Center for Environmentally Sustainable Transportation

Recent Advances in Sustainable Winter Road Operations – A Book Proposal

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Investing in winter transportation operations is essential and beneficial to the public and the economy. The U.S. economy cannot afford the cost of shutting down highways, airports, etc., during winter weather. In the northern U.S. and other cold-climate areas, winter maintenance operations are essential to ensure the safety, mobility, and productivity of transportation systems. Agencies are continually challenged to provide a high level of service and improve safety and mobility in a fiscally and environmentally responsible manner. To this end, it is desirable to use the most recent advances in the application of materials, practices, equipment, and other technologies. Such best practices are expected to improve the effectiveness and efficiency of winter operations, to optimize material usage, and to reduce associated annual spending, corrosion, and environmental impacts. Currently, no professional societies, scientific journals, or textbooks are dedicated solely to sustainable winter road operations, and key information is scattered across a variety of disciplines. The objective of the proposed book is to summarize the best practices and recent advances in sustainable winter road operations for the purposes of education and workforce development. This book is now in press and can be cited as follows: Shi, X., Fu, L. (2017). *Sustainable Winter Road Operations* (Eds.). ISBN: 978-1-119-18506-2. Wiley-Blackwell.

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winter road maintenance; road salt; best practices; deicer performance; environmental impacts; corrosion; workforce development

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RECENT ADVANCES IN SUSTAINABLE WINTER ROAD OPERATIONS – A BOOK PROPOSAL

FINAL REPORT

Prepared for
Center for Environmentally Sustainable Transportation in Cold Climates

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

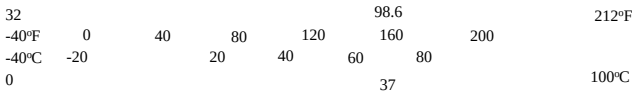
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4		mm
ft	feet	0.3048		m
yd	yards	0.914		m
mi	Miles (statute)	1.61		km
AREA				
in^2	square inches	645.2	millimeters squared	cm^2 ft^2
	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.4046	hectares	ha
MASS (weight)				
oz	Ounces (avdp)	28.35	grams	g lb
	Pounds (avdp)	0.454	kilograms	kg T
	Short tons (2000 lb)	0.907	megagrams	mg
VOLUME				
fl oz	fluid ounces (US)	29.57	milliliters	mL gal
	Gallons (liq)	3.785	liters	liters ft^3
	cubic feet	0.0283	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (°F-32)	Celsius temperature	°C
ILLUMINATION				
fc	Foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2
FORCE and PRESSURE or STRESS				
lbf	pound-force	4.45	newtons	N psi
	pound-force per square inch	6.89	kilopascals	kPa

Note: Volumes greater than 1000 L shall be shown in m^3

These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	Miles (statute)	mi
AREA				
mm^2	millimeters squared	0.0016	square inches	in^2 m^2
meters squared		10.764	square feet	ft^2 km^2
kilometers squared		0.39	square miles	mi^2 ha
hectares (10,000 m^2)		2.471	acres	ac
MASS (weight)				
g	grams	0.0353	Ounces (avdp)	oz
kg	kilograms	2.205	Pounds (avdp)	lb mg
megagrams (1000 kg)		1.103	short tons	T
VOLUME				
mL	milliliters	0.034	fluid ounces (US)	fl oz
liters		0.264	Gallons (liq)	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 °C+32	Fahrenheit temperature	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi



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EXECUTIVE SUMMARY

Currently, no single text is available that specifically focuses on recent advances or best practices in sustainable winter road operations. As such, this book will bridge a significant knowledge gap and address a pressing need for a source of information related to education and workforce development in the area of road operations. This book will be the first of its kind to provide a holistic perspective on the benefits and potential negative impacts of winter road operations, while promoting environmental sustainability concepts and practices. The book will serve as essential reading for maintenance professionals in charge of snow and ice control operations on highways and local roads, and it will serve as a textbook for senior elective or graduate-level courses, with outstanding potential for online education. Webinars and training modules could be developed using this book as the blueprint.

Our approach will be to assemble the best possible team to achieve the objectives of this task. Subject experts and stakeholders familiar with the multiple aspects and components of winter road operations will be engaged, and information from North America, Europe, and Asia on the state of the art and practice will be collected. This approach will provide a good foundation for developing the book chapters, each of which will be delivered by the identified subject experts and reviewed by editors and peer reviewers. Building on the editors' research in the last decade, we will gather and synthesize current information on the subjects tentatively outlined (see chapter titles and abstracts). The book will be written at the monograph/postgraduate level. Its readership will include academic researchers, consulting engineers, postgraduate and undergraduate students, practicing winter road operations managers and engineers, decision-makers, researchers, and engineers in the discipline of transportation, civil, and management engineering. The book may also appeal to stakeholders in the discipline of environmental management and environmental engineering.

FOREWORD

Author: Wilfrid Nixon

Abstract

This book aims to collect in one place all the information and understanding pertinent to conducting road operations to ensure safety and mobility in the transportation system when that system is impacted by winter weather of all types. This foreword is an enticement to dip into the chapters.

Various aspects of winter maintenance operations will be dealt with on a chapter-by-chapter basis. While each chapter is to some degree a stand-alone document, the authors do not intend to suggest that there is no interaction between the various issues addressed. An aspect of sustainability when it comes to road maintenance is recognizing that operations are part of a system and that each part of the system can influence other parts.

Winter maintenance operations are critical to the safety and mobility of our transportation systems. Equally, those operations must be conducted in a safe and sustainable manner. This book will detail how these operations can be conducted in such a way.

CHAPTER 1 – INTRODUCTION TO SUSTAINABLE WINTER ROAD MAINTENANCE

Authors: Xianming Shi and Liping Fu

Abstract

Winter transportation operations are essential and beneficial to the public and the economy of a nation. In the northern U.S. and other cold-climate areas, transportation operations rely on various winter maintenance activities such as plowing and salting to ensure the safety, mobility, and productivity of transportation systems. Transportation agencies have continually been challenged to deliver an effective maintenance program so that a high level of service (LOS) and a degree of safety and mobility are provided in a fiscally and environmentally responsible manner. More agencies are exploring the impacts of winter road maintenance operations, including voluntary and regulatory controls to reduce those impacts. Motivated by this pressing need, the editors of this book will consolidate the best practices and recent advances in sustainable winter road operations with the ultimate goal of helping to reduce the costs and environmental footprint associated with winter road operations. This chapter will provide a brief discussion on the motivation of and the need for this book, and describe how the different chapters and topics are organized.

CHAPTER 2 – A FRAMEWORK FOR LIFE CYCLE SUSTAINABILITY ASSESSMENT OF ROAD SALT USED IN WINTER MAINTENANCE OPERATIONS

Authors: Na Cui, Ning Xie, and Xianming Shi

Abstract

It is important to assess from a holistic perspective the sustainability of road salt widely used in winter road maintenance (WRM) operations. The importance of this assessment becomes increasingly apparent in light of the competing priorities faced by roadway agencies, the need for collaborative decision-making, and the growing concerns over the short-term and long-term risks of road salt use on motor vehicles, transportation infrastructure, and the natural environment. This chapter will introduce the concept of Life Cycle Sustainability Assessment (LCSA), which combines Life Cycle Costing, Environmental Life Cycle Assessment, and Social Life Cycle Assessment. The combination of these concepts captures the features of three pillars in sustainability: economic development, environmental preservation, and social progress. With this framework, it is possible to enable more informed and balanced decisions by considering the entire life cycle of road salt and accounting for the indirect impacts of applying road salt for snow and ice control. This chapter will propose a LCSA of road salt, which examines the three branches of the concept, their relationships in the integrated framework, and the associated complexities and caveats. While this framework provides a first step in the right direction, we envision that it will be improved upon and enriched by continued research and may serve as a template for the LCSA of other WRM products, technologies, and practices.

Keywords: winter road maintenance, road salt, sustainability analysis, life cycle assessment

CHAPTER 3 – WINTER ROAD MAINTENANCE: A HISTORICAL PESPECTIVE

Author: Leland D. Smithson

Abstract

This chapter will highlight the important progress that state Departments of Transportation and local public works agencies have achieved in discovering, developing, and implementing sustainable winter road maintenance practices during the past three decades. This chapter also will document how research findings from the comprehensive U.S. Strategic Highway Research Program, discoveries from the International Winter Maintenance Technology Scanning tours, and multistate consortium research efforts have produced better methods and equipment to accomplish winter maintenance, improve transportation safety and reliability, and enhance winter hazard mitigation. Research findings and scanning tour discoveries were the important and necessary first steps to get progress started. Technology transfer techniques provided the key to understanding the research results, and rigorous testing and field hardening efforts were the essential next steps to ensuring implementation success. The American Association of State Highway and Transportation Officials (AASHTO) provided the catalyst to keep the process moving by developing the vision for a national winter maintenance program. The AASHTO established a committee to guide the program, implemented a funding process to support the program, created the Snow and Ice List-Serve to connect—worldwide—the winter maintenance community, and developed a new approach for advanced training. This computer-based training program accommodates the multiple learning styles found in the maintenance community, making technology transfer possible for all levels of academic abilities. The bottom line of this 30-year effort has meant improved mobility, reliability, and safety, all of which

provide a good return on the funds and time invested, while concurrently monitoring environmental impact, to ensure that the total process is sustainable for the long term.

CHAPTER 4 – SOCIETAL AND USER CONSIDERATIONS FOR SUSTAINABLE WINTER ROAD OPERATIONS

Authors: David Veneziano and Laura Fay

Abstract

Providing a high level of service (LOS) to ensure the traveling public's safety and mobility is a key objective for winter maintenance operations. In general, the primary expectation of the public for winter road maintenance is safe roads that allow mobility during or shortly after a storm, while minimally impacting the environment. But what does it take to meet those objectives, and how can agencies modify their practices to better meet public expectations? This chapter will summarize the current state of knowledge with respect to societal and user expectations of winter road maintenance, as well as the approaches that agencies use to measure how well those expectations are met. Discussion of the technology-based mechanisms used by the public to obtain traveler information before a trip and en route will be discussed. Further, the text will include guidelines related to LOS, as well as case studies that highlight the approaches currently used by agencies in setting their guidelines.

Keywords: level of service, safety, mobility, user expectation, winter maintenance, technology, maintenance guidelines

CHAPTER 5 – WEATHER SERVICES

Authors: Chris Albrecht, Ralph Patterson, and Leigh Sturges

Abstract

Winter road operations are critical to both public safety and the economy. The effectiveness of these operations, as one would imagine, are highly dependent on a variety of weather factors. Furthermore, while a traditional atmospheric forecast can provide some insight into potential weather-related issues, those persons performing both winter maintenance and traffic management activities need to understand the breadth of potential impacts that weather has at the roadway surface. In recent years, the field of road weather forecasting and operations has evolved into its own area of expertise, with impact-based data and forecasts commonly used by many road agencies. This chapter will discuss how road weather services can be an integral part of sustainable winter road operations, the basics of weather and how it affects surface transportation, the critical elements that make up road weather services, and the ways these services are delivered.

CHAPTER 6 – THE FUNDAMENTALS OF PLOWING, ANTI-ICING, DEICING AND SANDING

Authors: Alex Klein-Paste and Rune Dalen

Abstract

Adverse weather conditions such as snowfall and freezing temperatures deteriorate road surface conditions to a level that threatens traffic safety and disturbs mobility. The main countermeasures to mitigate these effects are snowplowing, roadway scraping, application of anti-/deicing chemicals, or spreading of abrasives (e.g., sand). This chapter will cover the fundamentals of these operations. The different design parameters of a snowplow will be explained, as will the means by which chemicals melt ice, prevent water from freezing, and prevent buildup of compacted snow. Friction enhancement by abrasives will be covered by explaining how abrasives create friction.

CHAPTER 7 – SAFETY EFFECTS OF WINTER WEATHER AND ROAD MAINTENANCE OPERATIONS

Authors: Liping Fu and Taimur Usman

Abstract

This chapter will provide an overview of methodologies that can be applied to understand and quantify the effects of winter weather and road maintenance operations on safety. The latest findings on the effects of winter weather conditions and road maintenance operations will be summarized, and the applications of various safety effect models for quantifying the benefits of winter road maintenance (WRM) will be demonstrated. Both highly aggregate and disaggregate models, which differ in spatial and temporal modeling units and data requirements, will be covered. A quantitative understanding of the relationship between highway safety and winter weather and road maintenance is essential to the development of cost-effective, sustainable WRM programs, policies and standards, and operational strategies.

CHAPTER 8 – MOBILITY EFFECTS OF WINTER WEATHER AND ROAD MAINTENANCE OPERATIONS

Authors: Liping Fu and Tae J. Kwon

Abstract

As mentioned in the previous chapter description, a good understanding of the relationship between highway mobility and winter weather and road maintenance is essential to the development of cost-effective, sustainable winter road maintenance programs, policies and standards, and operation strategies.

This chapter will provide an overview of the effects of winter weather and road maintenance operations on highway mobility, summarize the latest findings on the micro- and macroscopic effects of winter road weather conditions, and demonstrate applications of various mobility effect models for quantifying the benefits of winter road maintenance.

CHAPTER 9 – ECONOMIC BENEFITS OF WINTER ROAD OPERATIONS

Authors: David Veneziano, Xianming Shi, and Laura Fay

Abstract

Various benefits are produced while performing winter maintenance operations. However, in many respects, these benefits remain identified and understood only in a vague sense. Therefore, this chapter will summarize the current knowledge base as it relates to winter maintenance benefits, going beyond simply listing what they are and delving into their quantified values (when available). We will examine how that information can be used in cost-benefit analysis to justify future expenditures. This chapter will provide winter maintenance practitioners with a better understanding of how the work they perform benefits the traveling public, and equip them with the information needed to better communicate such information to decision-makers, legislators, and the public in general.

Keywords: benefits, costs, benefit-cost analysis, safety, mobility

CHAPTER 10 – ENVIRONMENTAL RISKS OF SNOW AND ICE CONTROL MATERIALS

Authors: Xianming Shi, Sen Du, and Laura Fay

Abstract

Though abrasives and deicing chemical products are widely used for snow and ice control, the past decade has seen increasing concern over the detrimental impacts of these products on the surrounding environment. Generally, application of these snow- and ice-control materials can affect air quality, water quality, soil, flora, fauna, and human health. The added cost of cleanup and the paradigm shift from reactive to proactive snow- and ice-control strategies in recent years have led to the growing use of chemicals instead of abrasives. There is a need to better understand and assess the environmental impacts of deicers, in an effort to conduct sustainable winter operations in an environmentally and fiscally responsible manner. This chapter will discuss relevant background information and provide a review of the environmental impacts of snow- and ice-control materials, including abrasives, chlorides, acetates and formats, glycols and urea, and agro-based deicers, according to a survey of published work (with a focus on the last two decades).

Keywords: snow and ice control, environmental impacts, abrasives, deicers

CHAPTER 11 – THE IMPACT OF DEICING CHEMICALS ON ROADWAY INFRASTRUCTURE: RISKS AND BEST MANAGEMENT PRACTICES

Authors: Xianming Shi and Gang Xu

Abstract

In this chapter, the impact of deicers on roadway infrastructures will be introduced in terms of physical and chemical interactions. Concrete deterioration such as salt scaling and alkali-aggregate reactions caused by various deicers will be discussed and compared, and deterioration mechanisms will be introduced. Recent best practices in managing the impact of deicers on concrete will be reviewed, with a focus on the use of alternative deicers, additives, or materials to mitigate the effect of deicers and improved concrete design specifications. Deicer effects on asphalt concrete as concerns aggregate, binder, and mixture damages will be discussed, and acetate/formate-based deicers will be introduced, since significant airfield pavement deterioration has been caused by them. Application of polymer modifiers, nanomaterials, and high-quality aggregates will be reviewed as best practices to mitigate deicer-induced deterioration of asphalt concrete. Corrosion of metal, such as rebar, steel bridges, and barriers, caused by chloride-based and acetate/formate-based deicers will also be reviewed. Monitoring and protection have proved effective measures in mitigating deicer-induced corrosion. In general, this chapter will provide a comprehensive review of the deterioration mechanisms by which common deicers compromise the life cycle performance and durability of roadway infrastructure. Best practices for managing risks will be reviewed as well.

CHAPTER 12 – VEHICLE RISKS OF WINTER ROAD OPERATIONS AND BEST MANAGEMENT PRACTICES

Authors: Mehdi Honarvar Nazari and Xianming Shi

Abstract

Recent studies and field observations have confirmed that winter maintenance equipment used for applying chemical deicers on roads corrodes at an accelerated rate. Exposure to roadway deicers, which usually feature chloride salts as their freezing point depressant, has a significant impact on highway maintenance equipment. This chapter will review practices available to manage the risk of deicer corrosion to equipment assets and will present recommendations for future research in this field. The chapter's scope will include technologies available to mitigate the corrosion of metallic components, by enhancing the inherent corrosion resistance of the metal itself, altering the metal/electrolyte interface, or reducing the corrosivity of the service environment. The chapter will conclude with a summary of the most common laboratory test methods used for evaluating the resistance of metallic components to corrosion, and with recommendations for further research, such as laboratory investigation and field validation of each corrosion prevention method's effectiveness.

CHAPTER 13 – STRATEGIC PLANNING AND MANAGEMENT FOR SUSTAINABLE WINTER ROAD OPERATIONS

Authors: Matthew Muresan, Tae J. Kwon, Liping Fu, and Xianming Shi

Abstract

Effective delivery of winter road maintenance (WRM) services requires significant resources ranging from plows and salters, to materials and condition monitoring technologies. This chapter will cover the planning and management of these resources, two essential aspects of delivering a sustainable WRM program that meets service requirements with minimal costs and impact on the environment. In particular, the chapter's focus will be on four major design problems: network partitioning or districting, fleet sizing and mixing, vehicle routing and scheduling, and siting of RWIS (Road Weather Information System) stations, with general principles, guidelines, and methods covered. Salt management will be discussed, including level of service policies, use of weather services, monitoring and record keeping, roadway and pavement design, vegetation management, and design/operations of road maintenance yards.

CHAPTER 14 – SOURCE CONTROL TACTICS FOR SUSTAINABLE WINTER ROAD MAINTENANCE

Authors: Xianming Shi and Liping Fu

Abstract

Decisions to achieve sustainable winter road maintenance range from operational and tactical, such as selection of snow/ice control materials and application rates, to strategic, such as placement of maintenance yards and selection of maintenance vehicles. This chapter's focus will be on the former, including the best sustainability practices in the domain of source control tactics. Specifically, the chapter will provide a general discussion on innovative snow fences for drift control; anti-icing, deicing and pre-wetting practices; decision support systems; fixed automated spray technology (FAST); equipment maintenance and calibration; advanced snowplows and spreaders; and material and snow storage.

CHAPTER 15 – REACTIVE APPROACHES FOR ENVIRONMENTALLY SUSTAINABLE WINTER ROAD OPERATIONS

Authors: Xianming Shi, Eric Strecker, and Scott Jungwirth

Abstract

This chapter will present information on strategies used to reduce the impacts of snow- and ice-control materials once they move from the roadway to the surrounding environment. Commonly used techniques consist of the implementation of structural best management practices (BMPs) that comprise reactive measures implemented along roadsides or near sensitive water sources to capture abrasives and treat deicer-laden stormwater runoff. Due to the highly mobile nature of chlorides, increased chloride concentrations in the environment associated with roadway deicers pose a significant environmental concern, and traditional BMPs often fail at effective chloride management. This chapter will provide an overview of using stormwater structural BMPs for management of suspended solids and chlorides. A summary of criteria for BMP selection and alternative approaches to chloride removal will follow the overview. Methods for cleanup and recycling of winter maintenance abrasives will be discussed, followed by methods for recycling salt brine.

Keywords: winter road maintenance, chlorides, deicers, traction control, best management practices, stormwater, road salt, abrasives, recycling, phytoremediation, wetlands, detention ponds, infiltration basin, retention pond, vegetated swales, evaporation ponds, dilution, infiltration

CHAPTER 16 – INNOVATIVE WINTER MAINTENANCE EQUIPMENT

Authors: William H. Schneider IV, William A. Holik, and Mallory J. Crow

Abstract

Winter maintenance operations are traditionally a costly expense for various agencies. Because of these expenses and the inherent challenges of maintaining roadway operations immediately before, during, and after storm events, many agencies are seeking innovative ways to improve safety, reduce their workforce, and lower operating costs, while simultaneously maintaining or improving the level of road service. This chapter will focus on the decision-making process for selecting appropriate types of innovative equipment, considering topics such as plowing capacity, material distribution, increased life cycle, and sensor reliability and calibration associated with GPS/AVL systems. The appropriate selection of equipment requires information on roadway, traffic, fleet size, and weather patterns. The ultimate goal of this chapter will be to provide the end user with the tools required to optimize the selection of innovative equipment with individual roadway operations.

Keywords: winter maintenance equipment, equipment optimization, snowplow, salt spreader

CHAPTER 17 – THE SEARCH FOR "GREENER" MATERIALS FOR WINTER ROAD MAINTENANCE OPERATIONS

Authors: Xianming Shi, Scott Jungwirth, and Daniel Stuart Hoffman

Abstract

Presently, the most common freezing point depressants used for roadway winter operations are sodium chloride (NaCl), magnesium chloride, ($MgCl_2$), calcium chloride ($CaCl_2$), and potassium acetate (KAc). The search for "greener" materials for winter road maintenance (WRM) operations is an ongoing effort. This effort has led to the introduction of agro-based chemicals and other non-chlorides, sometimes used alone, but more commonly used as additives in chloride-based products. We will present a holistic approach to the evaluation and selection of materials for WRM operations, followed by a review of recent advances in alternative deicers and additives, concluding with a case study about developing "green" liquid deicers.

Keywords: holistic approach, deicer evaluation, deicer selection, collaborative decision-making, alternative deicer, corrosion inhibition, agro-based

CHAPTER 18 – PAVEMENT TREATMENTS FOR SUSTAINABLE WINTER ROAD MAINTENANCE

Authors: Xianming Shi, Jiang Huang, and Zhengxian Yang

Abstract

In cold regions, snow- and ice-control operations in winter are of critical importance to safety and mobility on roadways. Snow and ice on asphalt pavement surfaces can create hazardous driving conditions, thus presenting serious traffic safety risks (e.g., tire skidding, brake failure, loss of directional control). It is estimated that weather-related crashes account for as much as 35% of total reported accidents in the USA. Large amounts of solid and/or liquid deicers as well as abrasives are applied annually to keep winter roadways clear of ice and snow and/or to provide roadways with a surface layer of good friction. However, concerns have been raised about high residual chloride levels and the adverse effects of chloride on motor vehicles, transportation infrastructure, and the ecosystem. This chapter will describe various pavement treatments designed to prevent or reduce the bond between ice or compacted snow and pavement. Such pavement treatments present a desirable supplement to chemicals and abrasives used for snow- and ice-control, as they reduce the amount of winter traction materials needed for a given level of service. Some of these treatments/technologies become particularly attractive at extremely cold temperatures (e.g., below 15°F or -9.4°C), when most chemical deicers lose their effectiveness and the use of conventional methods (abrasives and snowplowing) becomes costly and inefficient.

CHAPTER 19 – PERFORMANCE MEASURES FOR SUSTAINABLE WINTER ROAD OPERATIONS

Author: Tina Greenfield

Abstract

This chapter will describe the benefit of performance measurement in responsible and sustainable winter maintenance management, an overview of common performance measures, and how to overcome the challenges associated with analyzing winter operations performance. In particular, this chapter will provide guidelines for the computation and proper use of indices to normalize the varying influence of weather and level of service expectations so that useful comparisons can be made over time or between different locations. Performance measurement and normalization theories will be applied in a step-by-step example. Finally, some techniques that make performance and expenditure data more accessible to their intended users will be described.

Keywords: performance measurement, outcomes, inputs, weather index, normalization, dashboards

CHAPTER 20 – APPLICATION GUIDELINES FOR OPTIMAL DEICING AND ANTI-ICING

Authors: S. M. Kamal Hossain, Matthew Muresan, and Liping Fu

Abstract

This chapter will present a review of current snow- and ice-control methods, and a guide for selecting an optimal application rate for specific weather, treatment, and level of service requirement. Determining the proper treatment course for a given winter event is extremely important, both from an economic and environmental perspective. Excess salt has been shown to cause corrosion to infrastructure and vehicles, and can negatively affect the surrounding soils, wildlife, and lakes. Current maintenance practices will be highlighted, as well as application strategies (e.g., deicing, anti-icing, pre-wetting) and mechanical strategies (e.g., plowing, using icebreakers) in common use. This chapter will include a discussion on the snow melting process, an understanding of which is essential for deriving application rates, and will end with an overview of recommended procedures that can be used to select application rates and maintenance actions. In addition to roadway maintenance strategies, the selection of maintenance actions and application rates for parking lots and sidewalks, separate from highways, will be discussed. Such facilities have unique safety considerations and pose challenges to maintenance practitioners that are unlike the challenges posed by highways.

CHAPTER 21 – A LOOK INTO THE FUTURE

Authors: Liping Fu and Xianming Shi

Abstract

In this chapter, we will summarize the main challenges facing the winter road maintenance industry in its attempts to deliver a cost-effective and environmentally sustainable maintenance program. These challenges include climate change, the demand for higher levels of service, changes in driver behavior, road weather and condition forecasting, and operator fatigue. The chapter will provide a brief discussion of opportunities for winter road operations. In the management domain, these opportunities include enhanced communications and coordination between stakeholders and better training. In the technology domain, the opportunities include possible future advances in weather forecasting, vehicles, sensors, and communication technologies, with a focus on their potential impacts on the maintenance sector. Technologies imminently available, such as connected vehicles (CV), Internet of Thing (IoT), new plowing/materials application technologies, and crowdsourced road condition monitoring and maintenance will be highlighted. The chapter will conclude with future research directions.