Sustainability Analysis of the Commercial Winter Management Industry's Use of Salt

Sustainability Analysis of the Commercial Winter Management Industry's Use of Salt

Phillip C. Sexton

A Thesis in the Field of Sustainability and Environmental Management

for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

May 2017

Abstract

There is a quiet yet significant environmental epidemic occurring. Freshwater resources throughout North America are becoming increasingly contaminated with chlorides as a result of salt used for managing snow and ice conditions. This thesis evaluates the current snow & ice management practices of the commercial winter management industry and how the industry can leverage existing research, data and best practices to reduce its use of sodium chloride ("rock salt") for managing slippery conditions in parking lots and roadways.

My research focus is on the primary drivers and variables that influence the amounts of salt being applied to mitigate these slippery conditions. The primary question I address is: How can a highly fragmented industry reduce the rate and frequency of salt it applies? My main research objective is to develop a context based analysis of the commercial winter management industry's sustainability issues that ultimately influence how much salt is applied and reveal possible reduction interventions. The primary hypotheses I examined are: current rates of salt applications used in commercial winter management operations for parking lots, and private roadways are higher than established guidelines indicate they need to be; less salt is applied when the established salt application guidelines are followed; the rates and frequencies of salt application increase when contracted levels of service or perceived levels of quality for snow & ice control are increased; and the amount of salt applied is higher when property owners or contractors are liable for slip and fall claims.

I utilized five sets of existing salt application rate guidelines, five categories of industry context data and three methods of analysis to develop: 1) a comparative analysis of salt application rates; 2) a sustainability analysis of the commercial winter management industry; and 3) a materiality analysis of the primary drivers and variables that influence salt application.

My research results revealed the two most heavily weighted drivers that influence the rate and frequency of salt applications are the clients' level of service expectations, and contractors' reliance on salt applications as the primary driver of profit margins. The results further suggest that rather than invest in government regulation of salt application rates, which would be impossible to enforce in an extremely fragmented industry, a model of self-regulated interventions and guidelines is more likely to be accepted by the industry. The context analyses also revealed a number of other sustainability issues experienced by the commercial winter management industry that are important to understand and include for future salt reduction research and initiatives. The issues I examined include: fear of liability for slips and falls, budget constraints, variable perceptions of quality, lack of education and training at the field level where salt is applied, and lack of automation and consistent tracking of salt application data.

I merged my findings of the current sustainability issues assessed in this research into a proposed framework of solutions interventions that could reduce chloride contamination of freshwater bodies from salt applications. These interventions I advocate can be reasonably adopted by the broad categories of winter management stakeholders as a future national model for developing standards of policies and practice.

Dedication

This work is dedicated to all winter management and landscape professionals. May they further improve and sustain the industry that is often unknown or overlooked by those that benefit from their hard work and dedicated service.

Most of all I dedicate this work to my wife Jenny and our three children Grace, Jack and Gavin who are my reason for being and for pursuing my studies in sustainability. I’m hopeful this thesis will play a small role for their future and the future generations’ experiences when swimming, fishing and drinking clean water.

Acknowledgements

My sincere thanks and gratitude is extended to the many people and organizations that helped advice and support me for this endeavor. I'm particularly thankful to my thesis director Dr. Mark Leighton who inspired my inner potential to think deeper than I ever have. I also thank him for his sincere interest and concern for my industry and the issues this research is intended to help solve.

The team I work with at the Snow and Ice Management Association has been a tremendous support for me while I've researched the issues of salt use for the past two years. I especially thank my good friend, colleague and mentor Raqib Omer for the countless hours of conversation, supporting the Sustainable Salt Initiative (SSI) and for his advice and inspiration that helped me decide what to focus on for this research. Thank you Cheryl Higley who graciously helped me access and collect survey data. Thank you Sarah Burbules-Sexton for her contribution to formatting this work.

There are many other people from organizations who were very generous with their time, advice, and brainstorming for this thesis including: The New Hampshire Department of Environmental Services, The Fund For Lake George, The Lake George Waterkeeper and Fortin Consulting. Other companies were very generous by donating equipment and products to be used for the field observation portions of my study including: Arrowhead Equipment, Deicing Depot, Douglas Dynamics, Synatec and Viaesys. I'm extremely grateful for the collaboration with all the people from these organizations.

Table of Contents

List of Tables

List of Figures

Definition of Terms

Anti-icing: The act of applying a deicer chemical (a liquid or a solid) to a surface before the storm starts in an effort to prevent snow and ice from forming and bonding to the surface or to enhance plowing efforts. Referred to as 'pre-treating' a site. Not to be confused with Pre-treating salt with an enhanced agriculture bi-products such as beet juice.

Bare Pavement Regain / Recovery Time (BPRT): The amount of time elapsed to expose at least 80% of a paved surface from snow & ice accumulation (Hosseini, Hossain, Fu, San Gabriel, & Seters, 2015).

Calibration: Determining a precise measurement of the material output of a given deicer spreading/spraying unit under different settings and vehicle speeds. The goal of calibration is measuring and applying a consistent set of output rates over time.

Deicing: The act of applying a deicer chemical (typically a solid or pre-wet solid) to an accumulation of ice or snow in an effort to melt it and weaken its bond to the surface.

Deicer: A material to melt snow and ice. Commonly used deicers include sodium chloride, magnesium chloride, calcium chloride, and potassium chloride in either solid or solution (liquid) form. A deicer can be used in the anti-icing or deicing mode of operations. Synonym: Ice Melt.

Effective Temperature: The lowest temperature at which it is cost effective or practical to use a deicer. (e.g., salt works down to -6° but below 15° becomes less effective).

Event: A meteorological weather system with a defined start and stop time that produces any type or combination of winter precipitation (ice, snow, hail, sleet, freezing rain, etc.). Synonym: Snow Event.

Geo Fence: A technology defined virtual boundary around a real property / area. Doing so establishes a radius of interest that enables a software technology (e.g., Viaesys "Field Wiz") to initiate an action in a geo-enabled hardware technology such as a smart phone or other mobile or fixed vehicle device. (Techopedia, 2016)

Ice Management: The mitigation of ice accumulation or potential ice accumulation using chemical or physical processes.

Level of Service (LOS): A description of the expected outcome(s) on a site or set of sites from the completed performance of snow and ice management services. Level of Service typically defines expectations for surface conditions at specific times (completion times) or timeframes, or alternate/additional expectations for events that exceed a defined timeframe and/or a defined amount of accumulation(s).

Scope of Work (SOW): Defines the service criteria (e.g. snow clearing, ice management, etc.) and specific areas to be serviced on a site or set of sites. The SOW can include any issues that may impact the execution of service (i.e. poor site drainage, slopes/hills etc.). Synonyms: Statement of Work, Statement of Services. Related term: Level of Service.

Service Area: Specific locations on a site where some portion of work will be performed as a part of the service agreement.

Site: The property or collection of contiguous properties where services are to be performed.

Snow and Ice Management Association (SIMA): A 501-c6 non-profit trade association serving the private snow management industry.

Snow Belt: A region or market where the average annual snow accumulation and occurrences is significant. SIMA considers 20 inches / 10 snow events or more in a season to be significant.

Total Maximum Daily Load (TMDL) is the total maximum level of a pollutant allowed in a waterbody defined by either a local, state or federal regulatory body.

Winter Management Industry: A professional term developed by the author that is synonymous with the term snow and ice management industry.

Winter Severity Index (WSI): An algorithm of variable conditions including Air temperature, surface temperature, wind / wind chill, precipitation accumulation, precipitation moisture, and relative humidity.

Chapter I

Introduction

There is a little known and significant environmental epidemic occurring. Chloride contamination of freshwater resources is increasing as a result of salt used for commercial winter management operations. Yet the drivers and variables that influence the rate and frequency of salt applications are not well understood.

Awareness of this issue is important because only 2.5% of all of the water on this planet is fresh water rather than salt water. Of that, less than 1% is available for use. Salt is also a significant factor contributing to the corrosion of bridges, buildings and vehicles, increasing maintenance costs by billions of dollars each year (Schwartzberg, 2016).

Chloride contamination is particularly evident in Snow Belt states and provinces throughout North America. Environmental assessments performed in urban and suburban regions of Minnesota, New Hampshire New York and Ontario (among other regions) have confirmed many of their surface and ground water resources - particularly primary sources of drinking water - exceed the EPA's allowable total maximum daily load (TMDL) for chloride concentration. (SASC, 2010) TMDL is a representation of the total maximum level of a pollutant allowed in a waterbody defined by either a local, state or federal regulatory body.

In New Hampshire, the Department of Environmental Services (NH DES) is the regulatory body assigned by the Environmental Protection Agency to monitor and enforce EPA minimum and maximum TMDL standards (NH DES b, 2016). Research conducted to assess the effects de-icing salts have on freshwater systems along the I-93 corridor in Southern New Hampshire confirm the contamination of chlorides in lakes, streams and groundwater sources is on the rise, particularly as a result of unregulated winter management operations in private parking lots and roadways (Burack, Steart & Trowbridge, 2008).

Similarly, sodium and chloride contamination measures increased three times over a period of 30 years from 1980 – 2009 in Lake George, NY. This increase is a result of sodium chloride used for road de-icing operations in winter (Boylen, Eichler, Swinton, Nierzwicki-Bauer, Hannoun, & Short, 2014).

Many state and provincial departments of transportation (DOTs) throughout North America have formally established best practice guidelines for managing their salt use (Nixon & DeVries, 2015.) Similar best practices for the commercial snow and ice management industry have only just begun to be developed and adopted. This is particularly concerning for a growing commercial real estate and retail economy where a majority of surfaces require the management of slippery conditions during winter seasons (IBIS, 2014).

Research Significance Goals and Objectives

Several of the research studies, initiatives, innovations and technologies for reducing salt use have been developed and implemented without first answering the question: Can salt (chloride) pollution resulting from winter management operations be reduced? To address this I first evaluate: 1) if there is an issue with deicing salts being over applied by the commercial winter management industry; 2) why this is happening; and 3) what the opportunities are to reduce salt use pollution.

The primary goal of this thesis is then to answer the question: How can a highly fragmented industry reduce the rate and frequency of salt it applies? The primary objective of the research is to deliver an inclusive context analysis of the commercial winter management industry's current practices of salt application through the lens of sustainability.

I aim to provide data, methods and matrices that can empower the development of future salt reduction initiatives, research and standards of practice. I then discuss the future outlook and provide a set of recommended solutions interventions to consider for implementing future salt use policies that enable standards of practice.

Background

Salt is a chemical compound formed from a cation or positive ion attached to an anion or negative anion. Salt is inexpensive and readily available as an anti-icing or deicing material that is spread easily on roads, parking lots and sidewalks to ensure safe driving and walking conditions. The three types of salt that are typically used the most by the commercial winter management industry, based on my professional experience, include rock salt (NaCl), magnesium chloride (MgCl) and calcium chloride (CaCl). Chloride-based salts are most commonly used for deicing purposes. Sodium chloride (NaCl), magnesium chloride (MgCl), and calcium chloride (CaCl) are used worldwide with NaCl being the most commonly utilized (Evans & Frick, 2001). Sodium Chloride (NaCl), also referred to as rock salt, is the most commonly used chemical for de-icing surfaces according to surveys conducted by the Snow & Ice Management Association and reported in the New York State Department of Transportation (NYSDOT) highway maintenance guidelines (NYSDOT,2012).

Approximately 17 million tons of sodium chloride is being broadcast annually on roadways, parking lots and sidewalks for winter management operations throughout the United States (Howard, 2014). In Canada over $1 billion is spent annually on winter maintenance of various transportation facilities throughout all its provinces, which includes the use of an average five million tons of salts (TAC, 2013).

Effective Use of Salt

To efficiently use salt, it's important to understand each type of salt and its level of effectiveness to melt ice and snow at different temperature ranges. Determining the appropriate salt to apply related to varying surface temperatures can be tricky. A good rule of thumb to memorize is "*15/5/-25*" (Table 1). These numbers are the lowest practical melting temperatures in Fahrenheit for rock salt (NaCl), magnesium (MgCl2) and calcium (CaCl2) to be effective for melting snow & ice conditions on paved surfaces (MLLRB, 2012).

Table 1. Comparison of practical melting temperatures for different salts. (MLLRB, 2012).

Comparison of Salt			
Salt	Effective °F/°C	Eutectic °F/°C	Concentration (% by weight)
Rock salt (NaCl)	15 / -9	-6 / -20	23
Magnesium (MgCl)	5 / -15	-28 / -33	22
Calcium (CaCl)	-25 / -32	-60 / -51	30

Salt works by lowering the freezing point of moisture on the road surface below 32 degrees Fahrenheit / 0 degrees Celsius. NaCl, the common salt used, is typically most effective to 15 degrees Fahrenheit. Before salt can become effective, it needs to be crushed by vehicle or pedestrian traffic, and requires heat from pavement before it begins to dissolve. When it begins to dissolve and create brine, it prevents ice from forming on the pavement (US Roads, 1997).

The single most important condition, besides temperature, that influences salt's effectiveness is moisture. Moisture from either the air or from precipitation directly affects salts ability to convert to a liquid known as brine. The effective temperatures of salt will also be influenced by existing conditions that affect salts reaction times including vehicle and pedestrian traffic that is required to efficiently break down solid forms of salt. (MPCA, 2015). The speed at which NaCl works is dependent on pavement temperatures, not air temperatures (Table 2).

Table 2. Speed of melting with NaCl at variable pavement temperatures (MPCA, 2015).

Pavement Temp. ºF	One Pound of dry Salt (NaCl) melts	Melt Times
30	46.3 lbs. of ice	5 min.
25	14.4 lbs. of ice	10 min.
20	8.6 lbs. of ice	20 min.
15	6.3 lbs. of ice	1 hour

Refreeze occurs when the concentration of salt is diluted by moisture and causes the freeze point of the brine to equal the pavement temperature. At this point, the material will stop melting and water may refreeze if pavement temperatures are dropping. This process is known as "dilution of solution" (MLRRB, 2012). For example, sodium chloride (NaCl) brine is most effective for melting ice at 23.3% concentration by volume of water. From my professional experience I've learned once salt is diluted below 22% and or is over concentrated above 24% it rapidly loses its effectiveness.

Effect of Salt on the Environment

Research studies and white paper publications focusing on chloride and sodium contamination in lakes, streams and rivers have been conducted dating back as far as 1950 (Kelting & Laxson, 2010). For example, sodium chloride concentrations as high as 5 g/l (25% of the concentration of sea water) were measured in urban streams regions located throughout New York, Maryland and New Hampshire during winter months. During the summer months concentrations were upwards of 100 times higher than unpolluted streams in undeveloped forest regions. (Kaushal, et al., 2005).

Over the past 25 years, the NH-DES has been testing chloride levels in well water for drinking, streams, rivers, ponds and lakes. The testing has consistently validated that elevated chloride levels are high enough to be concerned about drinking water quality and threaten the health of sensitive fish species and smaller organisms that serve as a food source for fish (Hintz & Relyea, 2017).

Public perception is that a majority of these salt loads originate from state highway snow management operations (NH DES, 2016a). Research conducted to support the expansion of the I-93 highway in New Hampshire determined that more than 50% of salt introduced into the I-93 corridor / Policy-Porcupine watershed was originating from parking lots and private roads that require snow and ice management service and 36% of salt loads originate from state and municipal roads (Figure 1). (Burack et al., 2008)

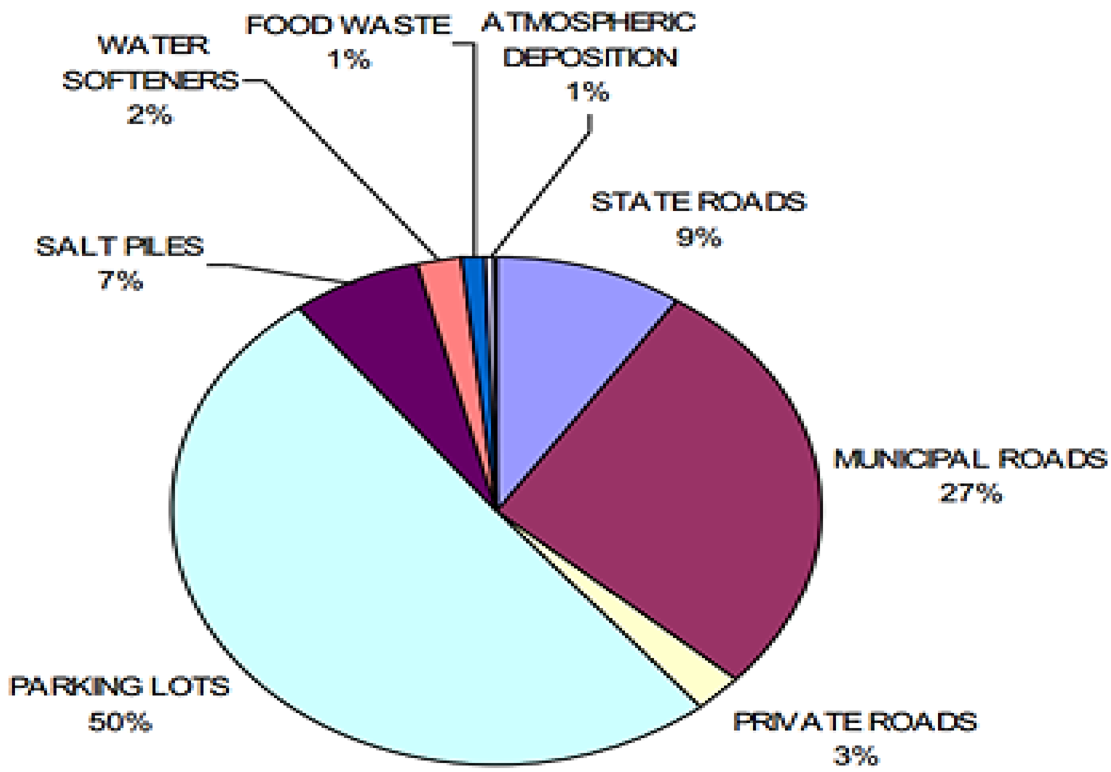

Figure 1. Chloride loads measured in Policy - Porcupine New Hampshire watershed region (Burak, et al., 2008).

The close linear increase of sodium and chloride ions concentrations in Lake George from 1980 – 2009 (Figure 2) “leaves little doubt that the main source is sodium chloride from road de-icing in winter” (Boylen, et al., 2014).

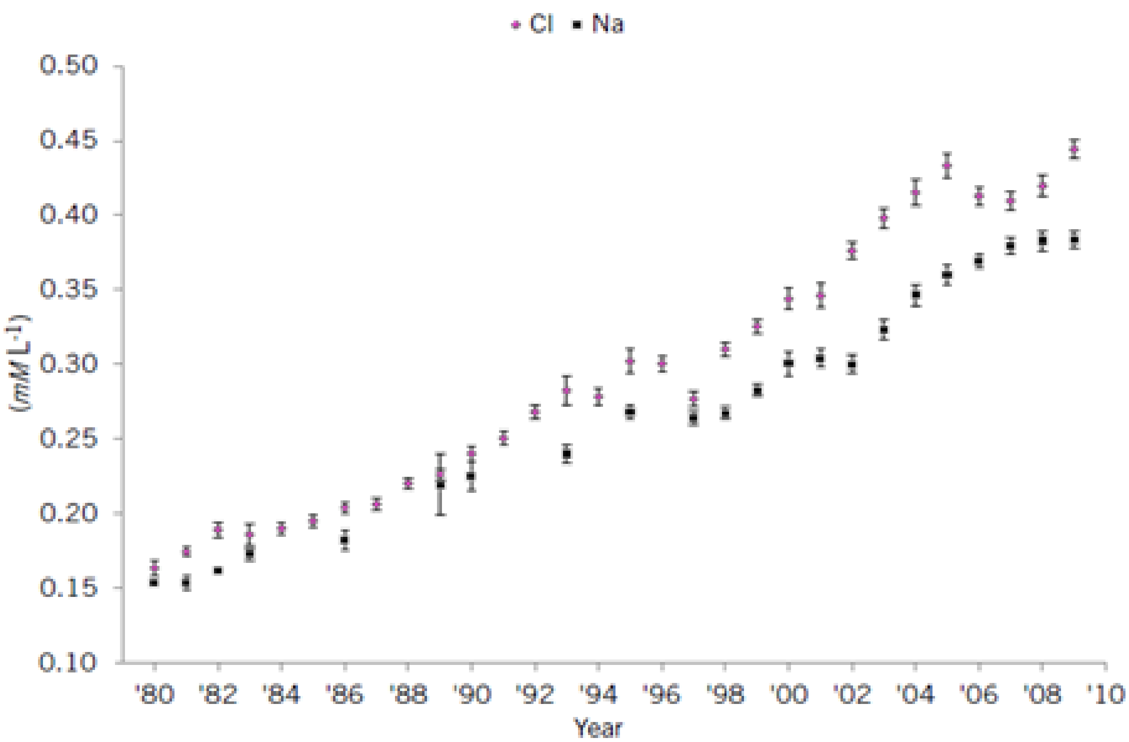

Figure 2. Mean annual sodium and chloride concentrations (millimoles per liter) measured in Lake George, New York, from 1980-2009 (Boylen, et al., 2014).

Analysis of NaCl concentrations of urban drinking wells in the region of Waterloo, Ontario, revealed that as much as 40% of salt loading can be attributed to salt application on private roads, parking lots and sidewalks. (Novotny, Murphy & Stefan, 2007).

A 20-year study in upstate New York found a doubling in salt concentrations in the watershed, with 91% attributed to road salt application and 9% to sewage and water softeners (Kelly et al. 2008). In the Mohawk River basin of Upstate, NY, concentrations of Ca, Mg and K ions during the1990s were similar to estimates from the 1950s with all three showing a modest increase of around 10% (Godwin, Hafner & Buff, 2003). More concerning was that sodium (Na) and chloride (Cl) ions increased by 130 to 243%, respectively, from 1950 to 1990. Compared to 1970 levels all ions showed a decrease by 1990, except Na and Cl ions, which displayed increases of 34 and 40%, respectively (Godwin et al., 2003). The only source of Na and Cl the study could account for the large mean daily yields was concluded to be road salt.

NaCl also influences the chemistry of the soils it infiltrates. Chloride anions are conservative substances that have little effect on soil chemistry. However, sodium ions take part in a chemical process that changes the soil properties that affect the fertility of the soil (Novotny, et al., 2007). In my professional experience, this is typically why turf and landscape plant damage is observed in areas where salt applications have been over broadcast beyond the target surfaces.

The most important environmental impact of salt that is not visible is its effect on fresh-water resources, which impacts aquatic life and drinking water quality. Only 2.5% of all of the water on this planet is fresh water, not saltwater (Figure 3). Of that, less than 1% is available for use as the majority is frozen in glaciers (Freshwater Crisis n.d.).

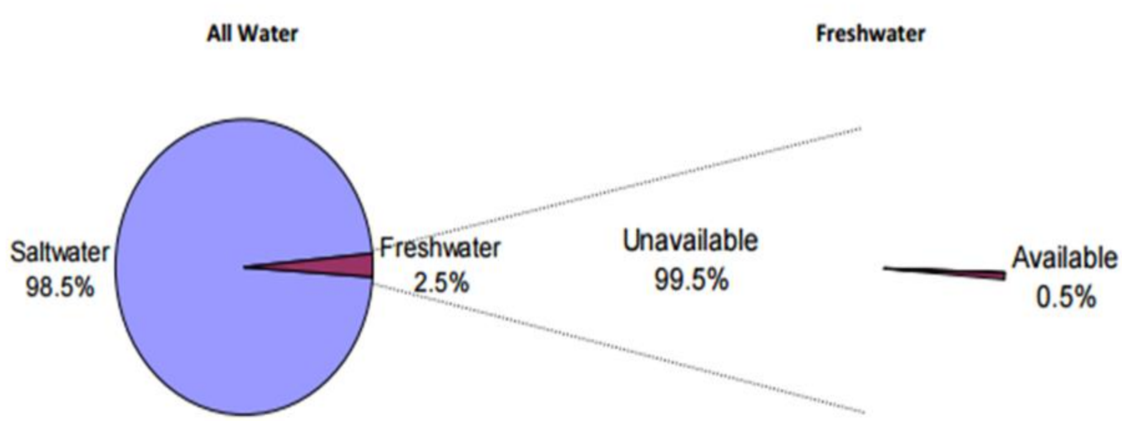

Figure 3. Freshwater availability (Freshwater Crisis n.d.).

Chloride (Cl) contamination in surface waters can be toxic to many forms of fresh water aquatic life including fish, macro invertebrates, insects and amphibians. Contaminants from salt used for winter management enter fresh water resources by infiltration to groundwater, non-point source runoff to surface waters and storm drains. The chlorides (Cl) from salt discharged into these water systems remain in solution with no chance of removal through natural means (Figure 4) (Sander, Novotny, Mohseni, & Stefan, 2007). Only dilution with more fresh water can reduce its concentration (NH DES a, 2016). Some fish species are affected by impaired water, which is equivalent to about 1 - 1.5 tablespoons of salt in five gallons of water (MPCA, 2015).

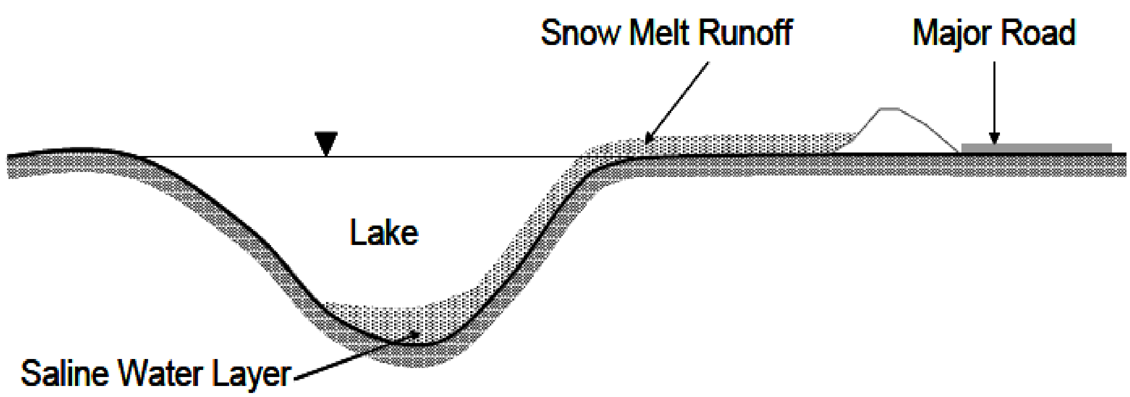

Figure 4. Nonpoint source run off of chlorides (Cl) from salt used for de-icing roads and parking lots (Sander et al., 2007).

Elevated chloride concentration in streams and rivers leads to acidification and mobilization of toxic metals through facilitated ion exchange (Kaushal et al., 2005). This in turn can cause changes in the rate of mortality and reproduction of aquatic plants and animals (Sarma, Morales-Ventura, Delgado-Martínez, & Gonzáles-Valverde, 2005) and alter the structure of riparian and wetland plant communities and their nutrient cycling (Baldwin, Rees, Mitchell, Watson, & Williams, 2006).

At environmentally relevant levels, studies show that high concentrations of deicing salts (mostly NaCl) reduce the abundance of several freshwater species (Heintz & Relyea, 2017; Karraker, Gibbs, & Vonesh, 2008; Morgan II, Kline, Kline, Cushman, Weitzell, & Churchill, 2012; Petranka & Francis, 2013; Searle, Shaw, Hunsberger, Prado, & Duffy, 2016). Changes in the composition of fish assemblages are known to occur at chloride concentrations below 110 mg (Morgan et al., 2012).

The highest observed deicing-salt concentrations occur in streams (Kaushal et al., 2005) and elevated concentrations can persist throughout the year (Kelly, et al., 2008; Corsi, Graczyk, Geis, Booth, & Richards, 2010). In fact, many stream ecosystems often exceed both the chronic (230 mg Cl) and acute (860 mg Cl) thresholds established by the United States Environmental Protection Agency (USEPA,1988) for the protection of freshwater organisms (Kaushal, et al., 2005; Corsi et al., 2010; Allert, Cole-Neal & Fairchild, 2012).

Sodium chloride's environmental effects stretch beyond water. The addition of the compound into the soil has a ripple effect. Plants and trees don't get the nutrients they need that become bound up in the soil profile and increased saline levels can reduce species diversity, particularly in wetlands regions (NH DES a, 2016).

The most visible impact salt contributes to landscape environments’ is to grass, shrubs and other landscape foliage. Salt run off from roads and sidewalks enters the natural environment in a variety of ways from my professional experience including:

splash and spray from vehicles, wind, snow melt into the soil, run off to surface waters, and 'bounce and scatter' once salt exits a spreader.

The other most visible environmental impact is damage caused to infrastructure including roads, bridges, parking decks, sidewalks, doorways, and entrance flooring. Chloride (Cl) in salts, whether it is in a blended product or not, increases the conductivity of water and accelerates corrosion of metals (NH DES a, 2016). From my experience installing concrete and managing snow and ice, I've observed salts that are absorbed during the freeze thaw cycles when melting snow or ice will contribute to the deterioration of concrete that isn't properly cured or sealed. Salt will also cause corrosion and damage to reinforcing rods and structural steel which results in compromised structural integrity (Schwartberg, 2016).

Commercial Winter Management Industry

The commercial winter management industry also referred to as snow and ice management, snow removal, snow plowing and other descriptions, primarily provides snowplowing and ice management services to commercial and retail markets (IBIS, 2014). There are a variety of practices and equipment the industry currently utilizes to prevent or mitigate the effects of snow & ice accumulation including snowplowing & snow clearing, deicing & anti-icing techniques (IBIS, 2014).

The majority of revenue comes from commercial businesses, including owners of office, manufacturing and retail locations (IBIS, 2014). There are over 27,000 companies and over 110,400 snow plow and salt application owner / operators according to SIMA's 2016 industry survey (Wolf Works, 2016; IBIS, 2014). Four out of five of the companies in the industry are sole proprietors, also referred to as non-employers. Nearly two thirds of these companies classify landscaping as their core business (Wolf Works, 2016; IBIS 2014).

A Bloomberg Business article titled *The Snow Business is a Mess* described the commercial winter management industry as “highly fragmented” and “lacking sophistication”, particularly when dealing with the multiple variables of weather and workforce availability, and trying to normalize pricing and staffing (Clark, 2017). The article further emphasizes the fact there are no required qualifications of education, knowledge, experience or licensing to own a business or work in the industry.

Industry demand and revenue is subject to changing weather patterns and risk each winter season. Winter management operators are increasingly offering new services for controlling slippery pavement conditions that help ensure steadier streams of income and minimize risk from slip and fall liability. They are adopting new contract structures and implementing new equipment innovations for increasing production efficiencies and controlling operating costs that enable competition in pricing (IBIS, 2014).

An April 2016 industry research study (Wolf, 2016) conducted for the Snow & Ice Management Association (SIMA) reported the annual revenue earned by the 50 largest companies’ who provide commercial winter management services. The top four 4 largest winter management companies control less than 5% of the industry’s annual revenue. The top 50 largest companies comprise only 8% of the industry’s annual revenue (Wolf, 2016; IBIS, 2014). The remaining 110,350 operators earn average annual revenues of $152,100 for providing winter management services (IBIS, 2014).

New York State has nearly one seventh of all reported snowplowing business establishments in the United States (US) according to a US Census Bureau poll and SIMA's April 2016 industry research study (Wolf, 2016). The remaining Top-10 largest markets for commercial winter management business are located in the Northeast, Upper Midwest, Mid-Atlantic States and Colorado (Figure 5).

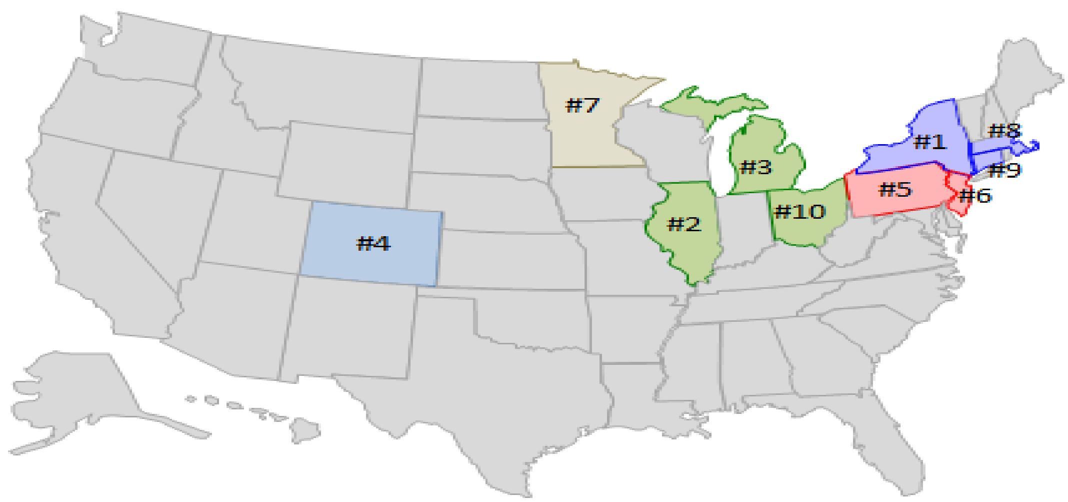

Figure 5. Top 10 commercial winter management service markets (IBIS, 2014).

Stakeholders

A contextual background and integrations of the commercial winter management industry's primary stakeholders is important to understand for future salt reduction strategy. Winter management operators and their clients are the two primary industry stakeholder groups.

Winter management operators, typically referred to as contractors, include: employers, employees, and subcontractors who perform the physical labor and equipment operation necessary to plow snow and apply de-icing products to parking lots, roadways and sidewalks. Over two thirds of companies are landscape contracting firms and owner / operators that offer winter management services as a secondary source of revenue (IBIS, 2014; IBIS 2015).

Clients are typically commercial real estate property owners who hire facility managers (FMs) to manage their property or portfolio of real estate. Facility managers in turn hire contractors for winter and landscape management services typically referred by FMs as exterior services. Commercial properties include retail, commercial office, industrial, warehouse, and home owners associations (HOAs).

A subcategory of FM's is service brokers, who typically refer to themselves as national management companies (NMCs). Service brokers' generally serve a purpose for property owners and real estate investment trusts (REITs) who own or manage a large regional or national portfolio of properties. The NMC's primary role is to broker a network of contractors to provide winter management services for a portion of or an entire portfolio, which sometimes may include hundreds or thousands of properties.

Manufacturers & suppliers who typically serve the winter management industry design and build new snow plows, salt spreading equipment and supporting technology. Dealer networks are normally how manufactures distribute new lines of equipment products and technology innovations. From my experience there are occasions when manufacturers will sell to large end user companies directly.

The salt industry is categorized by the supply chain that mines, produces and delivers salt to the end users the operators who apply salt and their clients who compensate for it being applied. The mining and primary supply chain has evolved into a consolidation of salt companies including Morton, Cargill and American Rock Salt, who are among the larger companies in the United States that supply a majority of salt inventory to the commercial winter management industry (Salt Institute, 2017).

Software and hardware companies are more rapidly entering the market space with new innovations for tracking time and materials used for winter management operations. Innovations these companies offer include GPS and other cloud based technologies for automating payroll, invoicing and tracking salt application rates and inventories.

Insurance carriers and agents provide commercial general liability and legal liability protection policies for contractors, both in prime and surplus market categories. Liability is discussed further in this chapter and in chapter IV.

Two trade associations exist which educate and advocate for the commercial winter management industry. Both offer a professional certification and publish their own industry trade magazine. SIMA is a 501(c) (6) nonprofit association and currently reports 1,900 + company members in 2016 (Wolf, 2016). The Accredited Snow Contractors Association (ASCA) was founded in 2011 as a for profit association owned by publishing company GIE Media (ASCA, 2017). ASCA does not report the number of active members.

Volatility

Although winter weather patterns each season are typically volatile by nature, the overall earned revenue and business growth throughout the industry experiences moderate to low volatility (Figure 6) (IBIS, 2014).

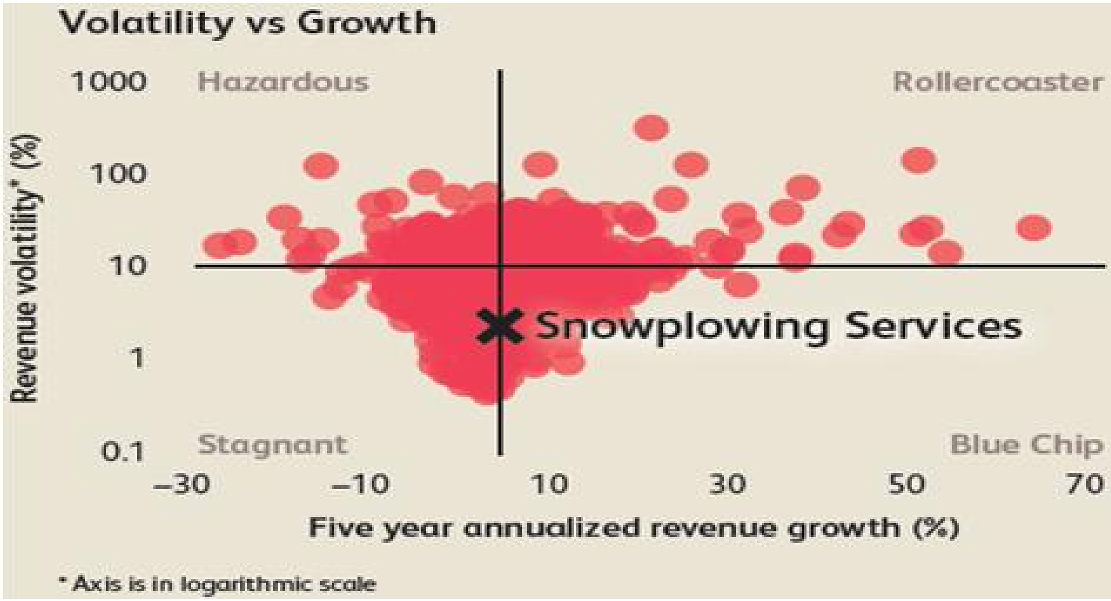

Figure 6. IBIS 2014 industry volatility graph (IBIS, 2014).

Variable contract models typically utilized to balance annual revenue streams include: 1) per occurrence, also referred to as “per push”, that invoice for each occurrence that plow or salt applications are performed; 2) time and material (T&M) that charge for hours and quantities of materials used, 3) per event, also referred to as “per inch”, which compensates for different categories of storm events (i.e. a 1-3” versus a 4”-6” storm); 4) seasonal contracts that charge one flat fee no matter how many storms or events occur; and 5) seasonal variance contracts that charge a base fee and add charges if a basic number of storms or events have been exceeded. From my professional experience, variance contracts can also be structured to allow for credits if a minimum number of storms or events have not occurred in a given season.

Liability

The Fund for Lake George describes the use of deicing salts as “The Acid Rain of Our Time” (Lake George, 2015). This description is a representation of the social reputational liability that is being directed to the commercial winter management industry’s effects on the environment.

In the more recent decade, slip and fall claims are increasing. The National Center for Injury Prevention and Control reports in the United States there are more than 8.7 million people injured from slip, trip and fall incidents every year (Zurich, 2017). According to Zurich Insurance North America study, $1billion is paid annually for slip, trip and fall claims with 25% of this total to handle incidents due to snow and ice (Zurich, 2017).

Forecasted expansion in the US economy during the next three years through 2019 will enable growth in the commercial real estate sector (IBIS, 2014). An unintended result of this economic growth will require businesses to spend more to protect their employees and customers from potential slips and falls related to inclement weather. According to IBIS’s 2014 Snow Plowing Services report, it is predicted that by 2019 more snowplowing service companies are expected to offer around-the-clock ice-watch services. These services will include winter management operators constantly monitoring local temperatures and visiting customer sites to clear and deice surfaces on an even more regular basis (IBIS, 2014).

Licensing and Certification

There is no required licensing or certification requirements for purchasing & applying salt or other deicing products, although SIMA sponsors a voluntary Certified Snow Professional (CSP) program. The CSP tests six areas of knowledge including one module focused primarily on snow plowing operations, and one section related to salt use.

The ASCA owns SN-9001, a subcategory of the International Standards Organization (ISO) ISO-9001 quality management standards. SN-9001 audits standards of business management quality but does not verify standards of snow operations practice. The ASCA also sponsors their own voluntary certification, ASCA-C, that specifically tests proficiency of knowledge specific to the SN-9001 requirements.

The New Hampshire Green Snow Pro certification is an annual voluntary education program managed by NH DES. The program trains individuals about salt application best practices for reducing salt use. The salt application rate guidelines discussed in chapters II and III of this thesis are a key component to the training curriculum. A unique benefit the Green Snow Pro certification offers is legal limits of liability for voluntary certified companies who perform winter management services. The same legal protection is extended to clients (property owners) who hire professionals actively certified in the program (NH DES, 2017).

In Ontario Canada, the Smart About Salt winter salt management training curriculum includes improving winter salting practices on facilities and recognizes industry leaders through certification. (SASC, 2017). The program is managed by the

Smart about Salt Council, founded in part by the region of Waterloo government with the sole intent of reducing salt contamination of drinking water wells in the region. (SASC, 2017).

Best Practices Guidelines and Standards

Industry involvement related to the effects of deicing salts on the environment has only recently been initiated. SIMA has committed itself to advocacy and research focused on salt use best practices in the past two winter seasons since 2015/ 2016 and 2016/ 2017. SIMA recently published a first version of guidelines for Salt Use Best Practices in the last quarter of 2016. However there is resistance within the industry for reducing salt use, as recently ASCA's executive director publicly denounced the reduction and regulation of salt use due to fear of slip and fall liability for its members (ASCA, 2015).

State and provincial departments of transportation (DOTs) throughout North America have formally established best practice guidelines for managing their salt use (Kelting & Laxson, 2010). Similar best practices for the commercial snow & ice management industry have only just begun to be developed by SIMA. This is particularly concerning in a growing commercial real estate and retail economy where a majority of surfaces require the management of slippery conditions during winter seasons (IBIS, 2014).

Salt Rate Guidelines

Salt rate application guidelines exist for the industry to benchmark against their own rates. Five known sets of established rates include:

1. Salt application rates developed by the University of Waterloo- SICOPS research study (Table 3) I use these as the “control” to compare with other established salt rate guidelines in this study. The rates determined for two hour bare pavement regain time (BPRT) desired levels of service (LOS) are what I recommend and compare with other sets of rates.
2. Sustainable Salt Initiative (SSI) case study rates (Figure 7). The salt application rates selected are a representative average of the total rates collected during the 2015-’16 and 2016-’17 winter seasons.
3. Salt rate guidelines developed in Minnesota (Table 4). A portion of the recommended salt application rate guidelines for deicing was compared from the Winter Parking Lot and Sidewalk Maintenance Manual -Third Revision, June 2015, published by the Minnesota Pollution Control Agency. LOS for achieving BPRT is not specified in this set of guidelines.
4. New Hampshire Green Snow Pro certification training guidelines (Table 5). These rates are a portion of the recommended dry salt application rate guidelines for deicing from the NH Green Snow Pro certification training guidelines. The matrix format was adopted from the Minnesota Winter Parking Lot and Sidewalk Maintenance Manual -Third Revision, June 2015, published by theMinnesota Pollution Control Agency. LOS for BPRT is not specified in this set of guidelines.
5. SIMA’s salt production rate guidelines (Figure 8). BPRT is not defined in SIMA’s recommendations.

Table 3. University of Waterloo SCIOPS study of salt application rates for parking lots (Hossain, 2014).

Stall		Application Rate for Desired LOS in BPRT (hr)					
Snow depth cm (in.)	Avg Tp °C (°F)	1	2	3	4	5	6
0.1 to 0.5 (0.04 to 0.2)	-1 to -3 (30 to 27)	6 (29)	3 (15)	2 (10)	1 (5)	1 (5)	1 (5)
0.1 to 0.5 (0.04 to 0.2)	-4 to -6 (25 to 21)	17 (83)	9 (44)	6 (29)	4 (20)	3 (15)	3 (15)
0.1 to 0.5 (0.04 to 0.2)	-7 to -9 (19 to 16)	35 (171)	18 (88)	12 (59)	9 (44)	7 (34)	6 (29)

The term "Stall" represents parking space.

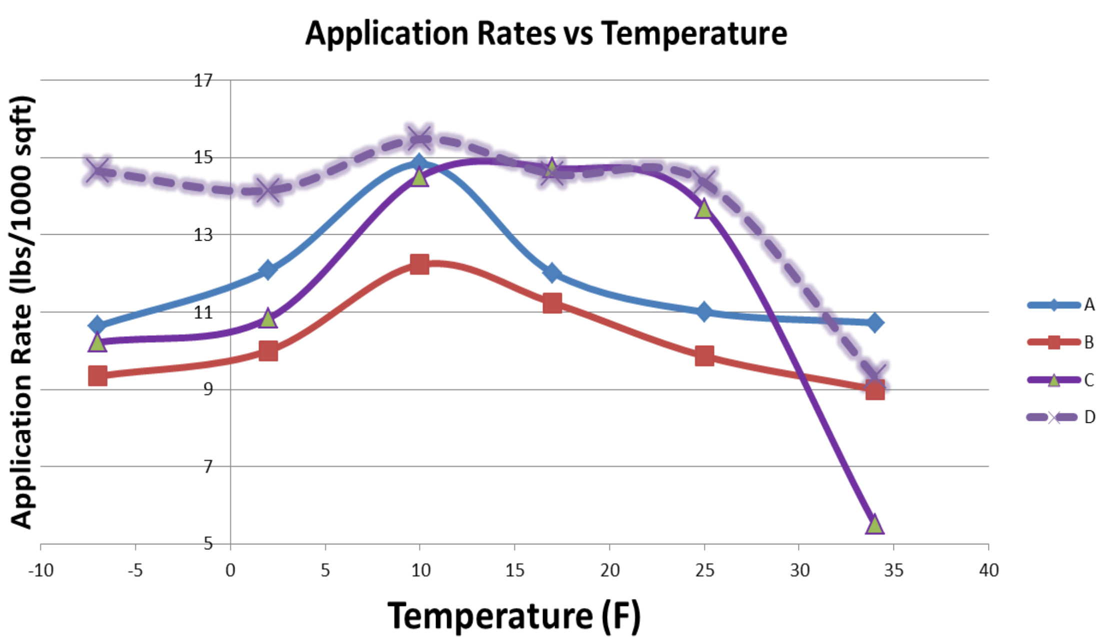

Figure 7. Example of Sustainable Salt Initiative (SSI) case study application rates collected (Graph created by Raqib Omer, Viaesys Inc.).

Table 4. Minnesota salt rate guidelines for parking lots. (MPCA, 2014)

Pavement Temp. (ºF) and Trend (↑↓)	Weather Condition	Maintenance Actions	Application Rate in lbs./per 1000 square foot area			
			Salt Pre-wetted/ Pretreated With Salt Brine	Salt Pre-wetted/ Pretreated With Other Blends	Dry Salt	Winter Sand (abrasives)
>30º	Snow	Plow, treat intersections only	0.75	0.5	0.75	not recommended
	Frz. Rain	Apply chemical	1.25	1.0	1.5	not recommended
30º ↓	Snow	Plow & apply chemical	1.25	1.0	1.5	not recommended
	Frz. Rain	Apply chemical	1.5	1.25	1.75.	not recommended
25 - 30º ↑	Snow	Plow & apply chemical	1.25	1.0	1.5	not recommended
	Frz. Rain	Apply chemical	1.5	1.25	1.75	not recommended
25 - 30º ↓	Snow	Plow & apply chemical	1.25	1.0	1.5	not recommended
	Frz. Rain	Apply chemical	1.75	1.5	2.25	3.25
20 - 25º ↑	Snow or Frz. Rain	Plow & apply chemical	1.75	1.5	2.25	3.25 for frz. rain
20 - 25º ↓	Snow	Plow & apply chemical	2.0	2.0	2.75	not recommended
	Frz. Rain	Apply chemical	2.5	2.0	3.0	3.25
15º to 20º ↑	Snow	Plow & apply chemical	2.0	2.0	2.75	not recommended
	Frz. Rain	Apply chemical	2.5	2.0	3.0	3.25
15º to 20º ↓	Snow or Frz. Rain	Plow & apply chemical	2.5	2.0	3.0	3.25 for frz. rain

Table 5. New Hampshire Green Snow Pro salt rate guidelines for parking lots.

Pavement Temp. (°F) and Trend (↑ ↓)	Weather Condition	Maintenance Actions	Salt Prewet/ Pretreated with salt brine	Salt Prewet/ Pretreated with other blends	Dry salt	Winter sand
>30 ↑	Snow	Plow, treat intersections	4.5	4	4.5	Not recommended
	Frz. Rain	Apply chemical	5.75	5.25	6.5	Not recommended
30 ↓	Snow	Plow and apply	5.75	5.25	6.5	Not recommended
	Frz. Rain	Apply chemical	6.5	5.75	7	Not recommended
25 - 30 ↑	Snow	Plow and apply	5.75	5.25	6.5	Not recommended
	Frz. Rain	Apply chemical	6.5	5.75	7	Not recommended
25 - 30 ↓	Snow	Plow and apply	5.75	5.25	6.5	Not recommended
	Frz. Rain	Apply	7	6.5	8.25	10.5
20 - 25 ↑	Snow or frz. Rain	Plow and Apply	7	6.5	8.25	10.5 for frz. Rain
20 - 25 ↓	Snow	Plow and apply	5.75	7.5	9.5	Not recommended
	Frz. Rain	Apply	7	7.5	10	10.5
15 - 20 ↑	Snow	Plow and apply	7.5	7.5	9.5	Not recommended
	Frz. Rain	Apply	8.75	7.5	10	10.5
15 - 20 ↓	Snow or Frz. Rain	Plow and apply	8.25	7.5	10	10.5 for frz. Rain

SIMA - Salt Production Rates

Ice Control Product for Walkways:
50 # Bag will cover an average of 750 sq. ft.
50 # bag requires 15 minutes of labor for handling and application.

Bulk Rock Salt for De-Icing Lots:
There is no set standard for salting parking lots, and any figures below are simply estimates and examples. Keep in mind:

Application rates for salting parking lots are variable and dependent on the following conditions:

- Cycles times and timing of storm vs. expected time to be 'open for business'
- Expectations from clients, known as Level of Service or LOS – see SIMA Standard Glossary of Terms
- Type and moisture level of precipitation (dry vs. wet vs. freezing), as well as conditions at the site (pavement surface temperature, time of day, etc.)
- Quantity of precipitation
- If an anti-icing process is implemented

Application rate ranges:

- 250-300 # per acre for pre-treating surfaces prior to or upon accumulation (1/2 inch or less) and maintaining after each snow clearing cycle
- 500-600 # per acre for de-icing lots after clearing snow (no anti-icing/ pre-treat process implemented)
- ~30 minutes to apply 1 ton of bulk rock salt with 1.5-3 yard gas powered or electric spreader/plus time for loading and cleaning hoppers

Average 30 minutes to spread per ton of salt.

Figure 8. SIMA salt production rate guidelines (SIMA, 2017).

Research Questions, Hypotheses and Specific Aims

This research combines data on salt application rate benchmarks and variables that have been established by academic and environmental research and compares it with a sustainability analysis of the commercial winter management industry - to ask these research questions:

How do the current salt application guidelines compare with the reality of how the industry applies salt? Would following the available salt application guidelines prevent salt from being over applied? What is driving the commercial winter management industry's rate and frequency of salt use in terms of causal factors? What are the difficulties in reducing the amount of salt used? Does a majority of the industry measure and calibrate salt output? If not would measuring and analyzing salt output data reduce salt use?

My primary hypotheses related to these research questions are the following:

1. Current rates of salt applications used in commercial winter management operations for parking lots, and private roadways are higher than established guidelines indicate they need to be.
2. Less salt is applied when the established salt application guidelines are followed.
3. The rates and frequencies of salt application rates increase when contracted levels of service or perceived levels of quality for snow & ice control are increased.
4. The amount of salt applied is higher when property owners or contractors are liable for slip and fall claims.

Specific Aims

The hypotheses support the need for a broad contextual analysis of the winter management industry that required addressing these specific research aims:

1. Demonstrate there is an issue with salt being over applied. I accomplished this by comparing the existing salt application rate guidelines against the SSI case study.
2. Identify existing salt application rate guidelines to be utilized as a model for furthering the development of a national standard. In the discussion chapter I

further interpret the results of the comparative analysis overlay of salt application rates to show where the opportunities for a national standard exist.

3. Evaluate and summarize the commercial winter management industry in its current state. I utilized a PESTLE analysis method for categorizing the political, economic, technology, legal, and environmental (PESTLE) issues that impact the sustainability of the commercial winter management industry.
4. Investigate the primary drivers & variables that influence the amount of salt used by the commercial winter management industry. I developed a weighted scale of the variables identified in the PESTLE analysis by utilizing a materiality matrix.
5. Discuss the practical constraints or implications from the analyses of the winter management industry to provide a foundation for the development of future salt reduction initiatives. These initiative and issues I discuss include future research, salt application rate standards, policy standards of practice, government regulation and legislation, and training and certification.

Chapter II

Methods

This chapter explains the various data and methods of analyses I utilized for this research. Data and methodologies incorporated from external sources and results are summarized and referenced in the corresponding tables and figures. This chapter also discusses a number of limitations of this research.

Research Approach, Data and Methods

The overarching approach I utilized for my research incorporates the three principles of sustainability: economic responsibility, social responsibility, and environmental stewardship (Pojasek, 2010).

In order to evaluate the relationship between salt use and the commercial winter management industry, I utilized five sets of existing salt application rate guidelines, five categories of industry context data and three methods of analysis to develop: 1) comparative analysis of salt application rates; 2) sustainability analysis of the commercial winter management industry; and 3) materiality analysis of the primary drivers and variables that influence salt use.

Comparative Analysis of Salt Application Rates

I developed a comparison table (Table 6) as a method to analyze "real world" salt application rates being measured from the ongoing SSI case study compared with a set of "control" rates determined from the SICOPS study, and with the recommended guidelines from MN, NH and SIMA. A majority of the application rates included in the table represent those that achieve bare pavement regain time (BPRT) in 2 hours or less. The MN Guidelines do not specify a BPRT level of service. The matrix format is based on the MN road application guidelines (MLLRB, 2012).

Table 6. Comparative analysis table for application rates of dry NaCl.

Pavement Temp. (°F) and Trend (↑ ↓)	Conditions	CONTROL (SICOPS Study)	Dry Salt (NaCl) Application Rate in Pounds per 1000 sq. ft.			
			SSI Case Study	Minnesota Guidelines	N. Hampshire Guidelines	SIMA Guidelines
15 - 20 ↑	Cleared snow from surface	18	14	3	10	14
15 - 20 ↓	Cleared snow from surface	18	13.5	2.75	10	14
20 - 25 ↑	Cleared snow from surface	9	13.25	2.75	9.5	13
20 - 25 ↓	Cleared snow from surface	9	12.75	2.25	8.25	13
25 - 30↑	Cleared snow from surface	3	12.5	1.5	8.25	12
25 - 30 ↓	Cleared snow from surface	3	11	1.5	6.5	12
30↑	Cleared snow from surface	3	11	1.5	6.5	11
>30 ↓	Cleared snow from surface	3	10	0.75	4.5	11

SSI Case Study Data Collection Method

Salt application rates data were collected from winter management companies participating in SIMA's Sustainable Salt Initiative (SSI) that I developed and sponsor in my role with SIMA. The data collection process, analysis and reporting is managed by

Viaesys, Inc. Founder / CEO, and former University of Waterloo SICOPS research associate, Raqib Omer.

The SSI salt rates I compared as the case study represents the average quantity of salt being applied for various surface temperature conditions compared with the combined sets of rates that have been collected over the past two winter season from an independent and diverse sample group of snow and ice management companies who apply salt on a contractual basis throughout North America. The salt application data was collected from calibration & tracking hardware designed by Raqib Omer and supplied by Viaesys, Inc., branded as 'Field Wiz'. We installed this salt application tracking technology on over 200 salt spreading vehicles that were evenly distributed throughout 25 companies servicing a combined total of over 1,500 properties throughout 10 states and two 2 provinces in the northeast and great lakes regions of North America.

The salt application measuring technology includes GPS enabled tracking of salt trucks that automatically measures each time a pre-determined and calibrated application rate is being applied for each property that has been assigned a geo-fence utilizing Google GIS mapping. The technology recognizes when a salt spreading truck enters a geo fenced property and applying salt (when the spreader is turned on). The salt application amount is automatically measured as a pre-calibrated salt application rate based on revolutions of the salt spreader conveyer or auger. This method of measuring revolutions removes the need to include the variability in ground speed of the truck that occurs based on the individual driver / operator and timing of each storm. If the operator chooses to use a different application rate that is higher or lower, a new calibration process that takes the operator approximately 10 minutes to perform is required.

The measuring technology does allow for an infinite number of pre-determined and pre-calibrated application rates to choose for measuring based on salt material flow rate adjustments made to any type of spreader that allows for adjustment. This in turn provides for an infinite number of possible independent application rates. The revolutions of the conveyer are measured in comparison with the pre-calibrated application rate that is then recorded through proprietary cloud based software that can be read both in real time and in a documented history of data sets categorized per site, per storm event, and per application.

When analyzing the past two seasons' worth of data from the SSI participating companies, my colleague Raqib Omer determined the best set of average performing application rates for the SSI case study. I then overlaid this set of selected rates to compare with the University of Waterloo SICOPS "control" and the other existing regional guidelines for salt application rates (Figure 9).

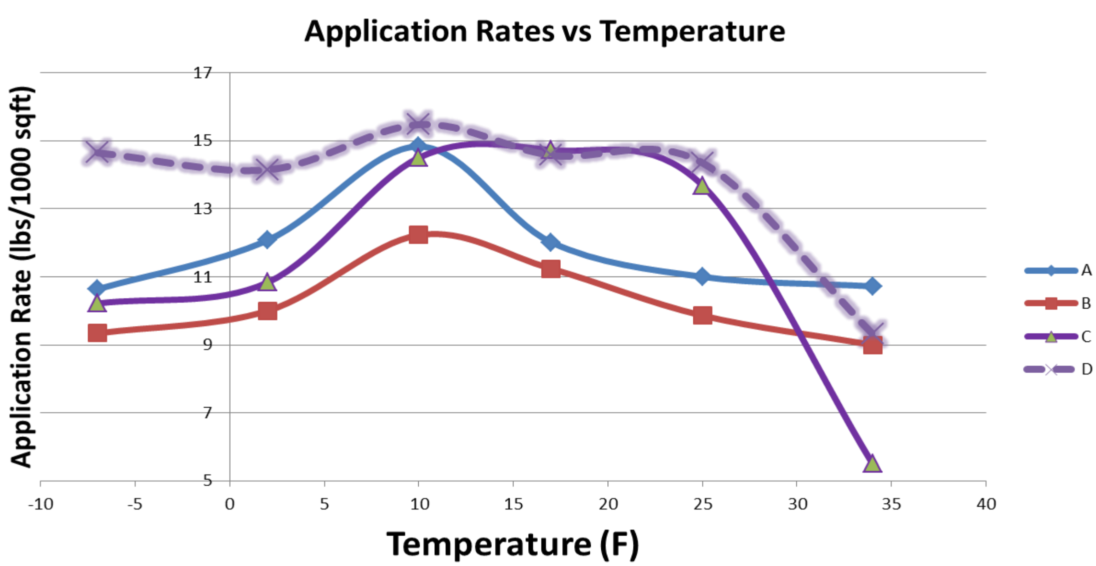

Figure 9. SSI sample group of anonymous companies A-D average salt application rates over one season (Graph created by Raqib Omer, Viaesys Inc.).

I then developed a chart of trend lines that represent all of the sets of application rates to compare with the SSI case study rates as a method for answering the question whether or not salt application rates are generally being over applied by the industry. I limited analysis to only the pavement temperature thresholds at which NaCl is most effective.

Sustainability Analysis of the Winter Management Industry

Five primary data sets were included for identifying and assessing the current sustainability issues of the industry including: 1) industry research conducted by SIMA and; 2) survey data from 5 years' worth of state of the industry surveys conducted by SIMA and a salt use survey I conducted ; 3) research literature reviews; 4) field observation data collected from a local study I designed; and 5) the experiential context derived primarily from my own experience and knowledge gained from working in the commercial winter management (and landscape) industry for over 28 years.

After I collected and organized the industry context data, I designed a PESTLE analysis chart (Table 7) to be used as the framework for categorizing and weighting (positively or negatively) the sustainability issues that impact the commercial winter management industry. I focused primarily on including issues that are related to salt use. The most heavily weighted issues specific to salt use identified in the PESTLE chart I then incorporated into a matrix I developed for the materiality analysis of the drivers and variables that influence salt use.

Table 7. PESTLE template for categorizing and weighting sustainability issues.

Issue	Effect / Impact	Salt Influencer? Y/N Environment? +/-	Materiality Quadrant (1,2,3,4)
Political			
Economic			
Social			
Technological			
Legal/ Legislative			
Environmental			

To help me define the issues represented in the PESTLE that influence the commercial winter management industry's use of salt, I evaluated an April 2016 research study of the snow and ice management industry conducted for SIMA. The primary sources of data for this research include: surveys conducted by SIMA, IBIS industry reports, US Census data and personal interviews performed by Steve Wolf of Wolf Works Consulting. The data I extracted from this research study I then summarized in the results and referenced in the tables and graphs.

Salt Use Survey Data

I analyzed five years' worth of state of the industry surveys conducted by the SIMA (via Survey Monkey) from seasons 2010 / 2011 through 2015 / 2016. The evaluation of these surveys was used for developing the inclusive context analysis (PESTLE) of the issues that impact the commercial winter management industry, particularly related to salt use.

I then developed a salt use survey via Survey Monkey with the goal of establishing statistical confidence in the variables I chose to evaluate. The results from this survey were also utilized for assessing statistical significance of the variables for the materiality analysis process.

Field Observation Data

During the 2016 / 2017 snow season I designed a field observation study with one contractor and one town municipality. The primary purpose was to segregate and measure their use of brine as an anti-icing and pre-wetting strategy for salt use efficiency and reduction. The sample group included an Albany, NY Landscape Company, and one municipality applying salt throughout the town of Lake George, NY. The Lake George basin is also connected with the larger Lake Champlain watershed region.

The initial design and purpose of this study was not successful for measuring the intervention of salt brine for anti-icing and pre-wetting. Rather an unintended result of the field observations provided valuable context for me to incorporate with the sustainability analysis results.

Experiential Context

My over 28 years' experience includes leading the largest commercial winter management operation in North America as Corporate Executive of Snow Operations for Brickman (now re-branded as Brightview). My more recent experience includes serving as Chief Knowledge Officer for SIMA. In 2011 I founded WIT Advisers, a boutique consultancy focused on developing, supporting and empowering sustainable landscape and winter management solutions for property owners and service providers. I conglomerated all of my industry experiences for assessing the current standards of practice and behaviors of the winter management industry.

Materiality Analysis of the Drivers and Variables that Influence Salt Use

I further evaluated the salt use survey questions and utilized the Survey Monkey statistical analysis tool for establishing confidence about which issues defined in the sustainability analysis PESTLE table were significant to include. The survey was sent to the entire Snow Business Magazine reader list, all SIMA members and all SSI participants. A total of 528 companies reported.

I then designed a materiality analysis matrix (Figure 10) as a method for prioritizing and weighting the survey responses revealed by the sustainability analysis that specifically related to the drivers and variables that influence salt use.

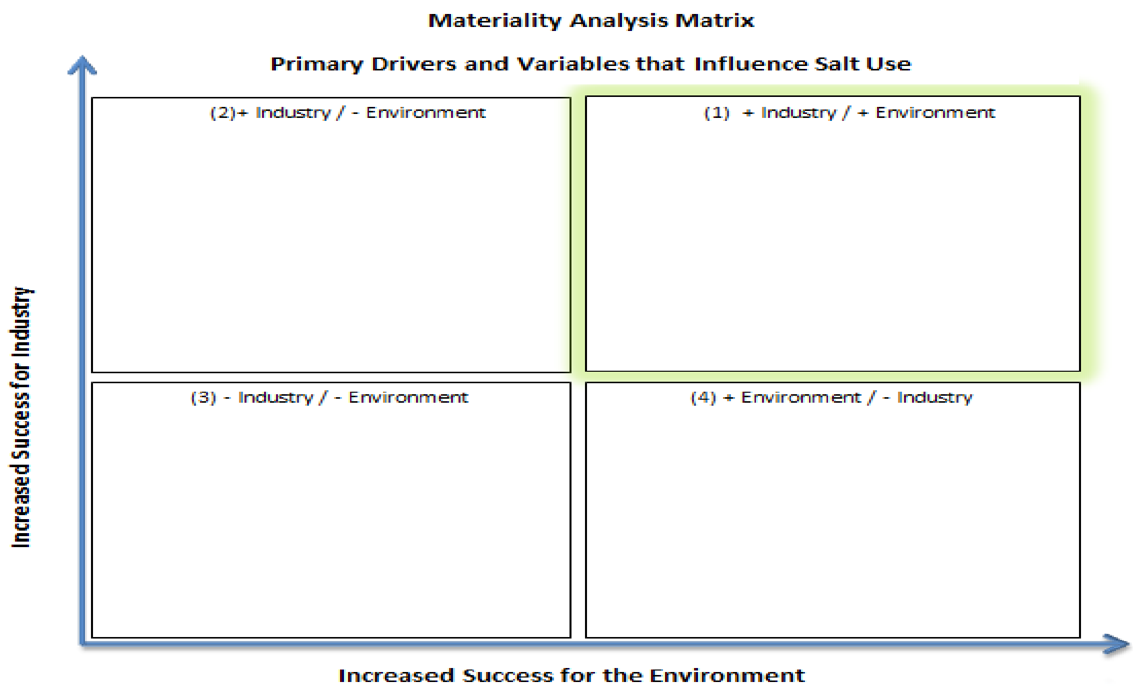

Figure 10. Materiality matrix used to prioritize the primary drivers and variables that influence salt use.

Materiality Analysis Method

A materiality analysis is a process typically used by large companies for corporate social responsibility (CSR) reporting and for prioritizing issues to focus on developing as a strategy for future improvements (Mohin, 2012). The materiality matrix helped prioritize issues that are more important to focus on or weigh more heavily as opportunities for improvement.

To weigh each of the improvement opportunities based on the principles of sustainability, I assigned a value of importance for each variable identified from the PESTLE method and transferred it to one of the four quadrants of the materiality matrix. The value assigned to each variable is based on my own professional experience, knowledge and reputation as a landscape and winter management subject matter expert (SME). The y axis represents importance for industry success and the x axis represents importance for the environment. The variables that are located closer to the top right corner represent a more heavily weighted ability to influence all stakeholders. The right hand corner also represents the greatest potential or gap for prioritizing future salt reduction efforts.

The primary goal for developing this materiality analysis was to create a framework of contextual assessment that easily identifies and communicates where future salt reduction efforts should be prioritized. The purpose for developing the materiality matrix is to provide a model for future sustainability reporting and benchmarking as it relates to winter management operations and the relationship with the environment. I discuss the future potential of this model in chapter IV.

Research Limitations

This research poses several limitations. The identification of issues I chose to evaluate for the sustainability and materiality analyses incorporate my experiential knowledge and therefore may unintentionally include personal bias.

The SSI case study is not a statistical mean average of all the rates collected. The accuracy of salt application rate guideline comparisons is limited by the size of the SSI sample group and the amount of time necessary to perform an inclusive statistical analysis of the SSI case study of salt application rates. Due to time limitations for this thesis a common sense selection of the best average performing rates was chosen based on broader comparison of SSI participating companies. In the future a more focused and time consuming statistical analysis of salt application rates collected via SSI compared with the SICOPS “control” and the other regional salt rate guidelines will be required.

Increasing the SSI sample group is important for SIMA (or another organization) to continue in future years in order to increase the statistical confidence for calculating a true statistical mean average of salt application rates.

Participants in the Sustainable Salt Initiative (SSI) were qualified and recruited by me or my colleague Raqib Omer and therefore are not completely random. The actual salt application rates being measured for determining the SSI case study represented in the salt application benchmarking overlay are completely independent. There was no method of intervention(s) other than the initial training for how to properly calibrate the measuring equipment to confirm the accurate collection of salt application rate data.

This thesis did not analyze the use of different types of salt other than NaCl. Although NaCl is typically the material of choice used for anti-icing or deicing techniques to manage snow & ice, it is known that salts other than NaCl, including MgCl and CaCl, and the conditions when they are most effective, are options that should be researched further.

Salt application rates collected for the comparative analysis does not include sidewalks settings. The main focus for this thesis is parking lots applications.

Salt optimization strategies and methods were not included for analysis. Methods including anti-icing for preventing the bond of snow & ice on paved surfaces and pre-wetting methods for optimizing dry salt applications with the addition of concentrated salt brine are briefly mentioned for discussion of future strategy in chapter IV. Salt storage issues are another important set of issues for controlling chloride contaminations that is not included in this research.

Chapter III

Results

The results are organized into categories of the overall findings for comparative analysis of salt application rates, sustainability analysis of the commercial winter management industry, and analysis of the drivers and variables that influence salt use.

Comparative Analysis of Salt Application Rates

This first of its kind comparative analysis of salt application rates for commercial parking lots revealed an extremely variable range of guidelines (Figure 11). The SSI case study rates compared with the control and the other guidelines support the hypothesis that current rates of salt applications used in commercial winter management operations for parking lots, and private roadways are higher than a majority of the guidelines indicate they need to be.

Evaluation of Salt Application Guidelines

The only rates included in the comparative analysis that have been scientifically validated are the University Waterloo's SICOPS study I used as the "control" (Figure 11). Interesting to note is for colder temperatures the control rates are the highest. The SSI case study shows the second highest rates for colder temperatures.

The Minnesota recommended rates are the lowest for all practical pavement temperature thresholds (MN, Figure 11). Minnesota's rates are a conversion of lane mile application rates developed by Minnesota DOT (MN DOT) (MPCA, 2015). For example, one lane mile is converted to being equal to one acre. This conversion does not make a similar conversion for conditions of roads vs. parking lots which are not comparable.

The New Hampshire (NH, Figure 11) guidelines matrix was adopted from Minnesota including a revised set of salt application rates that were determined in a study conducted by the University of New Hampshire Technology Transfer Center. New Hampshire Department of Transportation (NH DOT) and the Environmental Protection Agency (EPA) were also participating supporters of the study although neither organization has adopted or endorsed the guidelines (UNH-T2, 2017). The current set of guidelines have been adopted by the NH DES as the major focus for their one day training curriculum that qualifies individual operators for NH Green Snow Pro Certification (UNH-T2, 2017).

The recommended ranges of application rates from SIMA (Figure 11) were initially determined from a small survey group of SIMA members nearly 10 years ago. I recently advised SIMA in December, 2016 to decrease the high and low value and range of the rates. The revised rates are what I include for comparison.

Overlay of Salt Application Rates

The resulting overlay of existing salt application rate guidelines (Figure 11) reveals a fragmented "patchwork" of guidelines that currently exist. For example, recommended rates for the same pavement conditions of 15 -20 degrees Fahrenheit (F) range between 130 lbs. and 775 lbs. per acre. Although some of the current sets of rates do show linearity, the range of low and high rates creates a confusing gap of understanding what set of guidelines are best to follow.

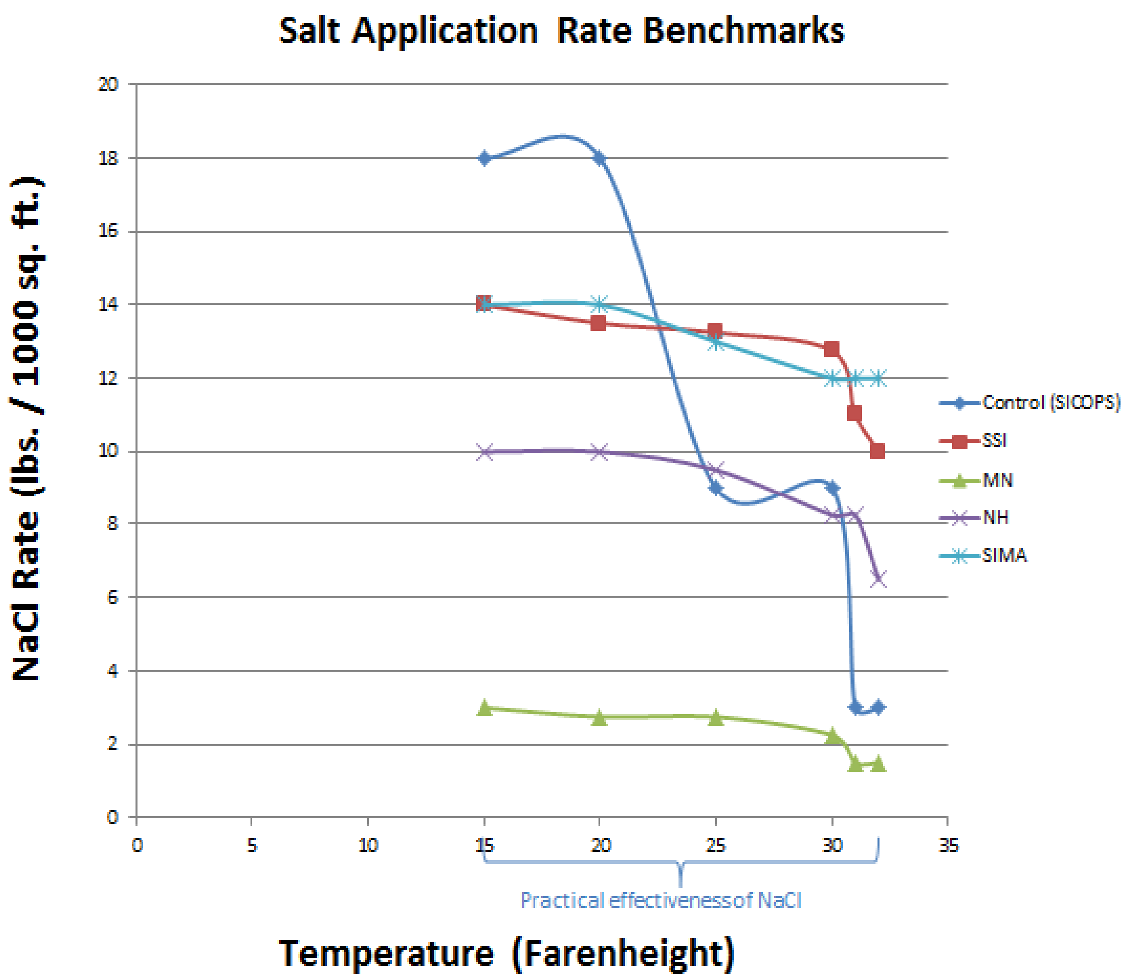

Figure 11. Overlay of salt rates at varied pavement temperature thresholds.

Sustainability Analysis of the Commercial Winter Management Industry

These results were aggregated into five categories of sustainability; 1) political, 2) economic, 3) technical, 4) liability, and 5) environmental. Results from the salt use survey I designed and evaluated provided confidence for validating and prioritizing the primary sustainability issues to be evaluated specific to the industry's use of salt.

The PESTLE analysis method summarized the primary issues within the context of evaluating the commercial winter management industry.

Political Analysis

The relationship between contractors' interpretations of their clients level of service expectations and the amount of salt they use reveals level of service (LOS) as the most heavily weighted issue that influences the rate and frequency of salt applications. In the salt use survey, 63% of the 528 companies surveyed reported they aren't confident or didn't know if maintaining their clients LOS expectations would be possible if they are required to reduce salt use (Figure 12).

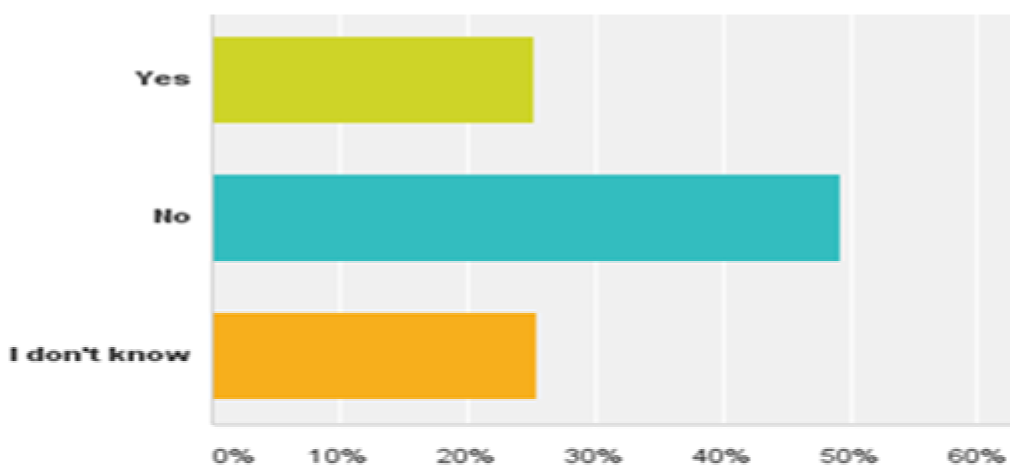

Figure 12. Survey responses for maintaining level(s) of service (LOS) if required to use less salt.

Economic Analysis

A majority of winter managment services are sold by the amount of salt applied and or the frequency of applications (Figure 13). According to a 2014/15 SIMA State of the Industry Survey, over 79% of companies reported agreeing to per occurrence or per event type contracts with their clients.

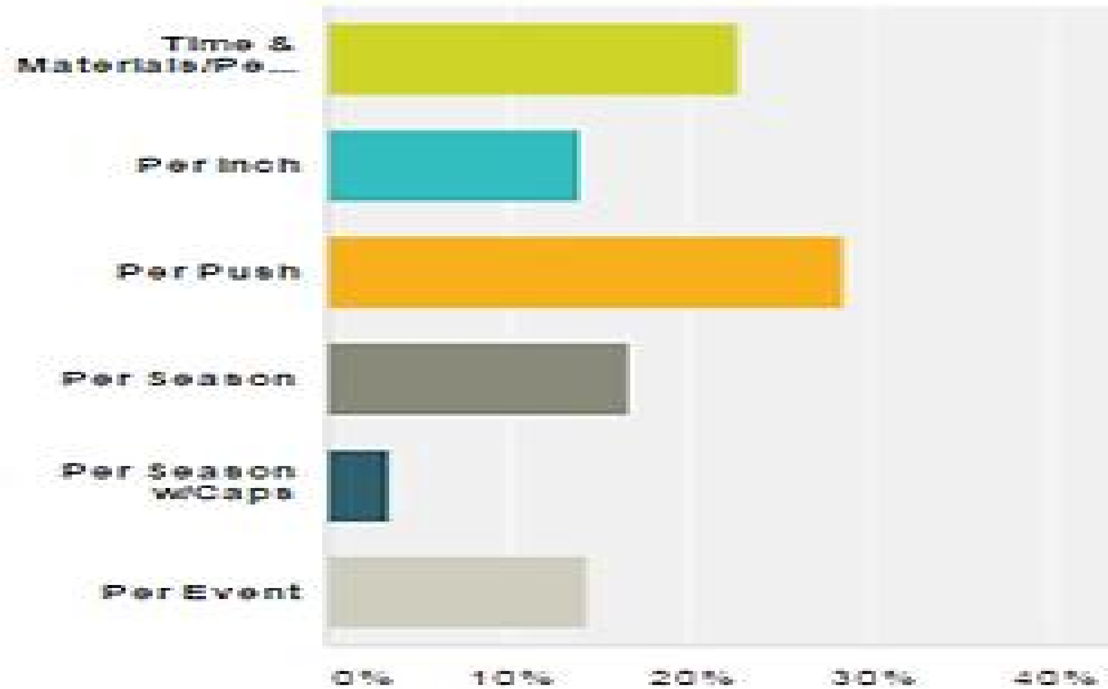

Figure 13. Survey of the most popular types of contracts.

My salt use survey of 528 companies throughout North America report nearly 75% of all contracts provide no financial incentives to use less salt. Charging for the number of salt applications is the most heavily weighted method (Per Application in Figure 14). The reported terms of agreements further validate that these types of compensation models are financially incentivised by the frequency of applications or the amount of salt used; these are the most heavily weighted types of contract agreements compared with lesser utilized seasonal variance contract models that incentivise efficiency in salt use.

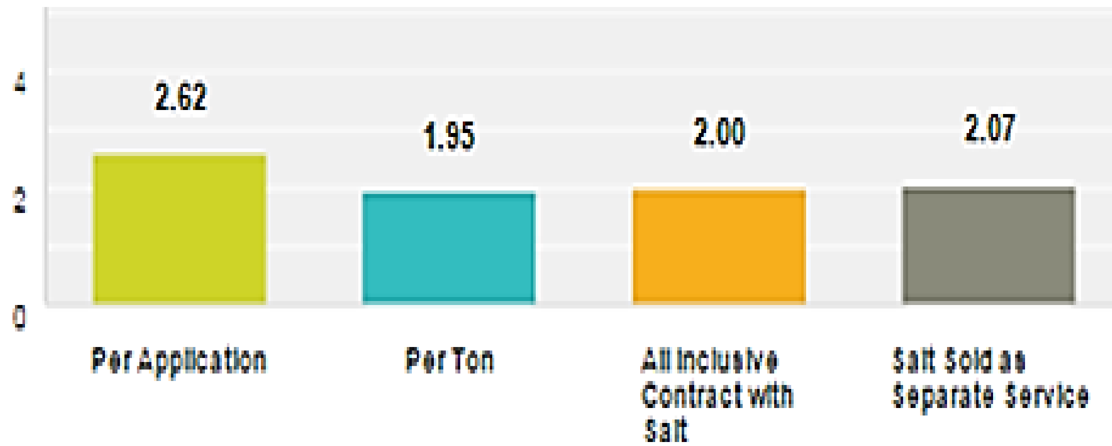

Figure 14. Survey of options for selling salt applications.

Shrinking business and lost profit is anicipated if companies choose to or are required to reduce their use of salt. Over 63% of companies reported anticipated losses in revenue or weren't sure if they could maintain their gross revenues. More than 53% of the same companies reported anticipated net profit losses (Figures 15 & 16).

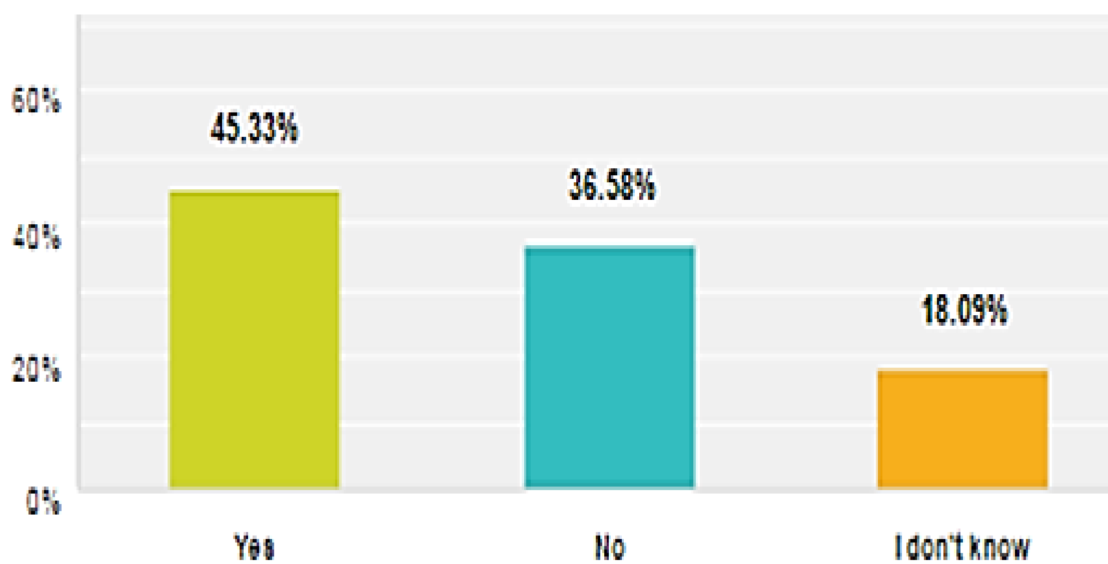

Figure 15. Survey of contractors who predict lost revenue if required to reduce salt use.

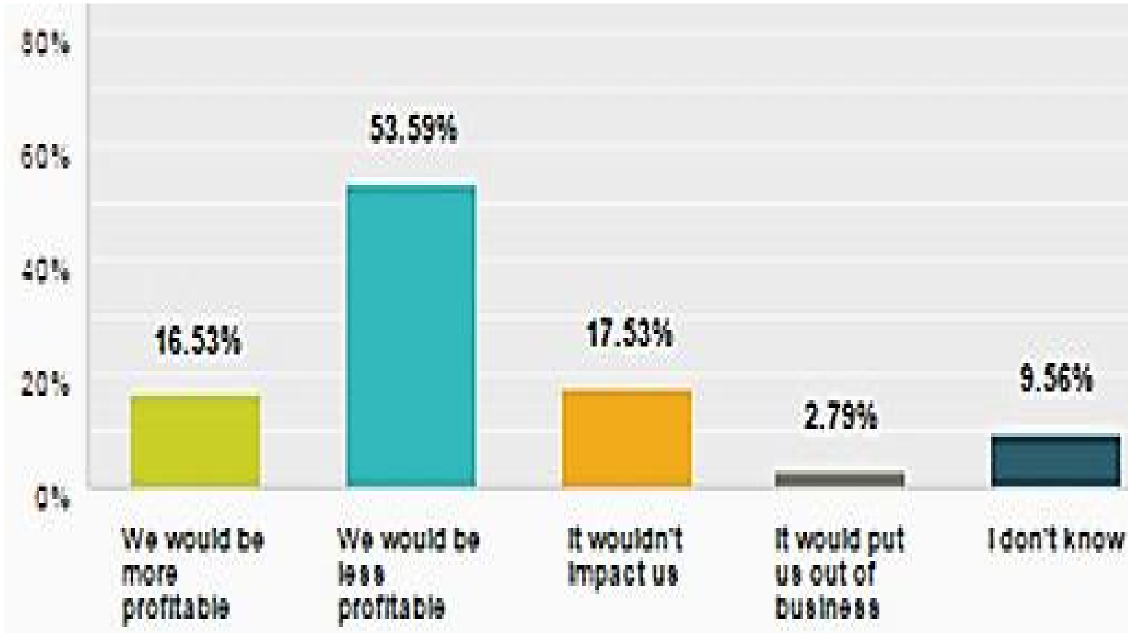

Figure 16. Survey of contractors' confidence to reduce salt use and maintain profits.

Social Analysis

An unintended result of the field observation process I initially designed for measuring salt optimization interventions was the validation of the many drivers and variables that influence the amounts of salt operators apply. The observations I collected included photo documentation: The salt application seen in the picture (Figure 17) is a "real life" level of service requested by the property representative who pays for salt application services on a time and materials basis. This picture shows approximately four times more salt applied than existing guidelines recommend for preventing black ice. The salt application was made two days prior to taking this picture. These observations provided me with a reminder and confirmation of the socially driven perceptions of quality that ultimately influence the rate and frequency salt is applied, regardless of the availability or affordability of best practices and technology to implement.

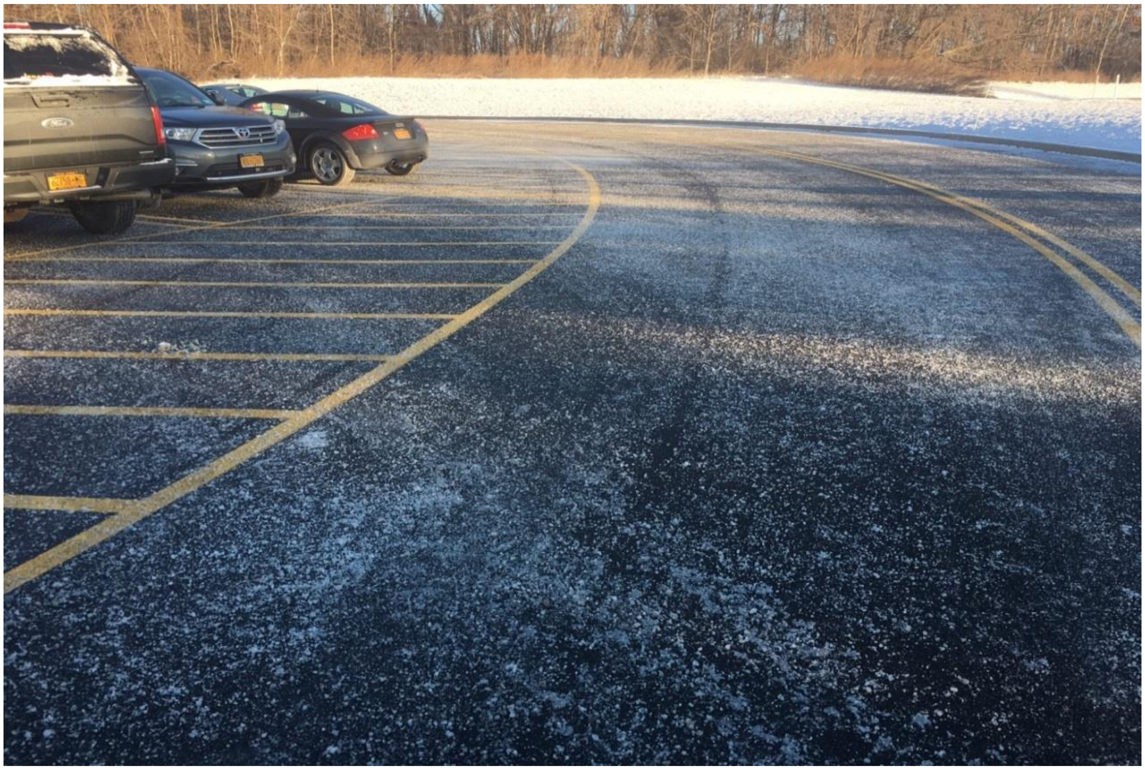

Figure 17. Observation of rock salt over applied in a commercial parking lot.

Technical Analysis

Companies consitently reported three issues as the primary impedements for adopting and implementing sustainable salt use best practices two years in a row: awareness; education / training, affordable access for implementing salt use efficiency interventions and technology (Figure18).

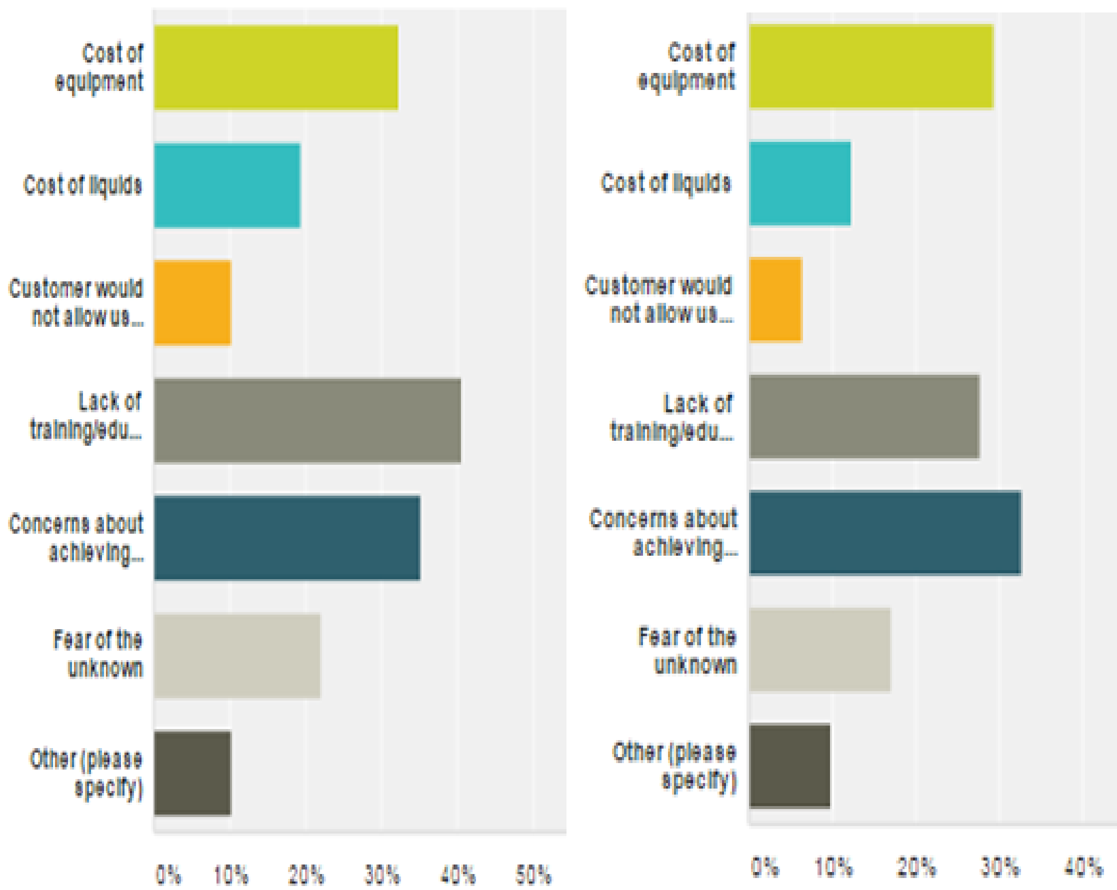

Figure 18. Two years of surveys reporting variables that impede the adoption of salt application efficiency best practices.

Liability / Legislation Analysis

Increasing fears of liability for slips and falls are in turn driving an increase in the level of service expectations and requests for more salt from property owners & facility managers. The salt use survey revealed over 83% of respondents reported concern for legal claims from slips and falls on properties they are responsible for (orange in Figure 19). Level of Service (LOS) was ranked second and clients requesting to see more salt was ranked third (blue and green in Figure 19). There were no options chosen or responses of concern for environmental liability associated with salt.

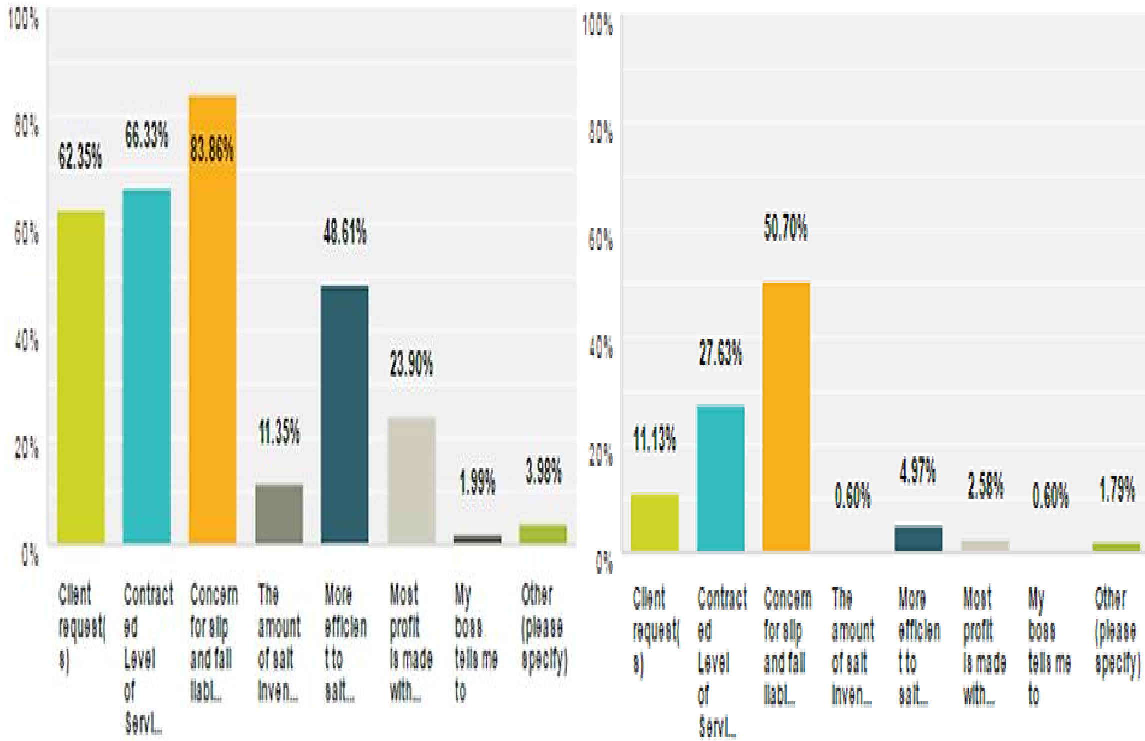

Figure 19. Two years of surveys reporting the drivers that influence salt application.

Three years of SIMA surveys 2012/13 – 2014/15 reveal on average over 77% of companies reported not having any slip and fall claims (Figure 20). These resuls reveal a future question to research: Is there a relationship between decreasing salt use and an increase in slip and fall claims?

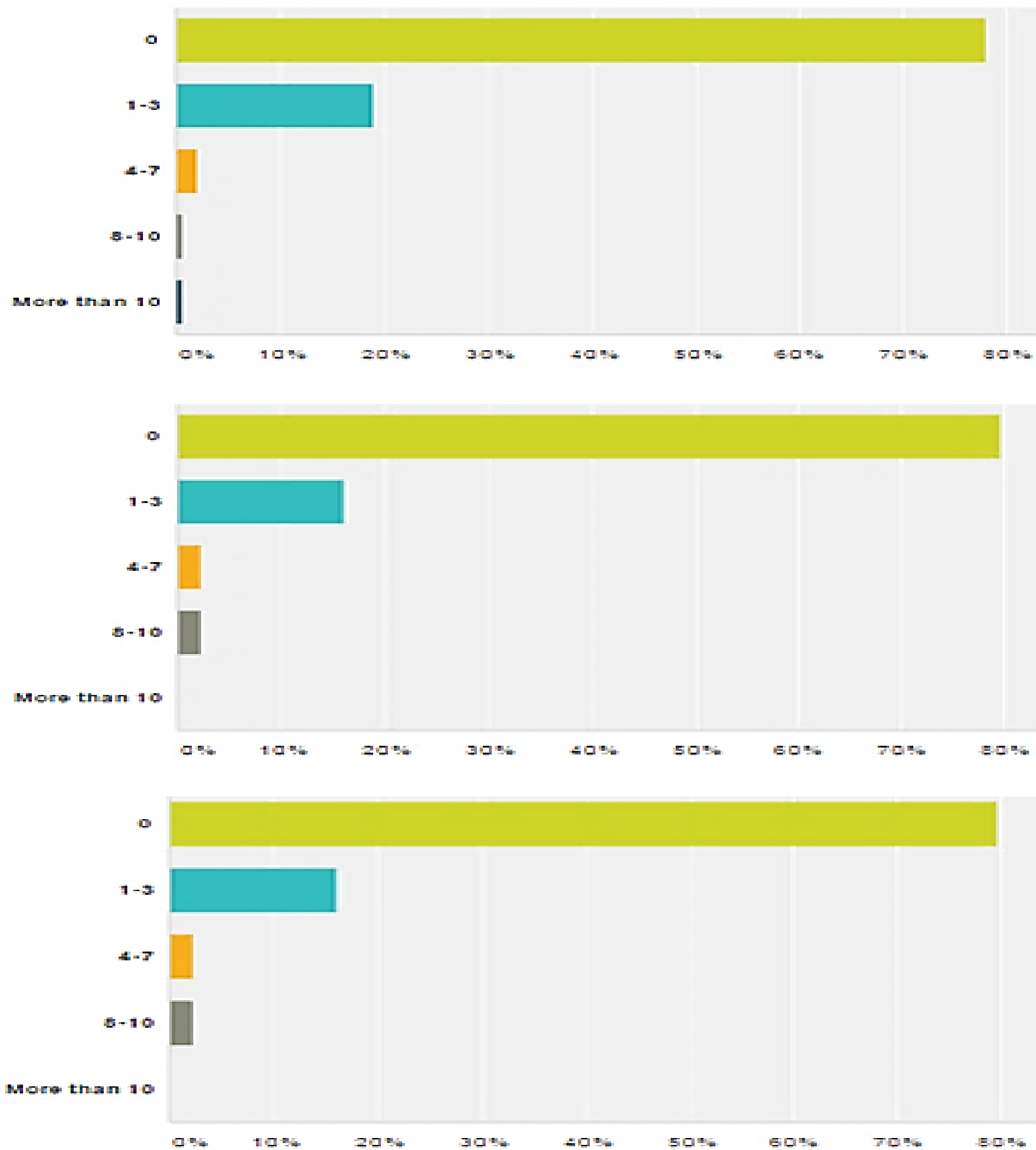

Figure 20. Three years of surveys reporting the number of slip and fall claims.

Environmental Analysis

Two years of surveys 2012/2013 & 2014/2015 conducted by SIMA reveal less than 10% of respondents on average were influenced by their clients to use less salt because of environmental pressures (orange in Figure 21). A change of weather patterns was the most significant factor for companies reporting a reduction in their salt use. Less than average amounts of snow events during seasons 2012/2013 & 2014/2015 did influence less salt use by respondents. Environmental concerns to reduce salt also decreased. (Figure 21). Interestingly there were no responses in the “other” category or “comments” option that listed environmental concerns as a factor.

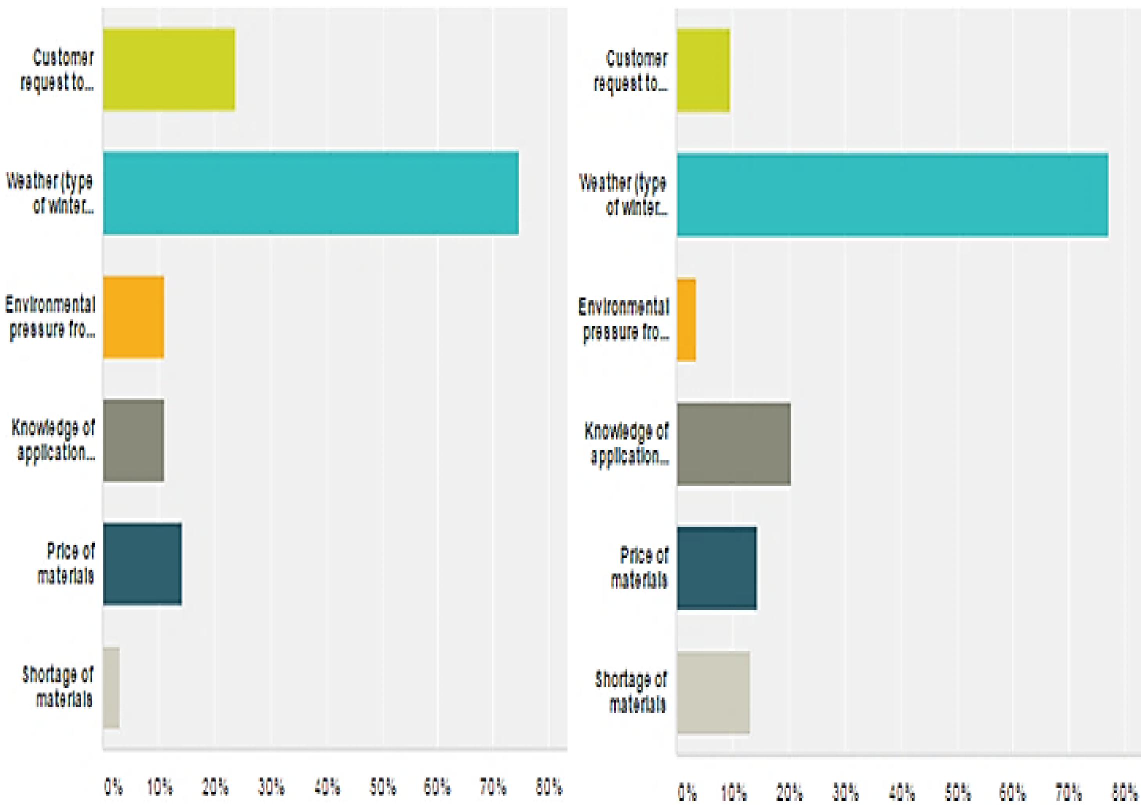

Figure 21. Two years of surveys reporting drivers that influence salt reduction.

The 2014 SIMA survey further confirmed that weather influences the purchase and use of salt. Over 51% of 355 companies surveyed reported the future forecast of a heavier snow season influenced an increase in purchasing and storage of salt inventories (Figure 22).

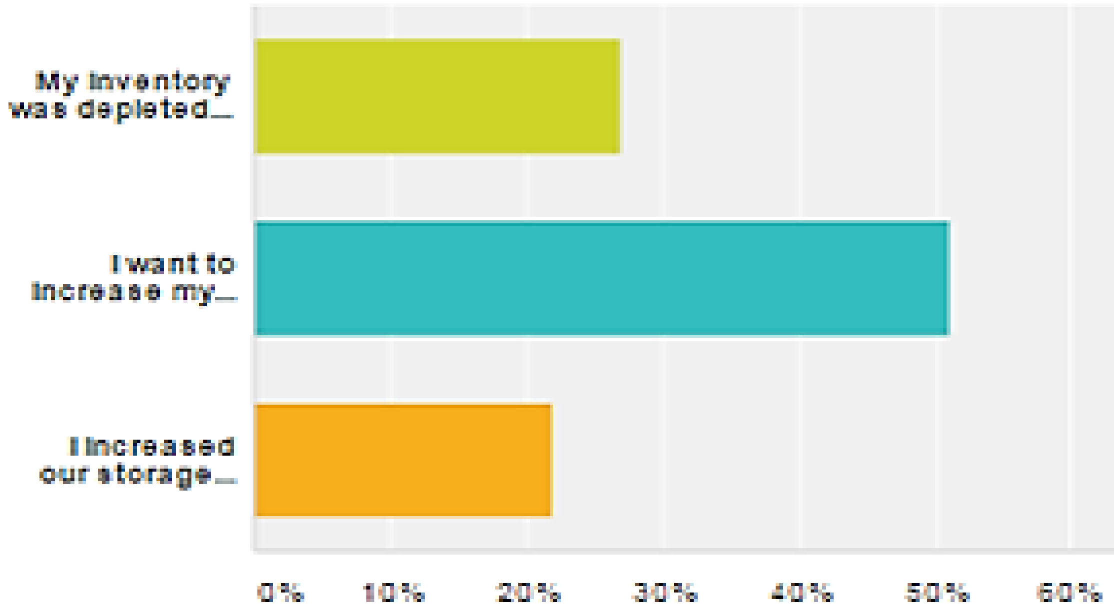

Figure 22. Survey of drivers that increase salt inventory investments.

PESTLE Analysis Summary

The resulting PESTLE analysis summary (Table 8) provides a first of its kind framework of context for the sustainability issues that impact the commercial winter management industry's use of salt. The issues that ranked the highest in materiality include: cost and profit pressures, clients' level of service expectations and fear of slip and fall liability. These primary issues and others identified are then further prioritized in the materiality analysis process.

Table 8. PESTLE Analysis

Issue*	Current State / Impact on Salt Use	Salt Influencer? Y/N How or why?	Materiality Rank (1,2,3,4)
Political			
Levels of Service	Clients expect "blacktop" conditions. "Seeing salt = increased perception of safety".	Yes; Clients want more than necessary	2
Economic			
Budgets	Cost pressures force cost efficiency; 'Melting' snow is more efficient than clearing snow.	Yes; More efficient to salt than plow	3
Revenue/Profit	A majority of contract agreements compensation for salt usage by the amount or frequency - #1 driver of salt use.	Yes; No financial incentive to use less salt	2
Social (Reputation)			
Quality	"My parking lot is safer than my competition across the street.	Yes; Better to use more than lose Business	2
"Green" Culture	Sustainable Best Management Practices (BMPs) are not well understood how to apply for winter management – current state.	Yes (potentially); BMPs	1
Technical / Technology			
Education & Training	A majority of the industry doesn't train on salt use effects or Best Management Practices	Yes; Lack of awareness & BMPs	3 (Not training) 1 (If training)
GPS / Software	A majority of the industry doesn't understand how to measure and track salt application rates. A majority do track salt inventory.	Yes; can't improve what you don't measure	1
Legal / Legislative			
Slip & Falls	#1 risk issue.	Yes; More salt vs. being sued.	3
Environmental			
Chlorides	Contamination of water & land resulting from use of de-icing salts	No (currently); Not regulated	3
Weather	The quantity of events influence the frequency of salt applications	Yes; frequency of events	2

*Issues listed are limited to the most significant drivers and variables that influence the commercial winter management industry's use of salt.

Materiality Analysis of the Drivers and Variables That Influence Salt Use

The materiality of sustainability issues within the context of the commercial winter management industry salt was prioritized (Table 8). A somewhat consistent result identified in the materiality matrix (Figure 23) is the gap between environment and industry. A majority of the sustainability issues and opportunities that represent industry and environment success are visually represented by this matrix as being at two ends of each spectrum.

The most heavily weighted issue in quadrant II that positively affects industry and negatively affects environment is level of service (LOS). Similar to results from the sustainability analysis, LOS expectations are the number one influencer of the rate and frequency of salt applications. Liability matched in quadrant III, was also a consistently weighted issue from the sustainability analysis.

An unanticipated result was none of the current issues matched the criteria for quadrant IV; such issues would prioritize opportunities for increasing the benefit to environment and issues that burden the industry.

The most significant result of the materiality analysis is the set of issues assigned to quadrant I in the matrix. These issues represent an unbiased assessment of the opportunities to incorporate for future salt reduction strategies that benefit industry and the environment. In chapter IV, I discuss the opportunity to leverage these balanced issues as a strategy for future acceptance (“buy in”) by all stakeholders of the salt reduction debate.

Materiality Matrix

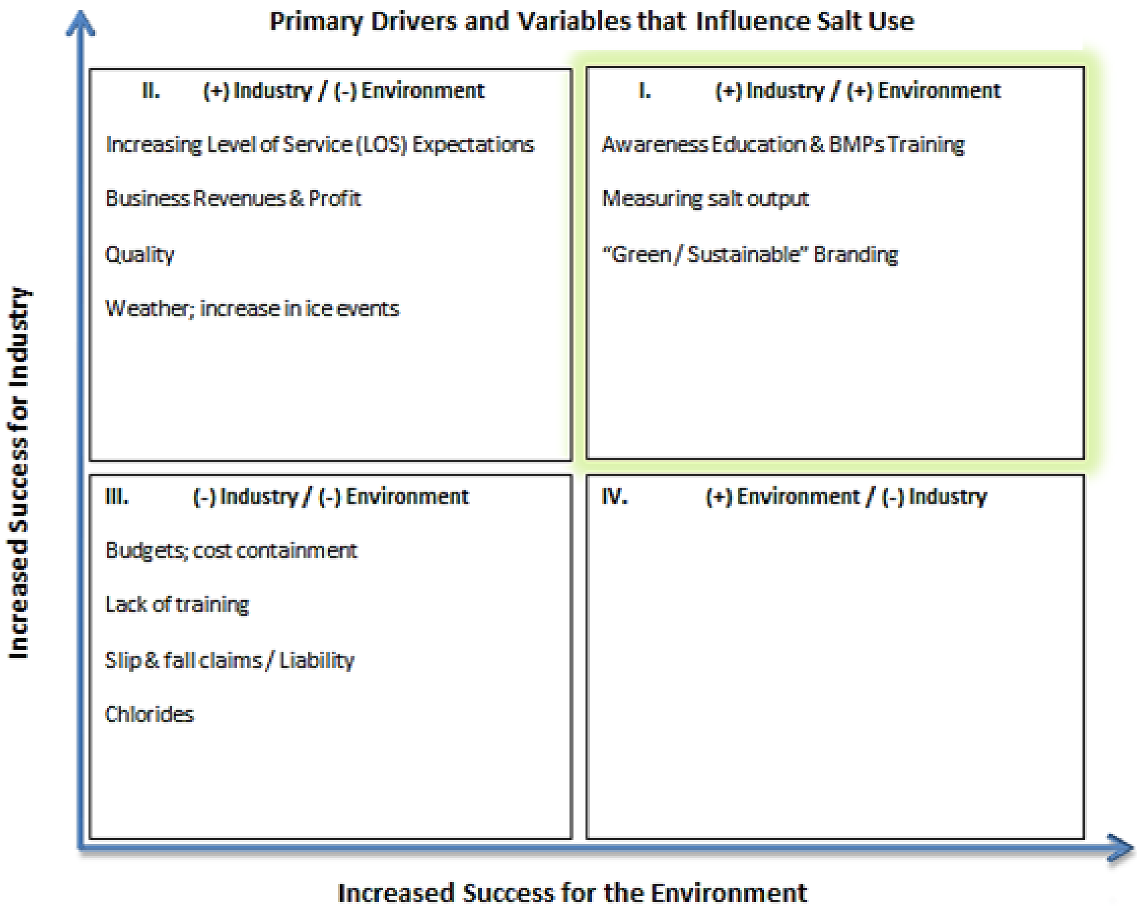

Figure 23. Materiality Analysis Results.

Chapter IV

Discussion

Upon reviewing the results of the industry context analyses, the data all broadly support my initial hypotheses. Perhaps a more a significant result is that the analysis identify additional issues that further emphasize opportunities to consider for future salt reduction research and solutions.

Interpretations of the Industry Analyses

The resulting salt application rate benchmarks, PESTLE table and materiality matrix produce an inclusive context of the commercial winter management industry. The primary issues the analyses reveal confirm the drivers and variables that influence salt are consistent with my experiential knowledge and current observations of the industry at a national level. I propose the resulting benchmarks and matrices from these analyses as a forward thinking model for developing a national standard of policy and practice for sustainable salt use in commercial winter management operations.

Comparative Analysis

The comparative analysis of salt application rates (Table. 6) and salt rate benchmarks overlay chart (Figure.11) support my first hypothesis: Current rates of salt applications used in commercial winter management operations for parking lots, and private roadways are higher than guidelines indicate they need to be.

The Sustainable Salt Initiative (SSI) case study of application rates are a representative median average of the larger sample group of rates being collected from over 1,500 sites. I interpret this to mean at least half of the rates are presumably higher than the next highest set of recommended rates put forth by SIMA. A more comprehensive analysis of the past two seasons of data collection is forth coming as part of the ongoing SSI study.

Using the salt rate benchmarks overlay chart, I added reference points for clarifying how I analyzed and interpreted the confusion of variability in the high and low range of recommended rates compared with the SSI case study (Figure 24). I also identify where the opportunity for industry acceptance currently exists. I propose this as an area of opportunity ("buy in") for salt application rates that are more likely to be implemented as a first attempt for developing a national standard. This range of rates I argue will be more easily understood and adoptable by industry based on my own industry experience. Incorporating my past and current professional experience, I advocate an industry lead approach has a greater opportunity for broad adoption rather than follow academic or environmental interests.

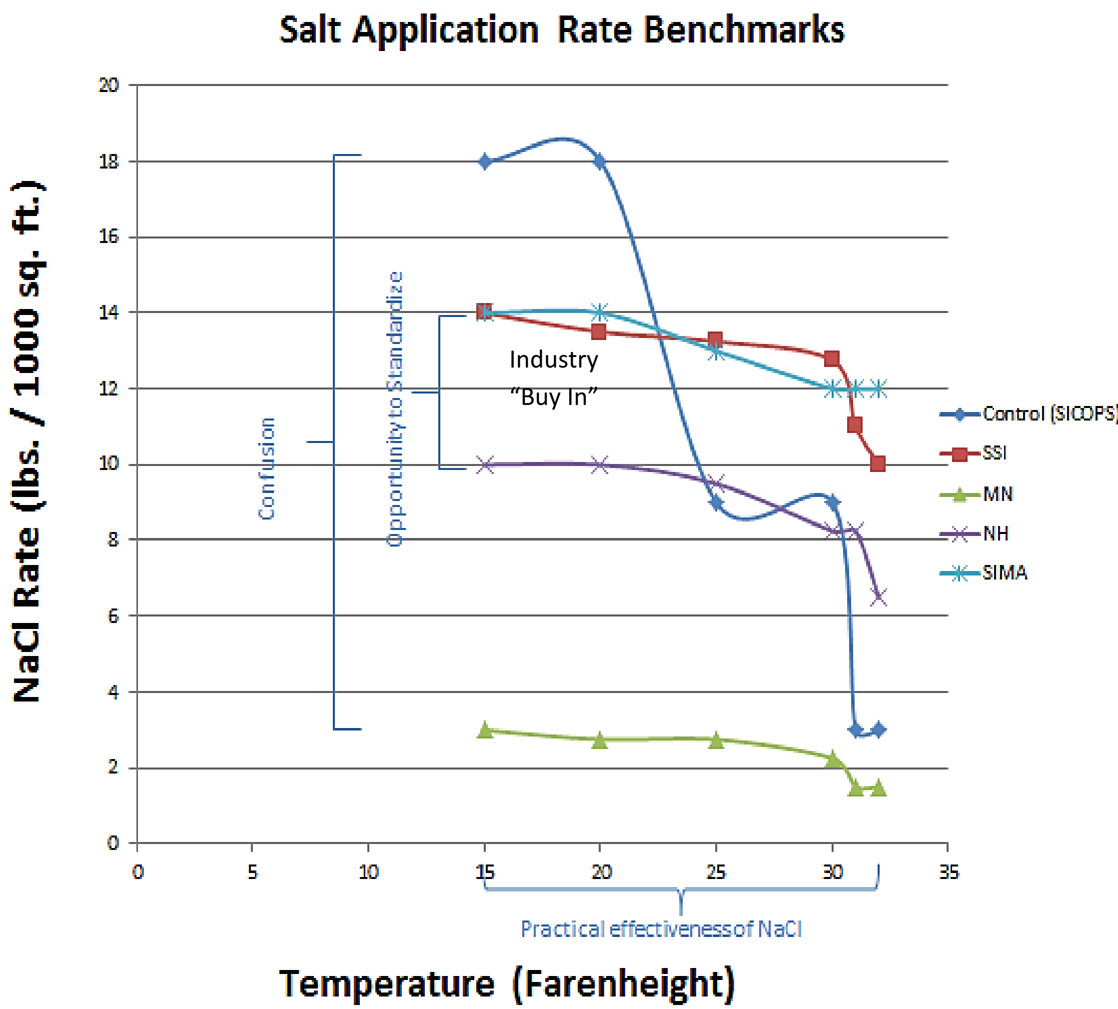

Figure 24. Interpretation of the comparative analysis overlay of salt rates.

Sustainability Analysis - PESTLE

The aggregated results of the surveys and the PESTLE analysis support these hypotheses:

1. The rates and frequencies of salt application rates increase when contracted levels of service or perceived levels of quality for snow & ice control are increased.
2. The amount of salt applied is higher when property owners or contractors are liable for slip and fall claims.

Nearly 90% of 528 companies reported fear of slip and fall liability as the top issue that influences their use of salt. This result prompts a new question: Is slip and fall liability the cause of using more salt or is the fear of liability driving the increase in levels of service specified in contracts as a strategy to increase quality, revenues and profits? An increasing trend is expected in level of service expectations and requests by property owners asking to see more salt as a perceived measure of safety and quality (IBIS, 2014). Salt use is expected to increase for these reasons due to anticipated growth in the commercial and retail economies over the next five years (IBIS, 2014).

Fear of losing profit is a similarly weighted influencer compared with the issues that directly support my hypotheses. More than 50% of the 528 companies who participated in the salt use survey reported a concern for maintaining profitability if their current rates and frequencies of salt applications are reduced (Figure 25). This resulting concern inspires a new question: How to develop standards of policy (vs practice) that financially incentivizes for efficient salt use rather than the amount used?

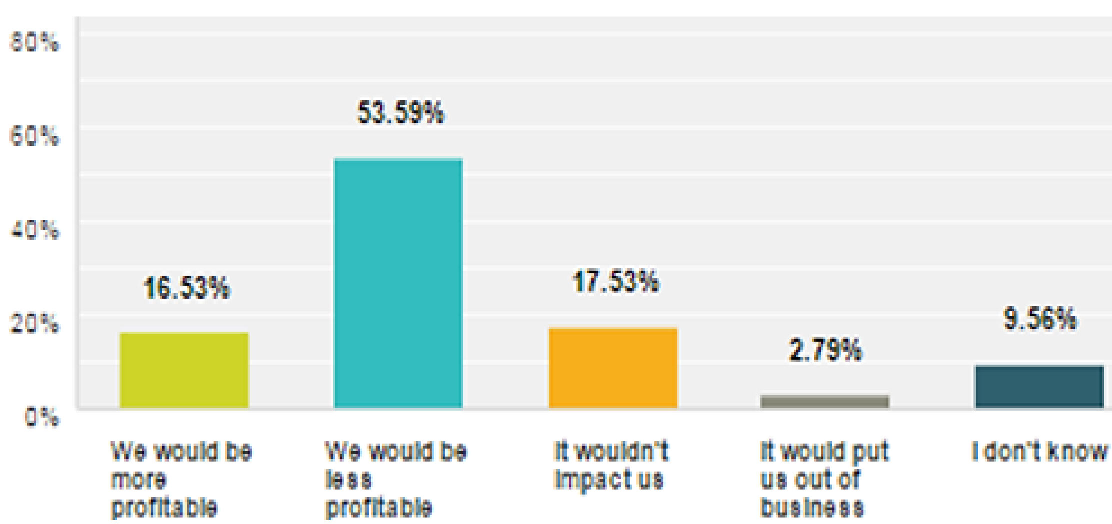

Figure 25. Survey of the most heavily weighted concerns contractors have if they reduce salt applications.

There is potentially an unintended consequence if contract structures that incentivise salt use effciency are promoted as the standard. Those that follow best practices to reduce salt use could suffer competitively compared with those that don't.

The overarching result of the PESTLE analysis indicates policies that support best practices are equal if not more important to focus on moving forward. Increasing fears of liability are in turn driving an increase in level of service expectations. Based on my field study observations and past experience, property owners and facility managers are literally asking to "see more salt" as a perceived standard of safety and quality. It stands to reason decreasing these issues may in turn decrease the amount of salt being applied.

Based on my experience as a winter management professional (contractor), so long as the amount of salt use is the primary driver for revenue and profit, then sustaining business growth will always be prioritized by contractors over reducing their use of salt. I advocate winter management service contracts that compensate for the amount and frequency of salt applied can no longer be considered a sustainable policy. I argue the winter management industry can't be expected to significantly reduce its use of salt unless there is a significant shift in policy for how salt and ice management services are compensated for.

Materiality Analysis

Drivers and variables that influence salt use identified in the materiality analysis matrix further support these initial hypotheses:

1. The rates and frequencies of salt application rates increase when contracted levels of service or perceived levels of quality for snow & ice control are increased.

2. The amount of salt applied is higher when property owners or contractors are liable for slip and fall claims.

The number one driver that supports these hypotheses and success for the industry is level of service (LOS) expectations from property owners. LOS was the most heavily weighted influencer in quadrant I, highest for supporting success of the industry and lowest for supporting the environment. The second most heavily weighted driver was profit or the loss of revenue and profit.

An unanticipated result was that none of the current industry issues matched the criteria to be represented in quadrant IV as a positive influence for environment and negative for industry. I interpret this to mean that none of the current issues identified in the materiality analysis reveal opportunities that benefit the environment and burden the industry. Rather the industry is only burdening the environment according to this analysis. For example if government / environmental regulation of salt use currently existed, it would be ranked in quadrant IV. Although there aren't any current issues that match the quadrant IV criteria, regulation would be the first and only issue that conceptually shifts the balance of success in favor of environment over industry.

This gap in quadrant IV initiates questions about possible future regulations for salt use. Is it possible the lack of issues represented in quadrant IV validates some people's opinion (not mine) that what's good for environment is bad for industry? What intended or unintended consequences (positive or negative) would introducing regulation of salt use cause the industry and the environment?

The most significant result of the materiality analysis is the issues that are assigned to quadrant I in the matrix (Figure 26). These issues represent an unbiased assessment of the opportunities for future salt reduction strategies that benefit industry and the environment. Awareness education and training of best management practices (BMPs) currently rank as the number one opportunity.

During my field observations of winter management on roadways in the town of Lake George, NY, the number one reason that surveyed truck operator rates had decreased over the past two seasons was the multiple awareness trainings and summits regarding salt use they had been required to attend. The only reason they were aware their adjusted salt rates were decreasing was because they now measure and analyze salt rates from tracking hardware and cloud based software technology they had installed on their trucks during the previous season 2015-’16, included as part of the SSI sample group.

Therefore measuring salt output is the second greatest opportunity to drive a change in current practice. If salt output can be measured and analyzed on a per application basis, then it can be improved and ultimately reduced. This theory is supported by the Lake George example, among many others that are participating in the SSI sample group.

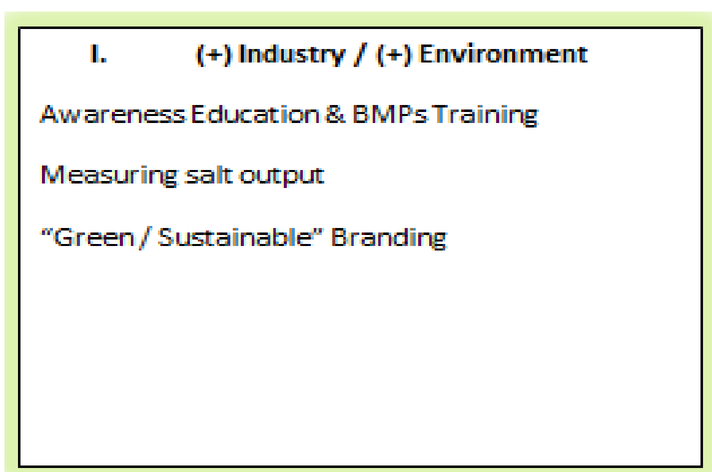

Figure 26. Quadrant I results of the materiality analysis matrix.

Questions for Furthering Research and Strategy

The interpretations, conclusions and proposed solutions I present are subject to a variety of questions for future salt reduction research and strategies. Question one 1 moving forward is: How can the commercial winter management industry significantly reduce its use of salt given what we now know from this research? The current answer is simply this: If the industry (and its clients) continues to practice "business as usual", it can't reduce its use of salt. Other questions to be answered for furthering salt reduction research and strategy include:

Q2. Is there a direct link to salt use and the lack of slip and fall liability a majority of survey respondents reported?

Q3. Is there a direct link to salt use and the lack of specific ice management training a majority of respondents reported?

Q4. Is there a direct link to salt use and the lack of environmental awareness and concern a majority of survey respondents reported?

Q5. Is there a direct link to the efficiency cost of salt and the amount of salt used? Is salt too inexpensive?

Q6. Who needs to change "business as usual"? Who ultimately determines how salt is sold and applied? Who determines level of service? Who ultimately controls the decision to apply the rates and frequencies of salt?

Q7. How much salt is the right amount? Do the operators who apply salt control the decision of how much to apply? How is the amount of salt measured and verified? Who should control the decision of much salt is applied?

Q8. Are there alternatives to using salt without sacrificing safety and desired level(s) of service? If there are what are the impediments that would prevent them from being utilized? What other unintended consequences would they cause?

Q9. Are claims of "environmentally friendly" salt options and EPA environmental design designations influencing an increase in the use of salt?

Q10. How do we develop a national standard of policy (vs. practice) that financially incentivizes for efficient salt use rather than the amount used?

Q11. Will the industry adopt and maintain standards for how salt is applied?

Q12. Who or what organization(s) is best suited to lead further research, initiate salt reduction strategies and develop standards of policy & practice for how salt is applied?

A Framework for Solutions Interventions

The data analyses and results from this thesis point the way forward for potential solutions interventions. No matter how future salt reduction initiatives evolve, I advocate always embedding the inclusive context of the commercial winter management industry's sustainability issues learned from this research. Future interventions of policy and practice for winter management and salt use may now be supported with this context data never before summarized.

Salt Rate Benchmarking

Continuous collection and analysis of "real world" salt application rates is necessary to further validate the salt application rate benchmarks as a standard model. The Sustainable Salt Initiative (SSI) for example should continue and be expanded to measure companies who are following the “control” or other recommended application guidelines.

I further contend the comparative analysis overlay of salt application rates is a model that can be utilized for developing a North American standard of practice for salt application rates. The current set of rates analyzed in the overlay could be considered as the initial set of guidelines to build from.

The PESTLE and materiality matrices provide a simple and unbiased tool for measuring and revising the issues that influence the rate and frequency salt is utilized. Although the issues currently represented are accurate and inclusive, it is certain there will be more to include and assess in the future.

Standards of Policy

Level of service (LOS), profit, and liability are the three most heavily weighted sustainability issues for the commercial winter management industry. Further they are ranked as the top three drivers that influence the rate and frequency salt is applied. Given these are all issues of policy rather than practice, the time for initiating a model of policy standards is now.

The opportunity for standards of policy that enable standards of practice is at the forefront of these three primary issues. The “business as usual” terms of contracts that enable charging for the quantity and frequency of salt applications are no longer sustainable if salt reduction is to be prioritized. Only one in five of the standard contract models (Figure 27) the industry typically utilizes support efficient use of salt. I advocate reversing the weight of these contract models would enable a similar trend for reversing the amount of salt being applied.

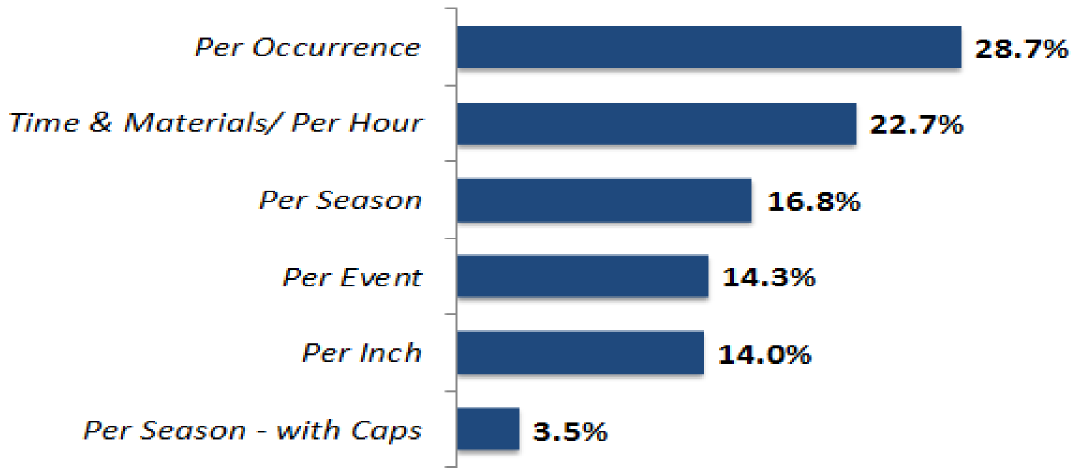

Figure 27: The top five 5 snow contract models. (Wolf, 2016)

The results suggest that a broad adoption of policy standards will be best implemented if they include financial incentives for efficient practice, including salt use application. Rather than regulate the rate of salt applications and other standards of practice, my belief is that standards of policy would better serve the regulation of salt use. Whether it is industry lead salt rate guidelines, seasonal variance contract models adopted by property owners, or liability reform legislation at the state or federal branches of government, standards of policy are necessary to enable reduced salt application. The current opportunities ranked in quadrant I and the gap in quadrant IV of the materiality matrix supports industry lead regulation of salt use rather than government intervention.

A broad group of stakeholders including the trade associations, environmental agencies, NGOs, and insurance industry have an opportunity to collaboratively lobby for commonsense liability reform for naturally occurring winter conditions. New

Hampshire's limited liability legislation granted to voluntary Green Snow Pro certified companies, individuals, and clients is a model to build from based on similar common sense liability protection granted to the ski resort industry.

When evaluating the full context of the commercial winter management industry, it's important to recognize the companies and operators who apply salt don't control the standards of policy. Rather it is the clients, property owners, facility managers and other constituents who are demanding the levels of service, quality and protection from liability that ultimately influence policy. The operators only control the standards of practice for delivering the service.

Standards of Practice

Best Management Practices (BMPs) for salt use have been researched and documented by several DOTs, NGOs and academic interests (Kelting & Laxson, 2010). The Minnesota Winter Parking Lot and Sidewalk Maintenance Manual (MPCA, 2010) is one of the first versions of best practices that attempt to provide a standard of practice within the context of commercial winter operations. More recently SIMA published its own best practice guidelines for salt use which I supported as subject matter expert (SME).

These straightforward stages for salt use efficiency I propose as a summary of minimum standards of practice to include (Figure 28):

1) Measure parking lot(s) and pre-determine the minimum and maximum application rates based on established salt rate guidelines. Measure surface temperatures (not

air temperature) for comparing with application rate guidelines. Analyze salt application rate output on a per application basis.

2) Calibrate salt application equipment to confirm minimum and maximum salt flow rates. Calibration should be performed pre-season and mid-season at a minimum. Re-calibration should also be performed anytime a repair or other change is made to salt application equipment.
3) Prevent the bonding of snow and ice on paved surfaces by incorporating anti-icing applications as a standard of practice when conditions allow. Although dry salt applied as an anti-icing application can be effective, salt brine is the recommend method for the prevention of dry salt 'bounce and scatter' waste.
4) Analyze inconsistencies of salt rates by category of variables: a) parking lot / road; b) fleet (vehicles); c) spreader / equipment and d) operator.
5) Improve salt rate output by analyzing inconsistencies of measured salt application rates. Identify the lowest measured rate that achieves desired level of service and recalibrate all salt application equipment to the lowest successful rate(s).
6) Optimize dry salt output by pre-wetting (with salt brine) dry salt flow at the spinner of the spreader.

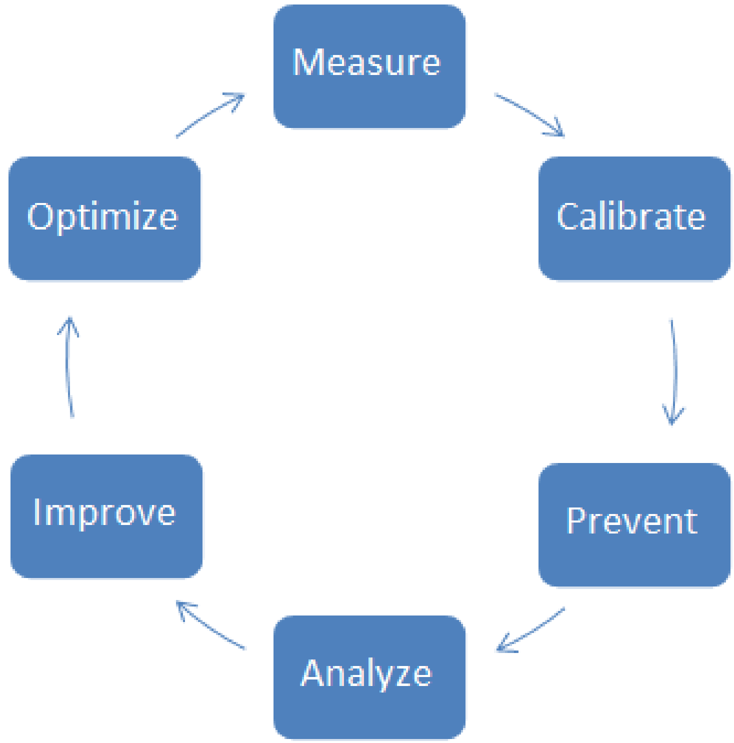

Figure 28. Recommended stages for sustainable salt use standards of practice.

Accountability

Trusting a highly fragmented industry with self-regulated standards of policy and practice requires a consistent and reliable method for verifying service levels and accounting for salt output rates on a per application basis. The first recommended stage of salt use best practices is measuring. The industry trade groups, environmental agencies, NGOs, salt suppliers, equipment manufactures and the software & technology industry have the opportunity to enable broad industry adoption of this first phase through a conglomerated initiative of information and resource sharing. Trade associations, suppliers and manufacturing could combine as a coalition of outreach efforts for influencing their members and clients to measure, analyze and improve salt output. For this effort to be successful requires establishing trust and transparency among all of these stakeholder groups and their respective interests. In the future its possible manufacturers of salt spreading equipment should be required to include salt rate tracking equipment as a standard option.

Code of Conduct

The industry context analyses validate the industry is highly fragmented and lacks a consistent set of professional standards to follow. Given the lack of standardization throughout the industry, I propose the trade associations and environmental groups collaborate to promote a “less is more” code of conduct campaign. Taglines for this campaign could include the premises of less salt being socially more acceptable, economically more efficient, and environmentally more responsible.

A current example where a code of conduct is necessary is for claims of “environmentally friendly” salt products that add a corrosion inhibitor. These claims are stretching the truth as a marketing scheme to influence the end users perception they are using a “safer” deicing product with no consequence to the environment. There are several examples of chloride based salt products that have ironically earned EPA environmental design credentials and accreditation (Figure 29).

[redacted] related products are a line of environmentally friendly, high-performance granular deicing products used to break the bond of snow and ice from roadways, walkways, driveways, and parking lots.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS No.	Amount
Sodium Chloride	7647-14-5	90-98%
Magnesium Chloride	7791-18-6	0.06-0.20%
Potassium Chloride	7447-40-7	0.20-0.40%
Calcium Chloride	10043-52-4	0.30-1.40%
Corrosion Inhibitor	Proprietary	Proprietary

Figure 29. Safety data sheet (SDS) and EPA "Designed for the Environment" and "Safer Choice" designations for salt based deicing products.

Value Branding

In this age of selling value based on brand recognition and reputation, there are opportunities for promoting "green" practices, sustainability, LEED, environmental stewardship, and "environmentally safe". Rather than continuing to be perceived as an exterior maintenance service industry, I advocate the sustainability issues related to salt reveal a new value added sales opportunity: Commercial winter management operators are seen as sustainability professionals when they sell and implement salt efficiency solutions.

Proposed Interventions

Aggregating the three industry context analyses brings forth a resulting conglomeration of possible intervention solutions. Highlighting the primary results of the industry context analyses and my knowledge of the industry, I propose Version 1.0, a summary of interventions as a possible model to deploy as an industry wide set of standards for self-regulating salt use (Table 9).

Table 9. Version 1.0: Summary of possible interventions for salt use policy standards by category of stakeholders.

Stakeholders	Policy / Law / Governance	Technology & Infrastructure	Awareness; Education & Training	Financial / Economic	Data; monitoring & accountability
Service Providers (contractors), Operators/Brokers	Sell salt as a service, not an amount. Apply salt based on surface temperature vs. air temperature Follow a "Less is More" code of conduct.	Estimating system for calculating salt quantities per property. Invest in technology to measure salt output. Invest in salt optimization technology	Salt pollution and damage awareness communication to clients. Be the experts. Follow established salt application rates and BMPs.	Implement seasonal variance contract structures.	Measure salt output by the application. Analyze, adjust (calibrate) = reduced rates.
Property owners and Facility Managers	Purchase salt as a service, not an amount.	Hire contractors who measure & analyze salt output.	Recognize salt pollution and damage awareness. Awareness of BMPs.	Implement seasonal variance contract structures.	Hold contractors accountable to analyze & adjust salt rates.
Supply	Products with chloride ingredients should not include "environmentally safe" claims.	Follow storage and distribution BMPs.	Chloride warning on salt bags, labels & MSDS.	Is salt too cheap?	Provide lists of 'buyers' for awareness outreach campaigns.

Manufacturing	Equipment to include measuring technology as standard option.	Salt application equipment designed to automate application rate guidelines	Chloride warnings on salt spreading equipment and owner's manuals	Provide pricing incentives for adding brine efficiency technology to new equipment orders	Provide lists of 'buyers' for awareness campaigns
Software & Technology	Enable a national standard of measuring.	Cloud based measuring of salt output by the application and alert when application rate guidelines are exceeded.	Enable calibration and analysis training. Enable furthering salt rates benchmarking research.	Enable reporting salt inventory and labor cost efficiency savings.	Enable per application data analysis and push notifications when rates are beyond national guidelines.
Insurance	Lobby for liability legislation protection from natural winter conditions.	Incentive programs for salt trained companies.	Educate property owners of the financial benefits for reducing salt damage claims.	Offer discounted rates for salt trained companies.	Benchmark experience modification ratings (EMR) for trained vs. untrained companies. Case studies focused on property damages related to salt use (i.e. parking decks).
Trade Associations & Lobbying	Establish national salt application rate guidelines and BMPs	Align with estimating tools and tracking technology for industry to adopt.	Develop and deliver awareness and BMPs education	Sustainable branding campaign to promote hiring "green" practicing companies.	Monitoring & reporting of SSI sample group rates.

Trade Associations & Lobbying (continued...)	Advocate for industry sustainability issues that influence salt use. Promote a "Less is More" professional code of conduct		Align and support further academic & environmental research.	Provide funding for future salt reduction research.	
Environmental Agencies & NGOs	Advocate for the amount of chloride reduction required. Support an industry lead "Less is More" campaign	Establish salt tolerance thresholds industry can easily understand and adopt.	Deliver awareness communication.	Grants for furthering industry research. Grants to fund industry's implementation of BMPs.	Annual measuring and reporting of chloride levels; promote reduced use case study success stories.
Government	Legislation protecting against liability for naturally occurring winter conditions. Stricter compliance rules for EPA accreditations & "Environmentally Safe" claims.	Salt pollution prevention benchmarks; EPA needs to establish reduction targets based on past 10 years usage history.	EPA research and or support research for salt alternatives.	Grants for furthering industry reduction research and initiatives. Grants to fund industry implementation of BMPs Tax incentives for training.	Report of total #'s of businesses applying salt – US Census. Salt use pollution standards industry can reference to their clients.

Impediments

These results and my proposed framework for developing a standard of policy and practice bring to question the potential needs for the future. Industry accreditation, certification strategies, and regulation of salt use are options to consider with a balanced view of past experiences.

The history of certification and professional designations specific to the winter and landscape management industry haven't proven to be particulalry successful for influencing the broad adoption of standards. For example the Certified Snow Professional (CSP) certification program, currently governed by SIMA, has historically maintained less than 200 certified individuals annually over the past 10 years. Compared with the more than 1,500 SIMA contractor members, over 27,000 established companies and over 110,000 owner / operators in the industry (SIMA,2016; IBIS,2014), less than 1% of companies and operators are influenced by certification. In another example the National Association of Landscape Professionals (NALP) currently certify ~3,000 individuals from an industry of over 400,000 companies (IBIS,2015).

Government regulation of this small business industry, that is primarly driven by owner operator entreprenuers, will only add to the list of sustainability issues identified in the PESTLE analysis. I further suspect if government regulation of salt use were implemented, the socio economic and political issues of sustainability, and other interests of the industry, would impede the sucessful enforcement of regulations. Contractors are primarily concerned with keeping customers happy, growing their business and avoiding lawsuits.

Salt application rates will continue to be debated as they already are. It's reasonable to expect that any individual or organization(s) that has developed a set of recommendations will advocate for their rates to be the standard. Academia wants to provide the correct answer. Minnesota and Waterloo Ontario need the lowest salt rates to be applied. SIMA attempts to provide a balance of answers for their members without being liable for those answers. The best interests of the salt supply industry do not include selling less salt.

Conclusion

The commercial winter management industry has an opportunity to leverage the lack of existing regulations tied to salt use rather than ignore the issues that research has clearly revealed. The lack of formal standards of policy and practice synthesized with the issues of salt is an opportunity for the industry to self-regulate and promote itself.

I propose the version 1.0 interventions framework as a way forward for enabling a highly fragmented industry to reduce the rate and frequency of NaCl it applies. If these interventions were to be adopted by the broad categories of stakeholders, I advocate this framework could be the future model for industry regulated standards of policy that enable standards of practice. In particular this model will need to include significant investment in awareness & outreach campaigns to the larger base of property owners and clients who outsource salt application services. Rather than invest in government regulation of salt applications that are impossible to enforce in an extremely fragmented industry, I argue that easily understood, accessible and affordable sets of guidelines have a better chance for broad adoption throughout all the industry stakeholder categories.

The assessment of current sustainability issues in this thesis, particularly the overuse of salt, offers the commercial winter management industry an opportunity to leverage sustainable salt use as a strategy, elevate its image as environmental stewards and bolster its credibility as a profession rather than a service.

References

Allert, A.L., Cole-Neal, C.L., & Fairchild, J.F. (2012). Toxicity of chloride under winter low flow conditions in an urban watershed in central Missouri*, USA*. *Bull. Environmental Containment Toxicology*. 89, 296-301.

Accredited Snow Contractors Association (ASCA). (2015). Fact from Fiction. Retrieved from: http://www.ascaonline.org/article/snow-asca-sima

Accredited Snow Contractors Association (ASCA). (2017). Snow and Ice Management Industry Background. Retrieved from: http://www.ascaonline.org/page/asca_snow_industry_history

Baldwin, D. S., G. N. Rees, A. M. Mitchell, G. Watson, & J. Williams. (2006). The short-term effects of salinization on anaerobic nutrient cycling and microbial community structure in sediment from a freshwater wetland. *Wetlands*, 26:455-464.

Boylen, C. Eichler, L. Swinton, M., Nierzwicki-Bauer, S., Hannoun, I., & Short, J. (2014). The State of the Lake: Thirty Years of Water Quality Monitoring on Lake George, New York, 1980 – 2009. Darrin Fresh Water Institute & Department of Biological Sciences*,* Rensselaer Polytechnic Institute, Troy, NY. Retrieved from: https://fundforlakegeorge.org/sites/default/files/site/default/files/lakegeorge/thestateofthelake-web-8-14-2014_final_web_version.pdf

Burack,T. Steart, H., & P. Trowbridge. (2008). Total Maximum Daily Load (TMDL) Study for Waterbodies in the Vicinity of the I-93 Corridor from Massachusetts to Manchester, NH. Policy Porcupine Brook in Salem and Windham, NH. *NHDES*-R-WD-07-41.

Clark, P. (2017). The Snow Removal Business is a Mess. *Bloomberg*. Retrieved from: https://www.bloomberg.com/news/articles/2017-02-09/the-snow-removal-business-is-a-mess

Corsi, S.R., Graczyk, D.J., Geis, S.W., Booth, N.L., & Richards, K.D. (2010). A fresh look at road salt: aquatic toxicity and water-quality impacts on local, regional, and national scales. *Environmental Science Technology*, Report No. 7376e7382. 44.

Evans, M., & Frick, C. (2001). The effects of road salts on aquatic ecosystems. Environment Canada- *Water Science and Technology Directorate*, Report No. 02e308

Godwin, K. S., S. D. Hafner, & M. F. Buff. (2003). Long-term trends in sodium and chloride in the Mohawk River, New York: The effect of fifty years of road-salt application. *Environmental Pollution*, 124:273-281.

Freshwater Crisis. (n.d.) National Geographic. Retrieved from: http://environment.nationalgeographic.com/environment/freshwater/freshwater-crisis/

Hintz & Relyea. (2017). Impacts of road deicing salts on the early-life growth and development of a stream salmonid: Salt type matters. Darrin Fresh Water Institute, Department of Biological Sciences, Rensselaer Polytechnic Institute, Troy, NY.

Hossain, SMK. (2014). Optimal Snow and Ice Control of Parking Lots and Sidewalks. iTSS Lab Department of Civil & Environmental Engineering, University Waterloo, ON.

Hosseini, F., Hossain, S.M.K., Fu, L., San Gabriel, P. & Seters, T. (2015). Field Evaluation of Organic Materials for Winter Snow and Ice Control. Paper submitted for presentation at the *94th Annual Meeting of the Transportation Research 34 Board* and for publication at *Transportation Research Record.* 17.

Howard, B.C. (2014). The Surprising History of Road Salt. National Geographic. Retrieved7/20/2016 from: https://news.nationalgeographic.com/news/2014/02/140212-road-salt-shortages-melting-ice-snow-science/

IBIS World (IBIS). (2014). Let it snow: A continued expansion in the US economy will underpin industry demand. Snowplowing Services in the US. *IBISWorld Industry Report*, OD5400.

IBIS World (IBIS). (2015). Greener grass: Renewed construction activity will encourage demand for industry services. Landscaping Services in the US. *IBISWorld Industry Report*, 56173.

Karraker, N.E., Gibbs, J.P., & Vonesh, J.R. (2008). Impacts of road deicing salt on the demography of vernal pool-breeding amphibians. *Ecological Applications*. Ecological Society of America, 18, 724-734.

Kaushal, S. S., P. M. Groffman, G. E. Likens, K. T. Belt, W. P. Stack, V. R. Kelly, L. E Band, & G. T. Fisher. (2005). Increased salinization of fresh water in the Northeastern United States. Proceedings of the *National Academy of Sciences* of the United States of America, 102:13517–13520.

Kelting, D.L..& Laxson, C.L. (2010). Review of Effects and Costs of Road De-icing with Recommendations for Winter Road Management in the Adirondack Park. Adirondack Watershed Institute - Paul Smith's College, Paul Smith’s, NY. *Adirondack Watershed Institute Report*, # AWI2010-01. Retrieved from: http://www.adkwatershed.org/files/road_salt-_final_dlk.pdf

Kelly, V.R., Lovett, G.M., Weather, K.C., Findlay, S.E.G., Strayer, D.L., Burns, D.J., & G.E. Likens. (2008). Long-term chloride retention in a rural watershed: legacy effects of road salt on stream water concentrations. *Environmental Science and Technology*, Vol.42, pp.410-415.

Minnesota Local Road Research Board (MLLRB). (2012). Minnesota snow and ice control: Field handbook for snowplow operators. Minnesota Local Road Research Board (MLLRB), St. Paul, MN. Retrieved from: http://www.mnltap.umn.edu/publications/handbooks/documents/snowice.pdf

Minnesota Pollution Control Agency (MPCA). (2015). Winter Parking Lot and Sidewalk Maintenance Manual -Third Revision, June 2015 Published by: Minnesota Pollution Control Agency. 22-41. Retrieved from: www.pca.state.mn.us/programs/roadsalt.html

Mohin, T. (2012). Changing Business from the Inside Out: A Tree-Hugger's Guide to Working in Corporations. 45. Berrett-Koehler Publishers. Kindle Edition.

Morgan II, R.P., Kline, K.M., Kline, M.J., Cushman, S.F., Sell, M.T., Weitzell Jr., R.E., & Churchill, J.B. (2012). Stream conductivity: relationships to land use, chloride, and fishes in Maryland streams. *North American Journal of Fisheries Management*, 32, 941e952. Retrieved from: http://dx.doi.org/10.1080/02755947.2012.703159

New Hampshire Department of Environmental Services (NH DES a).(2016). Salt Reduction Initiatives and Impacts - Overview. Retrieved 7/26/16 from: http://des.nh.gov/organization/divisions/water/wmb/was/saltreduction/initiative/impacts.htm

New Hampshire Department of Environmental Services (NH DES b). (2016). Total Maximum Daily Load - Overview. Retrieved 7/26/16 from: http://des.nh.gov/organization/divisions/water/wmb/tmdl/categories/overview.htm

New Hampshire Department of Environmental Services (NH DES c). (2016). Green Snow Pro Legal Liability Protection Legislation - Overview. Retrieved 7/26/16 from:http://www.des.nh.gov/organization/commissioner/legal/rules/documents/envwq2200.pdf

New Hampshire Department of Transportation (NH DOT). (2016). Rebuilding I-93 Salem to Manchester. Retrieved 4 August 2016 from: http://www.rebuildingi93.com/

New York Department of Transportation (NYSDOT). (2012). Highway Maintenance Guidelines. Retrieved 7/20/2016 from: https://www.dot/ny.gov/divisions/operating/oom/transportationmaintenance/repository/NYS_SI_Manual_Apr2006_RevJan2012.pdf

New York Department of Transportation (NYSDOT). (2016). Transportation Maintenance. Retrieved 7/20/2016 from: https://www.dot.ny.gov/divisions/operating/oom/transportation-maintenance/snow-and-ice

Nixon, W.A. & DeVries, M.R. (2015). Development of a Handbook of Best Management Practices for Road Salt in Winter Maintenance Operations - Final Report. *Clear Roads research for winter highway maintenance*. University of Iowa and Vaisala, Inc., Project 06742/CR14-10.

Novotny, E., D. Murphy, & H. Stefan. (2007). Road Salt Effects on the Water Quality of Lakes in the Twin Cities Metropolitan Area**.** Project Report No. 505, St. Anthony Falls laboratory, University of Minnesota, Minneapolis, Minnesota.

Pojasek, R.B. (2010). Sustainability: The Three Responsibilities. *Environmental Quality Management***,** DOI 10.1002. 87.

Salt Institute. (2017). Salt Institute Member Companies. Retrieved from: http://www.saltinstitute.org/about-salt-institute/member-companies/

Sander, A., E. Novotny, O. Mohseni, H.G. Stefan. (2007). Inventory of Road Salt Uses in The Minneapolis/St. Paul Metropolitan Area. University of Minnesota St. Anthony Falls Laboratory Engineering, Environmental and Geophysical Fluid Dynamics. Report No. 503. Prepared for Minnesota Department of Transportation. https://conservancy.umn.edu/bitstream/handle/11299/115332/pr503.pdf?sequence=1

Sarma, S. S. S., S. Nandini, J. Morales-Ventura, I. Delgado-Martínez, and L. Gonzáles-Valverde. (2005). Effects of NaCl salinity on the population dynamics of freshwater Zooplankton (rotifers and cladocerans). *Aquatic Ecology,* 40:349–360.

Schwartberg, E. (2016). New York's Hidden Road Salt Cost. Study Design – The costs of salt mediated corrosion to vehicles and highway infrastructure. ADK Action, Saranac Lake, NY.

Snow and Ice Management Association (SIMA). (2017). Sustainable Salt Use Best Practices Guidelines. Retrieved from: http://www.sima.org/resource/best-practices/sustainable-salt-guideline-download-and-terms-of-use

Smart About Salt Council (SASC). (2010). Regional Municipality of Waterloo. Educational Achievement and Award Submission to the Knowledge Management Working Group. Transportation Association of Canada. Retrieved 18 May 2015 from:http://conf.tacatc.ca/english/resourcecentre/readingroom/conference/conf2010/docs/z1/waterloo.pdf

Smart About Salt Council (SASC). 2017. About The Smart About Salt Council. Retrieved from: http://www.smartaboutsalt.com/about

Techopedia. (2016). Geo Fencing. Retrieved 7/27/16 from: https://www.techopedia.com/definition/14937/geofencing

University of New Hampshire – Technology Transfer Center (UNH – T2). (2017). Green Snow Pro Training and NHDES Certification. Retrieved from: http://t2.unh.edu/green-snowpro-certification

US Environmental Protection Agency (USEPA). (1988). Ambient water quality criteria for chloride–1988. Office of Water Regulations and Standards Criteria and Standards Division, US Environmental Protection Agency, Washington, DC. Retrieved from: http://www.epa.gov/waterscience/criteria/library/ambientwqc/chloride1988.pdf

US Roads. December 1, (1997). *Road Management Journal* (website). TranSafety, Inc. Retrieved 2August, 2016 from: http://www.usroads.com/journals/p/rmj/9712/rm971202.htm

Wolf, S. (2016). Snow and Ice Management Industry Research Study. Snow and Ice Management Association (SIMA). Retrieved from: http://www.sima.org/resource/snow-industry-impact-report-download

Zurich. (2017). Slip Trip and Fall Safety. Retrieved from: https://www.zurichna.com/en/knowledge/topics/slip-trip-and-fall-safety