,000
Operating Cost	$73,000	Travel Delays Benefit	$245,000
Total Cost	$127,000	Total Benefits	$665,000

Increase in public safety, reduced collision costs, and reduced travel delays are the major components of the benefit achieved by the installation of the FAAST and RWIS systems. These benefits are calculated as $665,000 per year. The life of the FAAST and RWIS is conservatively estimated at 15 years.

The installation of the FAAST and RWIS system resulted in a 100% reduction in accidents on the Highway 401/416 ramp since it's installation in 2000. This results in an annual benefit to cost ratio of, approximately, 5.24 to 1. The installation has also reduced the use of road salts containing chlorides at this location, which results in further benefits to the environment and increases the life of the ramp structure.

RENFREW COUNTY SALT MANAGEMENT INITIATIVES
The County of Renfrew is the largest county in the Province of Ontario, covering a total land area of 7,645.7 square kilometres. Renfrew County is responsible for the winter maintenance of 812 kilometres of roadway.

In 2000, Renfrew County retained MFPA to review their winter maintenance activities and develop an appropriate strategy for addressing salt consumption. This strategy became Renfrew County's SMP and set out a policy and procedural framework for ensuring that the County continuously improved its management of road salt.

One of the important criteria stated in the SMP was that any modifications to the winter maintenance activities had to ensure that roadway safety and public mobility was not compromised. To achieve this, road weather condition monitoring was included. Based on MFPA's recommendations, County officials decided to implement RWIS. The purpose of the RWIS was to:

- Remotely monitor atmospheric & pavement conditions
- Facilitate forecasting of pavement conditions
- Document the application and effectiveness of de-icing chemicals

With the RWIS system in place and a working SMP, the County was able to continue providing consistent and improved winter driving conditions. The planning and implementation of the County's strategy followed eight stages over a number of years.

		Year
Stage 1:	Salt Management Plan Development	2001-02
Stage 2:	Training	2001-02
Stage 3:	Winter Roads Condition Model	2001-02
Stage 4:	Route Optimization	2002
Stage 5:	RWIS Operation Started at 2 sites	2003
Stage 6:	Pre-Wetting Started	2003-04
Stage 7:	Salt Management Plan Update	2003

Stage 8: Operational Plan Revision 2003

Economic Evaluation
Table 3 and Table 4, page 13, summarize the capital and operating costs for the County's SMP and. RWIS The estimated annual cost for is $62,500. This includes the capital cost of $26,500 and operating cost of $36,000. The life of the RWIS is 15 roughly years.

Benefit Analysis
Assuming 4 collisions per year, the total cost for collisions would be $61,400/year as shown in Table 5 on page 13. The annual estimated cost associated with the delay is $70,000/year ($17,500 x 4).

An increase in public safety and reduced collision costs and travel delays are the major components of the benefit achieved by the installation of the RWIS system and implementation of the SMP. They are calculated as $119,400 per year.

The following table summarizes the annual costs and benefits discussed above. The annual benefit to cost ratio is approximately 1.91 to 1.

Costs		**Benefits**	
Capital Cost	$26,500	Collision Avoidance Benefit	$61,400
Operating Cost	$36,000	Travel Delays Benefit	$58,000
Total Cost	$62,500	Total Benefits	$119,400

The investments made by Renfrew County have resulted in measurable reductions in roadway collisions and salt consumption during winter conditions.

CONCLUSION

The application of appropriate advanced winter maintenance technologies are cost-effective countermeasures against adverse winter weather driving conditions and contribute meaningfully to improved safety for the travelling public.

There is very limited data available documenting the effects of specific advanced winter maintenance practices on safety. On the basis of the findings outlined in this report, advanced winter maintenance practices seem to show encouraging prospects for use as adverse winter road conditions countermeasures. Aside from immediately implementing some of these countermeasures, additional efforts to record and analyze the performance and measure the resulting safety improvements seems to be warranted.

Table 3 - Renfrew Capital Costs		
Stage	**Description/Year(s)**	**Capital Cost**
1	*Salt Management Plan 2001-2002*	$37,000
2	*Training 2001-2002*	
3	Winter Road Condition Model 2001-2002	
4	Route Optimization 2002	
5	*RWIS - 2/4 sites RWIS operating 2003*	$360,000
6	Pre-wetting started 2003-2004	
7	Updated Salt Management Plan 2003	
8	Revised Operational Plan 2003	
Total	$397,000/15 years => $26,500/year	

Table 4 - Renfrew Operating Costs		
Stage	**Description/Year(s)**	**Operating Cost**
1	*Salt Management Plan 2001-2002*	$4,000
2	*Training 2001-2002*	
3	Winter Road Condition Model 2001-2002	
4	Route Optimization 2002	
5	*RWIS - 2/4 sites RWIS operating 2003*	$32,000
6	Pre-wetting started 2003-2004	
7	Updated Salt Management Plan 2003	
8	Revised Operational Plan 2003	
Total	$36,500/year	

Table 5 - Renfrew Collision Cost		
Description	**Explanation**	**Cost**
Fatality	0.31% @ $1,600,000	$19,900
Injury	23.8% @ $28,600	$27,200
Damages	62.6% @ $5,700	$14,300
Total	$61,400/year	

Figure 1 - Safety Management System for Roads
Source: The Canadian Guide to In-service Road Safety Reviews, January 2004, pg 11

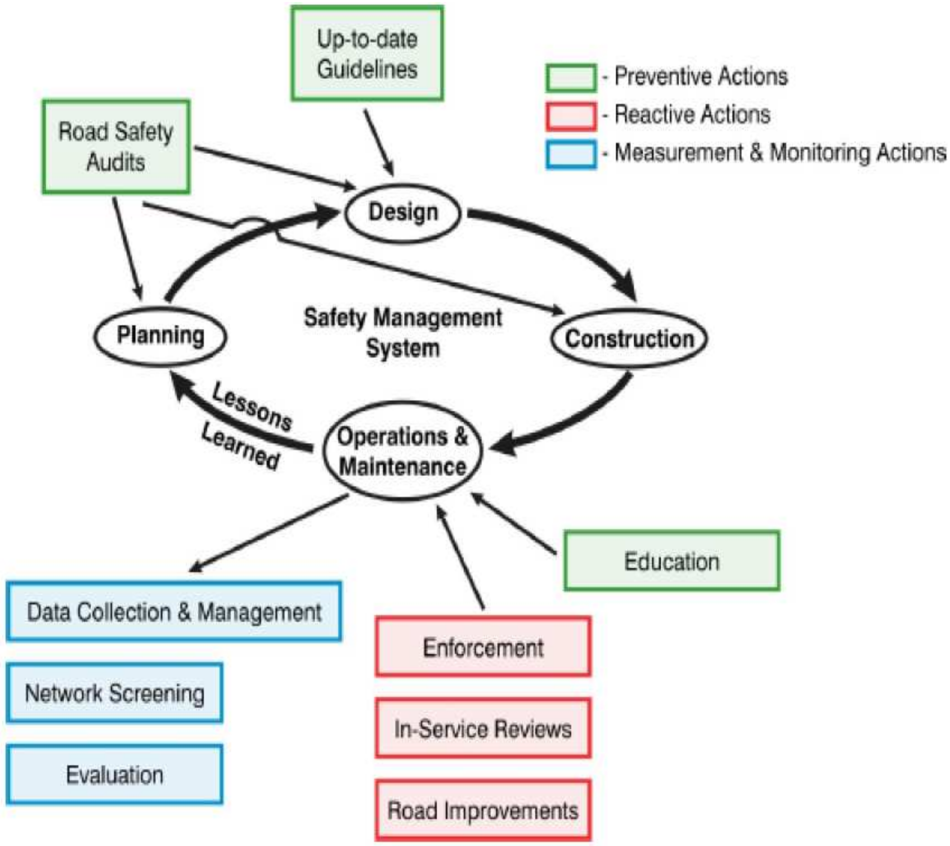


Figure 2 - Winter Control Costs vs. Year 1997-2001
Source: County of Renfrew Public Works Dept.

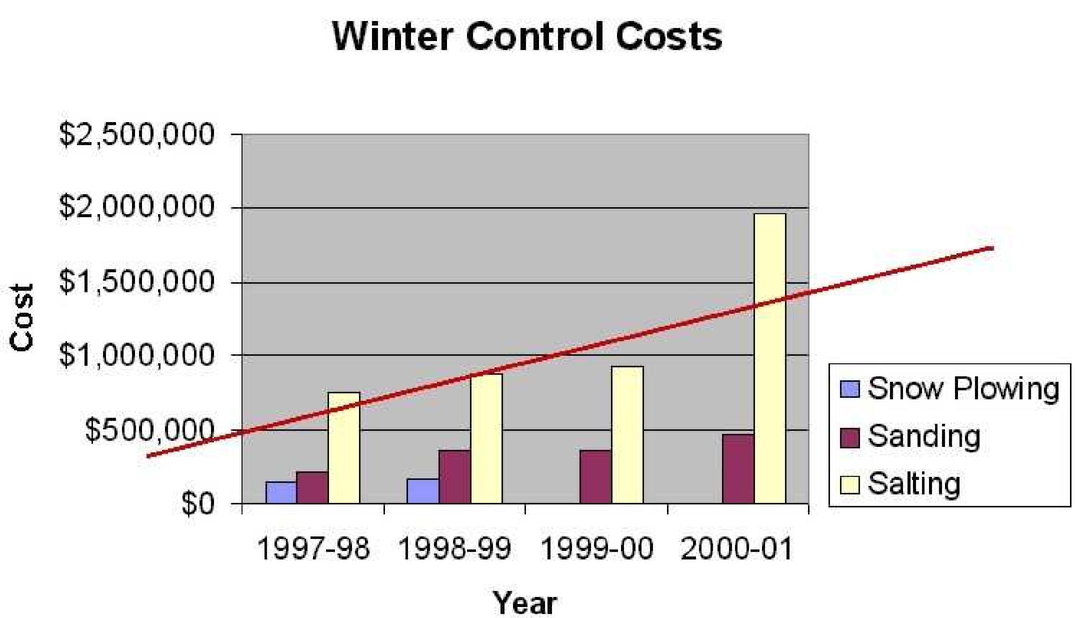


Figure 3 - Accident Rate vs. Accident Time
Source: Hanke and Levin (1988) –650 kms in Germany

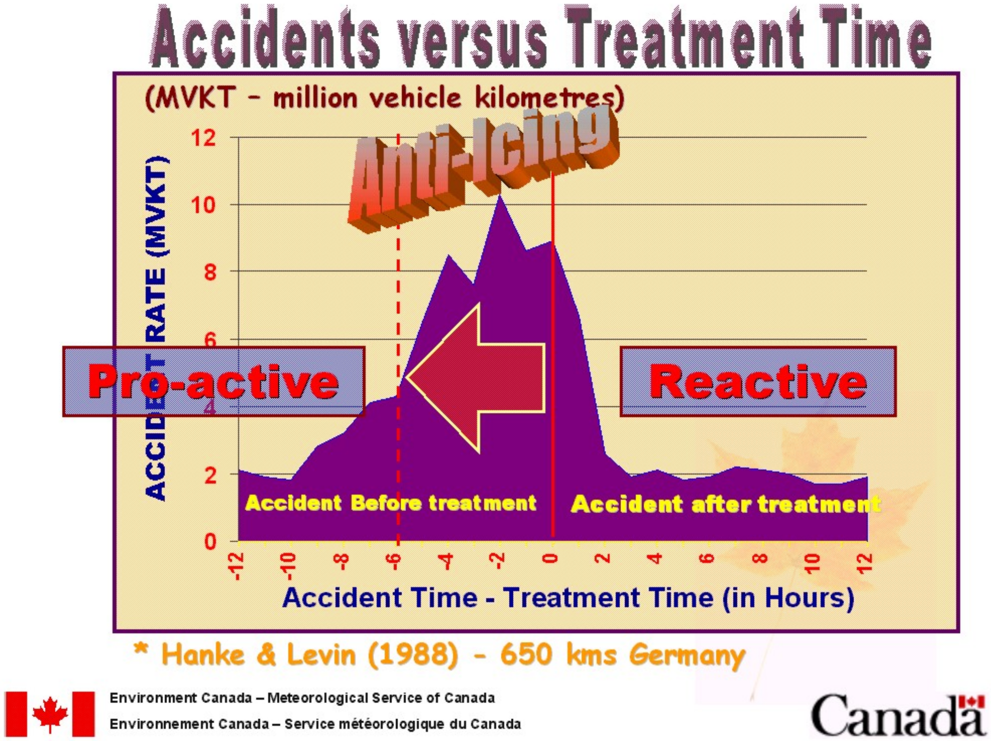
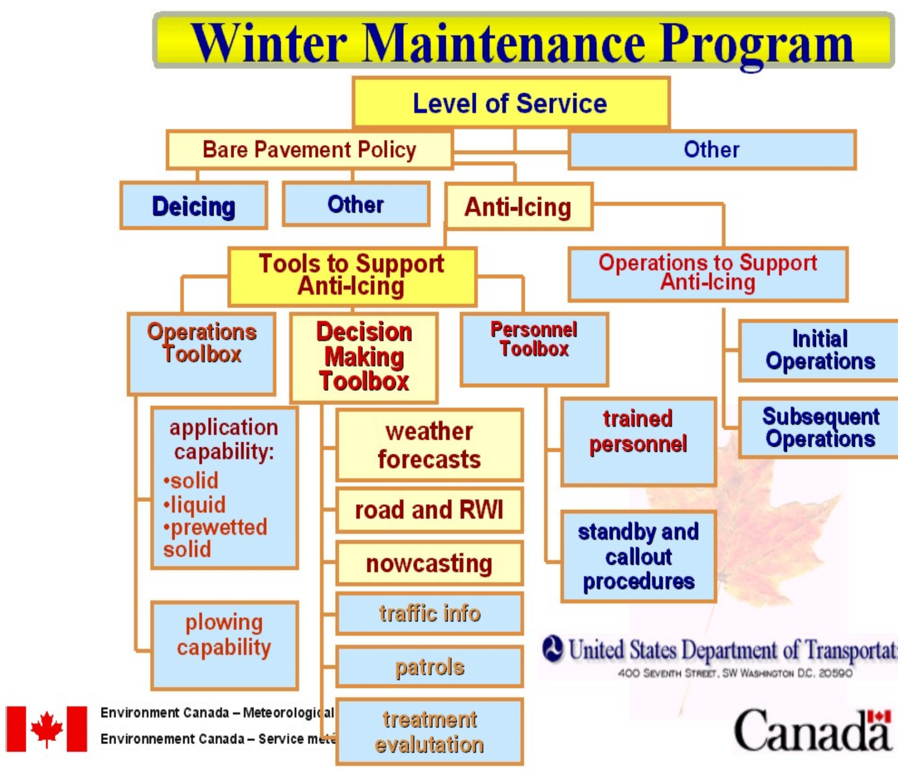


Figure 4 - Winter Maintenance Program
Source FHWA MOP Anti-icing



Article 1 - Toronto Star, May 25th 2001

Woman wins $6 million lawsuit because of “unsafe” Highway 401 Court rules province failed to clear road ice

A 53-year-old London, Ont., woman has been awarded almost $6 million after a court ruled the province should have cleared ice from a Highway 401 bridge where the woman suffered devastating head injuries in a crash.

Yesterday's award by a three-judge panel of the Court of Appeal in Toronto marks the end of a 12-year ordeal by Marilyn MacMillan, a mother of two sons, to prove the province failed to keep the highway safe.

The accident on Oct. 12, 1988 near Woodstock, just before 8 a.m. occurred after provincial ministry of transportation workers failed to inspect the bridge for ice despite repeated weather forecasts of unseasonably cold weather and snow in the Woodstock area, the ruling stated.

MacMillan's lawyer, Earl Cherniak, said the award shouldn't open the province up to a flood of lawsuits over highway crashes.

Article 2 - Globe and Mail, July 26th 1997

Ontario must pay $2.2 Million for crash: Ministry liable for not salting road

A superior-court judge has found the Ontario government partly liable for catastrophic injuries to a teen-age driver who stopped to help another motorist whose car had spun out on an icy section of Highway 401.

In a 133-page judgement released yesterday, Mr. Justice Joseph O'Brien of the Ontario Court's General Division found that the government's Transportation Ministry failed to maintain the highway properly by permitting ice to develop when it knew of an approaching ice storm.

In ordering the ministry to pay half the $4.45-million damages he awarded to Penny Roberts, the judge said evidence at a 43-day trial showed that salting of the highway had not begun until a few minutes before Ms. Roberts was struck by a car driven by defendant Salvatore Morana near Neilson Road in eastern Metro Toronto about 11:20 p.m., on March 3, 1991.

“I have concluded that there were dangerous and icy road conditions in the patrol area for 11/2 hours prior to the accident, Judge O'Brien said. He went on to conclude that the ministry official responsible for patrolling the road failed to monitor weather forecasts or road conditions, "and had little, if any, communication with adjoining patrolmen."