Recent Advances in Sustainable Winter Road Operations

Project Update Meeting

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Investing in winter transportation operations is essential and beneficial to the public and the economy.

It is desirable to use the most recent advances in the application of materials, practices, equipment and other technologies.

There are no professional societies or scientific journals or textbooks dedicated solely to sustainable winter road operations and the key information is scattered across a variety of disciplines.
Background

- Agencies are continually challenged to provide a high level of service (LOS) and improve safety and mobility in a fiscally and environmentally responsible manner.

- A project is timely to consolidate best practices and recent advances in sustainable winter road operations into a comprehensive book.
Project Objective

- Develop a book to summarize the recent advances in sustainable winter road operations.

- Editors: Dr. Xianming Shi (Washington State University), and Dr. Liping Fu (University of Waterloo)
Outreach activities to engage transportation professionals

Discuss and share innovative ideas and latest advances in the maintenance, management and operations of transportation systems in cold climates.

Engage stakeholders in the snow and ice control community, including:

- TRB committee on winter maintenance
- APWA subcommittee on winter maintenance
- AASHTO SICOP snow/ice list serve
- Winter Road Maintenance & Effects LinkedIn group
- China Academy of Transportation Sciences
- American Society of Civil Engineers (ASCE)
- Canadian Society for Civil Engineering...
Planning for the Book

- Engage local and national media

- Significant coverage of associated topics during the winter season of 2014-2015
Planning for the Book

- Outreach activities to publishers

Potential Audience and Outlets

- This book is written at the monograph/postgraduate levels.

- The readership will include academic researchers, consulting engineers, postgraduate & undergraduate students, and practicing winter road operations managers & engineers.

- As the 1st book of its kind, this book can be considered suitable for decision makers, researchers, and engineers in the discipline of transportation engineering, civil engineering, and management engineering. It may also appeal to stakeholders in the discipline of environmental management and environmental engineering.
Foreword
Wilfrid Nixon

F1: Impacts of economy and safety on transportation
F2: Impacts of winter weather on the transportation system
F3: Operations to ensure safety and mobility on the transportation system in winter weather conditions
F4: The congruence of winter operations and sustainable practices
F5: Conclusion

Chapter 1. Introduction to sustainable winter road operations
Xianming Shi, Liping Fu

1. Introduction
   1. Motivation for this book
   2. The need for this book

2. How the chapters and topics are organized

References
Chapter 2. Life-cycle sustainability assessment of winter road operations
Na Cui, Xianming Shi
2.1 Introduction
2.2 Methodology
2.3 Initial LCSA framework of NaCl used in winter road operations
2.4 Detailed anatomy
2.5 Range of values for the identified environmental impacts
2.6 Concluding remarks
2.7 Review questions
References
Chapter 3. Winter road maintenance operations: A historical perspective

Leland D. Smithson

1. Introduction

3.2 Pre-Strategic Highway Research Program (SHRP) (Prior to 1987)

3.3 Post SHRP (After 1993)

4. Other major efforts contributing to “Winter Road Operations”
   3. Aurora (1996)

5. Concluding remarks

6. Review questions

References
Chapter 4. Societal and user considerations for sustainable winter road operations
David Veneziano, Laura Fay

4.1 Overview
4.2 Societal/user expectations related to winter road operations
4.3 Traveler decision-making
4.4 Agency performance measures in use
4.5 Conclusion
4.6 Review questions...References

Chapter 5. Weather services for sustainable winter road operations
Chris Albrecht, Ralph Patterson

5.1 Introduction/background
5.2 Components of road weather (Inputs)
5.3 Road weather services (Outputs)
5.4 Benefits of weather services
5.5 Conclusion
5.6 Review questions...References
Chapter 6. The fundamentals of plowing, anti-icing, deicing and sanding

Alex Klein-Paste

1. Introduction
2. The fundamentals of snow plowing
   1. Introduction
   2. Important parameters
   3. Plow design
   4. Snow removal performance
3. Anti-icing
   1. Introduction
   2. Freezing point depression
   3. Changing the freezing process
   4. Application rates and different application methods
   5. Success factors for sustainable anti-icing operations

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Chapter 6. The fundamentals of plowing, anti-icing, deicing and sanding (cont’d)

Alex Klein-Paste

4. Deicing
   1. Introduction
   2. Physics of chemically melting snow/Ice
   3. Different application methods
   4. Success factors for sustainable de-icing operations

5. Sanding
   1. Introduction
   2. How tire-pavement friction is created
   3. Loss of friction due to snow/ice
   4. Friction mechanisms of sanding
   5. Improving sanding operations

6. Conclusion

7. Review questions

References
Chapter 7. Safety effects of winter weather and road maintenance operations
Liping Fu, Taimur Usman

1. Introduction
2. Factors affecting winter road safety
3. Winter road safety management
4. Winter accident prediction models
5. Safety benefits of winter road maintenance
6. Conclusion
7. Review questions

References
Chapter 8. Mobility effects of winter weather and road maintenance operations
Liping Fu, Tae J. Kwon
8.1 Introduction
8.2 Factors affecting winter road mobility
8.3 Effect of winter weather and maintenance on traffic volume
8.4 Effects of winter weather and maintenance on traffic operations
8.5 Mobility benefits of winter road maintenance
8.6 Conclusion
8.7 Review questions
References
Chapter 9. Economic benefits of winter road operations

David Veneziano, Xianming Shi, Laura Fay

9.1 Overview
9.2 Defining winter maintenance benefits
9.3 Methods to estimate winter maintenance benefits
9.4 Benefits of winter maintenance
9.5 Cost benefit analysis in winter maintenance
9.6 Conclusion
9.7 Review questions

References
Chapter 10. Environmental risks of winter road operations
Xianming Shi, Sen Du, Laura Fay

10.1 Introduction

10.1.1 Factors that define the environmental factors of materials

10.2 Environmental assessment of snow and ice control materials

10.2.1 Abrasives
10.2.2 Chloride salts
10.2.3 Acetates and formates
10.2.4 Urea and glycols
10.2.5 Agriculturally Derived (Agro-based) Deicers
10.2.6 Additives in snow and ice control materials

10.3 Concluding remarks

10.4 Review questions

References
Chapter 11. Infrastructure risks of winter road operations and best management practices
Xianming Shi, Gang Xu

11.1 Introduction

11.2 Deicer effects on hydraulic cement concrete
   11.2.1 Deicer scaling – a physical process
   11.2.2 Reactions between deicers and concrete
     • Sodium chloride
     • Magnesium chloride
     • Calcium chloride
     • Other deicers and additives
       11.2.3 Deicers aggravating alkali-aggregate reactions
     • Chloride-based deicers affecting ASR
     • Chloride-based deicers affecting ACR
     • Acetate/formate-based deicers affecting ASR

11.2.3 Best practices to manage deicer effects on hydraulic cement concrete

11.3 Deicer effects on asphalt concrete
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Chapter 11. Infrastructure risks of winter road operations and best management practices (cont’d)
Xianming Shi, Gang Xu

11.3.1 Deicers affecting pavement structure
11.3.2 Effects of deicers on asphalt materials (aggregate, binder, and mixture)

- Chloride-based deicers
- Acetate/formate-based deicers

11.3.3 Best practices to manage deicer effects on asphalt concrete

11.4 Deicer effects on embedded steel rebar or dowel bar

11.4.1 Mechanisms of chloride-induced corrosion of embedded steel
11.4.2 Best practices to manage deicer effects on embedded steel

11.5 Effects of winter road operations on other infrastructure

11.5.1 Steel bridges
11.5.2 Signage
11.5.3 Pavement markings
11.5.4 Best practices to manage deicer effects

11.6 Concluding remarks
11.7 Review questions...References
Chapter 12. Vehicle risks of winter road operations and best management practices
Mehdi Honarvar Nazari, Xianming Shi

12.1 Introduction
12.2 Corrosion definition
12.3 Causes and effects of corrosion
12.4 New equipment specification
12.5 Repair, rehabilitation and retrofitting of existing equipment
12.6 Preventive maintenance practices for equipment
   12.6.1 Anti-corrosion coatings
   12.6.2 Inhibitors for corrosion protection
   12.6.3 Frequent washing
   12.6.4 Other proactive methods
   12.6.5 Practical examples
   12.6.6 Operations and maintenance methods for corrosion mitigation
   12.6.7 Recent advances
12.7 Concluding remarks
12.8 Review questions ...References
Chapter 13. Source control strategies for sustainable winter road maintenance
Liping Fu, Matthew Muresan, Xianming Shi
13.1 Introduction
13.2 Optimal Zoning
13.3 Fleet Sizing and Mixing
13.4 Staffing and Crew Scheduling
13.5 RWIS: Density and Siting
13.6 Salt Management Program
13.7 Concluding remarks
13.8 Review questions...References
Chapter 14. Source control tactics for sustainable winter road maintenance
Xianming Shi, Liping Fu

14.1 Introduction
14.2 Innovative snow fences for drift control
14.3 Anti-icing, deicing and pre-wetting practices
   14.3.1 Selection of treatment tactics
   14.3.2 Application rate guidelines
14.4 Decision support systems
14.5 Fixed automated spray technology (FAST)
14.6 Equipment maintenance and calibration
14.7 Material storage and recycling
14.8 Advanced snowplows and spreaders
14.9 Concluding remarks
14.10 Review questions
References
Chapter 15. Reactive approaches for environmentally sustainable winter road operations
Xianming Shi, Eric Strecker, Scott Jungwirth
15.1 Introduction
15.2 Cleanup and recycling of winter maintenance abrasives
   15.2.1 Abrasives cleanup
   15.2.2 Abrasives recycling
15.3 Traditional stormwater structural BMPs to manage suspended solids
15.4 Traditional stormwater structural BMPs to manage chlorides
   15.4.1 Recycling of salt brine
   15.4.2 Storage and release
   15.4.3 Infiltration
   15.4.4 Alternative methods to remove chlorides (e.g., phytoremediation)
15.5 Concluding remarks
15.6 Review questions
References
Chapter 16. Workforce development and training

Wilfrid Nixon

16.1 Introduction to workforce training and development: Learning domains, learning levels, and learning styles
16.2 Current training options in winter operations: computer based training, classroom training, on the job training, video training, others
16.3 Identified shortfalls in winter operations training: needs that are not being met, learning styles that are not being addressed
16.4 Options to remedy observed shortfalls
16.5 Conclusion
16.6 Review questions
References
Chapter 17. Equipment optimization
William H. Schneider IV, William A. Holik

Introduction
1. Why would an agency want to use innovative equipment
2. What factors make equipment innovative
3. Discuss problems and inefficiencies with winter maintenance equipment

1. Areas of Innovation
   1. Plowing Roads
   2. Delivery of Material
   3. Plow Blades
   4. Managing Assets

2. Decision Matrix Associated with Site Selection for Innovative Equipment

3. Quantifying Innovation Benefits

4. Case Studies
   1. Equipment implementation studies
   2. DOT’s in-house innovative equipment implementations

5. Concluding remarks

6. Review questions...References
Chapter 18. The search for “greener” materials for winter road operations
Xianming Shi, Scott Jungwirth

18.1 Introduction

18.2 Holistic approach to materials evaluation and selection
   18.2.1 Development of deicer evaluation matrices
   18.2.2 Holistic approach to collaborative decision-making

18.3 Recent advances in alternative deicers and additives
   18.3.1 Alternative deicers
   18.3.2 Additives for corrosion inhibition
   18.3.3 Additives for enhancing ice-melting capacity or salt solubility
   18.3.4 Other additives for snow and ice control materials

18.4 A case study of developing “green” anti-icers
   18.4.1 Background
   18.4.2 Methodology
   18.4.3 Results and discussion
   18.4.4 Summary of findings

18.5 Concluding remarks

18.6 Review questions...References
Starting the Book Chapters

Chapter 19. Pavement innovations: Alternatives to chemicals and abrasives
Xianming Shi, Jiang Huang, Zhengxian Yang

1. Introduction
2. Rough surfaces and physical bending pavements
3. High friction anti-icing polymer overlays
4. Asphalt pavements with anti-icing additives
5. Icephobic concrete pavements
6. Heated pavement technologies
7. Innovations in heated pavement materials
8. Geothermal heating
9. Electrical resistive heating
10. Alternative heating
11. Concluding remarks
12. Review questions
References
Chapter 20. Performance measures for sustainable winter road operations

Tina Greenfield

1. Performance measurement in responsible and sustainable winter maintenance management

2. Overview of common performance/outcome measures — benefits and drawbacks
   1. Time To Normal and Visual Road Condition Categorization
   2. Traffic Speed Regain Time
   3. Road Friction
   4. Traffic Speed

3. The challenges of analyzing winter operations performance
   1. Why simple cost or outcome comparisons fail — why normalization is necessary
   2. Introduction to various winter weather indices — seasonal and storm
   3. How to choose an index that is right for your situation

4. Normalizing the influence of weather and traffic for performance measurement

5. Management tools and dashboards
   1. The benefit of regular, organized data presentation tools
   2. Examples in practice

6. Conclusion

7. Review questions...References
Chapter 21: Application guidelines
S. M. Kamal Hossain, Liping Fu

21.1 Introduction
21.2 Basic Winter Road Maintenance
   21.2.1 Deicing
   21.2.2 Anti-icing
   21.2.3 Pre-wetting
   21.2.4 Pre-treating
21.3 A Review on Common De-icing Materials:
21.4 Optimal Winter Maintenance Guide
   21.4.1 Application rate matrix for road for North American context
   21.4.2 Application rate for European Context
   21.4.3 Application rate for Pedestrian facilities
21.5 Conclusion
21.6 Review questions
References
Chapter 22: A look to the future
Liping Fu, Xianming Shi

22.1 Introduction

22.2 Main Challenges in winter road maintenance
   21.2.1 Climate change
   21.2.2 Demand for high level of services (zero collision)
   21.2.3 Driver behavior
   21.2.4 Spatial and temporal variation of winter storm events
   21.2.5 Road weather and condition forecasting
   21.2.6 Operator fatigue
   21.2.7 Mobilization of work force and outsourcing

21.3 Main Opportunities for winter road maintenance
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Chapter 22: A look to the future (cont’d)
Liping Fu, Xianming Shi

21.3 Main Opportunities for winter road maintenance
  21.3.1 Enhanced communications and coordination between stakeholders
  21.3.2 Computer-based training and beyond
  21.3.3 Enhanced and customized weather services
  21.3.4 New technologies: CV, sensor weather networks – Internet of Thing (IoT), smartphones
  21.3.5 Maintenance technologies: new plowers, new ice/snow breakers, new controller
  21.3.6 Better materials: non-chloride deicers and additives
  21.3.7 Better pavements

21.4 Future Research and Development

21.5 Review questions

References
Starting the Book Chapters

- We have identified the authors for each chapter.

- We expected to use **10 months** to draft the book chapters.

- The estimated number of pages will be 380 to 450 pages, based on 400 words per page and counting illustrations and tables as word equivalents.

- We estimate to have an average of 4 black and white/halftone illustration pages and an average of 2 color illustration pages per chapter.


T3. Planning and Conducting the Webinars (45% complete)

- **Shi, X.** Effect of Potassium Acetate, Sodium Chloride and Magnesium Chloride Deicers on Concrete. Oct. 6, 2014. Invited by the Washington State Department of Transportation Bridge and Structures Office.


Foreword Wilfrid Nixon

Chapter 1. Introduction to sustainable winter road operations
Xianming Shi, Liping Fu

Chapter 2. Life-cycle sustainability assessment of winter road operations
Na Cui, Xianming Shi (80% complete)

Chapter 3. Winter road maintenance operations: A historical perspective
Leland D. Smithson (100% complete, with Publisher)

Chapter 4. Societal and user considerations for sustainable winter road operations
David Veneziano, Laura Fay (100% complete, with Publisher)

Chapter 5. Weather services for sustainable winter road operations
Chris Albrecht, Ralph Patterson

Chapter 6. The fundamentals of plowing, anti-icing, deicing and sanding
Alex Klein-Paste (100% complete, with Publisher)

Chapter 7. Safety effects of winter weather and road maintenance operations
Liping Fu, Taimur Usman (95% complete)

Chapter 8. Mobility effects of winter weather and road maintenance operations
Liping Fu, Tae J. Kwon (95% complete)
Chapter 9. Economic benefits of winter road operations
David Veneziano, Xianming Shi, Laura Fay (100% complete, with Publisher)

Chapter 10. Environmental risks of winter road operations
Xianming Shi, Sen Du, Laura Fay (85% complete)

Chapter 11. Infrastructure risks of winter road operations and best management practices
Xianming Shi, Gang Xu (80% complete)

Chapter 12. Vehicle risks of winter road operations and best management practices
Mehdi Honarvar Nazari, Xianming Shi (90% complete)

Chapter 13. Source control strategies for sustainable winter road maintenance
Liping Fu, Matthew Muresan, Xianming Shi (95% complete)

Chapter 14. Source control tactics for sustainable winter road maintenance
Xianming Shi, Liping Fu (95% complete)
Chapter 15. Reactive approaches for environmentally sustainable winter road operations
Xianming Shi, Eric Strecker, Scott Jungwirth (80% complete)

Chapter 16. Workforce development and training
Wilfrid Nixon

Chapter 17. Equipment optimization
William H. Schneider IV, William A. Holik (95% complete)

Chapter 18. The search for “greener” materials for winter road operations
Xianming Shi, Scott Jungwirth (60% complete)

Chapter 19. Pavement innovations: Alternatives to chemicals and abrasives
Xianming Shi, Jiang Huang, Zhengxian Yang (90% complete)

Chapter 20. Performance measures for sustainable winter road operations
Tina Greenfield (100% complete, with Publisher)

Chapter 21: Application guidelines
S. M. Kamal Hossain, Liping Fu (95% complete)

Chapter 22: A look to the future
Liping Fu, Xianming Shi
Products and Timeline


Products and Timeline


Products and Timeline

- A book to be published by Wiley: fits under the CESTiCC research thrust of “reducing environmental impacts during construction, operations and preservation through effective design, management and preservation strategies”.

- *Planning and conducting the webinars*

1. Benefits of highway winter operations

- Fewer accidents
- Improved mobility
- Reduced travel costs & reduced fuel use
- Sustained economic productivity, continued emergency services, ...
1a. Winter maintenance operations in the U.S.

- > 70% roads, 70% population
- **Highways:** $2.3 \text{ bln/yr} + 5 \text{ bln/yr}

**Minnesota DOT current practices**

- (4,600 crashes) = 29% avoided
- $10.9M in travel time savings
- $48.4M in user fuel savings
- Total $227M saved, b/c of 6.2
- *Intangible benefits*

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Emerging challenges